Water Quality and Tile Drainage in Addison County

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Middlebury College
ENVS 401
Spring 2016

TABLE OF CONTENTS

INTRODUCTION………………………………………………………………… 4

Overview………………………………………………………………… 4

Vermont Agriculture…………………………………………………… 4

Components of the ENVS 401 Project………………………………… 6

Vermont's Clean Water Initiative and Act 64……………………… 7

Phosphorus Loading and Eutrophication in the Lake Champlain Basin…. 9

Champlain Valley Farmer Coalition Inc. ……………………………… 10

Tile Drains……………………………………………………………... 10

McKenzie Brook Watershed…………………………………………….. 11

FARMER SURVEY……………………………………………………… 12

Survey Methods………………………………………………………... 12

Survey Results………………………………………………………….. 14

INTERVIEWS…………………………………………………………… 18

Interview Methods……………………………………………………….. 18

Interview Results………………………………………………………… 19

Farmer Case Studies 1 - 7………………………………………… 19

Interview with Eric Howe (Technical Coordinator of the Lake Champlain Basin Program)………………………………………………… 33

FARMER SURVEYS & INTERVIEWS DISCUSSION……………………… 37

Water Quality……………………………………………………………. 37

Act 64 and RAPs…………………………………………………………….. 38

1. Site-Specific Challenges……………………………………………… 38

<u>Recommendations: Site-Specific Challenges</u>…………………… 40

2. Stewardship & Solidarity………………………………………………… 40

<u>Recommendations: Stewardship & Solidarity</u>…………………… 41

3. Monitoring & Enforcement…………………………………………… 41

<u>Recommendations: Monitoring & Enforcement</u>………………… 42

4. Subjectivity and Semantics…………………………………………… 42

<u>Recommendations: Subjectivity and Semantics</u>………………… 43

5. Environmental and Economic Externalities…………………………… 44

<u>Recommendations: Environmental and Economic Externalities</u>… 44

Tile Drainage…………………………………………………………………. 45

WATER SAMPLING……………………………………………………………... 51

Methods………………………………………………………………………. 51

Results……………………………………………………………………... 52

Discussion…………………………………………………………………….. 52

GIS MAPPING AND SPATIAL ANALYSIS……………………………………….. 53
Methods…………………………………………………………………….. 53
Results……………………………………………………………………… 54
Discussion………………………………………………………………….. 58
CONCLUSION………………………………………………………………………. 58
ACKNOWLEDGEMENTS………………………………………………………… 59
BIBLIOGRAPHY……………………………………………………………………… 59
APPENDIX A……………………………………………………………………... 63
Farmer Survey……………………………………………………………….. 63
Interview Template…………………………………………………………… 67

INTRODUCTION

Overview

Our project focuses on the relationship between agricultural practices and water quality within Addison County and the McKenzie Brook watershed, especially in the context of Vermont's new Clean Water Act (Act 64). This project was completed for the Middlebury College Environmental Studies 401 senior seminar course taught by Molly Anderson and coordinated by Diane Munroe. The project scope was initially designed with partner organizations from the community: UVM Extension, the Vermont Department of Environmental Conservation Watershed Management Division, and the USDA Natural Resources Conservation Service of Vermont. This initial design was later altered through our conversations with these partners, our professor, and our coordinator. The following introductory sections will outline topics and themes that are relevant to our project.

Vermont Agriculture

Vermont is the ultimate study in contrasts: a place where the working landscape, quintessential and quaint, is the stage for an ongoing tug-of-war between past and present, tradition and modernity, nature and man—tensions that, arguably, emerge most explicitly in the agricultural arena. While Robert Frost may be the most prominent native and household name, he is not the only one to be possessed by the urge to wax poetic about Vermont's irresistible charms; even matter-of-fact government documents, such as the Watershed Management Division's annual report, sometimes leave behind neutral language and sing the praises of their state, "truly a slice of Americana" whose "rich agricultural heritage" emerges in the iconic imagery of "grazing cows and a red barn set against a…backdrop" (VT WMD 2010).

All the same, these romanticized and rosy descriptions represent only part of the picture; absented are the economic decline, environmental degradation, and racial and class inequities that constitute current and future challenges for Vermont. It is the sheer dominance of dairy—an industry that corners up to 90 percent of the agricultural market and produces 2.6 billion pounds of milk annually—that simultaneously upholds and undermines the Vermont economy (VT WMD 2010; Sawyer et al. 2013b). Indeed, the paradox is that the state could not survive without dairy, yet disproportionate reliance on a single agricultural sub-sector is a perilous strategy, analogous—in gambling parlance—to "going all in" on cows. Indeed, Vermont invests heavily in the fragile hope that the economic, political, and environmental climate continues to be favorable to livestock (Holt 2015). But this is a risky assumption to make, because dairy farming has myriad downsides. To begin, the dairy market is notoriously unstable, sensitive to price shocks and dictated by the global rather than local economy. Secondly, Vermont dairy farming derives much of its labor from Hispanic migrant workers, many of whom are lacking in legal status, job security, and living wages; consequently, the human capital needed to sustain dairy farms hinges on a host of uncertainties, like inclusive legislation and unbiased (i.e. non-racist) law enforcement. On top of these present unknowns, there are also question marks that pertain to climate change and its potential impact on livestock, since temperature stress, as well as the increased prevalence of parasites and bovine diseases (brought about by warmer weather), could significantly jeopardize the dairy industry (Sawyer et al. 2013b). In sum, a dearth of agricultural diversity casts doubt on the ability of Vermont to weather what the future holds: in all probability, a greater abundance of economic, social, and climatic storms.

Aside from these external variables that can, and will, exert increasing pressure on dairy farmers, there are indications that the industry is fracturing from within due to internal stressors and growing inequality. The last decades have seen development, wetland regulations, and conservation easements gradually erode the extent of agricultural land access (VT WMD 2010). Thus, when Farm to Plate cautions that "farms are forced into a narrow band between profitable production and public environmental concerns," this statement not only signifies that farmers occupy a shrinking social and political space in Vermont, but also that they literally inhabit a contracting physical place in the landscape. The recent passage of Act 64 and its attendant Required Agricultural Practices (RAPs) might intensify marginalization and competition among farmers, because mandatory conservation measures, such as widened riparian buffers, will encroach on, and subtract from, crop fields and pastures. Yet Vermont farmers are not only subject to these new vertical (top-down) environmental laws—the ongoing horizontal trend of consolidation is also real cause for concern. Over the past 60 years, the number of dairy farms in the state has declined by almost 90 percent as corporate entities have shoved aside the small-scale and family-run operations that, once upon a time, were the idyllic face of Vermont dairy (Sawyer et al. 2013a). This paradigm shift has also gone hand-in-hand with the development of animal breeding, antibiotics, and agro-technology, which collectively, have contributed to a 200 percent increase in the milk-generative capacity of Vermont cows. However, enhanced cattle breeding acts as a double-edged sword for Vermont farmers, because while it technically raises farm revenue (at least on large farms that can afford investing in higher caliber cattle breeds), it also floods the market and thereby drives down milk prices.

Although larger farmers have wrested control of the market, increased their economies of scale, and expanded their profit margins, viewed as a whole, Vermont agriculture has been struggling for some time—in truth, the state has failed to keep pace with larger-scale progress in agricultural productivity. To illustrate, whereas the national average for aggregate gross farm income rose six percent from 1970 to 2009, over the same interval, Vermont's total and net farm income *dropped* 35 and 65 percent, respectively (Sawyer et al. 2013a). This decline, at least in part, reflects how Vermont's economic vulnerability has been heightened by an overdependence on dairy. Yet all the same, the state's financial burden has not been equally shouldered, because at the end of the day, it is still the small farmer who pays. A telling statistic proves this point: Between 2002 and 2004, a full 64 percent of small family farms in Vermont experienced net income loss, while 81 percent of large, very large, and nonfamily farms underwent financial *growth* (Sawyer et al. 2013a). Added to this income inequality is the fact that small Vermont farmers, unlike their larger counterparts, have historically been exempt from environmental accountability measures—routine monitoring, random audits, and formal nutrient management plans—so it seems likely that small farmers may be tempted to use excessive nutrient inputs (fertilizers and manure) in order to keep up with their bigger competitors.

However, small farms, once given legal leeway, have largely lost this privilege due to Vermont's new Clean Water Act. Whereas it was relatively uncommon for "the little guys" to be caught in the past—in part because enforcement played out through internally filed complaints rather than externally initiated investigations—Act 64 has significantly ramped up active monitoring of small farms (VAAFM 2011). Consequently, small farms will now be held to similar stewardship standards as medium and large operations. Ultimately, our project is situated at a confluence—not merely where river meets lake, but also where two conflicting value systems come together and clash. On one side, the New England farmer, the literal embodiment of an endangered way of life, strives to endure. And on the other, Lake Champlain, the once crystal-clear, crown jewel of Vermont, begs for the chance to see its own reflection again.

Components of the ENVS 401 Project

While our community partners affirmed that local farmers were aware of various conservation management practices and the connection between these practices and water quality and environmental stewardship, our partners had not formally surveyed farmers regarding their perceptions of water quality conditions or their own management practices and environmental impact. As a result, one component of our project was to survey farmers about these topics. Our community partners also raised concerns about the fact that state water quality data are often only available online in spreadsheets—a format that could be somewhat overwhelming and difficult to interpret for farmers. These data thus create a gap in terms of farmers' knowledge of local water quality conditions and do little to validate farmers' compliance with conservation management practices. We hypothesized that outreach materials in the form of maps, concise brochures, or persuasive infographics could make water quality issues more transparent to local farmers, potentially enabling them to better comprehend the importance of conservation initiatives. We therefore decided to focus another aspect of our project on interpreting water quality data to create straightforward, informational graphics and maps. These graphics will not only help local farmers to better understand the status of water quality in the region, but they will also help our community partners to identify pollution hotspots that require particular attention.

Tile drains are another topic of particular interest to our community partners, as there is a lack of knowledge about tile drain usage in Vermont, including within Addison County and the McKenzie Brook watershed. Definitive information about the relationship between water quality and tile drains is relatively scarce and often cannot be applied universally across soil types and geographic locations. We therefore decided to highlight the use of tile drains specific to Vermont in several components of our project. To address the questions and ideas raised by our community partners, professors, and ourselves, we focused our project to include three main goals:

A. Compile and collect information to understand the current status of water quality issues in Addison County and the McKenzie Brook watershed, both in terms of numerical data and farmers' perceptions
B. Produce graphics displaying water quality information (particularly in relation to phosphorus and nutrient loading) that make this information more easily accessible and understandable for local farmers
C. Compile and collect information on tile drains in Vermont by surveying and interviewing farmers on their practices and perceptions

To meet these goals, we divided our project into four distinct but related components:

1. A farmer survey regarding water quality and management practices, focusing on tile drains
2. Interviews with farmers, as well as state agencies and organizations
3. Water sampling
4. GIS mapping and graphics

We will describe each of these components in detail after first introducing and explaining various topics that are relevant to our project.

Vermont's Clean Water Initiative and Act 64

Over the past two decades—and especially in the last five years—Vermont has created legislation and enacted plans to help protect its waterways. This issue is relevant to the citizens of Vermont, as, in the words of Vermont Governor Shumlin, "Clean water is essential to all Vermonters" (Perkins 2015). Of particular concern is Lake Champlain, which is especially culturally significant and is threatened by pollution. Phosphorus pollution threatens overall water quality and ecosystem balances in Lake Champlain; phosphorus loading can cause algal blooms, harm drinking water, cause illness to people and animals, disrupt recreation, and decrease property values (VT ANR 2014b).

Vermont's initiatives help to augment and support the federal Clean Water Act, which was amended in 1972 and allows the Environmental Protection Agency (EPA) to implement programs to control pollution (EPA 2015b). On November 17, 2014, the Vermont Agency of Natural Resources released the Vermont Clean Water Initiative (VT ANR 2014a). The Initiative strives to comply with the state of Vermont's obligations under the federal Clean Water Act and the EPA requirements for Total Maximum Daily Load (TMDL) in Lake Champlain (VT ANR 2014c). TMDL refers to the maximum amount of a pollutant that can enter a water body in order to meet water quality standards (EPA 2015a). TMDL is equivalent to the sum of wasteload allocations (point sources), load allocations (nonpoint sources), and the margin of safety (EPA 2015a). Lake Champlain's TMDL was first set by Vermont in 2002; however, the EPA disapproved these standards in 2011 (Perkins 2015). On May 29, 2014, the State's Lake Champlain Phosphorus Total Maximum Daily Load Phase One Implementation Plan (Phase I Plan) was submitted to the EPA (VT ANR 2014c). The EPA will either accept or make final changes to this plan (Perkins 2015). The Phase I Plan outlines methods and management strategies for decreasing phosphorus loading in Lake Champlain (VT ANR 2014c). Strategies include cooperation from farmers, businesses, landowners, and municipalities (VT ANR 2014b).

Approximately 97% of phosphorus loading in Lake Champlain comes from nonpoint sources (VT ANR 2014c). Because agricultural runoff is an example of a nonpoint source—and constitutes approximately 40% of this loading—it is important to target agricultural management practices to improve water quality (VT ANR 2014c). Indeed, of the five Clean Water Priorities outlined in the Clean Water Initiative, the first priority listed is "Implementing agricultural best management practices" (VT ANR 2014). Not only will the strategies of the Clean Water Initiative improve water quality in Lake Champlain, but making changes such as improved fertilizer management can also benefit soil health and reduce costs for farmers (VT ANR 2014c).

This Clean Water Initiative was strengthened after the passing of Vermont's Clean Water Act (Act 64), which was signed into law by Governor Shumlin on June 16, 2015 in an effort to protect Vermont's waterways from pollution (VT WMD 2015b; Act No. 64 2015). Governor Shumlin has said that the act "is not only about cleaning up Vermont's waterways and Lake Champlain, it is about protecting our economy and a natural habitat that binds Vermonters tightly to our state and inspires others to put roots down here… this bill is about protecting what makes Vermont so special" (State of Vermont 2015). The Act encompasses many aspects of the protection of Vermont's waterways—such as the mitigation of stormwater runoff from impervious surfaces—in addition to focusing specifically on agriculture and farmers.

One change in regards to farming is the renaming of "accepted agricultural practices" (AAPs) to "required agricultural practices" (RAPs) (Act No. 64 2015). The AAPs were originally created in 1995 and mandated the implementation of various management practices to help protect water quality (VT ANR 2014c). As the name "required agricultural practices" implies, these practices are mandated, forcing farmers to comply with the standards; farms must eventually receive certification of compliance with these RAPs (Act No. 64 2015). These practices have been updated to include nutrient management planning, increased vegetative buffers from waterways, installation of fences to keep livestock out of waterways in cases of erosion, and soil conservation methods (VT DEC 2015; VT WMD 2015b; Dolan 2015). In addition, farms will be inspected, with frequency of inspection depending on farm size (Act No. 64 2015). To help farmers comply with these RAPs, the Agency of Agriculture, Food, and Markets (AAFM) will hold trainings, paid for by government water quality initiatives. Commercial manure applicators will be trained and certified as well (VT DEC 2015). Act 64 also gives AAFM and the Agency of Natural Resources (ANR) more authority to enforce water quality violations (Act No. 64 2015). An additional aspect of Act 64 is the creation of the Vermont Clean Water Fund, which helps to fund state water quality programs in addition to other relevant expenses. The Clean Water Fund Board includes the Secretaries of AAFM and ANR (Act No. 64 2015).

Phosphorus Loading and Eutrophication in the Lake Champlain Basin

Phosphorus is a limiting nutrient in freshwater aquatic ecosystems. This means that phosphorus abundance can determine the growth rates of aquatic plants and algae. Therefore, excess loading of phosphorus and phosphates, soluble in water or in particulate form, have great potential to cause eutrophication in freshwater ecosystems (King et al. 2015b). Eutrophication is the process by which a water body becomes more nutrient rich and can occur naturally as lakes age.

Algae have a rapid growth rate and limited lifespan. When algae die, they quickly fall to the lake floor or river bottom where they are broken down by bacteria through *aerobic* (requiring free oxygen) processes. These decomposition processes quickly reduce levels of dissolved oxygen (DO) and can cause what are known as aquatic “dead-zones.” Dead-zones can be found in any area of a water body that is colonized by algae “blooms.” Many shallow bays of Lake Champlain are susceptible to blue-green algae blooms during warmer months (LCBP 2015). Dead-zones are named because of the oxygen-poor *anoxic* environments they produce. No fish or aquatic life requiring cellular respiration can survive there, which directly correlates to lack of biological diversity and threats to overall ecosystem health.

Human processes have the potential to increase rates of eutrophication. This is known as *cultural eutrophication*, which has been studied for its potential adverse effects in freshwater ecosystems around the United States (Bachmann et al. 2013). The Lake Champlain Valley has a strong history of agriculture and subsequent phosphorus-based fertilizer use, which can contribute to this eutrophication. Lake Champlain is about 9,000 years old, having formed by retreating glaciers after the last ice age (LCBP 2015). In regards to phosphorus loading, Lake Champlain is particularly challenged due to the presence of *legacy phosphorus* (legacy P). Legacy P is solid state phosphorus deposited in sediments over time (Bachmann et al. 2013). This stored legacy P has the capacity to be resuspended in the water column when it is oxidized. The presence of legacy P in Lake Champlain makes current efforts to reduce phosphorus loading more difficult to assess. There is no way to differentiate between phosphorus that has just entered the water column as a result of agricultural runoff and legacy P that has been resuspended from sediments.

Phosphorus can enter bodies of water in several ways. Phosphorus commonly enters surface waters from surface runoff and subsurface flow (King et al. 2015b). Most phosphorus in surface runoff from agricultural fields is associated with or adsorbed to fine sediments, known as particulate phosphorus (King et al. 2015b; Murphy 2007). Phosphorus can also be in the form of dissolved phosphorus (DP), meaning that the phosphorus is not bound to any particulate matter (Murphy 2007). Total phosphorus (TP) is a measure of all forms of phosphorus, both particulate and dissolved (Murphy 2007). Both DP and TP are referred to throughout this report.

Champlain Valley Farmer Coalition Inc.

The Champlain Valley Farmer Coalition Inc. (CVFC Inc.) is a key stakeholder in understanding the relationship between Vermont agriculture and water quality in Lake Champlain. The group was founded in 2013 as a non-profit that would provide farmers with a unified voice and better address their concerns about the lake's water quality (CVFC N.d). Members of the group include dairy, beef, grain, and vegetable farmers within the Lake Champlain basin, as well as non-farming individuals, businesses, government groups, and other non-profit members (CVFC N.d.).

The official webpage states that the coalition "strives to help farmers in adopting and implementing agricultural practices to improve local farm resiliency and environmental stewardship with the goal of improving and maintaining the ecological integrity of Lake Champlain and its tributaries" (CVFC N.d.). The group seeks to provide member farmers with assistance in the implementation of environmentally-beneficial farming practices, discounts on specific equipment, and networking opportunities with other farmers through farm tours (CVFC N.d.). In addition, the group seeks to take a leadership role in demonstrating that a strong local farm economy and a healthy, clean lake are not mutually exclusive, a goal accomplished through public education initiatives and conversations with the Vermont Legislature (CVFC N.d.). Outside organizations, namely the Champlain Valley Crop, Soil, and Pasture Team of UVM Extension and the USDA Natural Resource Conservation Service of Vermont, have provided key financial and organizational support to the CVFC to help the coalition accomplish these objectives (CVFC N.d.).

Tile Drains

Subsurface tile drainage systems are a particularly important agricultural management practice in the context of water quality concerns in Vermont and the new RAPs, as one of the Clean Water Initiative's objectives is to "evaluate and employ technical, regulatory, and educational options for tile drain management" (VT WMD 2015). Tile drainage systems, also referred to as tile drains, have been used since the 1830s to improve land for crop growth by removing excess water from the subsurface zone (VAAFM and VANR 2016). According to the 2012 Agricultural Census, tile systems currently drain 4.8% of the agricultural cropland in Vermont (VAAFM and VANR 2016). These systems generally consist of slotted plastic tubing buried in a standardized pattern throughout agricultural land (Panuska 2012; VAAFM and

VANR 2016; Wright and Sands 2001). Historically, tile drainage was installed as random tiling or target tiling only in particularly low-lying areas of fields, sometimes called draws (King et al. 2015b; VAAFM and VANR 2016). More recently, however, tile drains have increasingly been installed in grids (also referred to as pattern tiling or systematic tiling) across entire fields (King et al. 2015b; VAAFM and VANR 2016). Once installed, tile drains produce a variety of potential benefits (Panuska 2012; VAAFM and VANR 2016).

Because of these benefits, the USDA encouraged tile drains through technical assistance and subsidized payment plans until the 1970s, when the federal government began to recognize some adverse effects of both tile drains and drainage policy (VAAFM and VANR 2016). Vermont has addressed the need for more research on tile drain usage and best management practices in the context of these environmental concerns and the state's specific agricultural conditions by creating a working group to help develop a report on tile drains for the Vermont legislature (VAAFM 2016a; VAAFM and VANR 2016). The final report, due to the legislature in January 2017, will help inform an amendment process of the RAPs to better address the impact of tile drainage on the state's water quality (VAAFM 2016a; VAAFM and VANR 2016). These RAP amendments will be completed on or before January 18, 2018, as required by Act 64 (VAAFM 2016a; VAAFM and VANR 2016).

While there are a number of previous studies that have researched the impacts of tile drains on water quality, especially in relation to the midwestern United States, there appear to be few conclusive results describing the net water quality impacts when different field management practices are used in conjunction with tile drains (King et al. 2015b). The majority of study results are highly case-specific, underscoring Vermont's need for research specific to Vermont's soil types, sloped topography, and feasible agricultural management practices (VAAFM and VANR 2016).

McKenzie Brook Watershed

Within the Lake Champlain region, various watersheds have been identified as especially harmed or threatened by pollution. The McKenzie Brook watershed (Figure 1)—which encompasses Hospital Creek, Whitney Creek, Braisted Brook, and Stoney Creek—is considered a "priority agricultural watershed" (VT WMD 2015a). Water quality monitoring efforts—including biomonitoring and chemical water monitoring—have determined that within the watershed, samples taken at various locations have been considered as having poor water quality (VT WMD 2014a). The negative effects of agricultural runoff within the watershed add to the degradation of water quality in the southern end of Lake Champlain (VT WMD 2015a).

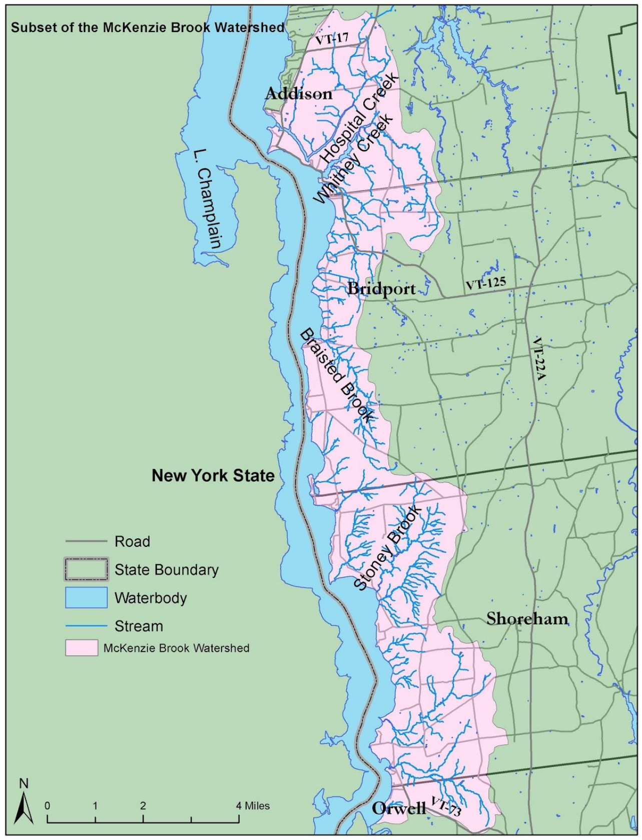

Figure 1. The McKenzie Brook watershed (highlighted in pink) is located to the east of Lake Champlain. Map from VT DWC 2015a.

The University of Vermont Extension has been chosen by the Department of Environmental Conservation (DEC) Ecosystem Restoration Program, the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS), and AAFM to help farmers within the McKenzie Brook watershed (VT WMD 2015a). This assistance includes the evaluation of nutrient management plans, the recommendation of best management practices, and the introduction of innovative methods of reducing nutrient loading (VT WMD 2015a). The McKenzie Brook watershed was chosen as a specific area of focus for this Middlebury College project—especially for the mapping component—because of its status as a priority watershed and the ongoing efforts to improve management practices within the region.

FARMER SURVEY

Survey Methods

The main purpose of the survey component of our project was to collect information on tile drain usage and related water quality perceptions among Vermont farmers, specifically in the context of the tile drain report due to the Legislature next year. Vermont's Subsurface Tile Drainage Interim Report lists the information on tile drains still needed for Vermont, including the amount of tile drains in impaired watersheds, the amount of standpipes in impaired watersheds, the net impact of subsurface drainage and phosphorus loss, and the phosphorus concentrations and outlet flows in Vermont (VAAFM & VANR 2016). Our survey was designed to primarily address the need for information regarding the amount of tile drainage in our study area, as well as how much knowledge farmers have about the placement of these drainage systems. Additionally, our survey focused indirectly on understanding the net impact of subsurface drainage and phosphorus loss by prompting farmers to answer questions about management practices on fields drained by tile systems. This information could potentially be useful in understanding the net phosphorus impact of these drains.

To create a survey that would effectively provide information about regional farmers' perceptions of water quality and tile drains, we worked in collaboration with our community partners at UVM Extension throughout both the design and distribution process. We drafted our initial survey with an emphasis on water quality in the McKenzie Brook watershed and farmers' use of tile drains in this area. Additionally, we used both our community partners' knowledge and information from Vermont's Subsurface Tile Drainage Interim Report to draft the initial survey questions on tile drainage systems (VAAFM & VANR 2016).

After receiving input from our community partners, we revised our survey to more appropriately address their questions. Most importantly, we widened the area of focus within our survey from the McKenzie Brook watershed to Addison County to make it applicable to a larger group of farmers. We also shortened the survey's length to increase the proportion of questions concerning tile drainage. The final survey had 16 questions in total, most of which were framed as multiple choice (see Appendix A).

We distributed our survey on two separate occasions, both of which were events intended for local farmers in which our community partners from UVM Extension had some sort of leadership role. We first distributed our survey on April 7 at a Corn Planter Tune-Up and No-Till Clinic hosted at Monument Farms Dairy. Our community partners introduced our project at the beginning of the workshop and helped us to distribute surveys to farmers throughout the event. Ultimately we collected 9 surveys from this clinic. We distributed our survey again on April 13 at the Champlain Valley Farmer Coalition meeting. We were once again introduced by our community partners, and after a brief explanation of our project, our partners distributed our survey. Farmers were given time during the meeting to fill out the surveys, and we ended up collecting a total of 11 surveys from the event. However, only 10 of these surveys were eligible for our analysis; although we stated that our survey was only intended for farmers from Addison County, one survey was filled out by a farmer from a different part of the state.

To analyze our survey data and create subsequent figures and tables, we used SPSS, Excel, and R. For ranking questions (e.g. Question 5: "Lake Champlain is experiencing substantial nutrient loading and decreasing water quality. Why do you think this is happening?

Please rank the top three causes by writing 1, 2, and 3 in the spaces provided"), we created a coding system in which factors marked as cause number one were given three points, factors ranked as number two received two points, and factors marked as number three received one point. These points were added to calculate a total score for each factor. In a couple of cases where this question was answered incorrectly (for example, the participant checked four factors instead of marking the top three choices as 1, 2, and 3), we eliminated these responses from our data. In addition, several surveys contained blank responses for various questions; we decreased our sample sizes for the specific questions that were not answered. For question 14, which read, "Please select up to three potential advantages to using tile drains," as well as question 15, which was framed identically except instead asked about disadvantages, we simply tallied the number of times each advantage or disadvantage was selected. Two survey respondents selected more than three potential advantages in question 14; we included all selected answers in the final tallies.

Survey Results

We received and analyzed 19 surveys from farmers within Addison County. Our survey respondents included two farmers from small farms, 12 from medium-sized farms, and four from large farms. Respondents likely classified their farm sizes based on the size definitions created for the new RAPs: for example, in regards to livestock, small farms have 20-199 cows, medium-sized farms have 200-699 cows, and large farms have 700+ cows (VAAFM 2015). The majority of the respondents (14 of 19) farm livestock, and 11 respondents grow field crops. Four respondents selected 'other' in regards to what type of farm they operate; of these, two specified by writing "dairy" and one respondent wrote "rented land."

When asked about how they would characterize current water quality in Lake Champlain, most participants selected 'Poor' or 'OK' (7 respondents each) (Figure 2). No respondents selected 'Very poor.' Similarly, when asked about water quality in Addison County, respondents were varied in their responses but did not choose 'Very poor' (Figure 3). The most common answer was 'OK' (9 respondents).

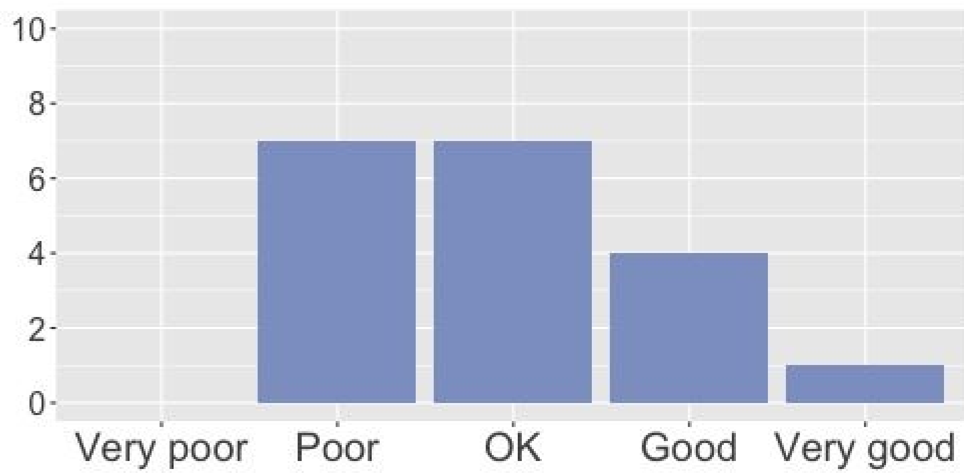

Figure 2. Responses from farmers in Addison County, VT, in regards to the question: "How would you characterize current water quality in Lake Champlain?" (n=19).

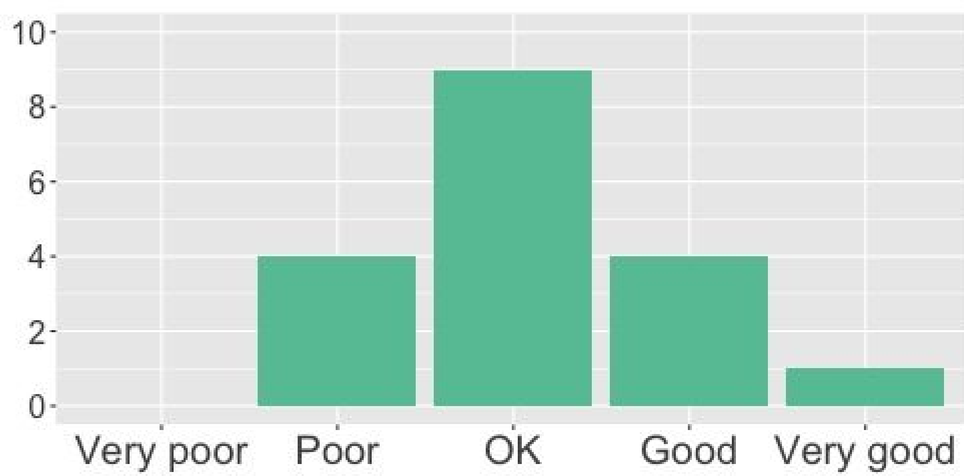

Figure 3. Responses from farmers in Addison County, VT, in regards to the question: "How would you characterize current water quality in Addison County?" (n=18).

Our survey also asked participants to rank various factors contributing to nutrient loading and decreasing water quality in Lake Champlain. In total, respondents selected 'wastewater treatment facilities' as the greatest cause (31 points using our coding system) (Figure 4). The other most prevalent responses were 'runoff from farmland' (27 points) and 'runoff from urban areas' (25 points). 'Nutrients from wetlands' did not receive any points. Three respondents selected 'other' and wrote, "lakeshore homes," "old septic in camps," and "Lake Champlain has historical nutrient loads in the lake bottom, which is constantly disturbed due to wind and wave action."

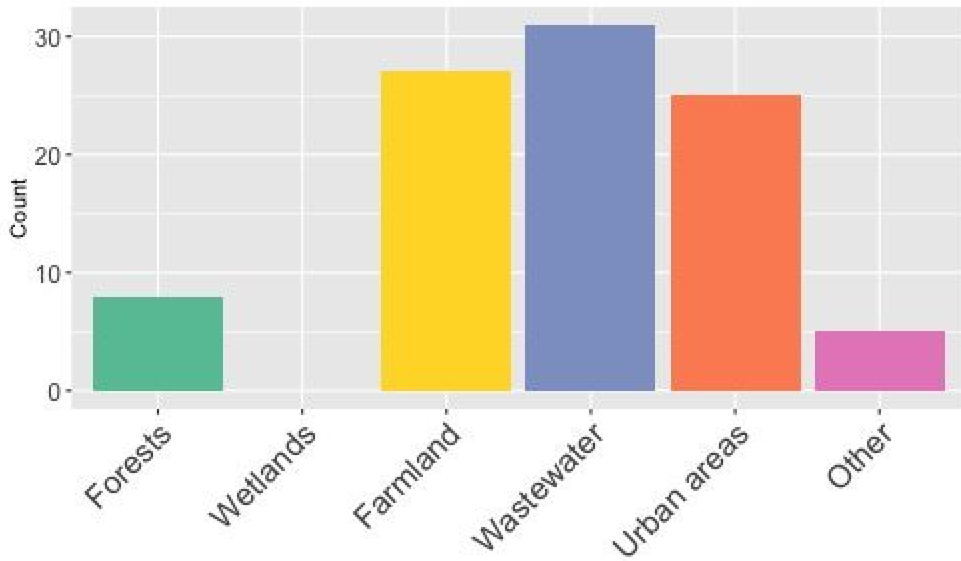

Figure 4. Responses from farmers in Addison County, VT, in regards to the top three causes of nutrient loading and decreasing water quality in Lake Champlain. Points were calculated using a ranking point system (n=16).

Of the respondents who answered our questions about tile drainage systems, 7 indicated that they had tile drains on their farms and 11 indicated that they did not. All of the farmers from large farms had tile drains, whereas the majority of farms from medium-sized farms did not have tile drains (Table 1).

Table 1. Distribution of farm sizes and presence of tile drainage systems. Data were collected from a survey administered to farmers within Addison County, VT (n=18).

	Tile drains	**No tile drains**
Small farms	1	1
Medium farms	2	10
Large farms	4	0

Several of our survey questions pertained solely to farmers with tile drains. Of the respondents with drains, six indicated that they had system grid tile and four indicated that they had runs and draws. All indicated that the approximate depth of their tile lines was between 3 and 5 feet. Six participants stated that they know the specific location(s) of the tile drains on their farm fields as well as the specific tile outlet location(s) on their farm, while one participant indicated that they know the tile drain locations ‘somewhat’ and that they do not know the specific tile outlet locations on their farm. All respondents with tile drains stated that they know which immediate stream or surface water their tile drains into. Five participants stated that they do not follow different management practices in their fields with tile drains versus those without. The two participants who indicated that they do follow different management practices explained by writing “tillage and harvest” and “more yield with less inputs.” Six respondents indicated that the locations of their tile drains do not impact how they choose to spread manure or fertilizer, while two stated that they did have an impact; one of the ‘yes’ respondents added, “saves manure nutrients.”

When asked to select up to three potential advantages to using tile drains from a list of answers, respondents most commonly chose ‘increased crop yields’ (16 respondents), ‘benefits to soil health and structure’ (15 respondents), and ‘reduced surface runoff’ (10 respondents) (Figure 5). One participant selected ‘other’ and wrote, “cropping entire field.”

When asked an identical question about potential disadvantages to using tile drains, respondents most frequently selected ‘pressure from the state against installing tile drains’ (10 respondents) (Figure 6). The responses ‘negative impacts on water quality,’ ‘difficulty of installation,’ and ‘loss of phosphorus and nitrogen from fields’ were each selected by five respondents. Two survey participants selected ‘none,’ and one participant selected ‘other’ (“high initial cost”).

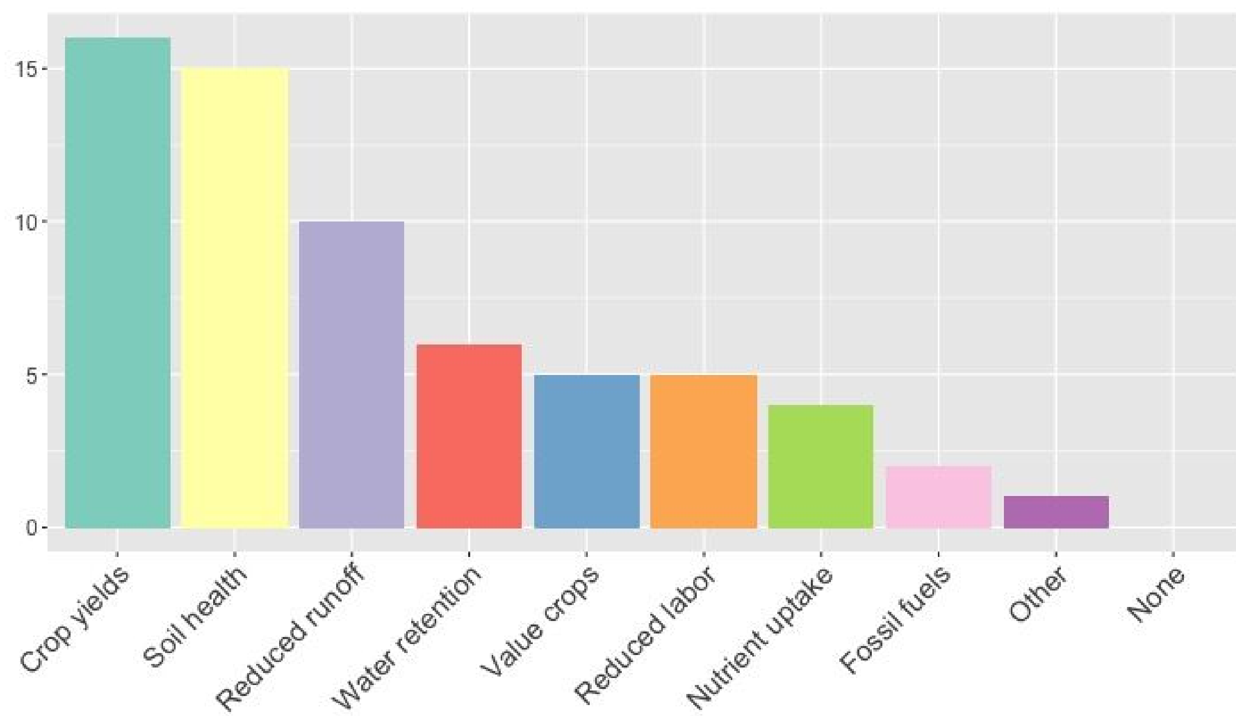

Figure 5. Responses from farmers in Addison County, VT, when asked to select up to three potential advantages to using tile drains (n=19).

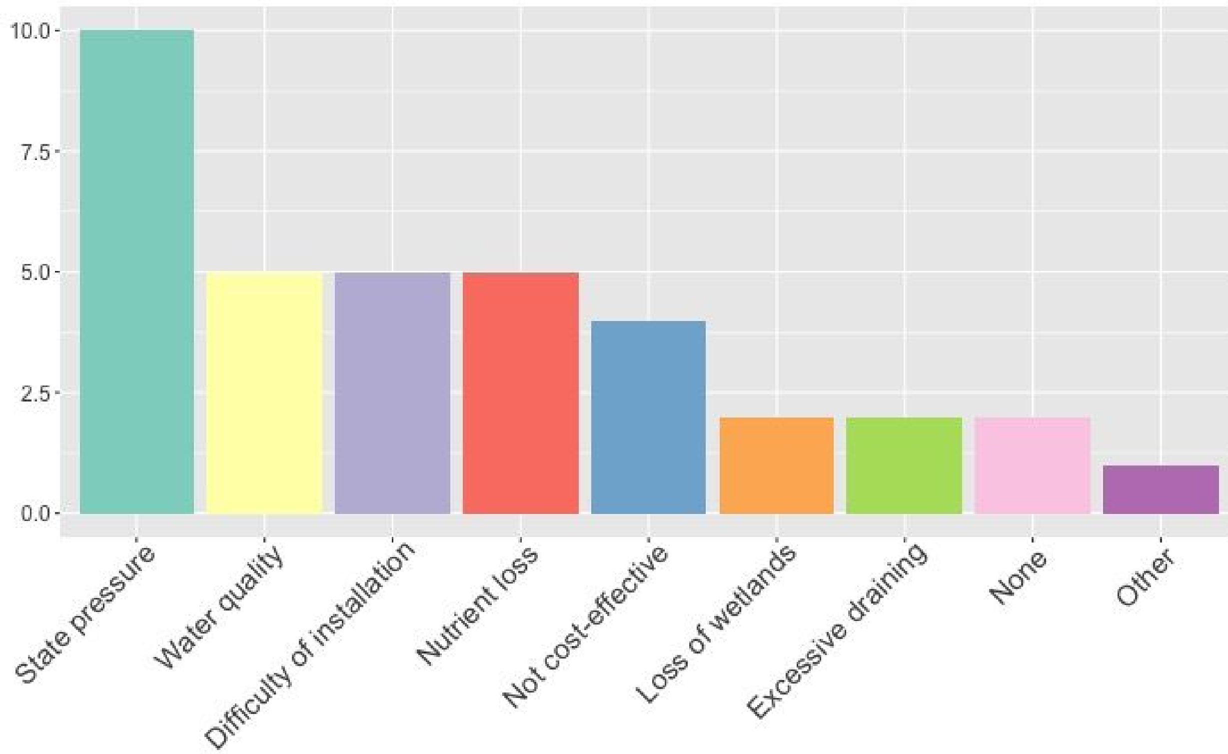

Figure 6. Responses from farmers in Addison County, VT, when asked to select up to three potential disadvantages to using tile drains (n=19).

Our last survey question asked, "If you do not already have tile drains, are you planning on installing tile in the future?" Seven respondents selected 'yes,' five selected 'no,' and three selected 'I already have tile drains.' One respondent created a new answer and wrote, "Maybe—depends on future regulations."

INTERVIEWS

Interview Methods

We conducted interviews either over the phone or in person and contacted farmers at or after the March 10 ACORN Producer and Buyer forum, the April 7 UVM Extension Corn Planter Tune-Up and No-Till Clinic, and the April 13 Champlain Valley Farmer Coalition meeting. We also contacted some farmers independently based on previously established relationships with members of our team and selected additional interviewees based on research about relevant organizations. In total, we conducted seven interviews with farmers: three organic vegetable farmers, three conventional dairy farmers, and one conventional biofuel producer. We also interviewed Eric Howe from the Lake Champlain Basin Program. For our farmer interviews, we asked each interviewee for permission to use the information from their interviews to create a case study describing their practices and perceptions; we explained that these case studies would not include the name of the farmer or the farm. We received consent from each interviewee. For our interview with Eric Howe, we received permission to include his name in our report.

Interview Results

Case Study 1

Farmer 1 grows about 7 acres of perennial crops on a certified organic farm in Addison County. In total, he owns approximately 50 acres of land with a sandy soil and subsoil. His farm is not located near any major streams or tributaries of Lake Champlain, but it is adjacent to a swampy area that constitutes the closest water body.

In our conversation with Farmer 1, he explained that a focus on environmental conservation and stewardship is central to the management of his farm. As a certified organic grower, the farm follows all of the practices outlined in the organic standards of Vermont. Among these, Farmer 1 highlighted that he does not spray anything toxic to either bees or mammals on his land and emphasized that he tries "to maintain a high level of beneficial life in [their] soil and on [their] farmland." He explained one particular instance when a killdeer nested in one of his fields during last farm season; he elaborated about how the farm "adopted" the bird by placing a stake near the nest location after they found it so that it could be easily avoided during tilling.

Following this ethic of environmental conservation, Farmer 1 spoke about his practices specifically in relation to water quality. He explained that the soils on his farm are tested "all the time," and because of his knowledge of the "out of control" soil phosphorus levels in many other parts of Vermont, he has never added phosphorus to his soils. Instead of adding nutrients on a regimented schedule, the need is determined based on soil testing results. He stressed the importance of adding nutrients only in the quantities that are needed because, "eventually, things make it from here into the lake." In keeping with this awareness, Farmer 1 explained the reasoning behind using soymeal as their main added nitrogen source: it is not immediately soluble and therefore prevents a "big runoff, during a big storm, of nitrogen into the water source." Additionally, Farmer 1 manages his land to avoid erosion, which he described as one of the greatest challenges to his farm aside from the standard pest and disease concerns. His land is located on sloping property, so he has tried to prevent erosion first by frequent use of mulching and second by cover crops, thus trying not to leave land bare whenever possible.

When asked to speak specifically to water quality, Farmer 1 explained that he has not seen any major challenges in relation to water quality and his management practices. He is aware of Act 64 and the required practices it outlines, and his farm has already been operating within the framework of these practices and standards. As such, his farm will not make any changes or be impacted directly by the Act. As he explained to us, he has a botany degree and studied conservation biology specifically, so much of Act 64 is focused on concepts and concerns that he had already been thinking about. He highlighted specifically that he has a good understanding of the ties between farming practices, high phosphorus levels in Vermont soils, and algae blooms in Lake Champlain, and that these are not new ideas to him. In addition, Farmer 1 shared his personal opinion that the practices outlined in Act 64 were primarily written for the dairy industry, but that no one wanted to single them out among other Vermont farmers.

Finally, we asked Farmer 1 to tell us about his experiences with tile drains, which he uses on one field where a rock ledge beneath the soil surface results in a seasonal wet patch where water cannot percolate through the soil during heavy spring rains. He explained that the use of tile drains leads to a dry, usable field where otherwise there would be a wet spot, leading to higher risks of disease, greater pressure, and rotting of crops. His tile drainage system is not important for season extension purposes because of the sandy soils on his farm, which allow water to percolate quickly, getting him onto his fields as "early as you can get in Vermont." With the tile drained system, he is able to and does use the same agricultural management practices on this field as on his other, non-tile drained fields. Farmer 1 expressed his satisfaction with the benefits of his tile drains, and has not seen any downsides. He explained that tile drains should have no negative impact on water quality if installed well, but that installing tile drains on steep hillsides can lead to problems.

Case Study 2

Farmer 2 grows sweet potatoes on a certified organic farm that is approximately 40 acres in size. Although his farm is not located within the McKenzie Brook watershed, his perceptions about management practices and water quality regulations were insightful for our project.

Farmer 2 acknowledged that there is a gap between his current management practices and ideal conservation practices. He discussed how many organic and small-scale farmers must compromise because they struggle with meeting environmental regulations and are limited financially. Currently, he has buffers on his farm that he extended from 10 to 35 feet when purchasing the farm, in part to comply with the Vermont Land Trust and other state and federal organizations. He has planted trees as well as highbush cranberry and elderberry in these buffers. He also uses cover crops, rotating annually between cash crops and cover crops. He finds that especially because he has an organic farm, he cannot grow crops continuously in one field. While he tries to cover soil as much as possible, he has to allow for a six-week fallow period. Other conservation practices on his farm include contour tillage and following contours when laying down plastic.

While these practices are environmentally beneficial, they can also be financially problematic to farmers. For example, buffer zones decrease the amount of land suitable for growing crops; Farmer 2 estimated that half of his farm is actually suitable for growing sweet potatoes and thus these buffer zones remove a significant amount of land from production. He guessed that over the course of the next 20 years, he could lose $40,000 of profit because of this decrease in production resulting from increased buffers.

Despite these financial setbacks, Farmer 2 was fairly supportive of regulations, stating that although farmers and regulators have known for several decades that agriculture can cause ecological harm, farmers have been exempt from labor and environmental standards, and "poor farming practices have gone on for too long." He expressed his environmental ethic and belief that "we're all in this together."

When asked about Vermont's Act 64 and the updated Required Agricultural Practices (RAPs), Farmer 2 expressed concerns about being able to keep ditches up to standard, as well as about the potential need to acquire a permit for installing tile drains.

Although Farmer 2 does not currently have tile drains on his farm, he answered several questions about the practice of using drains. He listed getting an earlier start to the season and ensuring drier crops during a wet season as major benefits for potentially installing tile. He named the possible need to obtain a permit as a drawback to installation. Currently, Farmer 2 is considering draining his fields this year to avoid the permitting process in the future. While Farmer 2 acknowledged that programs such as the Environmental Quality Incentives Program (EQIP) do not cover the cost of tile drains, he recognized that tile drains are fairly cost-effective and affordable, costing less than the price of purchasing more land.

In regards to tile drains and water quality, Farmer 2 did not think there was any evidence of tile drains improving water quality, especially if drains empty directly into a body of water; water-soluble nutrients would enter directly into streams. If he were to install tile drains on his farm, he would place the outlets in grassy areas or ditches to provide buffers before the water entered a stream.

Farmer 2 is enrolled in the EQIP program as well as a Current Use program (to decrease taxes on agricultural land). He receives reduced tax rates, which is a significant reduction, cutting his taxes nearly in half. Farmer 2 also has a forestry plan for his land, as his farm includes both field and forest with wildlife present.

Case Study 3

Farmer 3 has spent over 30 years working on a commercial, certified organic vegetable farm in Addison County. In total, the farm is approximately 84 acres, but much of the land is rented to an organic dairy farm. In any given year, only about 12 to 15 acres are in use for the vegetable operation; the best land, with loamy soils, has been chosen for this purpose. In addition, the farm has a couple of greenhouses for growing flowers, herbs, and hanging baskets, among other things, mostly to retail in the spring. Beyond selling direct from the farm, mainly in the spring with greenhouse plants, the farm sells wholesale to stores and restaurants in the area and has a small CSA of around 30 members.

Farmer 3 described three primary management practices related to nutrient cycling and conservation: crop rotation, composting, and cover cropping. First, Farmer 3 explained that he rotates his crops across his vegetable fields so that the same crop is never in the same field for two consecutive years. The farm strives for a four to five year rotation of families of crops in order to best avoid pest and disease problems. Additionally, vegetable crops are rotated across fields; ideally, vegetables will be grown on any given field three years out of five, with clover or a sod crop grown on the odd years. Farmer 3 stated that in reality, vegetables are grown on any given field four years out of five.

Secondly, Farmer 3 explained that the farm's fertility plan centers on compost. Typically, 10-15 tons of compost per acre are spread on the fields in the fall. In terms of timing, compost management is closely tied to cover cropping practices on the farm. Farmer 3 described that ideally, compost would be spread before cover crops are planted so that the nutrients are incorporated by the cover crop, but often the timing becomes difficult and cover crops are planted in September or October before the compost is spread.

In terms of cover cropping, Farmer 3 shared his personal philosophy, "green is good and brown is bad," to explain that he would like to see brown earth as little as possible to prevent erosion, along with other problems. The farm's cover crop practices consistently involve planting winter rye or winter wheat on as many acres as possible because of the plants' abilities to "mop up" and incorporate excess nutrients, particularly nitrogen, so that they don't leak out during the winter. Additionally, Farmer 3 described that they consistently sow hairy vetch, a legume used for its nitrogen-fixing capabilities, into the winter squash during the summer so that a cover crop is established on fields that would otherwise be difficult to seed after squash is harvested in the fall. As appropriate, the farm uses buckwheat or oats for cover crops, for instance on fields that require a fast turnover time between cover crop and vegetable crop. Farmer 3 also mentioned that his land may not currently be getting the most benefit from cover cropping, as the plants are plowed under before getting very large due to equipment requirements and moisture problems. Because of the amount of tilling needed over cover crops and in general, he also explained that he would classify most vegetable operations as intensive tillage, although the period of tillage is generally very short and most fields are green for many months of the year.

When asked about primary challenges on the farm, Farmer 3 listed labor, pests, weather, and disease. He also elaborated on the complexities of being driven by the markets, describing how challenges have increased as more people have gotten into the vegetable business. When prompted specifically about challenges in relation to Act 64, Farmer 3 described that although the farm has not yet faced specific challenges as a result of the Act, he expects to when the final rules are written. His two largest worries were 1) the need for compliance and 2) the need for a nutrient management plan. First, Farmer 3 expressed his concern that he will need to document his compliance and that even if he is following all of the required practices, there could be a violation if he does not document correctly. He explained that he is already following the RAPs surrounding erosion, drainage ditches, and deadlines for planting and adding nutrients, so the "compliance piece" worried him more than any of the practices specifically. He noted in addition that he has a problem with this likely because he has been farming long enough to remember a time when he did not have to document, unlike newer farmers who may have less of a problem because they have not known anything different.

Second, Farmer 3 explained that creating a nutrient management plan may be a concrete challenge for the farm. He explained that while he has talked with agronomists and has regular phosphorus testing done on his soils, he will likely face challenges managing nutrients, specifically phosphorus. Historically, Farmer 3 has been doing a "seat of the pants" application, and a nutrient management plan will require him to be a "little more scientific." In addition, he explained that because vegetables do not use a lot of phosphorus, applying compost to his fields on a regular basis in some ways means adding phosphorus over time; he described how the net effect of a vegetable farm is to have a net excess of phosphorus due to the small amount taken up by plants and taken off the field during harvest. This will present a challenge because the current draft of the RAPs states that compost or manure cannot be applied to soils with over 20 ppm of phosphorus; this is a problem given that compost "energizes soil" and is good for soil microorganisms aside from being a source of small amounts of phosphorus.

Farmer 3 has tile drains in a systematic grid on about 15 acres of fields, about 10 acres of which are hay fields. The farm installed tiles around 15-20 years ago because the soils were not well-draining sandy loams, meaning that water would pool and sit in the soils for a long time. The primary reason for installing tile drains was to be competitive with early markets by getting snowmelt and other water off of the fields as early and quickly as possible in the spring. Farmer 3 said that the tiles definitely make a difference and have worked well over the years. However, he has also seen one main drawback: the farm is geographically located in a "rain shadow," so during dry years when many storms pass by the farm, the tiles work against them. Essentially, the tiles make the dry years really dry, but this is the only downside Farmer 3 has seen. In terms of management practices, Farmer 3 explained that he does all the same things on tiled and non-tiled fields, with the only difference being that everything is done a few weeks later on non-tiled fields.

When we asked Farmer 3 about his perceptions on tile drains and water quality, he explained how his perceptions and concerns have changed over the years. In the past, the original concern with phosphorus had to do with phosphorus bound to sediments, so he used to think that if he could control erosion he would not be contributing to the problem. Lately, he has been learning more about phosphorus that is suspended in water, and this has prompted him to talk to UVM Extension about taking samples at the outflow of his tile drains in order to start creating a baseline idea of whether or not phosphorus is being leached out. His understanding as he explained it to us is that in some cases tile drains seem to turn a nonpoint source situation into a point source situation, similarly to the way a septic pipe from a factory may be classified, although he knows that not everyone agrees. On his farm, much of the tile currently drains into his irrigation pond and thus stays in a relatively closed loop on his farm, although he acknowledged that some fields drain into a ditch and may eventually end up in Lake Champlain.

Case Study 4

Farmer 4 owns a conventional, 1,800-acre dairy farm that has been in his family for many decades, starting with his grandfather in 1947. The farm began with only 50 cows, but today the farm has over 1,000 cows, 600 of which are of milking age. Farmer 4 has belonged to a co-op that sells to Agri-Mark and Cabot since the 1980s.

In regards to specifics about Farmer 4's dairy production, the cows produce 48,000 pounds of milk per day. Last year, the farm produced 16 million pounds of milk. The farm uses artificial insemination and has year-round calving. The cows consume approximately 180 pounds of feed and 55 pounds of water (from the city water supply) each day.

Farmer 4 has said that he is "a cow guy" and prioritizes cow comfort; he is aware that happy and healthy cows are necessary for production. One example of this emphasis on comfort is his use of sand—the "gold standard of cow comfort"—for cow beds. When first switching from sawdust to sand, he noticed an increase in cow comfort within days. While other farmers might worry about the downstream effects of the sand, Farmer 4 wants to prioritize his cows. In addition, Farmer 4 is careful not to relocate cows to other barns too often, as he does not want to create excessive physiological or social stress. Farmer 4 also promotes cow health by letting calves spend lots of time outdoors.

In the last five years, Farmer 4 installed a liquid manure storage system that can hold three million gallons of manure. The manure is stored and transported to fields when needed. The sand from the beds eventually enters the manure storage and may be beneficial for soil health. The farmworkers spread about 5% of the manure themselves; Farmer 4 contracts in work to spread the majority of the manure. Most of the manure is injected into the soil through a hose.

Farmer 4 also grows hay and corn on the farm and imports grain. The farm produces 55% of the feed for its cows. In the summertime, Farmer 4 also sells sweet corn at a farmstand.

When asked about Act 64 and the RAPs, Farmer 4 stated that he does not think that the state's regulations are unreasonable, as they are simply environmentally conscious. He said that while some farmers might be concerned that the regulations could harm crop production, he did not believe that to be the case, and if anything, the required practices could be beneficial to crops. He would implement the practices even if they were not required. He believes that small-scale farmers are most upset by the new regulations. His farm is considered medium-sized, and he does not want to expand to avoid being considered a large farm in regards to state regulations.

Farmer 4 has previously enrolled in EQIP, which he believes is a "great program." Through EQIP, the state has provided $300,000 for environmental projects. One of these projects was the installation of a leachate system, in which extra moisture from crops drains out into his manure pond. Unfortunately the system waters down nutrients in the pond during heavy rains (he admits a better design could probably be created), but the state funding was beneficial. The money from the EQIP program was also used for manure pits and new machinery.

Although Farmer 4 has not installed any grid tile, he does use some tile drainage on select fields to create more usable land in the spring. He does not plan on installing grid tile because of the high initial cost of installation. He believes that grid tile might also change soil composition over time.

In addition to our main interview framework, Farmer 4 provided interesting insight into conventional farming, the dairy industry, environmental concerns, and his work ethic. He spoke with us about the differences between conventional and organic farming, naming antibiotics as one distinction between the two. While organic dairy farmers do not use antibiotics for sick cows, conventional farmers do; however, Farmer 4 estimates that only 3 out of his 600 cows are given antibiotics each day. He believes that conventional farmers are scrutinized too much, as antibiotics are not problematic. He also stated that while organic farmers strive to "feed their neighbors," conventional farmers' goal is to "feed the world"; these two types of farming fill different niches. In addition, Farmer 4 expressed that if organic agriculture were to take over, crops would be more prevalent and cows would not be out in pastures as much. He thinks that conventional agriculture keeps the Vermont landscape looking good.

In reflecting on his farming priorities, Farmer 4 listed his main concerns as 1) profit, 2) environment, and 3) people. Profit varies greatly from year to year, but he is "in it for the long haul" and does not wish to sell the farm. His main concern about profit and economics is the globalization of the industry. China especially is a large exporter of dairy products. When the US dollar is strong, milk prices seem expensive to countries such as China, so instead they turn to Europe or New Zealand.

Farmer 4 also addressed various environmental concerns including water quality issues. He acknowledged that his farm is a large space with a big footprint. In addition, his farm is located very close to Lake Champlain, and as a result he must maintain a buffer near the lake because of the Lakeshore Protection Act. In general, he has experienced an increase in lake protection since his childhood. While his cow barns are now located farther away from Lake Champlain, they were initially kept in a barn closer to the water. After changing barns and moving his cows away from the lake, Farmer 4 noticed improvement in water quality and decreased plant growth in the water near his property. Yet while Farmer 4 is environmentally conscious, he wonders if Vermont's lead in the environmental movement has been too aggressive.

Farmer 4 has a strong work ethic, which he claims he inherited from his mother, who also still works on the farm. He believes that he and other existing dairy farmers are good at what they do, as dairy farmers can only survive the low milk prices and competitive industry if they are good at their jobs. He also stated that his job is multifaceted. He was very willing to speak with us, as he believes it is his responsibility to educate others about his farming. He spoke proudly of his career, farm, and heritage, highlighting the importance of family. He grew up on the farm and later raised his five children there; he considers himself lucky that his children might someday continue the business.

Case Study 5

Farmer 5 works on a medium-sized, conventional dairy farm in Addison County. His grandfather and parents started farming in New Hampshire with 23 cows, 14 of which were milking, and moved to Vermont when Farmer 5 was a teenager. Since then, the operation has grown to the 600-cow farm that it is today. The farm is classified as a medium-sized farm, and encompasses around 1,300 acres of owned land and 3,000 acres of land in total (both owned and rented). Today, Farmer 5's children help on the farm in addition to working for their own farming-related business.

When asked about his main farming practices, Farmer 5 explained a variety of management practices with which his farm has been experimenting and, it seems, finding to be very successful. First, the farm started using cover cropping last year on approximately 120 acres of land and found that it worked especially well with no-till practices. They planted into the hay stubble and then sprayed Roundup to prevent the grass from regrowing. Farmer 5 said that this land then yielded around 24 tons of corn per acre, and he expressed his extreme satisfaction with these results. Second, Farmer 5 explained a variety of manure management practices, the first of which was a system involving a home pit, into which manure drains throughout the year, and a remote pit, into which the contents of the home pit are pumped about once a year. From the remote pit, the manure is spread using a draghose or is spread on another piece of land owned by the farm. The farm also has a manure pit behind two of the barns, from which manure is spread using a draghose. Farmer 5 explained that the benefits of a draghose include less ground compaction as well as increased efficiency, which helps with the farm's overall attention to being cost-conscious.

In addition to these practices, Farmer 5 said that the farm is planning to inject manure on 40 acres of land this year. He explained the process of aeration to us by describing how the land looks like a pincushion after the process is complete; if manure is spread within the next 24 hours, the holes fill up with manure, which prevents runoff. He cited a current study being done by the state and federal governments in which monitoring stations have been installed on two very similar fields, one using aeration and one not using the practice. He told us that the case study is in its third year so far, and so far the results seem promising.

Farmer 5 described getting nutrients into the ground as one of the farm's main concerns because, as he said, spreading manure is a waste of time and money if the nutrients run off. He was also very aware of concerns surrounding water quality and expressed that the farm shares these concerns to a large degree. He explained that the main farm is bordered by a brook which then flows into a creek which then flows into Lake Champlain, so water quality is one of their largest concerns. The farm has trees along these stream banks as well as fences to keep the heifers out of the stream. He also referred to the connection between his farm's location and water quality by explaining how his farm is "in the spotlight" because of its position along a major roadway where "tons of cars go by everyday." He feels that the community in general knows what farming practices "look right," which adds another layer to the importance of best management practices on his farm. For instance, he explained that people understand that spreading manure on snow is not a good practice, even when it snows after the legal first date to being spreading; he said that whereas other farmers around the state might be likely to spread when it is legal regardless of snow conditions, he knows it is wrong and the community would also recognize it as wrong if his farm were to spread manure.

Farmer 5 explained that although his farm has always been conscious of water quality issues, they will face some serious challenges in complying with the new RAPs as outlined by Act 64. The farm is currently enrolled in EQIP and has eight grants open, although he would like to have more. He explained that the farm will have to be more conscious of every rule and regulation and will have to be more vigilant in order to meet RAP standards. For example, he explained that while he has previously had manure trainings done on the farm, he is going to have more trainings so that everyone on his staff understands exactly what they can and cannot do under the new regulations. They will also have to be more vigilant about record keeping, which Farmer 5 explained as "one more hoop they'll have to jump through," as he feels the transition to the new system will present challenges.

Overall, it seems that Farmer 5 expressed two main concerns with Vermont's new Clean Water Act: the importance of common sense in formulating the new standards and the fines if these standards are not met. Farmer 5 explained that in terms of setting the new RAPs, "some common sense has got to go into it," citing specifically the example of defining what constitutes a ditch. He feels that within the RAPs, there are some vague definitions. He also explained that he feels that the farmers are doing the best they can and that the RAPs make him feel like someone is constantly "looking over your shoulder at every turn"—a feeling that he does not like and does not think is productive. Along this line of thought, Farmer 5 seemed most concerned about the fines that will be established with the finalized version of the RAPs. He has heard from state representatives that some fines may be close to $50,000; he thinks that an attitude of working together would be more effective than using fines to punish farmers who are not in compliance. He expressed his personal opinion that "we're all in this together" and stated that he thinks that if the state adopted this attitude more fully, more farmers would "do better" with the new regulations.

Lastly, we asked Farmer 5 about tile drain usage. Although the farm currently does not have tile drains, he expressed serious interest in installing some on the wetter fields on his farm. He described the main benefits of tile drains as producing drier fields, which allows them to be worked earlier in the spring. Reduced wet spots and earlier planting would lead to more production. However, he expressed a variety of concerns regarding costs of tile. First, he said that his main concern is the high initial cost of installing tiles, which can cost up to $3,000 per acre. He also understands the state to be "dead set against tiles," and he worries that the state might prohibit the use of tile drains (for instance, by blocking their open ends), in which case he will have wasted a large amount of money if he installs them now. Farmer 5 is aware of the current studies being conducted by the state and expressed his personal interest in seeing the state's results because they could either be "really exciting" or "really depressing." He also expressed his own concerns over the highly concentrated water coming out of tile drains, although he personally feels that water coming off of fields from one (or a few) concentrated areas will be easier to treat than water widely running off of a field in multiple places.

Overall, Farmer 5 viewed tile drains positively as "another tool we can all use, if we're allowed to do it." He feels that they are something the state ought to at least be looking at in terms of options to help farmers manage their land; he told us that in his opinion, the best thing for the state and federal government to do would be to help farmers cost-share tile drainage along with other management practices to see that they get done in ways that are beneficial. As for his farm, he explained that the milk prices are too low this year to make tile drains a realistic investment, but he is definitely starting to think about it.

Case Study 6

Farmer 6 owns a dairy farm that was started by his grandfather in 1931. Together with his brother and cousin, Farmer 6 makes up the third generation of the farm. The fourth generation—including his son and nephew—are now also getting involved. The farm has expanded over time and processes its own milk. In total, the farm comprises 2600 acres, although some of this land is forested and thus is not usable as pasture. The farm has approximately 1200 cows.

Specific management practices on the farm include manure spreading through a hose; because the manure is mostly liquid, it can be transported and pumped over 2.5 miles through the hose. Farmer 6 also uses a methane digester, which can hold 600,000 gallons of manure and which is used to produce their own electricity. In regards to crops, Farmer 6 uses two- and four-year crop rotations. While Farmer 6 has used conventional tillage in the past, he is trying a no-till practice for the first time this year. He expressed that conventional tillage can be somewhat problematic when using cover cropping. Whereas conventional tillage necessitates the use of herbicides such as atrazine, no-till tends to require the application of Roundup, which is limiting when purchasing seed. This limitation is an issue for Farmer 6, as he does not want to purchase "Roundup-ready seed"; customers sometimes call the farm to ask if they use any GMO products. Because these seeds are genetically modified, Farmer 6 does not want to utilize them so that his products appeal more to customers and can be considered GMO-free. If he does continue to use a no-till method, he hopes to find an alternative to Roundup for this reason. When asked about the state's encouragement of no-till practices, Farmer 6 reasoned that the state would rather have farmers use Roundup than have increased soil loss from tillage. He agreed with this, stating that Roundup is not incorporated into soils and is thus less harmful.

Farmer 6 also discussed other challenges to his farming, including the changing of weather patterns. Labor is another challenge, as are milk sales; "people are drinking less milk." He also named input costs—such as purchasing sawdust—as a difficult aspect of his farming.

When asked about Act 64 and the RAPs, Farmer 6 expressed that in general, he is in favor of the RAPs. He has been part of a group that has argued with the state about the required practices. He also expressed some frustration with certain changes resulting from Act 64. He listed buffers as a large challenge, as they decrease productivity. While he cannot spread manure in the buffers, he can plant some crops and treat the buffers as grasslands. Because of the size of his mower, his buffers will be 30 feet wide. His farm is just barely considered medium-sized instead of large; he is glad about this distinction because of the regulations associated with these different farm size designations. Farmer 6 also discussed his nutrient management plan, which is such a large document that it is somewhat impractical for daily use. Because of the new RAPs, Farmer 6 will have to provide more notes and record keeping; for example, he will document daily conditions as well as information about field-specific crop yields. While Farmer 6 believes that the state should educate farmers, he also thinks that there should be more trust in farmers to do the right things. He believes that in general, most farmers are complying with standards.

Farmer 6 has participated in several state-funded programs. In the 1990s, he became particularly aware of the need to find funding sources. He has participated in a four-year manure spreading program, minimal till and cover crop programs, and an EQIP diversion ditch project. The state also paid for $1,000 for his nutrient management plan, which in total cost about $5,500.

In regards to tile drainage, Farmer 6 is not planning on installing any new tile. Several of his fields contain tile drains. Some of the land that he purchased was tiled in the 1940s with clay tile. In addition, he has installed some tile drains within the last 20 years to drain wet areas; these zones comprise single lines on their own and are sometimes located near ledges. Farmer 6 uses the same management practices on fields with tile as those without. He has several concerns about tile drainage, especially in regards to water quality: he is concerned that nutrient runoff will pollute waterways. He is aware that the manure he spreads is mostly liquid and that the water from his farm and tile drains will eventually enter into a waterway.

Case Study 7

Farmer 7 opened with a poignant punch line, asserting that "everything [he does] is sustainable, because if it wasn't, [he] wouldn't be here [for] very long"—words that bring to light the high stakes and thin margins confronting Vermont's farmers. His simple yet sobering statement testifies to the fact that, while farmers are necessarily attentive to short-term and day-to-day demands, they cannot afford to lose sight of the long-term vision and viability of their business model.

Time was a common thread throughout our interview, as Farmer 7 not only reflected on the historic and familial roots of his farming philosophy but also extrapolated into the future; much of his anxiety about Act 64 was anticipatory, and he offered a bleak prognosis of where Vermont agriculture is headed under current policies. “I’m afraid these RAPs are just kicking a can down the road,” he said. In the end, he predicts, the new legislation will be counterproductive and could ultimately compound the issue of water quality. And yet in spite of his skepticism, Farmer 7—when prompted—had no trouble envisioning a future in which real-time data, hard science, and advanced technologies combine to make farming an (economically) easier and more eco-friendly enterprise in Vermont.

When his father passed away in 1973, the interviewee took the reins and inherited an operation that, since its inception in 1958, has gone through various iterations (for example, at one point it was a dairy farm). Currently, Farmer 7 focuses on cultivating around 450 acres of #2 Flint corn and soybeans on his property, which is situated just north of the McKenzie Brook watershed. While he processes and sells the corn as an in-state heating fuel, the soybeans, he says, are harvested for the international grain market. The precise size of his business model remains a mystery, however; when asked to which size category his operation belongs, he provided a non-committal answer: “smaller than some, larger than others.” It is worth mentioning that his cryptic response is not the first that we have heard—several other interview subjects have also suggested that, in reality, farm size is more nuanced and fluid than the state’s narrow classification system allows. “Where do you want to draw the line between small, medium, and large? It’s kind of subjective,” he concluded. Ultimately, ambiguous (and, as some would argue, arbitrary) farm categories are not merely a source of confusion; they are also consequential, because size classification—at least in part—determines the degree of regulation and inspection that farms can expect to receive under Vermont’s new Clean Water Act.

Despite the myriad complexities and challenges that farming entails, our interviewee seemed able to summarize his methodology with a simple mantra: first and foremost, maintain a closed loop. “I’ve always viewed it as a cycle,” he affirmed, and then went on to explain that his approach to harvesting, animal husbandry, and manure application is premised, in brief, on preventing inputs from leaving the (local) agro-system. There were multiple instances during the interview when Farmer 7 reiterated that drainage ditches were a core component of his nutrient management strategy because they effectively curtail the velocity and volume of runoff, which, in turn, contains phosphorus and facilitates water infiltration. Although obstruction was clearly a favored tactic in Farmer 7’s toolkit, he qualified that Vermont’s Clean Water Act of 1985 cracked down on certain on-farm excavation projects and thereby made it more difficult to justify the installation of drainage infrastructure. In addition to ditches, cover cropping is integral to Farmer 7’s management practices; in his words, cover cropping produces a “synergistic effect,” yielding multiple benefits at once—such as increased organic matter content, expanded water holding capacity, and of course, reduced erosion rates. Although he has only recently adopted a no-till approach, Farmer 7 was enthused about the potential for no-till to raise the current ceiling that has been "set" on soil fertility and productivity. As for tile drains—like no-till, a trend that has recently risen to the fore of public (i.e. farmers') attention—Farmer 7 is well versed in their application and described how he uses tile drainage to move water in his fields from higher to lower elevations. Tile drains have allowed him not only to control soil saturation levels so that they remain constant, but also to redistribute moisture from wetter to drier locations on his property. In light of climate change and Farmer 7's repeated references to the destructive impact of Tropical Storm Irene, tile drains may become increasingly desirable in Vermont as a method of mitigating the heavy precipitation patterns that are projected. Given that Farmer 7 made a point of highlighting the various ways in which he experiences erosion (he explained the twofold threat of impact and sheet), it is evident that, on top of addressing soil loss itself, tile drains would alleviate the psychological stress that erosion engenders in farmers.

While Farmer 7 is a firm proponent of drainage ditches and cover cropping, he is (perhaps unsurprisingly) leery of the management practices that Act 64 explicitly promotes. Riparian buffers feature prominently in the new RAPs, but our interviewee questioned their efficacy, and in fact, he took his skepticism a step further, speculating that grassed buffer strips would actually backfire and exacerbate, rather than lessen, the effects of erosion. Invoking an economic maxim called "the law of unintended consequences"—the notion that "every problem has at least one solution that is worse than the original problem" (as he put it)—Farmer 7 argued that grassed strips placed on the edges of ditches or streams would fail to curb runoff. He put forth the possibility that instead of retaining runoff, grass buffers might only re-direct it to flow laterally (alongside the water channel) rather than downhill (i.e. into the channel). In essence, Farmer 7 believes that, instead of eliminating runoff, filter strips would merely deflect the flow of water and cause erosion to occur elsewhere in his fields. "Basically, I think they should reexamine their idea on the buffer strips—I think they are good, but if you have too much water coming down, it's [going to] overwhelm the buffer strip," he said. In sum, Farmer 7's suppositions about filter strips are markedly different than those of other interviewees, who, by and large, found the concept of vegetative buffers convincing; several suggested that artificial wetlands, bioswales, and other sorts of catchment basins could prove effective at "detaining" tile drain emissions and filtering out the nutrients before this outflow enters surface waters (e.g. a stream). Perhaps Farmer 7 is particularly critical of grass filter strips because he has dug ditches approximately "every hundred feet" in his fields, and as a result, he will lose substantial amounts of arable land because Act 64 mandates the creation of ten-foot buffers (composed of perennial vegetation) around each ditch. This goes to show that the specific type(s) of management practices that Vermont farmers choose to employ—their individual preferences—will likely inform their views on Act 64. In other words, farmers' judgments about the functionality and "fairness" of the RAPs may be colored by their own personal biases toward certain practices.

Throughout our conversation, Farmer 7 grounded his arguments in statistical analysis, empirical evidence, and specialized knowledge, all the while demonstrating impressive recall when it came to citing specific numbers and studies. "I've always been a firm believer in science," he adamantly asserted, and on more than one occasion during our conversation, he attributed his abiding distrust of water quality regulations to the dearth of what he deemed "real data" (or if the data exist, he contends they have not been broadcast to the public domain). Overall, Farmer 7 felt stymied by rigid regulations, unable to actualize the innovative solutions that he had imagined. In great detail, he described his desire to install additional sluices and water pipes in his drainage ditches, which would allow him to better "trap" runoff after rainfall. He claimed that the ability to retain this runoff for longer periods of time—say 24 to 40 hours—would allow stormwater to fully percolate into the soil, which would also minimize nutrient discharge from his fields and ultimately result in cost savings (because runoff is laden with dissolved and total phosphorus, any runoff that leaves his fields represents lost productivity that he must then replace with expensive soil amendments). But he conceded that making these changes to his management system would put him in a position of non-compliance; in effect, the water pipes that he wished to install in his drainage ditches would narrow the outflow from 18 inches to six inches (these are hypothetical numbers he provided), which would suddenly make his farm a source of point (rather than nonpoint) pollution. Of course, being labeled a point polluter carried potentially severe consequences, because were he "responsible for the entire watershed," state agencies could pin water quality problems solely on him. Farmer 7's imagined scenario is not merely an interesting thought experiment—on a broader level, it is emblematic of the kind of double bind that Vermont farmers encounter in water quality regulations. Here, we see how a farmer who devises a theoretical solution to mitigate phosphorus runoff has been deterred by the specter of punishment. The paradox is that Farmer 7 could be penalized for taking the initiative and exhibiting stewardship—the very behaviors that the state of Vermont has entreated farmers to adopt.

In keeping with his strong convictions and creative inclinations, Farmer 7 concluded by sketching out a "roadmap" for Vermont farming, including the directions he would like to see the sector take and the technologies and amenities that he hopes lie in store for those such as himself. For instance, he mentioned that he would appreciate if there were a mobile runoff gauge available to farmers, as this would allow them to measure, minute-by-minute, the rate at which water—and, by extension, nutrients—is flowing from their fields; such a device would come in handy particularly during heavy precipitation events. He also noted the need for more precise siting of water gauges. In his view, the USGS monitoring stations have been located primarily for convenience and ease of access, which to him seems like misplaced priorities. As a recommendation, Farmer 7 offered that gauges situated at zones of transitional land use (e.g. the urban-agricultural interface) in Vermont would yield data that are more relevant and useful to landscapers, city planners, conservation agencies, and the like. However, Farmer 7's vision for the future moves beyond the realm of small details and specialized technologies and pushes for a fundamental paradigm shift in the state's approach to water quality problems. "The phosphorus in the lake is not the problem; it's how it gets there," he observed. In the same vein, he argued, "the phosphorus in the lake, there's nothing you can do about it…that's gone." Currently, Vermont water quality issues are framed in the context of downstream effects; it seems that Lake Champlain has become the proxy, the "poster child," for the progress (or regress) that the overall state has made in improving water quality, and the lake is the last downstream location—the final resting place for waterborne nutrients. But Farmer 7's insights beg the question: what if water quality were instead couched in the terms of upstream effects? Farmer 7 suggested that reversing the stream—so to speak—might shift the spotlight onto the struggles that farmers face and prompt regulators to allocate more of their monitoring efforts to the smaller and lesser-known tributaries that separate farms from the lake. Perhaps in the end, Farmer 7 invites us to invert—or to at least challenge—the order of cause-and-effect as it relates to water quality problems. In the conventional perspective, Vermont farms symbolize the cause, while Lake Champlain evidences the negative effect. Yet, as Farmer 7 often intimated, the reality is not as black-and-white: with his parting words, he reminded us that, "whatever you do in this report, you have to understand that correlation is not causation."

Interview with Eric Howe (Technical Coordinator of the Lake Champlain Basin Program)

When a watershed encompasses no less than 8,234 square miles and 600,000 human inhabitants, it is not an easy task to balance environmental concerns with conflicting economic, political, and cultural interests (LCBP 2016). Yet such daunting management responsibilities are no deterrent to the likes of Eric Howe, who, as technical coordinator for the Lake Champlain Basin Program (LCBP), wears more than one hat, dividing his time between grant programs, research, and advising. Soft-spoken yet quietly confident, Howe boasts an impressive and well-rounded background that includes, among other credentials, a Ph.D. in Natural Resources and a M.S. in Wildlife and Fisheries Biology. Ultimately, Howe's trenchant insights reaffirmed the intractability of water quality issues and the imperative to tread lightly around the livelihoods of Vermont farmers.

The Lake Champlain Basin Program (LCBP), with administrative influence spanning New York, Vermont, and Québec borders, strives to "coordinate and fund efforts that benefit the Lake Champlain Basin's water quality, fisheries, wetlands, wildlife, recreation, and cultural resources" (LCBP 2016). Overseen by a cadre of state (e.g. the Vermont Agency of Natural Resources) and federal (e.g. The U.S. Environmental Protection Agency) programs, LCBP primarily serves as a grantmaking institution, providing agencies such as UVM Extension with the funding to pursue targeted water quality interventions, agricultural outreach programs, and technical research. LCBP operates under the auspices of a governor-endorsed, comprehensive pollution management and ecological restoration plan entitled "Opportunities for Action." Instituted in 1996 and last updated in 2010, the document outlines a series of objectives that should be observed to ensure the continuity of the Lake Champlain ecosystem. LCBP staff are currently in the process of refining the plan's purview. According to Howe, the latest iteration promises to narrow its emphasis to nutrient mitigation.

Overall, Howe's observations seemed to validate the grievances of Vermont farmers who feel perennially victimized by the regulatory system. Straight away, Howe suggested a fundamental reason behind agriculture's beleaguered status among polluting sectors. Although acre-for-acre, municipal areas actually generate more pollutant runoff than farmland, it is agriculture, above all, that has been scapegoated. What accounts for this trend? By way of explanation, Howe offered that, of the three primary land types that contaminate water —agriculture, developed, and forested—the first is the most cost-effective to treat. Elaborating on this idea, Howe provided a hypothetical (i.e. using ballpark numbers) example, in which he described how $100,000 allocated towards pollution reduction might only cover one acre of paved parking lot, whereas the same sum could be spread across *multiple* agricultural acres. Logically, then, organizations such as LCBP choose to focus on farmland, where their limited funds are likely to reap the most measurable, visible, and significant returns. In exposing the financial incentives that encourage the regulatory emphasis on agricultural runoff, Howe implicitly pushed back against the idea that water quality initiatives in Vermont are motivated mostly (or solely) by environmental concerns.

After discussing the overarching economic forces at play in the Vermont water quality debate, Howe segued into describing the specific LCBP-funded research projects that are currently underway. Although many technical investigations are only just progressing past the preparatory stages (he mentioned that several experiments recently concluded testing control groups and are now transitioning to field trials)—and therefore the "jury is still out" (as Howe put it)—noteworthy results have already begun to emerge, some of which run counter to what Howe and his colleagues expected to find. For instance, Howe mentioned that the amount of *dissolved* phosphorus washed from agricultural fields and deposited into waterways has far exceeded initial projections. Before commencing experiments on crop fields/pastures, Howe and his team supposed their study would corroborate prior research, which has shown that particulate phosphorus (P bound to soil particles) often comprises the majority of phosphorus pollution in surface water. This preliminary finding, assuming that it bears out in the end, holds troubling ramifications for Vermont water quality because unlike particulate phosphorus, which must undergo several chemical transformations before algae can access the nutrient, dissolved phosphorus can be directly and immediately utilized by phytoplankton. As a consequence, water quality in Lake Champlain might decline more rapidly if phosphorus increasingly arrives in dissolved rather than particulate form.

Queried about effective ways to intercept dissolved phosphorus before it enters Vermont waterways, Howe listed filter strips, retention ponds, contour farming, and riparian/grassed buffers as potential management strategies. However, the uncertainty surrounding phosphorous pollution and its highly unpredictable nature attests to the difficulty of devising conservation solutions when there is no guarantee they will work in every application. If nutrients behave differently from one location to the next—for instance, perhaps P is mobilized more easily on one farm than on another, due to local terrain, microclimate, or precipitation patterns—Vermont farmers are justified to challenge the notion that RAPs are "universal" fixes.

In Howe's experience, farmer responses to water quality agencies and the threat of regulation range from relative hospitality to open hostility. In the Missisquoi Bay watershed, for instance, LCBP outreach was met with positive feedback from farmers. Having produced a water pollution map and distributed it to local farmers, LCBP steeled for backlash, but it never came. Instead, and to the organization's surprise, local farmers were glad to have the map at their disposal. However, Howe described another time when LCBP staff, reaching out to producers in the Jewett Brook watershed (which drains into St. Albans Bay), earned the farmers' antagonism in lieu of their trust. This led, in turn, to the formation of a petition against LCBP's unwanted overtures.

Though he seemed perplexed by the striking contrast in how LCBP outreach was received in one watershed versus another, Howe conceded that, because the Jewett Brook area has a history of fraught relations between farmers and officials, this might have negatively colored farmers' perceptions of LCBP. Howe also allowed that a smaller watershed such as Jewett Brook, where farms are in closer proximity to one another, could strengthen farmer solidarity. Indeed, an innate and reciprocal sense of loyalty may have enabled Jewett Brook farmers to quickly mobilize and present a cohesive challenge to a common threat like LCBP—whereas within the larger Missisquoi Bay watershed, farmers might not have been impelled by neighborly ties and a commitment to unified "resistance." On the one hand, Howe's interactions with Missisquoi Bay farmers bode well for the outreach materials that we are in the midst of making, because it appears that the visual appeal and informative value of the LCBP map outstripped any suspicions that farmers might have had about water quality education. On the other hand, Howe's anecdote about Jewett Brook farmers—whose past altercations with water quality authorities informed their inherent distrust of LCBP's advances—goes to show that, regardless of the tact we show towards farmers, the success of our outreach efforts may be circumscribed by variables (e.g. a farmer's past encounters with water quality advocates) beyond our control.

The interview with Howe yielded additional ideas about how we might frame and present water quality issues to farmers in a constructive and non-threatening manner. In the aforementioned Missisquoi Bay project, LCBP ventured into potentially dangerous territory when it ranked farms "according to total phosphorus load per acre/year from the CSAs [critical source areas] identified on their land," because this singled out some farmers more than others (LCBP 2016). Although this classification system might have aggravated the vulnerability that Vermont producers feel, LCBP couched its intentions in careful language and thereby avoided further alienating farmers. Rather than hint at the legal repercussions that awaited those who refused to comply, LCBP highlighted the *benefits* that were in store for farmers if they allowed the agency to conduct water sampling near their fields and gauge agricultural runoff. LCBP suggested that if farmers chose not to work with the organization, LCBP would be forced to approximate the location and severity of critical source areas, which could actually be more consequential for farmers. This is because (as Howe said with a somewhat cynical laugh) if LCBP overestimated the phosphorus load in a watershed, farmers would pay for pollution they did not perpetrate.

Howe raised an important point for us to keep in mind as we began our water sampling: while instinctively we may be hesitant to ask farmers about gathering water samples on their property because of the request's sensitivity, this reluctance on our part may ultimately do farmers a disservice. Fewer sampling locations and less precise water quality data may set us up to over-measure the pollution in a watershed and mistakenly attribute the burden of pollution—and blame—to certain farmers. Moreover, as Howe maintained, increased water quality data enables LCBP to localize its management, enhance the effectiveness of its conservation efforts, and identify the specific farmers who fail to meet standards.

From there, Howe dove into discussion of Vermont's myriad agricultural and technical assistance programs. Once again, the interview underlined the inscrutability of farmers, whose attitudes and actions towards environmental groups are inconsistent and often impossible to predict. Take, for instance, cost-share programs, which subsidize—sometimes completely—the purchase of new equipment or the implementation of new conservation practices; if the cost share program provides one hundred percent coverage, participation in the program would seem, on the surface, to be a "no-brainer" for farmers—yet this is not the case, as many of Vermont's agricultural assistance initiatives are continually under-enrolled. Howe attributed low interest and attrition to several factors. To begin, there is an intrinsic distrust of government intervention that may account for why a farmer chooses not to partake in cost-free conservation initiatives. While farmers will sometimes shy away from programs that involve federal or state oversight or the involvement of big-name environmental groups (such as the EPA), they are often more receptive to initiatives that are overseen by local organizations like UVM Extension or LCBP.

However, Howe brought up a broader consideration that could also dissuade farmers from participating in incentive-based programs—namely, that cost-shares, while advertised as "free," are far from it. In reality, conservation practices mandated by a program such as EQIP are, in the long run, a financial strain, because taking land out of cultivation and converting it to non-productive uses often means that farmers lose a significant revenue source. In touching on these embedded or "hidden" expenses associated with environmental stewardship, Howe urged us to critically reexamine the assumption—often alluded to in Vermont water quality publications—that conservation programs are always "win-win" for farmers.

Overall, our conversation with Howe reinforced the centrality of relationship building and trust in water quality issues and revealed that even Vermont farmers who seem to stand on solid (and fertile) ground are, nevertheless, marginalized in many ways. As a whole, the Vermont dairy industry wields substantial clout, but this does not equate to the empowerment of individual farmers. The power, prestige, and brand recognition of Cabot or Ben & Jerry's often overshadow the Vermont family farmers who wear—in the words of Howe—"targets on their backs."

FARMER SURVEY & INTERVIEWS DISCUSSION

Water Quality

Our survey results suggest that, in general, farmers understand that there are concerns over the quality of water in both Lake Champlain and smaller bodies of water within Addison County. It is most relevant to note that while no farmers in our sample described the water quality of either the lake or the county as "very poor," only one farmer characterized the water quality as "very good." Based on the information that our community partners provided as we began our project, these results are expected. Our community partners from UVM Extension emphasized that they have been working with the same group of farmers from which we found our sample, specifically by providing informational and technical assistance related to improving agriculture's impact on water quality. Therefore, we expected farmers to indicate that there are some concerns over local water quality; the fact that most farmers selected "poor" or "OK" as the state of water in Lake Champlain and Addison County confirms this hypothesis.

Regarding water quality, our survey results also suggest that the sampled group of farmers perceives the water in Addison County to be slightly higher quality than the water in Lake Champlain in general. This is noteworthy given the focus on the McKenzie Brook watershed, which encompasses parts of Addison, Bridport, Shoreham, and Orwell, as a "priority agricultural watershed" due to especially poor water quality (VT WMD 2015a). This would initially seem to suggest that farmers have a skewed understanding of their local watershed in relation to Lake Champlain as a whole, as they characterized Addison County as having higher rather than lower water quality. However, our survey did not ask specifically about the McKenzie Brook watershed, so farmers may have given the county as a whole a higher rating under the assumption that the average water quality was higher than that specific watershed.

In relation to nutrient loading, our results indicate that as a whole, the sampled group of farmers has a relatively accurate understanding of the sources that contribute to nutrient loading within Lake Champlain, with a few key areas of difference. First, it is worth noting that many farmers recognized farmland as a key cause of nutrient loading, which reflects the statistic that agricultural land is responsible for around 40% of Vermont's total phosphorus loading to Lake Champlain (LCBP 2015). However, this statistic shows agricultural land to be the greatest contributor of phosphorus in comparison with other types of land use, while the sampled group of farmers identified wastewater treatment facilities as the primary cause of nutrient loading. Wastewater treatment facilities are actually responsible for only 4% of Vermont's phosphorus loading to Lake Champlain (LCBP 2015). Similarly, the sampled group of farmers overestimated the contribution of urban areas to phosphorus loading. Although urban areas were the third most significant source identified in our survey results and in fact are the third greatest contributor of phosphorus by land use (18% of Vermont's total loading), respondents overestimated this contribution; they believed urban areas to be responsible for 26% (25 out of a total of 96 points, using our ranking point system) of this loading (LCBP 2015). These results suggest that there is a small knowledge gap between farmers' perceptions of nutrient loading in Lake Champlain and the actual data; some further outreach to farmers on the subject could be useful.

One important limitation of our project is that we selected many of both our survey and interview participants from the farmers that attended the April 13 Champlain Valley Farmer Coalition, which by definition introduces a bias toward farmers with an interest in water quality concerns. This may have skewed our results to reflect a greater understanding of both water quality in Lake Champlain and the sources of nutrient loading than actually exist in Addison County as a whole. Our interviews gave a greater range in understandings of water quality, particularly our interview with Farmer 7, which indicates that further research would be beneficial to understand the issue more comprehensively. Additionally, our survey did not distinguish between farmers in the McKenzie Brook watershed and those that lived elsewhere, and this information could be useful in successfully understanding how farmers in this priority watershed view water quality and the contribution of agriculture to nutrient loading.

Act 64 and RAPs

In regards to Act 64 and the recent creation of the RAPs, farmers' reactions ran the gamut from assurance to anxiety, optimism to fatalism, camaraderie to competitiveness (i.e. with fellow farmers) in our interviews. Some felt singled out by Act 64 and audibly bristled at its mention; still others were, more or less, unfazed by the new rules and anticipated having to make minimal alterations to their current methods. We gleaned a diverse spectrum of opinions and insights from the interview process, but several unifying themes emerged that warrant deeper discussion.

1. Site-Specific Challenges

For starters, it was evident that site-specific variables—including microclimate, local topography, and proximity to surface water(s)—often played a large part in determining the attitudes of interviewees toward Act 64. The slope of a field or pasture, for instance, can dictate the amount of runoff that a farm contributes, which in turn (as we learned from interviews) affects how a farmer sees—or does not see—the severity of soil erosion and nutrient pollution. In a similar way, soil type, whose composition is unique to each farm, influences water-holding capacity, saturation levels, crop productivity, and ultimately, profitability; with all of this in mind, it came as no surprise to us that soils factored strongly into farmers' responses to regulation, as well as their appraisal of tile drains. For instance, Farmer 7 bemoaned the hydrological conditions that he regularly confronted, while Farmer 5, in noting that his predecessors had installed tile drains during the Depression era, underscored how Vermont's often supersaturated and clay-rich soils could set farmers up for an endless struggle to stay "afloat," in both the ecological and economic sense. But, whereas the prior two farmers spoke generally about their grievances with stubborn ground, a third interviewee made explicitly clear that soil constraints— *specific to his farm*—had led him to question the legislative language. He noted that because Vermont laws defined "flooding" in narrow terms, his fields failed to qualify as "flooded," even though they existed in a perennially waterlogged state—they "might as well be flooded," he quipped.

In addition to soil structure and slope, the baseline nutrient level (i.e. the initial concentration, before the addition of chemical inputs) in a farm's soil could color or "condition" a farmer's response to Act 64. Many interviewees referenced their soil's naturally occurring phosphorus content and indicated how this number—if above Act 64's allowable limit—could restrict the sorts of management practices they could legally put in place. Specifically, farmers mentioned that upon purchasing their property, they discovered that their soil's nutrient load already measured quite high, which, while advantageous on the one hand, also entailed a downside: It meant they had minimal freedom or flexibility to apply extra soil amendments, such as manure, fertilizer, or compost. Thus, farmers frequently lamented how the intrinsic properties of their agroecosystem could both prescribe and circumscribe the farming methods that were available to them. (This is assuming they wished to comply with water quality regulations; if not, they might continue to add fertilizer even with the awareness that their soil's phosphorus already exceeded permissible levels). Nutrient management plans (NMPs) are a way of accommodating the local land attributes—including soil properties (pH, available phosphorus, reactive aluminum, etc.)—that account for why no two farmers in Vermont confront the same set of challenges. In other words, NMPs encourage farmers to take stock of both their surroundings and the specific shortcomings (as well as potential advantages) that are inherent—and unique—to their property.

However, since VAAFM phased out the Nutrient Management Plan Incentive Grant Program due to increased "competition," Vermont farmers may now have to shoulder the not-insignificant cost of creating their own NMP. Furthermore, coinciding with the discontinuation of the NMP Grant Program is Act 64, which will eventually require small farms—which were previously exempt—to develop and implement NMPs (VT ANR 2014c). Overall, Act 64 functions at two levels—sweeping and sector-wide yet simultaneously sensitive to the individuality of Vermont farmers, since it prescribes NMPs that are tailor-made to the specific needs of a farm. But there is a caveat: for NMPs to significantly benefit Vermont farms—particularly the cash-strapped, smaller ones—the cost of designing and implementing these plans should be sufficiently subsidized; otherwise, NMPs may end up doing more harm than good.

Recommendations: Site-Specific Challenges

- Provide farmers with the funding and technical services they need to test their soils and achieve "precision-application" of nutrients. Farmers who could afford to test their soil on a regular basis were less likely to add superfluous fertilizer or manure, since they had a better sense of baseline nutrient levels in their fields. Furthermore, increased soil testing enables farmers to synchronize their manure/fertilizer applications with seasonal weather patterns (e.g. precipitation).
- Consider reinstating the Nutrient Management Plan Incentive Grant Program, or make available alternative cost sharing programs that minimize expenditures associated with creating and updating nutrient management plans (NMPs). As mentioned above, NMPs can cost around $5,500; without accompanying subsidies or financial support, the NMPs could be prohibitively expensive for small farmers. In general, providing additional outreach to farmers would facilitate their development of NMPs. The creation of an overarching committee to streamline and expedite the NMP approval process would be helpful, as this system is currently quite cumbersome for farmers to navigate.
- Consult with organic farmers about their preferences and recommendations for efficient and effective record keeping; then, convey this information to conventional producers. When it comes to satisfying the stricter documentation standards that Act 64 has mandated, organic farmers may have a leg-up over their conventional counterparts. This is because organic farmers are already required to keep more thorough records of their practice in order to attain and maintain organic certification. Thus, the organic sector would have valuable advice to offer to non-organic producers who may feel daunted by the prospect of increased paperwork.

Whereas the prior paragraphs focus on how highly specific and localized factors act on farmers' perceptions of water quality regulations, the following sections highlight the broader interlinkages between interviews. The individual circumstances of farmers varied widely, but they held similar sentiments (often skepticism) about regulation, enforcement, and compliance. Interviewees also voiced shared concerns about the economic impacts and environmental externalities of Act 64. Finally, many cited the law's cryptic and sometimes contradictory language as a source of confusion and stress.

2. Stewardship & Solidarity

Act 64 has ushered in a number of obligations that could become onerous to farmers. Yet, somewhat surprisingly, many interviewees hinted that they felt a kind of camaraderie in the face of these new demands. "We're all in this together" was a refrain that we heard, in one form or another, from multiple interviewees. As one might expect, the farmers who predicted they would come away from the RAPs largely unscathed were more likely to buy into the idea of “togetherness.” However, even interviewees who anticipated experiencing fallout from Act 64 appeared to derive a sense of solidarity—even comfort—from the knowledge that, in the end, they would not be suffering alone. “It’s true that it hurts…” one farmer conceded, a note of resignation in his voice, but from there, he quickly rallied, rising to the challenge, posed by Act 64, to become a better environmental steward. Other interviewees echoed these sentiments and expressed their cautious optimism that Act 64 would shape them into stronger and more well-rounded farmers. For instance, one interviewee intimated his readiness to refine his methods and approach his craft from a more “scientific” angle.

<u>Recommendations: Stewardship & Solidarity</u>

- Explore the possibility of forming additional farmer focus groups as a way to reinforce the support that farmers offer one another. Focus groups serve as forums for farmers to convene and collectively “troubleshoot” the problems and inherent challenges that are associated with Act 64. Providing a common, reserved venue where peer-to-peer dialogue can take place on a regular basis is essential to promoting the exchange of advice and technical assistance between farmers. In the end, adapting to the RAPs will be easier for all farmers *if* given the space to share their successes and setbacks in dealing with the new legislation. In addition, the creation of cross-sector focus groups (i.e. sectors within agriculture, such as dairy, horticulture, and maple) might help to “neutralize” negative feelings among farmers who feel as though they have been unfairly targeted by the new measures. To illustrate, if small farmers and dairy operators—both of whom insinuated in interviews their belief that they will be subject to stricter regulation compared to their colleagues—are able to correspond with farmers from other sectors, they may come away with better “coping mechanisms.” The Champlain Valley Farmer Coalition as well as the Farmland Access Network Task Force offer models for eliminating the siloed approach (VSJF 2015). Cooperation among staff from various agencies and organizations can also help to enhance farmer solidarity.

3. Monitoring & Enforcement

It came as no surprise that the majority of farmers expressed concern about the escalation of monitoring activity. Before Act 64 went into effect, the Accepted Agricultural Practices were policed by way of a “complaint driven system,” a less than comprehensive set-up for several reasons—for instance, farmers were, perhaps, hesitant to call out their colleagues and neighbors. However, Act 64 specifically seeks to ramp up inspection of small farms, raising the frequency of monitoring visits from once every five years to every three years (this applies to both Small Farm and Medium Farm Operators). Yet increasing the regularity of monitoring means that farmers expect to be scrutinized to a greater degree, a discomfiting notion to interviewees. One said, “I guess I hate the idea of someone looking over your shoulder at every turn...it’s just not a good feeling." Another farmer was equally averse to the idea of intensified monitoring, admitting, "I've got to be honest with you, we're right in the spotlight...whatever you do, you've got to be sure it looks right."

It is also worth noting that several farmers took issue with the concept of compliance itself. One interviewee was particularly candid, admitting, "The whole *need* to comply—it's kind of turned me into a libertarian." For farmers, it was disheartening to realize their stewardship would only be commended *if* they met the bar the state had set. Farmers could invest substantial time and resources in conservation yet ultimately come up short of these criteria, and consequently, their efforts would go unrecognized. As one farmer put it, "You can be doing an awesome job, but if you don't comply, then you're smeared." Additionally, interviewees reiterated the importance of a regulatory environment where the emphasis is on collaboration (or, in the words of one farmer, "working with [farmers]") and fines are regarded as a last resort. One interviewee suggested that civil penalties, which Act 64 has more than doubled in some cases, were all too convenient for regulators to levy.

<u>Recommendations: Monitoring & Enforcement</u>

- Since nearly all interviewees expressed anxiety about the intensified monitoring and raised fines[1] that go along with Act 64 , it might be a reassurance to farmers if enforcement were administered according to a farmer's *demonstrated efforts* to implement the RAPs, rather than the *measured effects* of a farmer's practices on water quality. Emphasizing participation instead of results would address the grievances of farmers who feel it is unfair to pay for non-compliance when they have shown commitment to the RAPs. Revising Act 64 to reflect—and respect—the relative participation of farmers might be achieved by instituting a system of sliding-scale penalties. In this case, state inspectors would levy fines based solely on the extent to which farmers were abiding by the RAPs. In general, increased communication regarding the structure and extent of fines would be beneficial.

4. Subjectivity & Semantics

The vague and open-to-interpretation language of Act 64 was referenced repeatedly by interviewees. Lack of consensus and confusion about the definitions, terminology, and meaning of certain clauses in Act 64 were not only common but also disconcerting and disorienting to farmers. For instance, several interviewees had a hunch that Act 64 was written with the dairy sector in mind, but of course, nowhere in the law is this suspicion explicitly confirmed or controverted. The opacity of Act 64 invited farmers to speculate on their own, or to rely on

[1] Prior to Act 64, a farmer could not be fined more than $25,000 for cumulative violations, whereas the fee limit is now $50,000.

word-of-mouth information, which means that, in all likelihood, multiple and possibly conflicting perceptions of the new regulations are circulating throughout the state.

Ambiguous wording or inadequate explanations in the law also appeared to generate inaccurate assumptions and questions among interviewees. To illustrate, one farmer asserted, “Even if [Act 64] doesn’t explicitly say that vegetables are exempted, they *are* exempted because they aren’t part of the definition.” Similarly, at least one farmer was not entirely sure under which size designation his operation would fall. (However, this lack of clarity did not seem to bother him, as he believed the categories were arbitrary, anyway.)

Interviewees’ misconceptions about Act 64 requirements called attention to imprecise language in the law. Yet their critiques not only suggested that Act 64 could be *reworded* better (perhaps articulated in a more straightforward fashion); comments from interviews also made the case for *redefining* terms in the law that, as they currently stand, have narrow definitions. Were these definitions expanded, they would improve the comprehensiveness and effectiveness of water quality protection. For example, Act 64 currently mandates that annual croplands classifying as “frequently flooded”—according to the USDA Soil Survey Flooding Frequency Class typology—must be planted with cover crops. However, one interviewee described how the soil on his farm was so perennially (super)saturated that his croplands, while not officially meeting the definition of floodlands, were effectively flooded *all the time*. The implication here is that the farmer would be exempt from having to plant cover crops because “flooding,” as presently defined, solely denotes overbank flooding conditions. In contrast, a constant state of oversaturation in fields does not count as flooding, which could mean that many farms in Vermont (a state laden with clay-rich and water-logged soils) will not be obligated to employ cover cropping. As a result of this exemption, soil integrity in Vermont could suffer. Although hypothetical, this scenario goes to show how subjective language and semantics can, in fact, carry significant consequences for environmental conservation and water quality.

<u>Recommendations: Subjectivity and Semantics</u>

- Agencies such as the DEC and VAAFM have published brochures and bulleted factsheets that describe Act 64’s stipulations (see, for instance, “What does the state Clean Water Initiative Mean?” (VT WMD 2015b) and “Vermont’s Clean Water Act and Farming” (VAAFM 2016b)). These outreach materials will certainly prove to be an invaluable resource for farmers, since they outline, in a clear and concise format, the practices to which farmers are expected to adhere under Act 64. However, farmers may not have web access to these summary documents, necessitating the distribution of hard copies. Organizations such as the Champlain Valley Farmer Coalition offer venues where farmers can receive these hand-outs, but farmers who are not members of collaborative nonprofits, or are only sporadic attendees of meetings, may not be presented with the opportunity to acquire print-outs. This suggests that a more active public outreach campaign is required to reach a broader farmer audience. Perhaps informational packets could be compiled and mailed out to farms in the Addison County vicinity (assuming they have been notified in advance).

5. Environmental & Economic Externalities

Far and away, of foremost concern for farmers was the economic fallout from Act 64. At the time of being interviewed, some farmers reported they were experiencing the detrimental effects of the RAPs, while others predicted the legislation would engender expenses further down the road. Interviewees highlighted a wide variety of ways in which Act 64 could incur additional costs, but several RAPs were cited more than once (presumably because interviewees considered them especially inconvenient and costly). Buffer margins and drainage ditch setbacks were singled out as measures that would be particularly burdensome, and even more so for the small farmers who, because they had less land to begin with, could expect to lose a greater proportion of their crop yields—in short, smaller profit margins will magnify the financial impacts of wider buffer margins. On top of these physical changes to farming practices, Act 64 will impose an increased amount of pricey "paperwork," including NMPs. Interviewees voiced their misgivings about mandatory plans, because (as previously noted) they entail high upfront costs to draft. Once again, the small farmer will foot the better part of this bill, since Act 64's NMP requirement specifically targets the Small Farm Operations that were exempted in the past.

Skepticism about the efficacy of the new RAPS was another sentiment that some farmers shared. One interviewee held the view that buffer strips would not be the silver bullet solution the state envisioned. Furthermore, this farmer contended that water quality issues had been couched in a narrow-minded fashion: the regulatory perspective interpreted runoff as a byproduct of agricultural productivity, when conversely (as the interviewee suggested), runoff could be construed as a *barrier* to productivity. While this interviewee is only one individual, his insights may be a microcosm of the manner in which water quality issues have been framed in Vermont as a whole. The sheer prevalence of water-related agencies and advocacy organizations in the state have, it could be argued, fixed the focus firmly on Lake Champlain and its tributaries, and the visible, looming threats, like algae blooms, that jeopardize aquatic health. Centering the dialogue around state waters has caused farmers to feel as though they occupy a peripheral position.

<u>Recommendations: Environmental and Economic Externalities</u>

- Since interviewees have voiced complaints about the costs of RAPs and expressed doubts that these new conservation practices will perform as well as the state has projected, the positive outcomes of Act 64 should be made fully transparent to farmers. As noted in a case study, one farmer was pleasantly surprised at the rate at which the nearby aquatic ecosystem rebounded after he installed livestock exclusion fences. From this, one might infer that visually apparent and dramatic improvements in water quality are more likely to increase a farmer's trust in, and commitment to, the RAPs. It is only logical that visible results provide greater validation and encouragement to farmers compared to invisible or incremental gains. Thus, in an effort to ward off the frustration of farmers who claim not to "see" any significant benefits from adhering to the RAPs, the state should be sure to make clear to farmers that visible improvements often take a while to materialize. In fact, the lag time between implementation of conservation practices and measurable (and visible) changes in water quality have been the rule, not the exception. A comprehensive survey of nonpoint source pollution watershed projects revealed that the majority culminated in "little to no improvement in water quality even after extensive implementation of conservation measures or best management practices" (Meals et al. 2010). The same study also mentioned that in situations of surplus phosphorus in soils, water quality changes may take years or even decades to unfold (Meals et al. 2010).

- In addition to ensuring that farmers are aware of lag time and how this phenomenon will postpone noticeable water quality improvements, it might be worth providing farmers with periodic or interim progress reports. These info sheets might, for instance, chronicle changes in phosphorus load that, while significant and measurable, are yet to be visible. In this way, evidence-based reports would reassure farmers that their management practices were not being implemented in vain.

Tile Drainage

Together, the survey and interview results indicate some clear patterns in the way that the sampled group of Vermont farmers thinks about tile drains. First, a relatively large proportion of the Addison County farmers in our sample uses tile drains to some extent (7 out of 11 surveyed, and 5 out of 6 interviewed). In addition, many surveyed farmers and interviewees without tile drains expressed their interest in installing them. As subsurface tile drains only 4.8% of total cropland in Vermont, our findings suggest that Addison County is likely one of the state's regions where tile drains are used at a disproportionately high rate in comparison to the state at large (VAAFM & VANR 2016). This makes sense given the county's geography, which is flatter and has higher clay content in soils than the more central regions of the state; these variations lead to uneven statewide distribution of tile, with up to 70% of some flatter subwatersheds drained by subsurface tile (VAAFM and VANR 2016). If more research confirms that areas of Addison County are among these subwatersheds, the state can better prioritize how and where to manage and invest infrastructure.

Overall, farmers identified similar perceived advantages to tile drains in the survey and interview results, with the interviews providing more specificity and explanation to the broader options provided in the survey. First, "increased crop yields" was the advantage most selected by surveyed farmers and was mentioned by a few farmers either explicitly or indirectly during our interviews. Most often, interviewed farmers explained simply that they installed tile drains to dry fields or areas within a field that otherwise would be covered with standing water for portions of the growing season. Often, farmers explained how particular soil types or subsurface ledges prevented water from draining quickly or completely from these areas, and therefore tile drains were necessary to bring the land into production. Other interviewed farmers explained that tile drains led to increased seasonal production through seasonal drainage, specifically in the spring when snowmelt makes fields wetter. One farmer summed it up nicely: “Because we don’t have this wonderful sandy-loam soil that drains really well, we wanted to be competitive, especially with early markets, and what that meant was getting water, snowmelt, whatever off of your fields as early and quickly as possible.” Other farmers echoed this sentiment, linking tile drains to earlier planting dates, which led to greater production earlier in the season. This perceived advantage to tile drainage has been documented in the literature, which shows that tile drains can increase crop yields, potentially as a result of plants’ increased nutrient uptake in tile-drained soil (King et al. 2015b; Panuska 2012; VAAFM and VANR 2016).

Among the group of surveyed farmers, “benefits to soil health and structure” was the second greatest perceived advantage to using tile drains. Although this perceived advantage was rarely cited explicitly in interviews, it is also well documented in the literature: studies have shown that tile drains can increase soil aeration, increase soil porosity and tilth, raise soil temperature, decrease soil compaction, and potentially increase the soil’s capacity to store water (King et al. 2015b; Panuska 2012; VAAFM and VANR 2016). The fact that farmers perceive tile drains to have these benefits is important as the state of Vermont moves beyond the Subsurface Tile Drainage Interim Report to eventually make amendments to the RAPs. As this report notes, the economic and environmental benefits that tile drains can provide to farmers must be weighed against any disadvantages that the state agencies find in the next year of research.

Farmers themselves also perceived a wide variety of disadvantages to tile drain usage, including economic, environmental, and logistical concerns, but by far the most often cited disadvantage was the state’s position on the issue of subsurface drainage. In our survey results, “pressure from the state against installing tile drains” was most often selected as a disadvantage, and farmers elaborated on this idea in our interviews. Some farmers perceived the state to be completely against the use of tile drains in any capacity; others felt that the state was against them but would not completely prohibit their use. This uncertainty seemed to be one of the largest sources of farmer concern and prompted a wide range of reactions. One farmer, for instance, referred to his concern that the state may in the future require a tile drain permit, explaining, “That’s the real issue there, it just creates another unknown….Like right now I’m thinking, ‘Well, should I go ahead and get it drained this year...and then I’m set, I’ve circumvented the requirements for now?’” In contrast to this farmer who is considering installing drains now, before the new RAPs are finalized, another farmer explained his opposing perspective: “If you spend, we’ll just say $3,000 an acre to [tile your fields] and then [the state] just comes out and blocks [the outlets], that doesn’t make a lot of sense.” For this farmer, the state’s increased focus on tile drainage led to increased hesitancy over installing the technology now, out of concern that it will not make economic sense long-term if the state prohibits tile drain discharge completely.

While many farmers worried about the state's actions, many also recognized the environmental disadvantages to tile drain usage and expressed a high level of environmental awareness regarding their personal use of tile drains. In the survey results, both "negative impacts on water quality" and "loss of phosphorus and nitrogen from fields" were among the disadvantages most often identified, and in our interviews, many farmers also touched on these concerns. One farmer, for instance, summarized how the water from tile outlets is "not going to have a lot of silt in it, coming from the fields, but really you're going to have water-soluble nutrients that are going to be put directly into the water system." These concerns are well-documented in the literature; tile drains increase the export of nutrients such as soluble nitrate-nitrogen and phosphorus, sometimes to the extent that nutrient loading from tile drain outlets accounts for between 17-41% of total phosphorus and 16-72% of the dissolved reactive phosphorus of peak flow (Panuska 2012; VAAFM and VANR 2016; Wright and Sands 2001).

This farmer's mention of silt also speaks to the important issue of balancing nutrient loss due to erosion with nutrient loss due to tile drainage—a key theme in our project as well as tile drainage research in general. Tile drainage is an old practice, dating back to the early 1800s. Between around 1935 to 1980, the USDA encouraged the installation of tile drains because of the known benefits (King et al. 2015b; VAAFM and VANR 2016). It wasn't until the 1970s when the government began to realize that tile drainage could have adverse effects, and it wasn't until the 1990s when subsurface flow was studied specifically in relation to phosphorus transport (King et al. 2015b; VAAFM and VANR 2016). Before this, agricultural fields were associated with phosphorus loss due to surface runoff, in which phosphorus was adsorbed to sediment particles, and it was assumed that subsurface transport of phosphorus had a negligible impact (King et al. 2015b).

In contrast, during the 1990s, scientists began to research dissolved phosphorus, which current studies show makes up the majority of phosphorus in tile drain outflow (King et al. 2015a). With this shift in understanding, tile drains have been identified as a significant pathway for phosphorus transport to bodies of water and a significant source of phosphorus at the watershed level (King et al. 2015a; King et al. 2015b). In some instances, tile drains export the same or greater levels of phosphorus as surface runoff does, although the phosphorus is largely in different forms (King et al. 2015b). One farmer spoke directly to this changing understanding of the balance, saying, "I've talked to some UVM folks about that. The original concern around phosphorus loading in Lake Champlain had to do with sediments and the phosphorus particles being bound to, typically, clay particles...So I used to think, 'I can control erosion and I'm not contributing to the problem. And that's fine.' But lately, I guess there's been more data or I've been learning more about it, and apparently you can have phosphorus in suspension in water." That this farmer clearly explained the growing awareness of dissolved phosphorus and the role of tile drainage suggests that there is not a large knowledge gap between our sampled group of farmers and the assistance organizations with which they work.

As farmers spoke about the potential environmental impacts of tile drains, many were also willing to discuss their own farming practices and their potential personal impact. The majority of surveyed farmers were aware of the exact outlet locations of their tile drains and into which bodies of water the outlets drained. Our interviews returned similar results, with some farmers tracing the potential route that their tile drain outflow could take to Lake Champlain, even though the outlets themselves were not located in a water body that flowed directly to the lake. Some farmers also spoke to how this problem might be reduced by their own management practices. Unprompted by our project framework, one farmer said that he had “talked to some Extension folks about taking samples at the outflow...to establish a baseline to see ‘is it that we are losing phosphorus through the drainage tile?’” Another farmer explained, “When I put tile drains into my fields...my goal would be to get it to a ditch, to a grass waterway where it can settle and sit and go through a couple of buffers rather than directly into the stream.”

Overall, while not all farmers associated tile drains with a negative impact on water quality, the trends in both our survey and interview results suggest that while farmers rely on tile drainage as an important management practice, they are aware of the concerns regarding the negative effects that tile drains may have on water quality. This fact, combined with the fact that some farmers are already thinking about their personal impact and how it can be reduced with management practices, seems to present a promising situation given the state’s current goals surrounding tile drainage. Given the positive perspective with which the majority of farmers viewed tile drains, it seems that these farmers want to adopt best management practices and work within the state’s framework of tile drain usage rather than risk losing their tile drainage completely. However, as the state itself has noted in its Subsurface Tile Drainage Interim Report, much of this information is largely unknown and dependent on a variety of specific conditions. In particular, phosphorus transport in tile drains is influenced by soil characteristics, drainage design and how the practice is combined with other management practices, and hydrologic effects (Figure 7; King et al. 2015b). Without knowing this information specific to the tile-drained fields in Vermont, it is difficult to determine best management practices for the region.

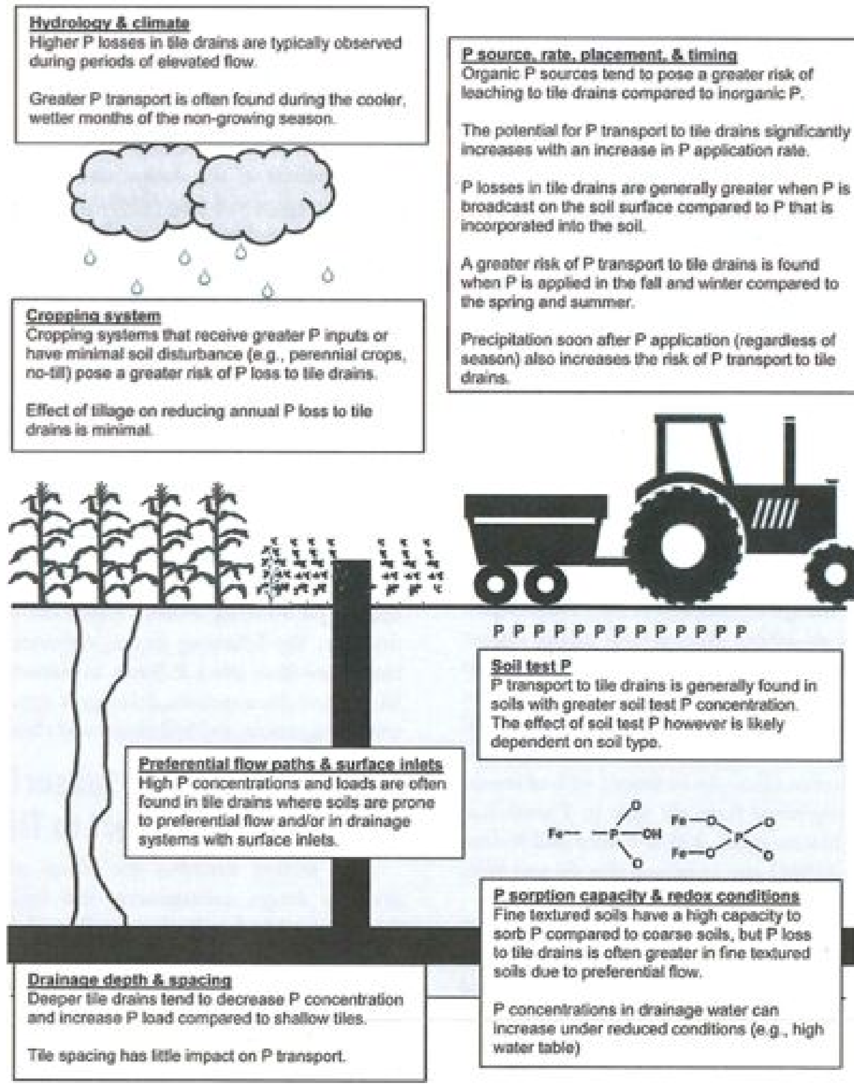

Figure 7. Diagram of factors that influence the subsurface transport of phosphorus into tile drainage system. Figure from King et al. 2015b.

That said, some previous work has been done that can, for lack of more definitive research, be compared with the current state of tile drain usage among our sampled group of farmers. First, all survey participants indicated that their tile drain systems had been installed at a depth of 3 to 5 feet, which is consistent with data on current tile drain installation (VAAFM and VANR 2016). Previous studies have shown that although shallow drains (2 to 2.5 feet) generally have outflow of higher phosphorus concentrations, deeper tile drains (3 to 5 feet) generally lead to greater total phosphorus losses (King et al. 2015b).

Second, the majority of our survey and interview participants indicated that they do not specifically target tile drained fields in their use of conservation management practices; most farmers indicated that they used the same practices on all fields regardless of tile drainage. However, as many of these same farmers listed various conservation management practices as crucial to the operation of their farm, conservation practices are being used on tile drained fields. Most notably, these practices included cover cropping, various combinations of low-till and no-till practices, and incorporation of fertilizer (either directly or by spreading manure after aeration). In general, cover cropping has not been found to have an impact on the subsurface transport of phosphorus, and ridge tillage and no tillage have been found to increase the subsurface transport of phosphorus (King et al. 2015b). In addition, incorporation of manure has been studied but with no generalizable results on its effect on phosphorus (for an in-depth review of factors influencing subsurface phosphorus transport, see King et al. 2015b) (King et al. 2015b). However, even these trends are highly dependent on specific soil types, as soils with small particles and large amounts of clay tend to develop preferential flow paths (also called macropores) that directly connect the soil surface to subsurface drainage and lead to increased phosphorus loss (King et al. 2015b; VAAFM and VANR 2016). Vermont's Subsurface Tile Drainage Interim Report has identified that potential research on cover cropping, cropping rotations, tillage patterns, and manure injection would provide useful information for Vermont farmers trying to mitigate the impacts of tile drains (VAAFM and VANR 2016).

Overall, our project provides only an initial survey of tile drain usage in Addison County, and its limitations should be recognized. First, given the timescale of our project, it was not possible to survey all farmers in the county, and therefore our data are incomplete in representing the county as a whole. This is in addition to the aforementioned bias toward farmers with an interest in water quality issues. Second, because our surveyed and interviewed farmers were selected from the same larger group, there may be overlap in our results, making some trends appear stronger than they may actually be.

Third, in one specific instance, an interviewed farmer confirmed that he had also filled out the survey but had stated that he did not have tile drainage when in fact he did have a few strategically placed drains to drain spots within larger fields. This raises the question of whether our survey was clear when asking farmers about the presence of tile drains in their fields, as tile drains can be installed as either random (target) tiling to drain particular wet spots or as systematic tiling across an entire field (King et al. 2015b; VAAFM and VANR 2016). Although we did distinguish between gridded tile and runs and draws, this question may have led to some confusion over what was to be considered as using a "tile drainage system."

Fourth, both our farmer survey and interview template are best viewed as preliminary methods of gathering data about tile drain usage, as neither asked the questions needed to provide comprehensive information on the topic. For instance, our survey asked about tile drain usage, but it did not ask farmers to list the soil types on their farm. Soil type has proven to be a significant factor in phosphorus transport because of its relationship to preferential flow paths (King et al. 2015b). While our survey asked about differences in manure application, it did not ask the more general question of whether farmers apply inorganic or organic sources of phosphorus to fields; studies have shown that phosphorus losses from subsurface drainage are generally greater from organic than inorganic sources of phosphorus (King et al. 2015b). Finally, as one farmer mentioned in a short feedback session after our surveys were distributed and returned, our survey did not account for tile drain outlets that did not flow immediately into a waterway. This is significant given that some farmers in our interviews discussed outlets with such a buffer, and the Subsurface Tile Drainage Interim Report identifies end-of-tile practices that make up both current research projects (drainage control structures, phosphorus removal systems and media, and soil amendments) and potential research projects (saturated buffers) (VAAFM and VANR 2016). Subsequent projects using our survey design as a foundation ideally would include questions to garner information on these topics as well as those studied in our research.

WATER SAMPLING

Methods

For the water sampling component of our project, we collected samples directly from tile drain outlets. Our sampling was contingent upon us finding farmers who were willing to let us sample from their farms. We contacted farmers through the Champlain Valley Farmer Coalition as well as some independently. The sampling process was anonymous to protect the privacy of the farmers. We sampled from a dairy farm (three outlets) as well as an organic vegetable farm (one outlet). All samples were collected on the morning of April 27, 2016. The temperature was between 30 and 40° F. The previous day's weather had been snow and some rain following several days of dryness.

We sampled from the organic vegetable farm between 0830 and 0900. The outlet at the vegetable farm drained approximately eight acres. The outlet was draining slowly, creating a backup of water that could potentially cause backflow to affect our results.

We then sampled from the dairy farm between 1000 and 1100. Many of the fields at the farm consisted of sand over clay and were located next to the Green Mountains. Because of this location, the drain outlets are almost always running at the farm. The first outlet drained 13 acres of no-till hay. The dairy farmer had wanted to plant corn the previous year but could not because the field was too wet. To decrease the saturation, he installed tile drains in the fall. He also applied manure in the fall. The other two outlets both drained the same field: approximately 24 acres of no-till corn. It was the farmer's third year of planting corn on the fields, and he also planted cover crops each fall. He installed the tile drains two years ago and applied manure this past fall.

The samples were tested for both total phosphorus and dissolved phosphorus at the UVM laboratory with the help of Ethan Swift from the Vermont Department of Environmental Conservation Watershed Management Division.

Results

At the time of submission, our water samples are still being analyzed and processed in the state lab. These results will be sent to Ethan Swift at Vermont's Watershed Management Division. To access our results, Ethan can be contacted at ethan.swift@vermont.gov.

Discussion

We hope that our water sampling results can provide interesting and beneficial information. While there are some stream monitoring efforts in Addison County, mostly through the Addison County River Watch Collaborative, as well as some tile drain sampling in other parts of Vermont, there have been no major projects involving tile drain sampling in Addison County. Because there is a lack of information as to how much tile drainage contributes to nutrient loading (especially pertaining to Lake Champlain), it is important to gather basic information about nutrient levels from tile drains. In addition, because there are currently no regulations in Vermont regarding water quality from tile drains, it was both a convenient (i.e. farmers could not be punished for the nutrient levels from their outlets) and important (i.e. agencies need a general understanding of nutrient levels from outlets) time to take samples. Furthermore, because Vermont's Agency of Natural Resources and Agency of Agriculture, Food & Markets must submit a final report on tile drainage to the Vermont Legislature in January 2017 and because the RAPs will be amended by January 2018 to include requirements relating to tile drainage, any new information regarding nutrient levels from tile drains is crucial.

Ultimately, our water sampling information is not only interesting to us, but it can also be helpful for our community partners as well as farmers. Several of our community partners work for Vermont's Agency of Natural Resources and thus may play a role in the 2017 tile drainage report. In addition, some farmers expressed interest in knowing more about the amount of nutrients they are losing from their tile drain outlets. Farmer 3 stated in his interview that he was already thinking about "taking samples at the outflow to establish a baseline" to see if he was losing phosphorus.

Although we were successful in sampling from two farms, the water sampling component of our project encountered various challenges. The weather was somewhat of a challenge; long periods of dryness can cause tile drain outlets to stop flowing. Our sampling period was quite dry and included very few days with precipitation events. Several outlets from which we intended to sample were not flowing during our weeks of sampling; the weather thus limited our results. Our primary challenge, however, was arguably finding farmers who were willing to let us sample from their tile drain outlets. Although these samples were anonymous and the locations remained confidential, this topic is somewhat sensitive and we noticed some hesitancy from various farmers. However, our role as students was beneficial. Because we approached farmers as students conducting educational research, we may have seemed less intimidating than someone from a government agency.

Despite the challenges associated with our water sampling, we hope that in the future, other Middlebury students can continue the sampling process. Perhaps students from the Environmental Studies senior seminar course (ENVS 401) or from Natural Science & The Environment (ENVS 112) could continue our work and contribute more to data collection.

GIS MAPPING AND SPATIAL ANALYSIS

Methods

For the last component of our project, we produced visual materials to display the current status of phosphorus concentrations in the McKenzie Brook watershed. Currently, the Agency of Natural Resources (ANR) website provides all of the data we analyzed for public view. We first organized mean, minimum, and maximum dissolved phosphorus (DP) readings from ANR water quality data sheets and compared these readings to accepted phosphorus levels. We formatted the data into a figure that allows the comparison of DP across locations in the McKenzie Brook watershed that have previously been monitored by ANR. All DP readings used in this section of the report are from a baseflow sampling period during June, July, and August of 2012 through 2014.

Although these data are publicly available online, the information is not in an easily transferrable or accessible format; data points with water chemistry readings are separate from spatial layout. Our community partners at UVM Extension asked that we create a map that incorporates the available water chemistry data and spatial reference data into one comprehensive document.

For our first map, we used data collection locations, cartographic hydrological data, and a shapefile representing the boundaries of the McKenzie Brook watershed to show where water chemistry is currently being collected and analyzed by ANR.

We then created a second map in which we highlighted the tributaries and corresponding subwatersheds in the McKenzie Brook watershed. We calculated the surface area of each subwatershed using flow direction, flow accumulation, and pour point tools over a 10 meter data elevation model (DEM). We then used the watershed tool to determine which surface areas within the larger McKenzie Brook watershed are accounted for by current water chemistry readings. Our spatial data sources included World Imagery, Vermont ANR Watershed Management Division, and the Middlebury College Geography Department.

Results

Baseline readings for DP concentrations in this region were generally much higher than accepted total phosphorus (TP) concentrations (27 µg/L) for Class B waters (warm-water medium-gradient streams) (VT WMD 2014b); the lowest DP reading was 42.6 µg/L at Braisted Brook (Figure 8). The highest was 2440 µg/L at Hospital Creek. It is important to note that these readings are just for DP and do not account for other forms of phosphorus that may be contributing to TP loads at each location.

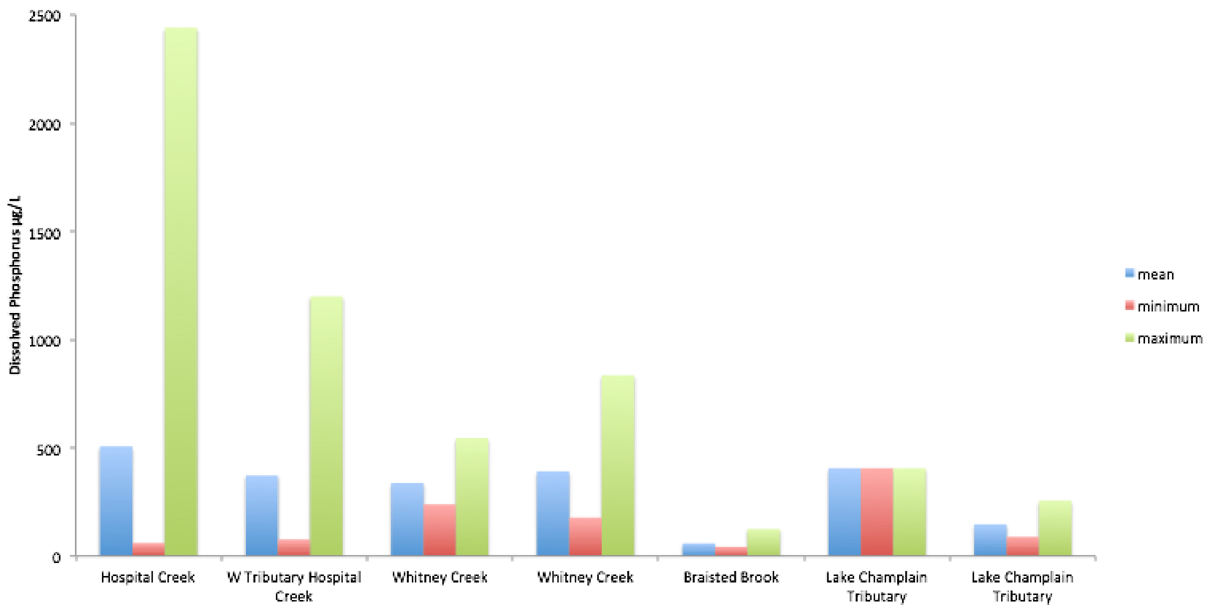

Figure 8. Dissolved phosphorus readings from water sampling locations within the McKenzie Brook watershed. Duplicated sampling site names are listed in order from north to south (see Figures 9 and 10 for geographic reference). Data were collected by VT ANR between 2012 and 2014.

Figure 9 visually matches the mean DP readings from Figure 8 with corresponding locations. This map also shows that ANR currently monitors only seven locations within the McKenzie Brook watershed.

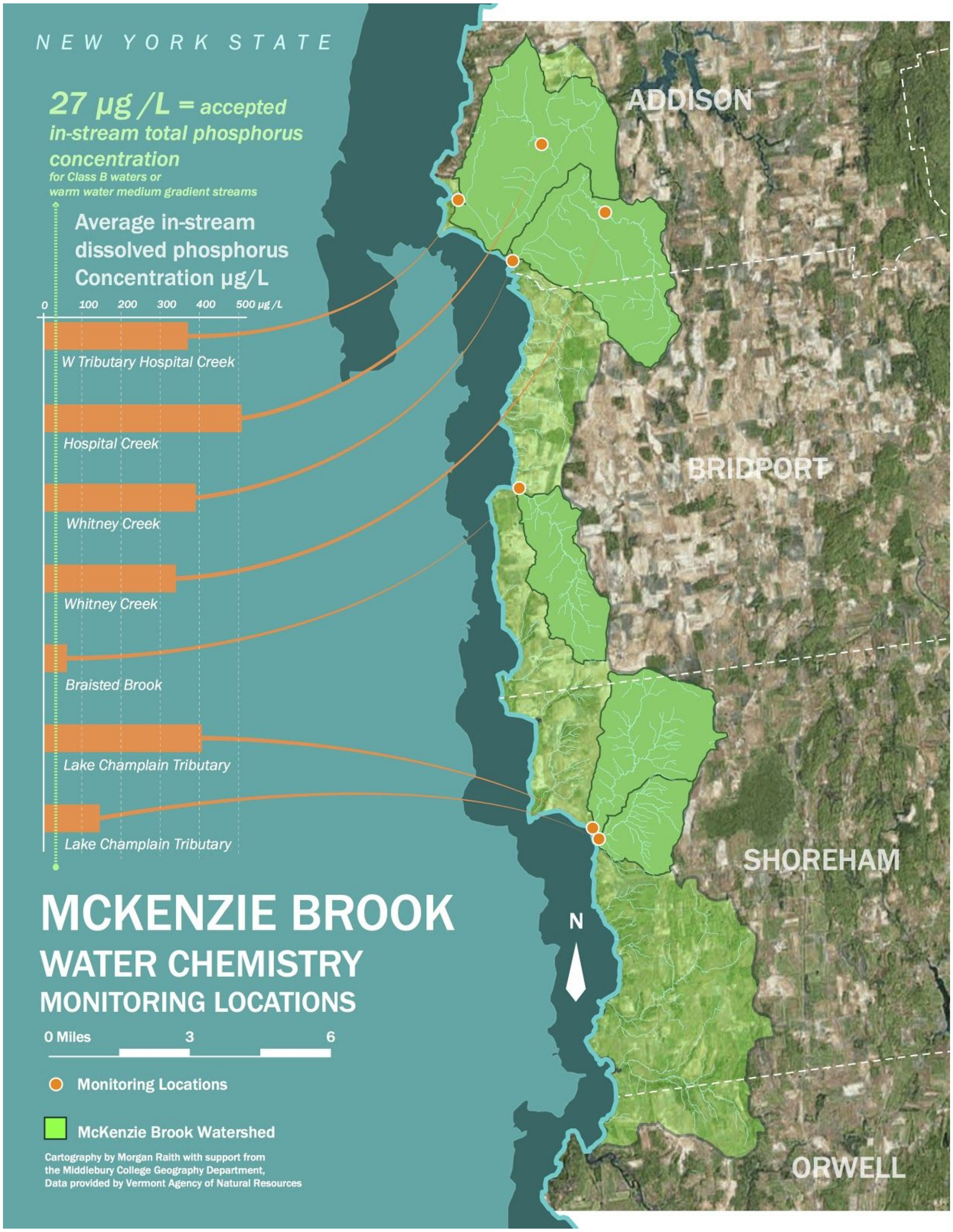

Figure 9. The McKenzie Brook watershed (highlighted in green) and respective water sampling points (highlighted in orange) correlated with average dissolved phosphorus concentrations collected by VT ANR between 2012 and 2014. The vertical green dashed line on the bar graph indicates the accepted in-stream total phosphorus concentration for Class B waters.

Five subwatersheds have been accounted for in VT ANR's water sampling (Figure 10). However, a large portion of the McKenzie Brook watershed has yet to be profiled by ANR. The subwatershed containing Hospital Creek as well as the subwatershed containing northern Lake Champlain Tributary represent the highest DP readings within the McKenzie Brook watershed. The subwatershed contained Braisted Brook represents the lowest DP readings.

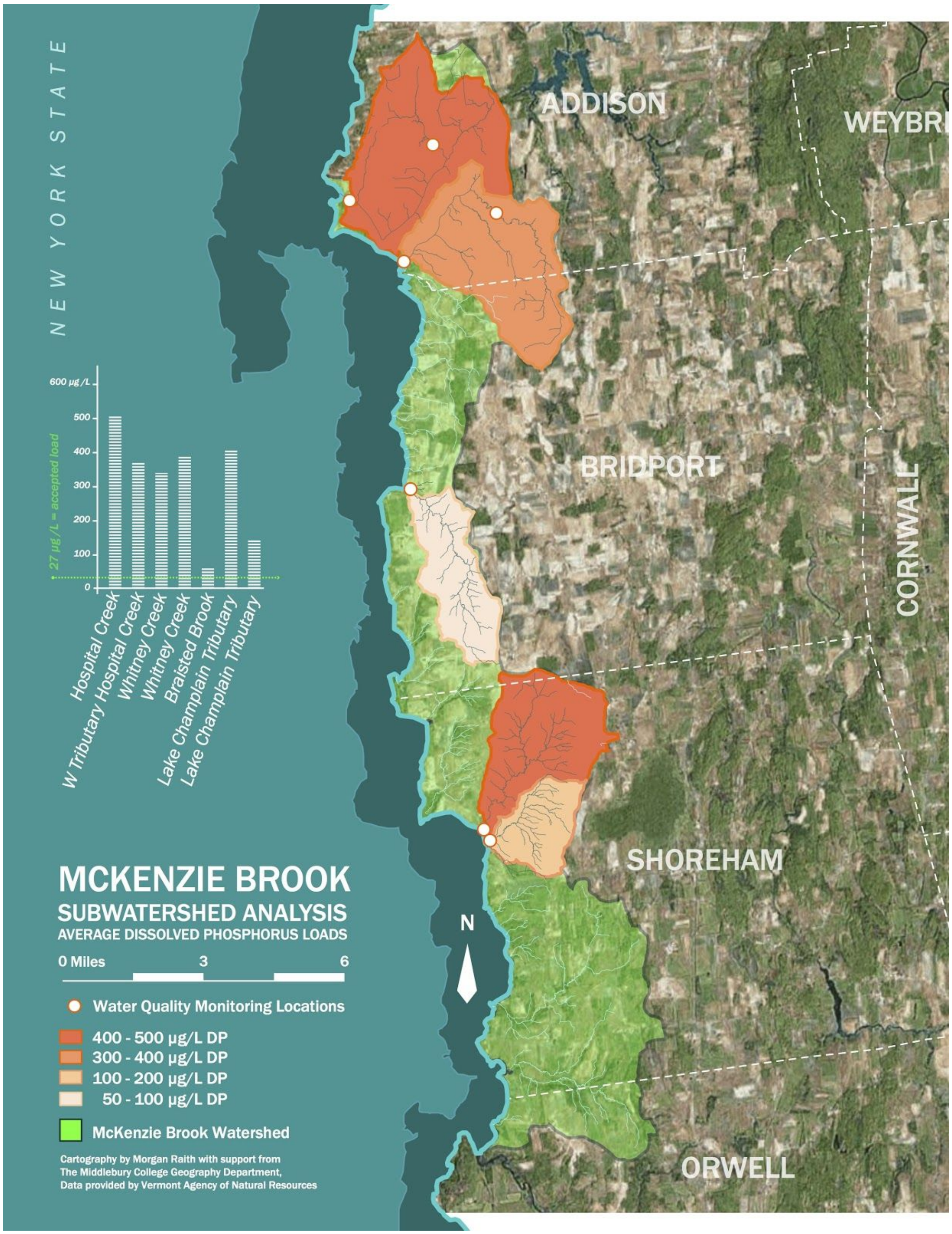

Figure 10. The McKenzie Brook watershed sectioned out by currently monitored subwatersheds (highlighted in shades of orange based on average dissolved phosphorus readings). Data collected by VT ANR between 2012 and 2014. Surface areas within the watershed that are not currently accounted for are highlighted in green. The vertical green dashed line on the bar graph indicates the accepted in-stream total phosphorus concentration for Class B waters.

Discussion

Vermont's Agency of Natural Resources provides DP data for only seven sample sites within the McKenzie Brook watershed through its online Atlas. These points are only attached to web links with box-and-whisker plots; there has been no readily accessible visual format that synthesizes or compares water chemistry data between locations. Our project was therefore helpful in combining this information and visually representing the water quality data.

Although only a handful of tributaries in the McKenzie Brook watershed contain DP readings, there is still enough information to map a conservative estimate of DP loads in this region. These readings are especially high in some stream outlets and shallow bays, particularly the Hospital Creek region and the northern Lake Champlain Tributary. These exceptionally high DP readings demonstrate that the McKenzie Brook watershed is threatened by nutrient loading and reinforce the watershed's status as a priority agricultural watershed.

Not all tributaries in the McKenzie Brook watershed are accounted for by ANR's current water chemistry sampling. There is little known about how various ratios of land cover types directly affect phosphorus loading. Our community partners at UVM Extension are interested in expanding analysis of land cover types. Our division of subwatersheds within the McKenzie Brook watershed has created an opportunity for future Middlebury College Environmental Studies courses to organize additional sampling over a longer time period of time in partnership with ANR and the Addison County River Watch Collaborative. This future sampling could lead to further mapping and data sorting opportunities through the College's Spatial Thinking with Geographic Information Systems class (GEOG 120) or Geography majors' senior work.

A valuable potential project could be an interactive map available over the web. Farmers could use this map to easily access water chemistry data taken from tributaries nearest to their properties. UVM Extension has already initiated pilot projects for the assessment of altered land use practices such as no-till and cover cropping. These practices have great potential to reduce runoff, and it would be interesting to pair the relative land area percentage of the practices with water chemistry readings from nearby tributaries over a period of several years.

CONCLUSION

Overall, the relationship between water quality and agriculture in Vermont is a highly complex issue. Though this project offers no clear solutions, our multi-faceted approach allowed us to touch on many different perspectives and therefore make contributions to the current work being done in Addison County. This project provides valuable insight into Addison County farmers' perceptions about water quality as well as how Act 64 and the RAPs might impact these farmers' practices. Our research also specifically offers insight into tile drain usage in Addison County; this information may be beneficial as the state moves forward with its final report on tile drainage. In addition, through our water sampling and mapping components, we can offer suggestions for future experimental design and monitoring of tributaries in the McKenzie Brook watershed. Our partnership with UVM Extension, the Vermont Department of Environmental Conservation Watershed Management Division, and the Natural Resources Conservation Service of Vermont not only has allowed us to engage with our community, but has also, we hope, laid the foundations for future collaboration between our community partners.

ACKNOWLEDGEMENTS

We would like to thank our community partners Ethan Swift, Kristin Williams, Marli Rupe, Jeff Carter, and George Tucker for their invaluable help in shaping and assisting with our project, as well as our professor Molly Anderson and coordinator Diane Munroe for their endless support and guidance. Additional thanks go to our farmer interviewees and Eric Howe for speaking with us and providing insightful information, and to the farmers who let us take water samples from their farms. We would also like to thank Dave Allen for help with data analysis and Bill Hegman for help with GIS mapping.

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APPENDIX A

Farmer Survey

Dear Vermont Farmer,

We are surveying farmers in Addison County in an effort to learn more about perceptions surrounding water quality and tile drain usage in the area. Responses from this survey will remain completely confidential. The survey includes 16 questions and is the result of a collaboration between University of Vermont Extension, the USDA National Resources Conservation Service, the Vermont Department of Environmental Conservation, and students at Middlebury College.

Any questions regarding this survey should go to:

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Middlebury, VT 05753
(802) 388-4969 x331
kristin.williams@uvm.edu

Hilary Niles
Middlebury College '16
htniles@middlebury.edu

- ***This survey should take no more than 15 minutes to complete.***
- ***Your answers will be anonymous.***
- ***This survey is intended for all farmers in Addison County.***

1) How would you characterize your farm size?
   - ❑ Small
   - ❑ Medium
   - ❑ Large

2) What type of farm do you operate? (Please check all that apply.)
   - ❑ Livestock
   - ❑ Field crops
   - ❑ Other ________________________________

3) How would you characterize current water quality in Lake Champlain?
   - ❑ Very good
   - ❑ Good
   - ❑ OK
   - ❑ Poor

- ❑ Very poor

4) How would you characterize current water quality in Addison County?
- ❑ Very good
- ❑ Good
- ❑ OK
- ❑ Poor
- ❑ Very poor

5) Lake Champlain is experiencing substantial nutrient loading and decreasing water quality. Why do you think this is happening? Please rank the top three causes by writing 1, 2, and 3 in the spaces provided.

___ Nutrients from forests
___ Nutrients from wetlands
___ Runoff from farmland
___ Wastewater treatment facilities
___ Runoff from urban areas
___ Other: ________________________________

6) Do you use a tile drainage system on any of your farm fields?
- ❑ No ***(Please skip to question #14)***
- ❑ System Grid _____ approx. # of acres ***(Please continue to question #7)***
- ❑ Runs and Draws _____ approx. # of acres ***(Please continue to question #7)***

7) Approximately when were your tile drains installed? (Please list multiple dates if you have old and new tile.)

Month: __________ Year:__________
Month: __________ Year:__________
Month: __________ Year:__________

8) What is the approximate depth of your tile lines?

_____ # of feet
- ❑ Unsure

9) Do you know the specific location(s) of the tile drains in your farm fields?
- ❑ No
- ❑ Somewhat
- ❑ Yes

10) Do you know the specific tile outlet location(s) on your farm?
- ❑ No
- ❑ Yes

11) Do you know which immediate stream or surface water your tile drains into?

- ❏ No
- ❏ Yes

12) Do you follow different management practices in your fields with tile drains versus your fields without tile drains?

- ❏ All my fields have tile drains
- ❏ No
- ❏ Yes

If yes, please briefly explain:

____

____

____

13) Do the locations of your tile drains impact how you choose to spread manure or fertilizer?

- ❏ I don't know exactly where my tile drains are located
- ❏ No
- ❏ Yes

If yes, please briefly explain:

____

____

____

Please answer the following questions whether or not you have tile drains on your farm.

14) Please select up to three potential advantages to using tile drains:

- ❏ Benefits to soil health and structure
- ❏ Increased crop yields
- ❏ Fields can be planted with higher value crops
- ❏ Reduced labor time in dry fields
- ❏ Less fossil fuel use in dry fields
- ❏ Reduced surface runoff
- ❏ Increased water retention in soils
- ❏ Increased nutrient uptake by crops
- ❏ Other:_____________________________________
- ❏ None

15) Please select up to three potential disadvantages or challenges to using tile drains:

- ❑ Pressure from the state against installing tile drains
- ❑ Contribute to loss of wetlands
- ❑ Negative impacts on water quality
- ❑ Excessive draining of fields
- ❑ Not cost-effective
- ❑ Difficulty of installation
- ❑ Loss of phosphorus and nitrogen from fields
- ❑ Other:_____________________________________
- ❑ None

16) If you do not already have tile drains, are you planning on installing tile in the future?

- ❑ I already have tile drains
- ❑ No
- ❑ Yes

Thank you for your time! We appreciate your participation.

Interview Template

Farmer Interview Template:

I. Introductions

II. Project goals

   A. Background of project

   B. Clarify if willing to let us include anonymous case study in final report

III. Farm overview

   A. Brief description of farm—size, crops, etc.

   B. What are your main management practices? (Cover crops, fertilizer, etc.)

   C. Are there particular challenges on your farm?

   D. Have you been impacted by Act 64 and the implementation of RAPs? Do you envision having to make future changes to your management practices in response to Act 64?

   E. Are you enrolled in any state-funded programs?

IV. Tile drains

   A. Do you have tile drains on your farm? Why or why not?

   B. Major pros and cons of tile drains?

   C. Do you think there is any relationship between tile drains and water quality?

V. Conclusions, clarifications