LAKE CHAMPLAIN BASIN WETLAND RESTORATION PLAN

December 31, 2007

Prepared for

VERMONT AGENCY OF NATURAL RESOURCES

VERMONT DEPARTMENT OF FORESTS, PARKS AND RECREATION

LAKE CHAMPLAIN CLEAN AND CLEAR ACTION PLAN

FORESTS, PARKS & RECREATION VERMONT AGENCY OF NATURAL RESOURCES

VERMONT CLEAN AND CLEAR AGENCY OF NATURAL RESOURCES

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Many individuals voluntarily contributed their time and energy to the creation of this plan. This plan is significant since it represents the first study of its kind in Vermont, and one of the first in the nation.

To begin the plan creation process, a committee was formed to craft the Request for Proposals (RFP), review the proposals, and review and comment on the proposed methodology. We would like to thank the following individuals that were involved in this process: April Moulaert, Committee Chair, Vermont Department of Forests, Parks, and Recreation; Mike Fraysier, Vermont Department of Forests, Parks, and Recreation; Peter Telep, Vermont Agency of Natural Resources; Kip Potter, United States Department of Agriculture Natural Resource Conservation Service; Ray Godfrey, United States Department of Agriculture Natural Resource Conservation Service; Chris Smith, United State Department of Fish and Wildlife; Erin Haney, Vermont Department of Environmental Conservation; Alan Quackenbush, Vermont Department of Environmental Conservation; and Mike Kline, Vermont Department of Environmental Conservation. Matt Schweisberg of the United States Environmental Protection Agency and Ralph Tiner of the United State Fish and Wildlife Service provided comments on the RFP and the proposed methodology.

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EXECUTIVE SUMMARY

Introduction

One of the most important functions of wetlands is the ability to attenuate nonpoint source phosphorus (P) and thereby maintain and improve downstream water quality. Because of this capacity, restoration of degraded wetlands could be an important component of overall efforts to reduce nonpoint source P loading to Lake Champlain. This project was conducted to develop a basin-wide wetland restoration plan through the identification and prioritization of wetlands in the Vermont portion of the Lake Champlain Basin (LCB) with the greatest potential for P removal through restoration.

Site Selection

- Potential restoration sites on the 2.9 million acres of the Vermont portion of the LCB were identified using a geographic information system (GIS) model. Non-forested agricultural and other open land sites were inventoried according to criteria that included hydric soils, slopes equal to or less than five percent, National Wetlands Inventory data, and size equal to or greater than three acres. The result was a preliminary set of potential agricultural and other open area sites for wetland restoration.

- The model identified 4,883 potential restoration sites occupying 86,480 acres (135 square miles) within the Vermont LCB. Sites ranged in size from 3 to 1,490 acres with a mean area of 18 acres. These sites were distributed among the six subbasins across the LCB, with the greatest number of sites in the Lake Champlain Direct, Otter Creek, and Missisquoi River watersheds.

Site Prioritization

- A quantitative prioritization model was developed to rank the potential of each restoration site to mitigate P loading to Lake Champlain based on 11 variables focusing on site function and upslope drainage. Site function reflects a given site's suitability for wetland restoration in the context of P retention, focusing on factors related primarily to soils and hydrology. Upslope drainage reflects a given site's drainage area for its potential to transport P to the site, focusing on factors such as land use and soil erodibility. The specific variables that were evaluated for each of the two categories follow:

  - **Site Function**

    - Soil texture
    - Erosion risk
    - Size class
    - Flood class
    - Proximity to surface waters

  - **Upslope drainage**

    - Slope
    - Erosion risk
    - Estimated P load
    - Hydrologic soil group
    - Land cover
    - Drainage area to wetland area ratio

- The model scoring and weighting system resulted in an ordinal ranking of candidate sites, where highest scoring sites have the greatest potential for P removal. While the model identified highly-ranked sites in all subbasins in the Vermont LCB, sites in the Otter Creek subbasin had the highest mean restoration score, followed by sites in the Lake Champlain Direct subbasin. These scores reflected a high proportion of agricultural land in close proximity to surface waters with clay soils in soil hydrologic groups C and D characteristic of these subbasins. The high ranking of sites in the Otter Creek subbasin, which generates high nonpoint source P loads and is targeted for significant P load reduction in the Lake Champlain P TMDL, suggests that the Otter Creek subbasin would be an appropriate target for initial wetland restoration efforts. At the same time, the model identified high ranking sites in all sub-basins. The Missisquoi River subbasin has been targeted with the highest P reduction goal of all LCB subbasins, and as such may also be a good place to focus initial restoration efforts along with the Otter Creek subbasin.

- Model results have been displayed in various ways using a GIS, including county-level maps showing the location of each site color-coded by size and restoration score, and USGS topographic base maps showing restoration sites as color-coded polygons. The report includes a complete set of county-level maps; the complete set of USGS topographic base maps is included on the CD-Rom that is enclosed with the hardcopy report The maps provide a useful reference for the number, distribution and size of potential restoration sites across a particular area within the Vermont LCB.

- The model results were used to target visits to sites within the top 200 based on the restoration score. The site visit process included pre-screening via photo interpretation, preparation of an individual site map, securing landowner permission for access when possible, and an on-site evaluation when permission was attained.

Feasibility Study

- 82 of the 200 top-ranked sites were visited in order to:
    - Confirm whether the site was truly a converted or degraded wetland,
    - Determine whether restoration of the site would help meet P mitigation goals, and
    - Determine the actual potential for site restoration with respect to technical feasibility and constraints such as landowner interest and potential impacts on adjacent land or structures.

- Each visit involved an overall walkover (where possible) of the site focusing on current land management practices of both the site and surrounding areas, water flow paths, hydrologic manipulations, and potential P transport into and out of the site. Site visits were conducted within each of the six subbasins for the Vermont LCB.

- Most of the sites that ranked high in the prioritization model were confirmed as degraded wetlands, although the estimated magnitude of P mitigation and the technical feasibility of restoration varied among the sites.

- Most of the sites visited were in active agricultural land use, consisting of pasture, hay and/or corn fields. The most common hydrologic manipulation observed across the visited sites was constructed agricultural ditches, often involving straightening and dredging of pre-existing stream courses. About half the sites visited were located in floodplains.

- Observed nutrient sources varied among the visited sites, ranging from off-site sources such as P transported by floodwaters of adjacent rivers to on-site sources such as manure or fertilizer applications.

- Field assessments documented some existing P-retention capacity resulting from current land management practices on half of the visited sites.

- Forty-three of the 45 landowners that agreed to be interviewed stated an interest in participating in a restoration project on their property depending on the compensation package; two stated that they would not be interested. In addition, six landowners for visited sites were not willing to be interviewed and stated that they were not interested in participating in any potential restoration activities for their land.

Restoration Alternatives for the Final List of Priority Sites

- Restoration alternatives were identified for each of the 82 sites visited with respect to the target natural community type(s) for the restoration area and the specific hydrologic manipulations recommended for the restoration area.

- The three proposed wetland community restoration types were:

    - Floodplain Forest
    - Shrub Swamp
    - Shallow Emergent Marsh

- Restoration of original site hydrology is crucial to fully realize the P mitigation goal of a restoration effort, where moving waters are slowed and provided access to floodplains and functioning wetlands. The recommendations for hydrologic manipulations include:

    - Removals, e.g., plugging or filling of ditches and disabling tile drains, and
    - Installations, e.g., depression excavations, floodplain re-establishment and channel restoration

- Template restoration plans were developed for each of the three natural community types: floodplain forest, shrub swamp and shallow emergent marsh. A specific high-priority site for each of these three community types was selected to illustrate the restoration concepts put forth in this implementation plan.

- The report presents general guidelines that may be used to design and implement most restoration projects, which should be tailored to the specific restoration site, as needed. The report presents guidance for:

    - Re-establishment of natural communities
    - Hydrologic manipulations
    - Control of invasive and noxious species
    - Inspection and maintenance
    - Long-term monitoring
    - Reporting
    - Recommended project time frame

- Sites should be monitored following restoration for both progress in vegetation and hydrologic restoration and for P retention effectiveness. By monitoring the effectiveness of wetland restoration projects, the overall progress of restoration in the LCB can be evaluated and fine-tuned, particularly with regard to achieving the goals for P load reduction to Lake Champlain.

- Landowner interest may be a challenge to implementing restoration plans at many sites. State and federal agencies should investigate appropriate compensation or incentive packages that would attract landowners to the idea of potentially taking land out of agricultural production to implement restoration activities. Additional outreach and education throughout the LCB may be warranted to promote understanding and appreciation of the effects of P on downstream waters such as Lake Champlain, and the role wetlands play in mitigating these effects.

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1.0 INTRODUCTION

The State of Vermont, as part of Governor Douglas' Clean and Clear Action Plan, and in order to meet applicable portions of the Phosphorus Total Maximum Daily Load (TMDL) clean-up plan requirements for Lake Champlain (Vermont DEC and New York State DEC 2002), contracted with environmental consultant Pioneer Environmental Associates, LLC. (Pioneer) and Pioneer subconsultants Arrowwood Environmental, Stone Environmental, and Donald W. Meals, for the preparation of a Wetland Restoration Plan for the Lake Champlain Basin (LCB). This plan presents a basin-wide plan for reducing phosphorus (P) loading in Lake Champlain through restoring historically converted wetland areas that have the greatest potential for P removal. The effort was a success in that a large number of degraded wetlands have been identified as potential restoration areas throughout the LCB; and that the implementation of such restoration efforts will help reduce P loading to Lake Champlain. The plan is a technical document that has been written for those involved in planning ecological restoration efforts such as local conservation commissions, planners, consultants, and state and federal agencies.

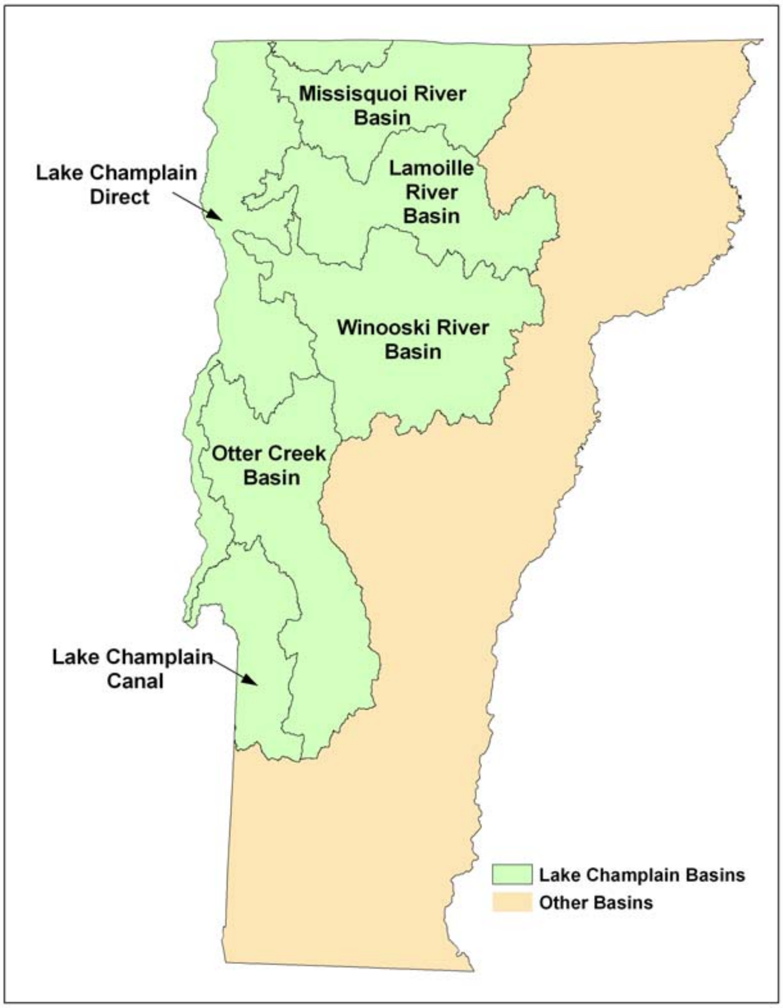


Figure 1: Study Area

The study area included the Vermont portion of the LCB (Figure 1). This area is approximately 2.9 million acres (4,650 square miles) in size, covers much of Northwestern Vermont, and includes part or all of six United States Geological Survey (USGS) eight-digit hydrologic units (subbasins). These include the entire Otter Creek, Winooski River and Lamoille River basins, and portions of the Missisquoi River, Lake Champlain Direct and Lake Champlain Canal subbasins.

The plan is presented as follows. The remainder of Section 1.0 provides readers with contextual background illustrating the importance and need for the development of the plan, as well as an outline of tasks involved in the overall project. Section 2.0 describes and summarizes the spatial analysis employed to develop the set of candidate restoration sites, and the ranking procedure applied to prioritize the sites for restoration. Section 3.0 describes the on-the-ground evaluations and field methods used to ultimately determine a site's suitability for restoration. Sections 4.0, 5.0, and 6.0 present the recommended restoration concepts and guidelines. These concepts are illustrated more specifically through the development of three template plans for three representative natural community types.

1.1 Background

P loads to Lake Champlain are above the TMDL allocation and P concentrations continue to exceed criteria in many lake segments. High P levels contribute to large algae blooms and other water quality impairments resulting from accelerated nutrient enrichment of the lake. Despite substantial management efforts in recent decades to reduce P loading to Lake Champlain from both point and nonpoint sources, P-reduction programs in the LCB have not yet succeeded in attaining P reduction goals. P loads remain above the tributary target loads in nearly all cases and P concentrations in most lake regions are either increasing or show no significant trend (LCBP 2005, Medalie and Smeltzer 2004). Because major progress has been made in reducing point source P loads to the lake, nonpoint sources are now believed to represent approximately 90 percent of the total P load to Lake Champlain, and failure to meet water quality goals has been attributed to insufficient management of nonpoint sources and/or to increasing P loads from urbanizing portions of the LCB (Vermont DEC and New York State DEC 2002).

Nonpoint source P is contributed to Lake Champlain by a variety of land use activities in the LCB. Historically, agricultural land had been thought to contribute the majority of nonpoint source P to the lake, with urban/developed land contributing P at a level disproportionate to its small but growing presence in the LCB (Hegman et al. 1999, Meals and Budd 1998). A recent assessment reflecting increasing urbanization, as well as improved land use classification in the LCB (Troy et al. 2007), now indicates that developed land, including urban, exurban, suburban land, and roadways, contributes the majority of nonpoint source P to Lake Champlain, whereas agricultural land contributes 39%. While urban land areas are the largest nonpoint source of P in the LCB overall, the proportion varies greatly among subwatersheds. For example, agricultural sources are still the highest contributor (about 68%) in the Missisquoi Bay watershed in Vermont. For several decades, approaches to reducing nonpoint source P loads, especially from agricultural sources, have focused on implementation of various Best Management Practices (BMPs) for animal waste and land management through federal and state programs based on voluntary participation of landowners (Jokela et al. 2004, Meals 1990, Meals 2001, USDA-NRCS 2005, VT RCWP CC 1991). Despite high levels of landowner participation in some of these programs, these efforts have yielded limited success in reducing nonpoint source P loads to Lake Champlain.

Major sources of nonpoint source P from the land in the LCB include particulate P from soil erosion and dissolved P from animal waste, fertilizers, and other materials deposited on the land surface. Transfer of P from the land to receiving waters is a function of weather, geology, soils, land use, and land management activities. P transport generally occurs when high P source areas (e.g., high P soils, soils with high erosion potential, and land receiving P fertilizers or animal waste) coincide with hydrologic transport pathways. In most settings, P transport occurs primarily in overland storm-related flows, particularly during wet seasons or major storm events (see Figure 2). Shallow subsurface flows, preferential flow (soil macropores), and artificial drainage can also transport significant quantities of P.

Figure 2: Constructed ditch draining agricultural fields within the floodplain of the Lemon Fair River. During high flow events, runoff and associated P flows through adjacent fields, into the ditch and ultimately discharges into the Lemon Fair River.

Particulate P movement is a complex function of precipitation, runoff, and soil management factors affecting erosion. Dissolved P movement is controlled by desorption, dissolution, and extraction of P from soil and plant or other organic materials. In surface runoff, most P is generally transported in association with particulates (i.e., eroded soil particles), but significant quantities of dissolved P can also be moved in surface runoff if soils are excessively high in P. There is often a positive association between soil P level and P loss in surface runoff. Runoff from grasslands and land receiving heavy manure or fertilizer applications may transport a high proportion of dissolved P. In subsurface flow, most P is transported in the dissolved form, although artificial drainage and soil macropores can transmit particulate P as well. In general, all of dissolved P and some particulate P are considered to be available to support algal growth in fresh water. Because of their position in the landscape, wetlands may receive a high proportion of the P transported from land to water.

Wetlands serve numerous functions and provide many values to both aquatic and terrestrial ecosystems. Recognized functions and values of wetlands include reducing flooding, groundwater recharge/discharge, protecting shorelines from erosion, providing habitat for fish, wildlife, and plants, and improving water quality by intercepting surface runoff, filtering sediments, and retaining nutrients (e.g., Carter 1997, Johnston et al. 1990, Mitsch and Gosselink 2000, Sipple 2003). One of the most important functions of wetlands is their ability to attenuate nonpoint source P loads and thereby maintain and improve the water quality of adjacent water bodies by the retention and removal of significant amounts of sediment, P, and other pollutants transported in land runoff (Kao and Wu 2001, Uusi- Kämppä et al. 2000). This function is due to the nature of wetlands as dynamic biological systems and their unique position in the landscape between upland areas and receiving waters. In undisturbed landscapes, surface runoff often flows through riparian wetlands prior to discharging into streams, rivers and lakes. P-containing sediment can be deposited in riparian wetlands as surface runoff flows through dense wetland vegetation. Floodplain wetlands may also receive P deposited by sediment settling out from flood waters when a river spills out of its banks (Figure 3). P and other nutrients can then accumulate in wetland soils through direct soil addition and as deposited nutrients may be taken up by vegetation and cycled into wetland soils with decaying organic matter.

Figure 3: Wetland adjacent to Lemon Fair River during spring flooding (May 2006).

The importance of wetlands in the retention and removal of significant amounts of sediment and P from runoff has been well documented in the scientific literature (e.g., Brinson 1993, Kao and Wu 2001, Lockaby and Walbridge 1998, Richardson and Qian 1999, Uusi- Kämppä et al. 2000, Walbridge 1993). Water velocity is generally reduced when wetlands intercept runoff enabling sediments and adsorbed P to settle, as well as promoting other biogeochemical processes that are potentially important in wetland processing of P, including the following list cited by Mitsch and Gosselink (2000):

- precipitation of insoluble phosphates with iron, calcium, and aluminum,
- adsorption of phosphates onto clay particles, organic peat, and ferric and aluminum hydroxides or oxides, and
- binding of P in organic matter via incorporation into living biomass.

Figure 4 shows a schematic of these processes.

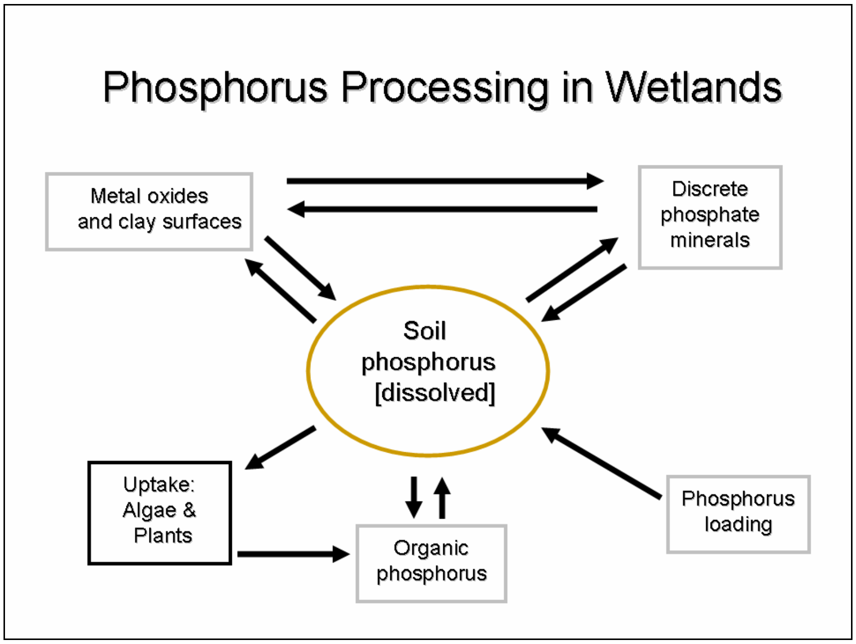


Figure 4: Phosphorus Processing Schematic

Soils of forested riparian wetlands have been shown to have higher P sorption capacities than adjacent uplands or streambanks (Axt and Walbridge 1999, Bruland and Richardson 2004, Darke and Walbridge 2000).

All wetland types appear to have some capacity to store some P and thereby prevent to some extent the increase of downstream P concentrations (Kadlec 2005, Richardson 1999); however P retention in individual wetlands is highly variable in response to such factors as P input, season, hydrologic regime, soil type and chemistry, structure of the vegetation, algal, and microbial communities, and rates of primary production and decomposition. Mitsch and Gosselink (2000) cite numerous studies showing that many freshwater marshes and forested swamps act as annual or seasonal sinks for P, although they note that not all wetlands are P sinks and patterns of P retention may not be consistent from year to year or from season to season.

Wetland vegetation may exhibit high P uptake from water and sediment during the growing season. While some of this P may be moved to roots and rhizomes, a substantial portion of plant P may be lost to senescence and leaching from above-ground vegetation, leading to a net export of nutrients in fall and early spring.

Soil accumulation is thought to be the dominant mechanism of long-term P retention in wetlands. The largest reservoir (~80%) of P in wetlands is in peat and soil and includes buried organic P from plant litter as well as annual additions from adsorption and chemical precipitation. P adsorption and retention in freshwater wetland soils is controlled by redox potential, pH, available Fe, Ca, and Al minerals, and the amount of native soil P (Richardson and Craft 1993).

Kadlec (2005) summarized P removal processes in emergent wetlands. P interacts strongly with wetland soils and biota, which provide both short-term and sustainable long-term P storage. Soil sorption may provide initial removal, but this partly reversible storage eventually becomes saturated. Uptake by biota, including bacteria, algae, and macrophytes provides another initial removal mechanism. Cycling through growth, death, and decomposition returns most of the biotic uptake, but an important residual contributes to long-term accretion in newly formed sediments and soils.

The P assimilative capacity of a wetland is believed to be finite and strongly influenced by P loading to the wetland. Research suggests that below a threshold of about 1 g P/m^2/yr, most North American wetlands can retain P with no increase in outflow P concentration and no significant wetland ecosystem alteration (Richardson 1999, Richardson and Qian 1999). Above this threshold, some added P will “leak” from the wetland, even though some net P retention is maintained at a lower efficiency.

While P retention by individual wetlands appears to be quantitatively variable, at a landscape scale wetlands are believed to play an important role in maintaining regional water quality (Darke and Walbridge 2000). During high flow events, natural wetlands in the LCB have been shown to be a significant sink for nonpoint source P (Wang et al. 2004, Weller et al. 1996). In the LaPlatte River watershed (VT), Windhausen et al. (2004) found that the areas of hydric soils on nonagricultural land functioned as significant P sinks in the landscape; the presence of wetlands in the landscape was significantly correlated with reduced P export. The authors recommended that managers consider seasonally saturated areas, even lacking wetland vegetation, as important watershed resources for P retention.

Because of their effects on water quantity and quality, wetlands could play a critical role in reducing runoff pollution. However, many wetland acres have been destroyed or degraded by agriculture, urbanization, and other land development activities. When European settlers first arrived, wetland acreage in the lower 48 states probably exceeded 220 million acres, or about five percent of the total land area according to estimates by the U.S. Fish and Wildlife Service. Unfortunately, by 1997 total wetland acreage declined by more than 50 percent to 105.5 million acres. Some 10 million acres of natural wetlands have been destroyed or severely degraded across the U.S. since 1954 according to the USDA-NRCS. The LCB has been no exception to this trend. Approximately 35 percent of Vermont's wetlands have been lost since European settlement (Dahl 1990). Loss of wetlands in the LCB through draining, filling, ditching, alteration of vegetation, etc. has undoubtedly allowed more direct contribution of pollutants from the land to receiving waters, as well as loss of support for fish, wildlife, and other values. Restoration of key wetlands, with particular attention to enhancing P retention, could be an important component of overall efforts to reduce nonpoint source P loading to Lake Champlain. To facilitate this endeavor, the wetlands with the greatest potential for restoration and retention of nonpoint source P must be identified and prioritized for restoration. This project was conducted to develop and prepare a LCB-wide wetland restoration plan through the identification of wetlands in the Vermont portion of the LCB with the greatest potential for P removal through restoration.

1.2 Project Overview

The following tasks were completed in the development of the Wetland Restoration Plan:

1. **Identification of Potential Restoration Sites (Site Selection Model).** Potential restoration sites were identified on the approximately 2.9 million acres of the LCB within Vermont using ArcGIS® 9.1 software to generate a polygon layer of potential restoration sites. Non-forested sites were inventoried according to a set of criteria that included hydric soils, slopes equal to or less than five percent, and areas equal to or greater than three acres in size. The result was a preliminary set of potential agricultural and other open land wetland restoration areas to be further refined in subsequent tasks.

2. **Prioritization Model**. The prioritization model screened potential restoration sites identified in Task 1 to determine which sites are best suited for restoration based on criteria such as the ability of the site to effectively retain P, the proximity to surface waters, and the amount of P from the contributing drainage area potentially treated. The model was constructed in ArcGIS® using existing GIS data available from state (Vermont Center for Geographic Information, Vermont Mapping Program), regional (Lake Champlain Basin Program), and federal (United States Geologic Survey, and Farm Service Agency) sources. The model scoring and weighting system resulted in an ordinal ranking of candidate sites, where highest scoring sites have the greatest potential for P removal.

3. Site Evaluation and Feasibility Study. A field evaluation and feasibility analysis was conducted on a total of 82 sites according to the final prioritization model rankings, with emphasis on sites in the highest-ranking category. The analysis centered on three primary factors that reflect the suitability of sites for restoration:

1. whether on-site evaluation supports the finding that the site is a degraded or converted wetland,
2. whether restoration of the site has the potential to remove significant quantities of P, and
3. whether restoration of the site is possible.

The field evaluation also included landowner contact when possible and assessment of the landowner's interest in future wetland restoration, evaluation of the technical feasibility for restoration, and the identification of significant obstacles to restoration, including the potential impacts on adjacent properties.

4. Development of the Wetland Restoration Plan. The resulting Wetland Restoration Plan presents a series of restoration strategies for the list of suitable wetlands that were identified and prioritized. Sites that received a field visit (i.e., the sites that received the highest priority for restoration in the prioritization model) were used as a basis for developing template restoration plans for three specific natural community types. These community types were determined to be most representative of those sites visited during the course of the feasibility study. A specific site is highlighted as an example for each of the three template plans. The selected sites are included for illustration purposes, and do not necessarily indicate landowner interest in the restoration project.

2.0 SITE SELECTION AND SITE PRIORITIZATION MODEL

In order to identify and prioritize potential wetland restoration sites suitable for P mitigation in the LCB, two models were developed, the site selection model and the site prioritization model. The site selection model was used to identify candidate wetland restoration sites and the site prioritization model was used to prioritize those sites. Both models were developed using GIS data with ESRI® GIS tools and model builder software.

In combination, the two models were used to generate a GIS data set of potential wetland restoration sites ranked according to their potential value for mitigating P loading in Lake Champlain. This data set was then used as the basis for conducting site visits and field work at the most promising potential restoration sites located in the six subbasins. The site visits consisted of an evaluation of the potential value for P mitigation based on a field observation and, when possible, a land owner survey.

2.1 Site Selection Model

2.1.1 Site Selection Model Introduction and Methods

The site selection model identified areas that could be restored to functional wetlands capable of mitigating P loading to Lake Champlain. The concept for the model was based on a screening process developed by the United States Department of Agriculture (USDA) using Common Land Unit (CLU) data (see metadata link on page 1 of Appendix I). The CLU data covered approximately 1.2 million acres out of the 2.9 million acre study area and was based on 1994 land cover data.

Originally, the work plan called for the use of the screened CLU data for the approximately 1.2 million acres of the LCB that had been previously evaluated by USDA, with additional modeling to identify sites within the remaining 1.7 million acres of the LCB that had not been previously evaluated by USDA. However, it was decided that using the methodology that USDA used to screen the CLU data (instead of the actual data) to build a single model for identifying sites for the entire LCB would provide a more consistent and therefore more useful data product. It should also be noted that Vermont Center for Geographic Information (VCGI) incorporated the CLU dataset into its latest version of the land cover layer, produced in 2002, which the project team used within the site selection and site ranking models.

The site selection model was designed to identify areas three acres or greater in size with the following characteristics: slope less than five percent, hydric soils, and land cover/land use defined as barren lands, orchard, other agriculture, non-forested wetland, hay/pasture or row crop (Figure 5). A more detailed description of the site selection model including source data and criteria is provided below.

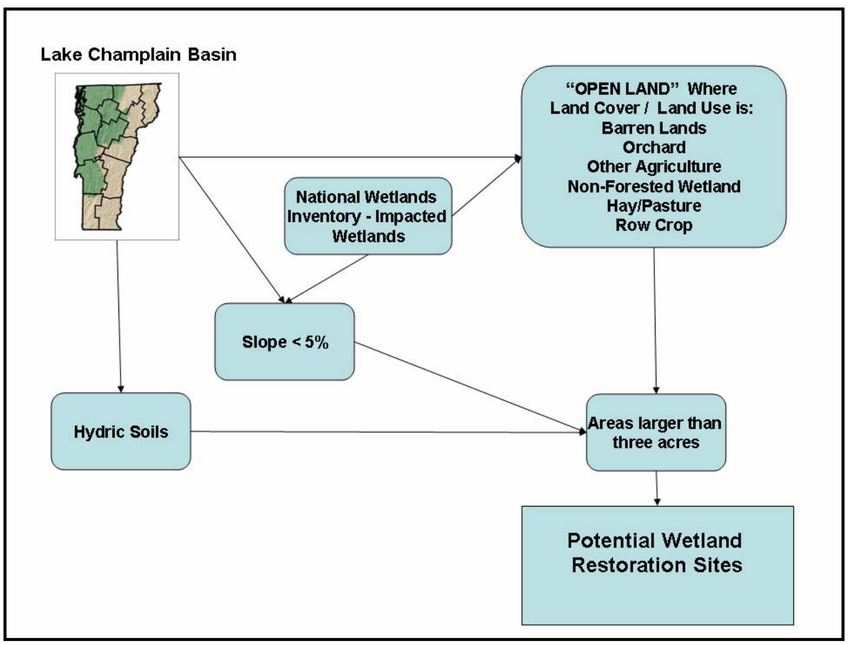


Figure 5: Site Selection Concept Diagram

Areas that failed to meet one or more of the above criteria were excluded from further evaluation, while areas that met all of the above criteria were considered potential restoration sites. Additional areas within the LCB that were categorized by the National Wetlands Inventory (NWI) as disturbed wetlands were also evaluated independently of the hydric soils criterion. For example, areas of impacted wetlands that met the slope, land cover/land use, and size criteria were included as potential sites.

The final product of the site selection model was a GIS dataset of polygon features that represented potential restoration sites. However, intermediate modeling steps and output were in grid format, sometimes referred to as raster format, with a minimum analysis unit of ten square meters. ESRI Model Builder software was used to build the site selection model, and a schematic of the model is presented on page 2 of Appendix I. GIS data from state and federal sources were used to construct the model and are presented in Table 1.

Table 1: Site Selection Model Base Data

Model Input	GIS Data Source(s)	Data Type	Scale/Cell Size	Data Provider -Date
Hydric Soils*	Soil Survey Geographic Database (NRCS Soils)	Vector	1:12,000	National Resources Conservation Service (NRCS) – 1992 – 2006
Slope < 5%	HydroDEM	Grid	10 Meter	Vermont Center for Geographic Information (VCGI) - 2005
Open Land	LCLU 2002	Grid	30 Meter	VCGI - 2002
Disturbed Wetlands**	National Wetlands Inventory	Vector	1:24,000	United States Fish and Wildlife Service (USGWS) – 1980s – 1990s

* Caledonia County not available, 51,200 acres of LCB excluded from the overall analysis.
** Selected quads available see Figure 6 below.

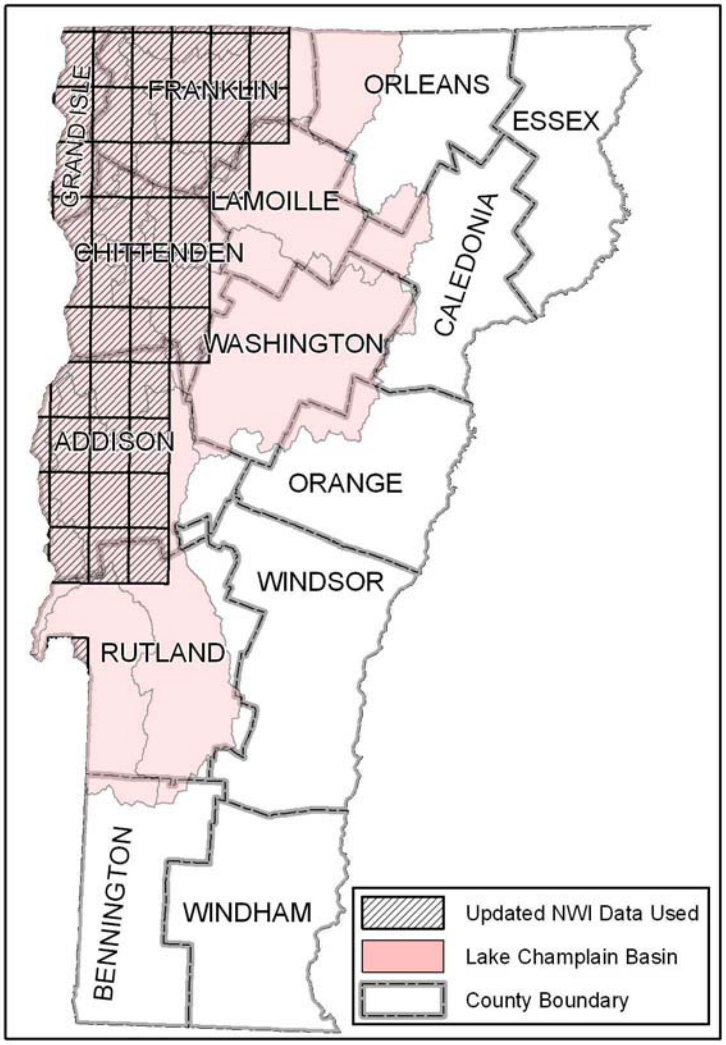


Figure 6: Updated NWI mapping data availability map

The individual model inputs were evaluated based on the value of specific attributes of the source data, and are presented in Table 2.

Table 2: Site Selection Model Attributes

Model Input/Data Source	Attribute	Potential Values	Potential Site	Notes
Hydric Soils/SSURGO Soils	Hydric	Y	YES	Soils with null values were not considered hydric
		N	NO	
Slope ≤ 5% / HydroDEM	Slope %	≤5%	YES	None
		> 5%	NO	
Open Land/LCLU 2002	LCLU Class	Water	NO	Residential areas were not considered open due to variability in the density of the residential development
		Barren Lands	YES	
		Residential	NO	
		Industrial	NO	
		Commercial	NO	
		Transportation / Utilities	NO	
		Other Urban	NO	
		Orchard	YES	
		Other Agriculture	YES	
		Deciduous Forest	NO	
		Coniferous Forest	NO	
		Mixed Forest	NO	
		Forested Wetland	NO	
		Non-Forested Wetland	YES	
		Hay / Pasture	YES	
		Row Crop	YES	
Disturbed Wetlands/ National Wetlands Inventory	Last digit of field - Attribute	b - Beaver	NO	NWI wetlands over 3 acres in size that were considered possible sites were further evaluated to include only areas with ≤ 5% slope and open land
		r – Artificial Substrate	NO	
		s - Spoil	NO	
		h – Diked/Impounded	YES	
		f - Farmed	YES	
		d – Partially Drained / Ditched	YES	
		x - Excavated	YES	

For the LCB, each ten square meter area was considered a potential site if it satisfied all three criteria of the model, or was removed from consideration if it failed to meet any of the model criteria. To complete the model process, the grid cells were aggregated into polygon features and areas that were less than three acres were eliminated from consideration.

A final step included in the original work plan, the screening of sites identified by the model, was not conducted. The purpose of screening the process was to determine improperly identified sites using photo interpretation of the National Aerial Inventory Program color orthophotographs from 2003. Due to the use of satellite imagery from 2002 to produce the land use data layer used within the model, there is only a single year of landscape change between the model data and the comparison data set. During this brief interval it is unlikely that significant landscape change has occurred on more than a handful of sites, thus reducing the potential usefulness of screening all of the sites identified in the site selection model. Due to this brief interval between the model and comparison data sets and the opportunity to conduct screening of a subset of the data sets, screening prior to visiting the sites in the field was elected.

2.1.2 Site Selection Model Limitations

Any model is limited by the choice of input data and the criteria selected for evaluation. The 2002 land use layer was the most limiting factor in the site selection model. The relatively large size of the individual grid cells, 30 square meters (9,687 sq. ft.), required some generalization of the land use features. For example, even though the model result grid unit was set at ten square meters, a relatively small country road, or small stream that was captured by the land use layer would be 30 meters wide due to the grid cell size of the land use layer. In addition to the limitation of grid cell size the errors inherent in the base layers used within the model are passed through and become part of the model results. For example, any errors within the HydoDEM elevation model would be passed through to the final results resulting in either the inclusion of areas that were actually too steep or the exclusion of areas that were within the desired 5 percent slope and under range. For a more complete picture of the limitations of the input data sources please refer to the online links to the model source metadata listed on page 1 of Appendix I.

An additional observation was made during the field study related to the slope criterion of the site selection model. Because sites were only selected that were relatively flat (i.e., less than or equal to 5 percent slope), the sites that were chosen were not as obvious P source areas as they may have been if steeper (i.e., more erodible) sloped areas were included in the results. However, if the threshold value for the slope criterion were increased, the selected sites may have been less suitable for wetland restoration due to their landscape position. Nonetheless, the idea of increasing the slope criterion threshold value came up several times during the course of the field study as a means to capturing more extreme P-source areas that could be potentially converted to P-sink areas.

2.1.3 Site Selection Model Results

The site selection model identified 4,883 potential sites occupying approximately 86,480 acres (135 square miles) within the Vermont portion of the LCB. Potential sites ranged in size from the minimum value of 3 acres to a maximum of 1,490 acres with a mean site area of approximately 18 acres. These sites are distributed among the six subbasins across the LCB as shown in Table 3.

Table 3: Site Selection Model Results

Subbasin	Area (Acres)	Number of Sites	Area of Sites (Acres)	Percentage of Subbasin
Lake Champlain Canal*	238,210	60	420	0.2%
Lake Champlain Direct*	591,430	2,203	42,720	7.2%
Lamoille River	462,650	376	3,500	0.8%
Missisquoi River*	391,929	785	10,030	2.6%
Otter Creek	604,160	1,081	24,900	4.1%
Winooski River	680,380	378	4,910	0.7%
Total	2,968,750	4,883	86,480	2.9%

*Vermont portion of subbasin only, areas in New York and Canada excluded.

The Lake Champlain Basin Atlas (LCBP 2004) indicates that the Missisquoi Bay and Otter Creek lake segments have the highest P loads to the lake and require the greatest reductions to meet goals (39 t/yr or 26 percent and 5 t/yr or 8 percent, respectively). Sixteen percent of the sites covering 12 percent of the area were located in the Missisquoi subbasin; 22 percent of the sites covering 29 percent of the total area were located in the Otter Creek subbasin. In other words, approximately 40 percent of the identified sites are located in the areas of the Vermont LCB where the greatest P load reductions are needed.

2.2 Site Prioritization Model

2.2.1 Site Prioritization Model Introduction and Methods

The site prioritization model was developed to rank each potential restoration site for its potential to mitigate P loading in Lake Champlain. The methodology for this model was fashioned through a collaborative process between the project team, VT FPR, and other stakeholders. The basic concept for this model was the scoring and weighting of various attributes for each of the sites and the sites' upslope drainage areas to generate a final restoration score. The final restoration score was used to rank the site for its potential to mitigate P loading in the LCB.

The site prioritization model was initially designed with three components: site function, site location, and upslope drainage area, composed of 15 individual model variables. Each model variable was ranked on a scale of 0 to 5 or 1 to 5 based on its potential for mitigating P, reflected by the value of a particular attribute or combination of attributes. In addition, each model variable was assigned a weight within the model. The model weight represented the relative importance of the particular model variable within the overall model. The final restoration score was arrived at by summing the product of the individual model input rank by its model weight.

A series of discussions with the project team, VT FPR, and other stakeholders was conducted to set the relative importance (or weight) of each model variable and component within the model. These discussions resulted in a group consensus on the format and weighting assignments for the first draft of the site prioritization model. The first draft model was then run for a pilot watershed, the Otter Creek subbasin, and the results were tested in the field.

After field testing, the structure of the model was modified to include only two model components, site function and upslope drainage area, made up of 11 model variables. The site function component was calculated for areas identified in the site selection model. The upslope drainage area component was calculated for the drainage areas or watersheds of the individual sites.

Several model variables that were originally considered were eliminated due to practical limitations of the input GIS data and field-based determination of the variables' contribution to the model. The four model variables eliminated were site slope, channel sinuosity, proximity to Lake Champlain, and location within the watershed.

The site slope variable was eliminated because the sites that were identified as a result of the site selection model were already limited to relatively flat sites (i.e., less than or equal to 5 percent). Further distinguishing sites between 0 and 5 percent in the prioritization model seemed inappropriate due to the narrow slope range under consideration. Once in the field, a site that had been identified as having a one percent slope, for example, did not appear significantly different than one that had a five percent slope in terms of its potential restoration value.

The channel sinuosity variable was removed from the model as it was determined that the model should ideally prioritize those sites that contain channels that had been artificially straightened in the past, where sinuosity (and associated P retention properties) could be reinstated as part of a restoration plan. Upon reviewing available GIS data layers that could potentially evaluate whether and how much a channel had been altered in this capacity, it was determined that such a data layer did not exist.

The proximity to Lake Champlain variable was removed from the model because it was determined that using this variable would erroneously favor lake margin wetlands that are more influenced by the lake itself than by drainage from the surrounding terrestrial landscape. Furthermore, it has been shown that streams in the LCB have a limited potential for long-term retention of P loads; over periods of a year or more, most of the P entering a tributary is likely to be delivered to Lake Champlain, regardless of travel distance (Wang et al. 1999). It was therefore determined that the proximity to surface water variable better captured the project team's intent for the model.

The location within the watershed variable was removed from the model as the vast majority of sites (+/- 85 percent) identified by the site selection model already fell within the "low elevation" class. It was determined, therefore, that this factor would not significantly affect the overall results of the model.

The final version of the site prioritization model, including the 11 model variables, is presented below in Figure 7.

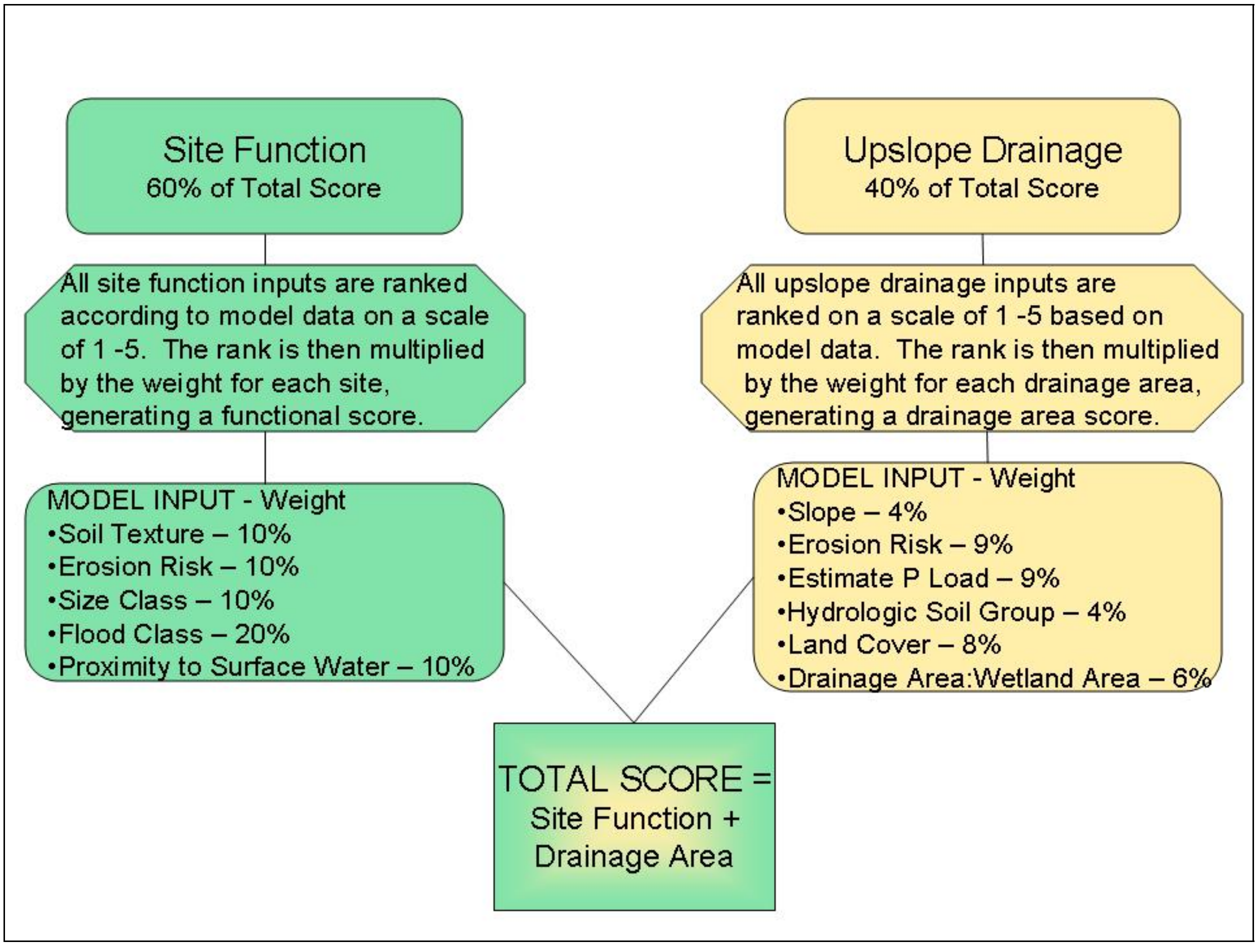


Figure 7: Site Prioritization Model Diagram

The justification behind each of the 11 model variables follows:

<u>Site Function</u>

The site function category focuses on a given site's suitability for wetland restoration in the context of P retention.

Soil Texture – Soil texture influences the cation exchange capacity of a wetland and thus the amount of nutrients that can be stored in the specific soil and wetland. Texture also affects such factors as the wetland soil's hydraulic conductivity, and initial water permeability rates (Hillel 1982).

Erosion Risk - The erodibility of a wetland's soil contributes to the likelihood for the wetland (especially disturbed wetland systems) to contribute sediment and its associated nutrient load to surface waters.

Size Class - All other factors being equal, the greater the size of the wetland, the larger its water holding capacity and typical water inflow rates. The greater the inflow and volume of sediments, the greater the potential of retaining these same sediments (and attached nutrients) within the wetland soil and basin. In addition, in general, the greater the wetland size, the greater the volume of sediment and plant material, and the higher the retention and processing capacity of the wetland for nutrients such as nitrogen and phosphorus.

Flood Class - Wetlands within floodplains retain both sediments and nutrients such as P and nitrogen (Yates and Lohner 1983). Wetlands associated with flooding waterways make a significant positive contribution to water quality.

Proximity to Surface Water - Riparian wetlands intercepting upgradient runoff before delivery to surface waters have a higher potential to keep P out of surface waters than do wetlands that do not occur between P source areas and streams.

Upslope Drainage Area

The upslope drainage area category evaluates a given site's drainage area for its potential to transport P to the site.

Slope – Slope contributes to both soil loss and runoff potential within the upslope drainage area, and ultimately into the restoration site.

Erosion Risk – Erosion risk considers both the native erodibility of a soil as well as its current land use, both of which affect the quantity of P that would be transported through the drainage area and into the restoration site. The calculation of this factor is addressed in more detail below.

Estimated P Load – This factor consists of the average areal P load of the drainage area estimated using export coefficients appropriate to the LCB (Hegeman et al. 1999).

Hydrologic Soil Group – Soils are classified by the NRCS into four Hydrologic Soil Groups (A – D) based on the soil's runoff potential, with A soils generally having the lowest runoff potential and D soils the highest. Because the majority of P is transported from the land to receiving waters by surface runoff, a drainage area with soils of a greater runoff potential (e.g., HSG C or D) received a higher score than a drainage area with soils of lower runoff potential.

Land Use – Land use in the drainage area contributing to the restoration site largely determines the amount of P potentially delivered to the site.

Drainage Area: Site Area – For management measures such as vegetated filter strips and constructed wetlands, hydraulic loading is a key parameter determining pollutant-removal performance.

Where such measures are severely overloaded, pollutant-removal performance is substantially diminished. Sites with a high drainage area to wetland area ratio are more likely to have high hydraulic load and their P removal performance therefore lower than sites with more moderate loading. On the other end of the scale, sites with very small contributing areas, while not hydraulically overloaded, are not likely to receive high volumes of runoff and their absolute potential for P removal is probably small. Therefore, sites with a moderate drainage area to wetland area ratio were scored higher than either areas with a very high or a very low ratio.

The site function component of the model represented 60 percent of the final restoration score and the upslope drainage component represented 40 percent of the final restoration score. The 11 variables that made up the two components were represented by GIS data as shown in Tables 4.a and 4.b.

<table>
<tr><th colspan="5">Table 4.a: Site Prioritization Model
Site Function Component</th></tr>
<tr><th>Model Variable</th><th>GIS Data Source(s)</th><th>Ranking Attribute</th><th>Formula and Ranking</th><th>Overall Model Weight (%)</th></tr>
<tr><td>Soil Texture</td><td>NRCS Soils</td><td>Soil Texture</td><td>See Table 5.a</td><td>10</td></tr>
<tr><td rowspan="2">Erosion Risk</td><td>NRCS Soils</td><td>K factor</td><td rowspan="2">LU X K
* See Table 5.b</td><td rowspan="2">10</td></tr>
<tr><td>LCLU 2002</td><td>Land Use (LU) Code</td></tr>
<tr><td rowspan="5">Size Class</td><td rowspan="5">Site Selection Model</td><td rowspan="5">Area</td><td>3-4 acres : 1</td><td rowspan="5">10</td></tr>
<tr><td>4-10 acres : 2</td></tr>
<tr><td>10-25 acres : 3</td></tr>
<tr><td>25-70 acres : 4</td></tr>
<tr><td>>70 acres : 5</td></tr>
<tr><td rowspan="6">Flood Risk</td><td rowspan="6">NRCS Soils</td><td rowspan="6">Flood Risk</td><td>Water : 0</td><td rowspan="6">20</td></tr>
<tr><td>None : 1</td></tr>
<tr><td>Very Rare : 2</td></tr>
<tr><td>Rare : 3</td></tr>
<tr><td>Occasional : 4</td></tr>
<tr><td>Frequent : 5</td></tr>
<tr><td rowspan="5">Proximity to Surface Water</td><td rowspan="4">Vermont Hydrography Data Set</td><td rowspan="4">Distance from Site Centroid to Nearest Water Body (D)</td><td>R(2.5)>D : 1</td><td rowspan="5">10</td></tr>
<tr><td>R(1.5)<D<R(2.5) : 2</td></tr>
<tr><td>R(1.25)<D<R(1.5) : 3</td></tr>
<tr><td>R<D<R(1.25) : 4</td></tr>
<tr><td>Site Selection Model Data</td><td>Site “Radius” based on assumption of a round site
(R = $\sqrt{\frac{Area}{\pi}}$)</td><td>D<R : 5
Site is coincident with mapped surface water:5</td></tr>
<tr><td colspan="4">Total</td><td>60</td></tr>
</table>

Table 4.b: Site Prioritization Model
Upslope Drainage Area Component

Model Variable	GIS Data Source(s)	Ranking Attribute	Formula and Ranking	Overall Model Weight (%)
Slope	HydroDEM	Slope	Slope < 2.45 : 1 2.45<Slope<3.77 : 2 3.77<Slope<5.66 : 3 5.66<Slope<9.04 : 4 9.04<Slope<42.7 : 5	4
Erosion Risk	NRCS Soils	K Factor	LU X K** See Table 5.c	9
	LCLU 2002	Land Cover / Land Use (LCLU) Code		
Estimated P Load	Phosphorus Load	Phosphorus Load (kg/ha/yr)*	<0.2 kg/ha/yr :1 0.2-0.3 kg/ha/yr : 2 0.31-0.4 kg/ha/yr : 3 0.41-0.5 kg/ha/yr : 4 >0.5 kg/ha/yr : 5	9
Land Cover	LCLU 2002	Land Use Code	Forest : 1 Open : 2 Row Crop : 4 Urban : 5	8
Hydrologic Soil Group	NRCS Soils	Hydrologic Soil Group	A : 1 B : 2 C : 4 D : 5	4
Drainage Area / Site Area**	Site Selection Model Data	Area (DA)	Formula - DA : SA >50:1, and <3:1 : 1 30:1 to 50:1 : 2 20:1 to 30:1 : 3 5:1 to 20:1 : 4	6
	Drainage Area Data	Area (SA)	3:1 to 5:1 : 5	
Total				40

* P coefficients from Hegeman et al. 1999 provide basis for ranking.
** This criterion was not included in model if site was ranked 4 or 5 for flood risk.

The method for calculating a restoration score was dependent on the spatial interaction of the model variables within the site or upslope drainage area and can best be described by providing a description of the site prioritization model process for a sample site. For example, site number 268 has a soil texture of muck (rank 2, see Table 5.a), an erosion risk of 0.4 (rank 0.4, see Table 5.b), an area of 19.9 acres (rank 3), a flood ranking of none (rank 1), a “radius” of 90.5 meters, with the site centroid 186 meters from the nearest surface water, however the site overlaps with mapped surface water (rank 5). Using the equation for the site function score, the sum of the product of the variable rank and the weight, the project team arrives at:

(2*10) + (0.4*10) + (3*10) + (1*20) + (5*10) = 124

The upslope drainage area has an average slope of 13.7 percent (rank 5), an erosion risk of 0.8 (rank 0.8, see Table 5.c), a P load of 0.230 kg/ha/yr (rank 2), average land cover score of 1.66 (rank 1.66), average hydrologic soil group score of 4.5 (rank 4.5), and a DA:SA of 2515:19.9 acres or 126:1 (rank 1). Therefore the upslope drainage component of site number 268 is:

(5*4) + (0.8 *9) + (2*9) + (1.66*8) + (4.5*4) + (1*6) = 82.48 rounded to 82.

The total restoration score for site number 268, expressed as the site function score added to the upslope drainage score, is 206. The model results for site number 268, specifically, are included on pages 23 and 24 of Appendix I.

The NRCS attribute for soil texture and its relationship to the site prioritization model is summarized in Table 5.a.

Table 5.a: Soil Texture and Site Prioritization Model Rank

Soil Texture	NRCS Code	Model Rank
Weathered Bedrock Unweathered Bedrock Water	WB UWB WATER	0
Sand Loamy Very Fine Sand Sand and Gravel Very Fine Sand Cobbly Alluvial Land Alluvial Land Pits Sand and Gravel	S LVFS SG VFS CAL ALLUV PIT	1
Fresh Water Marsh Muck Muck-Peat Peat Sapric Material	FWM MUCK MPT PEAT SM	2
Fill Land Sandy Clay Loam Sandy Loam Variable Very Fine Sandy Loam	FILL SCL SIL VAR VFSL	3
Sandy Clay Silty Clay Loam	SC SICL	4
Silt Silty Clay Terrace & Escarpments, Silty and Clayey	SI SIC TESIC	5
Extremely Shaly Extremely Slaty Extremely Stony Extremely Stony Mucky Mucky Peaty Rubbly Shaly Slaty Stony Stratified Unknown Very Shaly Very Slaty Very Stony Very Stony Mucky Stony Mucky	SHX SYX STX SXM MK PT RB SH SY ST SR UNK SHV SYV STV SVM SL	Not Used - these attributes are only used as modifiers to the base textures above.

Table 5.b and 5.c display the formula used to calculate the erosion risk value for both the site function and upslope drainage area component. The erosion risk factors LU and K were determined separately because erosion risk is considered to be a function of the native erodibility of a soil (K), modified by the land use (LU) influence on the exposure of the soil to erosive forces. As shown in Table 5.b, for example, for a soil of the same erodibility, land in row crops (LU factor 1.5) is considered to have a much larger erosion risk than land in hay/pasture (LU factor 0.5).

Table 5.b: Erosion Risk for Site Function Model Component

Land Use	Factor (LU)	Soil erodibility	Factor (K)	Erosion Risk
Orchard	0.2	K ≤ 0.2	1	Erosion Risk = LU * K (LU x K ≥ 5 : 5)
Other Agriculture	0.4			
Non-Forested Wetland	0.4	0.21 ≤ K ≤ 0.39	3	
Hay/Pasture	0.5			
Barren Lands	0.8	K ≥ 0.4	5	
Row Crop	1.5			

Table 5.c: Erosion Risk for Upslope Drainage Model Component

Land Use	Factor (LU)	Soil erodibility	Factor (K)	Erosion Risk
Water Forest Wetland	0	K ≤ 0.2	1	Erosion Risk = LU * K (LU x K ≥ 5 : 5)
Forest Deciduous Forest Coniferous Forest Mixed	0.1			
Orchard	0.2	0.21 ≤ K ≤ 0.39	3	
Other Agriculture Non-Forested Wetland Hay/Pasture	0.4			
Barren Lands Residential Commercial Industrial Transportation/ Utilities Other Urban	0.8	K ≥ 0.4	5	
Row Crop	1.2			

The site prioritization model was built using both model builder and standard GIS tools. The source data for model variables were generated using standard GIS tools and the final rankings calculations were conducted in model builder. A schematic of the model is included on pages 3 and 4 of Appendix I.

2.2.2 Site Prioritization Model Limitations

As stated above in the site selection model limitation section, the model results are limited by the input data associated with the model variables. These limitations are detailed in the full metadata for the model results data layer included on pages 5 through 14 of Appendix I. For the site prioritization model, the ranking and weighting of those variables also limit the model. For example, as a result of the group process that was involved in weighting the various model variables, it was determined that the flood risk variable was of particular importance in determining a site's potential for mitigating P, and was given the highest weight (20 percent) of all model variables. Consequently, a large portion of the high ranking sites that became the subject of the feasibility study, discussed in greater detail below under Section 3.0, were positioned within active flood zones and tended to be dominated by ditches as the primary method for hydrologic manipulation. Drain tiles are not typically utilized in floodplain areas, and correspondingly drain tiles were not identified at any of the high priority sites that were evaluated during the feasibility study. Should prioritization of restoration of sites with drain tiles become part of a restoration strategy or approach, the flood risk variable should be given less importance in the model.

Additional observations were made in the field regarding limitations of the model. In general, the model appropriately identified a general area for potential restoration. However, the area that was demarcated by the model always changed following field review, reflecting details that the model could not ascertain due to the limitations of the input data. For example, pockets of upland areas that were distinct in the field were identified within areas mapped as hydric soils by the model. Also, site boundaries were often set well back from a river or stream, a function of the width of the stream polygon which was used in the model. From a P mitigation standpoint, a given site's boundaries should extend to, and in many cases include the adjacent watercourse. In any case, the model is a good place to start to get a rough location for a potential restoration site; field review, however, is always necessary to truly define a site's boundary.

The current model can be applied to other restoration objectives as well. While the focus of this study has been the mitigation of P, the methodology developed can also be applied to meet other restoration goals. Both the site selection and prioritization model can be modified to incorporate additional or alternative criteria. For example, the prioritization model could be modified by a conservation organization interested in habitat preservation to contain variables reflecting a site's suitability for wildlife habitat. Sites could also be targeted that are located adjacent to existing functioning wetland complexes with the goal of expanding existing corridors or natural areas. In addition, the results could be used by both state/federal agencies and the regulated community to identify appropriate wetland mitigation sites in the context of wetlands permitting.

2.2.3 Site Prioritization Model Results and Discussion

The result of the site prioritization model was a polygon data set of individually scored potential restoration sites in the LCB. The results are presented by component and in total, in Tables 6 through 8. Out of a possible maximum restoration score of 500, the highest ranked site scored 460 and the mean score was 271. For the site function component, the highest ranked site scored 288 out of a possible 300, with a mean score of 155. The upslope drainage area component maximum was 190 out of a possible 200 and the mean score was 116.

Table 6: Site Function Component Descriptive Statistics

Subbasin	Minimum	Maximum	Mean	Standard Deviation
Lake Champlain Canal	71	269	164	50
Lake Champlain Direct	60	272	154	36
Lamoille River	33	283	145	49
Mississquoi River	55	268	142	51
Otter Creek	53	288	169	44
Winooski River	70	287	159	49
Overall	33	288	155	44

The Otter Creek subbasin has the highest mean site function score when compared with the other subbasins. This is a reflection of the prevalence of clay soils in the LCB. The mean soil texture rank for sites in the Otter Creek subbasin was 4.4 compared with 3.7 for the remaining subbasins. The Otter Creek subbasin also scored slightly above the mean for each of the other site function variables including size, erosion risk, distance to surface water and flood risk.

Table 7: Upslope Drainage Area Component Descriptive Statistics

Subbasin	Minimum	Maximum	Mean	Standard Deviation
Lake Champlain Canal	52.8	148	98	23
Lake Champlain Direct	47	186	122	23
Lamoille River	42	161	100	25
Mississquoi River	47	181	101	25
Otter Creek	46.3	190	122	27
Winooski River	49	173	112	27
Overall	42	190	116	27

The upslope drainage area component mean scores are highest in the Otter Creek and Lake Champlain Direct subbasins. These subbasins are located predominately in the Champlain Valley and include a large amount of agricultural land as well as much of the urban development in Vermont. This combination results in a high potential for P loading and thus a high upslope drainage area score.

Table 8: Restoration Score Descriptive Statistics

Subbasin	Minimum	Maximum	Mean	Standard Deviation
Lake Champlain Canal	158	378	262	52
Lake Champlain Direct	125	417	276	44
Lamoille River	91	418	245	51
Mississquoi River	110	435	243	53
Otter Creek	120	460	291	54
Winooski River	155	429	271	53
Overall	91	460	271	52

The dominance of highly ranked sites in the Otter Creek subbasin is a reflection of the model design. The Otter Creek subbasin is characterized by a high proportion of agricultural land in close proximity to streams and surface waters with clayey soils in soil hydrologic groups C and D. This combination results in a landscape that has the potential to generate a large amount of non-point P loading. While the Otter Creek subbasin leads all of the subbasins in total restoration score it is important to note that the model has identified many important sites in the remaining subbasins.

The distribution of the site function, upslope drainage area, and overall scores followed that of a normal population. This normal distribution, expressed as a standard bell curve, suggests that the final restoration score provides differentiation between the potential restoration sites as it was designed to do (Figure 8). While it is encouraging that the model produced variable results allowing differentiation between potential restoration sites, further model validation is required to complete an assessment of the accuracy of the site prioritization model.

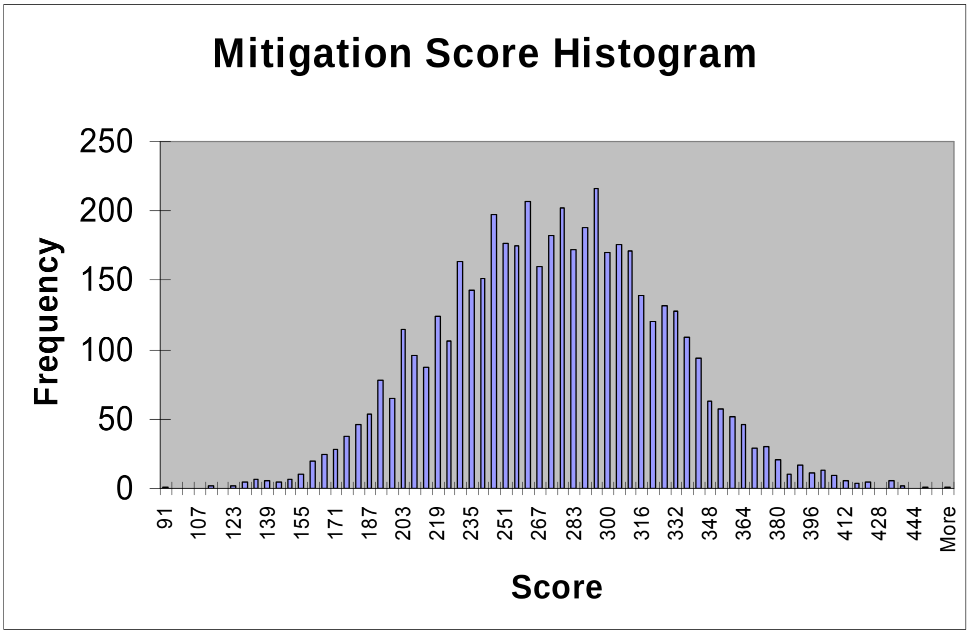
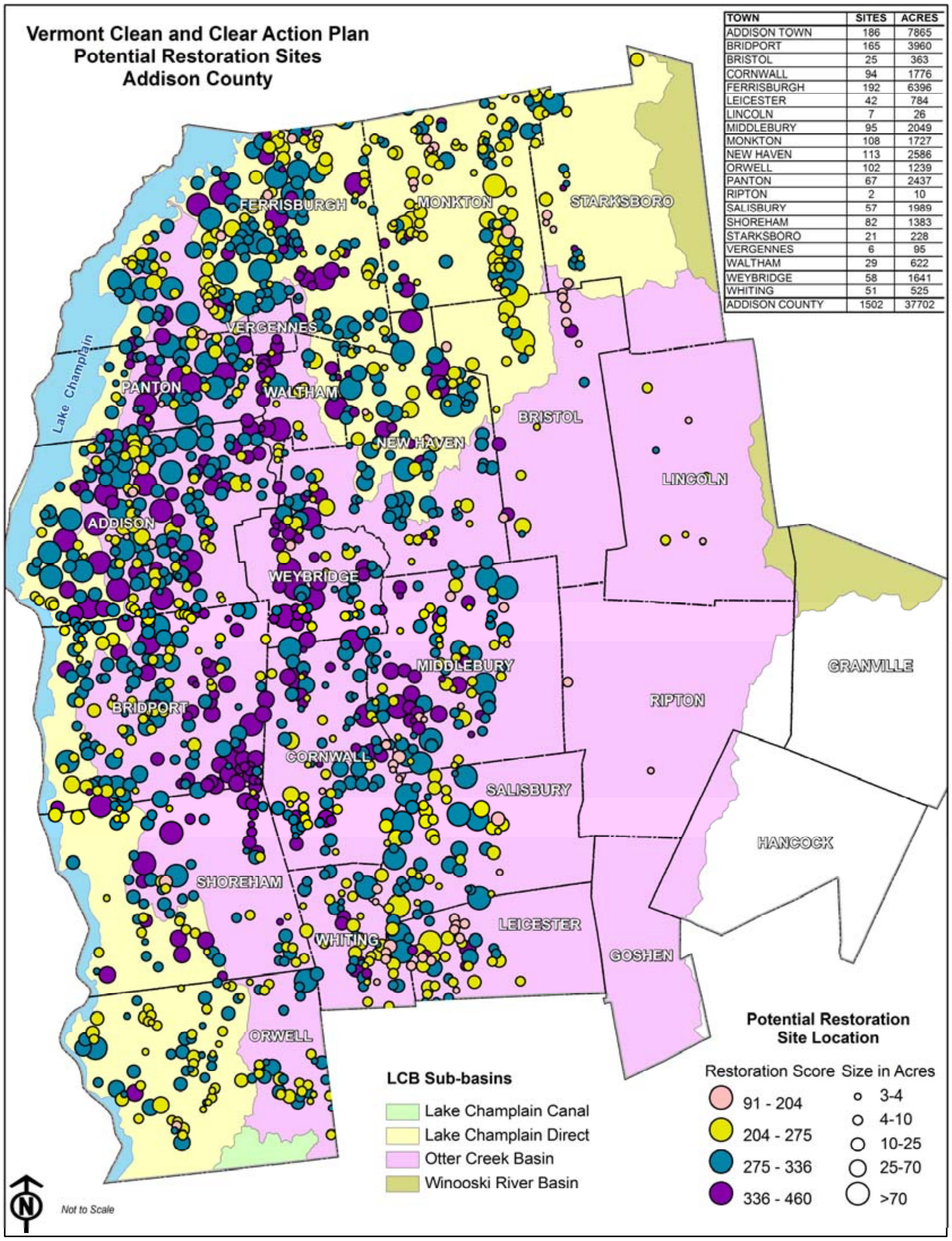


Figure 8: Histogram of Site Restoration Score

As stated above, the model results were in the form of spatial data that can be displayed in a variety of methods using a GIS. For illustrative purposes the sites are displayed below in two formats. The first example map, Figure 9, is an example of a county level map displaying the location of each site as a dot that varies in size and color based on the size of the site and the restoration score respectively. The full size set of county maps is displayed on pages 15 through 22 of Appendix I. The second example map displays the sites as color coded polygons based on the restoration score on a United States Geologic Survey topographic base map and is displayed in Figure 10. A complete set of full size topographic index maps is included on the attached data CD. These two sets of maps are intended to be used in combination to provide a useful reference for the number, distribution and size of potential restoration sites across a particular area of interest. In addition to these static map products the spatial data, also provided on the attached data CD, can be displayed, manipulated, and queried in an almost unlimited variety of ways using a standard GIS.



TOWN	SITES	ACRES
ADDISON TOWN	186	7865
BRIDPORT	165	3960
BRISTOL	25	363
CORNWALL	94	1776
FERRISBURGH	192	6396
LEICESTER	42	784
LINCOLN	7	26
MIDDLEBURY	95	2049
MONKTON	108	1727
NEW HAVEN	113	2586
ORWELL	102	1239
PANTON	67	2437
RIPTON	2	10
SALISBURY	57	1989
SHOREHAM	82	1383
STARKSBORO	21	228
VERGENNES	6	95
WALTHAM	29	622
WEYBRIDGE	58	1641
WHITING	51	525
ADDISON COUNTY	1502	37702

Figure 9: Example County Map

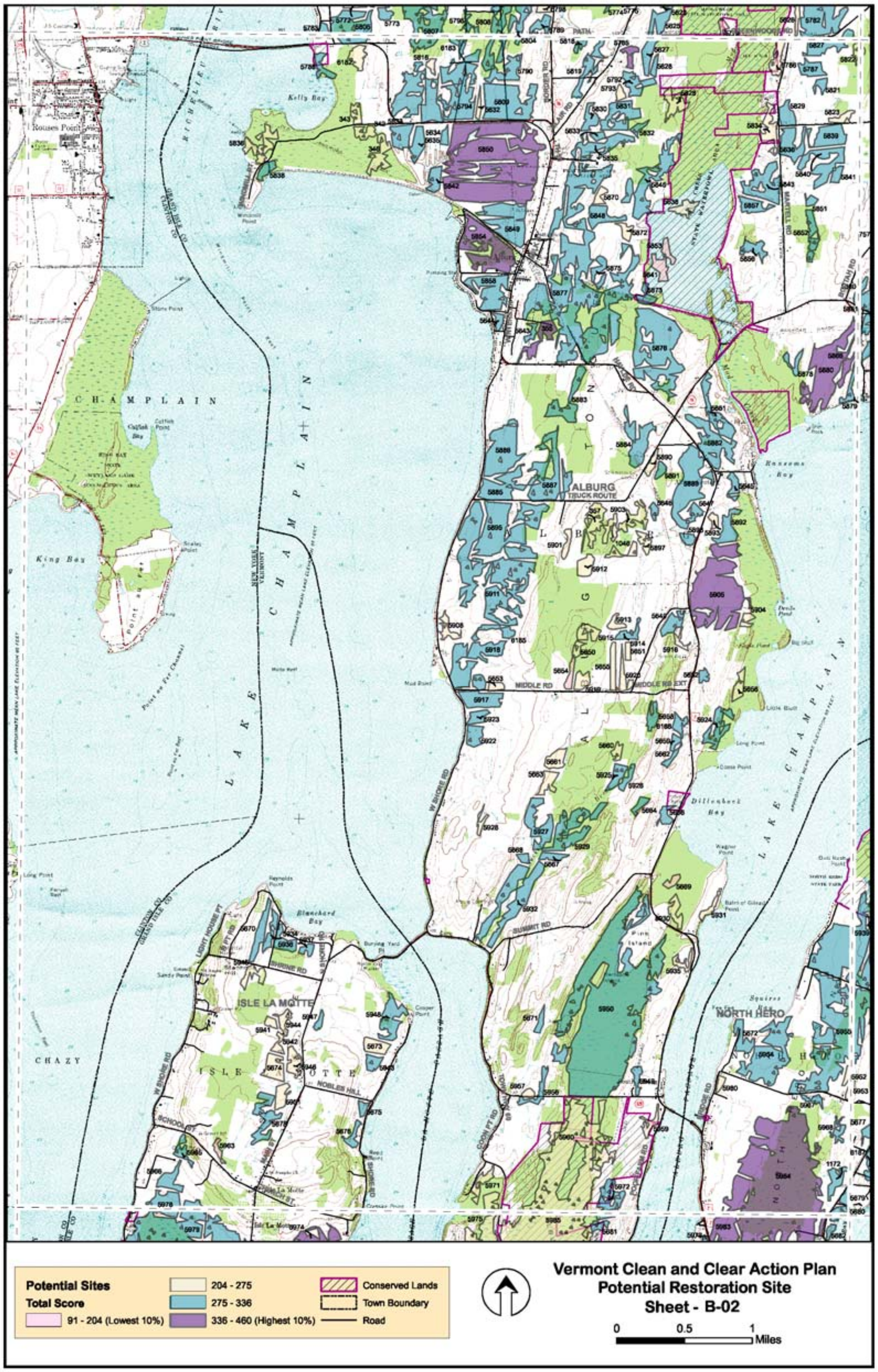


Figure 10: Example Topographic Index Map

Model results were used to target site visits within the LCB. The top 200 sites, as determined by the restoration score, were selected from the model for potential site visits. The site visit process included pre-screening via photo interpretation, preparation of an individual site map, identification of landowner contacts, securing permission to conduct a site visit, and finally (if landowner permission was secured) an actual site visit and evaluation. An example spreadsheet of the site function component attributes and upslope drainage area attributes and a site map for site number 268 is included on pages 23 to 25 of Appendix I.

3.0 FEASIBILITY STUDY

During the course of the feasibility study, the project team visited a total of 82 sites. The goals of the feasibility study were to: (1) confirm whether the site truly is a converted or degraded wetland, (2) determine whether restoration of the site would help meet P mitigation goals, and (3) determine whether restoration of the site would be possible given constraints such as landowner interest, effects on adjacent land or structures, and the technical feasibility of any recommended actions.

3.1 Landowner Contact

At the start of the feasibility study, an attempt was made to contact landowners for each of the top 200 sites that were identified by the site prioritization model. As 4,883 sites were identified by the model, this subset represented the top four percent of ranked sites. The original work plan specified a minimum of 70 sites to be visited for the feasibility study. Landowners for a significantly greater number of sites were contacted, given the expectation that landowner permission would not be granted for all sites.

However, prior to acquiring the data necessary for landowner contact, the subset of 200 sites was screened using aerial photography and orthophotography, to determine if there were any reasons to eliminate potential sites that may have been incorrectly targeted by the site identification model. Conversely, sites in the vicinity of the subset of 200 that appeared to be good sites for potential restoration were added to the list targeted for landowner contact. The rationale behind the photo interpretation process was to add an element of human analysis and quality assessment that were outside the parameters of the model. The main factors that were used to include or exclude sites from the subset of 200 were: 1) the apparent wetness of the site, 2) connection to surface waters, and 3) the current land use of the site.

The apparent wetness of the site could be determined using both black and white orthophotograph and aerial photograph sources. Both of the photographic sources were images taken during the spring and often show fields that may support wetland conditions. This factor was not used to exclude sites from the original subset since the images are only an indication of wetness and are not a definitive determination of wetness. This factor was, however, used in conjunction with the other factors to add sites to the subset. All sites that were added showed signs of wetness in the photographic sources.

The connection to surface waters in this part of the assessment took two primary forms: direct physical connection to surface water and/or connection to surface water via drainage ditches. Sites that had no apparent connection to surface waters by physical proximity or connection via drainage ditches were excluded from the subset. In addition, sites that had a direct connection to surface waters were considered, in combination with other factors, for inclusion in the subset. Most of the sites that were added to the subset contained a network of drainage ditches. These sites usually consisted of fields broken up by a network of drainage ditches that drained directly into surface water.

Finally, the photographs allowed for an interpretation of the current land use of the sites. For example, to the extent possible, areas that were noted to constitute intact wetlands were excluded from the subset. Conversely, only areas that appeared to be under a land use that could potentially contribute P to downstream waters were considered for addition to the subset.

Sites that were added to the subset of 200 sites usually exhibited a combination of the above listed factors. For example, sites that appeared to be wet, were in agricultural production, were located near surface water and contained drainage ditches were added to the 200 site subset. In many cases, these sites were already ranked high by the model. The photographic interpretation allowed for the "bumping up" of these sites into the subset of 200. The list of sites that were excluded versus those that were added based on the photographic interpretation process is displayed on page 26 of Appendix I.

Once the list of sites requiring landowner permission for access was finalized, the process for making landowner contact involved several steps:

1. Site maps were generated for all 200 sites on the list. These maps contained an orthophoto background and showed the site boundary (as well as any other sites in the vicinity that appeared in the view screen), roads, soils, surface waters, NWI wetland polygons, and parcel boundaries (when available).
2. Town clerks were contacted to confirm land ownership and obtain landowner contact data.
3. Letters requesting permission for access were sent to landowners of sites where contact data could be acquired. A copy of this letter is provided on pages 1 and 2 of Appendix II. A total of 245 letters were sent during July and August of 2006. This number exceeds the number of sites for which

landowner contact was being sought because of multiple ownership of some sites.

The response to the landowner contact letters was very low. Because the majority of written requests elicited no response, follow-up phone calls were made to obtain permission for site visits.

During the course of the feasibility study, the decision was made to add additional potential sites to the original subset of 200 that was under consideration. All of the sites added were within the top 10 percent of the model sites. If, during the course of visiting a site or communicating with landowners, it was determined that a consenting landowner had another identified site on their property that fell within the top 10 percent of ranked sites, and they were willing to grant permission, this site was also visited. Some high priority sites where landowner permission was not granted (either by not being able to contact landowner, or by the landowner denying permission), and if located along a road, were assessed from the road without entering the property. In the end, 82 sites were evaluated. Eleven of the 82 evaluations were conducted from the road without accessing site, while the remaining 71 involved a visit to the actual site.

3.2 Site Visits

The field evaluations of potential restoration sites were conducted by one or more of the following parties: Dori Barton, Michael Lew-Smith, Jeff Parsons, Shelley Gustafson, and Don Meals. To achieve consistent evaluations amongst reviewers, all of the above met as a group on several occasions to conduct evaluations together.

If available, the landowner was interviewed prior to visiting the site, either by phone or in person. A landowner questionnaire form, which was developed with input from VT FPR, was used as a basis for the interviews and is included on pages 3 and 4 of Appendix II. The interview questions centered on understanding existing and historical management practices of a given site, learning historical patterns of flooding and drainage, and assessing the landowner's interest in participating in future restoration actions.

The site visit generally involved an overall walkover of the site (although, as noted above, some sites were evaluated only from the road) with a specific focus on current land management practices (both of the site and surrounding areas), water flow paths, hydrologic manipulations, and potential P transport pathways into and out of the sites. The field assessments also served to refine the physical boundaries of the restoration area from those identified by the GIS model, to identify sources of degradation at a site, and to identify potential restoration techniques. Ultimately, the goal of the site visit was to determine whether or not a site would be a good candidate for restoration. While in some cases soil cores were examined, field measurements such as water table depths, topographic survey, and stream geomorphic assessments were not conducted. A site assessment form, also developed with input from VT FPR, was used to aid in the evaluation of a given site (see form on pages 5 and 6 of Appendix II). The field assessment included assigning overall provisional ranks, on a scale from 1 to 10, for both restoration feasibility and the opportunity for P removal if the site were restored.

3.3 Results of Feasibility Study

The data collected during site visits, including completed data forms (i.e., landowner questionnaires, if available, and site data forms) and corresponding site maps, have been scanned and organized by site, and are provided for the 82 visited sites in a digital format on the enclosed CD-Rom. A summary data table has also been compiled for each of the 82 visited sites and is viewable as an attribute table associated with the ArcGIS® compatible shapefiles for these sites. Shapefiles for all sites evaluated by the GIS model (i.e., 4883 sites) are also included on the CD-Rom enclosed with this report. Finally, an overall table summarizing results for all visited sites is displayed on pages 7 through 9 of Appendix II. Specific restoration recommendations for visited sites are presented under Section 4.0.

The sites visited displayed varying degrees of past site alteration and disturbance. Figures 11 through 13 below present three sites that were visited that represent the range of past disturbance that was observed during the feasibility study.

Site 5169 (Figure 11) is located in Shoreham within the Lemon Fair River's floodplain. While the site is hayed during drier years, there was no evidence of ditching or other hydrologic manipulations.

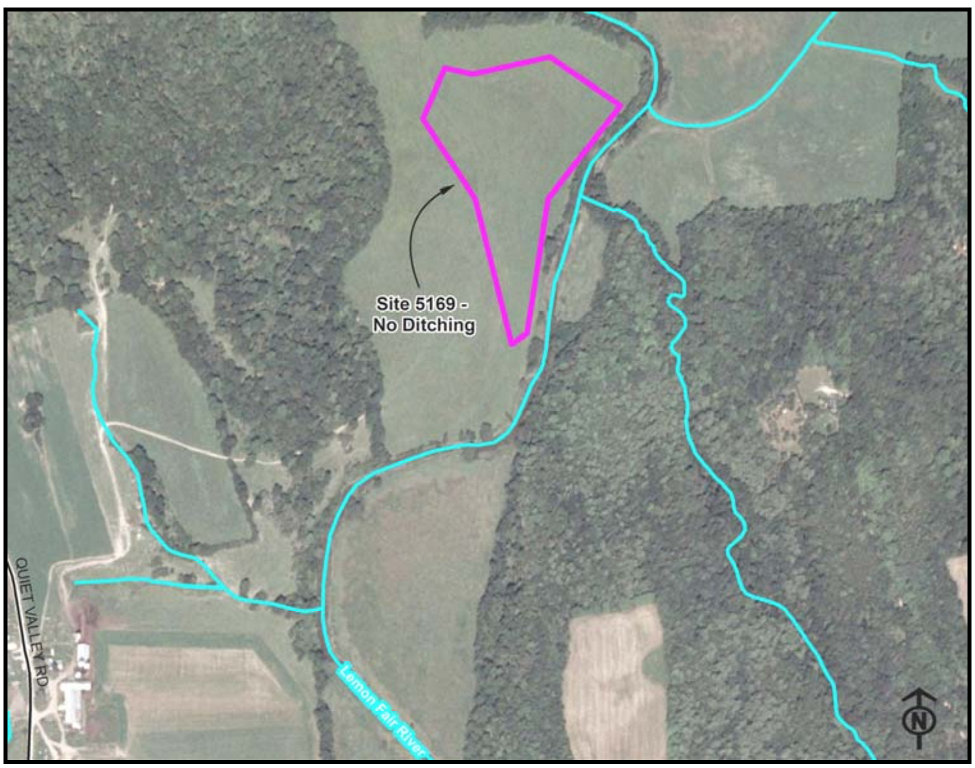


Figure 11: Site 5169

Site 5194 (Figure 12), also located in Shoreham, contains one segment of ditched stream that flows along the lower edge of the site, and represents a moderately altered site of those visited.

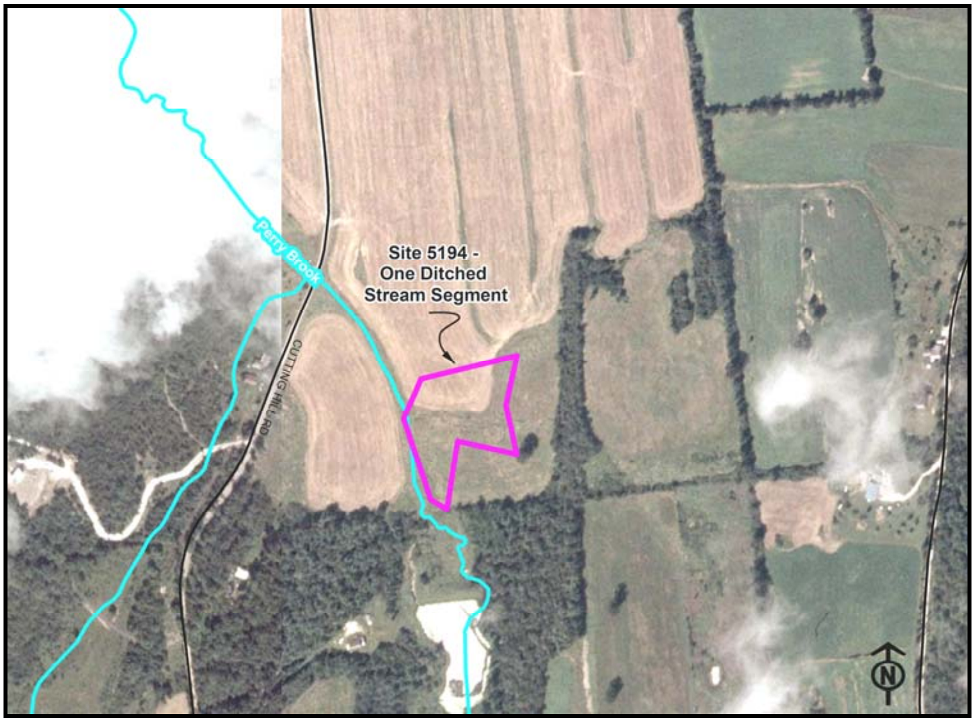


Figure 12: Site 5194

Site 3176, located in Waltham, contains extensive ditching throughout the site as evident within Figure 13 below, and is representative of a more extensively altered site that was visited during the feasibility study.

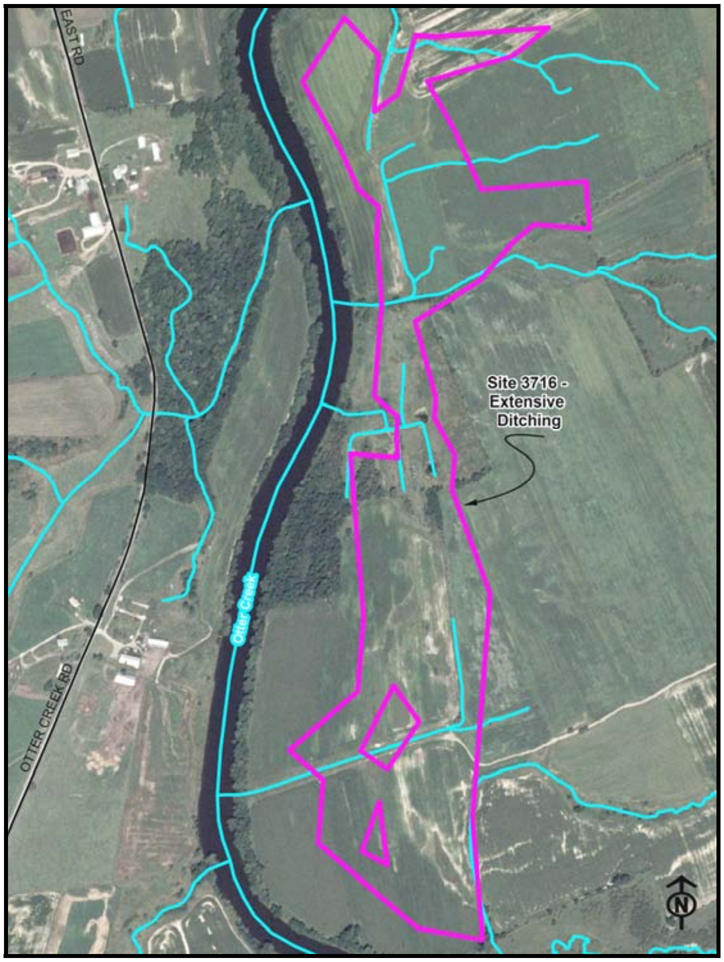


Figure 13: Site 3176

A portion of the visited sites occurred within each of the six subbasins for the Vermont portion of the LCB. The breakdown of sites by subbasin is presented below in Table 9.

Table 9: Number of Sites by Subbasin	
Subbasin	**Number of Sites**
Lake Champlain Canal	1
Lake Champlain Direct	17
Lamoille River	4
Mississquoi River	17
Otter Creek	29
Winooski River	14
Total	82

Seventy-four of the 82 sites visited were active agricultural land, consisting of pasture, hay and/or corn fields. Six sites were currently abandoned, one site was a currently functioning wetland that was missed during the pre-screening process using aerial photos, and one site was a recreational pond. As will be discussed further below under Section 4.0, the most common hydrologic manipulation observed across the visited sites was constructed agricultural ditches (50 of the 82 sites contained documented ditches). Used to enhance on-site drainage, many of these ditches were constructed through the straightening and dredging of pre-existing stream courses.

Nutrient sources were variable across the visited sites, ranging from off-site sources such as P transported by floodwaters of adjacent rivers and streams, to on-site sources such as fertilizer applications. At many sites, multiple nutrient sources were identified. The distribution of nutrient sources by site is presented below in Table 10. For purposes of this table, the projected primary nutrient source to the site is presented. All identified nutrient sources for sites are presented in the appended summary data table (pages 7 through 9 of Appendix II). It should be noted that, where nutrient source information could not be obtained through the landowner interview process, nutrient source data were inferred from observed land use practices from visiting the site.

Table 10: Number of Sites by Primary Nutrient Source

Primary Nutrient Source	Number of Sites
Manure	40
Fertilizer	12
Floodwaters	14
Upslope erosion	8
Other	4
None	4

As noted above under Section 2.2, the flood risk factor in the site prioritization model was weighted higher than any of the other factors, and as a result, many of the high ranking sites are situated in floodplains. Of the 82 sites evaluated in the field, 40 were located in floodplains. The visited sites have been grouped into 5 categories of hydrologic condition: potential floodplain, saturated (i.e., to soil surface), inundated, manipulated, and upland. The fact that a number of sites were determined to be natural uplands reflects back to errors inherent to the data layers that were used to build the model. For example, the soil survey data that were used may include areas that were erroneously mapped as hydric soils. Table 11 shows the distribution of sites across the 5 hydrologic categories.

Table 11: Number of Sites by Hydrologic Condition

Hydrologic Condition*	Number of Sites
Potential Floodplain	40
Saturated (non-floodplain)	17
Inundated (non-floodplain)	3
Manipulated (non-floodplain)**	12
Upland	10

Many sites fell into more than one category; for this table, the dominant condition was tabulated.

** The manipulated category represents those sites that did not display wetland hydrology primarily due to artificial drainage systems.

Forty-one of the 82 visited sites were documented as currently having some capacity to function to retain P. For example, a site may be kept in hay, and ditches have silted in over time and have become well-vegetated. The landowner may have indicated that there was no intent to clean out ditches or rotate the fields within the site to corn, and that he/she applies manure only during typically dry periods of the growing season. Certainly, these sites still present potential restoration opportunities given that manure application is still likely occurring, that land management practices do change over time, and because hydrologic restoration could increase the wetland area on site.

However, this data may still be helpful in prioritizing restoration activities throughout the LCB.

Landowner interviews were completed for 45 of the 82 visited sites. Of the 45 interviews completed, 43 stated that they may be interested in participating in a restoration plan for their property depending on the compensation package, while two stated that they would not be interested. In addition, six landowners for visited sites, who were not willing to be interviewed, stated that they were not interested in participating in any potential restoration activities for their land. As noted above, if a landowner for one of the 82 visited sites did not grant permission to access their property, the evaluation was conducted from public roads.

4.0 RESTORATION ALTERNATIVES FOR FINAL LIST OF PRIORITY SITES

A two-tier approach was developed for identifying specific restoration alternatives at each of the 82 sites visited in the field. Tier 1 involves identifying the target natural community type(s) for the restoration area. Tier 2 involves the identification of the specific hydrologic manipulations within the restoration area. Each of the 82 sites was assigned a target natural community type(s) and a suite of recommended hydrologic manipulations where appropriate.

The selected Tier 1 community types evolved from field evaluation of priority sites. Field review of the priority sites resulted in the identification of three general communities: shallow emergent marsh, shrub swamp, and floodplain forest.

Each of the 82 visited priority restoration sites was assigned to one or more of the three general community types. The assignment of the target community may or may not ultimately result in a recommendation for actively planting or seeding within the restoration area. Some of the sites have remnants of the target community nearby and given time would revegetate naturally with the native plants. For these sites, the natural community that is already re-establishing, or would likely re-establish if the site is taken out of agriculture, was identified. For sites that do not have native seed sources nearby, that have bare ground or erosion problems, or would otherwise benefit from accelerated revegetation, active plantings are recommended. A detailed description of the three selected community types is given below under Section 4.1.

The Tier 2 list of alternative hydrologic manipulations also evolved from field evaluations of priority sites. Of the sites visited, the most commonly observed site alterations included ditching, site grading, and channel straightening. It was not uncommon to visit a site and observe a network of ditches within plowed crop/hay fields that drained into a historically straightened and sometimes actively dredged stream channel. While not easily observed or identified in the field, drainage tiles are likely another hydrologic alteration present at some restoration sites. Restoration of these sites would generally involve active manipulations to re-establish the hydrology of wetland and stream areas. Where sites did not show any historic hydrologic alterations, were not in active agricultural use, or contained ditches that were filling in and/or becoming plugged naturally, manipulations are not recommended.

The objective of the proposed hydrologic manipulations is to re-establish the historic hydrology on the site that is conducive to either detaining or slowing down the movement of surface water to prevent P laden sediment from entering nearby surface waters and ultimately Lake Champlain. This is accomplished by increasing the residence time within wetland areas (ditch plugs, ditch filling, tile drain disabling, depression excavation) and/or slowing down moving water (channel restoration and floodplain re-establishment).

Tier 1 and Tier 2 restoration alternatives are described in more detail below.

4.1 Tier 1: Natural Communities

Knowledge of the appropriate natural community for a particular site is essential in achieving a successful restoration. A natural community is defined as an “interacting assemblage of organisms, their physical environment and the natural processes that affect them.” (Thompson and Sorenson 2000). This section includes a description of the three broad plant community types recommended to be used as goals of the restoration process. Below is a description of the hydrologic and ecologic factors that shape each of these communities, as well as the vegetation that is typically dominant at these sites. Finally, the relationship between these community types and P retention is discussed.

Because this study included much of the State of Vermont, a wide variety of wetland types exist, along with a great deal of plant diversity that is possible to restore. It was not the goal of this project to detail this wide variation. Rather, during the field work, the project team attempted to find patterns in the wetland types and functions that existed on the priority sites. This was done by examining remnant natural communities on or near the identified potential restoration sites. These remnants usually consisted of narrow tree lines, fence rows, small patches of wetland or, in rare cases, large intact functioning wetlands. Nearby intact natural communities can act as valuable guides in planning the revegetation and hydrologic manipulations of a potential restoration site. Care must be taken, however, to ensure that the natural community being used as a guide is shaped by the same (or similar) environmental factors as the restoration site. Physical proximity does not always ensure environmental similarity.

As an example, Site #3158 consisted of an agricultural field along Lewis Creek that was planted in corn (Figure 14).

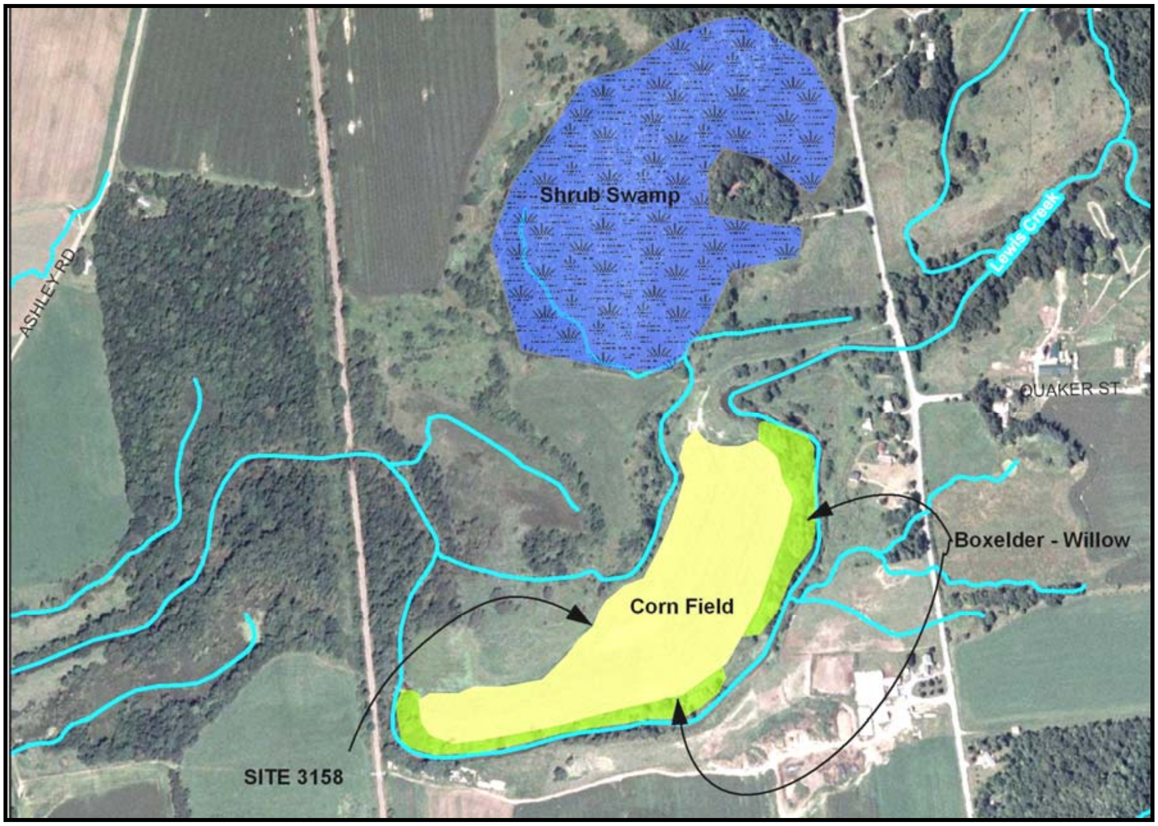


Figure 14: Site 3158

The field is in a floodplain position and buffered from the river by a narrow band of boxelder (*Acer negundo*) and willow (*Salix spp*.) trees (shown in green). Adjacent to this agricultural field away from the river is a large, relatively intact hardwood swamp (shown in blue). This swamp was impressive in its vegetation structure and diversity. Using this swamp as a template for restoring the cornfield, however, is not appropriate and would likely result in a failed restoration. The hardwood swamp is in a “back swamp” position. It is shaped by very different hydrology and soils than what is present in the corn field. The appropriate model for the restoration of this site would be the narrow band of floodplain forest along the river (shown in green). The vegetation in this area has developed in similar environmental conditions; using this site as a guide would more likely lead to a successful restoration.

As mentioned above, the project team encountered a wide variety of wetlands and wetland types during the field work phase of this project. Ultimately, the sites that were identified as having the highest potential for P retention and mitigation fell into three broadly defined types: floodplain forest, shrub swamp and shallow emergent marsh. These three community types are largely based on the vegetation classification presented in Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont (Thompson and Sorenson 2000). This community classification is used by environmental professionals throughout the state as a means of communicating about plant communities. While this classification is based largely on vegetation, the different types of vegetation arise in large part due to physical and environmental factors such as soils, hydrology, surficial geology, and landscape position. Therefore, knowing these factors on a particular restoration site enables one to determine the natural community that is appropriate for restoration even if there is no remnant natural community to use as a guide. These combinations of environmental factors and vegetation also play an important role in the interactions that a particular wetland has with P as it moves through the landscape.

Other in-office methods can be employed to predict the appropriate natural community that should be established at a given restoration site. The Natural Resource Conservation Service (NRCS) Electronic Field Office Technical Guide (eFOTG) (Section II Natural Resources Information) provides guidance regarding what natural community type(s) (per Thompson and Sorenson 2000) would be associated with a given soil series. The guide documents associations between soils and natural communities for the entire State of Vermont, and can be used as a tool for determining a reference community type. The guide can be accessed online at http://www.nrcs.usda.gov/Technical/efotg/.

Many of the visited sites, especially the larger sites, contained areas that could simultaneously support different communities. At site #4963 for example, which is described in detail under Section 5.1, the project team recommended restoring the floodplain forest along the Lemon Fair River in addition to hydrologic manipulations away from the river that would lead to the development of a shrub swamp.

While the three target community types are very useful in determining the goal of a particular restoration, they are to be used as templates only. The specifics of which species to include, specific planting densities, and overall methods will depend largely on the nature of the restoration site and the nature of a remnant community, if present.

As noted within the introduction to this report, many wetlands and wetland types (such as marshes and swamps) have a strong influence on nutrient concentrations in surface waters. The role that wetlands play within the global P cycle has gained the attention of regulatory agencies looking to decrease the amount of P in surface waters. The role of P as an accelerator of the eutrophication of freshwater surface waters has been recognized and major efforts in controlling the release of P have been made in Vermont and in the United States.

Wetlands have been recognized as sources, sinks, and transformers of P in freshwater surface waters such as lakes, ponds, streams, and rivers. To be a P “sink”, more P must enter a wetland than leave it through surface waters on a net annual basis (Richardson 1987). Wetlands are considered a “source” of P (on a net annual basis) if they generate and release into surface waters more P than enters the wetland. Wetlands that function mainly to transform P from one molecular state to another (for example from inorganic to organic forms) are termed “transformers” of P.

Wetlands remove P from surface waters by three primary mechanisms (1) soil sorption; (2) incorporation in wetland biota (primarily plants); and, (3) the formation and accretion of new sediments and wetland soils (Reddy et al. 2005).

The retention of P on a net annual basis (the "sink" function) of wetlands differs somewhat between wetland types. The following text describes in greater detail the three wetland restoration types that have been proposed (floodplain forest, shrub swamp, and shallow emergent marsh) and how each function in the context of P transport through the watershed.

4.1.1 Floodplain Forest

The floodplain forest community is the most common type recommended for restoration during this study. This community type as described here actually includes three different community types as outlined in Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont (Thompson and Sorenson 2000). These community types consist of the Silver Maple-Ostrich Fern Riverine floodplain forest, the Silver Maple-Sensitive Fern Riverine floodplain forest and the Sugar Maple-Ostrich Fern Riverine floodplain forest. These three community types were grouped together because it was often not possible to determine the specific community type during the site visit, especially if no intact remnants of a natural community were present. Before an actual restoration is undertaken, however, additional work should be conducted to determine which specific floodplain forest community is the goal for the particular site.

Floodplain forests historically covered vast stretches of land along Vermont's major rivers. Because of their lack of stones and high fertility, these areas were among the first to be converted to agriculture. Only small remnants of these natural communities remain intact today. In addition to restoring floodplain forests for mitigation of P, the restoration of these communities can also prevent erosion by stabilizing the riverbank sediments and benefit wildlife by acting as riparian travel corridors.

Floodplain Forest Environmental Conditions

As the name implies, floodplain forests, at least historically, were flooded by the adjacent rivers during periods of high water. Depending on the nature of the river and the position of the forest, these sites may have flooded several times each year. These flooding events typically deposit sediment into the floodplain forest community as the flood waters slow upon encountering trees and woody debris. These flooding events also scour the soils and often prevent the establishment of a shrub layer. This is why floodplain forests commonly have an open understory dominated only by herbs.

Depending on the type of river or stream and the nature of the site, the soils in floodplain forests can be loamy sands, sandy loams, or silt loams. They are characterized by alluvial deposition which can inhibit soil horizon formation, at least in the upper part of the solum. Given the well-drained nature of the soils, these sites are not typically influenced by perched water tables. These areas are also generally not influenced by groundwater inputs.

A backswamp is often a feature of intact floodplain communities. This landscape position describes an area that is separated from the river by the floodplain forest but sits lower than the adjacent floodplain forest. These backswamps are generally wetter than floodplain forests because they are more often influenced by ground water or may have low-permeable soils. During flooding events, flood waters may enter the backswamp through the floodplain forest. The backswamps typically retain the floodwaters longer than the floodplain forests as these floodwaters recede. Because of the extreme wetness of these communities, these sites are only rarely converted to agriculture.

Floodplain Forest Vegetation

While there are three community types present in the broadly defined floodplain forest, there is a fair amount of overlap between the types. Vegetation for floodplain forests is detailed in Table 12.

Table 12: Floodplain Forest Vegetation

Layer	Common Species	Secondary Species	Supplemental Species
Overstory (Dominant)	Silver maple *(Acer saccharinum)* Sugar maple *(Acer saccharum)*	Black willow *(Salix nigra)* Cottonwood *(Populus deltoides)* American elm *(Ulmus Americana)*	**Early successional** Boxelder *(Acer negundo)*
Shrub	None	None	**Vine** Riverbank grape (*Vitus riparia)*
Herbaceous	Ostrich fern *(Matteucia struthiopteris)* Wood nettles *(Laportea canadensis)* Sensitive fern *(Onoclea sensibilis)*	Spotted touch me not *(Impatiens capensis)* Wild rye *(Elymus spp.)* Jack in the pulpit *(Arisaema triphyllum)*	None

The frequent scouring of the soil that accompanies flood events often leaves a floodplain site with disturbed, exposed soil. In recent times, this has led to many floodplain forests being colonized, and in some cases overrun, by non-native invasive plant species. Dame's rocket (*Hesperis matronalis*), Garlic mustard (*Allaria petiolaria*), goutweed (*Aegopodium podagraria*), honeysuckles (*Lonicera spp.),* buckthorn (*Rhamnus cathartica*) and Japanese knotweed (*Polygonum cuspidatum*) are all invasive plants that are now commonly found in floodplain forests of

Vermont. Floodplain forests that do not contain at least small colonies of one or more of these species are now quite rare.

Floodplain Forest Phosphorus Retention

Floodplain forests are located in areas that flood at least annually. Sediments associated with flooding often contain adsorbed P and other nutrients and as the flood waters retreat this sediment and its associated P load is deposited within the floodplain. An evaluation of two floodplain forests in North Carolina found that as much as 68 percent of incoming P was removed (Kuenzler 1980, 1988), largely due to incorporation of P by floodplain soils. Other floodplain wetland P retention studies emphasize the importance of sedimentation to retention in these environments (Childers and Gosselink 1990). As pointed out by Reddy et al. (2005), it is this continual flooding and sediment deposition that is paramount in P retention within floodplain environments.

Sediment retention is enhanced in these environments by the presence of persistent vegetation such as trees which help create eddies which then slow waters and enable the deposition of sediments. Some additional adsorptive capacity is also available within the already present soil matrix as well as by biological uptake by floodplain plants and animal life. This uptake by plants and animals can occur during the growing season with re-release of nutrients during the non-growing season. In summary, floodplain forests, where soil accretion takes place, function as P sinks and remove P from surface waters.

4.1.2 Shrub Swamp

For the purposes of this project, the shrub swamp community, like the floodplain forest community, is broadly defined. Per Thompson and Sorenson (2000), there are two different, but related, wetland shrub types:

alder swamp and the alluvial shrub swamp. The alder swamp occurs in a wide variety of landscape positions whereas the alluvial shrub swamp typically occurs along high to moderate gradient streams and rivers.

Shrub Swamp Environmental Conditions

Periods of high water result in the flooding of alluvial shrub swamp areas and the deposition of mineral soil material. These areas therefore usually consist of mineral soils with or without a high organic content. In contrast, the ecology of the typical alder swamp is not driven by flooding from surface waters because these sites occur in a wide variety of hydrologic conditions and landscape positions. Those associated with surface waters are either in backswamp positions of the larger rivers or situated along the banks of higher gradient streams. Alder swamps that are isolated from surface waters and develop either because of impermeable soils or ground water discharge are also common. Soils can range from deep organic mucks to mineral soils with varying amounts of organic content. The wettest sites, those with organic soils, are rarely converted to agriculture use. The drier alder swamps and the alluvial shrub swamps are the sites that were most commonly encountered during this inventory.

Shrub Swamp Vegetation

Shrub swamps are dominated by shrubs, with a highly variable herbaceous layer, depending on the hydrology and soils of the particular wetland. The vegetation present is variable depending on the wetness of the site (see Table 13).

Table 13: Shrub Swamp Vegetation

Layer	Common Species Wet sites	Common Species Moderately wet sites
Shrub (Dominant)	Speckled alder *(Alnus incana)*	Speckled alder *Alnus incana*
Herbaceous	Lake sedge *(Carex lacustris)* Tussock sedge *(Carex stricta)*	Spotted touch-me-not (*Impatiens capensis)* Bluejoint grass *(Calamagrostis canadensis)* Drooping sedge *(C. crinita)* Sensitive fern *(Onoclea sensibilis)* Cinnamon fern *(Osmunda cinnamomea)* Joe-pye-weed (*Eupatorium maculatum)*

Shrub Swamp Phosphorus Retention

Shrub swamps can be found in similar hydrological situations and perform similar P retention roles as floodplain forests. Shrub swamps in alluvial landscape positions often accumulate sediments. Shrub swamps which are located along stream and rivers accrete sediment within the soil matrix. Some of this sediment has P and other nutrients that are incorporated into the soil. While there is little or no direct evidence of the positive role that shrub dominated (versus forested) wetlands play in P removal, some inferences can be made. Most importantly, at times of spring flooding, alder wetlands have persistent woody vegetation that slows the movement of water and creates eddies which favor sediment deposition. In fact, the density of woody stems in these environments is often much greater than that of larger woody species found in floodplain forests. In addition, shrub swamps also remove (at least seasonally) P through uptake by plants and animals.

4.1.3 Shallow Emergent Marsh

Unlike the general classification of the shrub swamp and the floodplain forest communities, the shallow emergent marsh is a single community type. It is, however, an extremely variable community. The wide variety of environmental conditions and vegetation is briefly discussed below.

Shallow Emergent Marsh Environmental Conditions

The shallow emergent marsh occurs in a wide variety of landscape positions and hydrologic conditions. It can be found in association with lakeside wetlands, in old oxbows, riverine wetlands, beaver floodings, and on the margins of forested or shrub swamps. These communities may be permanently, semi-permanently or seasonally flooded, or only moist. The hydrology driving this community is also variable. Sites with a perched water table, ground water discharge areas, or areas associated with flooding of surface waters are all common. Depending on the hydrologic conditions present, the soils range from deep organic mucks to mineral soils with varying amounts of organic content. Most of the agricultural sites visited during this study contained mineral soils.

Shallow Emergent Marsh Vegetation

Given the large amount of variation in the ecological conditions of this community, it is not surprising that the vegetation found in this community is also highly variable. Most herbaceous wetlands that consist of a mix of graminoids and herbs can be considered a shallow emergent wetland. The vegetation present is variable depending on the wetness of the site (see Table 14).

Table 14: Shallow Emergent Marsh Vegetation			
Layer	**Common Species Wet sites**	**Common Species Moderately wet sites**	**Secondary Species**
Shrub	None	None	Speckled alder *(Alnus incana*) Willow *(Salix spp.)* Dogwood *(Cornus spp.)*
Herbaceous (Dominant)	Cattails (T*ypha spp.)* Bur-reed *(Sparganium spp.*) Lake sedge *(Carex lacustris)* Tussock sedge *(Carex stricta)*	Reed canary grass *(Phalaris arundinacea)* Bluejoint grass *(Calamagrostis canadensis)* Bulrush *(Scirpus spp)* Rush *(Juncus spp*.) Foxtail sedge *(Carex vulpinoidea)* Wetland asters *(Aster spp)*	Speckled alder *(Alnus incana)* Willow *(Salix spp.)* Dogwood *(Cornus spp.)*

Shallow Emergent Marsh Phosphorus Retention

Shallow emergent marshes retain P on a net annual basis and are “sinks” for P in freshwater ecosystems. Marshes are perhaps more markedly seasonal in their ability to retain P than are other wetland types. Marshes in the southern United States have been found to retain roughly 30 to 40 percent of P on a net annual basis (Dolan 1981, German 1989). In northern environments, similar efficiencies have been reported in Wisconsin and Minnesota (Brown 1984, Spangler et al. 1977). However, retention efficiencies were generally higher during the growing season and marshes often release substantial amounts of P during the late fall, winter and early spring periods (although often in organic forms, forms that are generally not bioavailable and which may have an overall lesser effect on eutrophication in receiving surface waters). Much of this organic P is in the form of large organic material such as undecomposed plants, stems, and leaves and is not immediately available for plant uptake. Overall, lake-side and stream-side marshes have a net positive effect on P concentrations in surface waters. Long-term P retention in marshes has been positively correlated with sediment deposition and the frequency of flooding.

4.2 Tier 2: Hydrologic Manipulations

Restoration of the original hydrology on-site is often crucial to fully realize the P mitigation goal of the restoration effort. Wetlands that have been drained or ditched and surface waters that have been dredged or channelized act as conduits for the discharge of surface waters with elevated P concentrations in agricultural areas. Re-establishment of original hydrology, where moving waters are slowed down and provided access to floodplains and functioning wetlands, will result in the reduction of P transported to downstream surface waters and ultimately Lake Champlain.

The recommendations for hydrologic manipulations are organized into: (1) removals and (2) installations. Removals include plugging or filling of ditches and disabling tile drains. Installations include depression excavations, floodplain re-establishment and channel restoration. Each of the removal and installation techniques is described below.

4.2.1 Removals

Ditch Plugging: Many of the identified sites have at least one and often several ditches draining wetland areas. These drainage ditches typically feed directly into rivers, streams and other surface waters without treatment. The intent of the ditching was to reduce the presence of excess standing water on agricultural lands. Ditch plugging is a quick and inexpensive way to re-establish wetland hydrology. Ditch plugs can prevent excessive drainage of wetland areas and permit the re-establishment of open water habitat and re-establishment of wetland vegetation. The plug is typically installed at the lowest point of the ditch.

Earthen material is installed in the ditch, causing water to back up into the formerly drained area. The literature suggests the following general specifications for ditch plugging: plug at least 50 feet and up to 150 feet of ditch (depending on soil hydraulic conductivity, slower conductivity requires less length of ditch plugging); create side slopes of 3:1 or flatter; provide additional crown material on the plug to account for settling (approximately one foot); extend ditch plug to the right and left to create wing dikes (length depends on site conditions); and allow native vegetation to grow on the ditch plug. Site specific hydrologic conditions may result in modifications to ditch plug design (Cantrell 2001, NRCS Technical Guide 657 1996).

Ditch Filling: Back filling and regrading the entire ditch is an alternative to a ditch plug. In some cases filling may be preferred to a plug to restore site topography and hydrology. Ditch filling is particularly attractive when the ditches are rimmed by soil berms, spoils made up of the earth excavated when the land was ditched. Spoils can be on one or both sides of the ditch and create an unnatural rise that serves as a barrier to water flowing across the site. Ditches can be filled with the spoils from the sides of the ditch to restore historic site hydrology. Once completed, the filled ditch does not usually require further maintenance, as a ditch plug may.

Berm Removal: Removal of berms can be an effective means of reestablishing a streams connection with its floodplain. In many instances, spoil material from the original excavation/ditching is piled/bermed along the length of the waterway. This material can be used in conjunction with ditch plugging and/or ditch filling activity within the same project area.

Tile Drain Disabling: While tile drains were not identified on any of the priority sites visited, it is included as an active restoration technique. In many cases, especially those for which the landowner was unavailable for an interview, it was unknown whether or not the site contained tile drainage. Drain tiles are perforated, hollow tubes buried underground, usually in an array of parallel tile lines 2 to 5 or more feet deep. Once the lines are located, they can be removed and the trench is then re-filled. Alternatively, they can be broken up at regular intervals. Clay tiles can be crushed and reburied. Most tile lines drain to a ditch so re-grading the ditch and removing or destroying the line will increase the probability of successfully restoring the original hydrology. It is equally important to disable the "soil conduit", the space created by compacted soil surrounding the tile lines that forms a distinct channel.

4.2.2 Installations

Depression Excavations (scrapes): Many farm fields visited during this study have been drained and regraded to prevent the ponding or retention of surface waters. Small depressional wetlands, or “scrapes”, can be excavated in active farmlands to provide areas for retaining P laden surface waters. On suitable sites, topsoil is stripped away to expose sub-surface soils, which are removed to create a berm. Then the topsoil, composed of wetland soils and the seed bank, is redistributed over the surface of the newly formed basin. On some sites, eroded topsoil deposited in a former wetland depression in the field can be scraped out, uncovering the original wetland soils. Clusters of depressions can vary in size, shape, and depth to create habitat diversity. Depressional wetlands can provide an appropriate remedy in some situations, but in the long term they may not become self-sustaining wetlands. Maintenance of depressional areas may be required, involving occasional dredging and nuisance plant removal.

Floodplain Re-establishment: Many streams and rivers flowing through agricultural lands have been ditched and straightened to eliminate flooding and reduce the residence time of moving water on the site. Bank heights have been raised (berming), stream banks armored, and channels deepened to disconnect the stream from its floodplain. The literature shows that riparian areas, which include floodplain uplands as well as wetlands, are considered perhaps the most important buffer areas for protecting receiving water quality (Gilliam 1995). In particular, riparian buffers can be effective in removing P attached to finer sediments (Gilliam 1995).

Floodplain re-establishment can be accomplished by removing berms and/or regrading the riparian corridor to allow flood waters access to the original floodplain. Detailed stream geomorphic data is required to determine the target floodplain elevation and design specific hydrologic manipulations. For the purposes of this project, straightened and dredged stream segments that have been cut off from their floodplains were identified and targeted for floodplain establishment. Detailed survey data have not been collected from these sites in order to develop construction specifications. Re-establishment of floodplain hydrology is further complicated by off-site factors such as the presence of culverts, dams and other in-stream structures, as well as the occurrence of dredging and straightening elsewhere along the river or stream. All of these factors must be considered before undertaking a floodplain restoration project.

Channel Restoration: Most sites that feature stream channelization and realignments included other drainage techniques. A meandering stream may have been realigned and its channel straightened, widened, and deepened, as well as tiled or ditched. In such sites it may be possible to restructure and restore the original waterway using old aerial photos and the topography of the site as guides.

Reconfiguring an active stream requires extensive design and engineering work. For the purposes of this project, segments of straightened stream channel (as opposed to ditched wetlands) were identified and targeted for restoration. Channel realignments were developed from existing stream geomorphic data, where available, and from orthophoto and USGS topographic map interpretation. Beltwidths and channel sinuosity patterns shown on the concept plans below are approximate. Restoration of these sites would involve increasing sinuosity to slow down moving water and in most cases regrading stream banks to re-establish connections with floodplain. Regraded banks would be vegetated with plant species appropriate for the given hydrologic and soil conditions present. Specific planting plans would be developed on a site-by-site basis. The abandoned ditched channel would be filled with material excavated for the new realignment.

Passive Restoration: The recommendations within both the Tier 1 and Tier 2 restoration alternatives include options for passive restoration techniques. While sites recommended for passive restoration may benefit from active manipulations in the short term, given time they are likely to achieve the same end result.

A number of the visited priority sites had a history of agriculture but are currently fallow, and will remain so for the foreseeable future. For many of these sites, the source of wetland degradation (and often the source of P) has been removed and the site is recovering. These sites are no longer being cropped or hayed and are naturally re-establishing with native and/or non-native plant species. Hydrologic alterations, such as ditches, are not being maintained and are filling in on their own. These wetlands are re-establishing naturally. As these wetlands recover, their ability to remove P will increase without physical manipulation of the site. A passive approach to restoration is recommended for these types of sites that involves maintaining the current management regime of no active cropping or maintenance of drainage structures. While no active restoration may be required, this approach would involve working with the landowner to ensure that agricultural activities do not resume.

Tier 1 and Tier 2 recommendations for the 82 field-evaluated sites are summarized in Table 15.

Table 15: Recommended Community Type and Hydrologic Manipulations by Site

				Hydrologic Manipulations	
Site Number	Site Evaluation	Restoration Strategy	Tier 1: Community Type (Desired)	Tier 2: Removals	Tier 2: Installations
417	Driveby	Hydrologic Manipulations/Plantings	Shrub swamp	Ditch plugging/filling	Channel restoration
442	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest	Ditch plugging	Depression excavations
445	Driveby	Plantings	Floodplain Forest	None	None
625	Field visit	Plantings	Floodplain Forest	None	None
626	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest	Culvert removal	Depression excavations
773	Field visit	Preservation	Shallow Emergent Marsh	None	None
904	Field visit	Hydrologic Manipulations/Plantings	Upland	Ditch plugging	None
911	Field visit		Floodplain Forest/ Shallow Emergent Marsh	Ditch plugging	Channel restoration; Depression excavations
935	Field visit	Hydrologic Manipulations/Plantings	Floodplain forest	Ditch plugging	None
946	Driveby	Hydrologic Manipulations/Plantings	Floodplain Forest/Shallow Emergent Marsh/Shrub Swamp	Ditch plugging	Depression excavations
951	Field visit	Plantings	Floodplain Forest	None	None
1034	Driveby	Hydrologic Manipulations/Plantings	Floodplain Forest/Shrub Swamp/Shallow Emergent Marsh	Ditch plugging	Depression excavations; Channel restoration

Table 15: Recommended Community Type and Hydrologic Manipulations by Site

				Hydrologic Manipulations	
Site Number	**Site Evaluation**	**Restoration Strategy**	**Tier 1: Community Type (Desired)**	**Tier 2: Removals**	**Tier 2: Installations**
1049	Driveby	Hydrologic Manipulations/Plantings	Shallow Emergent Marsh/Shrub Swamp	None	Depression excavations; Channel restoration
1230	Driveby	Hydrologic Manipulations/Plantings	Shrub Swamp	Ditch plugging	None
1261/1262	Driveby	Plantings	Floodplain Forest	Ditch plugging	Channel restoration; Floodplain reestablishment; Depression excavations
1961	Field visit	Preservation	Shallow Emergent Marsh	None	None
2155	Field visit	Hydrologic Manipulations/Plantings	Shallow Emergent Marsh	Ditch plugging	None
2156	Field visit	Hydrologic Manipulations/Plantings	Shallow Emergent Marsh	Ditch plugging/filling	None
2224	Field visit	None recommended	Shrub Swamp	None	None
2228	Field visit	Hydrologic Manipulations/Passive Revegetation	Shallow Emergent Marsh/Floodplain Forest	Ditch plugging	None
2230	Field visit	Hydrologic Manipulations/Plantings	Shrub Swamp	Ditch plugging	Depression excavations
2318	Field visit	Hydrologic Manipulations/Plantings	Shrub Swamp/Emergent Marsh	Ditch plugging	None
2321	Field visit	Hydrologic Manipulations/Plantings	Emergent Marsh/Shrub Swamp	Ditch plugging/filling	Channel restoration; Depression excavations
2325	Field visit	Hydrologic Manipulations/Plantings	Shrub Swamp	Ditch plugging	Floodplain reestablishment; Depression excavations
2326	Field visit	None recommended	Floodplain Forest	None	None
2330	Driveby	Hydrologic Manipulations/Plantings	Shrub Swamp	None	Floodplain reestablishment
2333/2338	Driveby	Hydrologic Manipulations/Plantings	Shrub Swamp	Ditch plugging	Floodplain reestablishment
2337	Field visit	None recommended	Floodplain Forest	None	None
2341	Field visit	None recommended	Floodplain Forest	None	None
2342	Field visit	None recommended	Floodplain Forest	None	None
2349	Field visit	None recommended	Shallow Emergent Marsh	None	None
2508	Field visit	None recommended	Floodplain Forest	None	None
2510	Field visit	None recommended	Floodplain Forest	None	None
2543	Field visit	Hydrologic Manipulations/Passive Revegetation	Shrub Swamp	None	Depression excavations
2550	Field visit	None recommended	Shrub Swamp	None	None
2552	Driveby	Hydrologic Manipulations/Plantings	Floodplain Forest	None	None
2684	Field visit	None recommended	Shallow Emergent	None	None

Table 15: Recommended Community Type and Hydrologic Manipulations by Site

				Hydrologic Manipulations	
Site Number	**Site Evaluation**	**Restoration Strategy**	**Tier 1: Community Type (Desired)**	**Tier 2: Removals**	**Tier 2: Installations**
			Marsh		
2686	Field visit	None recommended	Shallow Emergent Marsh	None	None
2931	Field visit	Hydrologic Manipulations/Passive Revegetation	Floodplain Forest	Ditch plugging/filling	None
2969	Field visit	Plantings	Shallow Emergent Marsh	None	None
3113	Field visit	None recommended	Shallow Emergent Marsh	None	None
3158	Field visit	Plantings	Floodplain Forest	None	None
3525	Field visit	None recommended	Shallow Emergent Marsh	None	None
3553	Field visit	Preservation	Shallow Emergent Marsh	None	None
3556	Field visit	Preservation	Shallow Emergent Marsh	None	None
3606	Field visit	None recommended	Shrub Swamp	None	None
3670	Field visit	None recommended	Shallow Emergent Marsh	None	None
3710	Field visit	Plantings/Preservation	Floodplain Forest	None	None
3716	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest	None	Channel restoration
3775	Field visit	Preservation	Shallow Emergent Marsh/ Floodplain Forest	None	None
4104	Field visit	Preservation/Plantings	Shrub Swamp	None	None
4105	Field visit	Preservation	Shrub Swamp	None	None
4382	Field visit	Preservation	Floodplain Forest	None	None
4392	Field visit	Hydrologic Manipulations/Plantings	Shrub Swamp	None	Depression excavations; Floodplain reestablishment
4395	Field visit	Preservation/Hydrologic Manipulations/Plantings	Floodplain Forest	None	Floodplain reestablishment
4399	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest	None	Floodplain reestablishment
4763	Field visit	Preservation	Shallow Emergent Marsh	None	None
4924	Field visit	Hydrologic Manipulations/Plantings	Shallow Emergent Marsh	None	Channel restoration; Depression excavations
4952	Field visit	Plantings/Preservation	Floodplain Forest	None	None
4963	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest	Ditch plugging/filling	Channel restoration
5166	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest/Shrub Swamp	None	None
5169	Field visit	Plantings	Floodplain Forest	None	None
5175	Field visit	Plantings	Floodplain Forest	None	None
5193	Field visit	Plantings/Preservation	Shrub Swamp	None	None
5194	Field visit	Hydrologic Manipulations/Plantings	Shallow Emergent Marsh	None	Channel restoration
5195	Field visit	Plantings/Preservation	Shrub Swamp	None	None

Table 15: Recommended Community Type and Hydrologic Manipulations by Site

				Hydrologic Manipulations	
Site Number	Site Evaluation	Restoration Strategy	Tier 1: Community Type (Desired)	Tier 2: Removals	Tier 2: Installations
5200	Field visit	None recommended	Shrub Swamp	None	None
5390	Field visit	Preservation	Floodplain Forest	None	None
5409	Field visit	Hydrologic Manipulations/Passive Revegetation	Shallow Emergent Marsh/Shrub Swamp	Ditch plugging	None
5429	Field visit	Preservation	Shallow Emergent Marsh	None	None
5479	Field visit	Hydrologic Manipulations/Passive Revegetation	Shallow Emergent Marsh/Floodplain Forest	Ditch plugging	None
5512	Field visit	Preservation	Shallow Emergent Marsh/Shrub Swamp	None	None
5585	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest/Shrub Swamp	None	Floodplain reestablishment; Depression excavations; Channel restoration
5602	Field visit	Hydrologic Manipulations/Plantings	Shrub Swamp/Shallow Emergent Marsh	None	Floodplain reestablishment; Channel restoration
5603	Field visit	None recommended	Shrub Swamp	None	None
1507/1504	Driveby	Plantings	Shrub Swamp	Ditch plugging	None
1512/1510	Field visit	Hydrologic Manipulations/Plantings	Floodplain Forest/Shrub Swamp	Ditch plugging	Depression excavations; Floodplain reestablishment
4392a	Field visit	Hydrologic Manipulations/Passive Revegetation	Floodplain Forest	None	Depression excavations

5.0 TEMPLATE RESTORATION PLANS

Template restoration plans were developed for each of the three Tier 1 natural community types: floodplain forest, shrub swamp and shallow emergent marsh. A priority site, field-evaluated for restoration, was selected for each of the three community types to illustrate the general restoration concepts put forth in this plan. The communities described for each site represent the dominant community types based on the ecologic and hydrologic conditions present. Given the large size of some of these sites, it is likely that more than one community type would be appropriate for many of the sites. These secondary natural communities are mentioned in the narratives for each site below. This concept is illustrated in the template restoration plan developed for the floodplain forest community type (Section 5.1). Drawings have been developed for each of the three sites to illustrate restoration concepts. Detailed field surveys were not conducted; such surveys are necessary to develop detailed species planting lists, to determine precise locations of hydrologic manipulations such as ditch plugs and depression excavations, and to design stream channel realignments, if proposed.

5.1 Floodplain Forest (Illustrated by Site #4963)

Restoration Site #4963 was selected amongst the priority sites to demonstrate the restoration techniques for a representative floodplain forest natural community type. The restoration recommendations outlined here are based upon preliminary field investigation. Detailed field surveys are necessary to develop a site-specific restoration plan.

Restoration Site #4963 is located on the Lemon Fair River in Shoreham, Vermont. The Lemon Fair River is part of the Otter Creek Watershed. The site is most easily accessed from Quiet Valley Road from the west and Vermont Route 74 from the north. Figure 15 below graphically depicts the existing conditions on this site.

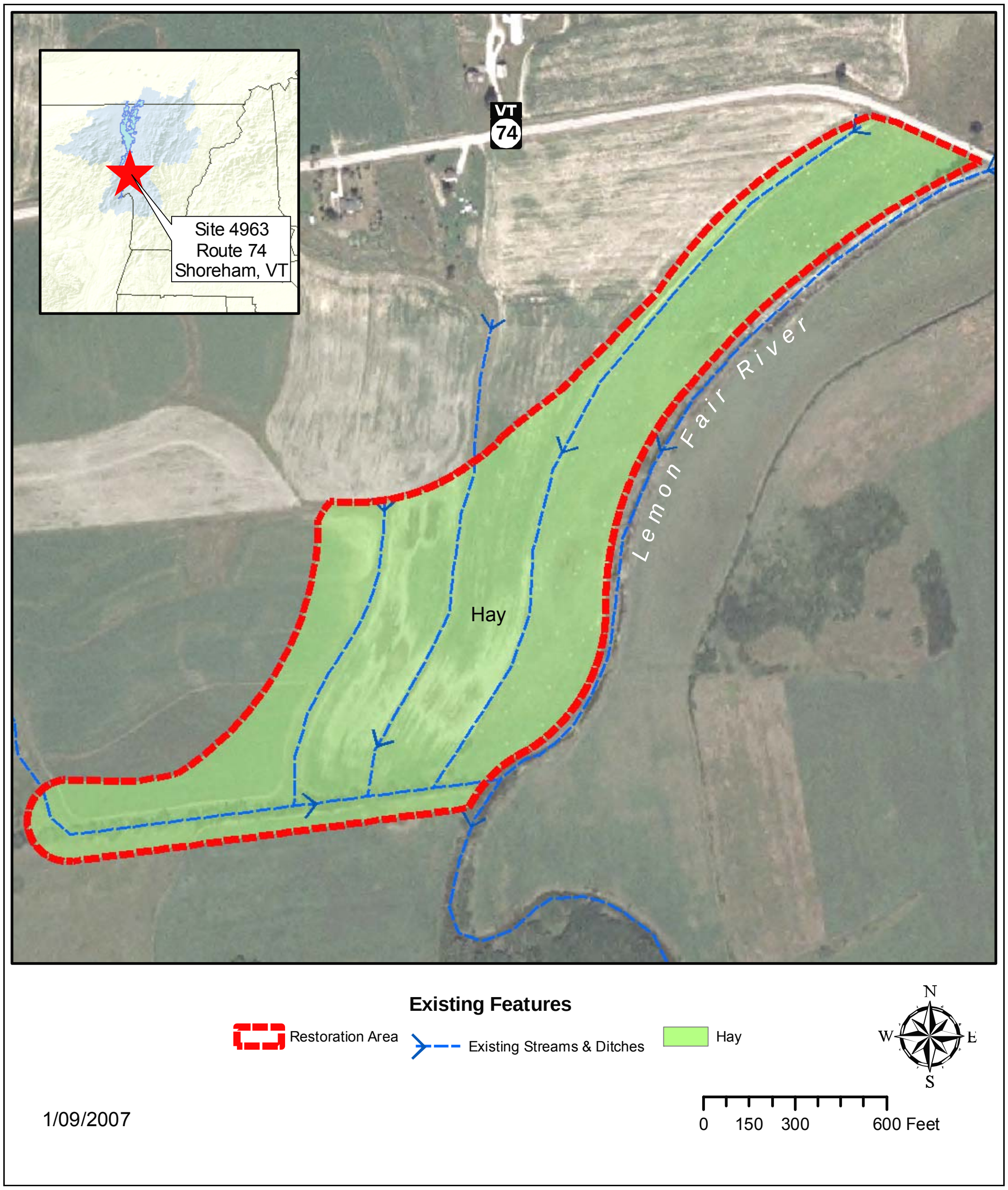


Figure 15: Site 4963, Shoreham, VT, Existing Conditions

The site received a rank of 23 by the prioritization model, receiving high scores for size, flooding, soil texture, and erosion risk. Information obtained from the field visit and landowner interview resulted in high provisional ranks for restoration feasibility and opportunity for P retention for the defined restoration area. The current land use practices of the site (manure spreading) provide a source for excess P and the site has a good landscape position in relation to nearby surface waters which provides an opportunity for the retention of P.

The site identified by the prioritization model is approximately 37 acres. The soils are characterized as Vergennes clay and Covington silt loam and are frequently flooded. The slope of the site is relatively flat. There is one stream located within the southern extent of the site that flows in an easterly direction, discharging to the Lemon Fair River, which forms the eastern boundary of the site. The land use of the site is characterized by active hayfields (Figure 16).

Figure 16: Site 4963, Hay field with no riparian buffer along Lemon Fair River (1/12/2007).

Hydrologic manipulation of the site includes a network of drainage ditches within the hayfields. The fields appear to be plowed, likely indicative of a hay/crop rotation. These fields were likely a combination of floodplain forest (along the Lemon Fair) and shrub swamp (adjacent to the stream and north into the hay fields) wetland ecosystems prior to agricultural conversion. In addition to wetland alteration on site, the stream on the property has been historically straightened and likely dredged.

Drainage ditches located within the hayfields run in an approximately north/south orientation, draining into the stream and then ultimately to the Lemon Fair. The fields drained by these ditches are treated with manure and provide a source of P to surface waters. The ditch network is effectively eliminating any retention of P before discharge to the Lemon Fair and ultimately the Otter Creek.

As a result of field review, the proposed restoration area for this site was increased to approximately 41 acres, as shown on the restoration concept plan (Figure 17), as well as page 10 of Appendix II. The northern boundary of the site was extended to include site #4956, a separate small site just south of Route 74, to develop an approximately 10 acre floodplain forest zone along the Lemon Fair River.

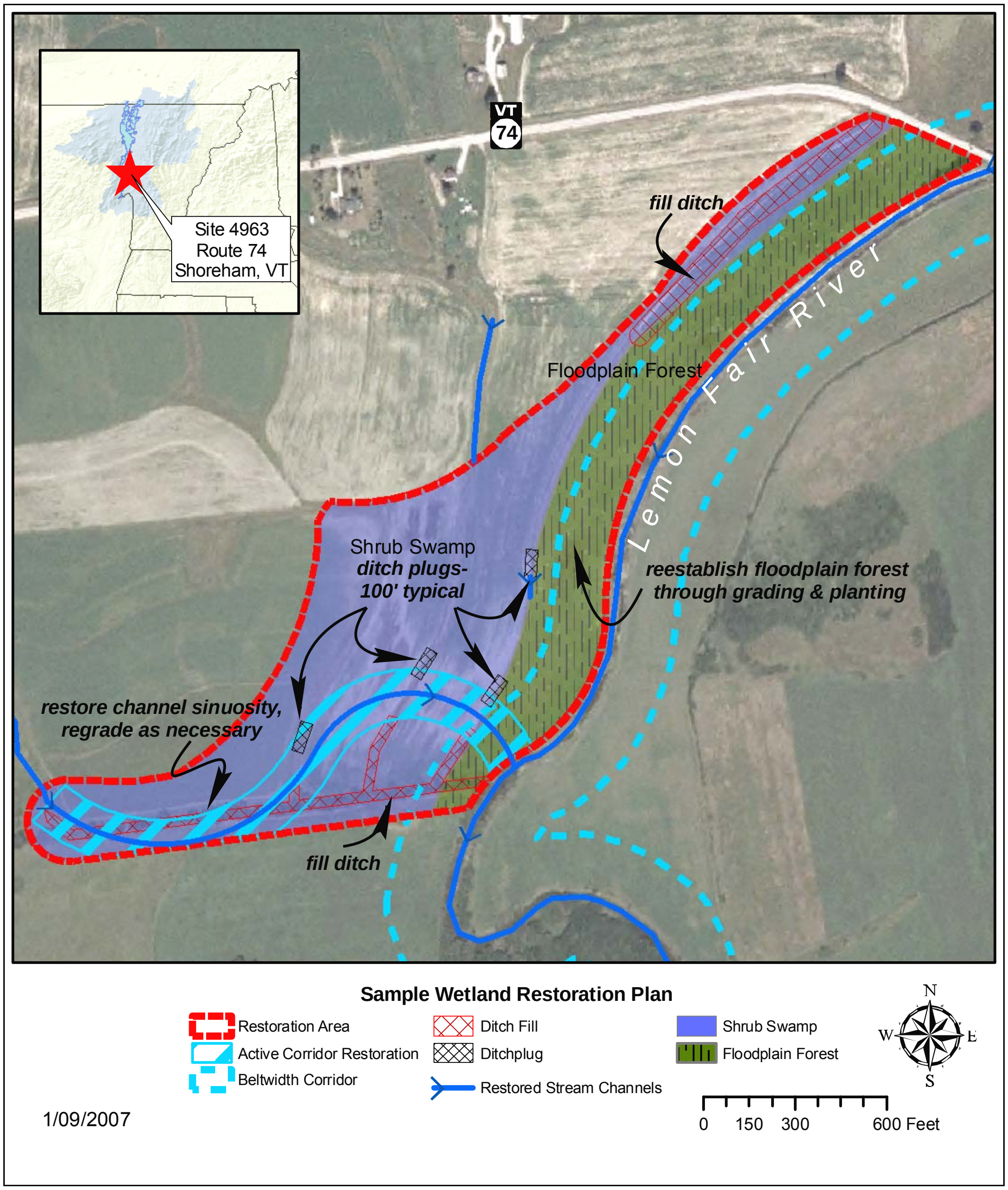


Figure 17: Site 4963, Sample Floodplain Forest Restoration Plan, Shoreham, VT
(see page 10 of Appendix II for complete restoration plan).

It is technically feasible to restore a wetland at this site because of easy site access, relatively straightforward restoration recommendations (described below) and low risks to adjoining properties. The closest structure is the roadbed for Quiet Valley Road. Detailed survey work needs to be conducted prior to actual implementation of a restoration plan at this site to adequately address flooding potential to this roadway.

5.1.1 Floodplain Forest Restoration Plan

A combination of Tier 1 and Tier 2 restoration techniques, including floodplain forest revegetation, ditch plugging, ditch filling, and channel restoration were recommended for the site. General descriptions of these restoration alternatives were given in Section 3.0 above.

The targeted Tier 1 natural community is floodplain forest. This community was selected based upon the anticipated ecological conditions that would be present at the site after the Tier 2 hydrologic manipulations are conducted. See the restoration concept plan for details (Figure 17 and page 10 of Appendix II).

The Tier 1 target community for the site is floodplain forest. An approximately 10 acre zone adjacent to the Lemon Fair River has been targeted for floodplain forest re-establishment. This area is prone to annual flooding from the Lemon Fair and was likely a floodplain forest prior to agricultural conversion. In addition to re-establishing a floodplain forest community on site, the project team anticipates that a shrub swamp community would re-establish within the remainder of the restoration area upon plugging of the drainage ditches and restoration of the stream channel.

The Tier 2 hydrologic manipulations include ditch plugging, ditch filling and approximately 1,300 feet of channel restoration (see Table 16). The ditch plugs would be located just upslope of the restored stream channel running west/east along the southern border of the site. Ditch plugs would re-establish wetland conditions conducive to shrub swamp re-establishment in the area of the channel restoration and the fields directly to the north. The upper terminus of the large north/south running ditch would be filled to promote sheet flow of runoff into the re-established floodplain forest zone.

The channel restoration corridor dimensions have been estimated from orthophotos. The beltwidth corridor is estimated to be approximately 160 feet wide. Channel sinuosity, as presented on the restoration concept plan (Figure 17), was also approximated and meant for illustration purposes only. Detailed stream assessments would be necessary to determine an actual meander pattern prior to implementation of the restoration plan.

Table 16: Site #4963 Restoration Techniques

Tier 1	Tier 2: Removals	Tier 2: Installations
Floodplain Forest Shrub Swamp	Ditch Plugs (4) Ditch Filling (~2,900ft)	Channel Restoration (~1300ft)

The site maintenance issues identified for the restoration include monitoring for flooding of Quiet Valley Road; erosion of ditch plugs; channel stability of the realigned stream channel; and invasive species monitoring in the proposed floodplain forest area.

5.1.2 Potential for Phosphorus Mitigation

As mentioned in Section 4.1.1, floodplain forests can act as P sinks if the flooding regime is intact and the site can act to receive alluvial deposits from the river. When an agricultural field is placed within a floodplain position, some sedimentation may still occur, but there may also be additions of P to the surface waters from fertilizer or manure applied to the field or from upstream contributing fields. Removing the site from agricultural production can help to minimize the amount of P that is being added to the surface waters during flooding events, thereby decreasing the amount that the site acts as a P source. Establishing floodplain forest vegetation can create eddies and slow the movement of floodwaters through the site, resulting in an increase in alluvial deposition (and adsorbed P) onto the site.

This particular site is well situated to receive floodwaters from the Lemon Fair River and, if floodplain vegetation is re-established, to mitigate P in those floodwaters via the processes described above. The additional restoration of the shrub swamp area would prevent the site from acting as a source of P to the Lemon Fair River and ultimately Lake Champlain. The restoration of this area to a shrub swamp would also act to slow incoming flood waters thereby increasing alluvial deposition during flooding events. Both of these efforts would act to create a P sink at this location along the Lemon Fair River.

5.2 Shrub Swamp (Illustrated by Site #417)

Restoration Site #417 was selected among the priority sites to demonstrate the restoration techniques for a representative shrub swamp natural community type. The restoration recommendations outlined here are based upon roadside investigation only. This site was not accessed because the landowner did not grant permission. As a result, this restoration plan is meant only to illustrate concepts relating to the restoration of a shrub swamp community that may be applied to similar sites with a willing landowner. As the site could be viewed easily from the road, a planning-level evaluation could be conducted from off-site. However, detailed field surveys would be necessary to develop a site-specific restoration plan.

Restoration Site #417 is located on the Pike River in the town of Berkshire, Vermont. The Pike River flows north into Canada and into the Missisquoi Bay of

Lake Champlain. The site is most easily accessed from Mineral Brook Road. Figure 18 below graphically depicts the existing conditions on this site.

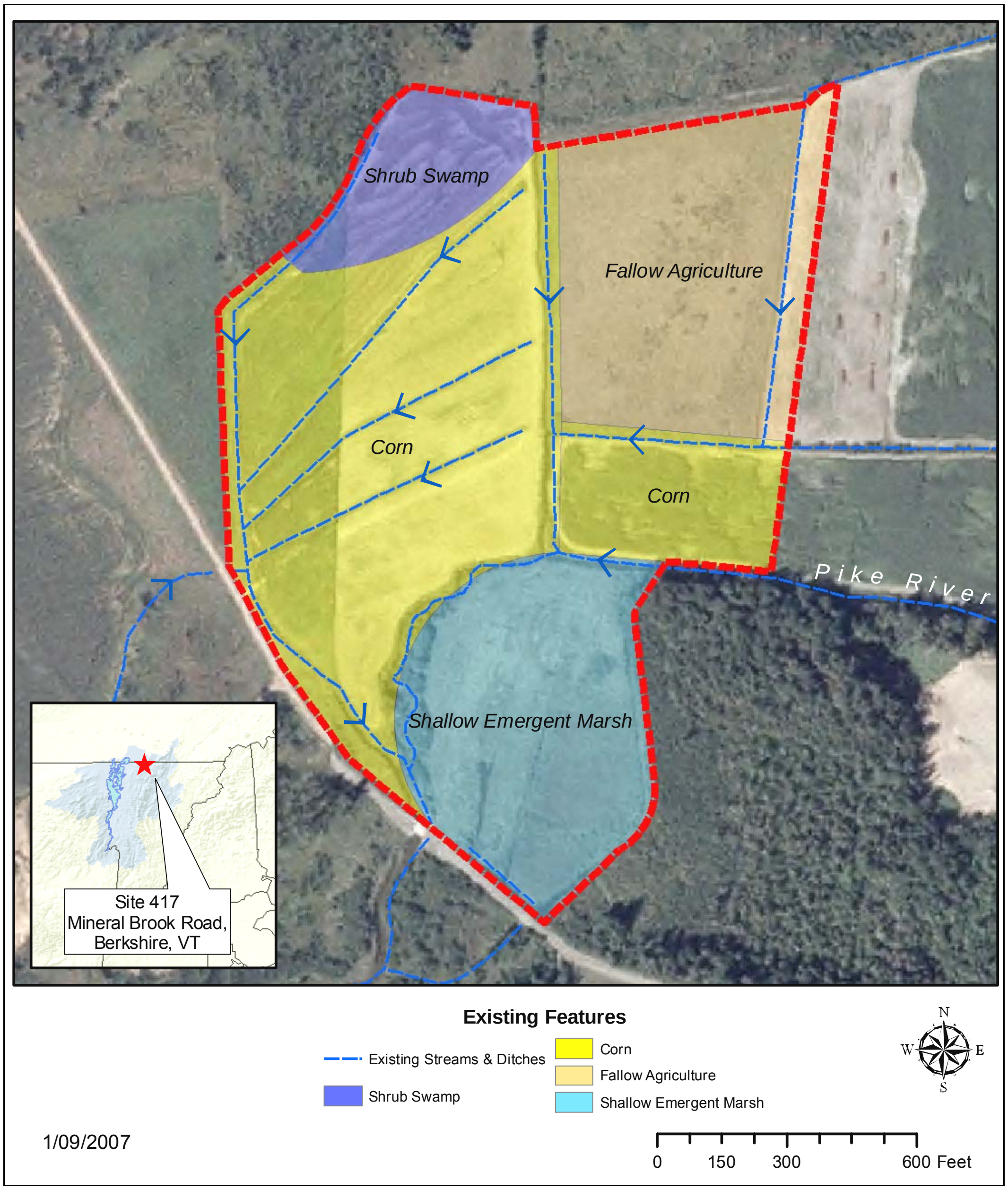


Figure 18: Site 417, Berkshire, VT, Existing Conditions

The site received a rank of 161 by the prioritization model, receiving high scores for size, flood class, soil texture, and erosion risk. The Pike River flows through the eastern portion of the site. An unnamed tributary flows into the Pike River within the eastern central portion of the site.

The field assessment for this site was conducted from Mineral Brook Road because landowner permission could not be obtained to access this parcel. Much of the site is under cultivation, mainly in corn. Even though specific management practices were not determined from the landowner, the relationship between the cultivated fields and the surface waters suggest that the site acts as a source for P into the drainage ditches and the Pike River. This is likely the result of both soil erosion (with adsorbed P) and nutrient additions from manure and/or other fertilizers.

The site identified by the prioritization model is approximately 40 acres. The soils are characterized as Rumney silt loams that are frequently flooded. The slope of the site is relatively flat. There is a relatively intact shrub swamp shown on the existing conditions map (Figure 19) that is dominated by a mix of willow and dogwood shrubs as well as a diversity of herbaceous vegetation. The shallow emergent marsh shown on the map is largely dominated by reed canary grass. This area may have been in agricultural production but has been abandoned.

The existing hydrologic manipulations at the site include a network of drainage ditches within the corn fields. Given the surrounding vegetation and hydrology, it is likely that these fields were shrub swamp communities prior to agricultural conversion. In addition to wetland alteration on site, the unnamed tributary and the Pike River itself have been historically straightened and likely dredged.

Drainage ditches located within the cornfields run in an approximately northeasterly to southwesterly orientation, ultimately draining into the Pike River (see Figure 19). The fields drained by these ditches are likely treated with manure and fertilizer that would act as a source of P to surface waters. The ditch network is effectively eliminating any retention of P before discharge to the Pike River and ultimately Missisquoi Bay.

Figure 19: Site 417, From the east with view of drainage ditch (11/27/2006).

As a result of field review, the proposed restoration area for this site was slightly increased to approximately 42 acres, as shown on the restoration concept plan (Figure 20 and page 11 of Appendix II).

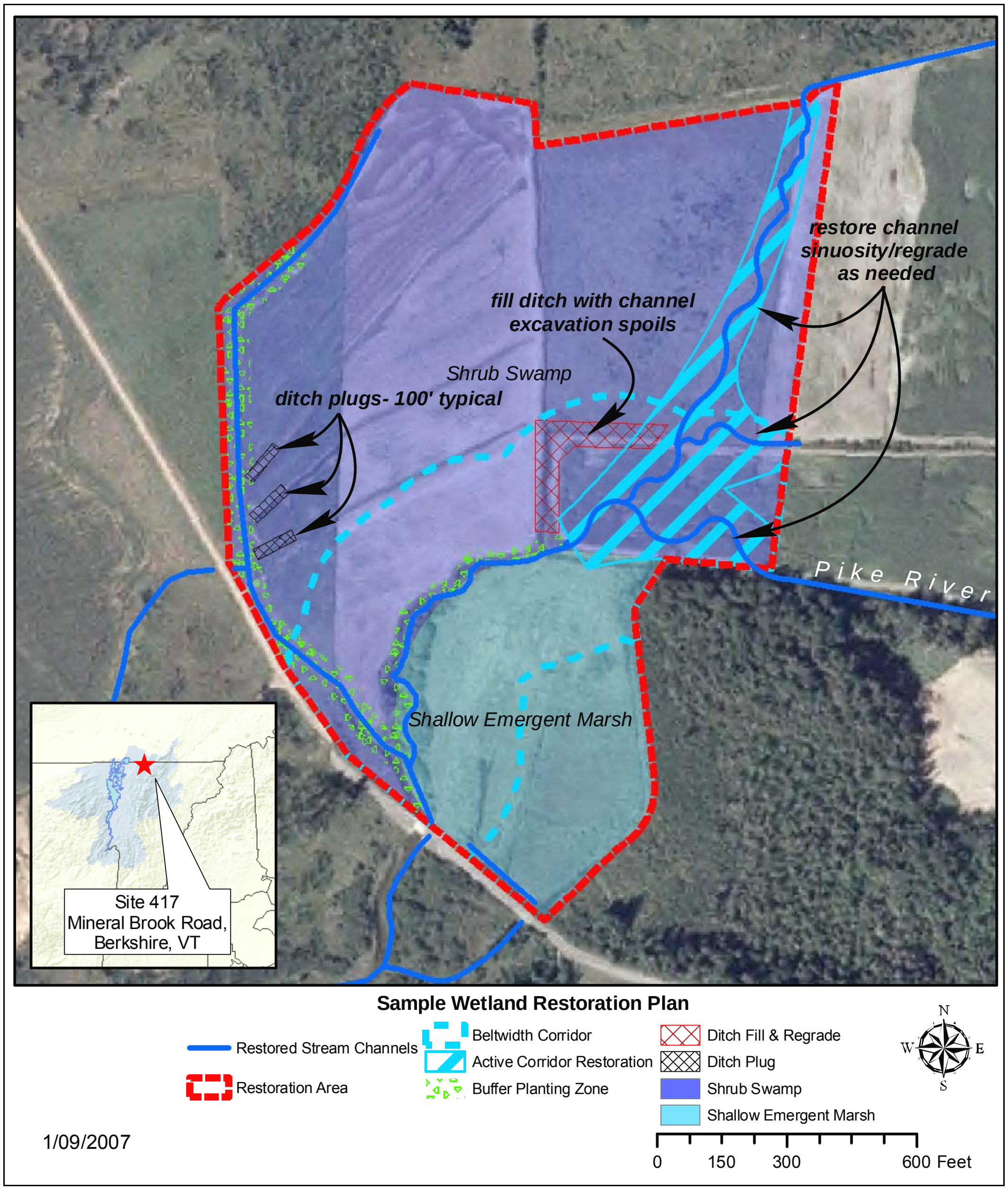


**Figure 20: Site 417, Sample Shrub Swamp Wetland Restoration Plan
Berkshire, VT
(see page 11 of Appendix II for complete plan)**

5.2.1 Shrub Swamp Restoration Plan

The restoration recommendations for this site are organized by the two-tier system discussed above under Section 4.0. Detailed descriptions of the specified restoration alternatives are also provided under Section 4.0.

The targeted Tier 1 natural community is a shrub swamp. This community was selected based upon the ecological conditions that would likely be present at the site after conducting hydrologic manipulations. There are two nearby shrub swamp communities that can serve as reference communities and potential seed/plant sources for this restoration.

Given the proximity of a reference shrub swamp community, the specific vegetation and structure present in these reference areas can guide the planting process. As shown on the restoration concept plan (Figure 20 and page 11 of Appendix II), planting of shrubs would be focused along the western ditch and areas along the Pike River that currently have limited vegetative buffer. These areas would aid in the slowing of flood waters from surface waters and act as a seed source from which more of the site could be colonized. Additional plantings along the plugged ditches and the restored stream channel could also be beneficial in establishing shrub vegetation on the site. Given the potential variability present on a site of this size, it is likely that some areas within the restoration site would favor the development of a shallow emergent marsh community. This might occur in the wetter areas, especially in the remnants of the plugged ditches.

The Tier 2 hydrologic manipulations recommended for this site include three ditch plugs along the interior drainage ditches, one ditch filling (approximately 480 linear feet), and the restoration of channel sinuosity for a segment of the Pike River and a ditched tributary in the eastern portion of the restoration area (see Table 17).

Table 17: Site #417 Restoration Techniques		
Tier 1	**Tier 2: Removals**	**Tier 2: Installations**
Shrub Swamp	Ditch Plugs (3) Ditch Filling (~480 feet)	Channel Restoration (~2000 feet)

The plugging of ditches would result in flood waters maintaining a higher residence time on the site. The ponded water would create the hydrologic conditions necessary to establish and maintain the shrub swamp vegetation. The ditch that runs parallel to Mineral Brook Road would be kept in place in order to ensure that the road would not be flooded during high water events. The ditch filling as illustrated on the restoration concept plan (Figure 20 and page 11 of Appendix II) is part of the effort to restore the sinuosity of the ditched stream and Pike River in the eastern restoration area. This restored stream channel would increase the residence time of the water flowing through this site and allow for flooding of the site during high flow events.

The channel restoration corridor dimensions for the Pike River segment were developed from existing Phase 1 stream assessment data for the Pike River obtained from the State of Vermont Rivers Program. From that data, a 480 foot-wide beltwidth corridor was projected. The channel restoration corridor dimensions for the small tributary segment of the restoration area were developed from an office review of orthophotos of the area. A beltwidth corridor approximately 80 feet wide was estimated for this section of stream channel. Channel sinuosity for both the Pike River and the stream segments, as presented on the concept plan (Figure 20), was also approximated from historic orthophotos and the USGS topographic map, and meant for illustration purposes only. Detailed stream assessments would be necessary to determine an actual meander pattern prior to implementation of the restoration plan.

The site maintenance issues identified for the restoration include monitoring for channel stability of the realigned river and stream, erosion of ditch plugs, and monitoring for the spread of invasive species.

5.2.2 Potential for Phosphorus Mitigation

The potential for mitigation of P on this site is twofold. First, given the current management of the site and the drainage patterns present, it is likely that this site is acting as a source of P into the surface waters. Taking the site out of agricultural production would likely decrease the amount of P entering the surface waters at this location. The restoration techniques outlined above would result in a greater residence time for the water that continues to flow through this site, thus leading to greater sediment deposition and uptake by biota. Both of these factors would contribute to a greater P retention efficiency. This would be a result of the changes in hydrology and the establishment of dense, woody shrub vegetation. Overall, these factors would result in the removal of P from the waters that enter the Pike River at this location.

Secondly, conducting the channel restoration of a section of the Pike River that is straightened would encourage the flooding of the Pike River onto the site containing the restored wetland. This would create the possibility for the removal of P from the surface waters that originated from off-site upstream sources, thereby creating a P sink at this location. There are a number of agricultural fields along the Pike River upstream from this location. While these sites were not assessed in the field, there is the possibility of an increased P load from these agricultural fields. The presence of an established shrub swamp community on this site would act to mitigate the P present in the floodwaters during high water events.

5.3 Shallow Emergent Marsh (Illustrated by Site #2321)

Restoration Site #2321 was selected among the priority sites to demonstrate the restoration techniques for a shallow emergent marsh natural community type. The restoration recommendations outlined here are based upon preliminary field investigation. Detailed field surveys are necessary to develop a site-specific restoration plan. Site #2321 is one of seven different high priority sites along the Sunderland Brook drainage. Only site #2321 was assessed due to lack of landowner permission for the other sites. From remote sources, it appears that other sites further south (particularly #2335 and #2330) may have higher P mitigation potential if restored. Techniques similar to those outlined here may be appropriate for these other sites as well.

Restoration Site #2321 is located on Sunderland Brook in Colchester, Vermont. Sunderland Brook is a tributary to the Winooski River. The site is most easily accessed from Pine Island Road. Figure 21 below graphically depicts the existing conditions on this site.

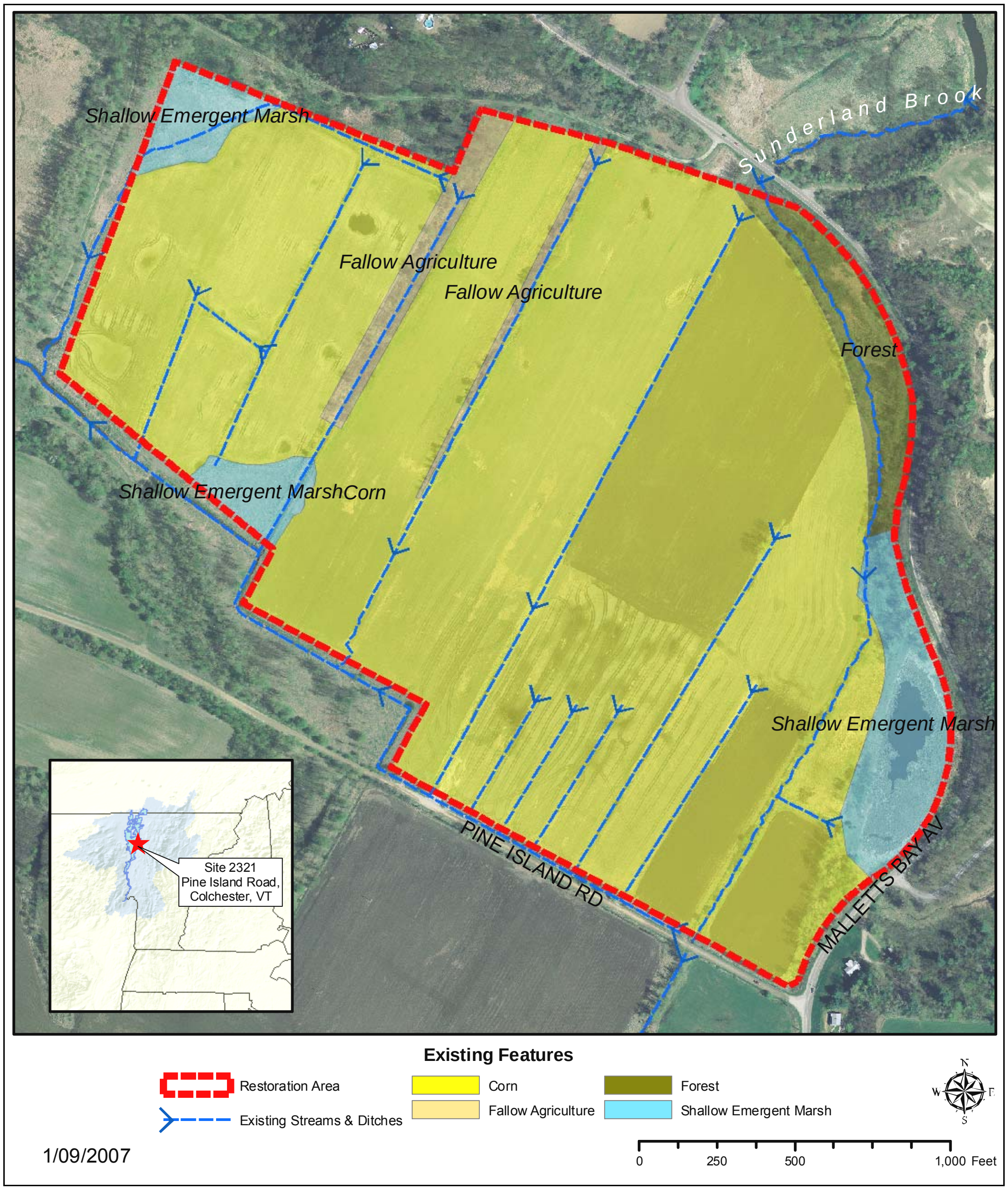


Figure 21: Site 2321, Colchester, VT, Existing Conditions

The site received a rank of 37 by the prioritization model, receiving high scores for size, flooding, soil texture, and erosion risk. The restoration area generated by the site selection model encompasses several properties. Information obtained from the field visit and landowner interview resulted in high provisional ranks for restoration feasibility and opportunity for P retention for the defined restoration area. The current land use practices of the site provide a source for P and the site has good landscape position in relation to nearby surface waters to provide an opportunity for retention of that P.

Permission was obtained from parcels 02-007032, 03-043002, and 03-04200. Only these parcels of the site were visited. While proposed restoration activities extend on to parcels for which permission was not granted, field assessments were restricted to areas where permission was granted. For areas without landowner permission, the site was viewed from Pine Island Road. See field data sheets and accompanying maps on the enclosed CD-Rom for parcel information

The site identified by the site selection model is approximately 124 acres. The soils are characterized as limerick silt loams that are frequently flooded. The slope of the site is relatively flat. There are two streams present on the site. Both are tributaries to the Winooski River. The land use of the site is characterized by a large forested wetland (green ash swamp) to the west and active corn fields for the remainder of the site (Figure 22).

Figure 22: Site 2321, Cornfield with standing water in tractor ruts (9/13/2006).

Hydrologic manipulation of the site includes a network of drainage ditches within the cornfields. The fields are actively cultivated for corn production. These fields were likely shallow emergent wetland ecosystems prior to agricultural conversion. In addition to wetland alteration on site, the two streams on the property have been historically straightened and likely dredged. Field evaluation of the site revealed that the drainage ditches located within the site flow in a southerly direction to a stream that discharges to the large forested wetland to the west. The fields drained by these ditches are treated with fertilizer and provide a source of P to surface waters. In addition, these fields are periodically flooded by the Winooski River from the south, which is an additional source of P. The ditch network is effectively eliminating any retention of P before discharge to nearby surface waters.

As a result of field review, the proposed restoration area for this site was reduced to approximately 118 acres, as shown on the restoration concept plan (Figure 23 and page 12 of Appendix II). The western part of the site was excluded from the recommended restoration area because it is already functioning as an intact wetland.

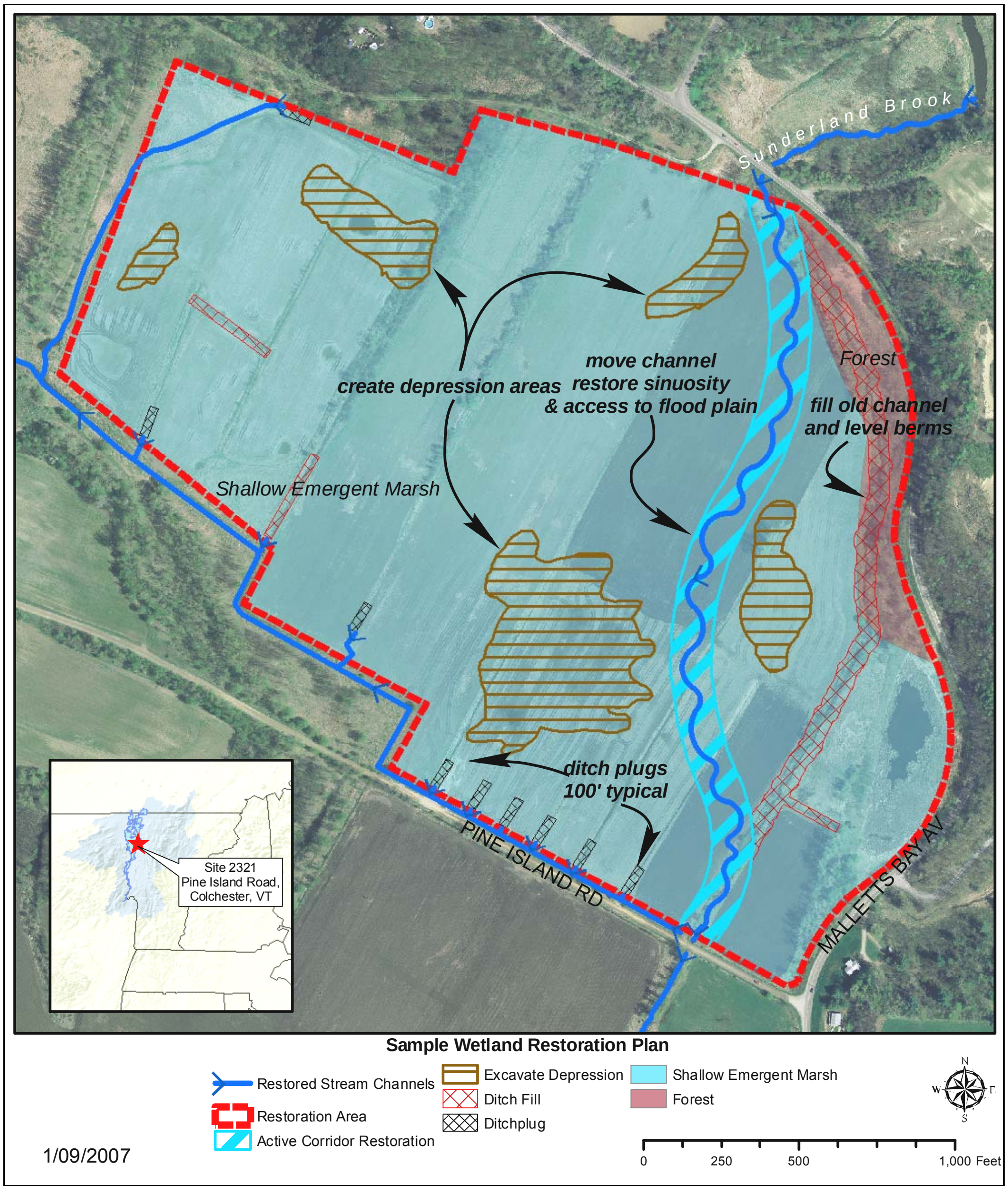


Figure 23: Site 2321, Sample Shallow Emergent Marsh Wetland Restoration Plan Colchester, VT (see page 12 of Appendix II for complete plan)

It is technically feasible to restore a wetland at this site because of easy site access, relatively straightforward restoration recommendations (described below) and the potential risk to adjoining properties is low. The closest structure is the roadbed for Pine Island Road, which already has a history of flooding. The restoration plan addresses in part flooding issues for this road by leaving intact the drainage ditch running along it, so as to avoid compounding the existing flooding problem. Detailed survey work would need to be conducted prior to actual implementation of a restoration plan at this site to adequately address flooding potential to this roadway.

5.3.1 Shallow Emergent Marsh Restoration Plan

A combination of Tier 1 and Tier 2 restoration techniques, including shallow emergent marsh revegetation, ditch plugging, depression excavations, and channel restoration are recommended for the site and outlined in the following section. Detailed descriptions of the specified restoration alternatives are provided in Section 4.3 above.

The restoration recommendations for Site #2321 are organized by the two-tier system discussed above. The targeted Tier 1 natural community is shallow emergent marsh. This community was selected based upon the anticipated ecological conditions that would be present at the site after the Tier 2 hydrologic manipulations were conducted. There are two nearby shallow emergent marsh sites that can serve as reference communities and potential seed/plant sources for this restoration. Shrub swamp is a secondary natural community that would be established within the stream channel restoration area.

The Tier 2 hydrologic manipulations would include ditch plugging, ditch filling, depressions excavation, and approximately 2,500 feet of channel restoration (see Table 18). The ditch plugs (of varying lengths) would be located just upslope of the main running east/west ditch along Pine Island Road. Numerous shallow depressions totaling approximately 11 acres are located in low spots within the existing cornfields. The ditch plugs and shallow depressions are intended to create permanently ponded water throughout the defined restoration area. The ponded water would create the hydrologic conditions necessary to establish and maintain shallow emergent marsh vegetation.

The channel restoration corridor dimensions were developed from existing Phase 2 stream assessment data for Sunderland Brook obtained from the Vermont Rivers Program. The assessment data identifies a beltwidth corridor approximately 130 feet wide. Channel sinuosity, as presented on the restoration concept plan (Figure 23 and page 12 of Appendix II) was approximated and meant for illustration purposes only. Detailed stream assessments would be necessary to determine an actual meander pattern prior to implementation of the restoration plan.

Table 18: Site #2321 Restoration Techniques

Tier 1	Tier 2: Removals	Tier 2: Installations
Shallow Emergent Marsh	Ditch Plugs (8)	Channel Restoration (~2500ft)
Shrub Swamp	Ditch Filling (~2800ft)	Depression Excavations (~11 acres)

The site maintenance issues identified for the restoration area include monitoring for any flooding problems on Pine Island Road; erosion of ditch plugs; channel stability of the realigned Sunderland Brook; target water levels in the depression areas and associated shallow emergent marsh; herbivory and plant competition; and invasive species monitoring in the proposed marsh area.

5.3.2 Phosphorus Mitigation

The potential for the mitigation of P from this site is twofold. First, the site is likely acting as a source of P into Sunderland Brook and nearby Winooski River. This conclusion is based on the current land use and the drainage patterns on the site. Taking the site out of agricultural production would likely decrease the P load from these fields. The restoration of the hydrology would increase the residence time of the water that continues to flow through the site. By re-establishing vegetation, seasonal uptake of P would be encouraged and retention efficiencies would be maximized.

Second, conducting the channel restoration of a section of the brook that is straightened would encourage the flooding of Sunderland Brook onto the site (containing the restored wetland). This would create the possibility for the removal of P from the surface waters that originated from off-site sources, thereby creating a P sink at this location. Sunderland Brook is likely acting as a source of P at this point in the watershed, having flowed through extensive urban areas upslope of the site. The presence of an established shrub swamp community along the re-established floodplain of this Brook would act to mitigate the P present in the floodwaters during high water events (often a critical period in high P transport in surface waters).

6.0 GENERAL RESTORATION GUIDELINES

The following general guidelines may be used for most restoration projects. The guidelines should be tailored to the specific restoration site, as needed. This section provides guidance for Tier 1 and Tier 2 restoration alternatives, construction details, control of invasive and noxious species, inspection and maintenance protocol, long-term monitoring, reporting, and the recommended timeframe for a project.

6.1 Tier 1: Natural Community Re-establishment

As discussed above, detailed species planting specifications can only be developed from additional field assessment of both the specific restoration site and the surrounding area. For projects only involving revegetation activities, additional information required for development of site specific planting plans includes soil type and soil saturation conditions. Soil type can be obtained within proposed planting zones relatively easily with hand augered soil cores. Soil saturation conditions may need to be monitored over the course of a growing season. From these field observations, planting zones can be developed for specific vegetation community types.

For projects involving hydrologic manipulations, planting zones are likely to be determined from proposed final grades and predicted hydrology. These planting zones may or may not reflect the natural communities currently within the project area. Field observations related to soil type and soil saturation will be equally important within these more complex projects to develop site grading plans and ultimately establish desired wetland restoration zones.

The template plans and priority sites selected to represent each of the Tier 1 community types are illustrative of a common type of restoration. They are not presented as detailed plans for any particular site.

Ideally, planting materials from nearby reference communities would be obtained for a restoration area. At a minimum, plant species identified within a nearby reference community would be specified for a restoration area. If nearby seed stock and/or cuttings cannot be utilized, there are a number of local nurseries that can be contacted for plant materials. Currently the following local nurseries can be contacted for plant materials for wetland restoration projects:

- Vermont Wetland Plant Supply
  Orwell, Vermont

- High Reach Farm
  Danville, Vermont

- Intervale Conservation Nursery
  Burlington, Vermont

- Hillcrest Nursery
  Marshfield, Vermont

- Cobble Creek
  Bristol, Vermont

In addition, plant materials from the region can be acquired from:

- New England Wetland Plants
  Amherst, Massachusetts

- Champlain Valley Native Plant Restoration Nursery
  Whitehall, New York

General guidelines for planting and initial care of trees and shrubs can be found in the following reference document:

Wetland Planting Guide for the Northeastern United States: Plants for Wetland Creation, Restoration, and Enhancement (Thunhorst 1993).

For most restoration projects, plant installations will take place in the spring or fall (depending on the plant species and the project schedule). Suppliers of plant materials can provide guidance for particular species. It is recommended that suppliers be contacted early in the planning stages to verify ability to handle desired volumes and delivery schedules. Larger projects may require using multiple suppliers and may result in a longer timeframe to acquire the materials. Based on the project team's previous experience, it is not unusual to order desired plants a year in advance of the proposed work.

6.2 Tier 2: Hydrologic Manipulations

A detailed site assessment, including topographic survey of the project site and adjoining lands, is necessary to design and engineer most hydrologic manipulations that are proposed for restoration sites (e.g., identifying low points for ditch plug placement and depression excavation). Detailed site elevation data combined with observed hydrologic conditions (groundwater monitoring wells and/or stream gage data as needed) will be used to design site grading that will not result in flooding of adjoining properties.

Depending on the complexity of the restoration project, groundwater monitoring and stream gauging may be required. For projects involving significant earthwork, such as regrading to reestablish historic floodplain access or stream channel realignments, detailed site monitoring will be required. For projects involving minor earth work, such as ditch plugging or ditch filling, berm removal, or tile removal, detailed site monitoring is not likely necessary. Projects with potential risks to adjoining properties will likely require detailed monitoring to prevent impacts to surrounding lands.

6.3 Construction Details

Another major component of the site design will include the development of an erosion prevention and sediment control plan (EPSCP). One of the primary objectives of the EPSCP will be to ensure that sediments (and by association P) are not released from the restoration site. Once the design work is complete, a construction schedule can be developed. Utilizing experienced local contractors, to the extent possible, is recommended. The following construction guidelines are general and can be applied to most restoration situations.

1. Prior to commencement of site work, permitting agencies (U.S. Army Corps of Engineers and/or State of Vermont Wetlands Office) should be notified.
2. Prior to commencement of site work, restoration area boundaries should be clearly marked with flagging in the field. Limits of disturbance are best established by installing snow fence.
3. Prior to commencement of site work, locations of specific hydrologic alterations should be staked and reviewed with the excavation contractor.
4. Appropriate erosion control features should be installed within and around the restoration site (such as silt fence, check dams, etc.).

5. The erosion controls should be maintained on a regular basis. Sediment collected by these devices should be removed and placed upland in a manner that prevents its erosion and transport to a waterway or wetland.
6. The use of heavy machinery should be minimized outside of the restoration area by installing construction barriers to prevent machinery from entering the remaining wetland area. A combination silt fence/rope barrier should be used on the downgrade side, rope barrier on the upgrade side.
7. Construction should be restricted to the period between May 30 and October 1 to ensure appropriate site stabilization following earthwork through re-vegetation.
8. Excess material not utilized in the restoration effort should be removed to a suitable non-wetland and non-wetland buffer site for disposal.
9. Construction should be supervised by a wetlands ecologist.
10. The construction duration should be kept to the minimum necessary to accomplish the goals set out by the restoration plan.
11. Erosion controls should remain in place for at least one growing season and until vegetation has been established.

6.4 General Control of Invasive and Noxious Species

Careful attention to the control of invasive and/or noxious species must occur during a restoration project to avoid introducing or increasing the risk of invasion by unwanted plants. If the site and surrounding area do not currently have colonies of invasive plants such as common reed (*Phragmites australis*) purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*) the risk of introduction is most likely restricted to off-site materials being brought to the site. To prevent the introduction of invasive plants, the following procedures are recommended:

1. Wash all equipment prior to work in restoration areas to remove potentially contaminated soil, seed, roots, and rhizomes. This shall include the excavator bucket, rakes, shovels, etc.
2. In the event that common reed or purple loosestrife are found on the restoration site, all practicable measures should be used to eliminate them. This may include hand pulling and removal from site. A written plan should be developed at the time of the control to identify the area and method to be used. Some methods, such as dredging, may require additional permits.
3. Other invasive species may become established but shall not be considered a problem as long as all invasive species present occupy 10 percent or less of the restoration area.

For many sites, reed canary grass may already be present on the site. Eradication of this species is a very difficult process, often complicated by the fact that it is still being planted as a forage and conservation species. Numerous methods for the control or eradication of this species have been proposed. Application of herbicide in combination with plowing or burning is often recommended (Hovick and Reinartz 2007, Lyons 1998, Reinhardt and Galatowitsch 2004). Frequent cutting (five or more times in a season) can also be effective if used in combination with subsequent planting of other native species. This, however, may not be practical in wetter areas. In all cases, frequent and diligent monitoring and management is necessary to eradicate this species from a particular area.

For restoration projects in floodplain forest areas, eradication of invasive species is complicated by the constant reintroduction of propagules during flooding events. Japanese knotweed (*Polygonum cuspidatum*) is an especially ubiquitous and persistent invasive species. Frequent cutting (more than three cuttings per season) or control using selective herbicides is often a recommended control method (Seiger 1991). For sites that do not contain this species at the time of restoration, constant monitoring to prevent establishment is critical.

6.5 Inspection and Maintenance

The following general guidelines for inspection and maintenance are put forth for restoration activities implemented in the LCB. Specific requirements may be necessary or appropriate for individual sites.

Plants and materials should be monitored on a weekly basis for three to four weeks after installation to ensure the success and survival of the plants and the integrity of the materials. The plants should be watered and monitored more regularly if necessary (such as during drought conditions) during the establishment phase. All plant materials should be checked periodically or after storm events to ensure they remain properly secured. Necessary repairs should be made promptly. Temporary and permanent erosion control practices should be maintained and repaired as needed to ensure continued performance of their intended use.

A qualified wetland ecologist should inspect the restoration area as follows:

1. During construction of the wetland restoration; at least once per week, and otherwise as necessary to ensure proper construction.
2. During five successive growing seasons following completion of the restoration plan.

6.6 Long-Term Monitoring

It is recommended that monitoring occurs for each of the first five full growing seasons following the construction of the restoration site. Annual monitoring reports should be submitted to the appropriate permitting and/or funding agencies if required.

On a site-by-site basis, indicators should be selected for use in determining/demonstrating the success of the project. For instance, target water levels are a likely measure for determining the success of a Tier 1 community type of shallow emergent marsh. If target waters levels are met, site conditions are likely supporting the successful establishment of the desired community. For a floodplain forest community, a target may be set for frequency of flooding. If the target is not met, the desired community type is not likely to be established. For a channel restoration project, channel stability, as demonstrated by a lack of erosion, is a likely target. Development of erosion problems would be used as an indication that the project is not succeeding.

Specific target criteria should be selected prior to the implementation of the site-specific restoration plan and then monitored for a period of no less than five years after the plan is implemented. Selection of the target criteria also involves establishing monitoring locations at the site. The target criteria would be measured at the specified locations.

Remedial measures should be implemented if the target goals are not being attained within the first three growing seasons after completion of construction of the restoration site. Measures requiring earth movement or changes in hydrology should not be implemented without written approval from the appropriate permitting agencies. The length of the monitoring period may need to be extended if a series of remedial measures is necessary.

Overall success standards are also established on a site-by-site basis. Success standards are established in the form of amounts, ranges and/or time frames such as trees per acre (threshold density), plant survivorship, species composition, percent cover by species within each stratum, average height or diameter by tree species, establishment of preferred vegetation (species and structure), control of exotics, etc. A typical success standard for forested and shrub swamp wetlands is establishment of 400 to 500 trees/shrubs per acre that are healthy and vigorous. Another success standard that can be set for any restoration site is establishment of 80 percent aerial cover by non-invasive species. Desired planting density may vary from project to project depending on site specific conditions, desired natural community types, available funding resources for the project, and/or other variables.

A final example of a success standard would be the presence of stabilized slopes within and adjacent to the restoration site.

The monitoring report should include the following components (Amended from the Army Corps of Engineers Mitigation Plan Checklist, 1/12/07):

1. Description of the monitoring inspections that have occurred.
2. Concise description of remedial activities either done during the monitoring years or needing to be done to meet the established success standards-actions such as removing debris, replanting, methods and success of controlling invasive plant species, regrading the site, applying additional topsoil or soil amendments, adjusting site hydrology, etc.
3. Report status of erosion control measures.
4. Visual estimates of percentage vegetative cover, and percentage cover of the invasive species in the restoration area.
5. Fish and wildlife use of the project area.
6. Description of site hydrology and soils
7. Description of the general health and vigor of the surviving plants (by species planted), the prognosis for their future survival and diagnosis of the cause of morbidity or mortality.

8. Description of remedial measures recommended to achieve or maintain achievement of the established success standards and otherwise improve the extent to which the restoration site accomplishes the overall goal of P mitigation.
9. Provide an as-built planting plan showing the location and extent of the designated plant species and the hydrologic manipulations conducted at the site.
10. Include a vegetative list of dominant volunteer species in each plant community type. Dominant volunteer species should include those that cover over 55 percent of their vegetative layer.
11. Take representative photographs of the restoration area from the same location for each monitoring event.

The final assessment report should include the following:

1. Summary of the original or modified restoration goals and discuss the level of attainment of these goals at the restoration site.
2. Description of significant problems and solutions during construction and maintenance (monitoring) of the restoration site.
3. Outline of long-term management requirements for the site.
4. Identification of agency procedures or policies that encumbered implementation of the restoration plan.
5. Recommendations for measures to improve the efficiency, reduce the cost, or improve the effectiveness of similar projects in the future.

6.7 Typical Timetable for a Restoration Project

An eight-year period is presented as an average time frame for conducting a wetland restoration project. As each restoration site will provide a host of unique circumstances, this time frame is only suggested as an average. There will be sites for which additional time is needed to collect background/existing site conditions, or for which permitting takes longer than anticipated. For relatively straightforward sites, this time frame should provide a reasonable guide.

Years 1 and 2: Collect site information, develop design plans, acquire necessary permits, identify sources of materials, and order materials. It is recommended that plant materials be ordered as soon as possible to avoid long delays in implementation of the restoration plan.

Year 3: *Spring*: conduct Tier 1 hydrologic manipulations (removal and/or installations) and site stabilization with groundcover. Monitor manipulations for desired results throughout the spring and summer.

Fall: Plant trees and shrubs for targeted Tier 1 natural community re-establishment.

Year 4: Conduct 1st monitoring round: monitor target variables; evaluate health of plants, identify and remove invasive plants, correct hydrologic manipulations as needed, complete as-built drawings, prepare and submit 1st monitoring report.

Year 5: Conduct 2nd monitoring round: monitor target variables, install replacement plantings as needed, final corrections of hydrologic manipulations, develop invasive species control plan if needed, prepare and submit 2nd monitoring report.

Year 6: Conduct 3rd monitoring round; monitor target variables, evaluate health of plants, implement invasive species control plan, remove erosion control features if site is stabilized, prepare and submit 3rd monitoring report.

Year 7: Conduct 4th monitoring round, prepare and submit 4th monitoring report.

Year 8: Conduct 5th monitoring round, prepare and submit final assessment report.

6.8 Recommended Manuals on Wetland Restoration

There are numerous published manuals and other documents that could provide additional useful guidance in developing a wetland restoration plan. The following lists a few of these.

Illinois Wetland Restoration and Creation Guide

Admiral, A.N., M.J. Morris, T.C. Brooks, J.W. Olson, and M.V. Miller. 1997. Illinois Wetland Restoration and Creation Guide. Illinois Natural History Survey Special Publication 19. Champaign, IL. 188 pp.

Wetland restoration handbook for Wisconsin Landowners, Second edition

Thompson, Alice L. and Charles S. Luthin, Martin P.A. Griffin and Dreux J. Watermolen (eds.). 2004. Wetland restoration handbook for Wisconsin Landowners, Second edition. Wisconsin Wetlands Association, Bureau of Integrated Science Services, Wisconsin Department of Natural Resources, Madison, WI.

Stream Corridor Restoration: Principles, Processes, and Practices

Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN3/PT.653.

An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement

Interagency Workgroup on Wetland Restoration: National Oceanic and Atmospheric Administration, Environmental Protection Agency, Army Corps of Engineers, Fish and Wildlife Service, and Natural Resources

Conservation Service. 2003. An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement.

6.9 Contacts

Numerous contacts for technical support and funding sources exist in the State of Vermont for those interested in providing land for, or participating in wetland restoration activities. Example contacts are listed below:

Vermont Department of Forest Parks and Recreation
Wetland Protection and Restoration Program
http://www.vtfpr.org/wprp/index.cfm

Contact
April Moulaert - Wetland Restoration and Protection Specialist
Department of Forests, Parks, and Recreation
103 South Main Street, 10 South
Waterbury, VT 05671-0601
email: April.Moulaert@state.vt.us
phone: 802-241-1054

Wetlands Reserve Program
http://www.vt.nrcs.usda.gov/programs/wrp/

Contact
Fletcher Potter – Environmental Specialist
Natural Resources Conservation Service
365 Mountain View Drive
Suite 105
Colchester, Vermont 05446
Email: Kip.Potter@vt.usda.gov
phone: 802-951-6796

Wildlife Habitat Incentives Program
http://www.vt.nrcs.usda.gov/programs/whip/

Contact
Toby Alexander – Resource Conservationist
Natural Resources Conservation Service
365 Mountain View Drive
Suite 105
Colchester, Vermont 05446
Email: Toby.Alexander@vt.usda.gov
phone: 802-951-6796

Partners for Fish and Wildlife Program
http://www.fws.gov/r5lcfwro/complex.htm

Contact
Chris Smith – Fish and Wildlife Biologist
Lake Champlain Fish and Wildlife Resources Office
11 Lincoln Street
Essex Junction, Vermont 05452
Email: chris_e_smith@fws.gov
Phone: 802-872-0629

7.0 SUMMARY

This project developed a rational, quantitative approach to screen and identify potential wetland restoration sites within the 2.9 million acres of the Vermont LCB. Within this varied landscape, the site selection model identified nearly 5,000 potential sites occupying more than 86,000 acres (135 square miles). Potential sites ranged from the pre-set minimum of three acres to a maximum of 1,490 acres, with an average area of approximately 18 acres.

To prioritize potential wetland restoration sites, the project team developed and tested a site prioritization model that included both site function and upslope drainage area criteria. This prioritization model was applied to all the potential sites identified in the initial screening process. Out of a possible maximum restoration score of 500, the highest ranked site scored 459.9 and the mean score was 271.

Identified sites within the Otter Creek subbasin received the highest mean scores for both site function and upslope drainage area compared to the other subbasins in the Vermont LCB. The Otter Creek watershed is characterized by a high proportion of agricultural land in close proximity to surface waters with clay soils in hydrologic soil groups C and D. This combination results in a landscape that has the potential to generate a large amount of non-point source P, and is reflected in the Otter Creek sites' overall high model scores. The Otter Creek lake segment receives the third highest non-point source P load among all the Vermont lake segments and the Lake Champlain P TMDL calls for an 8.6 t/yr P load reduction from agriculture (Vermont DEC and New York State DEC 2002), second only to the reduction slated for the Missisquoi Bay lake segment. Combined with the results of the site prioritization model, these facts suggest that the Otter Creek subbasin would be an appropriate target for initial wetland restoration efforts. It is, of course, important to note that the models have identified important restoration sites in other parts of the LCB. Because the Lake Champlain P TMDL (Vermont DEC and New York State DEC 2002) targets the Missisquoi Bay as the lake segment requiring the largest overall reduction in P load, the Missisquoi River subbasin would also be an important place to start targeting wetland restoration efforts within the LCB.

More than 80 highly-ranked sites were visited in the feasibility study to confirm whether the identified sites were degraded wetlands, determine whether restoration of the sites would be worthwhile for P mitigation, and to assess the feasibility for restoration given such constraints as landowner interest, effects on adjacent land or structures, and technical feasibility of any recommended actions. In general, most of the sites that ranked high in the prioritization model were confirmed as degraded wetlands, although the estimated magnitude of P mitigation and the technical feasibility of restoration varied among the sites. It is worth noting that the majority of the 45 landowners that agreed to be interviewed for the study indicated some interest in participating in a restoration plan for their property depending on the compensation package. However, it was also observed that landowner contact in general was a challenge to conducting the feasibility study (i.e., finding landowners willing to conduct an interview and allow site evaluators to visit their land) and found that many were wary of becoming involved with a project that may take their land permanently out of agricultural production. These observations suggest that a continued public outreach effort may be warranted as VT FPR moves forward with the plan, and that careful consideration with regard to the kind of compensation package required to attract landowners to the program will be necessary.

The most common hydrologic manipulations observed across the visited sites were constructed agricultural ditches. Restoration of hydrologic regime – the foundation of wetland restoration – can be accomplished by increasing the residence time of water within wetland areas (ditch plugs, ditch filling, tile drain disabling, depression excavation) and/or slowing down moving water (channel restoration and floodplain re-establishment).

The floodplain forest community was the most common wetland vegetation type recommended for restoration during this study. Shrub swamp and shallow emergent marsh wetland communities are also important for restoration. Because floodplain forest and emergent marsh appear to have greatest potential for P retention based on published literature, these two types should be prioritized for restoration.

Template restoration plans for all three wetland community types have been presented to guide the formulation of specific site plans. These templates, along with some general practical restoration guidelines, can serve as starting points for design of specific restoration projects. However, restoration projects must be tailored to each specific site and need to be properly managed.

Finally, careful monitoring of sites should occur following restoration both for evaluating progress in the re-establishment of appropriate wetland vegetation and hydrologic regime and for P retention effectiveness. By monitoring the effectiveness of wetland restoration projects, the overall progress of restoration in the LCB can be evaluated and fine-tuned, particularly with regard to achieving the goals for P load reduction to Lake Champlain.

8.0 RECOMMENDATIONS

The current study and resulting plan lay the groundwork for promoting strategic wetland restoration efforts in the LCB. This plan provides the mechanism to locate potential restoration sites and a roadmap to develop site specific restoration plans for sites. Some next steps for implementing a basin-wide wetland restoration plan include developing a strategy for selecting project sites, conducting a marketing and public relations campaign about the project, developing a formula for compensation packages for participating landowners, and realistically assigning resources to contact landowners of potential project sites as further explained below.

The GIS models and plan were developed to address the P TMDL clean-up requirements for Lake Champlain. The site selection model identified approximately 5,000 potential wetland restoration sites within the LCB in Vermont. The Missisquoi River and Otter Creek subbasins have the highest targeted P reduction goals and should be the focus of actual restoration projects in the LCB. Concentrating restoration efforts in these two subbasins is a good first step in mitigating P loading to the lake. Restoration projects can be expanded out from those subbasins as funds and resources are available.

In addition to adopting a selection strategy to guide the implementation of the plan, a next step in the process must include public education and outreach. A multimedia marketing and public relations campaign should be developed to advertise the project. The campaign should focus on explaining the problem, explaining the proposed solution (wetland restoration), and explaining how landowners can participate. The campaign needs to carry a very positive message, not pointing fingers of blame at anyone for the problem, and presenting real incentives for getting involved.

A critical next step is to develop a formula for determining compensation packages. The results of the feasibility study presented above suggest that landowner participation will be a significant challenge to implementing restoration plans at selected sites. Landowners want to know what kind of compensation they will receive for participating in the program. Once the financial component is presented, the landowner can often make a very quick mental calculation of cost and benefit and decide whether they are interested in continuing with the conversation.

Landowner contact is a time consuming component of this process. While the site selection model identifies the geographic area for a potential restoration site, it can only provide property boundaries for towns with up to date and digitized tax maps. It does not identify current landowners or provide current telephone numbers for contact. Realistic allocation of time and resources needs to be assigned for this activity. Potential use of volunteers and/or interns may be the most efficient and/or cost effective way to accomplish this task.

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