

# Phase 1 Geomorphic Assessment of the Bolles Brook/City Stream Watershed in Woodford, Vermont

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Assessment conducted Summer 2007  
Report completed November 29, 2007

(Updates to the Phase 1 project in the Vermont Data Management System database were made by staff from Gomez & Sullivan Engineers in November 2007, as part of their Phase 2 geomorphic assessment of this watershed. Those updates are reflected in the findings of this report and the attached DMS reports.)

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## **I. EXECUTIVE SUMMARY**

In summer 2007, the Bennington County Conservation District conducted a Phase 1 geomorphic assessment of eight reaches in the Bolles Brook/City Stream watershed in the towns of Woodford, Glastenbury, and Stamford in southwestern Vermont.

Many of the study reaches have been highly altered by human activities, and this assessment quantifies some of those alterations. (Because they are what is consequential in terms of future management actions in the watershed, this report focuses on those human-induced impacts.)

- Six of the eight reaches received a “high” impact rating due to urban land uses in the stream corridor.
- Five reaches received a “high” impact rating due to straightening.
- Seven reaches received a “high” impact rating due to encroachment, primarily by roads.
- One reach was ranked “high” by virtue of armoring.
- One reach received a “high” ranking for depositional features.

Despite these rankings, the overall condition of the reaches in this watershed is either good or reference as compared to rivers statewide. Reaches assessed as “Good” are in equilibrium, but may be in transition. For reaches assessed as “Reference,” channel geometry is likely to be in balance with flow and sediment produced in the watershed.

- Five reaches received a statewide reach condition score of “Good” and three a statewide reach condition score of “Reference.”

In a different context, and to assist with prioritizing future restoration activities, the Phase 1 assessment assigns “project” reach conditions, which compare reaches within the watershed to one another based on the range of scores assigned project reaches. Here, Bolles Brook/City Stream reaches scored lower.

- Two reaches received a “Reference” score; one a “Good” score; four a “Fair” score; and one – the downstream reach on Bolles Brook – a “Poor” ranking.

(Note: A Phase 2 geomorphic assessment of this watershed is now nearing completion. Per the assessment protocols, when entering Phase 2 data into the River Management Program’s Data Management System, the Phase 2 consultants updated Phase 1 data where they were different. BCCD thanks Gomez & Sullivan Engineers for their contribution to this report.)

## **II: PROJECT OVERVIEW**

### **Introduction**

Physical features such as channel slope, width, depth and planform are essentially responses to the water and sediments a watercourse must transport. In natural systems, these geomorphic features are in a dynamic balance with sediment supply and water volume and velocity. Where systems have been disturbed, rivers are likely to be “in adjustment” – evolving toward a new, sustainable dynamic equilibrium between profile, dimension, and pattern on the one hand and watershed inputs of water and sediment on the other.

Empirical studies of rivers worldwide have enabled river scientists to characterize rivers in dynamic equilibrium according to their geomorphic features. We know, for example, that, in nature, a northeastern valley bottom stream typically occupies a wide, gently sloping valley; that the channel is a good deal wider than deep, and that sinuosity is moderate. In nature, a northeastern headwaters stream is usually steep, deeply entrenched, and often exhibits numerous cascades. For the river researcher, a red flag is raised where any feature of a stream departs in an important way from what would be typical of a watercourse in that landscape setting. Assessments of physical features of rivers are useful because, by uncovering and describing these departures, they can help us understand how and why a watercourse is changing, and guide us in managing for those changes.

### **Goals and objectives**

In summer 2007, the Bennington County Conservation District conducted a geomorphic assessment of that portion of the Walloomsac watershed lying upstream of the confluence of Bolles Brook and City Stream, primarily in the Town of Woodford in Bennington County, Vermont. The purpose of the project was to lay a foundation for future targeted field investigation of the causes of instability in the watershed and, eventually, for the design and implementation of their “cures.” The long term objective was to reduce instability and its impacts on natural and cultural resources. The assessment and accompanying Phase 2 geomorphic study complemented Phase 1 and Phase 2 assessments conducted over several years in much of the Walloomsac watershed downstream of the confluence of Bolles Brook and City Stream, in the Towns of Woodford and Bennington.

The results, summarized in this report, describe the sort of rivers typical of the watershed’s geologic setting, and red-flags departures from the typical, reach by reach. The assessment made use of the May 2007 Vermont Agency of Natural Resources (ANR) Vermont Stream Geomorphic Assessment Phase 1 Handbook (ANR 2007 SGA Phase 1) and the Stream Geomorphic Assessment Tool software developed for the ANR. More information on the protocols and SGAT can be found at [http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv\\_geoassesspro.htm](http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm) Study findings were uploaded to the agency’s web-based Data Management System (DMS) and are available for public review at <https://anrnode.anr.state.vt.us/ssl/sga/>.

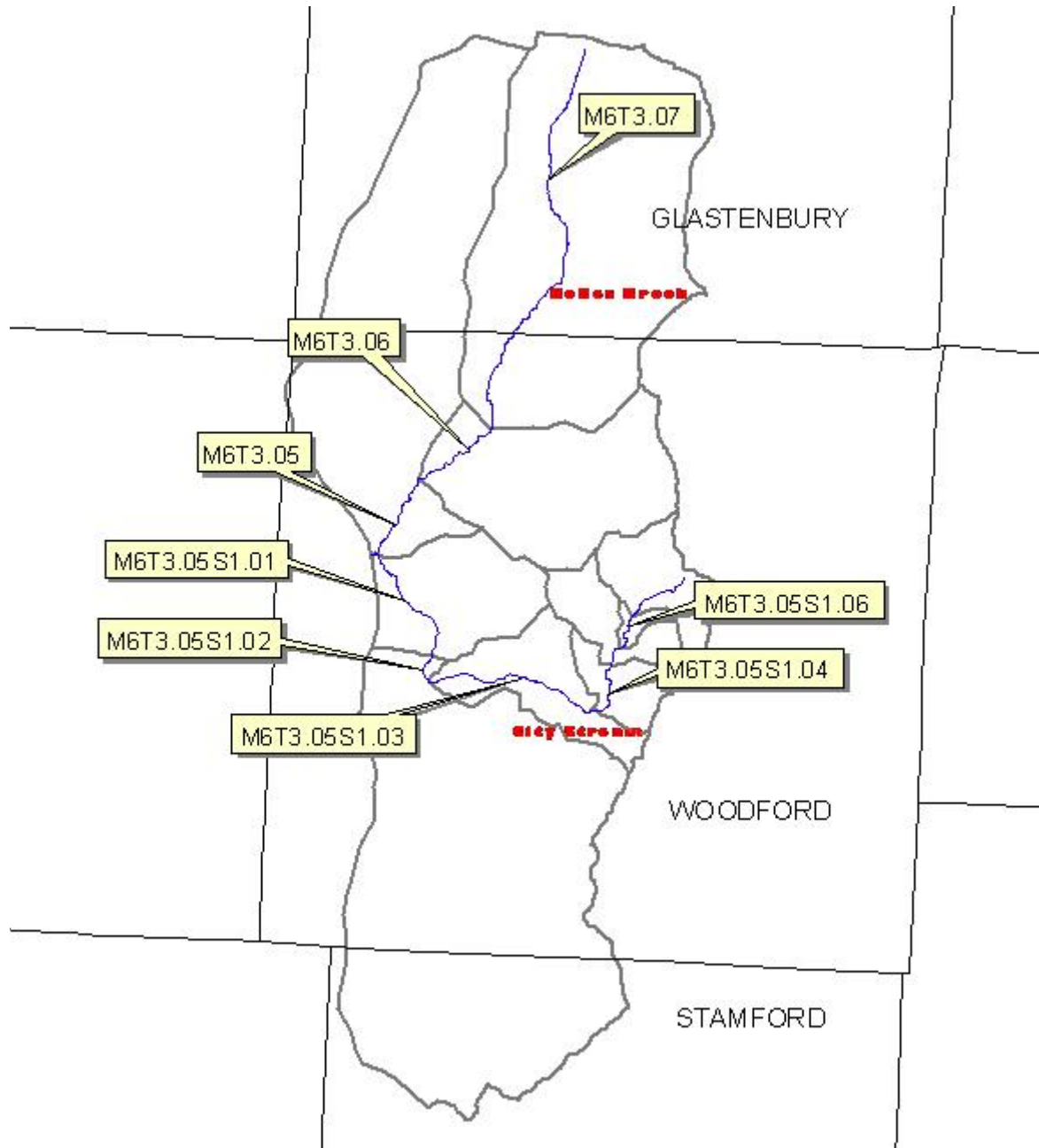
### **III. PROJECT AREA AND FLUVIAL GEOMORPHIC SETTING**

The portion of the Walloomsac watershed drained by Bolles Brook and City Stream occupies about 99 square miles in the headwaters of the Hoosic River watershed in Vermont. The Hoosic drains to the Hudson River – with the Batten Kill, the only rivers in Vermont to do so. The Walloomsac/Hoosic drainage divide separates the Hudson drainage in Vermont from the Connecticut River drainage in Vermont.

Eight reaches on Bolles Brook and City Stream were examined.

Map 1 illustrates the study area.

**Map 1. Bolles Brook/City Stream study reaches**



#### **IV. METHODOLOGY**

The Phase 1 assessment of the Bolles Brook/City Stream watershed used the 4.56 version of the SGAT Arcview extension (which helps automate much of the data collection and creation), a Feature Indexing Tool, and the May 2007 version of the Vermont Stream Geomorphic Assessment Phase 1 Handbook. Orthophotography was flown in 2001. Study findings were

uploaded to the agency’s web-based Data Management System (DMS) and are available for public review at the web address referenced above.

## V. ASSESSMENT RESULTS

### A. Pre-intervention: the reference condition

Phase 1 stream geomorphic assessments begin by describing a watercourse’s reference condition, that is, the kind of stream it most likely would have been absent human intervention. The following table illustrates the stream typing scheme used by the VT ANR (ANR 2007 SGA Phase 1, p. 29).

**Table 1. Stream Typing Chart**

Reference stream type	Confinement (Valley type)	Valley Slope	Bed form
A	Narrowly confined	Very Steep > 6.5%	Cascade
A	Confined	Very Steep 4.0-6.5%	Step-pool
B	Confined or semi-confined	Steep 2.0-4.0%	Step-pool
B	Confined, semi-confined, or narrow	Mod. – Steep 2.0-3.0%	Plane Bed
C or E	Unconfined	Mod. –Gentle <2.0%	Riffle-pool or Dune-ripple
D	Unconfined	Mod.-Gentle <4.0%	Braided Channel

The eight study area reaches were found to have the following stream types:

**Table 2. Study Area Reach Types**

Reach number	Watercourse name	Stream type
M6T3.05	Bolles Brook	B Step-pool
M6T3.06	Bolles Brook	D Braided
M6T3.07	Bolles Brook	A, bed feature not evaluated
M6T3.05S1.01	City Stream	C Step-pool
M6T3.05S1.02	City Stream	B Step-pool
M6T3.05S1.03	City Stream	A Step-pool
M6T3.05S1.04	City Stream	C Riffle-pool
M6T3.05S1.06	City Stream	D Braided

### B. Post-intervention: human-induced impacts – in the watershed or stream corridor, and in the stream

The concept of dynamic equilibrium acknowledges the primacy of change in watercourses over time. Streams free of human intervention erode their banks, cut off bends, move laterally in response to new obstructions, grow deeper in one location and shallower in others, and otherwise move up and down and from side to side within their valley walls.

Although such change sometimes can be dramatic and nearly instantaneous, human intervention usually leads to comparatively greater instability (that is, more change) and generally more violent change within a watercourse. Degraded natural resources and drained public coffers can result. Vermont ANR's Phase 1 assessments collect information on anthropogenic alterations in the watershed and in or along the stream itself which might cause atypical instability in stream profile, dimension, or pattern. Such human-induced changes uncovered in the Bolles Brook/City Stream watershed assessment include:

Land uses (Step 4 of the Phase 1 SGA)

- Urban development in the watershed or stream corridor, frequent.
- Reduction in the width of the naturally occurring riparian buffer, occasional

Instream modifications (Step 5 of the Phase 1 SGA)

- Bridges and culverts, infrequent
- Bank armoring, occasional
- Channel straightening, frequent

Floodplain modifications (Step 6 of the Phase 1 SGA)

- Encroachment by berms and roads, frequent
- Deposition, infrequent

**B1: Riparian land uses: forests, agricultural lands, urban areas**

Land use and land cover in the stream corridor and in the riparian zone are indicators of watercourse stability and resiliency for a number of reasons. Forested corridors and buffer zones are more likely than urbanized or agricultural lands to capture precipitation. Storm-induced flows in forested streams are smaller in volume and slower in velocity – and therefore less powerful – than non-forested watercourses. Water that doesn't quickly infiltrate the soil moves more slowly over the ground in forested landscapes compared to non-forested ground because of the friction provided by downed logs and limbs, leaf litter and other large and small organic particles. And stream banks on which trees and shrubs are growing are secured by plant roots; they are less likely to erode than unvegetated banks.

Using land use/land cover data derived from LANDSAT imagery created in the early 1990s, the Bolles Brook/City Stream watershed Phase 1 study looked at land uses within each reach's stream corridor (often that polygon defining the boundaries of a stream's meandering, but never less than 100 feet from the stream center line on either side of the stream). Watercourses in forested corridors are at minimum risk of land use-induced instability. Residential, commercial, and other urban uses pose a greater risk to stream stability.

River corridors in which urban land uses predominate are at highest risk. But even lesser degrees of development can be highly destabilizing, so much so that the Phase 1 study protocol considers urban land uses of 10% or more of the corridor to have a high impact. The following table summarizes urban land use impacts within the study corridors according to both dominance of urban land uses and according to this 10% threshold. (A caveat is in order: in the land use/land cover GIS layer, lands of at least two acres in size as pictured in the satellite images are

classified as wetland, forest, shrub, field, crop, residential, commercial, industrial or several other more specific classes. At the corridor scale, this data is coarse and can be misleading.)

**Table 3. Urbanization in reach corridors**

Total number reaches	8
Number of reaches with predominantly urban land uses	3
Number of reaches with at least 10% or “high” impact: urban land uses (includes those above)	6

The Phase 1 study also looked more closely at the riparian zone itself. Using orthophotography from April 2001, the study determined the width of the vegetated buffer along each reach. Substantial buffers are the rule in the watershed. Table 4 summarizes vegetated buffer widths by percent of each watercourse.

**Table 4. Buffer Widths**

Reach #/Stream Name	Dominant buffer width, left and right bank	
	Left bank	Right bank
M06T3.05	>100	>100
M06T3.06	>100	>100
M06T3.07	>100	>100
M06T3.05S1.01	51-100	>100
M06T3.05S1.02	26-50	>100
M06T3.05S1.03	>100	0-25
M06T3.05S1.04	>100	0-25
M06T3.05S1.06	>100	>100

**B2: Channel Modifications**

Phase 1 assessments of instream channel modifications look at five elements: flow regulation; the number and length of impact of bridges and culverts; bank armoring, channel straightening; and dredging history.

a) *Flow regulation*

Except for a small drinking water bypass on Bolles Brook (for the Bennington water supply system), no flow regulations were discerned on the orthophotographs nor during the windshield survey. That Bolles Brook bypass was ranked as “low” impact.

b) *Bridges and culverts*

Six of the reaches studied are bridged or culverted, some in more than one location. In every case, though, the assessor rated those impacts “low.”

c) *Bank armoring*

Four reaches could be seen as being armored on review of the orthophotographs or during the windshield survey. On those four reaches, impacts were ranked “not significant” in two cases,

“low” in one case, and “high” in one case – on reach M6T3.05S1.02 (on City Stream). There, 33% of the reach had been armored.

d) *Channel straightening*

Five reaches in the study area have been straightened to some extent. Four reaches have been straightened over more than twenty percent of their length and received therefore a “high” impact rating for straightening. Much of the study reaches are located along roadways.

**Table 5: Straightening**

Reach #/Stream Name	Length Straightening	Impact
M06T3.05	76%	High
M06T3.06	None	Not significant
M06T3.07	None	Not significant
M06T3.05S1.01	70%	High
M06T3.05S1.02	96%	High
M06T3.05S1.03	None	Not significant
M06T3.05S1.04	32%	High
M06T3.05S1.06	11%	Low

e) *Dredging history*

The Natural Resources Conservation Service district conservationist reports that no dredging has taken place in the watercourse in her more than 25 years in Bennington County. A walk along portions of City Stream as part of the Phase 2 scoping, however, led to the discovery of lengthy, historic berms along VT Route 9. That information was used to update the Phase 1 DMS entries.

**B3: Floodplain Modifications**

A floodplain is essentially the land the stream made, primarily through accretion of alluvial deposits during times of bankfull flows or flood, or through lateral movement back and forth as the watercourse struggled to balance inputs from upstream. Valley walls limit the maximum width of a floodplain naturally; in the human-impacted setting, berms and roads along watercourses further restrict the area a watercourse might work while in bankfull stage or in flood.

a) *Berms and Roads*

Although the watershed is almost entirely forested, many of its watercourses are impacted by roads and berms. Table 6, Berm and Road Restrictions, summarizes this feature. (Impacts greater than 20% were ranked “high.”)

**Table 6. Berm and Road Restrictions**

Reach number	Percent restriction		Impact
	Road	Berm	
M6T3.05	68%	0	High
M6T3.06	34%	6%	High
M6T3.07	Not evaluated	Not evaluated	Not evaluated
M6T3.05S1.01	49%	56%	High
M6T3.05S1.02	97%	6%	High
M6T3.05S1.03	70%	0	High
M6T3.05S1.04	23%	0	High
M6T3.05S1.06	21%	0	High

Most of the other floodplain modification features analyzed in the Phase 1 assessment are results of modifications to the channel or the floodplain. They include depositional features, meander migration histories, meander width ratios, and wavelength ratios.

*b) Depositional Features*

Except for Reach M06T3.05S1.01 on City Stream, no noteworthy depositional features were discovered. On that reach, depositional feature impact was rated “high.” Several instances of a variety of depositional features were seen on the orthophotographs or observed during the windshield survey on that reach.

*c) Meander migration*

Infra-red photos from 1977 were examined for signs of meander migration. No evidence of such an event on any of the study reaches was seen.

*d) Ratios*

Meander width ratios and wavelength ratios were not evaluated in this study.

**C: Impact Summary**

The Phase 1 assessment of the Bolles Brook/City Stream watershed first collected information on largely human-induced changes in the study area. When entered into the River Management Program’s web-based Data Management System (DMS), those changes were each assigned a score of “2” or “high,” “1” or “low,” or “0” “not significant.” Those scores were then combined for a total impact score of from 0 (representing the least impact) to 32 (the most impact).

Because the DMS assigns parameters not assessed a score of 0, lack of information on a certain kind of impact can skew an impact score lower than might be warranted. In this study, bed material information and bank erosion/bank height were lacking for all but a few access points on just some of the reaches. Had it been possible to assess those parameters, total impact scores might have been higher.

The DMS also makes use of parameter impact values to suggest which of four adjustment processes – degradation, aggradation, widening, and planform change – are most at work in any reach. A cut-off score of 4 was established to distinguish (very broadly) between streams in

equilibrium and those in adjustment. In general, the two highest scores indicate the adjustment processes most active in the reach.

Finally, these scores are used to generate a reach condition score for each reach in two different contexts – within the project area (the reaches are compared to one another), and statewide (in which the study reaches are compared to adjustment statewide). In each context, “reference” (a score of 0.85-1.0) means the reach has suffered no significant channel or floodplain modifications and is well-buffered; “good” (a score of 0.65-0.84) means a stream is undergoing only minor adjustments or has adjusted to previous modifications and is nearly in balance again; “fair” (a score of 0.35-0.64) means a reach is experiencing major or rapid changes or that those changes are imminent; and “poor” (a score of 0.00- 0.34) refers to a reach that is severely out of regime.

Appendix B of the Phase 1 Handbook explains the process by which adjustment processes are assessed. (Because the processes are interrelated – one process entrains another – the adjustment process scores aren’t simply additive but are also weighted so as to capture that interplay phenomenon.) Page 76 in the May 2007 Phase 1 Handbook explains how reaches are assigned a reach condition.

Table 7 displays these DMS-generated findings for the study area reaches. “D” signifies degradation; “A,” aggradation; “W,” widening; and “P,” planform change.

**Table 7. Impact Summary, Adjustment Processes, Reach Conditions**

<b>Reach #/Stream Name</b>	<b>Highest adjustment processes</b>	<b>Total Impact Score</b>	<b>Project Reach Condition</b>	<b>Statewide Reach Condition</b>
M6T3.05	P (13), D (11)	16	Poor	Fair
M6T3.06	None > 4	6	Reference	Reference
M6T3.07	None > 4	0	Reference	Reference
M6T3.05S1.01	D (8), P (6)	17	Fair	Good
M6T3.05S1.02	D (10), P (5)	13	Fair	Good
M6T3.05S1.03	A (5)	8	Good	Good
M6T3.05S1.04	D (6), A (6), P (5)	10	Fair	Good
M6T3.05S1.06	D (8), A (7), P (6), W (5)	11	Fair	Good



## **VI. CONCLUSIONS**

This assessment of the Bolles Brook/City Stream watershed in southwestern Vermont describes a system altered by human activities and, in many reaches, one still actively adjusting to the impacts of those activities. Future field studies focusing particularly on “high” total impact, “poor” project reach condition reaches can help area residents and municipal officials craft short-term and long-term management plans. A Phase 2 geomorphic assessment of this watershed is scheduled for completion in early 2008.