Upper Lamoille River
Stream Geomorphic Assessment Phase 2 Report
Greensboro and Hardwick, Vermont
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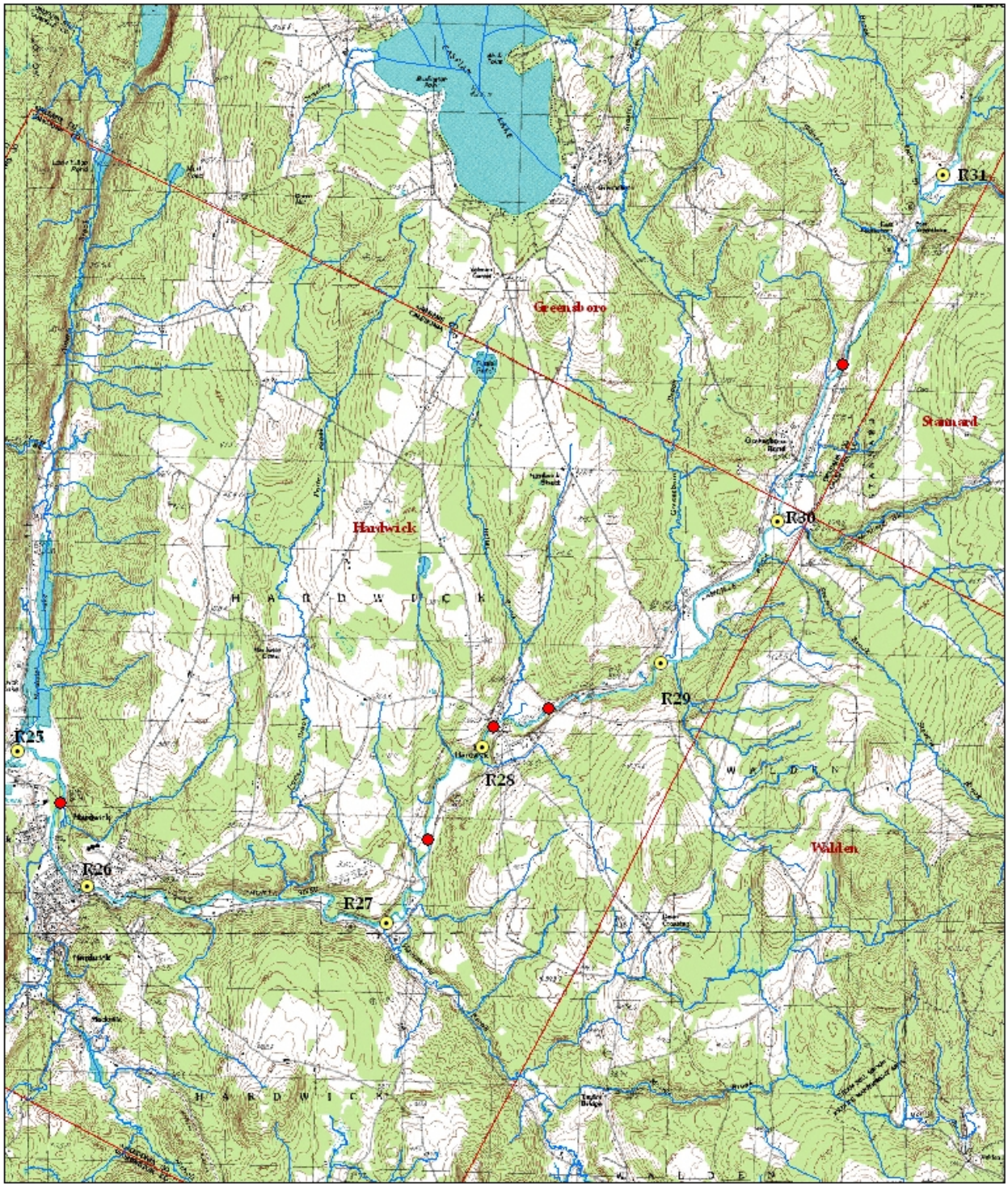
Introduction

The Upper Lamoille River, from the headwaters in Greensboro to upstream of the Jackson Dam in Hardwick, was first assessed in 2004 by a team from USDA Natural Resources Conservation Service and the Caledonia County NRCD. An assessment update began in 2007 and was completed in 2008 to meet the parameters of the current protocol and include feature indexing. Phase 1 and 2 geomorphic assessments were completed on six reaches of the Upper Lamoille River. The methods used to collect the updated data were the 2007 Vermont Stream Geomorphic Assessment Protocols (VSGAP); http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm; the original data was collected using the 2004 VSGAP. The update was carried out by the Caledonia County NRCD, with assistance from River Management Program staff, and with funding from the Vermont Department of Environmental Conservation's River Corridor Grants. Since 2004, a number of watershed projects have taken place including water quality work with the town of Hardwick to improve roadside ditches and reduce sediment runoff into the Lamoille River, as well as several buffer projects with private landowners.

One of the research questions concerning the Upper Lamoille River includes assessing sediment loading into Hardwick village. With the Jackson Dam at the downstream end of the village, increased sediment supplies into Hardwick are problematic. The main sources of sediment supplies include tributary inputs, erosion and mass failures, as well as sediment runoff from roads. Additional concerns have been noted about ice jamming upstream of Hardwick village, and a few landowners have voiced concerns over erosion and fracturing banks on their land.

The purpose of the following report is to summarize the current geomorphic conditions of the Upper Lamoille River and outline preliminary management strategies by reach. This report is to serve as a starting point for a more detailed analysis and future corridor plan. The management strategies and potential projects outlined below are intended to help restore channel equilibrium to the river corridor where possible. Long term areas of conflict are also indentified.

Figure 1. Location map of Upper Lamoille River and reach breaks



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Reach R25A

Segment Description

Reach 25A begins at a railroad bridge behind the Grand Union on Route 15 in Hardwick and ends just upstream of Jackson Dam. This segment is impounded and was not assessed. The impoundment causes the Lamoille River at this location to overflow, which has created a wetland area surrounding the river, and a nearby lake known as Hardwick Lake. Jackson Dam is a store and release dam and the waters are drained annually. There is no hydroelectric facility associated with the Jackson Dam. The dam was originally built around 1914 for the purpose of storing water for the downstream hydroelectric generating facility at Wolcott. Due to this annual drainage the wetland and lake environment that has been created is not high quality because the habitat cannot be sustained throughout the year. The drainage is done to help protect Hardwick village from flooding and ice jamming. A consideration of the removal of Jackson Dam is recommended as it affects additional segments upstream towards Route 16, and is at the downstream end of Hardwick village. The recommendation of the removal of Jackson Dam is also noted in the Lamoille River Basin Plan, authored by the Vermont Department of Environmental Conservation (http://www.anr.state.vt.us/dec/waterq/planning/htm/pl_lamoille.htm). From a fluvial geomorphic perspective, the removal of the Dam would have a significant impact on restoring the Upper Lamoille River through Hardwick to its natural equilibrium.

Reach 25B

Segment Description

This segment begins at the bridge on Main Street in Hardwick village and ends at the aforementioned railroad bridge. It is characterized by significant armoring as it turns through Hardwick village. There is a berm along the left bank for more than half the segment protecting Route 15. Development is also significant, particularly on the left bank, with multiple urban stormwater inputs. The stream bed features bedrock at the upstream end of the segment and slightly steeper gradient, which then slows to gravel dominated, featureless "plane bed" stream for the majority of the segment. The confinement is narrow due to streamside encroachments, however floodplain is still accessed along the right bank.

The geomorphic condition for this segment is recorded as "good" with channel degradation as the limiting factor. A "fair" rating for habitat was recorded, largely due to the channel alteration, substrate homogeneity and lack of buffers. The cross section data reveal C-type channel geometry (Rosgen, 1994) and cobble dominated substrate. There were no depositional features. A low to moderate incision ratio of 1.35 and extensive bank armoring suggest stage II channel evolution and related stream bed degradation. Dominant buffer widths are 0-25' for both sides of the stream. Along the right bank of the lower end of the segment there is a significant swath of undeveloped, open land within the stream corridor. The immediate streamside land is mowed, and a small community garden is in place at the upper end. There are three bridges in this segment though two are footbridges and are not channel constrictions.

Ice jamming is a prominent source of conflict along this stretch. The stream makes two sharp turns through the village, and then the slope flattens out due to the downstream impoundment. These features contribute to the likelihood of ice jams occurring in this segment. The last major ice jam and

related flooding occurred in 1991. Flows topped out over the berm along the left bank. After this flood, three "ice breakers" were installed upstream, in the downstream end of Reach R26, and were intended to break up ice before the stream entered the village of Hardwick. The ice breakers provide some relief from ice jams occurring in town; however, according to interviews, ice jams are still occurring despite the ice breakers. The ice jam flood history and mitigation site at Hardwick have been reported on and are monitored with real time web cameras by the USACE CRREL (US Army Corps of Engineers Cold Regions Research and Engineering Laboratory) http://www.crrel.usace.army.mil/icejams/page2.htm. The town continues to put resources into this area to deal with ice jams as they occur; such as keeping equipment at the Church Street Bridge to break up ice jams. These options are limited in how effective they can be in preventing flooding events from ice jams.

Preliminary Management Strategies

More segmentation and careful planning of each segment is recommended to address multiple areas of conflict through the village of Hardwick.

- Ice jamming mitigation should be considered through this segment and in conjunction with the upstream reach data.

- The open, undeveloped area along the lower right bank of this segment has potential for long term conservation, as well as possibly expanding floodwater storage. Long term planning with the town to protect this area could be highly beneficial to the village of Hardwick to protect it from ice jam and flood event inundation. Additional measurements should be taken to assess floodplain access along the right bank of this undeveloped area. If the access becomes challenged by bank and floodplain height, excavation of the floodprone area may be recommended to achieve additional floodwater storage, if necessary.

- Water quality issues were observed in this segment. Multiple stormwater inputs are a potential source of conflict, as the water quality makes a visible change when the stream enters the village of Hardwick. Water quality sampling is recommended to assess the largest causes of point source pollution. The installation of rain gardens and/or other stormwater improvements would be recommended to help protect water quality.

- Long term monitoring of the existing bank armoring will be necessary as the stream bed is degrading and the armoring is showing evidence of being undermined.

Reach R26

Reach Description

The reach begins at the confluence of Haynesville Brook near the junction of Routes 15 and 16 and continues until it reaches Hardwick village at the Main Street bridge. Porter Brook enters this reach about midway. The reach is flanked on its left corridor by Route 15 and the valley wall on its right. A historic railroad bed also follows the stream corridor and crosses the channel twice. Cross section data show B-type channel geometry (Rosgen, 1994) with gravel dominated substrate. Multiple depositional features were noted, two flood chutes and four grade controls. Six steep riffles were recorded but were typically upstream of channel constrictions such as riprap, sharp bends and/or

bridges. Stream banks are armored sporadically throughout the reach, either where the river abuts the railroad bed or the edge of the road. The incision ratio for this reach was moderate at 1.5 with a channel evolution at stage III. The geomorphic condition rating is "fair" for this reach, largely due to historic channel degradation and current pattern of aggradation. Habitat conditions are rated as "good."

Preliminary Management Strategies

As the reach immediately upstream of Hardwick village, sources of conflict are generally related to sediment inputs.

- Haynesville Brook and Porter Brook are the two main tributaries on this reach that should be monitored for sediment input. Haynesville's sediment source is largely due to erosion, planform change and lack of buffers. Porter Brook is steeper, and its sediment inputs are largely due to upstream inadequate road infrastructure, undersized culverts and land use. Continued work with the town of Hardwick is recommended to address road and structures along Porter Brook. Buffer opportunities along Haynesville Brook should also be considered.

- The historic rail bed along this reach does little to change valley width, but it does have two stream crossings where there is apparent long term conflict. The upstream bridge has alignment problems and mid-channel piers, forcing the stream to make wide meander bends upstream and downstream of the bridge. Modification of the upstream railroad bridge should be considered if the opportunity arises. Both bridges are accumulating sediment upstream.

- Some potential conflicts where river abuts Rte 15 on outside bends. There is existing armoring in most locations but there may be sections where conflicts will be observed in the future.

- Ice breakers in the reach should be monitored for efficacy.

- There is some potential along reach for smaller buffer projects, workable with Lamoille watershed program Trees for Streams.

Figure 2. R26 Railroad bridge with mid-channel pier and aggradation

Figure 3. R26 Riprap at river's abutment with railroad bed

<u>Reach 27A</u>

Segment Description

This reach begins at the Riverside farm bridge off Route 16 and continues downstream to the Haynesville Brook confluence at the junction of Routes 15 and 16. This section of stream features a very broad valley and moderate sinuosity. Route 16 is within the river's corridor but it does not change the valley type. There is a large amount of sediment working through this segment with related planform change, depositional features and sedimented riffles. Erosion is prevalent on meander bends and two mass failures are noted. This segment is also prone to ice jams according to the USACE CRREL. Streamside land use varies through the segment and includes wooded areas, cropland, a ball field and open, residential land. There have been a number of recent buffer projects that have connected nearly all the existing buffers throughout the segment. Tree revetments were installed along the ball field, just upstream of the mass failure. At the time of the assessment, the stream had moved away from them, but they do appear to be collecting some sediment along the eroded bank. Cross section data reveal C-type channel geometry and gravel dominated substrate with silt present (Rosgen, 1994). Geomorphic conditions are rated as "good" for this segment though the stream sensitivity is still very high. Habitat conditions were also given a score of "good" with embeddedness and sediment deposition having the greatest impact. The segment's incision ratio is 1.2 allowing floodplain access to occur for most events greater than and near bankfull flows.

Preliminary Management Strategies

This stream segment lies in the first broad valley upstream of Hardwick village. It may provide critical floodwater storage. The development is relatively minimal and there are only 3-4 main landowners from this lower segment break and upstream to the falls in Hardwick village.

- Buffers should continue to be monitored and enhanced where possible

- There is a large mass failure on the outside of the meander bend at the downstream end of the ball field which should be monitored. The river is developing unnatural channel geometry near the ball field and there is potential for avulsion. Flood flows currently cut across the floodplain that is on the inside of the meander bend where an avulsion could take place.

- Continued communication with landowners is recommended to inform them of potential planform changes and the potential role the section of stream has to store floodwaters.

- Bridges on Riverside Farm Lane and Pumpkin Lane have been noted to have ice/debris jams. Modification of these structures should be considered if the opportunity arises.

- Long term conflict evident with the river abutting Rte 16. Erosion is prevalent and with the existing planform change, the river will always be limited by the road. Past attempts at armoring have failed and there is a large bank failure where potential work may be considered in the future to address the erosion of the road bank.

<u>Reach 27B</u>

Segment Description

This segment begins at the downstream end of the falls in Hardwick village and ends at the Riverside Farm Bridge. This reach is flanked on its left corridor by cropland (vegetable farm) and the valley wall on its immediate right. Cross section data show C-type channel geometry and cobble dominated substrate (Rosgen, 1994). The incision ratio is a moderate 1.5 and it was determined the river is

degrading its channel and is in stage II channel evolution. The segment's bed form is "plane bed" which is a departure from its reference form of riffle-pool. Geomorphic conditions are noted as "good" due to some channel degradation but the stream sensitivity is moderate. The habitat condition rating was also recorded as "good", mostly due to lacking buffers on the left bank. There are minimal depositional features, showing minor evidence that the stream channel is attempting to pull away from the valley wall on its right. The landowner has noted erosion problems but has not installed any armoring or revetments along the fields.

Preliminary Management Strategies

The focus of the management strategy for this reach is the position of the river and its proximity to the valley wall on the right bank. Though no historic armoring was noted, this section of stream resides in a very broad valley and the river will undoubtedly work to reclaim its valley and develop equilibrium and related riffle-pool bed form.

- Continue to monitor erosion. Considering the proximity to the valley wall on the right bank, left bank stabilization through re-shaping or willow plantings would be recommended as opposed to riprap. The river will continue to pull away from valley wall, with gravel bars and meander patterns developing.

- Continued outreach with the landowner is important. Discussions have occurred with the current landowner to assess long term land use goals and how the predicted planform change will impact their plans.

- Conservation easement consideration for the agriculture fields would be recommended, which would allow for agricultural use, but consider river restoration in the long term.

- Reach 27A and 27B should be considered as critical floodwater storage upstream of the village of Hardwick. It is important to monitor incision ratios along both segments to ensure floodplain access in the long term.

Reach 28A

Segment Description

This segment is a cascade falls and no Phase 2 assessment was completed. No management strategies needed.

Reach 28B

Segment Description

This stream segment lies in the open area just upstream of the falls in East Hardwick village. The upstream segment is a B-type stream and transport reach, and there is a grade control at the downstream end of this segment. Both of these factors contribute to sediment accumulation on this segment, with related depositional features, sedimented riffles and planform adjustments. The grade control at the downstream end is a weir that serves to channel the river under the bridge, just upstream of the falls. The bridge and weir are channel constrictions, and there is deposition noted upstream. There is good floodplain access along the right bank, with an incision ratio of 1.0 and evident historic channels in the floodplain. As the stream comes into East Hardwick village, there are a number of stormwater inputs, particularly at the bridge. Cross section data show a C-type channel

geometry with gravel dominated substrate (Rosgen, 1994). Due to the planform adjustments and widening, the segment was determined to be in Stage III of channel evolution, with a geomorphic rating of "fair". Habitat conditions were also scored as "fair" due to sediment deposition and 0-25' buffer widths on the right bank.

Preliminary Management Strategies

- The floodplain area along the right bank upstream from the village is currently undeveloped and is providing critical floodwater storage for East Hardwick. Consideration of a conservation easement on this floodplain is recommended, both to protect the floodplain and to allow channel planform adjustment to continue to take place. Long term planning with the town to look at current and future zoning options may be another way to help protect this resource.

- Modification of the bridge is recommended when the opportunity arises. An assessment of the purpose and efficacy of the weir should be considered. Stormwater runoff from the bridge has eroded areas on and around the bridge and runoff is going directly from the road into the stream. Upgrades to the bridge should direct water towards vegetated area.

<u>Reach 28C</u>

Segment Description

This segment begins at the lower end of Michaud Farm's fields, follows along the railroad and ends at the open fields upstream of East Hardwick village. This segment was recorded as a sub-reach after a field check determined the confinement was natural. There are old channels (meander bends) visible from the aerial photo that are now acting as flood chutes and wetland areas. The segment is largely wooded, particularly along the left bank, with only small swaths of mowed or sparsely vegetated land. Cross section data reveal B-type channel geometry, and cobble dominated substrate (Rosgen, 1994). The segment serves as a transport reach with sediment accumulating in the downstream segment. The river is reasonably stable through this section, determined to be at Stage I in channel evolution and showing no incision. The geomorphic and habitat conditions are both recorded as "good" for this segment, with moderate stream sensitivity. The most significant fluvial geomorphic disturbance on this segment occurs where the stream crosses under Route 16. The stream and road are generally following the same direction in the river valley, and the crossing is characterized by sharp, armored bends both upstream and downstream of the bridge. Sediment is accumulating upstream of the bridge and scour is occurring below. There is a berm along the field just upstream from the bridge and dredging is noted as well.

Preliminary Management Strategies

- The bridge on Route 16 is the most prominent area of conflict. The upstream berm is not a priority for removal because it can currently be outflanked by the river. There does remain a high potential for avulsion or floodchute development on the field directly upstream from the bridge. Downstream of the bridge, there is armoring on the right bank and a house in the river's corridor, this also remains a long term conflict area. Opportunity of bridge modification is not likely, but alignment is a clear issue on the existing structure.

- Riprap should continue to be monitored

Reach R29

Reach Description

This reach begins upstream of the bridge on East Main Street in Greensboro and ends at the downstream end of Michaud's farm fields. The land use surrounding this reach is dominated by a working dairy farm and cropland. Agricultural influence is significant. Along the farmyard, the river is armored on both sides by historic riprap. The farm's barnyard is in close proximity to the river on the right bank. The left bank is open along the farmyard, but primarily wooded elsewhere, particularly where the river nears the valley wall. Cross section data reveal C-type channel geometry (Rosgen, 1994) with cobble dominated substrate. The bed form is recorded as plane bed, which is a departure from the reference riffle-pool form. The incision ratio for this stream segment is a moderate to high 1.6, though the channel degradation is historic and channel evolution is in Stage IV. The geomorphic condition for this reach is recorded as "fair", largely due to the current patterns of aggradation with related sedimented riffles, depositional features, erosion and planform change (where the stream is not armored). Habitat conditions were also "fair," with channel alteration, bed form and lacking buffers as the limiting factors. There are two major tributary inputs. At the upstream end of the reach is Stannard Brook, which appears to be accumulating sediment upstream of the confluence. Greensboro Brook enters at the downstream end of the reach, after flowing though farmland that is lacking a buffer upstream of the confluence. Water quality issues have been reported on Greensboro brook and the Lamoille River main stem near the farm. There are two bridges and both are recorded as channel constrictions.

Preliminary Management Strategies

- The proximity of the farm and barnyard to the river is a long term area of conflict. Runoff from the barnyard into the river is evident. It is recommended that agricultural activities be drawn back from the edge of the river and vegetated buffers installed, both along farmyard and croplands.

- The bridge near the farm is in fair to poor condition and is a constriction point on the stream. This area may pose long term conflicts including ice/debris jam as well as channel and floodplain encroachment. Considerations for modification to the structure should be looked at for future opportunities when the structure fails and/or is replaced.

- The lower area of the segment near Greensboro brook shows planform adjustment and related erosion and bar development. Water quality issues reported here are likely due to runoff from streamside land use. It is recommended that buffers are installed along Greensboro Brook.

- Stannard Brook should continue to be monitored for sediment input. The stream is now storing sediment in its downstream flat valley prior to entering the Lamoille River. This may be of benefit and a long term strategy of maintaining this sediment storage should be considered.

Reach R30A

Segment Description

This segment begins at the opening just downstream of the northern junction between Main Street and Route 16 in Greensboro, and ends at the bridge on East Main Street. The stream segment is

flanked on its right bank by Route 16 and on its left by Main Street in Greensboro. Land use is primarily residential with multiple property lots and dominant 0-25' buffer widths. There is a farm and some cropland at the downstream end of the segment. Incision and bank height is variable throughout the segment, but the selected cross section data records an incision ratio of 1.3 and C-type channel geometry with gravel dominated substrate (Rosgen, 1994). Channel evolution is in Stage II. Geomorphic condition was given a rating of "fair" due to historic channel degradation and channelization, with a high stream sensitivity rating. Habitat conditions were recorded as "good", limited by buffer widths. Floodplain has been filled on the left bank at a forest products industry yard located about mid-segment. Straightening and channelization is evident near bridges, with two bridges recorded. Some riffle-pool bed formation and planform adjustment is evident at the downstream end of the segment (near farm), but the rest of the segment is plane bed by reference.

Preliminary Management Strategies

- Farm practices in the lower section are contributing to water quality issues and bank erosion. Livestock exclusion and fencing is recommended.

- Considering the smaller lots and multiple landowners along this segment, small individual buffer projects are needed. The Trees for Streams program would be a appropriate program to re-vegetate individual landowner's streamside land.

- The mid-segment forest products industry yard needs to have a long term strategy for moving its operation back from the river's edge. The accumulation of fill and forest products at this site is not sustainable. Heavy erosion and fracturing of the bank has been noted at this section and it will continue as the bank becomes higher.

- Bridges are currently channel constrictions. Bridge upgrades should be considered when the opportunity arises.

Figure 4. Plane bed features in R30A

Figure 5. R30A. Bridge and channel constriction

<u>Reach 30B</u>

Segment Description

The segment begins at a farm bridge near 2651 Greensboro Road (Route 16) and ends downstream of the northern junction of Main Street and Route 16 in Greensboro. This stream segment is significantly

impacted by historic agricultural straightening and undersized structures which have increased the slope and velocity of the stream. The incision ratio is recorded as a moderate to high 1.6, with channel width varying, which is largely due to the historic straightening and undersized structures. Channel evolution is in Stage II. The geomorphic condition is "fair" with a high sensitivity rating due to historic channel degradation. There are four bridges recorded for this segment, with three noted as channel constrictions with related scour and upstream aggradation. Cross section data reveal C-type channel geometry with cobble dominated substrate; however, the entrenchment of 2.3 was very close to a "B" stream type and portions of the segment may be better classified as a B. (Rosgen, 1994) There is significant armoring and channel modification mid-segment at the residence at 1902 Greensboro Road (Route 16). Buffer widths vary with the left bank showing a dominant 0-25' buffer widths, and the right bank with a dominant 100' buffer or greater. Habitat conditions were rated as "good" with bed form and left bank buffer width as the limiting factors.

Preliminary Management Strategies

- There are multiple long term planning opportunities for the undersized bridge structures. A comprehensive bridge survey is recommended to help prioritize upgrades to these structures. The modification of the channel widths due to these undersized structures should be noted when the channel width of a new structure is considered.

- 1902 Greensboro Road (Route 16) is a long term area of conflict as the stream has been armored and modified around the house and yard. Restoring channel equilibrium at this section is greatly limited by the residence and land use. Installing vegetated buffers is recommended.

- The installation of buffers throughout open areas of the segment is also recommended.

Figure 6. Undersized bridge with poor alignment in R30B

Figure 7. Problem bridge and channelization in R30B

Next steps:

- Due to the number of structures impacting channel geometry noted in this report, it is recommended that a full Bridge and Culvert Assessment be conducted for the Upper Lamoille River main stem and its major tributaries to help prioritize future modifications.

- Continue to work with the Trees For Streams program to install buffers at noted locations.

- It is recommended that water quality sampling be conducted in Hardwick village to assess the impact of stormwater inputs.

- Consider future assessments for Upper Lamoille tributaries to better identify management and restoration opportunities.

- Develop landowner and municipal outreach program to discuss project opportunities; such as zoning, easements, buffers and other noted management strategies.

- Continue to update this report to a corridor plan that will include additional maps and tables tracking management strategies and potential projects as they are implemented.

Conclusion

The primary impacts on the Upper Lamoille River are undersized structures, agriculture, and village encroachments (roads and development). The overall concerns of this section of river are related to sediment inputs into Hardwick village, and flood storage capacities upstream. Many of the reaches have under gone some level of historic degradation and straightening; and are now undergoing planform adjustment and aggradation. These adjustments contribute to the sediment that is being delivered into the system. The Jackson Dam impoundment is a primary source of conflict for these concerns and limiting factor in channel equilibrium upstream. Floodplain access is adequate on some reaches, though there are feasible improvements to enhance flood attenuation and decrease sediment with the cooperation of landowners and the towns of Hardwick and Greensboro. Long term planning of infrastructure with the goal of addressing these overall concerns is highly recommended to achieve a greater level of channel stability and compatibility with corridor land use.

Literature Cited

Rosgen, D.L., 1994, A classification of natural rivers. *Catena,* 22(3), 169 – 199.

Appendices:

- Data Management System Phase 2 Reports
- Reach Maps