## COMPONENTS OF THE AREA-WIDE PLAN

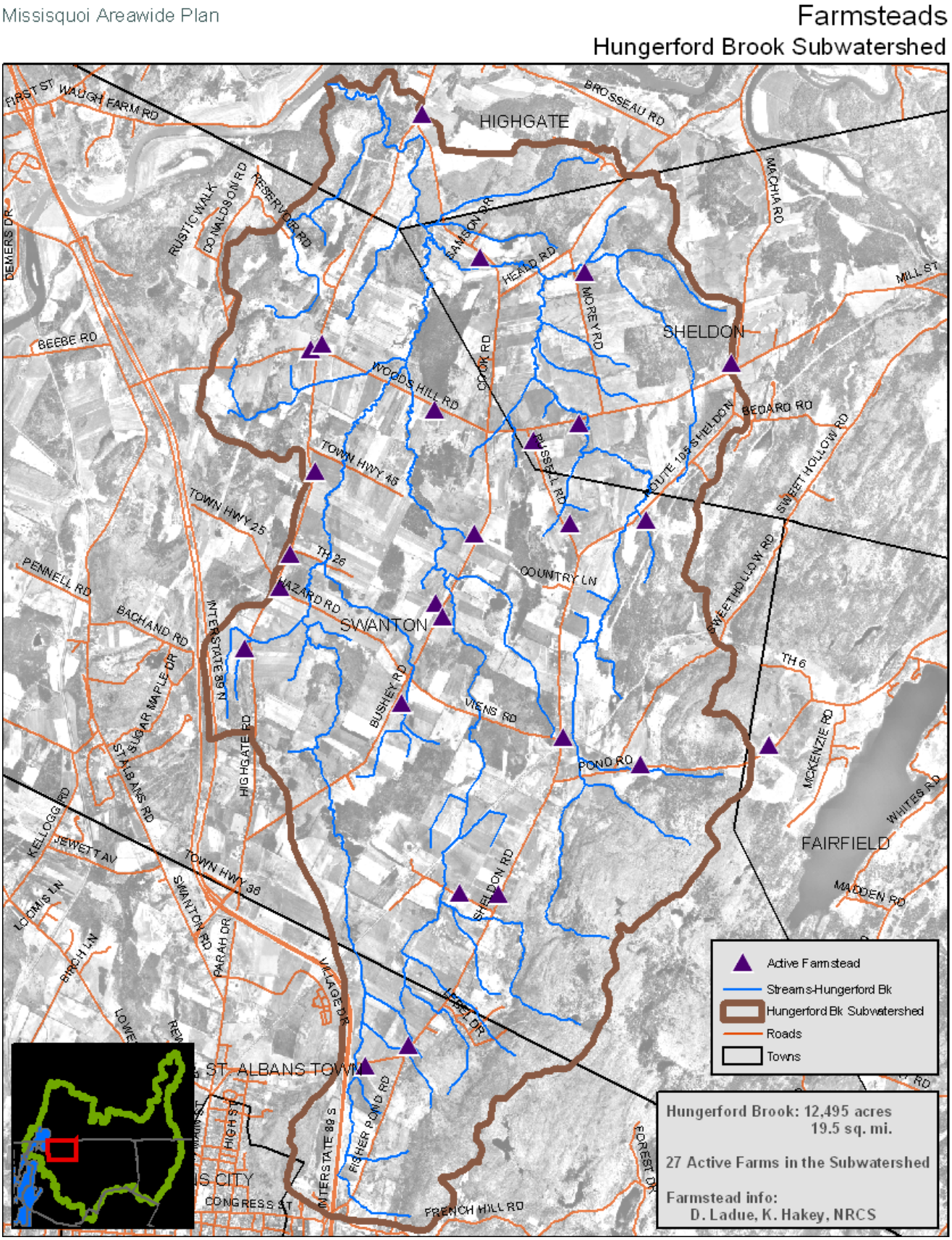
The major components of the Area-wide Plan focus on agricultural land, streams and stream corridors. The collected and analyzed data will be used to identify priority treatments for the Sub-basin and to spatially target conservation measures throughout the Sub-basin and the sub-watersheds.

### Farmstead Mapping

Most agricultural operations, including dairy operations, exhibit an area of concentrated use and activity. These farmstead areas are typically comprised of animal housing (barn), a milking center, an outside livestock concentration area, manure storage and feed storage areas. Because of the intensity of use, there is often the potential for significant discharges of manure and nutrients such as phosphorus from farmsteads. There are no readily available, up to date GIS layers depicting the location and describing the characteristics of these farmsteads. The Missisquoi Plan began the process of farmstead data collection with a pilot project in the Hungerford Brook Sub-watershed. The procedures developed to map farmsteads in the Hungerford Sub-watershed are found in Appendix B.

The resulting map allows USDA conservation planners and partners to identify potential sources of contaminants, estimate workloads, and better track past practice implementation. The maps will be primarily used by NRCS internally. Figure 5 provides an example farmstead location map developed for the Hungerford Brook Sub-watershed.

**Figure 5 - Example Farmstead Location Map for the Hungerford Brook Sub-watershed**



## Annual Crop and Hay Lands Mapping

### Background

The US Department of Agriculture, Farm Service Agency maintains an agricultural lands polygon data layer for their work with farmers that participate in USDA programs. It is maintained as the Common Land Unit layer, or CLU. The CLU layer, depicting cropland and other areas on a farmer's tract, was used as the basis to develop a corn and hay data layer for the Missisquoi Areawide Plan. Corn and hay fields in production in 2003, but not included in the CLU, were added to the layer by digitizing on-screen using 2003 natural color photography from the National Aerial Photography (NAIP) and ESRI's ArcMap software. These polygons were independently verified as cropland by the University of Vermont Spatial Analysis Lab (SAL), and by the Areawide Plan team. Detailed procedures developed to identify types of agricultural land are located in Appendix C.

The resulting layer can be differentiated within a GIS by attributing corn, hay, and other agricultural fields. NRCS had planned to map pasture lands as part of the Areawide Plan; but determined that available aerial orthophotography to be insufficient for accurately identifying and mapping pasture lands, especially grazed pasture. The digital pixel resolution for NAIP is 1.0 meter. It is simply too coarse to conduct accurate mapping for grazed pasture and idle land.

The distinction between grazed pasture, idle pasture, and other herbaceous areas is important to assess impacts of grazing animals on water quality, especially with respect to streams and streambanks. Pasture mapping, considered to be of value in conservation planning, needs to be conducted with higher resolution photography. The agency partnership, fostered by the Areawide Plan and Vermont's Clean and Clear Initiative, is working to find funding sources for the purchase of high resolution photography.

### Extent of Corn and Hay

In 2003 the Missisquoi Sub-basin contained 71,939 acres of cropland, 17,114 of these acres were planted to corn (see Table 8). Hay was managed on 50,009 acres. Only 4,816 acres were planted to other unidentified crops. It is not known how many of the corn and hay acres are continuously planted to the same crop. Most of the crop fields in the Missisquoi Sub-basin are managed in a corn and hay rotation of varying length. Figure 6 shows the geographical location of corn and hayland in the entire Missisquoi Sub-basin in the year 2003. Cropland is concentrated in the western half of the Sub-basin and the far eastern sub-watersheds. The higher concentration of corn acreage in the far western sub-watersheds is also obvious.

The extent of corn and hay acreage varies considerably between the sub-watersheds. The Rock River Sub-watershed had the highest acreage of corn at 3,296 acres, while the Trout River Sub-watershed only had 393 acres. This variation is partially due to the size of the Sub-watershed, as well as the extent of available good agricultural land. The Black Creek Sub-watershed had 8,652 acres of hay, while the Trout River only had 1,406 acres of hay.

Figures 7 and 8 show the high concentration of total cropland and corn acres in the Rock River and Hungerford Brook Sub-watersheds.

**Cropland Slope Analysis**

Terrain of the cropped landscape in the Missisquoi Sub-basin varies considerably. Even in the relatively flat areas of the Lower Missisquoi, glacial and fluvial activity have resulted in rolling terrain, such that 40% of the cropland occurs on slopes exceeding 8% (Table 8).

Figure 9 provides an example of mapped cropland slope classes for the Rock River Sub-watershed. Two thirds of the total cropland (47,146 ac, or 66%) is on slopes steeper than 8%. Corn is generally on the lower slopes throughout the Sub-basin. Forty-four percent of the corn acres are on slopes of 0-3%, and 40% are on slopes of 3% to 8%. Hay, conversely, is generally on steeper slopes, with 74% of the acres on slopes of 3% to greater than 8%.

There is considerable variation in slope of cropland between the sub-watersheds. In headwaters areas of the Trout River, the landscape consists of steeper mountain valleys. Croplands are sparse and 58% of the fields have areas of steep slopes (more than 8%). In the Hungerford Brook to mouth Sub-watershed only 18% of the cropland is on slopes steeper than 8%. In the "Trout River to Canada" Sub-watershed upwards of 38% of the corn acres are on slopes greater than 8%. In other watersheds, such as the Hungerford Brook to mouth Sub-watershed, most of the corn (81% for the Hungerford Brook to mouth Sub-watershed) is on slopes of 0% to 3%. Hay fields generally tend to be on steeper slopes. The Tyler Branch Sub-watershed has one of the highest percentages of hay on steep slopes with 58% of the hay acres on slopes greater than 8%.

## Table 8 - Extent of Water Quality Concerns by Watershed, with Important Sub-watersheds Noted.

| **10-digit Watershed Name (data for specific subwatersheds indented)** | **Land Area in Watershed** | **Cropland, all types** | **Land in Corn, 2003** | **Land in Hay, 2003** | **Cropland on Steeper Slopes (>=8%)** | **Cropland Adjacent to Steep Slopes (>25%)** | **Land in Corn, 2003, 0-3% Slopes** | **Land in Corn, 2003, 3.01-8% Slopes** | **Land in Corn, 2003, 8.01+% Slopes** | **Land in Hay, 2003, 0-3% Slopes** | **Land in Hay, 2003, 3.01-8% Slopes** | **Land in Hay, 2003, 8.01+% Slopes** | **Crop Fields with Good No-Till Potential** | **Restorable Wetlands** | **Streambank (left & right considered separately)** | **Streambank with Riparian Buffer Gaps** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (data for Subwatersheds indented) | ----------**acres in USA**---------- | | | | | | | | | | | | | | ----------**miles in USA**---------- | |
| **Missisquoi Bay** | 38,870 | 10,490 | 3,519 | 6,612 | 6,268 | 1,999 | 1,273 | 1,644 | 602 | 2,401 | 2,766 | 1,341 | 1,584 | 1,989 | 201 | 99 |
| Rock River (subwatershed) | 36,196 | 8,678 | 3,296 | 5,198 | 5,656 | 1,968 | 1,105 | 1,590 | 601 | 1,634 | 2,326 | 1,197 | 1,209 | 1,151 | 195 | 97 |
| **Riviere aux Brochets** | 25,133 | 6,037 | 1,263 | 4,587 | 4,609 | 743 | 288 | 637 | 338 | 806 | 2,096 | 1,662 | 1,726 | 329 | 179 | |
| Pike River (subwatershed) | 27,614 | 3,467 | 756 | 2,617 | 2,649 | 498 | 193 | 408 | 155 | 408 | 1,158 | 1,039 | 1,006 | 291 | 94 | |
| **Missisquoi River - Black Creek to mouth** | 44,638 | 11,332 | 5,226 | 5,907 | 4,340 | 1,779 | 3,164 | 1,710 | 352 | 3,027 | 2,240 | 590 | 4,721 | 2,592 | 347 | 165 |
| Missisquoi River - Hungerford Brook to mouth (subwatershed) | 16,147 | 3,559 | 1,735 | 1,786 | 656 | 484 | 1,397 | 315 | 23 | 1,149 | 539 | 61 | 852 | 1,820 | 107 | 48 |
| Hungerford Brook (subwatershed) | 12,495 | 5,014 | 2,080 | 2,777 | 2,024 | 290 | 1,176 | 830 | 74 | 1,417 | 1,183 | 168 | 2,393 | 603 | 112 | 64 |
| **Black Creek** | 76,855 | 10,812 | 1,777 | 8,652 | 7,749 | 2,858 | 854 | 528 | 395 | 1,753 | 3,351 | 3,537 | 1,933 | 735 | 491 | 156 |
| **Missisquoi River - Trout River to Black Creek** | 68,679 | 13,430 | 3,494 | 9,602 | 9,591 | 4,121 | 1,336 | 1,401 | 757 | 1,921 | 3,444 | 4,181 | 4,240 | 352 | 444 | 190 |
| Tyler Branch (subwatershed) | 37,100 | 4,022 | 608 | 3,342 | 3,202 | 1,562 | 172 | 249 | 187 | 516 | 890 | 1,899 | 1,161 | 63 | 227 | 68 |
| **Trout River** | 53,493 | 1,916 | 393 | 1,406 | 1,114 | 942 | 318 | 40 | 35 | 357 | 444 | 595 | 717 | 50 | 330 | 45 |
| **Missisquoi River-Riviere Missisquoi North to Trout River (aka "*Trout River to Canada*")** | 36,376 | 4,358 | 840 | 3,358 | 3,114 | 1,195 | 356 | 219 | 265 | 604 | 1,434 | 1,316 | 975 | 160 | 200 | 71 |
| **Missisquoi River-headwaters to Riviere Missisquoi Nord (aka "*Upper Missisquoi River*" - 4 *subwatersheds*)** | 111,880 | 7,356 | 582 | 6,364 | 5,140 | 1,071 | 208 | 281 | 93 | 1,571 | 3,491 | 1,274 | 3,153 | 304 | 514 | 128 |
| **Mud Creek (subwatershed)** | 36,703 | 6,208 | 657 | 5,297 | 5,221 | 683 | 21 | 516 | 120 | 634 | 3,663 | 921 | 509 | 124 | 153 | 78 |
| Totals for Plan Project Area* | 492,627 | 71,939 | 17,114 | 50,009 | 45,648 | 15,391 | 7,583 | 6,794 | 2,737 | 12,818 | 22,159 | 15,032 | 19,558 | 6,635 | 3,594 | 1,209 |

**Figure 6- Mapped Corn, Hay and Other Cropland Acres in the Missisquoi Sub-basin.**

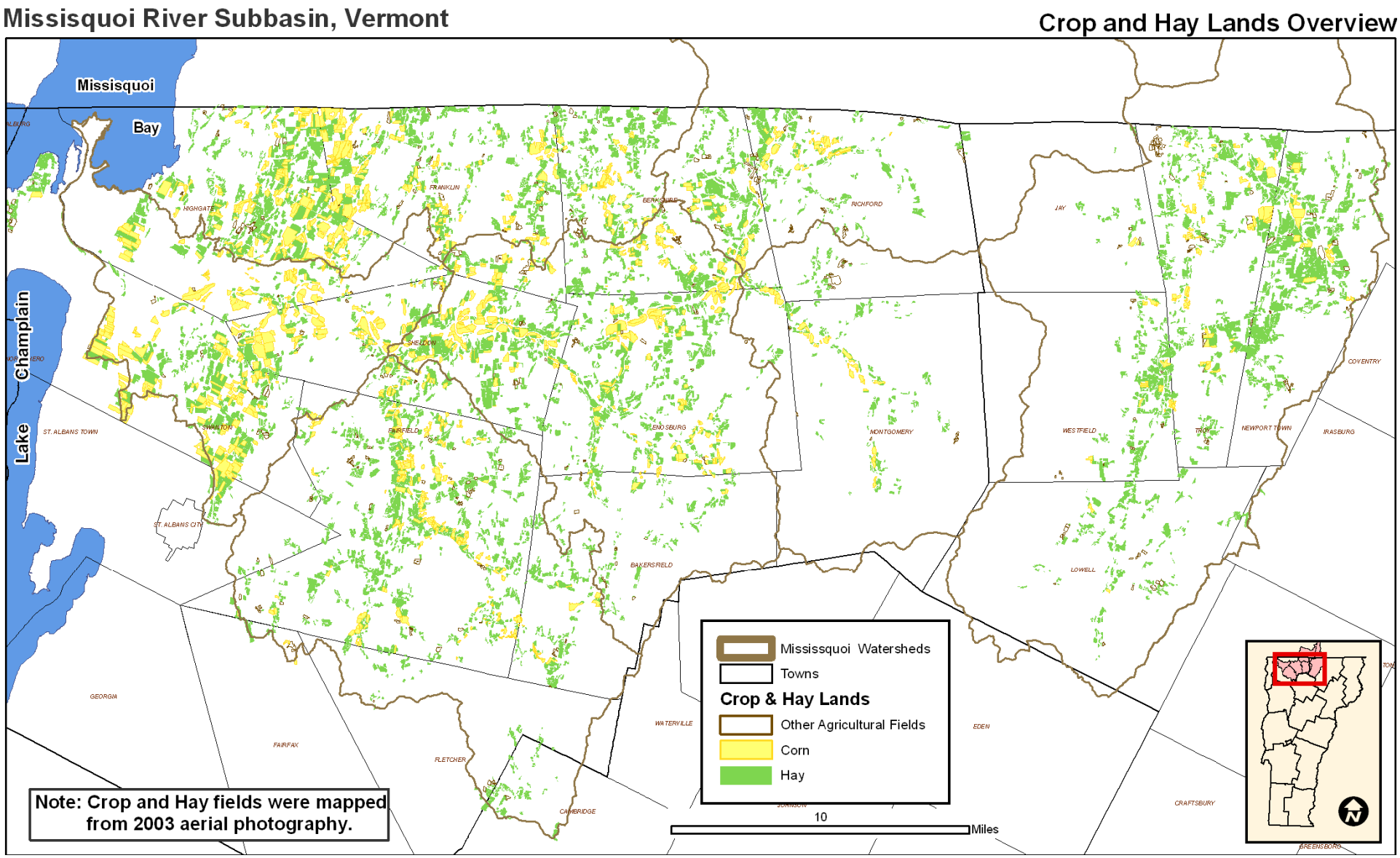


**Figure 7 - Mapped Corn, Hay and Other Cropland Acres in the Rock River Sub-watershed.**

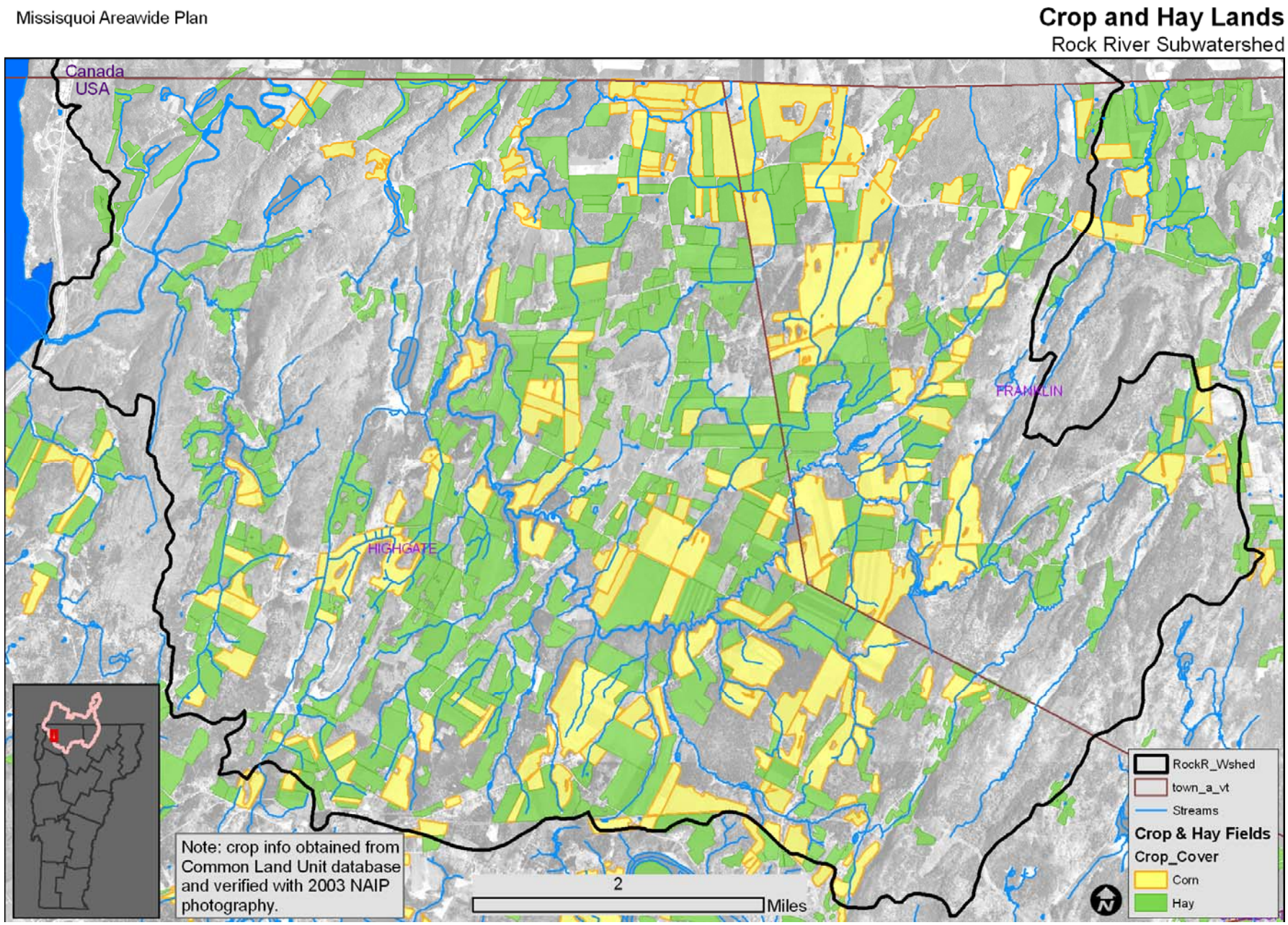


**Figure 8- Mapped Corn, Hay and Other Cropland Acres in the Hungerford Brook Sub-watershed.**

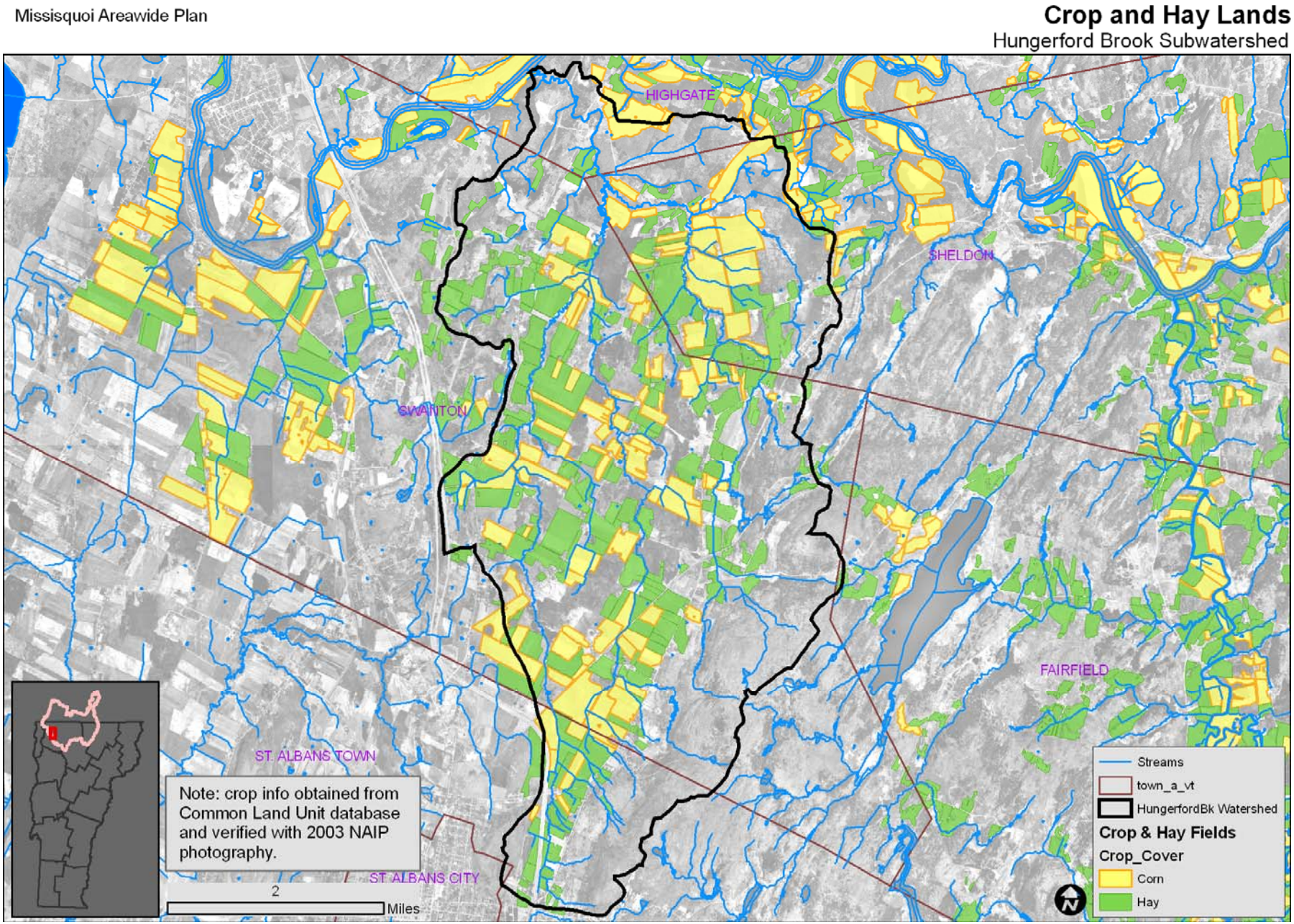
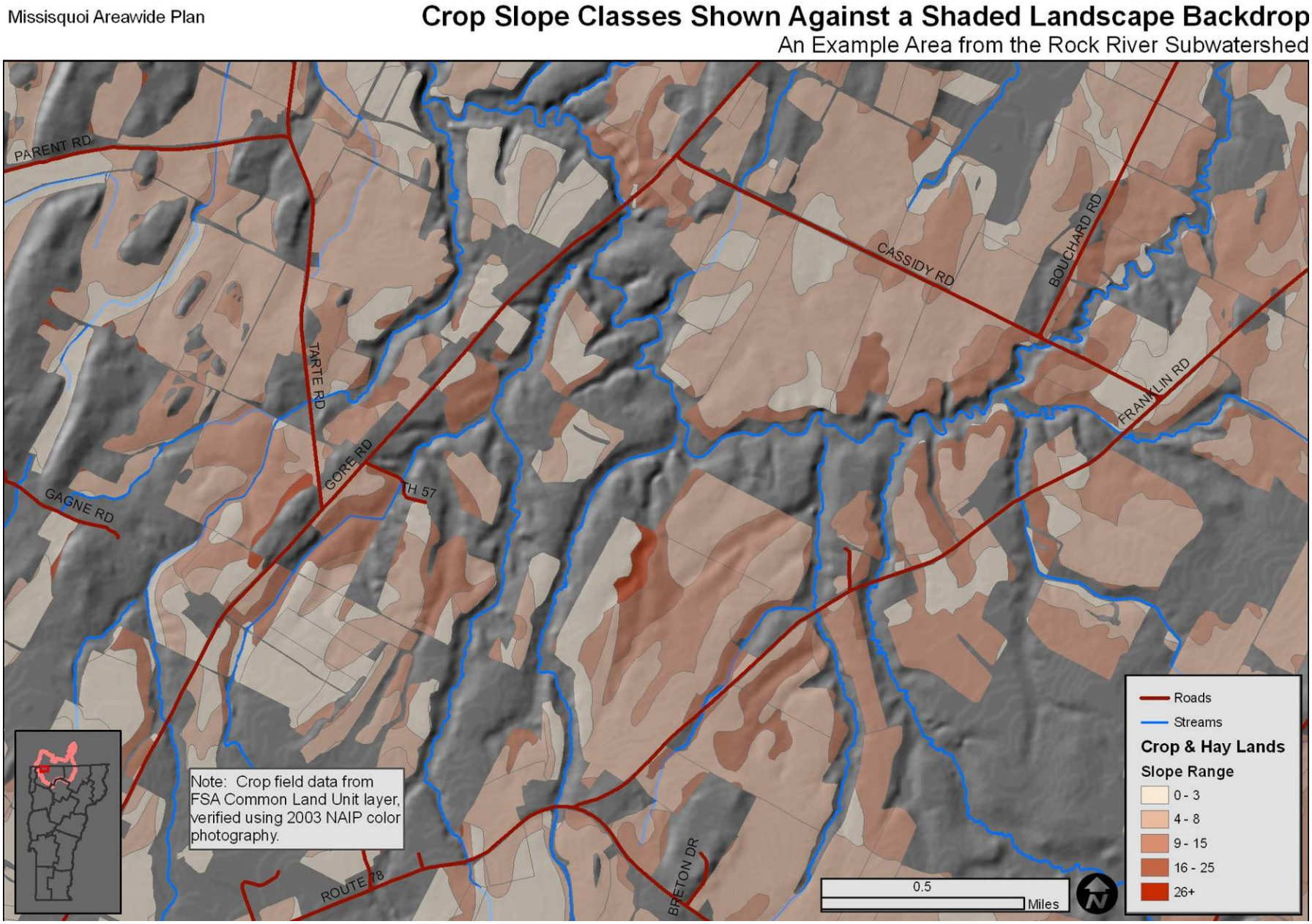


**Figure 9 - Cropland Slope Classes for the Rock River Sub-watershed.**



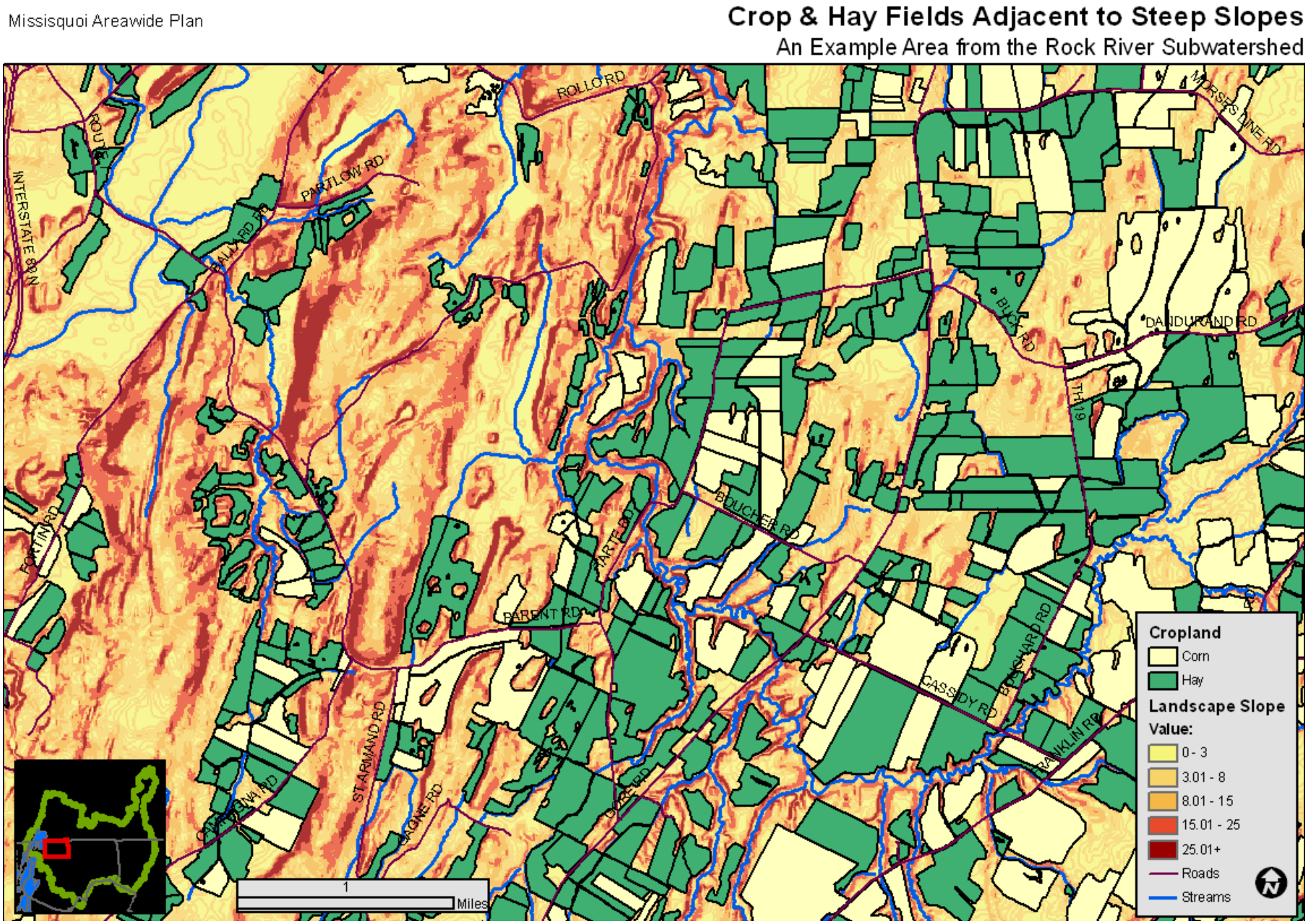
## Cropland and Steep Slope Adjacency

Cornfields with adjacent steep areas are a common land feature in certain watersheds of the Sub-basin. These landforms are typified by relatively flat plateaus with deeply incised stream valleys. Erosion and subsequent delivery of sediment and phosphorus to waterways is at a heightened risk for these fields. An analysis of this erosion risk was undertaken using a subset of slope polygons derived from existing elevation data (Vermont Center for Geographic Information's HydroDEM raster layer) to identify these areas in one pilot sub-watershed.

Many crop fields in the Rock River Sub-watershed are adjacent to areas with slopes of more than 25%. Adjacency is defined as a 1-meter separation in this study. For example, in the Rock River Sub-watershed, 23% (1,968 acres) of cropland acres are within a meter of steep slopes. These breaks are commonly found along edge of historically incised river valleys. The darker orange and brown areas depicted in Figure 10 displays these steep areas located adjacent to crop fields.

In many cases these fields have no buffer between the cropped areas and the steep slopes. As such, these areas are susceptible to the formation of classic gullies which can then head cut into the crop fields, if left untreated. NRCS and its conservation planning partners will use this information to promote practices to control gully erosion in those fields identified as being at risk. This includes practices such as grade stabilization structure, permanent seeding to grass, reduced tillage, cover crops, grassed filter strips and riparian forest buffers.

**Figure 10 - Crop and hay Fields Adjacent to Steep Slopes**



## Stream Geomorphic Assessment Data Viewer

The Stream Geomorphic Assessment Data Viewer provides a new, user friendly method for land managers and planners to gain access to the growing database of assessed streams across Vermont. Development of this viewer by the Vermont DEC River Management Program was partially funded by NRCS through the Missisquoi Area-wide Plan CCPI grant.

In the past, gaining information about the geomorphic condition of a stream required working with a river scientist to determine the proper reach number and then pursue a cumbersome search of the SGA Data Management System to find reports. Now, any user familiar with basic GIS can use the online viewer to zoom to a stream in Vermont and be able to view aerial photographs, topographic maps and various vector GIS layers such as roads, surface water, and buildings. Where the streams have been assessed, there is much more information.

### Phase 1 Stream Geomorphic Assessment Data

Where Phase 1 assessments have been completed, the user can view the approximate river corridor as well as the complete Phase 1 report for a reach within a watershed. The river corridor, as defined by DEC River Management, includes lands defined by the lateral extent of a stream's meanders necessary to maintain the dimension, pattern, profile, and sediment regime of the stream in equilibrium. This is an important piece of information for NRCS planners and partners in the state for stream restoration projects and buffer establishment, particularly on straightened or unstable streams. The Conservation Reserve Enhancement Program (CREP) uses the "River Corridor Approach" as planning guidance to help determine the extent of planned buffers on unstable reaches where the area and configuration of buffer is expected to change over time as the river moves toward equilibrium. This information is also important for landowners along Vermont's rivers. These corridors visually highlight potential areas of flood and or erosion hazard and would be areas to limit or preclude investments such as roads and buildings.

The Stream Geomorphic Assessment Data Viewer can be used to display a variety of information from the Phase 1 database. Figure 11 provides an example map from the data viewer showing a river corridor (in yellow) defined for a section of the Tyler Branch. The Phase 1 report provides general information about the watershed and selected reaches, which is the first level of assessment. This information is gathered primarily by remote sensing as well as windshield surveys. Figure 12 shows the type of data included in a Phase I Reach Summary Report.

**Figure 11 - Example of a River Corridor (in yellow) Displayed through the Stream Geomorphic Assessment Data Viewer.**

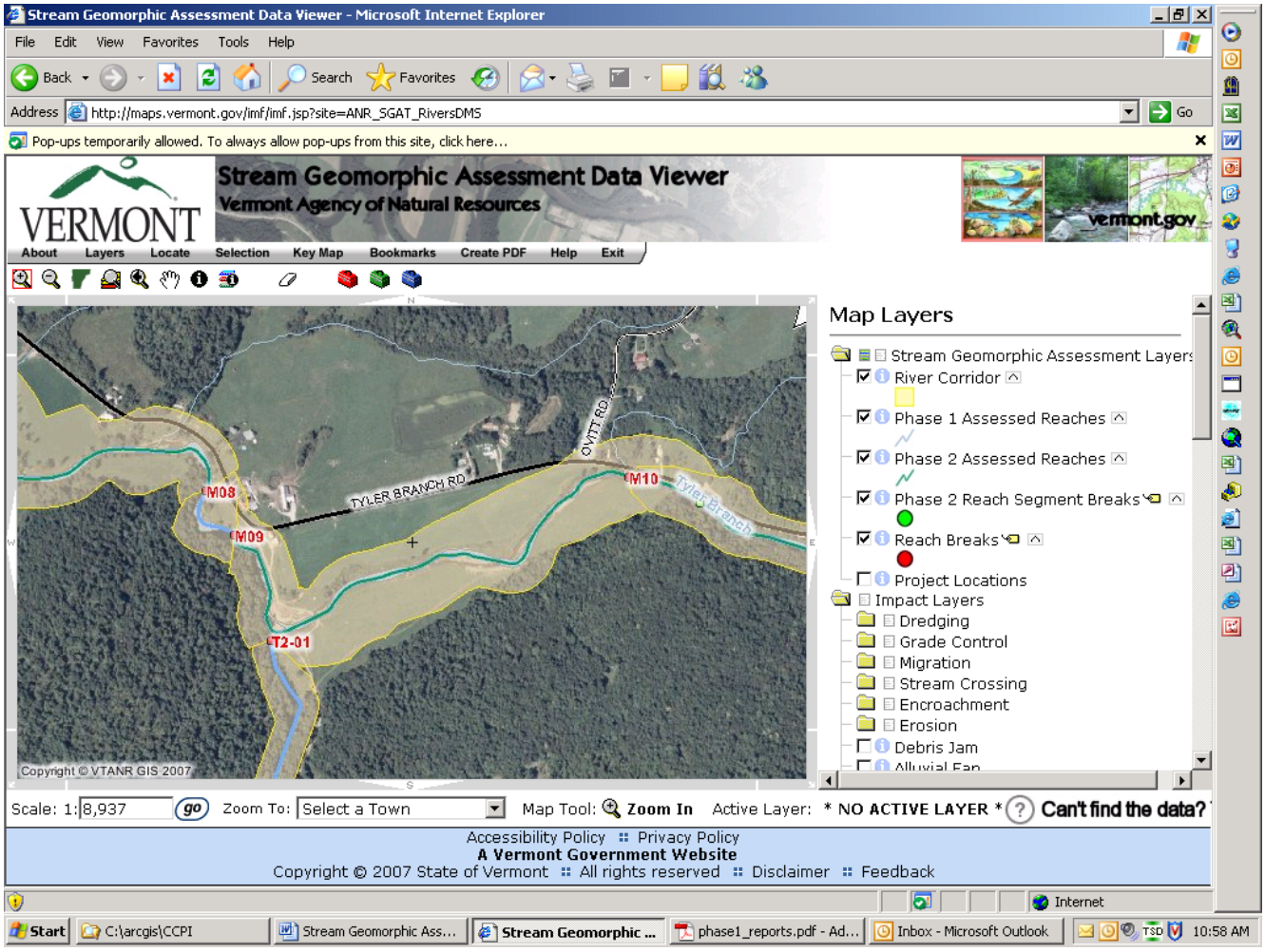


**Figure 12 - Example Phase 1 Reach Summary Report Viewed through the Stream Geomorphic Assessment Data Viewer.**

**Black Creek Mouth** — **Phase 1 - Reach Summary Report**

Basin: Misisquoi
Stream Name: Unnamed-2 to Wanzer — Reach T3.3S1.02
Topo Maps: Bakersfield
Date Last Edited:
Watershed: Misisquoi River
Sub-watershed: Black Creek (Misisquoi drainage)
Is Reach an Impoundment? No — Quality Control Status: Step 2 done

Step 1. Reach Location
1.1 Reach Description: ---
1.2 Towns: Fairfield
1.3 Downstream Latitude: 44.84
1.3 Downstream Longitude: -72.87

Step 2. Stream Type
2.1 Elevation Upstream: 744
2.1 Elevation Downstream: 647
2.1 Is Gradient Gentle? No
2.2 Valley Length: 2847 feet. 0.54 Miles.
2.3 Valley Slope: 3.41 %
2.4.Channel Length: 3048 feet. Miles.
2.5 Channel Slope: 3.18 %
2.6 Sinuosity: 1.07
2.7 Watershed Area: 1 Square Miles
2.8 Channel Width: 12 feet.
2.9 Valley Width: feet.
2.10 Confinement Ratio: 0
2.10 Confinement Type: Semi-confined
2.11 Reference Stream Type: B
Bedform: ---
Sub-class Slope:
Bed Material: No Data

Step 3. Basin Characteristics:
3.1 Alluvial Fan: None
3.2 Grade Control: None
3.3 Dominant Geologic Mat.: Till 79.7 %
3.3 Sub-dominant Geological Mat.: Alluvial
3.4 Left Valley Side Steep
3.4 Right Valley Side Steep
*3.5 Soils*
Hydrologic Group: D 71.0 %
Flooding: None/Rare 87.8 %
Water Table Deep: 2.0 71.0 %
Water Table Shallow: 0.0 83.2 %
Erodibility: High - 86.9 %

7.4 Comments:

Step 4. Land Cover - Reach Hydrology
*4.1 Watershed*
Historic Land Cover: Not Evaluated
Current Dominant land Cover: Forest 58.4 %
Current Sub-Dominant Land Cover: Field
*4.2 Corridor*
Historic Land Cover: Not Evaluated
Current Dominant land Cover: Forest 50.0 %
Current Sub-Dominant Land Cover: Urban
4.3 Riparian Buffer — Left Bank / Right Bank
Dominant: 0-25 / 0-25
Sub-dominant: >100 / >100
Length w/ less than 25 ft.: 1493 / 1493
4.4 Ground Water Inputs: Abundant

Step 5. Instream Channel Modifications
5.1 Flow Regulation - (old): No Data
Type: None
Use:
5.2 Bridges and Culverts: 1 1 %
5.3 Bank Armoring: 0.0
Left Right
5.4 Channel Straightening: 0.0
5.5 Dredging History: No Data

Step 6. Floodplain Modifications
6.1 Berms and Roads old 0.0 ft. 0.0
One Side / Both Sides
Road: ft. ft.
Railroad: ft. ft.
Berm: ft. ft.
Improved Path: ft. ft.
6.2 Development: 121.0 ft. 0.0 ft.
6.3 Channel Bars: No Data
6.4 Meander Migration: No Data
6.5 Meander Width: Ratio: 0.0
6.6 Wavelength: Ratio: 0.0

Step 7. Windshield Survey
7.2 Bank Erosion: 30.00 ft.
7.2 Bank Height: 1.00 ft.
7.3 Ice/Debris Jam Potential: Culvert

| 4.1 | 4.2 | 4.3 | 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 6.1 | 6.2 | 6.3 | 6.4 | 6.5 | 6.6 | 7.1 | 7.2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 High | 1 Low | 2 High | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 0 N.S. | 5 |

## Phase 2 Stream Geomorphic Assessment Data

Where a Phase 2 assessment has been completed, more site specific information can be attained through the data viewer and database reports. NRCS and other resource professionals can use the data viewer to help determine what the geomorphic condition of the stream is in their planning area, whether it is in equilibrium or in a state of adjustment. A number of 'Impact Layers' are included in the legend which display a variety of impacts or resource concerns such as dredging, stream crossings, erosion, encroachments, gullies, headcuts, armoring, straightening, buffers less than 25 feet, etc. Examples of 'Impact Layer" data is displayed in Figure 13. A link to the Phase 2 reports and more in depth information is

provided by clicking on the phase 2 assessed reaches layer. This is critical information both for planning conservation practices as well as for farm or land management along rivers.

For instance, streambank stabilization using rip-rap has historically been a common practice to arrest streambank erosion along Vermont's streams. However, when this is used on a stream that is midway through the channel evolution (adjustment) process, it may be prone to failure and may not provide a net environmental benefit to the river system. This information may also raise a red flag for other common practices such as riparian forest buffers. It is probably not a good investment to plant trees at the top of a bank in a highly sensitive river reach experiencing significant lateral adjustment. These are some of the examples of the information that is now at the planners' fingertips with the data viewer. The Phase 2 reach reports can be accessed through the 'Identify Results' pop up window as shown in Figure 14. The Phase 2 reach reports will provide much of the information discussed above, as shown in Figure 15.

**Figure 13 - Example Phase 2 Data, Viewer Impact Layers - Armoring in Blue and Straightening in Black, Viewed through the Stream Geomorphic Assessment Data Viewer.**

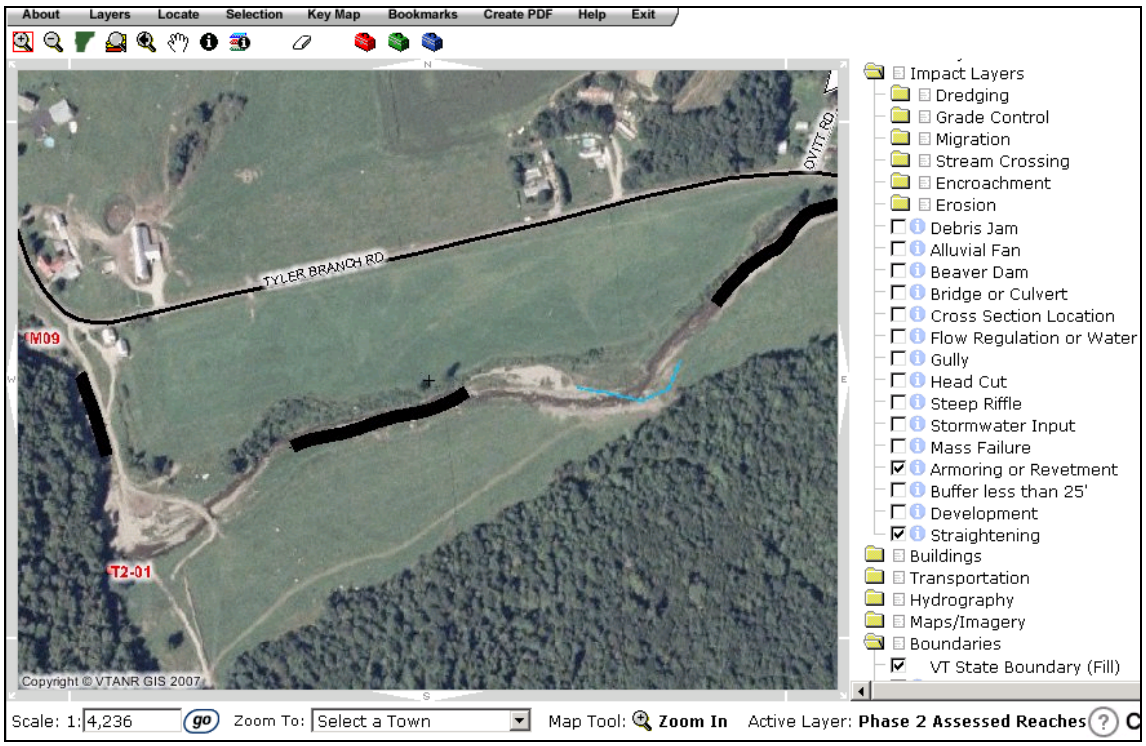


**Figure 14 - Example of Data Viewer 'Identify Results' Pop Up Window and Link to Phase 2 Reports.**

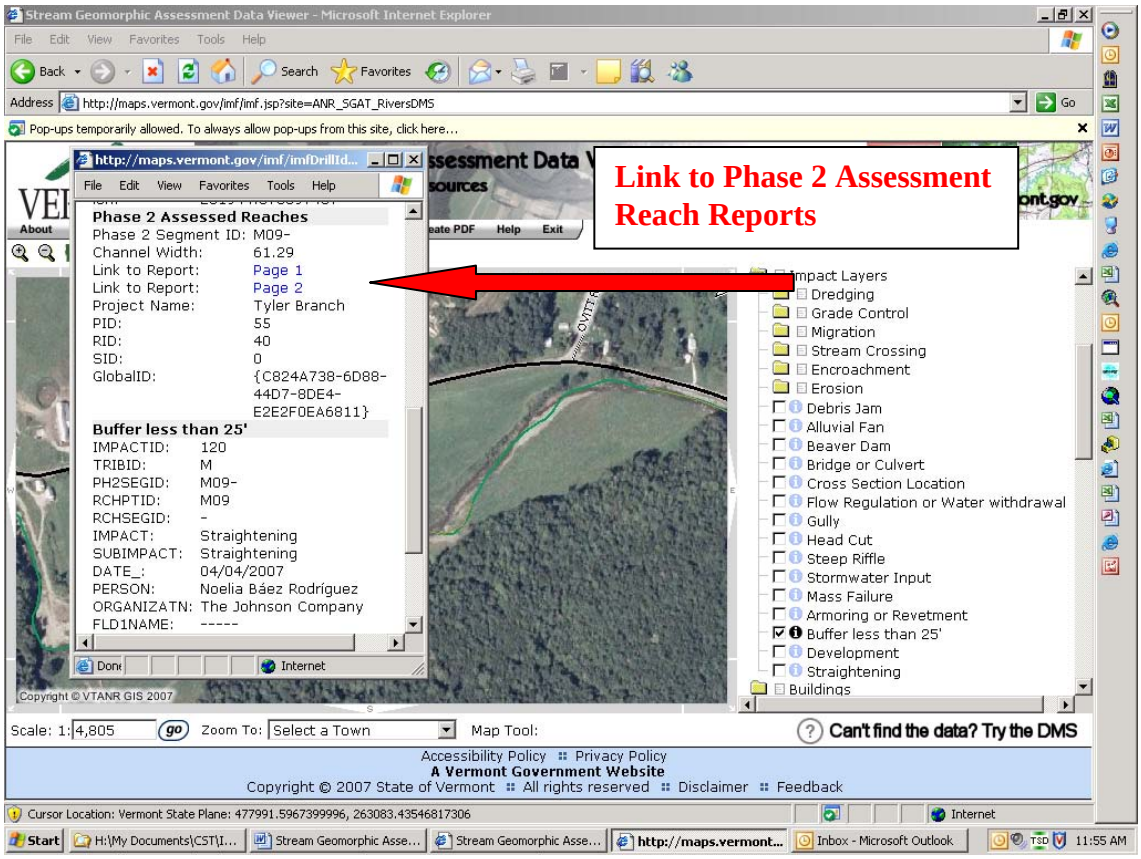
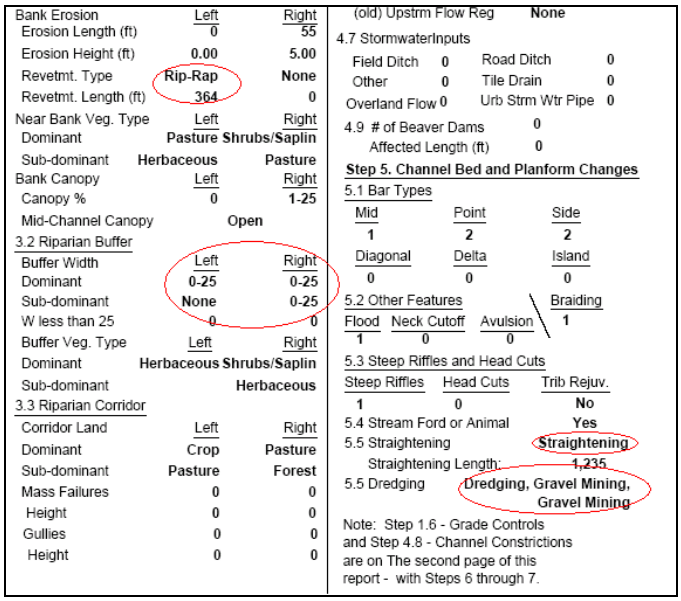



**Figure 15 - Excerpts from the Phase 2 Assessment Reach Reports.**



| Bank Erosion | Left | Right |
|---|---|---|
| Erosion Length (ft) | 0 | 55 |
| Erosion Height (ft) | 0.00 | 5.00 |
| Revetmt. Type | Rip-Rap | None |
| Revetmt. Length (ft) | 364 | 0 |
| Near Bank Veg. Type | Left | Right |
| Dominant | Pasture | Shrubs/Saplin |
| Sub-dominant | Herbaceous | Pasture |
| Bank Canopy | Left | Right |
| Canopy % | 0 | 1-25 |
| Mid-Channel Canopy | Open | |
| 3.2 Riparian Buffer | | |
| Buffer Width | Left | Right |
| Dominant | 0-25 | 0-25 |
| Sub-dominant | None | 0-25 |
| W less than 25 | 0 | 0 |
| Buffer Veg. Type | Left | Right |
| Dominant | Herbaceous | Shrubs/Saplin |
| Sub-dominant | | Herbaceous |
| 3.3 Riparian Corridor | | |
| Corridor Land | Left | Right |
| Dominant | Crop | Pasture |
| Sub-dominant | Pasture | Forest |
| Mass Failures | 0 | 0 |
| Height | 0 | 0 |
| Gullies | 0 | 0 |
| Height | 0 | 0 |

(old) Upstrm Flow Reg None

4.7 StormwaterInputs

| | | | |
|---|---|---|---|
| Field Ditch | 0 | Road Ditch | 0 |
| Other | 0 | Tile Drain | 0 |
| Overland Flow | 0 | Urb Strm Wtr Pipe | 0 |

4.9 # of Beaver Dams 0

Affected Length (ft) 0

**Step 5. Channel Bed and Planform Changes**

5.1 Bar Types

| Mid | Point | Side |
|---|---|---|
| 1 | 2 | 2 |
| Diagonal | Delta | Island |
| 0 | 0 | 0 |

5.2 Other Features

| Flood | Neck Cutoff | Avulsion | Braiding |
|---|---|---|---|
| 1 | 0 | 0 | 1 |

5.3 Steep Riffles and Head Cuts

| Steep Riffles | Head Cuts | Trib Rejuv. |
|---|---|---|
| 1 | 0 | No |

5.4 Stream Ford or Animal Yes

5.5 Straightening Straightening

Straightening Length: 1,235

5.5 Dredging Dredging, Gravel Mining, Gravel Mining

Note: Step 1.6 - Grade Controls and Step 4.8 - Channel Constrictions are on The second page of this report - with Steps 6 through 7.

**Figure 15 (cont.) - Excerpts from the Phase 2 Assessment Reach Reports.**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

| | Score | STD | Historic |
|---|---|---|---|
| 7.1 Channel Degradation | 15 | None | Yes |
| 7.2 Channel Aggradation | 14 | None | No |
| 7.3 Widening Channel | 15 | | No |
| 7.4 Change in Planform | 15 | | No |
| Total Score | 59 | | |
| Geomorphic Rating | 0.7375 | | |
| Channel Evolution Model | F | | |
| Channel Evolution Stage | III | | |
| Geomorphic Condition | Good | | |
| Stream Sensitivity | High | | |

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **High**

| | Score |
|---|---|
| 6.1 Epifaunal Substrate - Available Cover | 8 |
| 6.2 Embeddedness | 11 |
| 6.3 Velocity/Depth Patterns | 10 |
| 6.4 Sediment Deposition | 13 |
| 6.5 Channel Flow Status | 11 |
| 6.6 Channel Alteration | 14 |
| 6.7 Frequency of Riffles/Steps | 14 |
| 6.8 Bank Stability | Left: 9 Right: 7 |
| 6.9 Bank Vegetation Protection | Left: 5 Right: 2 |
| 6.10 Riparian Vegetation Zone Width | Left: 0 Right: 2 |
| Total Score | 106 |
| Habitat Rating | 0.53 |
| Habitat Stream Condition | Fair |

This is a brief summary of the functionality and uses of this tool. As the tool begins to be adopted and used for everyday planning activities it is hoped that users will be able to provide input for future improvements. For this tool to be fully used across the state, it is critical that the geomorphic assessment process continue to evaluate additional watersheds and streams. For additional information about the specific functions and tools in this tool see Appendix D for VTDEC River Management's *"MapServe" NRCS Training Document.* This tool and document were introduced to the Vermont NRCS Planning and Engineering Staff on November 5, 2007 by the VT DEC River Management Program.

Access to the Stream Geomorphic Assessment Data Viewer can be obtained on the VTDEC website at the following web address:

http://maps.vermont.gov/imf/sites/ANR_SGAT_RiversDMS/jsp/launch.jsp?popup_blocked=true

## Riparian Forest Buffer Gap Mapping

### Background

Conservationists in the federal, state, municipal and volunteer citizen sectors all agree that effective riparian forest buffers are an important component of stream ecosystems and water quality. In many parts of the study area, particularly in intensively used agricultural areas,

buffers are insufficient or nonexistent. Thus, there are known resource concerns but there has been no clear way to quantify the extent of the problem in the Missisquoi Sub-basin. This lack of objective data has made it difficult to decide where to target limited conservation funds. Newly developed riparian buffer gap data will help agencies and partners target outreach and available funds in programs such as Conservation Reserve Enhancement Program (CREP) to riparian buffer projects that will have the greatest positive impact.

**Methods**

As part of this Plan a method was developed to identify and digitize gaps in riparian forest buffers along streams and rivers. The photobase used for this work was the 2003 NAIP. Variable-width buffer evaluation areas were created along the streams using channel width as the formula basis for calculation. A 25-foot buffer from the top of bank was evaluated. This width was chosen based on water quality concerns, the primary focus of the Missisquoi Areawide Plan. Twenty-five feet is the minimum buffer width required under the NRCS standard for Filter Strips and as such is considered the minimum needed for any effective treatment of surface runoff.

Presence or absence of woody riparian vegetation was noted within these buffer polygons, which were split to represent beginning and ending points along the stream, on each side separately. Left and Right sides were determined looking downstream. Notations were also made regarding whether the vegetation was at least 50% woody or not. A small amount of ground truth investigation was performed in areas where the aerial photo interpretation was uncertain.

**Results**

Although presence or absence interpretation exposed actual gaps, the functional quality of areas showing adequate vegetation cover was not assessed. For instance, there may be channels cut through the buffer by rapid crop field runoff which circumvent the nutrient attenuation and velocity reduction functions buffers should provide. High resolution slope data, such as that derived from LiDAR, can be used to locate likely areas of concentrated flow from crop fields. Identifying the presence or absence of riparian buffers can help with conservation practice decision making. This ability to visualize the buffer gap situations across a large planning area has drawn comments from experienced conservationists like, "We already knew there was a problem, but seeing it and understanding the scale of the problem is really valuable."

Figure 16 shows the fragmented condition of riparian forest buffers in the Missisquoi Sub-basin. Agricultural fields are the primary encroachments on the 25-foot buffer zone. Road crossings were also noted throughout the Sub-basin. Of the 2,815 streambank miles assessed, 919 appear to have inadequate riparian buffers. The problem is more pronounced in the lower watersheds where agriculture dominates land use. There are also positional differences in gaps among the watersheds: the Rock River's buffer gaps (Figure 17) are prevalent in headwater streams and tributaries, whereas for Hungerford Brook (Figure 18), the headwaters are generally forested areas, and it is the mainstem which is impacted by gaps. Knowledge of these differences will help NRCS and partners tailor conservation practice promotion, design and implementation to the particular needs of a watershed. NRCS

and partnering agencies will evaluate buffer gap locations with cropping intensity, slope percent, and streambank susceptibility to scour erosion, to target CREP and other conservation program funds wisely. Ranking criteria have begun to include the results of GIS analysis now that we have information from which to draw conclusions.

**Figure 16 - Riparian Forest Buffer Gaps in the Missisquoi Sub-basin.**

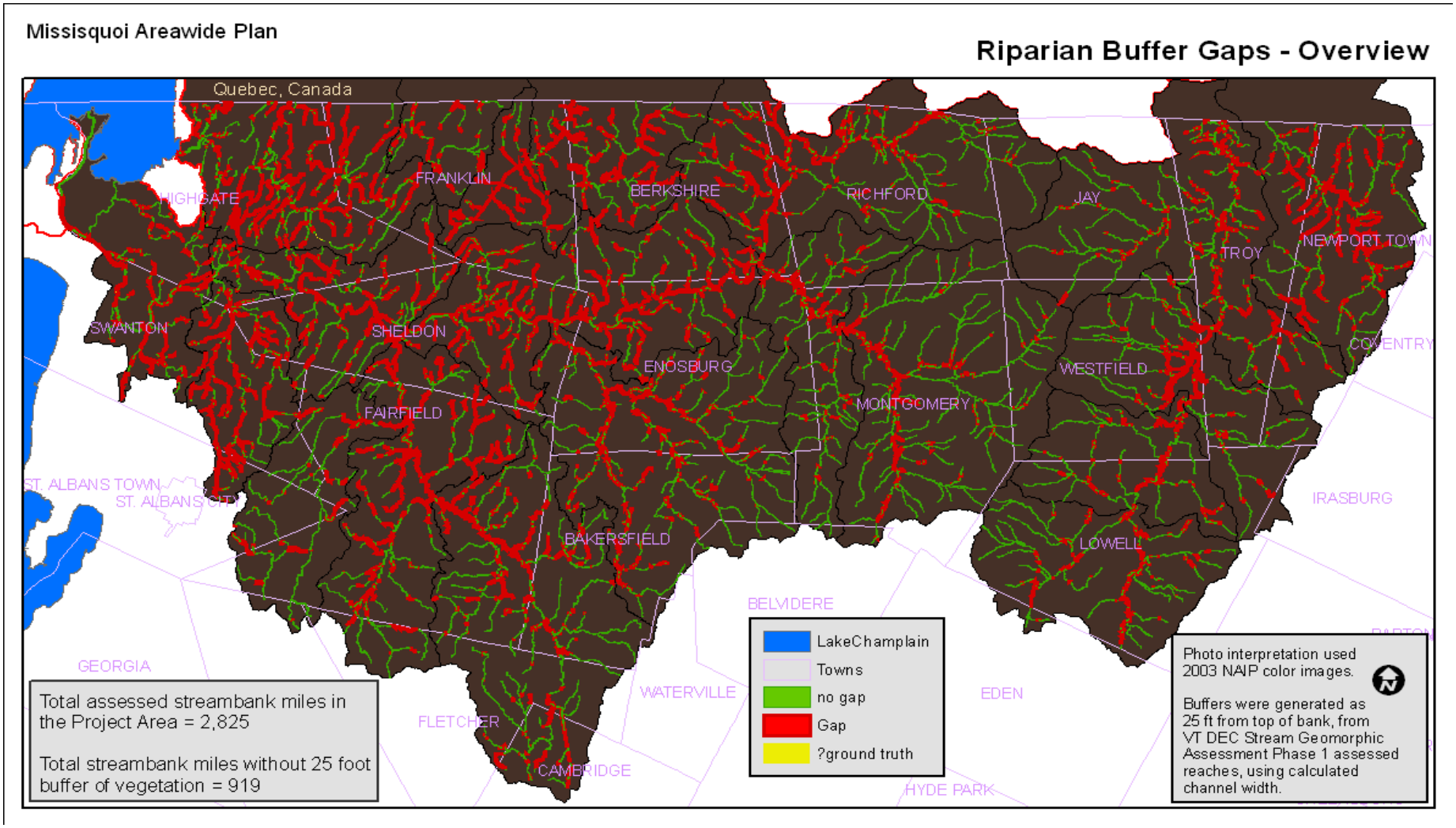


**Figure 17 - Riparian Forest Buffer Gaps in the Rock River Sub-watershed.**

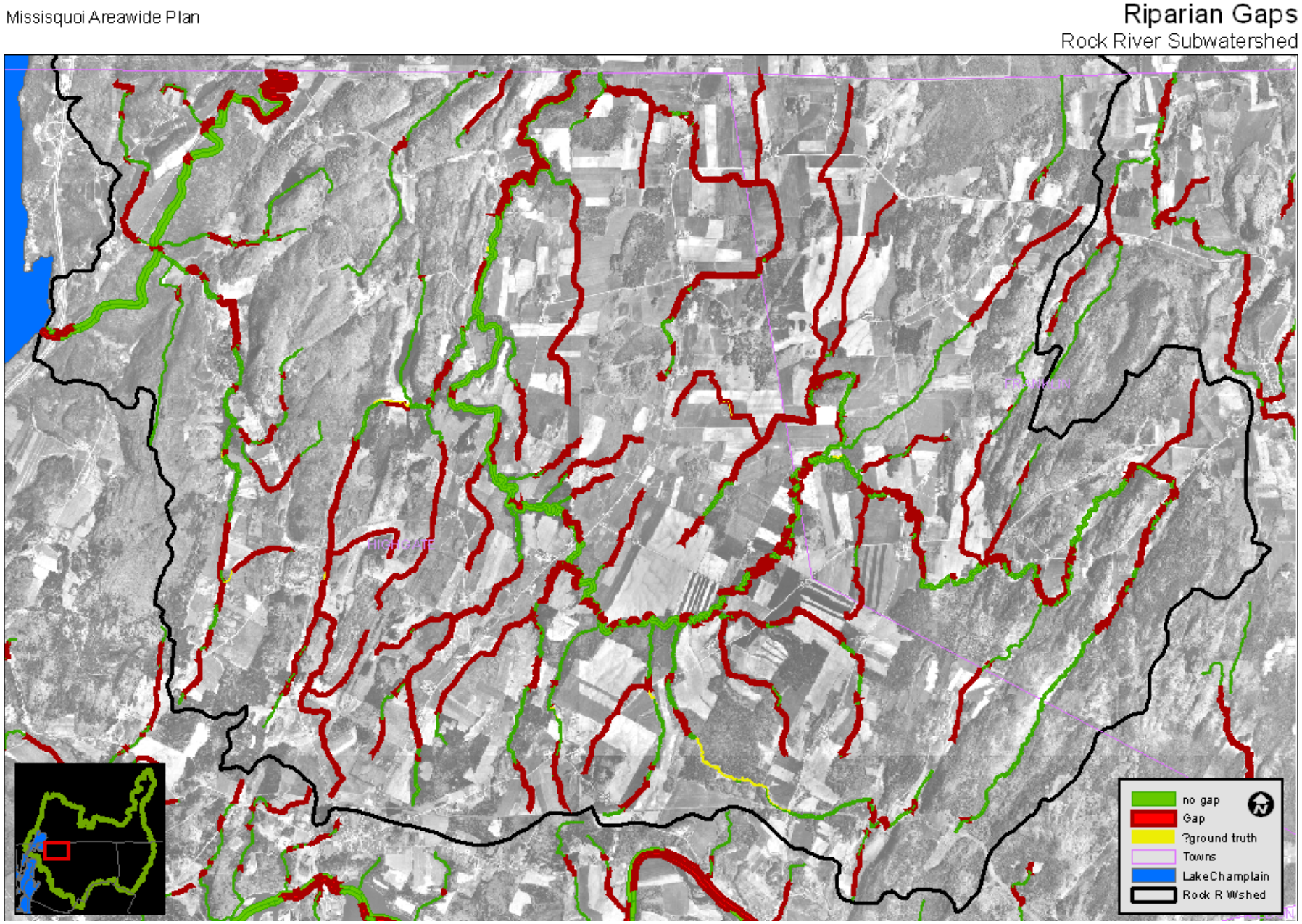
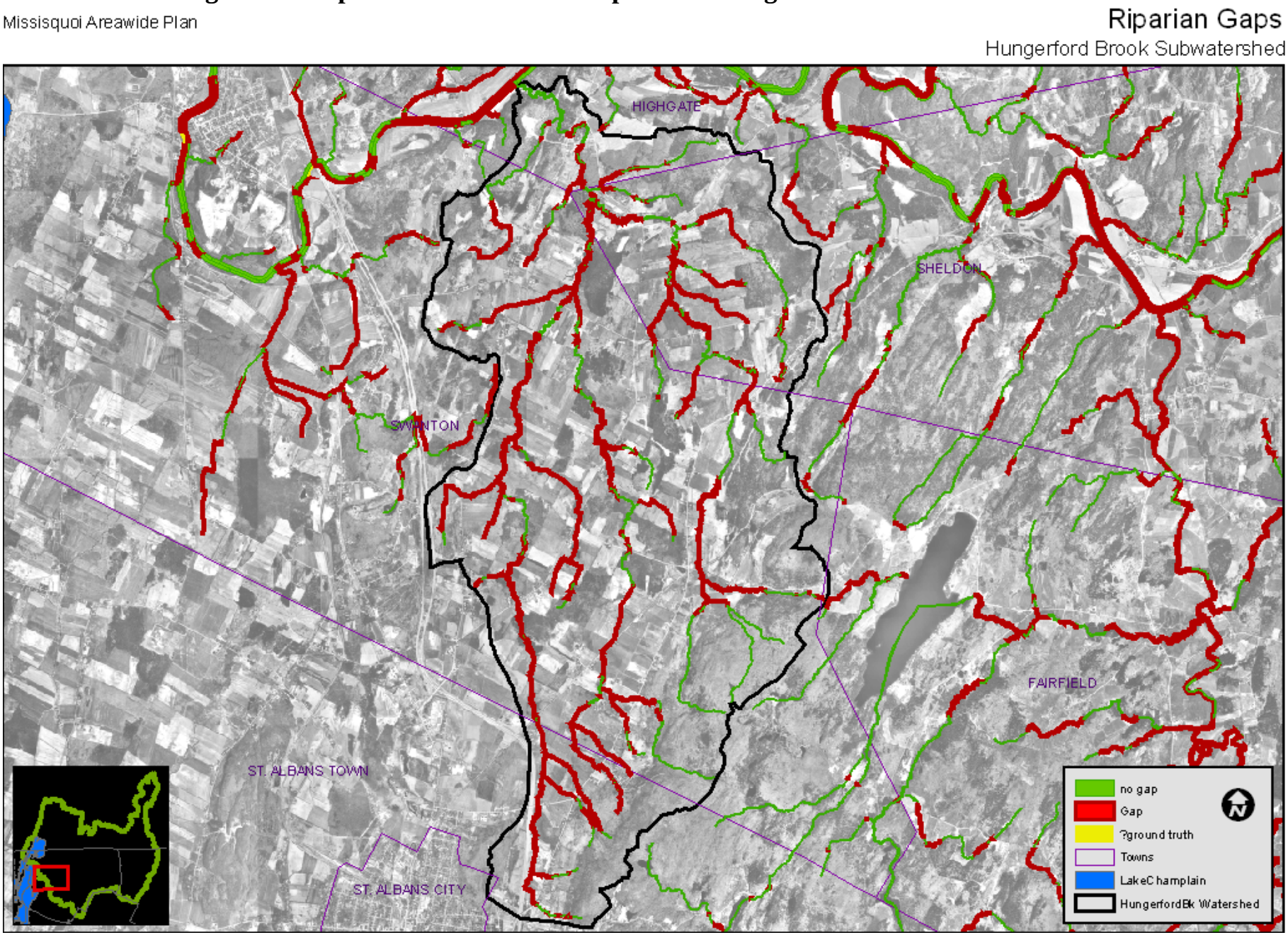


**Figure 18 - Riparian Forest Buffer Gaps in the Hungerford Brook Sub-watershed.**



## Streambank Scour Erosion Susceptibility

### Background

Soil characteristics can be used to predict the susceptibility that streambanks have to scour erosion by floodwaters. Friction from swift flowing water can cause substantial erosion and undercutting of the subsoils in areas where the stream has cut down through deep soils to form a channel with steep or vertical banks. The texture, method of soil formation, and organic matter content of a soil in this position will affect how easily water, and the sediment and debris it carries during flood events, can dislodge soil particles. As part of the Missisquoi Areawide Plan, NRCS refined a soil interpretation process developed 7 years ago by the NRCS for the adjacent sub-basin to the south, the Lamoille.

During the mid-1800's up to 70% of the Sub-basin's land was cleared of trees for either cropping, grazing or for the potash industry. The VTDEC River Management Group and the NRCS Cultural Resources Specialist report that anywhere from 3 to 6 feet of new soil eroded from upstream was laid down during that period of intensive land clearing. In the latter part of the 20$^{th}$ Century, forests reclaimed the upper elevations of the Sub-basin, and sediment load was reduced to more normal natural levels. However, the process of down-cutting and channel evolution is still continuing in the lower river channels. Because of the soils' characteristics in certain areas, the stream banks in these areas are more susceptible to erosion and mass wasting, and should be protected from flood waters.

### Methods

Detailed digital soil map unit information (SSURGO data) has been certified for the entire Plan project area. The standard "cutbanks cave" soil interpretation used nationally by NRCS to select map units that are susceptible to bank cave-in did not seem to capture all of the possibilities for scour susceptibility. We expanded that interpretation, and used this to query the agency's NASIS soils database to arrive at our set of susceptible soils map units. A representative value between 0 and 1.0 is assigned to each soil map unit after weighing its characteristics against the criteria; the result is a fuzzy rating from which we can infer susceptibility. The criteria we finalized for this interpretation query are shown in Table 9.

### Results and Data Usage

Soils susceptible to bank scour erosion were identified and mapped in the Missisquoi Sub-basin. The most susceptible soils are alluvial soils laid down by the streams themselves, but other soils found along streams also are moderately to highly susceptible (see criteria table above). An example analysis was conducted for the Rock River Sub-watershed. The most susceptible soils (fuzzy rating of 0.85 or higher) were intersected with the layer of known riparian gaps. Documented bank erosion and mass wasting sites in another layer from Vermont DEC's Stream Geomorphic Assessments were also used to refine the analysis. Thus, susceptible soils within the 25 foot buffer zone which are already eroding, were mapped as target areas for conservation efforts. The resulting map for the Rock River Sub-watershed from this analysis is shown in Figure 19.

**Table 9 - Streambank Scour Erosion Susceptibility Ratings for Soils.**

| | fuzzy rating | soil types |
|---|---|---|
| Most Susceptible | 1.000 | alluvial parent material EXCEPT very poorly drained OR poorly drained |
| | 0.850 | particle size class = sandy or sandy-skeletal OR loamy-skeletal OR anything over sandy-skeletal |
| | 0.600 | particle size class = coarse-silty OR sandy over loamy OR loamy over clayey |
| | 0.500 | E slope with densic contact OR E slope with clay soils |
| | 0.400 | particle size class = coarse-loamy NOT alluvial parent material NOT with a densic contact |
| | 0.400 | densic contact OR clay soils, NOT E slope |
| | 0.200 | shallow OR moderately deep to bedrock (would include moderately deep to deep) |
| | 0.050 | very poorly drained mineral or organic soil OR very shallow to bedrock |
| Most Armored / Least Susceptible | 0.000 | rock outcrop (water would get 0.000, too) |

In the Rock River Sub-watershed, there are 44 riparian gaps noted from 2003 color aerial photography, of varying length from 0.02 to 0.75 miles which occur in soils with susceptibility of 0.85 or higher. Of these, 5 gaps are within stream reaches where erosion has been observed during Stream Geomorphic Phase 2 Assessments by Vermont DEC and its' partners. These 5 stretches of riparian buffer gap are areas we may be able to target for further investigation and conservation practice implementation. While there is known erosion in these gaps, another way to look at targeting is to protect those gaps at high risk which have not yet begun eroding severely. The 39 other high-risk gaps thus may be targeted for protection using USDA or partners' funds.

An alternative way to look at and use the data is shown in Figure 20**.** This map is of the Hungerford Brook Sub-watershed. The map shows the range of susceptibility for soils within the riparian zone of streams that have been assessed for Phase 1 SGA.

**Figure 19 - Soils Near Streambanks Susceptible to Scour Erosion in the Rock River Sub-watershed.**

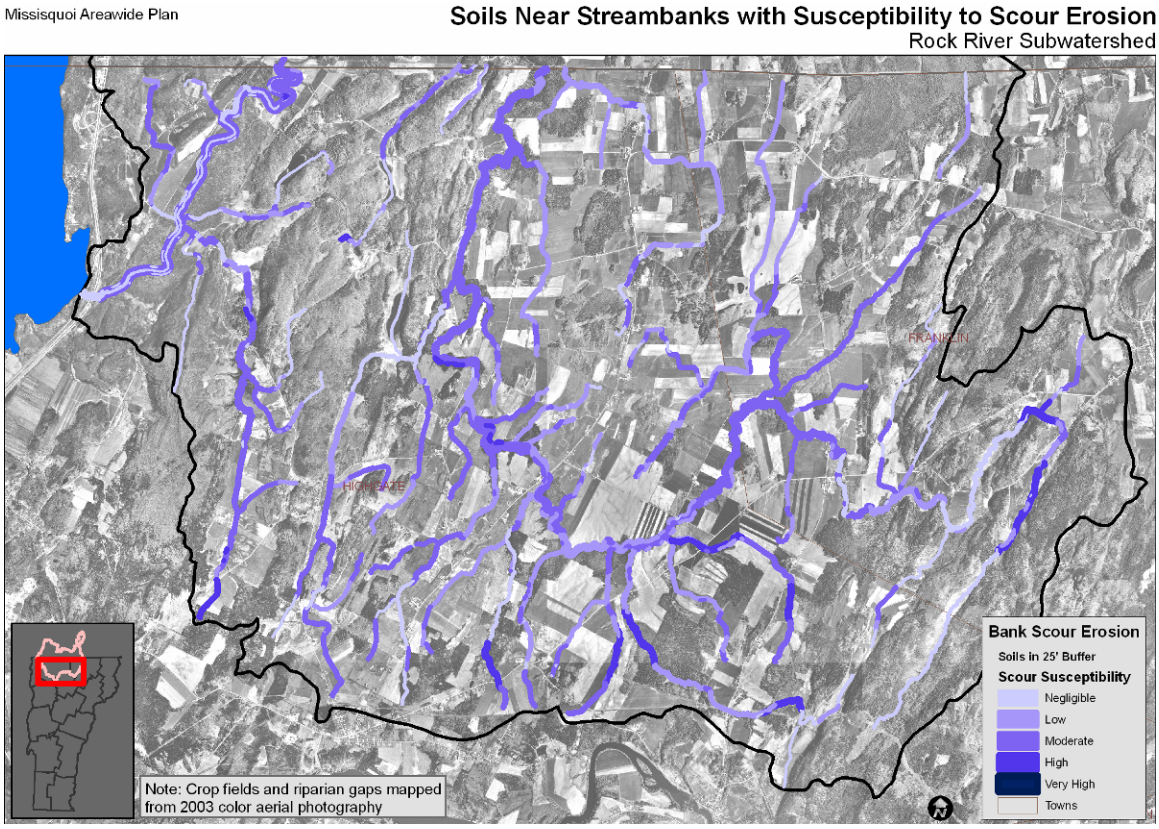
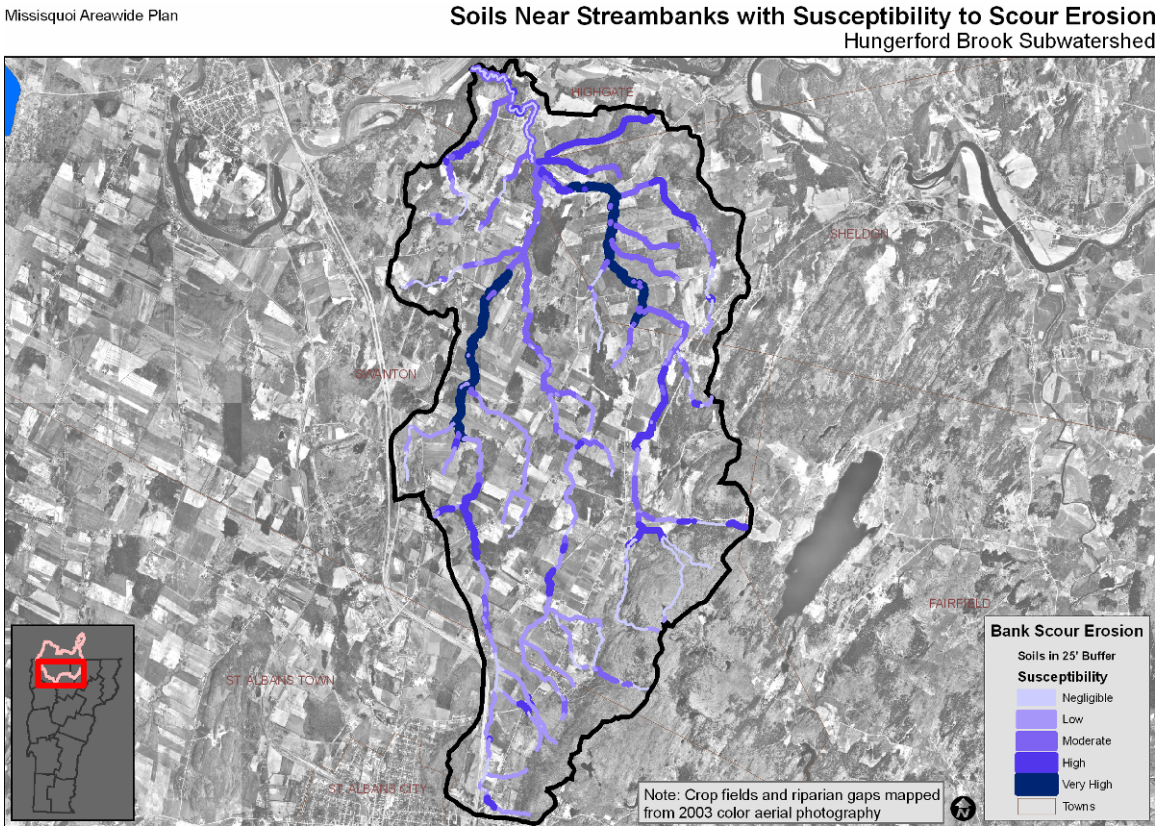


**Figure 20 - Soils Near Streambanks Susceptible to Scour Erosion in the Hungerford Brook Sub-watershed.**




## Lake Champlain Basin Wetland Restoration Plan

### Background

Wetlands provide a variety of functions and values that include high quality fish and wildlife habitat, storing floodwaters, groundwater recharge and discharge, and improving water quality. Wetlands improve water quality by a variety of means including capturing, filtering and retaining sediments and nutrients from source waters and upland areas. Of particular interest in the Lake Champlain Basin of Vermont is the need to prioritize potential wetland restoration sites based on which sites are most likely to retain significant amounts of phosphorous. The Lake Champlain Clean and Clear Action Plan – Lake Champlain Basin Wetland Restoration Plan has presented a framework and results of priority areas that are best suited for this purpose.

The goal for the Wetland Restoration Plan is to meet applicable portions of the Phosphorous Total Maximum Daily Load (TMDL) requirements for Lake Champlain on the Vermont side of the lake. The Wetland Restoration Plan presents a basin-wide identification and prioritization model for reducing phosphorous (P) loading in Lake Champlain. The plan

targets lands that have met specific criteria and that will have the greatest potential for phosphorus removal. The plan was developed for use by resource managers involved in planning and implementing wetland restoration projects in the Basin.

A Geographic Information System (GIS) model was developed to assess former wetlands for restoration. Non-forest agricultural and urban sites were evaluated using a variety of criteria including hydric soils, slopes $\leq$ 5%, National Wetlands Inventory (NWI) data, and size $\geq$3 acres. The resulting preliminary list of sites was prioritized using a model with eleven variables to rank potential to capture phosphorus. The variables included the following elements of site function:

- soil texture,
- erosion risk,
- size class,
- flood class,
- proximity to surface waters,

and a number of elements related to the watershed, including:

- upslope drainage area,
- slope,
- erosion risk,
- estimated phosphorus load,
- hydrologic soil group,
- land cover,
- and drainage area to wetland ratio.

The result of this analysis was a numeric value that ranked the potential sites from lowest to highest. One of the products of this plan was a siterank_final.shp' (siterank) shapefile that contains the wetland polygon features as well as twenty-three attributes including the total restoration score. A feasibility component of the plan and restoration alternatives was also developed following the GIS model.

Using the siterank shapefile, we determined the acreage of wetland restoration sites by the four score ranges highlighted in the draft plan for the entire Missisquoi Project Area (Table 10). ArcView 3.3 was used for the GIS processes and analysis. The siterank shapefile was clipped by the sub-basin and merged with the remaining siterank polygons within the Missisquoi Sub-basin.

Figure 21 shows the results in the form of a map of restoration sites for the Sub-basin. For each sub-watershed, all siterank polygons were selected within the sub-watershed and acreage was calculated from the siterank polygons. There are about 16,000 acres of potential wetland restoration sites within the Missisquoi Sub-basin that could help lower phosphorus loads to Lake Champlain (Table 10). For comparison at the sub-watershed level, there are about 1,050 and 3,160 acres of potential restoration sites identified within the Hungerford and Rock River Sub-watersheds, respectively (Figures 22 and 23).

The Clean and Clear Wetland Restoration Plan highlights the Otter Creek sub-basin for initial wetland restoration efforts due to the highest mean restoration scores. However, there

is also great opportunity to restore wetlands in the Missisquoi Sub-basin. The data table and maps show this graphically and visually. Additionally, there are significant areas for potential restoration; including many with 'highest' potential just outside the project area, in and around Maquam and St. Albans Bays.

The siterank GIS layer will be a useful planning and prioritization tool for conservationists in the Lake Basin. The siterank shapefile can easily be viewed and used within a GIS to help determine potential sites, acreages and proximity to other projects, important habitats (e.g. Vermont Significant Wetland Inventory, etc.) and protected lands. This flexibility of the GIS will help with strategically targeting restoration areas as phosphorous sources are better isolated. While the plan and shapefile were intended to highlight areas to target for water quality purposes, they can also be used to help highlight areas that can serve multiple purposes such as terrestrial-wetland-aquatic habitat improvement, storing floodwaters, etc. Finally, the layer/maps and plan can be used by program administrators to determine priority areas and also to direct funding. Conservationists in the Lake Basin are fortunate to have this set of tools that will help them direct outreach, funds and restoration to the most important areas.

**Table 10 - Extent of Potential Wetland Restorations Sites by Rank.**

## Potential Wetland Restoration Sites - CCPI Project Area

| Potential for Restoration | Restoration Score Range | Acres |
|---|---|---|
| Low | 91-204 | 2,277.1 |
| Moderate | 204-275 | 8,224.4 |
| High | 275-336 | 4,974.1 |
| Highest | 336-460 | 532.4 |
| **Total in Project Area** | | **16,008.0** |

## Potential Wetland Restoration Sites - Hungerford Brook Sub-watershed

| Potential for Restoration | Restoration Score Range | Acres |
|---|---|---|
| Low | 91-204 | 110.7 |
| Moderate | 204-275 | 474.7 |
| High | 275-336 | 458.8 |
| Highest | 336-460 | 0.0 |
| **Total in Sub-watershed** | | **1,044.2** |

## Potential Wetland Restoration Sites - Rock River Sub-watershed

| Potential for Restoration | Restoration Score Range | Acres |
|---|---|---|
| Low | 91-204 | 96.6 |
| Moderate | 204-275 | 1,928.9 |
| High | 275-336 | 1,120.8 |
| Highest | 336-460 | 9.2 |
| **Total in Sub-watershed** | | **3,155.5** |

**Figure 21 - Potential Wetland Restoration Sites in the Missisquoi Sub-basin, by Rank.**

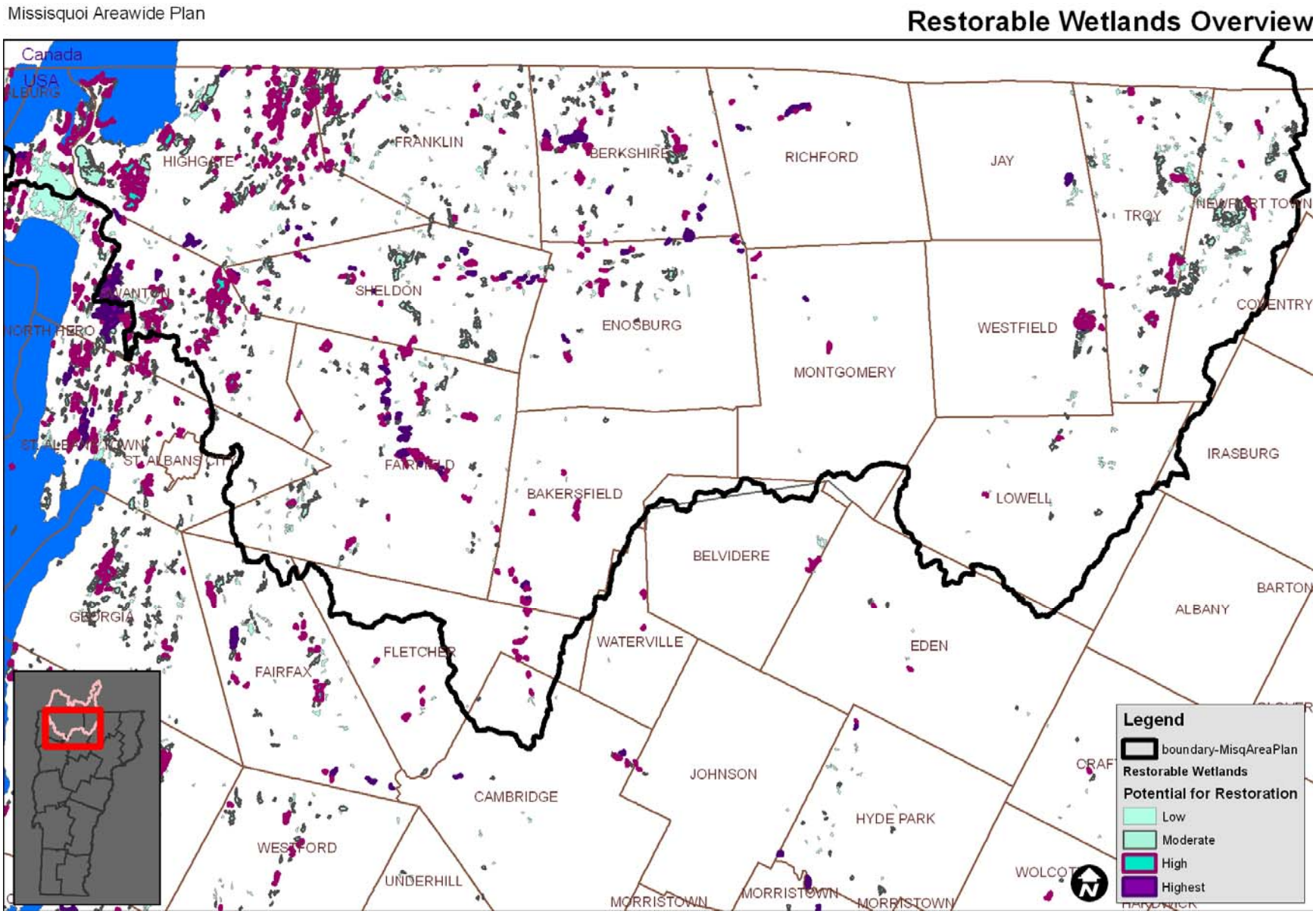


**Figure 22 - Potential Wetland Restoration Sites in the Rock River Sub-watershed, by Rank.**

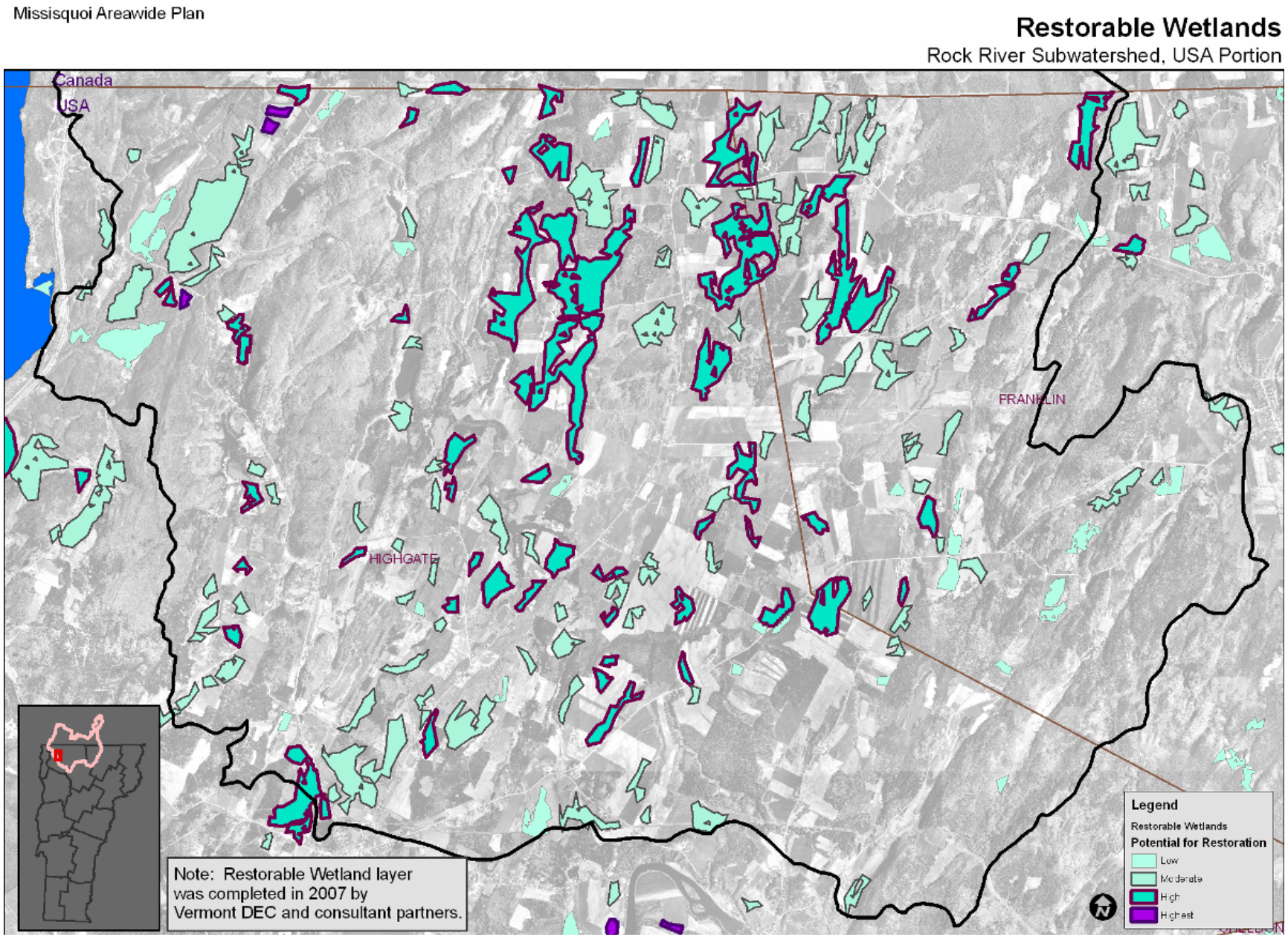
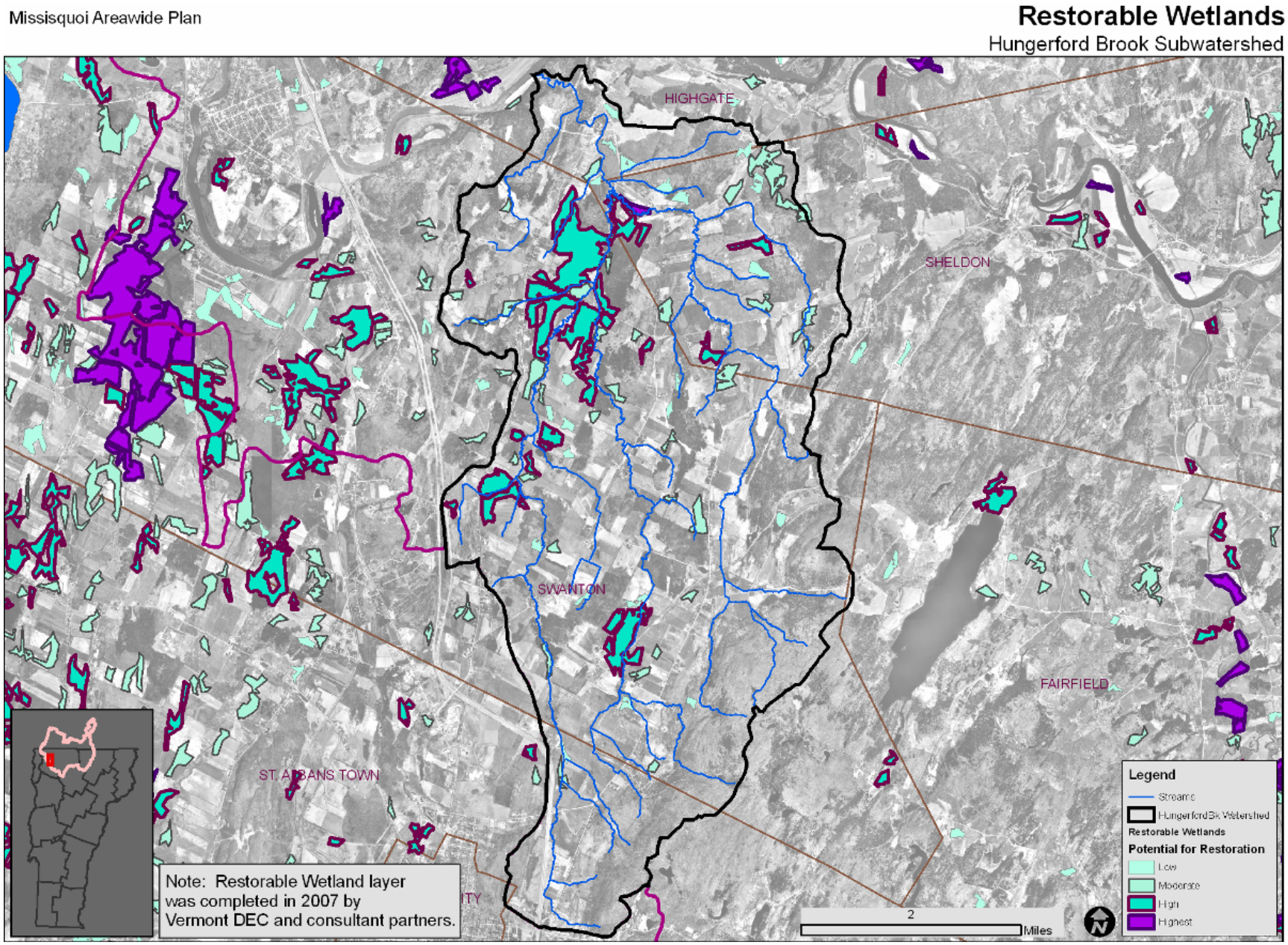


**Figure 23 - Potential Wetland Restoration Sites in the Hungerford Brook Sub-watershed, by Rank.**



**Links Between Geomorphic Condition, Streamside Land Use, and Phosphorus Loading in Hungerford Brook**

This study was conducted by Mary C. Watzin and Dani Newcomb of the Rubenstein School of Environment and Natural Resources. It was partially funded by NRCS through the Missisquoi CCPI project. Most of the text below was copied from the project report written by Watzin and Newcomb[20].

Transport of phosphorus and sediment within the watershed is a critical determinant in understanding loading. It has been observed in other studies that nutrient concentration and load increases from the headwaters to the outlet of the watershed[21,22,23,24.] However, processes of deposition and re-suspension can lead to discontinuous transport of phosphorus loads that do not always increase downstream[25]. Understanding the different transport mechanisms can be extremely important in trying to determine critical source areas, sinks, and areas that may act as both under different conditions.

The overall objectives of this study were to: (1) determine if rapid geomorphic assessment (RGA) scores are linked to phosphorus concentrations and loads during typical storm events using water total phosphorus concentrations and water soluble reactive phosphorus (SRP) concentrations. (2) Determine if watershed land use or near stream land use has a greater impact on phosphorus loads and if soil phosphorus is a covariate in the relationship. (3) Develop a model to look for the associations between soil phosphorus levels, soil type, RGA scores, land use, and phosphorus concentrations and load using data collected from tributary junctures and the mouth of Hungerford Brook. The model will also be used to look for locations and conditions in the watershed where conservation practice implementation or stream restoration would likely have the greatest impact in reducing phosphorus load at the mouth of Hungerford Brook. By systematically breaking a small watershed into its component sub-watersheds and collecting data at the sub-watershed and whole watershed scale, we explored the effect of assessment scale and thresholds of land use alteration and geomorphic condition on the overall sediment and phosphorus load.

The study was conducted in the Hungerford Brook Sub-watershed in northwestern Vermont.

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[20]Mary C. Watzin and Dani Newcomb, 2007, Links between geomorphic condition, streamside land use, and phosphorus loading in Hungerford Brook, unpublished report, Rubenstein School of Environment and Natural Resources, University of Vermont, 45 p.

[21] Allan, J.D. 2001. Stream ecology: structure and function of running waters. Kluwer Academic Publishers, Dordrecht, The Netherlands.

[22] Castillo, M.M., J.D. Allan, and S. Brunzell. 2000. Nutrient concentrations and discharges in a Midwestern agricultural catchment. J. Environ. Qual. 29:1142-1151.

[23] Sonoda, K., and J.A. Yeakley. 2007. Relative effects of land use and near-stream chemistry in an urban stream. J. Environ. Qual. 36:144-154.

[24] Harding, J.S., R.G. Young, J.W. Hayes, K.A. Shearer, and J.D. Stark. 1999. Changes in agricultural intensity and river health along a river continuum. Freshwater Biol. 42:245-357.

[25] Verhoff, F.H., D.A. Melfi, and S.M. Yaksich. 1982. An analysis of total phosphorus transport in river systems. Hydrobiologia. 91:241-252.

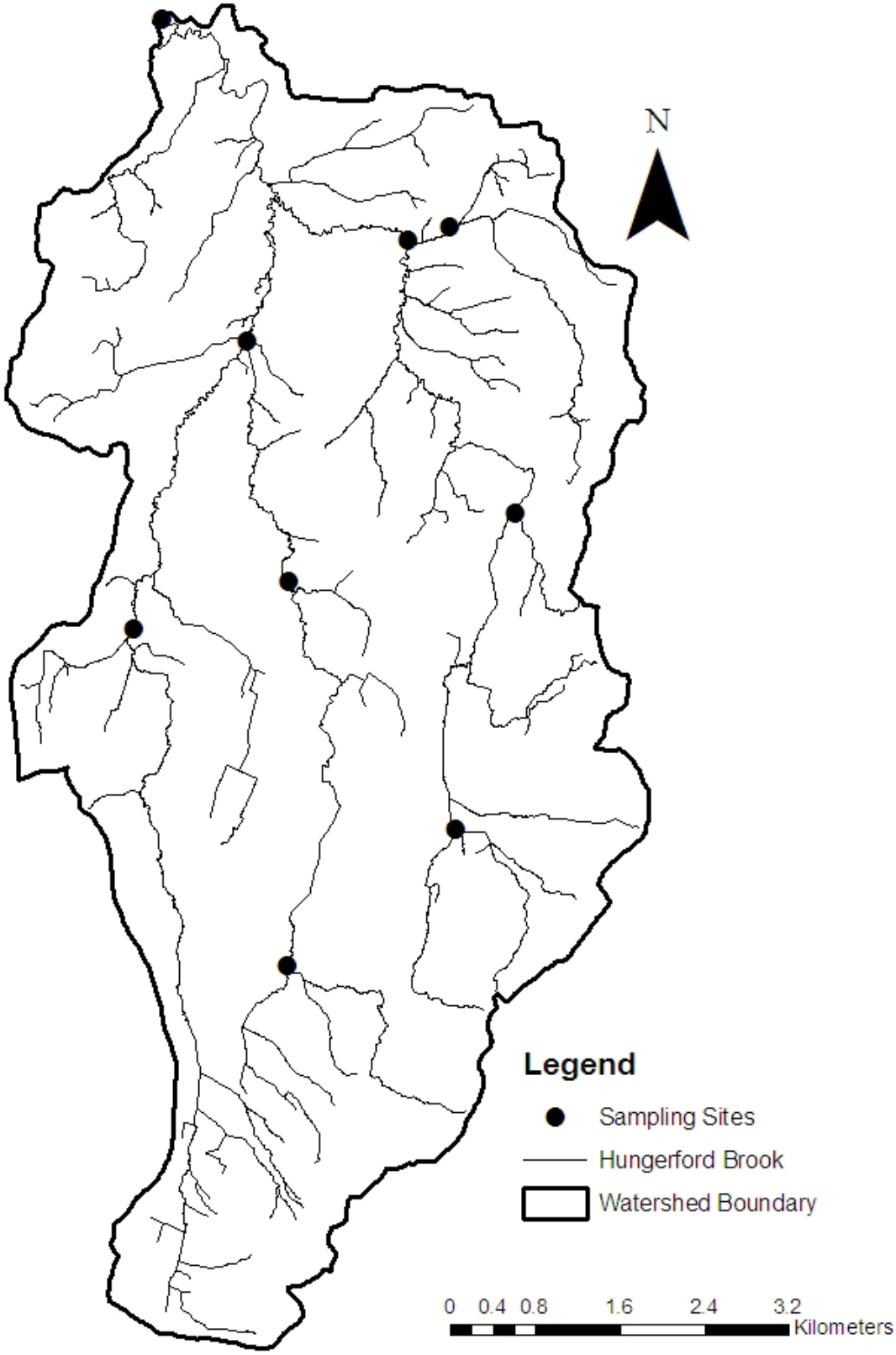
The Hungerford Brook Sub-watershed is part of the larger eight digit Missisquoi River Sub-basin (02010007). Hungerford Brook empties into the Missisquoi River which in turn empties into Missisquoi Bay in Lake Champlain (Figure 24). The mainstem of Hungerford Brook is approximately 16 km long with over 117 km of total stream length in the relatively flat watershed. The overall Sub-watershed is approximately 50 km2 in area and land use includes agriculture (53%), forest (28%), developed land (8%), and wetlands (11%) (from the National Land Cover Dataset (NLCD), 2001). Within the agricultural land use, 41% is hay, 25% pasture, and 32% corn.

This study shows that excess amounts of phosphorus and sediment are being transported throughout the Hungerford Brook Sub-watershed and may be accumulating at the mouth of the river. Phosphorus concentrations in the water leaving Hungerford Brook are above the 25 µg/L target for Missisquoi Bay. The Total Phosphorous (TP) and Soluble Reactive Phosphorus (SRP) concentrations exiting in Hungerford Brook are in excess of the water quality standards for Missisquoi Bay even under baseflow conditions.

In large storm events, accumulated phosphorus and sediment are transported downstream and exported in large amounts. SRP concentrations and loads in Hungerford Brook appear to be linked to near-stream agriculture, while TP and Total Suspended Sediments (TSS) are linked to agricultural land use in general. Additionally, it appears that agriculture in the riparian buffer area not only contributes to an increase in SRP, but also to a decrease in geomorphic condition, providing additional justification for the protection of riparian buffer areas. Management practices that result in lower phosphorus concentrations in the soil and that provide significant stabilization and nutrient removal in the riparian corridor should help reduce the phosphorus load leaving Hungerford Brook.

Future studies could greatly increase our understanding of the general dynamics of runoff and should focus on determining the relative contributions of sediment from overland flow and in-stream processes. This study design could also be replicated in a watershed without a high correlation between near-stream and whole watershed land use to further examine the relative importance of interventions in the watershed as a whole, and interventions focused on the riparian corridor.

**Figure 24 - Map of the Hungerford Brook Sub-watershed and Location of Water Quality Sampling Sites.**



The results of this study also suggest that targeted management in Hungerford Brook could be appropriate. Tributary data indicates that particular problems exist in the Pratt, Sholan, and Morey tributaries. Both Pratt and Sholan have higher sediment and total phosphorus loads and concentrations than other sub-watersheds, indicating that these areas are transporting sediment that is highly enriched with phosphorus. Management practices targeting sediment reductions should be focused in tributary watersheds. The Morey tributary has the highest SRP concentrations in the Hungerford Brook Sub-watershed. While sediment and phosphorus problems in Sholan and Pratt appear to be watershed-wide, most of the excess SRP levels in the Morey tributary can be attributed to a single large dairy farm with a barnyard very near to the stream. Following the completion of this study, a biodigester and manure composting system were installed on this farm. It would be worthwhile to examine the impacts of this installation before designing additional interventions. In the larger Hungerford Brook Sub-watershed, management should focus on two key areas: (1) nutrient management to reduce soil phosphorus concentrations, and (2) stream riparian buffers, especially focusing stream bank restoration in areas of high degradation.

## No-Till Practice Application Analysis

### Background

Some conservation practices can be successfully implemented on fields with particular soil and landscape characteristics. No-till (NRCS practice standard, Residue Management, No-till, #329) is one of these practices. No-till is commonly acknowledged as an effective practice to reduce soil erosion, nutrient loss and increase soil organic matter. However, the application of no-till in northern Vermont appeared to have limitations due to the presence of heavy soils and short growing seasons.

The Vermont NRCS Soils Staff recently developed a No-till soil interpretation which accounts for maximum slope, rock content, and other factors as quoted below. GIS was then used to find crop fields where at least half the field was rated Good or Excellent for this practice. The GIS procedure is included in Appendix D.

Here, quoted from the State Soils Staff, is the reasoning behind the interpretation of soil map units for No-Till potential: "Soils are classified for their suitability for No-Till conservation practices. These practices include planting methods commonly referred to as no-till, strip till, direct seed, zero till, slot till or zone till. Soils that are classified as excellent, good or fair are considered to be suitable for No-Till practices.

The soil properties and qualities considered in developing these classifications are those that affect tillage operation, crop growth, and other necessary mechanical operations. The soil properties that affect No-Till practice establishment and continuance are

1. soil drainage
2. surface gravel, cobbles and stones
3. flooding
4. ponding
5. depth to water table

6. slope
7. depth of soil

Flooding, ponding, high water table and soil depth also affect crop establishment, growth, and productivity."

**Sub-basin Summary**

The analysis showed that there is widespread potential for this practice throughout the Sub-basin. A total of 19,558 acres of crop or hay fields have potential for no-till (see Figure 25). Fifty percent or more of the soils in these fields are rated either Good or Excellent. The Rock River and Hungerford Sub-watersheds have 1,131 acres and 2,393 acres, respectively, of fields with Good or Excellent potential for no-till (see Figures 26 and 27). The practice may be especially helpful in curtailing erosion on fields that contain steep areas under corn production. We will use the resulting GIS layers maps to target the promotion and application of this practice.

**Figure 25 - Crop and Hay Fields with Good or Excellent Potential for No-till in the Rock River Sub-watershed.**

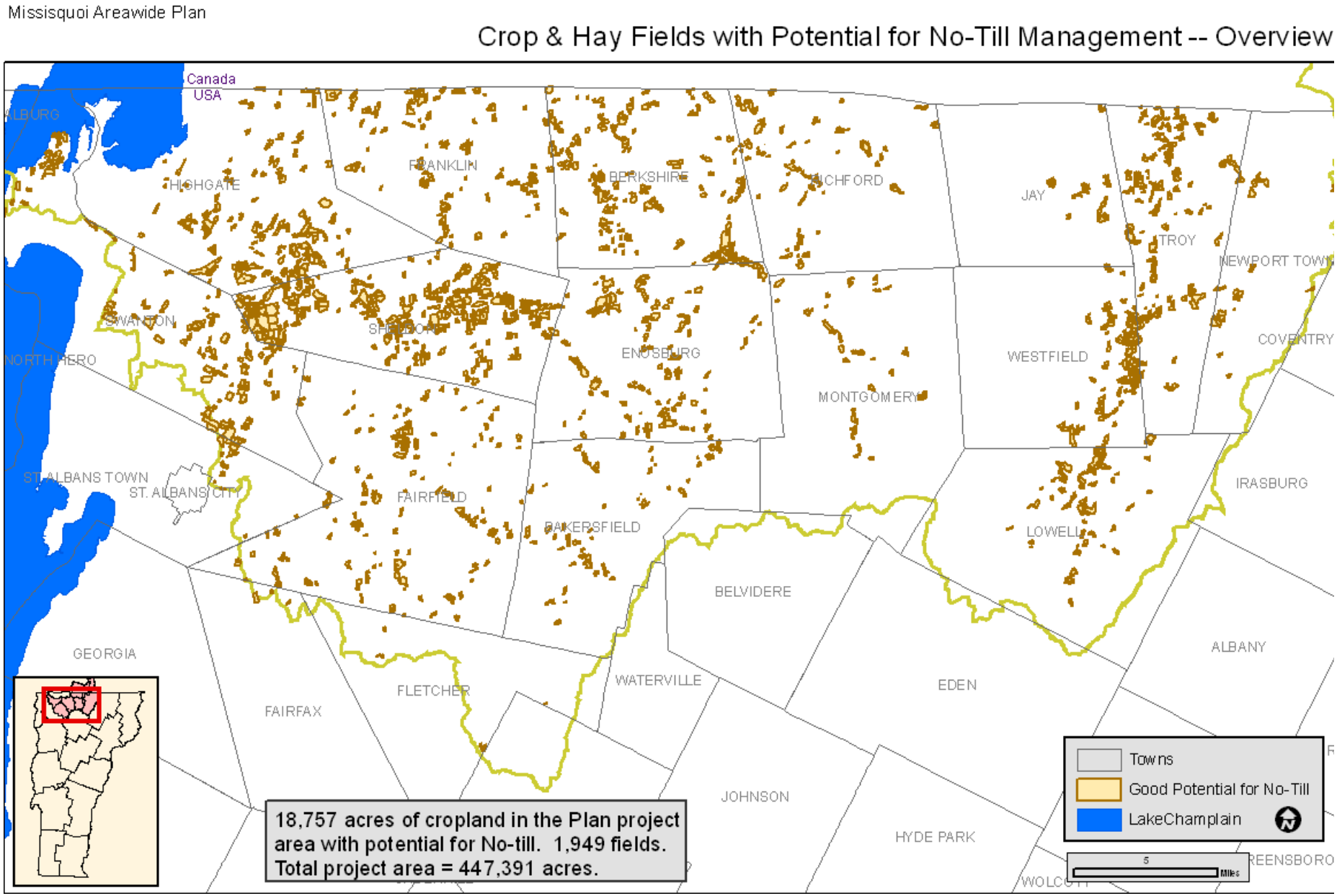


**Figure 26 - Crop and Hay Fields with Good or Excellent Potential for No-till in the Rock River Sub-watershed.**

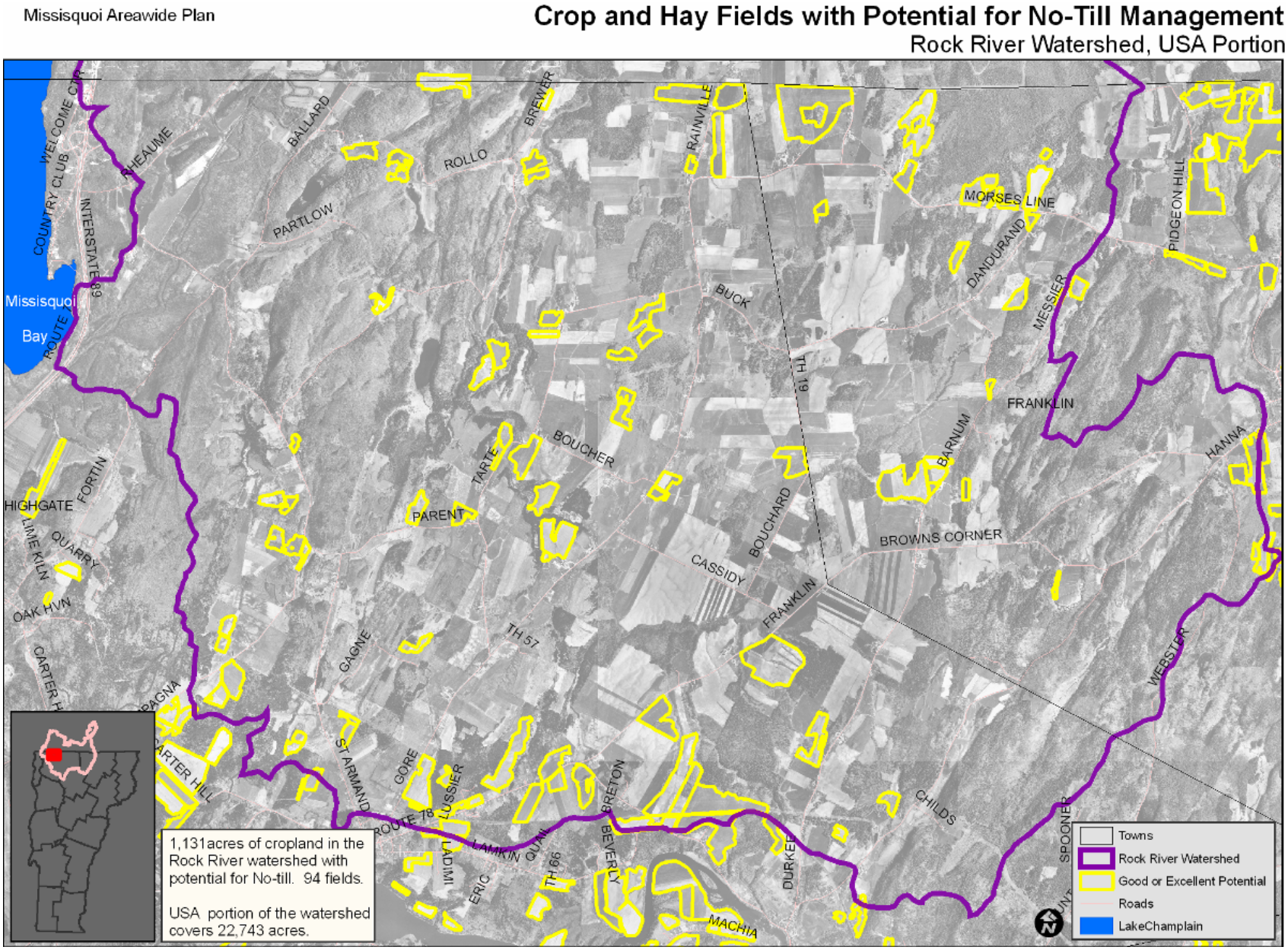
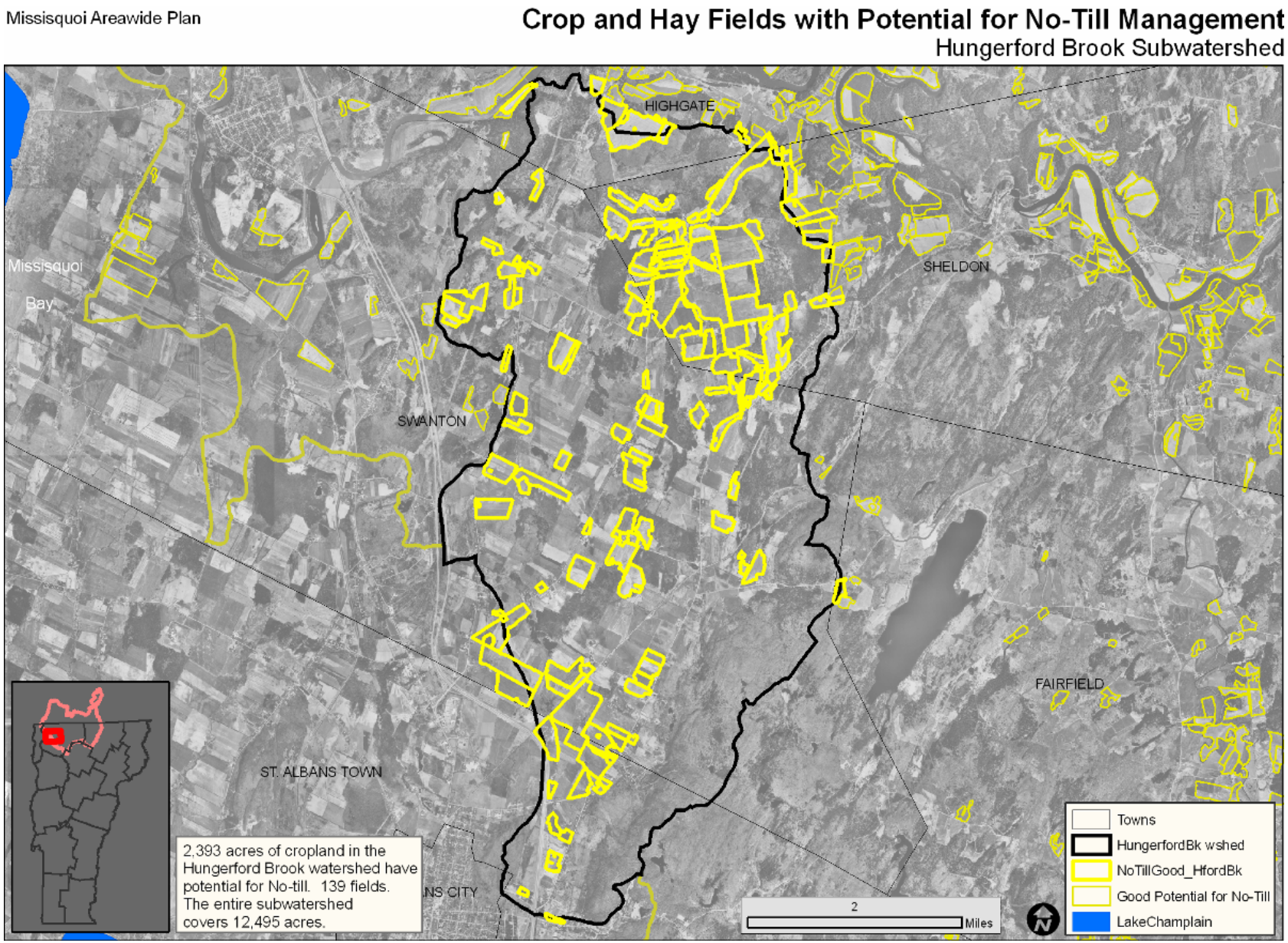


**Figure 27 - Crop and Hay Fields with Good or Excellent Potential for No-till in the Hungerford Brook Sub-watershed.**



## Examination of 10 BMP Scenarios on Cropland

Ten Best Management Practice (BMP) scenarios to improve water quality were developed for cropland in the sub-basin. The purpose of the scenarios is to compare the relative effectiveness of different conservation practices on estimated phosphorus export from the edge of fields. These scenarios were evaluated using a combination of RUSLE2, Vermont P Index and estimated cost data. RUSLE2 is a method developed by NRCS to estimate sheet and rill soil erosion on cropland. The Vermont P Index is a tool developed by UVM Extension to estimate the relative magnitude of phosphorus runoff from cropland.

The ten scenarios are described below. They were developed to represent actual conditions in the sub-basin and to include reasonable applications of accepted conservation practices. For each scenario the assumptions employed to develop the conditions for its application are described. **The phosphorus estimates resulting from this analysis should not be interpreted as absolute numbers.** They do not represent actual contributions of phosphorus to the lake or even to the edge of the field. However, the phosphorus estimates can be used to compare the relative magnitude of phosphorus reduction associated with each scenario.

**BMP Scenarios Used in this Analysis**

A "base" scenario was developed that was comprised of continuous corn on 3 different slope classes of fields. These slope classes included 0 – 3%, 4 – 8%, and greater than 8%. No BMPs were assumed to be present on these fields. For the RUSLE2 analysis we used a Georgia Stony Loam as the typical soil. This soil was used in all scenarios. An average slope of 2%, 6% and 11% were used to represent fields in each of the respective slope classes. A slope length of 200 ft. was used in the low slope class, 170 ft. in the medium slope class, and 100 ft. in the high slope class. Total cropland (71,939 ac), land in corn (17,114 ac) and land in hay (50,009 ac) were estimated from an interpretation of the 2003 NAIP photography (Table 8). The number of acres in corn production for this year was assumed to represent the amount of corn production in any given year in the Sub-basin, even though the actual fields in corn production change from year to year since many of the fields are in crop rotations. The acres in corn production for each of three slope classes were estimated from the cropland slope analysis, the results of which are reported in Table 8.

The P-Index analysis for this "base" scenario included spring and fall dairy manure applications, spring plowing and no incorporation of manure in the fall. The scenario also included 30 lb $P_20_5$ fertilizer per acre, incorporated on silage corn with very little residue. A 10 ft wide buffer was assumed on all fields.

All analyzes were conducted for the Sub-basin as a whole. Differences at the Sub-watershed level were not considered.

Scenario #1 – Permanent seeding on fields with steeper slopes

Under this scenario it was assumed that 50% of all the corn acreage in the steeper slope class would be seeded down to permanent grass. Thus the number of acres of corn in this slope class was reduced from 2,737 to 1,369. All other variables were held constant.

Scenario #2 – Implementation of no-till on a broad basis
It was determined that there were a total of about 19,558 ac. of soils in the sub-basin that were suitable for no-till. This was based on an analysis of the soil interpretations for soil map units in the sub-basin. It was assumed that 50% of field acreage with soils suitable for no-till in each of the 3 slope classes would be converted from continuous corn to no-till. All other variables were held constant.

Scenario #3 – Implementation of cover crops on a broad basis
Cover crops were assumed to be planted on 50% of the corn acreage in the high and medium slope classes. All other variables were held constant.

Scenario #4 – Use Manure Injection on Permanent Hay
Using 2003 as the base year, there are 51,100 acres of fields managed as hay in the sub-basin. This scenario assumed that manure injection would be used on 50% of this acreage.

A "base" hay scenario was also developed that used the same 3 slope classes and soils as the corn "base" scenario. Under the hay "base" dairy manure was surface applied twice during the summer, at a rate of 30 $P_2O_5$ lbs P per acre.

Scenario #5 – Reduce soil phosphorus in fields with test results of 'exceeds' to 'optimum' phosphorus levels
It was assumed that 10% of the fields in each slope class had soil phosphorus test levels of exceeds. Soil test results generally indicate that less than 10% of the fields have soil phosphorus levels of 'exceeds'. For the P Index we used soil test values of 7 to represent optimum phosphorus levels and 30 to represent exceeds. The scenario assumed 100% of the fields with exceeds levels of phosphorus were reduced to optimum levels.

Scenario #6 – Use of no-till and manure injection in combination
The same test conditions were used as in Scenario #2. In addition, manure injection was assumed to be used on all of the no-till fields to apply manure in both the spring and fall.

Scenario #7 – Manure injection used in combination with cover crops on corn
The same test conditions were used as in Scenario #3. In addition, manure injection was used in combination with the cover crops. In the fall, manure is often surface applied to corn fields with cover crops and not incorporated.

Scenario #8 – Addition of a filter strip of 50ft to fields at 'T'
It was assumed that 50% of all corn fields in each slope class had a 50 ft. wide filter strip installed. All other variables were held constant.

Scenario #9 - Reducing erosion on corn fields from 2'T' to 'T'
Erosion on 50% of the corn fields in the medium and high slope classes was reduced from 2'T' to 'T'. This can be accomplished by employing a variety of practices such as cross slope tillage, diversions, strip tillage, etc. All other variables were held constant.

Scenario #10 - Convert fields in silage corn to grain corn
It was assumed that 50% of the corn fields in each slope class would be converted to grain corn production. This change in cropping system results in a significant increase in residue left on the ground surface. A few small farms in Vermont have already switched to growing high moisture grain corn instead of silage corn. Apparently there are benefits from growing grain corn to soil conditions and field management, as well as decreasing sediment and phosphorus loss. All other variables were held constant.

**Overview of Results**
The total acres of corn estimated in the sub-basin for 2003 was 17,114 ac. Of this corn, 7,583 acres occurred on slopes of 0 to 3 percent, 6,794 acres occurred on slopes between 3 and 8 percent, and 2,737 acres occurred on slopes greater than 8% (Table 11).

There were an estimated 50,009 acres of hay in the sub-basin in 2003. Of these acres, 12,818 occurred on slopes between 0 and 3 percent, 22,159 occurred on slopes between 3 and 8 percent and 15, 032 occurred on slopes greater than 8 percent (Table 11).

Using these acreages and the assumptions stated above, savings in soil erosion rates (t/ac/yr) and totals (t/yr) were calculated for each of the 10 scenarios. Reductions in phosphorus losses were also calculated as a rate (lbs/ac/yr) and as a total amount (lbs/yr).

The cost of reducing phosphorus loss was estimated using the amount saved per acre and the estimated per acre cost of implementing the BMP(s). Cost estimates were derived from the recently developed NRCS Payment Schedules which are used to set conservation practice payments for cost-share programs. Estimates of cost per pound of phosphorus were developed for the cost of implementing the practice and for the cost of lost crop production associated with implementing the practice.

The results from the scenarios (Table 11) produced a wide range of results for sediment and phosphorus savings, and cost of implementing the practice(s). Reductions in soil loss rates varied from no change for several scenarios that do not significantly affect cover, such as manure injection, to 12.4 t/ac/yr for Scenario #1, permanent seeding on steep slopes. By implementing no-till, Scenario #2 also produced a high reduction in soil loss rate, 5.8 t/ac/yr. Several scenarios showed no reduction in total soil loss, such as scenarios #4, 5, and 8. Scenarios #2 and 6, the no-till scenarios, produced the largest reduction in total soil loss, 36,911 t/yr. The large reductions in total soil loss with no-till was a result of a good rate of reduction coupled with a relatively large acreage (8,558 ac.) on which this practice was applied. The number of acres for which each scenario was applied had a significant impact on the total estimated reductions of both soil and phosphorus loss.

**Table 11 - Summary of Soil Loss and Phosphorus Loss Reductions from 10 Selected BMP Scenarios.**

| Scenario | Total Acres Applied | Av. Soil Loss Reduction (tons/ac/yr) | Total Soil Loss Reduction (tons/yr) | P Loss Reduction (lbs/ac/yr) | Total P Loss Reduction (lbs/yr) | Practice Cost of P Reduction* ($/lb P) | Total Cost of P Reduction** ($/lb P) |
|---|---|---|---|---|---|---|---|
| #1 - Permanent Seeding on Steep Slopes | 1,369 | 12. 4 | 17,003 | 2.7 | 3,696 | 31 | 307 |
| #2 - No-till | 8,558 | 5.8 | 36,911 | 1.2 | 8,122 | 40 | 40 |
| #3 - Cover Crops | 4766 | 2.7 | 12,366 | 0.8 | 3,550 | 49 | 49 |
| #4 - Manure Injection on Hay | 25,005 | - | - | 0.7 | 17,066 | 9 | 9 |
| #5 - Reduce Soil P Levels | 856 | - | - | 1.0 | 733 | 14 | 14 |
| #6 - No-till and Manure Injection | 8,558 | 5.8 | 36,911 | 2.4 | 18,359 | 47 | 47 |
| #7 - Cover Crops and Manure Injection | 4,776 | 2.7 | 12,366 | 1.0 | 5,177 | 79 | 79 |
| #8 - Add Filter Strip | 8,558 (428)*** | - | - | 0.6 | 4862 | 15 | 324 |
| #9 - 2 'T' vs. 'T' | 4766 | 1.5 | 4,968 | 0.5 | 3,312 | 0 | 1,074 |
| #10 - Convert to Grain Corn | 8,558 | 4.9 | 5,498 | 1.1 | 7,795 | 0 | 0 |

* This represents the estimated cost per pound of phosphorus based on the cost of implementing the practice.
** This represents the estimated total cost per pound of phosphorus. It includes both the cost of implementing the practice and any costs associated with lost crop production.
*** Estimated number of acres actually planted to filter strips.

There were also a wide range of results for the reductions in phosphorus loss between the various scenarios. The rate of estimated reduction varied from 0.5 lbs/ac/yr for Scenario #9, 2 'T' vs. 'T', to a high of 2.7 lbs/ac/yr for permanent seeding of steeper slopes. Total reductions in phosphorus loss ranged from 733 lbs/yr for Scenario #5, reducing soil P levels, to a high of 18,395 lbs/yr for implementing no-till in combination with manure injection. The highest total reductions were again achieved by those scenarios that expressed a combination of high rate reductions and large acres applied.

Clearly, well accepted and documented Practices such as no-till and cover crops are well accepted by the agricultural community throughout most of the U.S. Based on the results above they can potentially have a significant impact on both soil and phosphorus reduction in the Missisquoi Sub-basin. Another interesting result is the very significant reduction in total phosphorus loss by implementing manure injection. This practice produced a good rate of reduction, 0.7 lbs P/ac/yr, but really benefited from the relatively large acreage on which this practice could be applied. This is due to the fact that there is significantly more estimated hay in production, 50,009 ac., versus the estimated acreage in corn, 17,114 ac. Permanent seeding on steeper corn fields, Scenario #1, produced very high rates of phosphorus reduction, but because of the small number of acres of corn on steeper slopes produced relatively lower total phosphorus reductions. One much discussed BMP, reducing soil phosphorus levels on fields with excessive phosphorus, Scenario #5, produced very low reductions in total phosphorus loss. This is primarily due to the relatively small number of corn acres that were estimated to exhibit excessive soil phosphorus levels (assumed to be 10% of all corn fields). Finally, Scenario #10, changing from silage corn to grain corn, shows how changing cropping systems and crops can have significant benefits in reducing soil and phosphorus losses. The large reductions associated with this scenario resulted primarily from the benefit of increased residue on the ground surface under a grain corn cropping system.

The final two columns of data in Table 11 include estimates of the implementation and total costs associated with each BMP. Rough cost estimates were developed using recently developed NRCS Payment Schedules. Included in the practice cost column in Table 11 are the estimated costs associated only with implementing the practice. The final column includes the total costs of implementing the practice plus the costs of lost crop production. There were 2 scenarios #9 and #10 for which there was no cost associated with implementation. In these situations there might be additional costs to the farmer for a different type of equipment or feed storage; these costs were not included in the analysis. Manure injection on hay (Scenario #4) showed the highest cost $78/lb P. If the cost associated with a loss of crop production is included, conversion to grain corn (Scenario #10) still showed the best rate of return. Increasing the length of hay in crop rotations (Scenario #9, 2'T' vs. 'T') had the highest phosphorus savings cost, $1,074/lb P.

These 10 scenarios are examples of the type of data that can be generated from using RUSLE2 and P-Index information. This information should be useful in establishing priorities and goals for phosphorus reduction activities related to agricultural crop production. It can be used to determine the extent of a particular phosphorus loss problem and estimate the relative amount of reduction of phosphorus loss that is associated with

different BMPs or systems of BMPs in order to assess when a phosphorus loss goal might be achieved. This information can also be used to evaluate the relative effectiveness of different BMPs and systems of BMPs in different cropping situations. Finally, relative cost information can provide insights as to the most cost effective methods in reducing phosphorus losses from cropping systems.