INTRODUCTION

With the increasing frequency of flooding over the past few decades culminating with the devastating impacts of Tropical Storm Irene in 2011, Vermont communities are focusing planning efforts on flood resiliency. Last year Lamoille County Planning Commission (LCPC) developed a new flood resilience component for the Lamoille County Regional Plan. Complementing this, LCPC has been working with several towns in the region to strengthen infrastructure and better prepare for future floods.

This project targeted two towns (Stowe and Belvidere) in which to identify areas where town road infrastructure is highly susceptible to future flood-related catastrophic failure and associated water quality concerns. LCPC conducted a GIS analysis for site identification and utilized a compilation of information from the following sources: river corridor layers, previous FEMA Community/Public Assistance grant site information, interviews with road foremen, BBR Category B grants completed projects list, culvert and bridge DMS/inventories, and river corridor plan/Phase 2 reports. The GIS analysis first involved determining which communities in Lamoille County have the most river road conflicts. LCPC then chose two towns including Stowe with abundant river/road conflicts and applied varying constraints to town road segments that included the following: within 50 foot stream buffer, within 100 year floodplain, within the river corridor, at a bridge or culvert crossing that was significantly undersized, near stream that has been downcut (incised), and steep road slope. The segments were then scored for total constraints to identify those sites that were highest priority for the town to pay attention to in making their infrastructure more flood resilient. This report summarizes the findings for the Town of Stowe. Included in the report are the methodology, results of the GIS analysis, maps, observations made during site visits by LCPC, and recommendations for protection of the Town’s infrastructure.

Stowe is located in the southwest region of Lamoille County and prides itself in its scenic beauty and its natural and recreational resources for both Vermonters and out of state visitors. The town has a high density road network with 27 percent of the road infrastructure in conflict with the Little River, West Branch Little River, and North Branch Little River and their tributaries. With climate instability plaguing our state, Stowe’s mountain and valley topography make it vulnerable to flood events as clouds come over the Green Mountains and create localized intense rainstorms in Stowe. In 2013, Stowe suffered major flooding that resulted in damage and/or flooding of many of its roads, stream crossing structures, and especially the Stowe Recreational Path. Through this project LCPC has targeted those areas in Stowe vulnerable to flood and fluvial erosion hazard in an effort to help the Town prioritize future infrastructure improvement projects and improve their flood resiliency.
METHODOLOGY

LCPC first conducted a GIS analysis to determine what the percent of roads in each town were in conflict with rivers by intersection them with the river corridor layer. A subsequent GIS analysis was then conducted to determine the total constraints of town road sites in two towns (Stowe and Belvidere). The constraints placed on the road segments for Stowe included the following:

- Within river corridor
- Within 50 foot buffer
- Within 100 year floodway
- Road slope
- Percent bankfull width of structures at stream crossings
- Stream incision (downcutting of bed)

A more detailed explanation of the methodology, is presented in Appendix A. This method was based on one used by Central Vermont Regional Planning Commission (Dubois & King and Bear Creek Environmental, 2015). LCPC also reviewed areas where Better Back Roads road repairs or bridge/culverts replacements have been done and reviewed FEMA damage reports in November 2015 to see where there has been recent damage to existing infrastructure.

In winter of 2016, LCPC met with the Assistant Town Engineer, Chris Jolly, to obtain input and feedback on the GIS analysis. Mr. Jolly provided LCPC with valuable information on whether the sites have experienced flood damage as well as indicating Town priorities for flood and fluvial erosion hazard protection. In May, 2016, LCPC visited those sites with five or more constraints except those along Miller Brook and its tributaries since these were not problem areas for the Town. Based on recommendations from Mr. Jolly, LCPC also visited some sites listed on the FEMA damage reports and others that were indicated as a problem for flooding or fluvial erosion hazards. Photos were taken at each site and observations of potential vulnerabilities to infrastructure damage from flooding or fluvial erosion hazard were noted.

RESULTS

Map 1 in Appendix B shows the sites within Lamoille County where Better Back Roads projects have been done and Map 2 depicts the various factors that are considered in the river/road conflict determination. For Stowe, there have been four areas where Better Back Road grants were used to repair roads and culverts/bridges. None of the historic better backroads sites correlated with sites with many constraints. Map 3 displays the number of constraints for each town road segment in Stowe. Seven locations shown on Map 3 had the highest total constraints (5-6). LCPC removed those sites with high constraints that were on private roads or trails. Based on the GIS analysis and recommendations from the Assistant Town Engineer, LCPC
visited a total of 14 sites in the Town of Stowe. The following photos and narrative are from visited sites listed below in Table 1.

### Table 1: Number of Constraints and Issues for Stowe Sites

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Road</th>
<th>Number of Constraints</th>
<th>Issues/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cemetery Road</td>
<td>5</td>
<td>In floodway, river corridor and 50 foot stream buffer, stream incised, undersized structures; there are two culverts (one a box culvert) and one bridge crossing</td>
</tr>
<tr>
<td>2</td>
<td>Stagecoach Road</td>
<td>5</td>
<td>In floodway, river corridor and 50 foot stream buffer, undersized structures (one double culvert)</td>
</tr>
<tr>
<td>3</td>
<td>West Hill Road</td>
<td>4</td>
<td>In floodway, river corridor and 50 foot stream buffer, undersized structure</td>
</tr>
<tr>
<td>4</td>
<td>Weeks Hill Road</td>
<td>6</td>
<td>In floodway, river corridor and 50 foot buffer, road slope &gt;5%, stream incised</td>
</tr>
<tr>
<td>5</td>
<td>Cape Cod Road</td>
<td>1</td>
<td>In river corridor; identified by Assistant Engineer as having been damaged in past</td>
</tr>
<tr>
<td>6</td>
<td>Stowe Recreation Path</td>
<td>4</td>
<td>In floodway, river corridor and 50 foot buffer, stream incised; Recreation Path damaged in 2013. Restoration project underway by Milone and MacBroom</td>
</tr>
<tr>
<td>7</td>
<td>Luce Hill Road</td>
<td>5</td>
<td>In floodway, river corridor and 50 foot buffer, stream very incised; head cut present; recent historic work done to stabilize bridge</td>
</tr>
<tr>
<td>8</td>
<td>Brook Road</td>
<td>5</td>
<td>In floodway, river corridor and 50 foot buffer, stream incised; Historic covered bridge</td>
</tr>
<tr>
<td>9</td>
<td>Notchbrook Road</td>
<td>3</td>
<td>In river corridor and 50 foot buffer, road slope &gt;5%; stream very close to road and riprapped</td>
</tr>
<tr>
<td>10</td>
<td>River Road (1)</td>
<td>4</td>
<td>In floodway, river corridor and 50 foot buffer, road slope &gt;5%</td>
</tr>
<tr>
<td>11</td>
<td>River Road (2)</td>
<td>3</td>
<td>In floodway, river corridor and 50 foot stream buffer; Identified by Assistant Engineer as having past washout damage</td>
</tr>
<tr>
<td>Site Number</td>
<td>Road</td>
<td>Number of Constraints</td>
<td>Issues/Notes</td>
</tr>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>12</strong></td>
<td>River Road (3)</td>
<td>1</td>
<td>In river corridor; Identified by Assistant Engineer as having past washout damage</td>
</tr>
<tr>
<td><strong>13</strong></td>
<td>Moscow Road (1)</td>
<td>5</td>
<td>In river corridor and 50 foot stream buffer, stream incised, undersized structure</td>
</tr>
<tr>
<td><strong>14</strong></td>
<td>Moscow Road (2)</td>
<td>5</td>
<td>In floodway, river corridor and 50 foot stream buffer, slope &gt; 5%, stream incised</td>
</tr>
</tbody>
</table>

“1” = Town of Stowe Priority

Stowe has experienced flooding along Cemetery Road in the vicinity of three structures. The most eastern structure is a box culvert that receives wetland drainage (Figure 1). There is another small cross culvert and an undersized bridge that crosses the North Branch of the Little River, which is vulnerable to both flooding and fluvial erosion hazards (Figure 2). According to the Assistant Town Engineer, the road has been overtopped with flood waters in the past at all of these structures.

There are two culverts that added together are still undersized for a major tributary to the North Branch of the Little River to cross Stagecoach Road (Figure 3). The GIS analysis showed that this site has a total of five constraints, which includes the undersized culverts. Upstream of the culverts, the tributary is experiencing geomorphic instability as it erodes its southern bank (Figure 4). Streambank erosion has led to increased deposition, which is accumulating on the downstream end of the culverts including an area where trees are growing in between the culverts (Figure 5). When these culverts are replaced, one structure with a span of 120 percent bankfull width should be put in to restore the natural channel dynamics across the road.
At West Hill Road there is a low bridge that is out of alignment with the North Branch of the Little River (Figure 6). This bridge and the road have been flooded in the past and it has four constraints including being undersized. Therefore, Stowe may want to consider enlarging this bridge in the future and to align it more with the natural stream to decrease flood and fluvial erosion hazard vulnerability.
The site with the largest number of constraints (6), was located on Weeks Hill Road at a bridge crossing on the West Branch of the Little River. The constraints on this road segment include: in floodway, river corridor and 50 foot buffer, road slope >5%, and incised steam channel. The bridge at this crossing has experienced damage in the past where abutments were scoured out and replaced with new sheeting (Figure 7). Fields both upstream and downstream of the bridge flood during high flow events and armoring that has been placed on the downstream end of the structure has washed out (Figure 8).
Chris Jolly, Assistant Engineer with the Town of Stowe, directed LCPC to a site that resulted in only one constraint in the GIS analysis, but has been damaged in the past. This site is on Cape Cod Road where the West Branch of the Little River comes very close to the road (Figure 9). Previous flooding events have resulted in abundant deposition in the channel, which has led to the river changing its course to be closer to Cape Cod Road. Figure 10 shows where the channel used to be located that is now acting as a flood chute behind a large depositional feature. Following the road washing out, the Town reinforced the bank with riprap armoring. Downstream of the riprap, a private landowner rebuilt and armored the northern bank in order to protect his property from the road (Figure 11). The armoring both along the road and the rebuilt bank will unfortunately not absorb the river’s energy and displace it to the downstream property making it more vulnerable to erosion potential as the riprap fails over time (Figure 12). Re-establishing floodplain on the northern side would help the West Branch to dissipate its energy before entering the downstream bend.

Figure 9-Site 5: Road encroachment along the West Branch Little River

Figure 10-Site 5: Former West Branch channel outlet

Figure 11-Site 5: Rebuilt bank near Cape Cod Road

Figure 12-Site 5: Property downstream of bank work near Cape Cod Road
One site that is of particular importance to the Town, but was not included in the GIS analysis is along the Stowe Recreation Path. LCPC did not include it in the analysis because it was a trail and not a road, but we have included it in this report due to the damage that occurred in 2013 and its high priority status for Stowe. In 2013, areas along the recreation path were washed out by the West Branch of the Little River (Figure 13). The Town of Stowe has retained Milone and MacBroom to conduct a floodplain restoration project in this area in order for the West Branch to regain its natural channel dynamics and improve flood attenuation in the watershed (Figure 14). As part of the project, the Recreation Path was moved outside of the fluvial erosion hazard (FEH) zone to protect it from future damage (Figure 15).
Another site with many constraints that has caused the Town of Stowe problems in the past is the bridge at Luce Hill Road (Figure 16). The constraints of this road segment include the following: in floodway, river corridor and 50 foot buffer, and very incised stream channel. Both the Recreation Path and the bridge have experienced damage in past flood events. The structure armoring and the Recreation Path under the bridge are creating a pinch point for the stream resulting in the channel cutting down into its bed. As a result, the downstream elevation of the stream is lower than the upstream elevation. This is evidence of what’s called a “head cut” under the bridge that can migrate further upstream and erode the streambed. It is recommended that Stowe looks into alternatives for the Luce Hill Bridge and Recreation Path placement to improve flood plain access and geomorphic stability of the West Branch.

The next site visited by LCPC was at the Brookdale Bridge on Brook Road due to the GIS analysis resulting in five constraints. During the field visit, it was noted that the bridge has a rather low clearance which is a concern for the potential of large woody debris blocking the inlet (Figure 17). If the inlet was blocked, flood waters could potentially overtop the upstream banks and flood nearby homes (Figure 18). The Brookdale Bridge is a historic covered bridge (built 1964) and therefore any replacement or retrofit to improve flood resiliency should take its historic nature into account.
As LCPC was driving around Stowe to observe sites, an area vulnerable to infrastructure damage on Notchbrook Road from the West Branch of the Little River was observed. There is a spot along Notchbrook Road that is located in the river corridor and within 50 feet of the West Branch (Figure 19). The road slope is greater than five percent increasing its constraints for fluvial erosion vulnerability.

The bridge that crosses River Road showed up as having four constraints in the GIS analysis due to being in the floodway, river corridor and 50 foot buffer, and having a road slope >5% (Figure 20). However, of more concern to the Town are the washouts that occur along River Road due to its proximity to the Little River (Figures 21-23). According to Chris Jolly, these areas have
been repeatedly in conflict with the Little River in the past. These sites should be looked at for the potential to re-establish floodplain to help prevent future damage to infrastructure.

Figure 20-Site 10: River Road Bridge over the Little River

Figure 21-Site 10: River Road just downstream of bridge

Figure 22-Site 11: River Road along Little River
The final two sites that LCPC visited as part of this study were along Moscow Road. Both sites are in areas where culverts cross Miller Brook and resulted in a total of five constraints. The constraints for the upstream site (Site 13) include the following: in river corridor and 50 foot stream buffer, incised stream, and undersized culvert (Figure 24). The culvert at this site is out of alignment with Miller Brook and appears to have the potential for jamming with debris and failing armoring in the stream channel.
The last site that LCPC looked at was on Moscow Road where the Little River crosses the road at a bridge (Figure 25) and just upstream of the bridge. The total number of constraints at this site is five due to the following: in floodway, river corridor and 50 foot stream buffer, slope > 5%, and incised stream. The Moscow Mills Dam is just downstream of the bridge and backwater influence from the dam extends upstream of the bridge. The Little River makes a turn to the south after the bridge and hugs the side of Moscow Road, making the road vulnerable to flood damage (Figure 26). Solutions to this problem would be complicated due to the buildings on the opposite corner of Moscow Road and Adams Mill Road. Moscow Road could potentially be moved out of the river corridor to be out of harm’s way, but movement may be difficult due to the presence of buildings and possible wetlands (Figure 27).
RECOMMENDATIONS

Stowe is challenged in managing its town roads due to the numerous streams and the abundant road network in conflict with those surface waters. Proper sizing of road crossings and other river management strategies that work with the rivers and not against them will help to avoid future damage to town infrastructure. Homes and businesses within the floodway, river corridor and within 50 feet of a stream would benefit from flood proofing measures and/or buyout programs to avoid financial loss. Although it would be a large endeavor for Stowe to move some of its infrastructure out of the floodway or river corridor, doing so would help to prevent future flood damage and avoid repair costs, making the Town more flood resilient. Stowe has made great strides in working with the rivers and not against them by adopting FEH zones and by implementing the floodplain restoration project on the West Branch Little River. More restoration projects such as this will help Stowe to have better flood attenuation thereby reducing flood and fluvial erosion impacts downstream.

References