STREAM GEOMORPHIC ASSESSMENT
of the
STEVENS BRANCH
WILLIAMSTOWN AND BARRE CITY UPSTREAM OF THE CONFLUENCE WITH THE JAIL BRANCH

Prepared for: Central Vermont Regional Planning Commission

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Prepared by:
Lori Barg
Step by Step Community Environmental
113 Bartlett Road
Plainfield, Vermont 05667
802-454-1874
loribarg@together.net

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Acknowledgements

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WHO SHOULD READ THIS REPORT AND WHY?

If you don't fish, why should you care about rivers? Here is who should care about rivers and why.

Town Managers/Selectboards: While roads are designed to carry traffic, every roadside ditch can turn into a river. Town managers/selectboards have to understand potential problem areas to help a town spend its limited resources wisely to reduce flood damage.

Road Commissioners/Foreman/Crew: The road crews are the frontline in channeling water safely. Roads and gravel are expensive. Understanding and anticipating potential erosion problems from running water can save time and money in the long and short run.

Property owners: Rivers move, sometimes they only move a little each year, sometimes they move a lot. Property adjacent to a drainage ditch, brook, stream, or river can be impacted by flowing water. What you do can affect your neighbor downstream. What your neighbor upstream does can affect you. Management of water on driveways, logging roads and Class 4 roads requires keeping culverts clean, maintaining waterbars and other preventive measures to avoid problems on town roads.

Property Owners at the foot of the hill. What happens when a steep stream comes down from the hill and hits the flatter valley floor? The stream has built up power on the steep slope, and that energy needs some place to go as the slope flattens out and velocities slow. Generally, a stream in this type of location will carry a large load of gravel, cobbles and boulders and this sediment will be deposited in multiple areas as the stream branches in multiple directions. This is a particularly sensitive area, and it is important to learn how to develop (or not) in these alluvial fan areas.

Driveway owners: Where does the water from your driveway go? Is the culvert at the base of your driveway crushed or blocked? Is your ditch clean? Does your driveway have multiple turn-outs for the water? In some towns, landowners could be responsible for repair costs for water funneling off the driveway and washing out the public road could mean that you are responsible for repair costs. Culverts, if used, should be sized properly. Multiple culverts should not be used as they tend to get blocked with debris easily.

ATV /Snowmobile clubs: Some ATV drivers routinely ride in, or cross streams. There are examples in Vermont of streams deciding to follow an ATV stream-crossing instead of the streambed, causing a major washout downstream (Cahoon, April, 1998). Every wheel rut could be a potential problem, every private bridge can be breached which could block another bridge downstream thus increasing the damage.

Taxpayers: Roads are often the biggest part of a town budget, understanding how roads and rivers interact can save the town and the taxpayer money.

Pond owners: What will happen if your pond washes out? Especially ponds that are on the stream? Whose property will be damaged? Who is downstream? VT ANR recommends against damming streams to build a pond.

Loggers: Loggers often have to build access roads on steeper slopes. Sometimes they have to beef up the bridges, or build culverts so that they can cross them with a loaded truck. Major damage can occur to the property owner and stream without carefully considering the possibility that a major flood might occur each and every day and night. Extra cribbing under a bridge can potentially cause the bridge to breach during a flood event.

Developers: Whether you are building one house, or many, it is important to understand that water runs differently off a roof, than it does off the woods. Flood damage can be reduced by trying to imitate natural conditions as much as possible. This means: flow should not be concentrated or directed, but allowed to infiltrate into the ground. Roof and footing drains daylighted over the edge of steep slopes, driveways that drain a steep slope, and septic systems that cause hydraulic loading can all lead to catastrophic failure depending on the geology of the area.

Fortunately, an ounce of prevention is worth a pound of cure. This report will help you avoid some common mistakes, save taxpayer money and protect public and private property.

Please read Appendix A for a primer on the basics of river science. The Central Vermont Regional Planning Commission and the Vermont Agency of Natural Resources River Management Section can provide additional resources to aid towns to implement the specific results of this study.

Channelized Alluvial Fan atT6.5, near the Chelsea Road in Williamstown.

SUMMARY

From Williamstown to Barre City, the 35 sq. mi. watershed of the north flowing Upper Stevens Branch of the Winooski River was assessed for geologic, geomorphic and river characteristics that contribute to stream stability. The results of this study can be used to 1) prepare maps delineating risk from fluvial erosion and slope instability, 2) to reduce flood damage from streambank erosion and 3) reduce loss of public and private property. The data in this report can be used in conjunction with the Vermont Agency of Natural Resources (ANR) recommendations on reducing flood damage from river erosion (Appendix B)

The study area starts at the confluence with the Jail Branch in the south end of Barre City and continues south to the headwaters in Williamstown. The headwaters of the Stevens Branch in Williamstown drain the Northfield Mountains to the west, and the granite hills to the east.

The Stevens Branch occupies a valley previously occupied by glacial lakes. The Williamstown Gulf, (elevation ~920 ft) was the spillway for south-flowing Glacial Lake Winooski. Fine and coarse grained glacial-lake and glacial-river deposits are located in the Stevens Branch valley. Wetlands subsequently formed on the silty lake bottom deposits, while some of the coarser sands and gravels have been mined. The glacial history has influenced the land uses, ranging from gravel resource extraction, location of groundwater, and the siting of commercial and industrial development on the flat former lake-bed.

The data gathered includes quantitative measurements of channel dimension and geomorphic features such as channel avulsions and mass failures. An inventory of bridges and culverts and flood plain encroachment show areas impacted by human development. 25 geomorphic assessments were completed during the 2003 field season. The mainstem was divided into “Like Reaches” based on geology, channel slope, valley confinement and stream type according to the Phase I ANR protocols (2003). Each reach is uniquely labeled as a mainstem (M) or tributary (T) reach.

Land use in the basin is primarily forested. Road density in the watershed is 3.0 miles of road per square mile, while the stream density is 2.4 miles per square mile. Roads channelize flow, changing slow-moving groundwater into fast moving surface water. Roads can increase flow during floods and can increase flood damage.

The Stevens Branch has wetlands and floodplain access along the mainstem. These features provide flood-storage and serve as a pressure-release valve reducing flooding downstream in Barre City. There are many areas of the mainstem that have been dredged and straightened, particularly near the centers of Barre and Williamstown, and near the interstate access road in Barre. The mainstem of the Stevens Branch has been re-located near the confluence with the Jail Branch (Belding, 1998). Rip-rap has been used to protect infrastructure. The use of rip-rap transfers the problem downstream and increases the impact of flooding on Barre City.

There are only four locations along the ~8.3 mile mainstem where channel-spanning bedrock is found. Two waterfalls are located in Barre City, one in the north end of Williamstown and to the south of Lotus Lake (Cutter Pond). Abandoned dams are located near these waterfalls.

Recent digital orthophotos were overlain on topographic maps to define areas where the stream channel has changed location. Historical data was used to locate areas of previous flood damage. Data is presented as point data that can be incorporated into a geographic information system (GIS).

INTRODUCTION

The Stevens Branch of the Winooski River, upstream of the confluence with the Jail Branch in Barre, was divided into 31 sections or “reaches” according to the Vermont Agency of Natural Resources (ANR) Phase I Stream Geomorphic Assessment Protocols (2003). A stream reach is an area that has similar characteristics, such as channel slope, valley setting and geology. Each reach surveyed was assessed to determine which, if any, stream geomorphic adjustment processes (widening, degrading, changing planform, aggrading) are occurring.

The study was conducted to identify areas:

1) that may be at risk from future floods;
2) where construction should be avoided to reduce risk to public or private property;
3) are constricted by bridges or culverts; and
4) have good fish habitat.

The results can be used to identify areas: 1) where hazards may exist from riverine erosion, channel constriction, or landslides; 2) that may need some “intervention” to restore, and 3) to be protected due to their value as flood storage, or aquatic habitat. Appendix B contains recommendations from the Vermont Fluvial Erosion Hazard Mitigation Program (ANR, 2003). These recommendations can be used in conjunction with the results of this study to help towns plan to reduce flood damage, protect private and public property and make informed decisions.

The study consisted of:

- Collecting and reviewing existing data including cross-sectional and profile data.
- Assessing reaches using the ANR Phase II Stream Geomorphic Assessment Protocols (ANR, 2003); the ANR Phase I bridge and culvert assessment, and dividing some stream reaches into segments on the basis of field investigation.
- Surveying approximately 20 miles of the tributaries and 8.3 miles of the mainstem from Williamstown to Barre.
- Measuring 25 cross-sections and conducting detailed assessments. Reaches surveyed were 12-20 bankfull widths in length.

The results of the field work are available in electronic format in the ANR Access database and as layers in a Geographic Information System (GIS).

SECTION 1.0 BACKGROUND DATA

1.1 DESCRIPTION OF THE STUDY AREA

The Stevens Branch is a 113 square mile watershed that joins the Winooski River upstream of Montpelier. Its major tributaries include the Jail Branch, and Gunner, Berlin Pond, Potash, Orange, Nelson, Martins, Cold Spring and West Hill Brooks. The study area starts at the confluence with the Jail Branch and has a drainage area of approximately 35 square miles.

The Upper Stevens Branch flows north through the towns of Williamstown and Barre Town to Barre City. It is located in Orange and Washington Counties in central Vermont (Figure 1). It encompasses parts of the towns of Williamstown and Barre and is shown on the Barre West, Barre East, Washington and Brookfield 7.5 minute topographic quadrangles.

The study area in the upper Stevens Branch watershed can be characterized as a mostly low-gradient, meandering stream flowing through wetlands on glacial Lake Winooski deposits. There are several steeper sections: 1) near the Barre Elementary School, where bedrock provides grade control; 2) near the bedrock falls in the village of Williamstown, and; 3) in the bedrock-controlled headwaters south of Lotus Lake (Cutter Pond).

The total stream length in the 35 sq. mile upper watershed is 84.4 linear miles as measured using Geographic Information Systems (GIS) with a drainage density of 2.4 miles per square mile. The Upper Stevens Branch watershed contains the named tributaries of Martin (3.84 sq. mi.) and Cold Spring Brooks (3.3 sq. mi.). There are more road miles than stream miles, with total road length of 105.2 miles and a road density of 3.0 miles per square mile. The average gradient of the mainstem is 0.6%.

The highest point in the upper watershed is the summit of Mt. Pleasant at 2053 ft. The watershed is primarily forested. Residential, paved, and "urban'" land, is concentrated near the Towns along the mainstem.

Two major roads - Route 302 and Route 14 - parallel the Stevens Branch for much of its length. Near Barre City, the watershed is densely developed with commercial, industrial and residential areas adjacent to the river along Route 14. Sand and gravel are mined in the Stevens Branch valley from esker (a river that flowed under the glacial ice) deposits. Several large reservoirs are located within the Stevens Branch watershed, including a flood-control dam on the Jail Branch in Orange. Two reservoirs in the upper Jail Branch watershed provide drinking water for Barre.

1.2 BEDROCK GEOLOGY

The Stevens Branch watershed is flanked on the west by the Northfield Mountains, which parallel the Green Mountains, and the Barre granite to the east. Most of the watershed consists of metamorphic schists and phyllites of the Gile Mountain and the Barton River member of the Waits River Formations (Murthy, 1957). These rocks were deposited about 400 million years ago as muddy sediments in a warm tropical ocean. They were later altered by heat and pressure into metamorphic rocks around 350 million years ago. This alteration occurred during a collision of the old North American continent with another of the Earth's plates in a mountain-building event.

Approximately 300 million years ago the continents were united in a large supercontinent called Pangaea. Around this same time, hotter, lighter rocks – now known as the Barre granite, began floating towards the surface. The bedrock in the east side of the watershed consists of the igneous Barre granite, which intruded into the metamorphic rocks. The tearing apart of Pangaea, and the creation of the Atlantic Ocean, began roughly 200 million years ago.

Reaches M1b, M3, M9 and M17 contain channel-spanning bedrock. Reaches with channel-spanning bedrock are less likely to move vertically and laterally.

Figure 1: Map of Upper Stevens Branch Watershed

1.3 GEOMORPHOLOGY

Geomorphology is the study of the shape of the land. The dominant influence on the Vermont landscape is the North-South trending Green Mountains and their associated geologic faults and fractures. The faults and fractures weaken the rock and the water follows these paths. The landscape we see today is primarily a result of three factors; 1) the bedrock geology; 2) the glaciers and surficial geology and 3) water and climate.

The newcomers-the glaciers -scraped away the softer schists and phyllites, while the hard, resistant granite remained as hills. The drainage pattern of the streams is different off the cone-shaped knobs of the Barre granite, than in the softer schists in the remainder of the watershed.

The glacier left behind regions of silt and muck in shallow marshy areas. Some of these wet areas were further developed into ponds and lakes. There are many named ponds and lakes in the watershed including Limehurst and Lotus Lake, Pecks Pond, Bolster Reservoir and an un-named large pond in the headwaters of Martin Brook. Numerous large wetlands are found in the headwaters of Martin Brook and are visible from Route 63.

An understanding of both geological processes and geologic materials is critical for understanding how a river may change over time. For example, streams may erode sand and gravel deposits more easily than clay deposits. A stream cannot incise where bedrock provides channel-spanning grade control.

The changes that typically occur in a river over time are demonstrated in a five-stage model called Schumm’s Channel Evolution Model (Figure 2). The channel evolution model can be influenced by the surrounding landscape and land use which affects how quickly the stream may move through the different stages. Most of the study area is “Stable” in Stage 1 or 5.

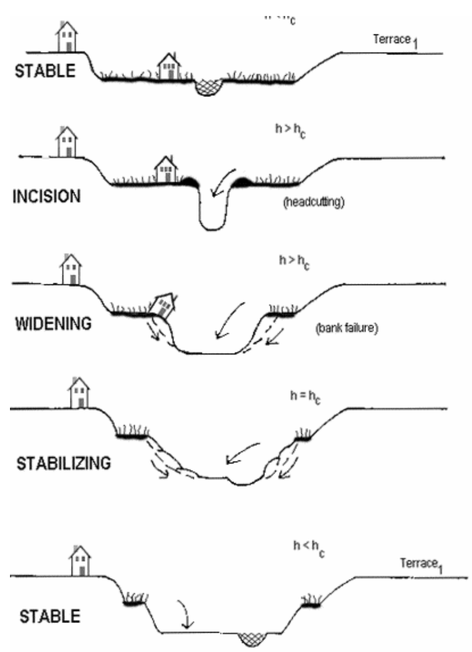

Figure 2: Five Stages of Channel Evolution.
Most of the Stevens Branch is Stable in Stage 1 or 5.

1.4 SURFICIAL GEOLOGY

The glacier left behind different types and amounts of surficial geological deposits. Glacial deposits can be divided into: 1) those left behind by water, either in lakes or rivers, and 2) those formed by crushing the bedrock under the heavy weight of the ice.

Coarser-grained sand and gravel was deposited near the edges of the lakes and along the channel of rivers that flowed under the ice. Rivers flowed under the ice and this river network left behind snake-like deposits after the glacier melted away. These are called eskers, and they are currently being mined for sand and gravel (Wright, 1999a, 1999b). Fine-grained silt and clays were deposited at the bottom of the lake.

Several glacial lakes occupied the watershed. Glacial Lake Winooski (elevation 920 feet), drained south into the valley of the Second Branch of the White River through Williamstown Gulf. As the ice retreated to the north, a new lake - north-draining Lake Mansfield - filled the valleys of the Winooski and finally drained into glacial Lake Vermont through a spillway at Gillett Pond in Huntington (present elevation 750 feet).

The Stevens Branch and its tributaries have reworked the glacial, glaciofluvial, and glaciolacustrine deposits that were left behind after the glacier melted around 12,000 years ago. Many of the sediments left behind by glacial Lake Winooski have been washed out of the Stevens Branch valley. Some of the evidence of the presence of the glacier can be seen in the presence of the eskers, deltas, and abandoned stream terraces.

Above approximately 920 feet in elevation (the elevation of Glacial Lake Winooski), the uplands are covered by glacial till, a mixed up combination of many different kinds of rock that was crushed under the weight of the glacier. This denser, thinner till has lower permeability and correspondingly lower flood storage and groundwater potential.

Surficial geology has practical economic applications. For example, the broad, flat areas previously occupied by the glacial lake are currently used for industrial, commercial and residential development; the mining of the glacial river and lake deposits has provided the fill for countless roads and houses; the deep gravels contain large amounts of groundwater that provide drinking water supplies and a steady stream flow for the fish. Groundwater keeps the river flowing, even in dry summers. The surficial deposits also affect flood storage capacity.

Abby Hemenway wrote *"An inexhaustible supply of peat or vegetable muck is found in all parts of the town [Williamstown], which is used by farmers as an absorbent, and afterwards spread upon the fields as a fertilizer with satisfactory results…around the Lime pond, underlying the soil, is an extensive bed of shell-marl, several feet in depth and covering an area of several acres; large quantities of quick lime have been manufactured from it…"* –Hemenway, 1871, VT Historical Gazetteer.

1.5 SOILS

The Stevens Branch has two main soil complexes. The valley bottoms are covered by the Colton-Buxton-Salmon series that form on sandy glaciofluvial and loamy glaciolacustrine deposits (NRCS, 2003). The Dummerston-Fullam-Vershire complex is found on the hillsides and headwaters on the glacial till. These are well drained to moderately well drained soils.

Soil formation is dependent on both the bedrock and the surficial geology. The calcium-rich waters of the ancient ocean left soils that support maple trees and rich woods on the Gile Mountain and

Waits River Formations. Poorer, more acidic soils formed on the granite outcrops.

The majority of mainstem reaches have well-drained NRCS hydrologic group A and B soils. Hydrologic group A soils have high permeability with high infiltration and low runoff grading to Hydrologic Group B soils which have high runoff and low infiltration (NRCS, 2003). Hydrologic group A and B soils located in steeper areas are more likely to experience more erosion due to their non-cohesive nature.

1.6 HYDROLOGY

Hydrology is a study of how much rain:

1) Falls;
2) Runs off to the rivers;
3) Soaks into the ground to replenish the groundwater;
4) Is used up by the vegetation and the sun (evapo-transpiration/evaporation).

There are no active United States Geological Survey (USGS) gages in the Stevens Branch watershed. Due to this lack of data, three USGS gages were chosen to estimate hydrology. These gages are on the Ottaquechee, Sleepers and the Dog River. These watersheds are relatively close to the Stevens Branch watershed, and the drainage area is between one-half to two times the drainage area as the upper Stevens Branch. The USGS gage on the North Branch of the Winooski was not selected because flows are highly regulated by the dam at Wrightsville.

Flood frequency from the USGS is summarized in Table 1. The bankfull, or channel forming flows, are the flows that move the most sediment (Leopold, 1973) and typically recur every 1.25 - 2 years.

Data collected by the USGS show that of the nine largest floods in this century, there were two major floods in the 1970’s, three in the 1980’s and one in 2000 (Table 3). Five of the nine large floods occurred in the summer months and are associated with intense cloudbursts; two occurred in the fall, and were associated with hurricanes; and two occurred in the spring and were associated with snowmelt. Flood flows usually occur after the soil has been saturated. Summer and fall floods are associated with greater flood damage than winter snowmelt floods. A study by the USGS of 400 gages from 1941 – 1999 found an increase in precipitation has occurred since 1970 due to a change in climate (McCabe, 2002). This has led to an increase in peak flood flows.

The East Barre flood control dam (built in 1935) will reduce the amount of flow by about one-third and the depth of flooding by 4.5 feet in Barre if there was a flood similar to the 1927 flood (Table 2).

There have been no systematic studies of groundwater in the Stevens Branch basin. However, a Groundwater Potential map shows areas of gravel and sand adjacent to the Stevens Branch have good groundwater potential (Stewart, 1971).

Table 1: Frequency flood flows-Cubic Feet per second per square mile (CFSM)

Frequency Data 1998 Bulletin 17-B	Winooski at Montpelier N=82	Stevens Branch tributary N=11	Ottaquechee N=13	Sleepers near St. Johnsbury N=7	Dog River near Northfield Falls N=63	Mean of three stations	Estimated Return flows Upper Stevens Branch (CFS)
USGS Station ID	4286000	4283470	1150900	1135300	4287000		
Mean Annual Precipitation * (in)	40.5	35.3	52.6	41.9	41.3		
Drainage Area. Sq. Mi.	397	0.49	23.4	43	76.6		35
Channel Slope %*	0.5	3.3	2.6	2.3	1.3		0.6
Flood Frequency	**cfsm**	**cfsm**	**cfsm**	**cfsm**	**cfsm**	**cfsm**	**cfs**
1.25 year return flood	12.4	31.4	24.8	30.1	25.7	26.9	940
2 year return flood	18.1	49.0	36.5	40.6	41.6	39.6	1385
25 year return flood	34.3	125.5	77.3	75.0	107.6	86.6	3032
50 year return flood	37.6	148.0	87.3	83.3	126.1	98.9	3461
100 year return flood	40.6	171.6	97.1	91.6	145.1	111.3	3895
500 year return flood	47.1	232.2	120.0	110.7	192.0	140.9	4932
Data source-USGS frequency analysis for VT and NH, 1998, Systematic Record (gage data) *Olson, S. USGS, 2002							

Table 2: Flood Plain Information, City of Barre, Vermont (Corps of Engineers, 1970)

Flood Stage 1927 flood	Depth of Flooding	Peak Discharge 97.4 sq. mi. drainage*	Peak discharge Upper Stevens Branch (35 sq. mi)	Flood velocities feet per second (fps)
570 ft. above sea level	7.5 feet	18,700 cfs	7250 cfs	19
Predicted flood stage with East Barre Dam-completed 1935				
565.5 ft.	3 feet	12,800 cfs	4,600 cfs	7

*at Barre City line (with Montpelier)

Table 3: Historical Floods

	Return Frequency	Precipitation (in)	Peak discharge (Q) Dog River 1935 – 2002		Stevens * 35 Sq. Mi.
			CFS	CFSM	CFS
July 1830	<100	>7(1)			
July 1850		5			
July 1858					
Oct. 1869	<100	4-6(1)			
April 1895		2-2.5 +snowmelt (1)			
Nov. 3 1927	>100	8.63 (4) (Northfield)			7300 (6)
March 17-18, 1936	7-10	4.87 Northfield	5700	74	2600
Sept. 22 1938	25	4.59 (3)	9750	127	4455
June 3, 1947		4.1 (1) Rutland	6450	84	2947
June 1, 1952			7140	93	32
June 30, July 1 1973	25	4.11 (2)	10600	138	4843
August 10-11, 1976	25	2.88 (5)	6680	87	3052
April 18, 1982		snowmelt	5550	72	2536
March 30- 31, 1987		1.58 (5)	7720	101	3527
August 5, 1989		6.72 (2)	8220	107	3756

Precipitation Data:
(1)The Vermont Weather Book Ludlum 1996
(2)NOAA National Weather-Montpelier Airport Station
(3) NOAA National Weather Service records for Northfield Station.
(4) USDA Weather Bureau Monthly Weather Review. Vol. 55 #11. November 1927. p 496 - 497
Flow Data from USGS records
(5) Waitsfield daily precipitation records. Fred Spencer, Mountain View Inn
*Stevens Branch discharge calculated by multiplying Dog River CFSM *35.
(6) Flood Insurance Administration-1970

1.7 HUMAN INFLUENCE

"The streams were formerly well stocked with the speckled trout, but of late years they have become exceedingly scarce." P34-Hemenway, 1882. The History of Washington County including a County Chapter. Vermont Watchman and State Journal Press.

Human activities have changed the flood characteristics of the watershed. Before the land was cleared the water flowed through a forested landscape, and infiltration occurred without concentrating runoff into small channels.

During the 19th century the Stevens Branch basin was mostly cleared of trees. Land clearing combined with the building of small dams and the quarrying of sand, gravel and granite changed the hydrology of the watershed. Human activity has caused more water to run off, and less water to infiltrate into the soils.

The Stevens Branch overflows its banks often. Because of this frequent flooding, construction has been limited near the river. This frequent flooding is fortunate for the city of Barre. Encroachment of the floodplain and restriction of the river upstream of Barre could cause increasingly serious flooding in Barre.

In 1910, the Stevens Branch was channelized and relocated from the confluence with the Jail Branch to downstream of Barre City (Belding, 1998). The City of Barre developed adjacent to the mainstem of the Stevens Branch. Little attention was paid to stormwater or floodplain encroachment, and in some areas development occurs right up to the bank of the Stevens Branch.

Several upstream reaches (M11, 12, 13 and 16) have been dredged, and straightened (channelized) and can be described as gullies through grassed wetlands. These reaches still mostly have access to the floodplain during bankfull events. The grassy (reed canary grass) vegetation adjacent to the channel has good root-binding capacity and severe erosion in these reaches is unlikely.

Other human influences include channel relocation for roads (M3), flood remediation projects including rip-rap, and other channel management practices. These practices can: 1) disturb bed armor which increases the potential for the streambed to lower it's elevation; 2) reduce roughness, which causes the water to flow faster; and 3) cause the channels to adjust their cross-sectional dimensions in response to the increase in velocity and reduced friction. The lack of forested riparian buffer along the mainstem has decreased the amount of large woody debris that can enter the channel. Woody debris provides fish habitat and can also serve to help stabilize the channel.

Historically dams were located near bedrock outcrops. The Woolen Mill dam, located upstream of the Webster Avenue dam breached during the 1927 flood. This breach caused the river to cut a new channel through Webster Avenue. This area was where the largest loss of life occurred during the 1927 flood (Belding, 1998). The 1889 map of Barre shows a dam at the J.S. Robinson Sash and Blind Factory and another at the Moorcroft Flannel Factory (The Hemenway 1882 History of Washington County). These two dams are inactive. They could be removed under a State program that pays 100% of dam removal costs (Finucane, pers. comm. 2004).

1.8 FLOOD DAMAGE HISTORY

Dams and undersized bridges and culverts can exacerbate flood damage. The confluence of the Stevens and Jail Branches are renowned in Barre history for extensive flood damage and loss of life during the 1927 flood (Belding, 1998). During the 1927 flood, Williamstown lost 30 bridges. Luther Johnson writes that an unnamed brook coming down from Northfield to Williamstown:

"*…carried out 5 small bridges on its upper course, at one point damming a bridge with debris and taking to the highway, which had to be reconstructed for some distance. As this brook approached the village...the stream…divided, a goodly portion of it driving a new channel through and alongside the highway for quite a distance….Swollen by the Northfield Brook, Stevens Branch….sought an additional outlet and poured through the railroad cut, washing out the tracks….near Mill Village, it dug a huge chasm, several hundred feet long and over a hundred feet wide and 25 feet deep at one point. [In Williamstown] thirty bridges were either washed out or rendered impassable.*" (Johnson, L. 1928).

Complete records of the cost of flood damage are not available. Some known costs of floods are summarized in Table 4. The costs of management practices such as rip-rap and dredging, culvert and bridge replacement and loss of property are not well-documented. Multiple federal agencies including: the Federal Emergency Management Agency (FEMA), the Natural Resource Conservation Service (NRCS), the Army Corps of Engineers (ACE), and their predecessors often do emergency work. Vermont Emergency Management and local road crews and property owners pitch in. Many costs have gone unrecorded. For example, Johnson (1928) documents 30 bridges that were washed out in Williamstown, but there is no record of the cost of fixing or replacing those bridges. Minsinger (2003) writes:

"Williamstown lost 30 bridges and about $38,000 in highway damage. The town was nearly cut off with the road to Barre cut off as the Gale bridge was partially washed out as well as a culvert further downriver. The road in the Williamstown Gulf was washed out, as was the road to Northfield where five small bridges were swept away. As the Northfield Road brook joined the Stevens Branch of the Winooski a number of buildings were partially damaged, undermined, or swept away. The Stevens Branch itself cut through the railroad cut below the Seaver mill washing out the tracks and dug a large chasm up to 25 ft. deep by several hundred feet wide. The road from Williamstown to Washington was heavily eroded with the loss of one bridge. The road from Williamstown to Broughton Corner lost three bridges. Several bridges on the East Orange Road were swept away and the road heavily eroded in several areas…As the Jail Branch was joined by the Orange Brook near East Barre the floodwaters carried away long lengths of state highway and eroded into the hills below East Barre washing out the 15 inch water main which supplied the city of Barre. The damage to Rte 302 in this area was estimated at $75,000."

A single culvert blocked by debris on Quarry Hill in Barre in 1983 washed out a "lengthy stretch of Quarry Hill Road" (Figure 3). The Nov. 8, 1927 Rutland Herald states that Barre had "property loss $2,000,000".

Figure 3: Quarry Hill Road, May 1983. A four-foot culvert blocked by debris washed out Quarry Hill from Johnson Paving to within several hundred feet of the Barre City line. Tributary not assessed during study. Times Argus Photo.

Table 4: Documented Flood Costs

Year	Town	Cost at time of flood
	Williamstown	**Total**
1927	Highway damage	$38,000
1928	900 –dwellings 350-stores and stock 700 – misc.	$1,950
1989-2000	$38,040	$38,040
	Barre-Town Report	
1927	Streets, water, fire, health, admin	$40,441
1928	$212,825-dwellings and contents $380,275-stores and stocks $360,400 misc.	$935,500
1938	$18,000 buildings	$18,000
1983	Quarry hill culvert washout	$68,000
1989-2000	$103,493	$103,493
Total Flood Damage		**$1,243,424**

Sources: CVRPC Central Vermont Disaster Records 1989-2000, Town Annual Reports and Vermont Flood Loss and Damage Survey 1928, Vermont Flood Survey Committee. Times Argus May 10,12, 1983 "Quarry Hill Work awaits a survey", "Price Tag for Hill Road".

1.9 DRAINAGE DENSITY AND ROAD DENSITY

The drainage density measures the number of stream miles per square mile of drainage area. Drainage density was calculated from a GIS surface water layer from 1:5000 series orthophotos to be 2.4 mi. of stream per square mile. The Stevens Branch watershed has more road miles than stream miles. The road density is 3.0 mi. per square mile (number of road miles per square mile). Each road potentially creates a drainage channel on either side of the road. If the road density exceeds the drainage density, it indicates that the water is being delivered more quickly to the streams than in times past. This increases the amount of water that runs off and can cause increased flooding.

The construction of the railroad (that paralleled the Stevens Branch from Barre to Williamstown) and the dense road network, with many undersized bridges and culverts, further influences the hydrology. The ditches on the side of the road channel water along the road, intercepting slow-moving groundwater and turning it into fast-moving surface water and creating isolated wetlands. The roadsides ditches increase erosion, and send more water to the rivers. The rivers respond to this increase in flow by becoming wider and/or deeper (Forman, 1998).

SECTION 2.0 ASSESSMENT METHODOLOGY

2.1 METHODOLOGY: DATA REVIEW

A comprehensive review of existing information included:

- Bridge assessment data from the Vermont Agency of Transportation.
- FEMA floodplain studies (1970, 1976, 1977).
- AOT bridge engineering drawings.
- Historical information from town clerks, town histories and books including: Luther Johnson’s: Vermont in Floodtime and Floodtide of 1927; Patricia Belding’s “Come Hell and High Water” 1998; Dean Perry's “Barre in the Great Flood of 1927”; A History of Williamstown Vermont, 1991, Minsinger’s 2003-The 1927 flood in Vermont and New England, November 3-7, 1927.
- Overlays of orthophotos and topographic maps along the mainstem.

2.1.1 SUMMARY OF BRIDGE DATA

The Vermont Agency of Transportation maintains a bridge inspection database that assesses the condition of the channel, the banks and the bridge. Table 5 summarizes results of the AOT database. 37 bridges are listed in the AOT database on the Upper Stevens Branch and it’s tributaries. Only 12 of these bridges have been rated in the AOT database, six of these bridges rated 4, 5 or 6 for Channel Protection indicating that they are susceptible, or have been damaged by flooding. Two bridges rated “1” for scour susceptibility and are the most likely to experience damage from scour.

If the bridge or culvert is too narrow and constricts the river, then during storms, the water can become “backed up” on the upstream side of the structure. On the downstream side, this fast-moving water causes scour and can undermine the structure. Flood damage can also be increased if private driveways direct flow onto town highways causing washouts and damage.

Table 5: AOT Bridge Database

Town Name	Route Name	Reach Number	Bridge Number	Feature Intersected	Location	Year Built	Length Of Max. Span	Channel Protection Rating	Scour Susceptibility
Barre City	C30mi	M1a	6	Stevens Branch	0.1 Mi To Jct W Cl1 Th2	1967	47	6	2
Barre City	C30pa	M1b	13	Stevens Branch	0.1 Mi To Jct W Cl1 Th2	1997	93	8	1
Barre Town	Fas 0214	M2	11	Stevens Branch	0.1 Mi W Jct Vt 14	1949	90	8	3
Barre Town	Vt63 - Conn	M3	5	Stevens Branch	0.1 Mi W Jct. Vt.14	1970	15 (2)	6	2
Barre Town	C3059	M3	10	Stevens Branch	Snowbridge Rd	1974	65	8	2
Williamstown	Vt14	M8	60	Stevens Branch	4.5 Mi S Jct. U.S.302 E	1929	23	5	2
Williamstown	C3025	M9	25	Stevens Branch	At The Jct Of Cl3 Th12	1991	26	7	2
Williamstown	C3012	M9	22	Stevens Branch	Beckley Hill	1996	35	7	2
Williamstown	NA	T5.01	20	Trib	NA	2003	NA	NA	NA
Williamstown	Fas 0205	M11	9	Stevens Branch	0.2 Mi E Jct Vt 14	1977	10 (2)	6	3
Williamstown	Vt14	M12	58	Stevens Branch	6.2 Mi S Jct. U.S.302 E	1931	23	6	2
Williamstown	NA	M14	54	Stevens Branch	NA	NA	7.5	NA	NA
Barre	NA	T1.5	64	Trib	NA	NA	8	NA	NA
Williamstown	NA	T5.01	61	Cold Spring	NA	NA	6	NA	NA
Williamstown	C3009	T3.01	26	Martin Brook	0.3 Mi To Jct W Vt14	1919	30	8	3
Williamstown	NA	T5.01	28	Trib	NA	NA	15	NA	NA
Williamstown	NA	T5.01	29	Trib	NA	NA	14	NA	NA
Williamstown	Vt64	T6.01	10	Brook	0.1 Mi W Jct. Vt.14	1900	21	4	1
Williamstown	NA	T6.01	2,59,10, 21	Trib	NA	NA	16	NA	NA
Williamstown	NA	T6.5	57	Trib	NA	NA		NA	NA
Williamstown	NA	T6.5	56,10,3, 35	Chelsea Road	NA	NA	12	NA	NA
Williamstown	NA	T7.01	55	Trib	NA	NA	11	NA	NA

Item 61 - Channel And Channel Protection

Code	Description
8	Banks Are Protected Or Well Vegetated. River Control Devices Such As Spur Dikes And Embankment Protection Are Not Required Or Are In A Stable Condition.
7	Bank Protection Is In Need Of Minor Repairs. River Control Devices And Embankment Protection Have A Little Minor Damage. Banks And/Or Channel Have Minor Amount Of Drift.
6	Bank Protection Is Being Eroded. River Control Devices And Embankment Protection Have Widespread Minor Damage. There Is Minor Streambed Movement Evident. Debris Is Restricting The Waterway Slightly.
5	Bank Is Beginning To Slump. River Control Devices And/Or Embankment Have Major Damage. Trees And Brush Restrict The Channel.
4	Bank And Embankment Protection Is Severely Undermined. River Control Devices Have Severe Damage. Large Deposits Of Debris Are In The Waterway.

2.2 FIELD ASSESSMENT

Field data was collected according to protocols developed by the Vermont Agency of Natural Resources (Phase 2, 2003). The location of features of special interest such as bedrock control, channel avulsions and mass failures were noted on 7.5 minute topographic maps or orthophotos in the field. Photographs of every cross-section and select features are in Appendix C.

Cross-sections were surveyed at the elevation of the top of bank as recommended in the Phase 3 protocol (ANR, 2003). Cross-sectional measurements included the floodplain beyond the top of bank. All assessments determined left bank/right bank by facing downstream.

The field work was completed in the fall of 2003. All cross-sections on the mainstem and tributaries were measured during a three day period during the last week of October. This period included a bankfull flow event on October 29th, the mean daily flow was 20.1 cfsm at the Dog River gage that day, the peak flow data on that date is not available at this time. Cross-sectional data was entered in ANR's Phase 3 spreadsheet for stream geomorphic data (Appendix D).

Since most of the vegetation adjacent to the channel is herbaceous, the occurrence of a bankfull event during the survey period was extremely important, as it is very difficult to determine bankfull elevations with herbaceous buffers. This fortunate timing for surveying cross-sections meant that the debris line was evident and bankfull elevations of the cross-sections were easy to determine. All cross-sections were measured during moderate to high flows. Of note, was the lack of turbidity in the mainstem during these high flows.

Lori Barg worked with Bill Toussaint and Russ Juergens of Central Vermont Regional Planning Commission to complete the field work. The Phase 1 stream geomorphic assessment was completed one year after the field work. Additional reaches were added during Phase 1, and some tributaries that were assessed during the field work are not included in the Phase 1 database. These tributaries are: T1.5 (a stormwater impaired tributary that flows west into the reach break at M4), T2.8 (north and adjacent to Cold Spring Brook-T3 watershed) and T6.5 (bedrock controlled tributary with alluvial fan that parallels the Chelsea Road south of Williamstown).

2.3 DATA PRESENTATION

Locations of features and cross-sections are provided as point data in Arcview 3.3, a geographic information system (GIS) program (Appendix E). Point location data is provided for:

- Rapid Assessment Sites on tributaries and mainstem.
- Reach breaks from ANR Phase I assessment.
- Phase I bridge/culvert survey sites.

The CVRPC and others can use these data layers to create a map of potential flood hazard areas. The Vermont ANR maintains an Access database with complete results of this study.

SECTION 3.0 SUMMARY OF RESULTS:

The results are generally organized by stream reach and are further subdivided into the tributary streams. Selected results of the field work are presented in the body of the report. A summary of results is in Appendix D. Photographs of each cross-section are found in Appendix C.

3.1 RESULTS OF QUANTITATIVE GEOMORPHIC ASSESSMENTS

3.1.1 HYDRAULIC GEOMETRY

Stream cross-sections are measured to determine if they are stable. Stable rivers have no large deposits of sand or gravel, there is minor erosion, and the river has the ability to move its water and sediment in balance. Unstable river systems have large sections of collapsing banks; the river widens and/or cuts deeper into its channel, and sand and sediment fill natural pools.

One measure of the stability of the river is the width-depth ratio (Table 6), which is determined by dividing the measured bankfull width by the mean bankfull depth. Over-widened rivers have larger width/depth ratios, often over 30. The width/depth ratios can be used to determine the departure from " normal" for similar stream types. Except for mainstem reach M14, which is slightly over-widened, all measured cross-sections in the Stevens Branch watershed are within "normal" ranges. There are some stream reaches with low slopes and width/depth ratios less than 10. These are typically channelized reaches with floodplain access.

The other important parameter is the entrenchment ratio (ER), which measures how easily the stream can access the floodplain. The floodplain serves as a pressure release valve allowing the river to spread out during floods. The ER is determined by dividing the floodprone width (the width at twice the maximum depth) by the bankfull width. Streams with an ER greater than 2.2 access the floodplain during bankfull events (Rosgen, 1996). Table 6 shows that reaches with access to the floodplain are found in the upper, middle and lower parts of the watershed indicating that there are multiple opportunities for floods to overflow the banks. This reduces the pressure on the channel banks at multiple locations. The mainstem reaches with low ER (<1.4) indicate reaches that are more likely to experience bank erosion and sideways movement (lateral migration) of the river channel. Steep headwater tributaries generally have low entrenchment ratios and are incised, this is "normal" for that type of stream.

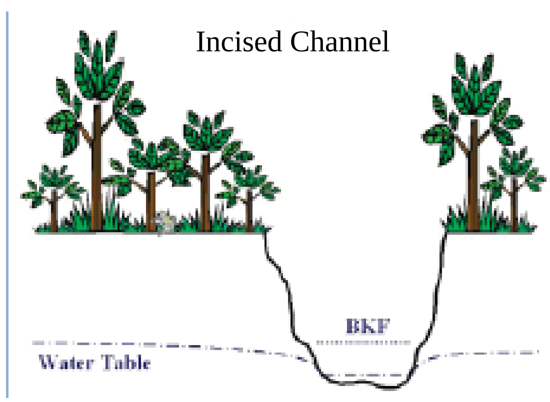

Figure 4: Incised Channels have low Entrenchment ratio. The flood flows are contained within the banks. This causes increased scour and erosion.

Table 6: Stream Geometry

REACH NO.	Drainage Area (sq. mi.)	Channnel Slope (%)	Area bankfull (sq.ft.)	Width bankfull (ft.)	Depth max (ft.)	Depth bankfull mean (ft.)	Flood Prone Width (ft.)	Bank Height (ft.)	Bankfull Width/ Mean Depth ratio	Entrench ment Ratio: Flood prone width/ bankfull width	Rosgen Stream Type
MAINSTEM REACHES											
M1A	34.79	0.91	127.36	40.24	4.35	3.16	60	5.7	12.71	1.49	B3
M1B	34.6	0.91	112.33	38.60	4.80	2.91	80	5.2	13.26	2.07	B5C
M2	34.33	3.82	114.47	54.08	3.05	2.12	200	4.5	25.55	3.70	C1A
M3	34.15	0.21	140.19	44.08	5.40	3.18	120	6.6	13.86	2.72	C5
M4	29.38	0.16	137.69	39.80	5.45	3.46	100	6.6	11.51	2.51	E4C
M5	26.20	0.31	127.26	39.00	4.00	3.26	70	6.3	11.95	1.79	E4
M6	23.62	0.32	95.23	39.48	3.00	2.41	60	5.7	16.37	1.52	B4C
M7	16.57	0.65	91.56	28.78	4.80	3.18	75	6.2	9.04	2.61	E4
M8	16.49	0.39	91.91	27.56	4.80	3.33	100	5.7	8.26	3.63	E5
M9	12.51	3.09	55.87	28.09	3.30	1.99	38	6.1	14.12	1.35	A1
M10	12.40	0.50	36.89	28.99	2.70	1.27	150	3.5	22.78	5.17	C4
M11	8.44	0.12	52.42	29.83	2.95	1.76	40	5.7	16.97	1.34	F4
M12	Not measured, similar to M13-channelized reach through wetland										
M13	6.44	0.44	31.38	8.70	3.80	3.61	200	3.8	2.41	22.99	G5
M14	2.10	0.72	23.95	29.85	1.50	0.80	65	1.5	37.21	2.18	C4
M15	Dredged in 2003										
M16	0.93	2.94	14.25	13.88	2.00	1.03	100	2.45	13.51	7.21	C4
M17	0.88	6.88	13.12	15.30	1.55	0.86	20	4.5	17.84	1.31	F2
TRIBUTARY REACHES											
T1.5	0.4	10	14.12	11.38	1.70	1.24	50	2.1	9.18	4.39	E3B
T2.8	1.3	6	7.80	8.00	1.50	0.98	12	6.0	8.21	1.50	G4B
T3.01	5.52	4.22	35.17	19.00	2.40	1.85	200	3.2	10.26	10.53	A4B
T4.01	1.33	5.6	7.81	10.85	1.05	0.72	20	4.2	15.07	1.84	B3
T5.01	3.3	1.73	19.45	15.88	1.85	1.22	100	3.4	12.96	6.30	C3B
T6.01	3.84	3.06	30.94	27.87	1.55	1.11	37	4.4	25.10	1.33	F2A
T6.5	1.4	5	20.30	15.27	2.00	1.33	22	4.5	11.48	1.44	A2
T7.01	1.52	7.07	18.84	20.15	1.50	0.93	100	3.1	21.67	4.96	C3B

3.2 QUANTIFYING HORIZONTAL AND VERTICAL CHANGE

The channel migration zone (King County, 1998) is an important parameter for determining potential hazard. It is derived by overlaying aerial photos from different time periods. Historic changes in channel location are combined with present day channel characteristics to delineate the channel migration zone. There are no areas of the Stevens Branch with substantive lateral migration. However, an overview of the map shows that there are several areas where the stream has been straightened and flood-plain encroachment has occurred. In these areas (Figure 5) flood damage can be expected to increase downstream due to the higher velocity of the water in the straightened reach. Historical records in Williamstown document downcutting of 25 feet in elevation along one reach in Williamstown (Johnson, Minsinger).

Beavers are active throughout the watershed. These beaver dams have several impacts: 1) they provide temporary grade control; 2) they can fail, increasing flood damage downstream; 3) beavers eat the stream-side trees.

A review of Agency of Transportation bridge drawings was conducted to seek historical information related to vertical and horizontal change. No surveys were found that could be used to quantify vertical change. Channelization of the Stevens Branch downstream of Route 63 is shown in Figure 6 (AOT, 1965). Channelizing a river increases the slope, which increases the velocity and the streams energy, which can increase flood damage downstream.

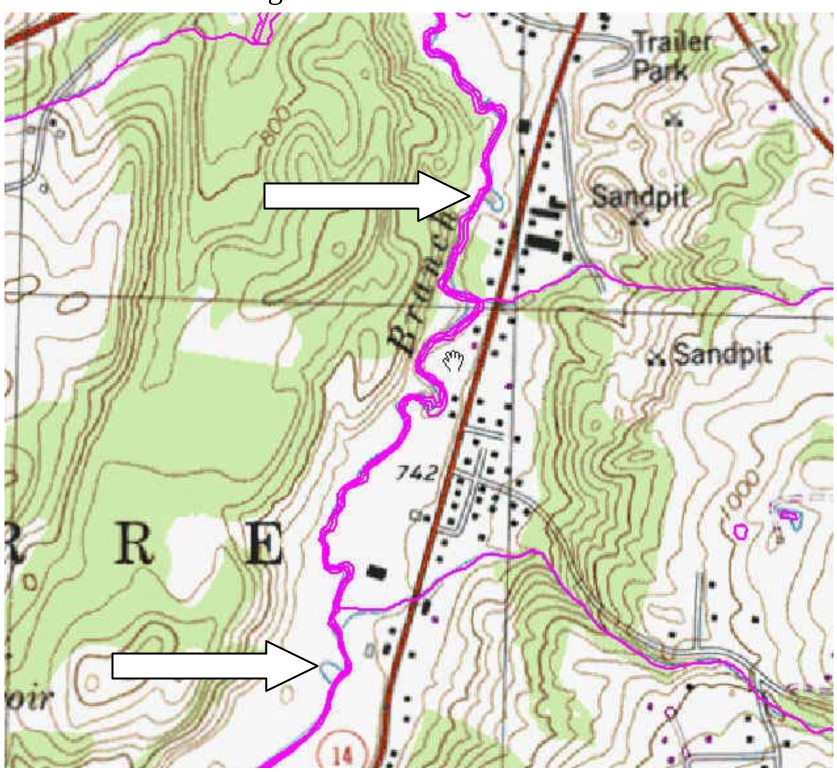

Figure 5: Channel Avulsions and flood plain encroachment. Note the two areas (arrows) where channel avulsions have occurred, or the stream has been straightened. The area to the north (west of the sandpit) has been filled in and construction has occurred.

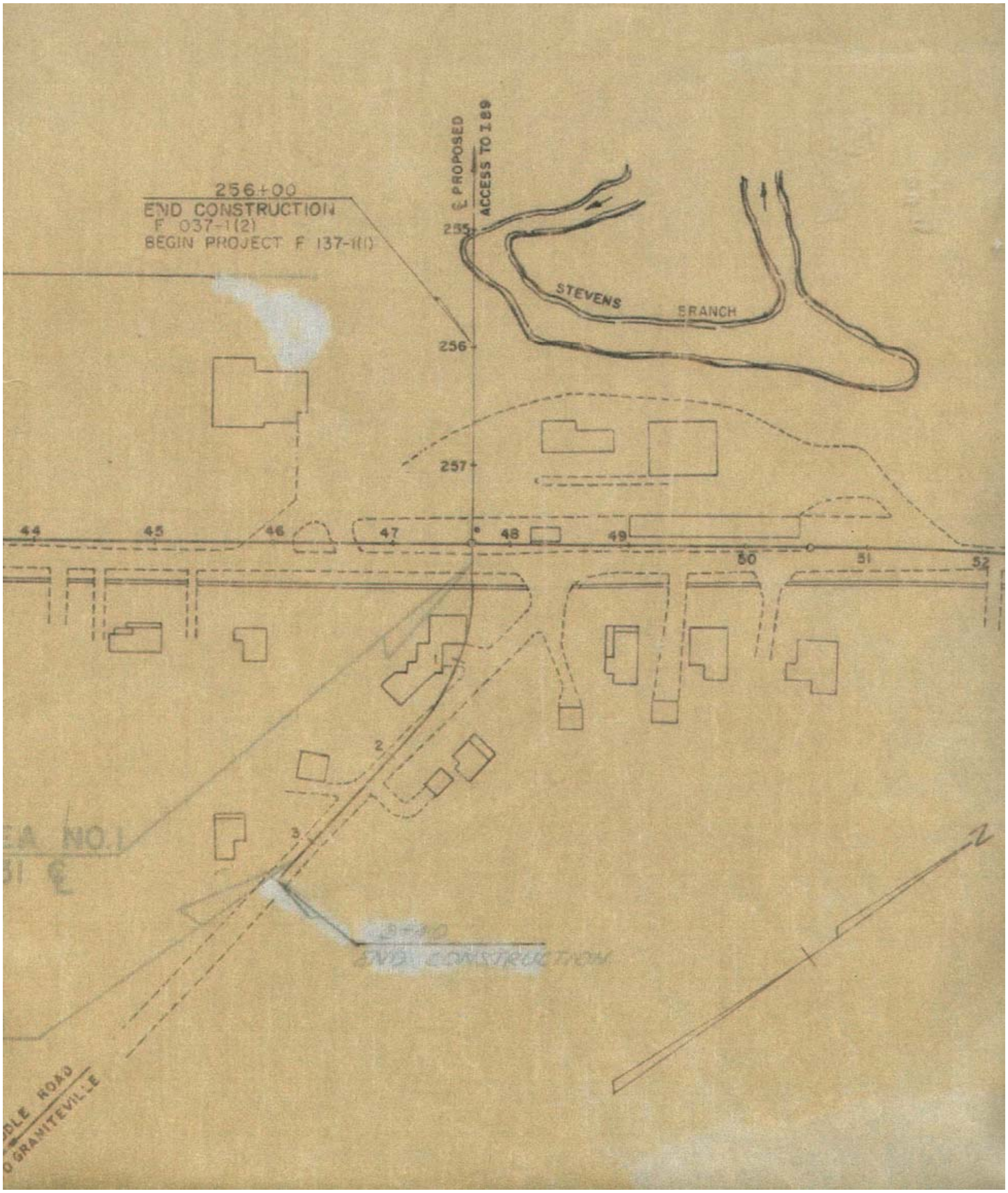

Figure 6: Channel Straightening. This Vermont Agency of Transportation survey shows a big bend in the Stevens Branch in 1965 prior to the construction of the Route 63 access road to Interstate-89 from Route 14 in Barre. The present channel has been straightened. The steeper channel slopes that resulted from channel straightening lead to increased stream velocity and increased flood damage downstream of the straightened area. Reach M3.

SECTION 3.3 CHANNEL CONSTRICTION WITH INFRASTRUCTURE

Data on bridge or culvert width was measured during the Phase 1 bridge and culvert survey or derived from VT Agency of Transportation database using the parameter titled "length of maximum span" which goes from abutment to abutment. Cross sections were surveyed away from the influence of bridges or culverts. Figure 7 shows that in about half of the structures, the channels were significantly constricted by either bridges or culverts. A channelized reach, M13 (not shown) has a triple culvert. On tributaries with multiple structures, the furthest downstream bridge or culvert was used in Figure 7.

Bridges and culverts that constrict infrastructure do two things:

1) Water slows down on the upstream side of the bridge, this causes sediment to deposit which blocks the bridge;
2) Velocities are increased as the water speeds up to squeeze through the bridge/culvert. This increases scour and erosion on the downstream side of the structure. It can also lead to undermining the footings of the bridge.

Sizing structures properly has long-term economic benefits. For example, on Bridge #00002 in Williamstown, the design by the Vermont Agency of Transportation notes "Taper from the design channel width (15')..' (TH2811, 1977). A measured cross-section on T6.01 upstream of this bridge has a bankfull width of 28 feet, this bridge constricts the channel by almost half. This tributary has seven culverts and bridges along a 1.4 mile stretch of road. The effect of multiple undersized structures increases the impact to the stream and adjacent property owners.

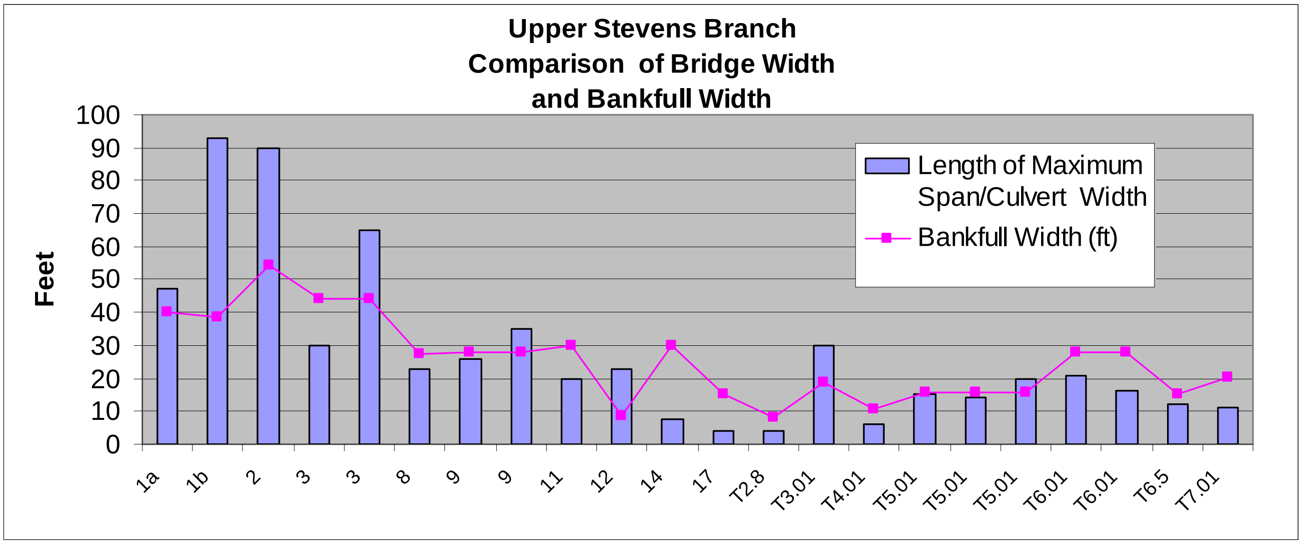

Figure 7: Comparison of Bridge/Culvert and Bankfull Width. Where line is above the vertical bars, the structures constrict the channel. Ideally all reaches would have a bridge/culvert width that is greater than bankfull width. The * indicate bridges with piers in the middle of the channel. Piers can catch debris and restrict flood flows.

SECTION 4.0 RESULTS OF QUALITATIVE GEOMORPHIC ASSESSMENTS

4.1 RAPID GEOMORPHIC ASSESSMENT AND RAPID HABITAT ASSESSMENT

The Rapid Geomorphic Assessment (RGA) rates a stream for four variables: widening, incision (degradation), change in planform and aggradation. The Rapid Habitat Assessment (RHA) is based on EPA's Rapid Bioassessment Protocol (EPA, 1999) and measures both physical and biological parameters. Streams that receive lower RHA and RGA scores are more unstable and less "friendly" for fish and bugs.

The six channelized reaches (M1B, M11, 12, 13, 15 and 16) scored the lowest on the Rapid Geomorphic Assessment. M15 was dredged in the fall of 2003. These reaches have been dredged and straightened or hard-armored. They act more like conduits for water than rivers. If these reaches had not been channelized, then most of the mainstem would fall in the fair/good category. Tributaries have often been channelized near their mouths. T6.5 on the Chelsea Road was recently dredged immediately downstream of a bedrock falls.

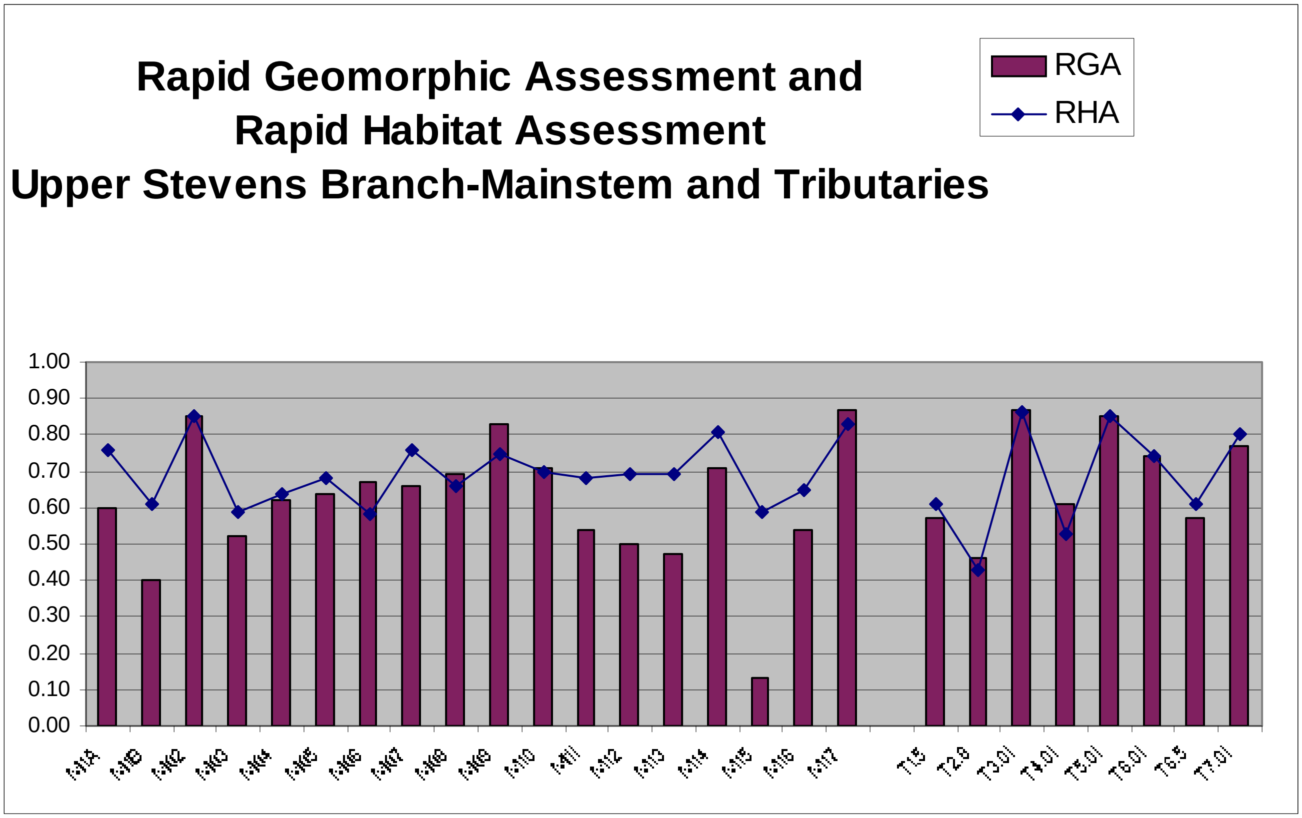

Figure 8: Rapid Geomorphic and Rapid Habitat Assessment Results

Key to RGA and RHA	
Score	**Condition**
0-0.34	Poor
0.35 – 0.64	Fair
0.65 – 0.84	Good
0.85 - 1	Reference

SECTION 4.2 SUMMARY OF RESULTS: PHYSICAL FEATURES

FEMA floodplain maps usually define the limit of inundation along the mainstem and some tributaries, but do not adequately represent hazards from fluvial erosion. Many of the hazards throughout the watershed are related to the surficial geology and geomorphology of the watershed. Other potential causes of hazard are due to anthropogenic disturbances and adjustments in the channel, including incision, widening, change in planform, aggradation and bar development. Appendix B contains recommendations by ANR on how to apply the results of this study to identify fluvial erosion hazard areas. Table 7 summarizes the physical features that can be used to assess riverine erosion. Most bridges are protected by rip-rap.

Table 7: Summary Of Physical Features

Reach #	Bedrock or dam control	Channel ization, Historic or recent	Under sized Bridge/ Culvert	Beaver (impacts buffer), provides grade control	Flood plain encroac hment	Minimal Riparian Buffer	Storm water
M1A		Y			Y	Y	Y
M1B	Y	Y			Y		Y
M2	Y	Y					
M3			Y	Y	Y	Y	Y
M4			Y	Y	Y	Y	Y
M5			Y	Y			
M6		Y	Y	Y	Y		
M7			Y				
M8			Y				
M9	Y			Y	Y		
M10			Y				
M11		Y	Y				
M12		Y					
M13			Y	Y			
M14			Y	Y			
M15		Y	Y	Y			
M16		Y	Y				
M17			Y				
TRIBUTARY REACHES							
T1.5	Y		Y	Y	Y		
T2.8	Y		Y				
T3.01	Y						
T4.01	Y		Y				
T5.01	Y		Y		Y		
T6.01	Y		Y		Y		
T6.5	Y	Y	Y		Y		
T7.01	Y		Y				

SECTION 5.0 DISCUSSION OF RESULTS:

The Upper Stevens Branch watershed is generally stable, although there is limited bedrock control. The relatively frequent flooding along the mainstem has resulted in the floodplain being somewhat protected from encroachment by development upstream of Barre City. The lack of floodplain encroachment (except by roads) provides a net benefit for the City of Barre and serves to reduce potential flood damage in Barre as the floodplain serves as a pressure release valve during floods. However, the straightening of the channel and floodplain encroachment (often right up to the banks) upstream of Route 63 has potentially negative consequences.

Two factors - agriculture and beavers - have contributed to the presence of a relatively narrow forested riparian buffer along much of the mainstem between Barre and Williamstown. A wider forested buffer would have multiple benefits including: water quality, habitat for fish and reduction of property damage from erosion during floods.

The cross-sectional measurements and the Rapid Geomorphic and Rapid Habitat Assessments indicate that the upper Stevens Branch is relatively stable. The biggest impacts to the river occurred last century and the early part of the 20th century when long reaches of the river were dredged, straightened or channelized. The river has had time to adjust to these activities, and while not being a “healthy” river is not actively trying to re-create a meander pattern within these straightened reaches.

The biggest long-term problem in the watershed comes from roads, private drives and other activities that channel water, rather than allowing it to infiltrate into the ground. One of the main problems associated with roads is the presence of undersized culverts and bridges. Sizing bridges and culverts for bankfull or floodprone width (twice the bankfull width) would serve to reduce the associated erosion and scour problems associated with undersized infrastructure.

One of the biggest unknown impacts on the river is the prevalence of private bridges. Multiple foot bridges and snow-mobile bridges criss-cross the river. Many of these are undersized or underbuilt. If they “get loose” during a storm, they could block the next bridge/culvert downstream increased flood damage.

Alluvial fans have formed near the mouth of many of the tributaries. Channel management activities at these locations has resulted in either a) the dredging of channels near the mouth of the tributaries; or b) the berming of the mouths to try to contain the tributaries. These alluvial fans are the areas where floodplain encroachment has typically occurred. There are few mass failures in the watershed, channel avulsions are mostly located in the tributaries and are associated with debris jams.

In this narrow valley, stormwater creates another problem. Concentrated industrial and commercial development has occurred without stormwater controls along the mainstem to the south of Route 63. Careful attention should be paid towards retrofitting these developments with stormwater controls. Mass failures by the ballfield behind Bond Auto, may be associated with hydraulic loading from stormwater.

There is little evidence of recent channel incision throughout the mainstem. This is probably due to two factors: 1) the presence of bedrock control at three locations; and 2) the prevalence of beaver dams throughout the watershed. Beavers are extremely active, and their dams (while somewhat temporary) provide a certain amount of grade control which has prevented the river from incising.

There is relatively little new rip-rap along the mainstem of the Stevens Branch.. Rip-rap is concentrated near bridges, and in the channelized reaches adjacent to the commercial/industrial development and downstream of the Webster Avenue bridge. The use of rip-rap "pushes" the problem downstream (King County 2000).

5.1 IN-STREAM IMPOUNDMENTS:

The Vermont Center for Geographic Information shows dams on Bolster Reservoir, Rouleau Pond and on the mainstem by Webster Avenue to the southwest of Spaulding High School. Private dams and beaver dams are found in other locations in the watershed.

The two mainstem dams are no longer used. Removing these dams would remove a potential hazard, as well as restoring fish passage through the upper mainstem. The Webster Avenue dam was breached during the 1927 flood. Bedrock control at both sites will limit incision.

Increased flood damage can occur when dams breach and a wave of water is released. Private ponds located on rivers create potential hazards when they breach. The Vermont ANR Pond construction guidelines (1999) recommends that streams not be dammed.

6.0 RECOMMENDATIONS

After a flood occurs, everyone pays to repair washed out roads and bridges. Money, public and private property and rivers can be protected by being pro-active. The following practical, affordable steps can help your community to protect the river, restore the fishery, reduce flood damage to private and public property and save your community money.

6.1 TOWN/CITY OPPORTUNITIES

The towns of Barre and Williamstown, and Barre City may have already taken the first steps. They are:

1. **Adopt the Codes and Standards for Roads**: The Codes and Standards enable your town to receive funding after a disaster to replace an undersized bridge or culvert with one sized for a larger flood and does not constrict the bankfull or floodprone width of the channel. The version of the Codes and Standards in Appendix F contains recommendations *to size bridges and culverts for the bankfull or floodprone width*; and 2) to size infrastructure for larger floods such as the *50 or 100 year event*. If your town has already adopted Codes and Standards, consider adopting this revised version.
2. **Develop a Pre-Disaster Mitigation Plan:** The Pre-Disaster Mitigation Plan is a new requirement that must be completed for a town to receive federal aid in case of disaster. The Regional Planning Commission can help complete this. This study provides base-line data needed for the fluvial erosion portion of the Pre-Disaster mitigation plan.
3. **Conduct a culvert survey:** The culvert survey enables your town to 1) keep track of infrastructure; 2) See where the problems may be and 3) receive an additional cost share of 10% from the Agency of Transportation for structures grants.
4. **Apply common sense principles** to locating new structures: Appendix G contains a questionnaire that can be used by a contractor, homebuilder or town zoning administrator to avoid common problems associated with construction and to reduce damage from erosion or flooding.
5. **Consider a driveway ordinance**, so that private costs do not become public costs. A driveway ordinance would prevent driveways from funneling water onto public roads.

Your town may have already completed these actions. There are clear economic benefits to towns that adopt some or all of these recommendations. A study for the Vermont Geological Survey found that over half of all flood damage is "avoidable" (SEI 1998). For example, Table 4 documents flood costs of $1,243, 424. Over half of this damage could have been avoided. There are multiple economic, environmental and public safety benefits. Each of these reasons provides an incentive for towns to plan and manage their resources.

6.2 DRIVEWAYS AND ROADS

Roads divert and intercept slow-moving groundwater and turn it into fast-moving surfacewater that increases the rate and extent of erosion and reduces infiltration. Increased road cover can cause increases in flood frequencies and increased flooding as well as degradation of aquatic ecosystems (Forman, 1998).

As the watershed develops, private costs can become public costs if concentrated flow from driveways is directed onto town highways. All private road and driveway construction should be designed NOT to direct flow onto public roads. Adequately sized culverts, encouraging the use of half culverts, arched culverts and bridges, and careful attention to maintenance of waterbars can prevent road washouts. The recommendations provided by the Vermont Local Roads program (1-800-462-6555) should be implemented to the maximum extent possible.

Some common-sense considerations for road design and maintenance include:

- Try to place bridges where the stream is relatively straight, not with a severe bend.
- Implement a driveway policy that can reduce impact from private roads onto public roads.
- If a bridge/culvert is located at a meander bend, then build it wider (about 1.5 x the bankfull width). The angle of approach should be as straight as possible.
- Install culverts at correct angles related to flows, water doesn't like to make a hard bend. Put in a longer culvert where necessary to keep flow from making a hard turn.
- Size culverts larger if there is a high sediment load.
- Avoid culverts with large road fills. The fill can acts as a dam which can fail catastrophically.
- Develop a maintenance and management plan for culverts. Blocked culverts either on the upstream or downstream side can cause major road washouts.
- Design stream crossings using bridges or ½ culverts, minimize the use of round culverts
- Pay attention to management of road runoff, especially during the construction phase of roads,
- Bridges should be designed so that they don't constrict the channel. They should be a minimum of bankfull width for entrenched channels, and allow for floodprone (twice bankfull) width flows for streams that access the floodplain.
- Bridges/culverts should be designed using the relaxation curve (Figure 9) (CWP, 1999). This tool is used in combination with town zoning and build-out analysis to predict how much wider a channel will become. If a town has no zoning, other indicators such as population growth, and number of building permits issued annually can be used. As a watershed develops, infiltration decreases and runoff increases. Channels become wider to handle the additional runoff. For example, a watershed with 20% impervious surfaces typically has a channel that is twice as wide as it was pre-development.
- Culvert and ditch maintenance, street sweeping and cleaning catchbasins need to be conducted on a regular schedule and especially as soon as possible after snow-melt.

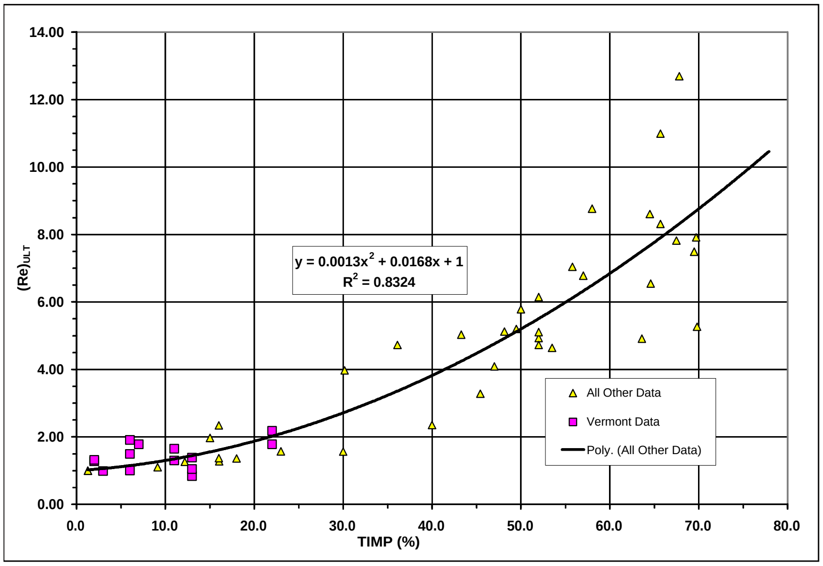

Figure 9: This Channel Enlargement Curve shows that as a watershed develops and impervious cover (roads, houses) increase, than stream channels get larger in response to the increased runoff from the roads and houses. In areas that are developing, a build-out analysis can be used to predict how many new houses will be built. For example, the graph shows that in areas with 20% Total Impervious Cover (TIMP) the channel will be two times wider (Re-ult) or ultimate enlargement. This enlargement process can take up to 60 years, but most widening will occur during the first 10 – 20 years. Vermont Streams (Squares) and All Other Stream Data (Triangles). CWP 1999.

6.3 STORMWATER

Stormwater –it sounds urban, but it is equally as important in rural areas. Roads, culverts, ditches, driveways and buildings have altered the way water flows. The best way to avoid problems is to try to mimic the natural drainage pattern of the watershed and to allow water to spread out and infiltrate. This prevents the problems associated with concentrated flow from roads, ditches, driveways and buildings, The three fundamental principles of stormwater management are:

1. **Disperse flow;**
2. **Don't concentrate flow**
3. **Infiltrate flow (unless it is toxic, you wouldn't want water coming off of a gas station to enter the groundwater)**

Damage will be reduced if water is allowed to infiltrate and spread out. Erosion hazards and failures are associated with concentrated flow from foundation and roof drains, driveways, and septic systems that can increase hydraulic loading on layered geologic deposits.

Commercial and industrial development adjacent to the Stevens Branch should be examined for stormwater management opportunities.

6.4 GEOLOGY/HABITAT/RIVER RESTORATION:

Geology and geomorphology are the foundation of the watershed. They can't be changed. Some areas are more sensitive and careful management can help to reduce flood damage to these sensitive areas. The results of this study can be used to identify "sensitive" areas. Some recommendations include:

- Leave a buffer around all streams, don't build to the edge. This provides multiple benefits, both in the stream and out of the stream. Some towns enact buffer ordinances. See www.stormwatercenter.net for examples of buffer ordinances.
- Don't build in areas with alluvial fans, or areas prone to debris jams, or areas with multiple channels, and flood chutes. If the river changed course before, it is likely to do so again.
- Steep slopes that have not yet reached a stable slope should have a setback for construction based on stable slope angles calculated on the basis of height of bank, and bank materials. A mass failure behind the ball field by Bond Auto is an example of an area that should be protected.
- The erodibility of the surficial deposits should be considered in watershed management. Don't build or concentrate flow on highly erodible deposits such as sands and gravels (these are often Hydrologic Group A and B soils). This is especially important on steeper sloped headwater streams such as T2, T3 and T7.
- Stream reaches that are actively adjusting, i.e., incising, widening, aggrading or sites of previous channel avulsions should have more protection from development. The reaches that are in Channel Evolution Model Stage 2, 3, or 4, (incising, widening, or stabilizing at a lower elevation) are contributing sediment to the channel.
- Use the data from Phase 1 part of this study that mapped the Channel migration zone (CMZ) and do not build within the Channel Migration Zone.
- Saturation (pond-building, septic or mound systems, footing drains, stormwater ponds….) in highly erodible deposits causes hydraulic loading of the deposits, which could lead to catastrophic failure.
- Avoid hydraulic loading, (construction of ponds or stormwater ponds) in areas with alternating layers of clay/silt and sand/gravel for example.

SECTION 7.0 REFERENCES

Annual Reports, Barre, Williamstown

Army Corps of Engineers on Flood Control on the Winooski River, VT Dec. 1938

Army Corps of Engineers, New York District, 1970. Floodplain Information Stevens Branch-Winooski River, City of Barre, Vermont

Barg, L, Streamside Sentinel, 1999, Vermont Agency of Natural Resources. 12pp.

Barre Daily Times: Vermont Thursday, November 10, 1927

Belding, Patricia, 1998, Through Hell and High Water in Barre, Vermont, Potash Brook Publishing 114 pp.

Cahoon, Barry, 1998. April 13. Letter from Barry Cahoon, VT ANR Stream Alteration Engineer to Rene Read, Zoning Administrator Town of Williston, Vermont.

Center for Watershed Protection et. al, 1999, Watershed Hydrology Protection and Flood Mitigation Project Phase II-Technical Analysis: Stream Geomorphic Assessment. Prepared for Vermont Geological Survey.

Czaplinski, R., Adamant, Vermont Feb. 2000, Draft/Outline of Assessment Criteria And Conditions For Issuance Of Zoning Permits In Flood Hazard Areas: Unpublished.

Denny, C.S., 1982, Geomorphology of New England: U.S. Geological Survey Professional Paper 1208, 18p.

Doll, C.G., 1970, Surficial geologic map of Vermont: Vermont Geological Survey, 1:250,000.

Environmental Protection Agency, 1999, Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: 841-B-99-002.

Federal Insurance Administration, 1977, Flood Insurance Study, Town of Barre, Vermont Washington County

Federal Insurance Administration, 1978, Flood Insurance Study, Town of Williamstown, Vermont Washington County

Finucane, Bob. 2004. Personal communication. Dam safety engineer, Vermont Agency of Natural Resources.

Forman, Richard T. T., Alexander, Lauren E. 1998, Roads And Their Major Ecological Effects: Annu. Rev. Ecol. Syst. 1998. 29:207–31

Goodnough, X.F., 1928, “Rainfall in New England During the Storm of November 3 and 4, 1927,” Journal of the New England Water Works Association, v. XLII, No. 2, pp. 150–187.

Hemenway, Abby Maria, 1882, Vermont History Gazetteer.Volume 4

Johnson, L.B., 1928, Vermont in Floodtime: Roy L. Johnson Co., Randolph, Vermont, 209pp.

Johnson, L.B., 1928, Floodtide of 1927: Roy L. Johnson Co., Randolph, Vermont.

King County Sensitive Areas Ordinance; 2000, www.metrokc.gov/ddes/lusd/chan_mig.htm Channel Migration Hazard Areas.

Library of Congress
http://memory.loc.gov/cgi-bin/map_item.pl?data=/home/www/data/gmd/gmd375/g37
19th century map of Barre

Ludlum, D.M., 1996, The Vermont Weather Book: Vermont Historical Society, Montpelier, 300p.

McCabe, Gregory, Wolock, David. 2002, A step increase in streamflow in the conterminous United States: Geophysical Research Letters December 24, 2002 http://ks.water.usgs.gov/Kansas/pubs/reports/dmw.grl.v29.html.

Minsinger, W.E. 2002, The 1927 flood in Vermont and New England, November 3-7, 1927. The Blue Hill Observatory 112 pp.

Montgomery, D., and Buffington, J., 1997, Channel-reach Morphology in Mountain Drainage Basins: Geological Society of America Bulletin; v. 109; no. 5; pp 596–611.

Murthy, Varanasi. R. 1957. Bedrock Geology of the East Barre Area, Vermont. Vermont Geological Survey bulletin no. 10. 121pp.

National Climate Data Center 1927, Chelsea station.

National Oceanic Atmospheric Administration, 1927, National Weather Service records for Northfield Station, VT.

Natural Resources Conservation Service, 2003. Washington County Soil Maps (on CD)

Olson, S. A,. Flow-Frequency Characteristics of Vermont Streams: USGS Water Resources Investigations Report 02-4238. 47pp.

Perry, Dean “Barre in the Great Flood of 1927” 117 pp.

Rosgen D., 1996, Applied Fluvial Morphology: Wildland Hydrology Books, Pagosa Springs, Co.

Schumm, S., 1984, The Fluvial System: John Wiley and Sons, New York.

Schumm, S. Harvey, M. and Watson, C 1984, Incised Channels, Morphology, Dynamics and Control: Water Resources Publication, LLC, 200 pp.

Stewart, D.P., 1971. Geology for Environmental Planning. Vermont Geological Survey, Environmental Geology #1 32pp.

Stone Environmental Inc., 1998, Final Report for Watershed Hydrology Protection and Flood Mitigation: Phase I: prepared for Vermont Geologica l Survey.

USGS Flood Frequency Analysis for Vermont and New Hampshire, 1998. Bob Hammond, unpublished.

Vermont Agency of Transportation, 2001, Bridge database from Pam Thurber.

Vermont Flood Survey Committee, 1928, Flood Loss and Damage Survey: Statement of Returns to March 1, 1928: Montpelier.

VT ANR, Feb. 1999, Options for State Flood Control Policies and a Flood Control Program.

VT ANR Dec. 1999, Status of Implementation of Agency of Natural Resources Flood Control Policies and Programs.

VT ANR, 2001 provisional, Vermont Regional Hydraulic Geometry Curves: Water Quality Division.

VT ANR River Management Section, Vermont Geological Survey, Fish and Wildlife Division and Barg, L., 2003, Stream Assessment Protocols. Phase 1, 2 and 3.

VT ANR, Vermont Pond Construction Guidelines, April 1999, Department of Environmental Conservation

VT ANR River Management Section, 2003. Vermont Fluvial Erosion Hazard Mitigation Program, Draft 12/30/03.

Vermont Agency of Transportation, August, 1977 TH2811. Engineering drawings for bridge project on TH 1, Bridge #2.

Vermont Agency of Transportation. Proposed Improvement F-037-1(2) 11/5/65

Williamstown Historical Society, 1781-1991. 1991 A History of Williamstown Vermont

Wright, S. 1999. Surficial Geologic Map of the Barre West Quadrangle, Vermont. Vermont Geological Survey Open File Report VG99-6, 3 plates and text, scale 1:24,000.

Wright, S. 1999. Deglaciation History of the Stevens Branch Valley: Williamstown to Barre, Vermont. In Guidebook to Field Trips in Vermont and Adjacent Regions of new Hampshire and New York. Ed. Stephen Wright. New England Intercollegiate Geological Conference, 91st annual meeting. October 1, 2 and 3, 1999. pp179-200.