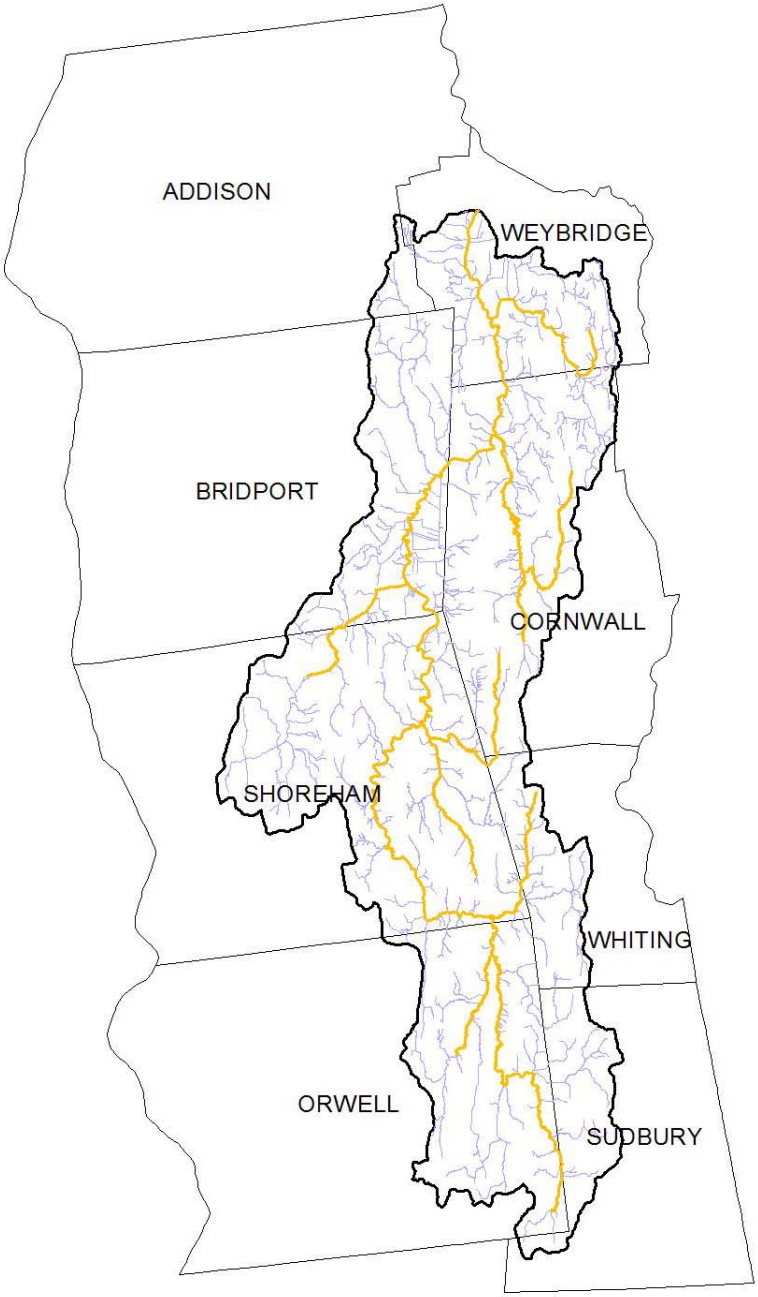
Lemon Fair River
Phase I Geomorphic Assessment
Addison County, Vermont

Draft Report
March, 2006



Prepared by:

Landslide Natural Resource Planning
P O Box 311
East Middlebury, VT 05740

Prepared under contract to:

Addison County Regional Planning Commission
79 Court Street
Middlebury, VT 05753

Table of Contents

Appendices

A. Phase 1 Data
B. Reach based topographic maps
C. Reach based orthophotos
D. Bridge and Culvert Assessment Data
E. Data CD

Executive Summary

The Addison County Regional Planning Commission (ACRPC) contracted with Landslide Natural Resource Planning (LNRP) to complete a Phase 1 Geomorphic Assessment on 56 reaches of the Lemon Fair River. The study was paid for by a grant from the Vermont Emergency Management Agency and the Department of Environmental Conservation with funding from the Federal Emergency Management Agency (FEMA). The Lemon Fair River is located in the Towns of Addison, Bridport, Weybridge, Cornwall, Shoreham, Whiting, Sudbury and Orwell and is a tributary of the Otter Creek River. The watershed encompasses 90.5 square miles in size and 69 linear miles of stream were assessed for this study.

The Lemon Fair River is located in the heart of Vermont's most productive agricultural county and as a result, the primary land use in the watershed is crop and field. There is limited but increasing residential development in the watershed with remarkably little of it occurring in the river corridor. The agricultural nature of the valley as well as the rivers' expansive access to floodplain has likely kept development away from the river. Primary human impacts aside from agricultural land use are historic channel straightening and 39 bridges and culverts.

A Phase 1 study includes collection of baseline information on the physical characteristics of the watershed and stream corridor. This information includes geology, soils, slope, and watershed size and results in "reference stream typing" which offers a description of the physical characteristics of a stream reach in the absence of human impacts. Forty-five of the reaches assessed are reference stream type C, six are E, four are B and one is an A. It is anticipated that most of the streams that have been classified as C in this remote sensing phase of the geomorphic assessment would be E in the absence of the extensive human induced straightening that has occurred throughout the watershed.

The Phase 1 study also evaluates impacts to the watershed that may result in channel adjustment. These include: land cover and reach hydrology, instream channel modifications, planform changes and floodplain modifications and a bed and bank windshield survey. Overall impacts in the watershed are primarily related to the dominant land use of crop and field, the related characteristic lack of riparian buffers, extensive straightening for agricultural production and undersized bridges and culverts. Twelve reaches also have impoundments that affect stream flow and channel shape.

Thirty five bridges and culverts were assessed during this Phase I assessment using the State of Vermont's Bridge and Culvert Assessment Protocol. Twenty seven of these structures were found to be undersized based on the State's Hydrologic Regional Curve derived channel widths for the watershed area.

This report recommends field measurements of channel widths where structures are noted to be undersized; establishment of a riparian planting program; working with communities to prevent development in the floodplain; a limited, prioritized erosion inventory; and Phase 2 Assessments on reaches with the highest impact ratings in sub-watersheds where there is citizen interest in restoration activities.

Project Overview and Background

Study Goals and Objectives

The Addison County Regional Planning Commission (ACRPC), as part of a Federal Emergency Management Administration (FEMA) grant through Vermont Emergency Management (VEM) and the Department of Environmental Conservation River Management Section, hired Landslide Natural Resource Planning (LNRP) to complete a Phase I Stream Geomorphic Assessment and Bridge and Culvert Assessments in the Lemon Fair Watershed in Addison County, Vermont. A Stream Geomorphic Assessment as outlined by the Vermont ANR Protocols is an important step in learning the factors that shape a watershed and its channels. This information is useful to inform future planning and restoration activities. The Vermont ANR Phase I Watershed Assessment and the Bridge and Culvert Assessment Protocols were followed, including all quality assurance and quality control protocols for successful completion of this assessment.

Description of Study Area

The Lemon Fair River is located in the Champlain Valley region of Vermont. It is a tributary of the Otter Creek River and is one of Vermont's most productive agricultural valleys (Nicholson, Hartline). The River is located in the Addison County towns of Addison, Bridport, Weybridge, Cornwall, Shoreham, Whiting, Sudbury and Orwell in the southwestern corner of the county. Like most of the rest of Vermont, the watershed was primarily forested prior to European settlement. With the introduction of agriculture (originally sheep farming now dairy) in the late 1800's the area was deforested for pasture and crop production (Albers). Today, this watershed remains primarily agricultural with increasing amounts of land being converted to residential use.

Reach Locations

Reach descriptions, town and latitude and longitude can be found in Step 1 of the data at the end of this report. Fifty-six reaches totaling 69 stream miles were assessed for this study. Seventeen main stem reaches were assessed; eight reaches on "Beaver Brook 1"; five reaches on "Beaver Brook 2"; four reaches on the first tributary of Beaver Brook 2; four reaches on the "Shoreham Cedar Swamp" tributary, six reaches of Perry Brook and four reaches on the first tributary of Perry; five reaches on Sawmill Brook and three reaches on the Little Lemon Fair. See Figure 1 Map of Phase 1 Reaches on Page 11 of this document. The following table summarizes stream length by tributary.

Table 1 Stream Lengths

Stream Name	Length Miles
Lemon Fair	33.9
Beaver Brook 1	4.48
Beaver Brook 2	6.88
First Trib. of BB2	4.47
Shoreham Cedar Swamp	4.03
Perry Brook	4.27
First Trib. Of Perry Brook	4.54
Sawmill Brook	3.87
Little Lemon Fair	2.94
Total	69.38

Flood History

The nearest United States Geologic Survey flow gauge is located on the Otter Creek River (drainage area 628 square miles) upstream of the Lemon Fair Confluence in Middlebury (gauge # 04282500). Data has been collected at this site since March 31, 1904, however, starting in 1947 the flow on the Otter Creek has been "affected to an unknown degree by Regulation or Diversion" (USGS website) so it is not possible to extrapolate flood history after that time from the historical data. Prior to 1947 there are two events where flow on the Otter Creek exceeded 10,000 cubic feet per second: November 4, 1927 and March 21, 1936.

Phase I Stream Geomorphic Assessment

Methodology

Phase I Parameters

The State of Vermont has developed a three phase geomorphic based assessment protocol for watershed assessment. The first phase, completed here, is considered the "remote sensing" level which evaluates geology, soils, slope, and watershed size to establish provisional reference stream type for each reach. The Stream Geomorphic Assessment Tool Version 4 (SGAT), an ArcView extension, was used to facilitate the collection of data. The Phase 1 study also quantifies human impacts in the watershed, and assigns a provisional impact rating to each reach based on the following parameters.

Table 2. Parameters included in impact scores.

Step Number	Parameter
4.1	Watershed Land Cover/Land Use
4.2	Corridor Land Cover/Land Use
4.3	Riparian Buffer Width
4.4	Groundwater and Small Tributary Inputs
5.1	Flow Regulations and Water Withdrawls
5.2	Bridges and Culverts
5.3	Bank Armoring or Revetments
5.4	Channel Straightening
5.5	Dredging and Gravel Mining History
6.1	Berms and Roads
6.2	River Corridor Development
6.3	Depositional Features
6.4	Meander Migration / Channel Avulsion
6.5	Meander Width Ratio
6.6	Wavelength Ratio
7.1	Dominant Bedform / Material
7.2	Bank Erosion – Relative Magitude
7.3	Debris and Ice Jam Potential

The Phase 1 information helps set the stage for understanding what the major watershed impacts are and can assist in identifying areas to focus additional assessment resources. The Phase 2 Assessment (not completed here) focuses on collecting field measurements and observations to check against the Phase 1, which can lead to the identification of Fluvial Erosion Hazard (FEH) zones as well as identifying areas for different types of restoration activities through the development of River Corridor Management Plans. Phase 3 assessments are completed only on

those reaches that will benefit from active stream restoration activities. Specific parameters assessed here will be discussed in the results section below. All data is located in Appendix A.

Phase I Quality Assurance Review

To assure a high level of confidence in this Phase 1 Assessment, strict quality assurance and quality controls were followed. These procedures included both manual and automated reviews of all data by LNRP as well as by the Department of Environmental Conservation River Management Program. The three base GIS themes developed by Landslide (valley walls, meander center line and sub-watersheds) were submitted to the State for their review prior to running the SGAT 4 extension. The third Quality Assurance check was completed on February 3, 2006 after the completion of Step 7.

Shannon Hill, River Scientist, with the State of Vermont, Agency of Natural Resources, Department of Environmental Conservation River Management Section was the State team leader for this project and performed the Quality Assurance checks. The State's Phase 1 Assessment Protocol and the Bridge and Culvert Assessment Protocol were used exclusively for completion of this project.

Results

Reference Stream Types

Reference stream types provide a framework for describing streams with similar physical characteristics in the absence of human impacts. Reference stream types are determined by reach valley slope and confinement. Additionally, sinuosity was used to distinguish between the C and the E types. Forty-five of the fifty-six reaches are reference stream type C, six are E stream types, four B and one A. C and E stream types occur in unconfined valleys with moderate to gentle slopes and have riffle-pool or dune-ripple bed forms. C and E stream types are also typically warmer and slower moving thus impacting the aquatic species that can live in them (ANR Phase 1 Handbook). A and B stream types occur in steeper, confined valleys. It is very likely that most of the streams in this watershed would be an E type of stream (more sinuous than C) if they had not been straightened. In the Phase 2 Assessment, reference stream types are checked and any stream type departures are noted. See Figure 2 on page 12 for a map of Reference Stream Types.

Basin Geology and Soils

The underlying geology and soils drive the physical characteristics of streams and also affect water chemistry and aquatic habitat. Fifty-two of the reaches have glacial lake as their dominant geologic material and 21 of those have till as the sub-dominant geologic material. The Lemon Fair is a low gradient stream whose valley side slopes are predominantly hilly and steep on a scale that runs flat, hilly, steep, very steep and extremely steep. There are no alluvial fans present as a consequence of the low gradient nature of the area.

The soils for all of the reaches in the study area are in "Hydrologic Group D" of the Natural Resource Conservation Service rating system. This means that they have a slow infiltration rate with high runoff potential. Much of the watershed is clay soil and a lot of the soil in the river corridor is rated "hydric" by the Natural Resource Conservation Service soil survey. Hydric soils are seasonally wet and may support wetlands.

All but six of the reaches are in the flood frequency category of "None/Rare". This means that they have a soil texture that is not indicative of frequent flooding. The remaining reaches are in the "Frequent" category which means that the soil texture is indicative of frequent flooding. Frequent flooding as defined by the NRCS is 50 times in 100 years. Most people who are familiar with the Lemon Fair watershed note that the river has good access to floodplain and that it floods frequently (Hartline, Nicholson, Collins). The soil survey information is derived from nation wide data and these ratings indicate that this soil type is not frequently flooded, which is incorrect for the Lemon Fair (Collins).

The depth to the water table ranges from -1, indicating water on the surface, to greater than six feet. Thirty seven of the reaches have a maximum depth to surface water of one foot, indicating a high potential for ground water inputs into the stream. Fifteen reaches are three feet to the water table and the remaining four reaches are greater than six feet at the deepest times of the year.

Soil erodability is important particularly in a watershed with significant straightening and limited riparian vegetation. Twenty reaches have "moderate" soil erodability, seventeen reaches have "slight" erodability, seven reaches have "severe" erodability and eleven reaches have "very severe" erodability. These rankings are based on the percent of the reach with highly erodable soil.

Land Cover and Reach Hydrology

Land cover affects the rate and volume of water runoff into streams and this in turn, affects the physical characteristics of that stream (ANR Phase 1 Protocols). The current land use pattern is a result of the productive clay soils in this watershed. The majority of land is either in field or crop production with forest and wetland being the next most common categories. Interestingly, zero to twenty five feet is the most common riparian buffer width but greater than 100 feet is the next most common. The split in riparian buffer widths is likely the result of agricultural land use in the watershed: if the land is productive in this watershed, it is under cultivation; if it is too wet or has a lot of rock and ledge, it has been left forested. All but four of the reaches have an corridor impact rating of "high" for land use/land cover. A reach is given a rating of high if more than 10% of it is in crop and/or developed. Only reach T4.06 has greater than 10% of the watershed in a developed category (residential). The lack of riparian buffers and livestock having access to streams has resulted in water quality degradation from nutrient runoff and *E.coli*. (Fraser, Hartline, Nicholson, Collins).

Ground water inputs are important to aquatic ecosystems, especially during periods of extreme high and low temperatures. They are also important to maintaining base flows during normal low flow periods in the summer months and during droughts. Thirty-four reaches have "Abundant" groundwater inputs meaning that there are "frequent wetlands, seeps, springs, or small tributaries adjacent to the channel" (ANR Phase 1 Protocols).

Historic Channel Modifications

Structures, such as dams and undersized bridges and culverts affect the quantity and duration of water and sediment runoff. They also act as physical barriers to streambed incision upstream of them.

Twelve impoundments (dams) were identified using aerial photos, the Vermont Hydrography Dataset 1:5000 scale surface waters theme as well as the State of Vermont Dam inventory. All but one of these has an impact rating of "high", meaning that channel geometry is affected by the structure. The largest, most significant and only dam on the mainstem is the Richville Dam, built in 1954 for "wildlife". This dam creates a large ponded area (reach M13) which was exclude from this assessment because it lacks fluvial characteristics. Dams as well as natural channel spanning ledge function as "grade control" which prevents the bed of the river from eroding downward upstream of it. Grade control has been identified in only two places during this assessment. See Figure 3 on page 13 of this document for a map of dams and ledge.

Bank armoring (i.e. rip-rap) was not assessed in the field. Both Fred Nicholson and Keith Hartline said in interviews that hard armoring was minimal and Nicholson has not issued a permit for rip-rap in twenty years in this watershed. Historic channel straightening is very significant, however, with 42 reaches having an impact rating of "high" for straightening. Reaches are rated "high" when greater than or equal to 20% of the reach is straightened. There is no recent knowledge of dredging on the Lemon Fair. In the past, property owners would windrow the stream, but they have learned that this is not an effective management technique, so they have stopped the practice (Nicholson, interview). See Figure 5 on page 15 of this document for a map of straightening.

There are no permitted water withdrawals on this river, according to Fred Nicholson (ANR) and Keith Hartline (NRCS). However, farmers adjacent to the river and streams do not need a permit for agricultural withdrawals and do use it for irrigation (Nicholson).

Bridge and Culvert Assessment

There are 39 bridges or culverts in the watershed with all of the impacts from these being assessed in SGAT as "not significant" or "low". Thirty five of these structures were assessed in the field using the Bridge and Culvert protocols. The remaining four are on private driveways or roads and were not assessed. Of the bridges and culverts assessed, twelve are less than 50% of the channel width, fifteen are between 50 and 100% of the channel width and six are greater than 100% of the channel width. The apparent under sizing of 27 structures may be an artifact of limited channel width data in the State's hydrologic regional curve database for smaller streams or a function of the curve over-estimating stream width for E type streams (Hill). A Phase 2 Assessment would determine the accuracy of regional curve channel widths for this watershed. Twenty eight of the structures assessed have the potential for ice or debris jams; all but two of the structures have the floodplain all or partially filled by roadway approaches; twenty two of the structures have the potential for "out flanking" (outflanking occurs when water passes around a structure as opposed to flowing through it) and eighteen of the structures have a poor location or alignment. For more details see the "Failure Modes Report – Geomorphic Incompatibility" in Appendix D. For a map of bridges and culverts, see Figure 4 on page 14 of this document.

Floodplain Modifications

Because the Lemon Fair is known to have good access to floodplain (Nicholson) and abundant wetlands, road and residential development have remained limited. Floodplain access is important for flood storage but also for allowing the river room to meander. Very few roads are parallel to the streams and in the river corridor. There are numerous impacts from bridges and culverts in the watershed from perpendicular crossings of the floodway. There are very few depositional features visible on the aerial photos, which may be due to the turbidity of the water

and the high flows when the photos were taken. Meander migration was low and not significant in all but six of the reaches where it was high.

Thirty-four reaches have an impact rating of "high" for meander width ratio (MWR). "Streams that are "in regime" have meander width ratios of 5 to 8 times the width of the channel (ANR Phase 1 Protocols). Lower values may indicate that the stream has become straighter and steeper, possibly degrading its bed and losing access to its floodplain. Higher values may indicate that the stream, possibly due to an increase in fine sediment, has started to aggrade and become more sinuous, decreasing its channel slope as it migrates laterally." Thirty-two reaches have wave length ratios(WLR) with "high" impact ratings. WLR are rated high if they are below 3 or greater than 10

Both MWR and MWL are in the low category, indicating that the stream is straighter and steeper than it would be in regime.

Bed and Bank Windshield Survey

Much of this watershed is not visible from a road and the bed is consistently obscured by the turbid waters. The limited bed and bank survey data in this report is from the bridge and culvert assessment. Erosion impacts are either "no data", "not significant" or "low" based on this limited data. Four structures have in impact of "high" for potential ice and debris jams due to alignment.

Phase I Data Analysis

Impact Scores

Impact scores are assigned to allow for comparison among reaches which can help in setting priorities for further evaluation and also aid in gaining a general understanding of overall watershed health. Impacts are measured and then rated according to the following: Not Significant (NS), low impact, high impact or no information. A zero is scored for options NS and No Information, a one for low impact and a two for high impact. Impacts are divided into four categories based on steps 4 through 7 of the Phase 1 Assessment. In the Lemon Fair Watershed:

- Step 4 "Land Use" accounts for 43.5 % of the total impacts in the watershed. Land Use includes: watershed land cover/land use, corridor land cover/land use, riparian buffer width and groundwater and small tributary inputs. The majority of the reaches evaluated have six out of six impacts. The lowest score is 3 on reach T4.S1.02.

- Step 6, "Floodplain Modification" accounts for 31.9% of the total impact scores in the watershed. Floodplain Modification encompasses: berms and roads, river corridor development, depositional features, meander migration, meander width ratio and wavelength ratio. Out of a possible score of 12, the highest score is 7 on reach T4.02 and on reach T4.S1.01.

- Step 5 "Instream Modification" accounts for 20.1% of the total impact scores. This category includes: flow regulations and water withdrawls, bridges and culverts, bank armoring or revetments, channel straightening and dredging and gravel mining history.

The highest score in this category, out of 10 is 5 on reaches T2.05, T2.S1.04 and T4.S1.03.

- Step 7 "Bed and Bank Survey" accounted for 4.5% of the total impact scores. This category includes: dominant bedform, bank erosion and debris and ice jam potential. Since a complete bed and bank survey was not done for this Assessment, the only parameter assessed for all of the reaches was debris and ice jam potential using aerial photos and the Vermont Hydrography dataset. The high score for this category is 3 out of 4 on M12 and T3.01.

Adjustment Process and Reach Condition

The following table describes the different adjustment processes that streams undergo (ANR Phase 1 Protocols).

Table 3 Phase 1 Adjustment Process Options	
Degrading	Downward erosion of stream bed via a head-cutting process
Aggrading	Excessive sediment build up on streambed and bars
Widening	Erosion of both banks leading to an over-widened streambed
Planform	Rapid and/or irregular meander movement and pattern
None	No significant adjustment process indicated
Multiple	Multiple adjustments indicated

Twenty reaches have multiple predicted adjustment processes. Aggradation and planform are the two most common predicted adjustment processes among all of the reaches in the watershed. Aggradation is indicative of "excessive sediment build up on streambed and bars". Planform is indicative of "rapid and/or irregular meander movement and pattern" (ANR Phase 1 protocols).

Thirty four reaches are in "Fair" condition, seventeen are in "Poor", four are in "Good" and none are in "Reference" for this watershed.

Reach Sensitivity

Stream sensitivity relates to the "inherent characteristics of the stream "in regime" and does not take into consideration any adjustments." (Phase 1 Handbook) Sensitivity is only assigned in the Phase 1 where bed material data was available. Only six of the 56 reaches in this assessment received sensitivity ratings. The scale ranges from "Very low" to "Low" to "Moderate" to High" to "Very High" and finally "Extreme". There are four C channels with sand substrate that have "High" stream sensitivity. The remaining two are both C channels with cobble substrate and "Moderate" sensitivity.

Recommendations

1. Twenty-seven bridges and culverts were found to be undersized during the bridge and culvert assessment. Field measurements of the channel width on reaches with undersized structures will confirm or deny this finding and assist towns and the State when planning for structure replacements.
2. Most of the reaches in this watershed lack riparian vegetation and the Lemon Fair has been found to have elevated phosphorus and *E.coli* levels (Fraser). Rivers depend upon riparian vegetation for: Streambank stability, to provide shade to keep the water cool, to create in-stream habitat as well as terrestrial habitat, to filter runoff entering the stream, and to capture sediment. A focused riparian planting program that includes fencing animals out of waterways would go a long way toward improving water quality throughout the watershed.
3. Flood inundation (as opposed to erosion) is likely the biggest threat in infrastructure and buildings in the watershed. Encouraging towns in the watershed to adopt development review standards that prevent development in the floodplain will mitigate the potential for future flood losses.
4. Although interviews with resource managers indicate that erosion is not a major problem in the watershed, the Lemon Fair consistently runs turbid and has been significantly straightened. An inventory of eroded sites targeting straightened channels and the five reaches that have a "high" impact for meander migration would begin to clarify how much bank erosion is affecting water quality.
5. Many of the streams in the Lemon Fair watershed have been straightened. As a first step toward restoring full fluvial function to the Lemon Fair, Phase 2 Assessments on reaches with the highest impact ratings in sub-watersheds *where there is citizen interest in restoration activities* is recommended. See Phase 1 Data in Appendix A, "Step 8 – Summary of Categorical Impacts".

Maps

Figure 1: Phase 1 Reaches

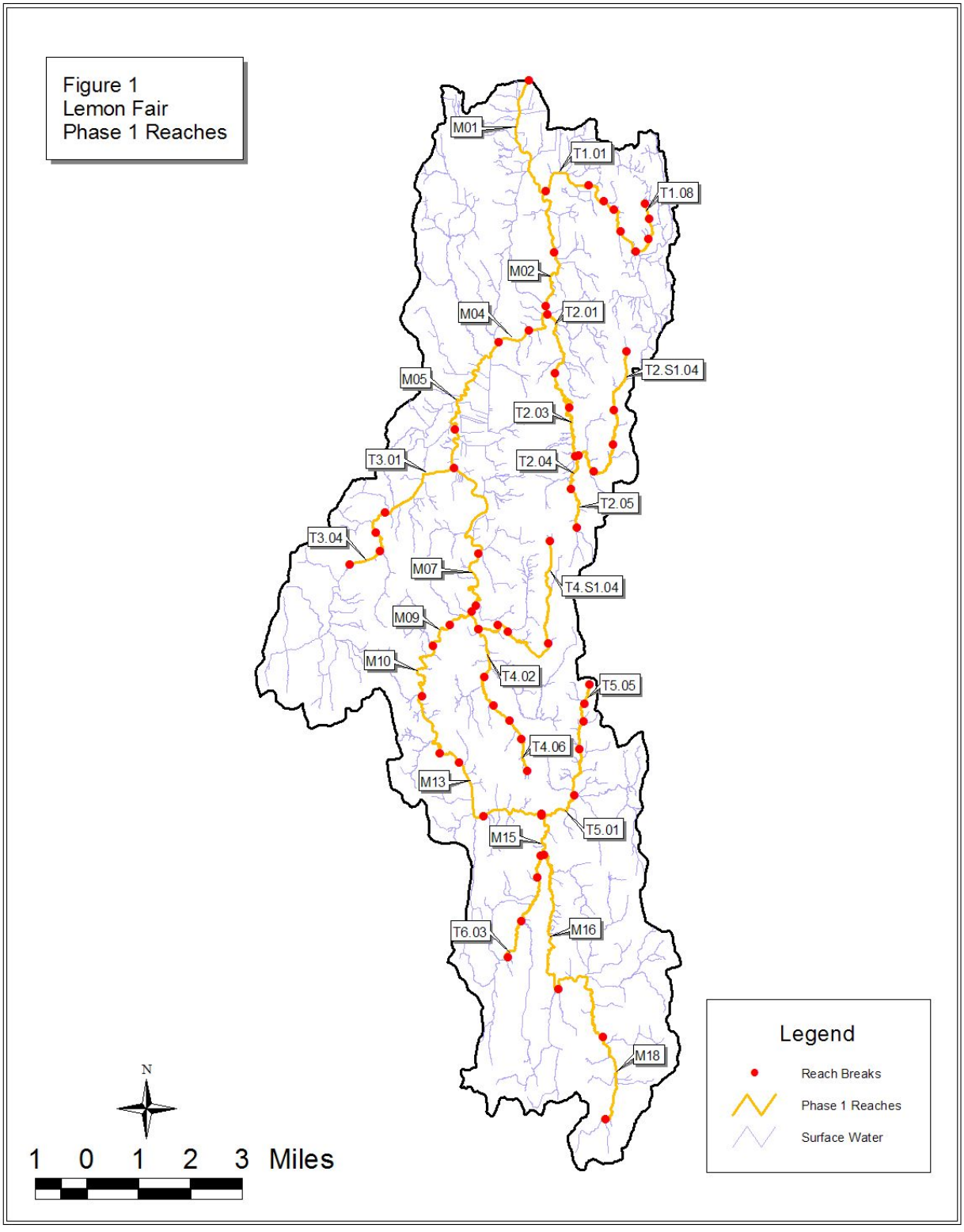


Figure 2: Stream Types

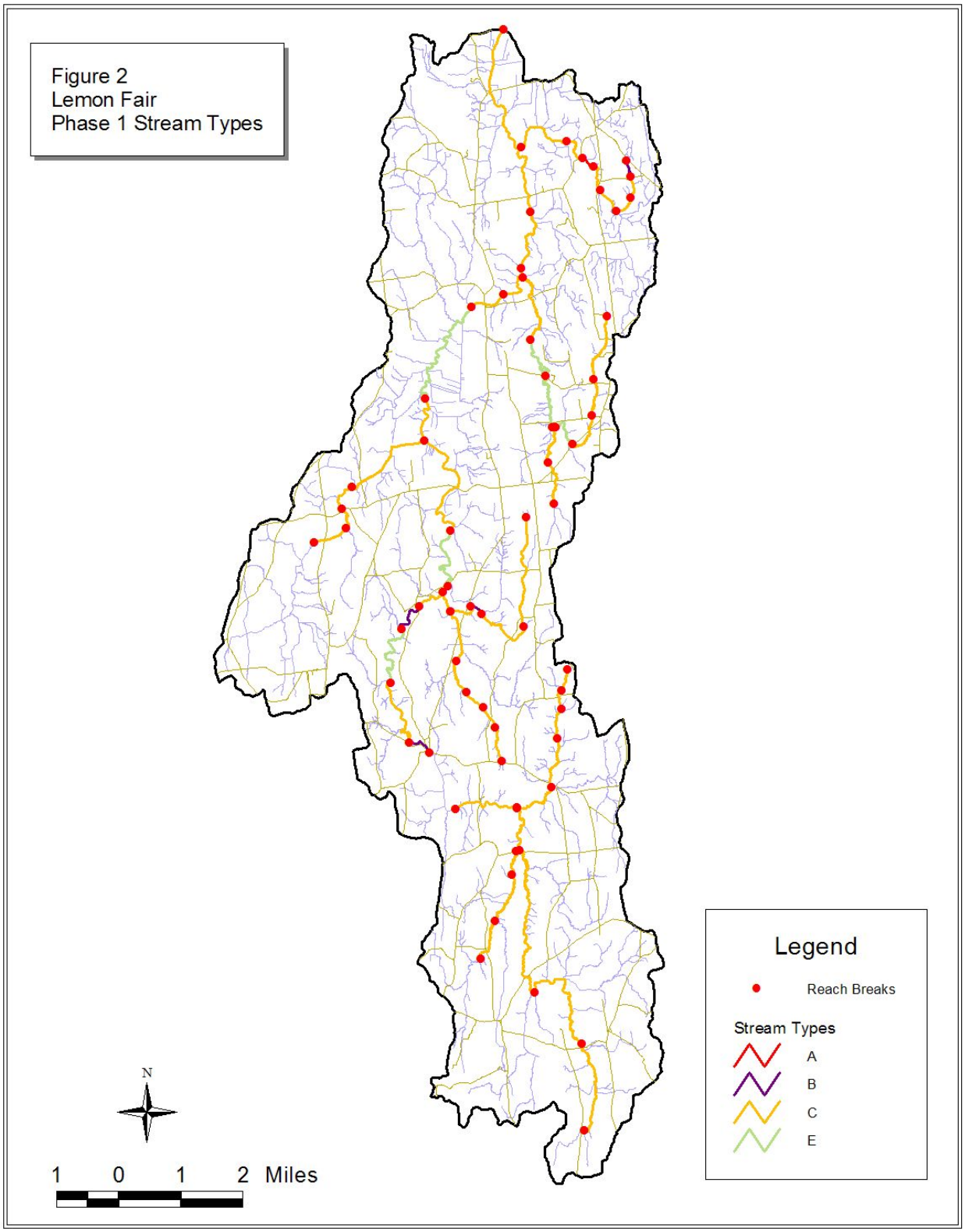


Figure 3: Grade Control and Impoundments

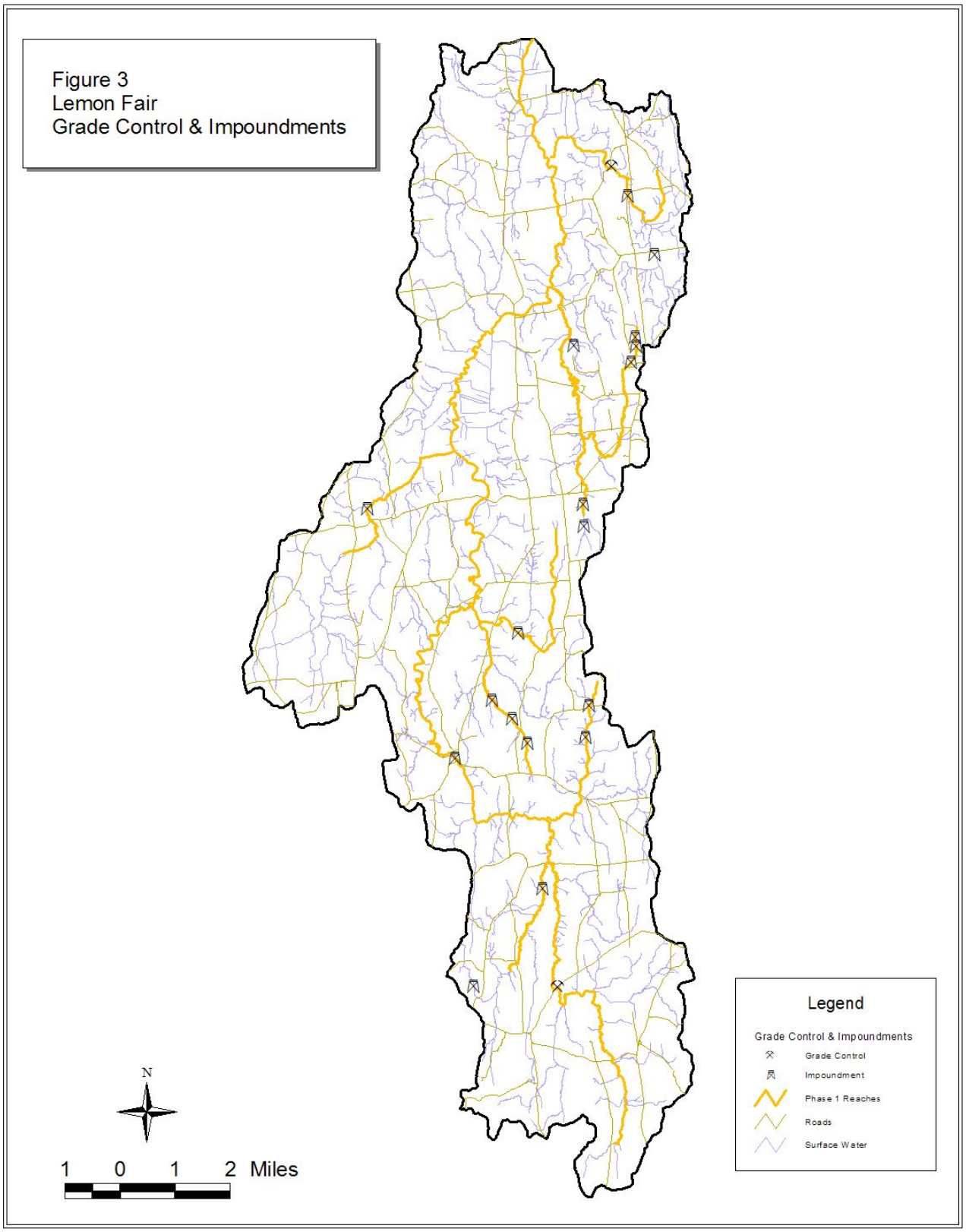


Figure 4: Bridges and Culverts

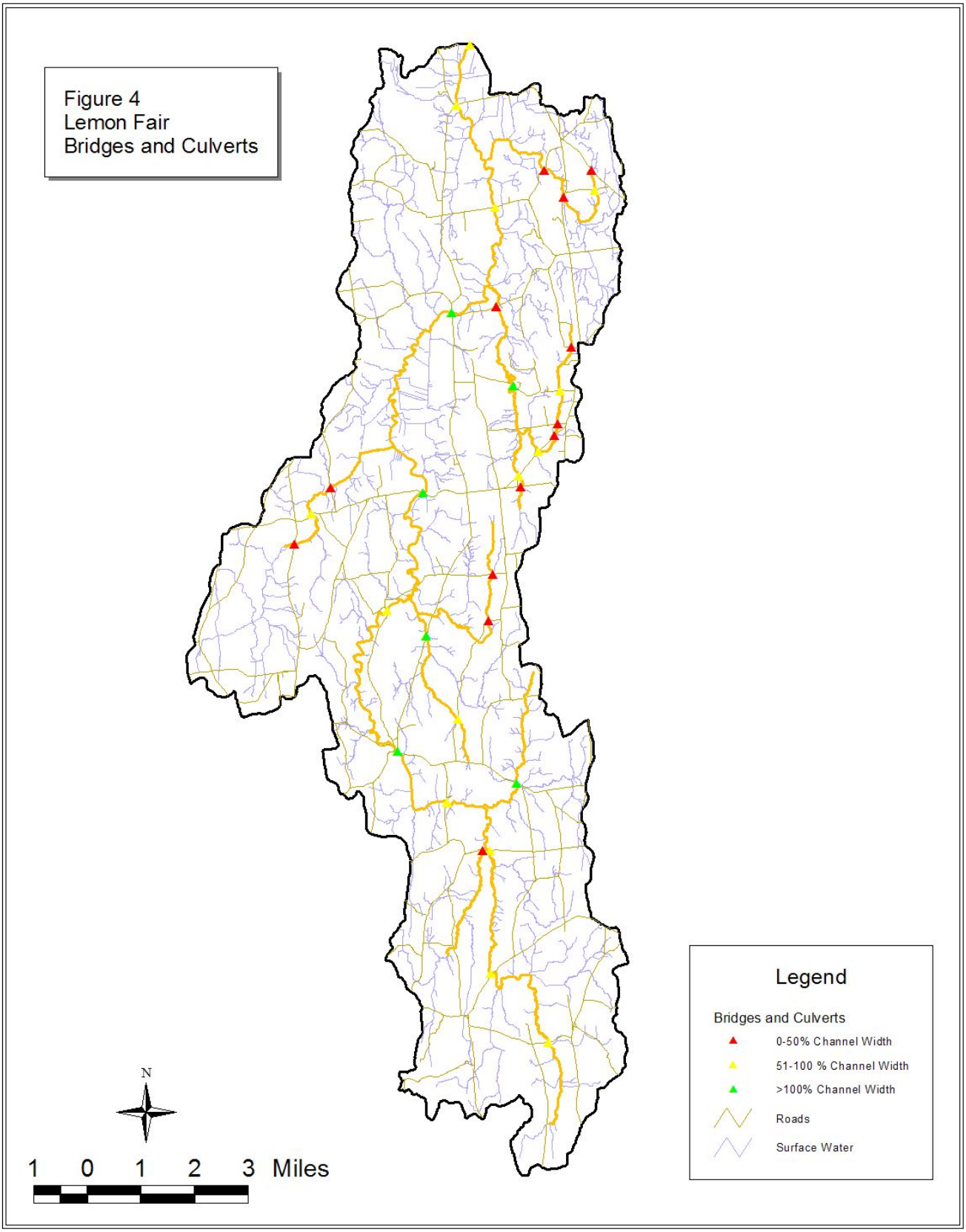
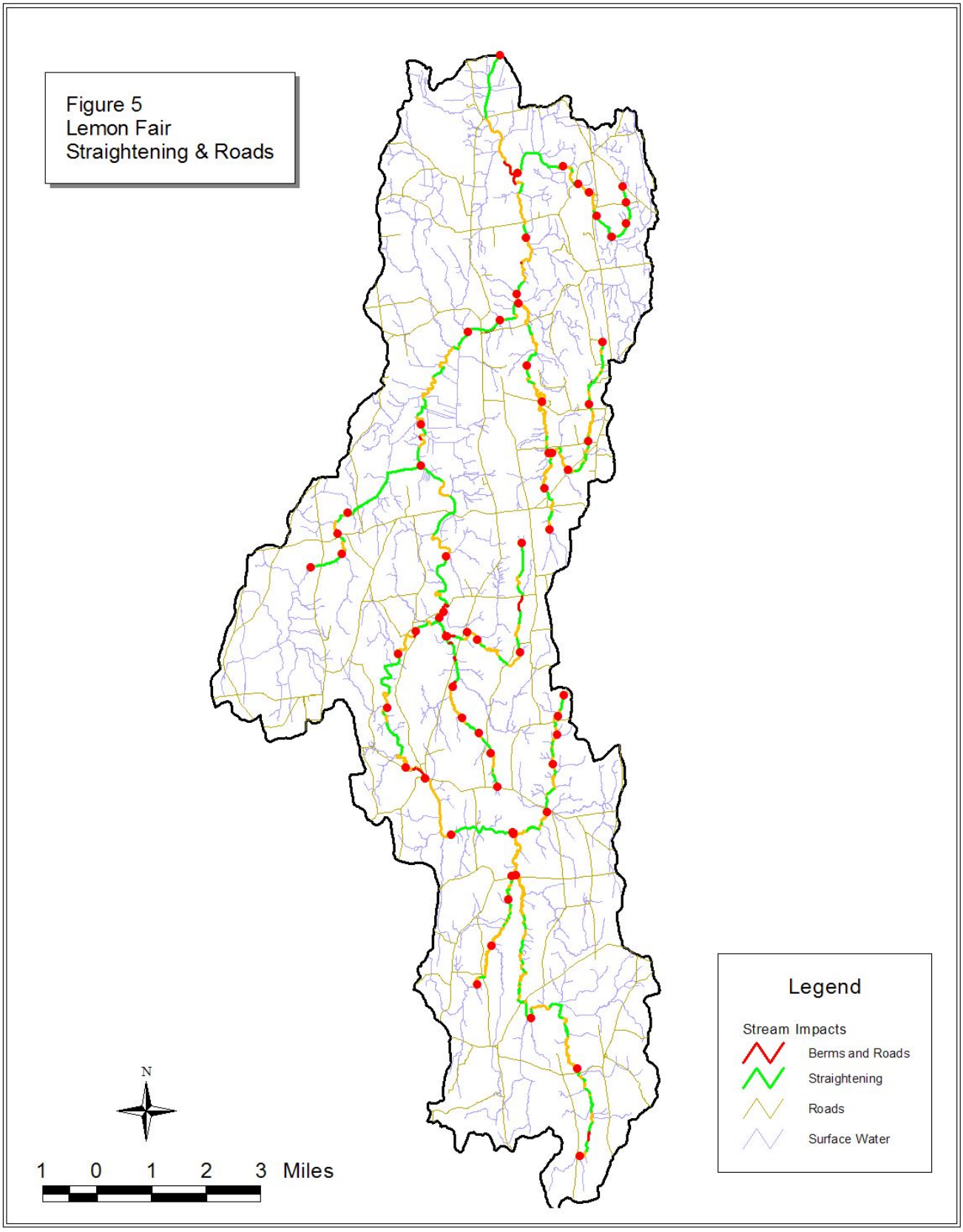


Figure 5: Straightening and Roads



References

Albers, Jan. Hands on the Land: A History of the Vermont Landscape. MIT Press, Cambridge MA, 2000.

C.L. Davis Consulting Associates for Vermont Agency of Natural Resources. Stream Geomorphic Assessment SGAT User Guide, Stream Geomorphic Assessment Tools, Version 4: An ArcView Extension. October, 2005.

Collins, Robert. Natural Resource Conservation Service, Addison County Retired District Conservationist. Phone conversation 2/23/2006.

Fraser, Nell. Addison County Regional Planning Commission, Watershed Coordinator. Phone conversation 2/23/2006.

Hartline, Keith. Natural Resource Conservation Service, Addison County District Conservationist. Phone conversation 1/19/2006.

Nicholson, Fred. Vermont Department of Environmental Conservation, Water Quality Division. Phone conversation 1/20/2006.

Vermont Agency of Natural Resources. Vermont Stream Geomorphic Assessment Phase 1 Handbook – Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. April, 2005.

Vermont Agency of Natural Resources. Vermont Stream Geomorphic Assessment Phase 2 Handbook – Rapid Stream Assessment Field Protocols. April, 2005.

Vermont Agency of Natural Resources. Vermont Geomorphic Assessment, Appendix E, River Corridor Delineation Process. April, 2004.

Vermont Agency of Natural Resources. Vermont Geomorphic Assessment, Appendix G, Bridge and Culvert Assessment. April, 2005.

Vermont Agency of Natural Resources. Vermont Geomorphic Assessment, Appendix H, Meander Geometry. April, 2004.

Vermont Agency of Natural Resources. Vermont Geomorphic Assessment, Appendix P, Mapping Channel Impacts Using the Reach Indexing Tool. January, 2005.

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E