# A Study of Bank Erosion Rates within Selected Reaches of the Housatonic River

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Project Number 195600459

## 1.0 INTRODUCTION

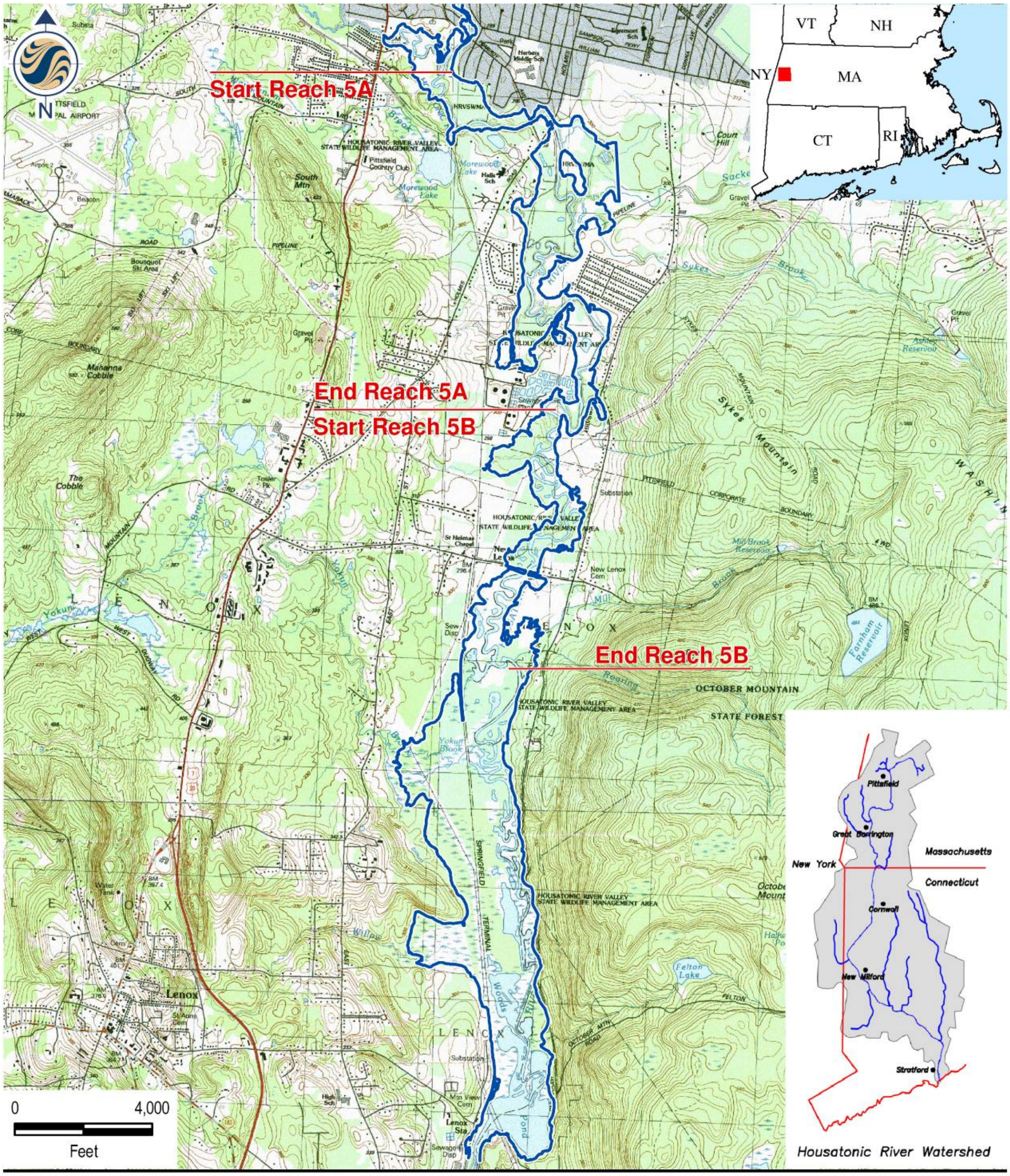
The United States Environmental Protection Agency (USEPA) is in the process of reviewing General Electric's (GE) Housatonic River – Rest of River Corrective Measures Study (CMS; GE 2008). Some of the alternatives presented in the CMS involve removal of contaminated river bank soil with subsequent bank restoration using a variety of methods that range from armoring with stone to using vegetation and some stone to stabilize reconstructed banks. A reconnaissance-level bank erosion study was conducted to estimate on-going erosion, which will facilitate USEPA review of the CMS and the proposed alternatives.

Streambank erosion rates can be predicted using the Bank Assessment for Non-Point Source Consequences of Sediment (BANCS; Rosgen 2006). The BANCS method provides an estimate of the rate of erosion and the amount of bank material being released from streambanks into the river system. It is a visual assessment tool that, when combined with more quantitative studies completed in other states, can provide a reasonable estimate of erosion rates. The BANCS method uses two bank erodibility estimation tools: the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS). The application involves evaluating the bank characteristics and flow distribution along river reaches, mapping the location and extent of each bank feature, and developing risk ratings per bank feature. In each reach of river or stream an overall estimate of erosion is made by multiplying the length and height of each bank type by the specific bank erosion term, and then summing the estimates of erosion. This provides an estimate of cubic yards and/or tons of sediment that erode per reach per year.

## 2.0 METHODOLOGY

During the week of May 18, 2009, bank erosion surveys were performed on the Housatonic River in Reach 5A and Reach 5B as indicated in Figure 1. Qualitative surveys were also conducted upstream between areas previously restored by GE and USEPA up to the TJ Maxx Plaza on Merrill Road in Pittsfield. In Reaches 5A and 5B data were collected from approximately 41,000 linear feet of stream channel and 82,000 feet of streambank (i.e., both banks were surveyed). Field surveys of bank erosion were stopped near the end of Reach 5B because the BEHI and NBS values began to decline due to the backwater effect of Woods Pond.

To ensure that the field data would be collected during a representative period of flow, recent flow data for two gauges on the Housatonic River were compared to long-term averages. It was decided to proceed with the data collection because flows were close to average and no significant rainfall events were predicted. After the field data were collected, the flow data for the study period were also compared with the historical average to verify that flows had remained average.

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**Legend**

— Primary Study Area Boundary

Client/Project
**Weston Solutions, Inc.**
**General Electric Housatonic River Project**
**Bank Erosion Study**

Figure No.
**1-1**

Title
**Primary Study Area**
8/11/2009

During field surveys, the left and right banks of Reach 5A and most of Reach 5B were classified based on both the BEHI and NBS. Figures 2 and 3 show example BEHI and NBS data forms, respectively. As part of classification, banks were divided into segments and inventoried based on the changes of physical bank characteristics and the applied shear stress, e.g., bank height, root depths, root density, bank angle, and amount of surface protection. The locations of bank segments and sampling locations were marked on aerial photographs during the field survey (Appendix A). Representative photographs of banks (Appendix B) were taken to visually document BEHI conditions and factors contributing to NBS.

In the BANCS model there are seven methods that can be used to assess energy distribution against streambanks, which is referred to as NBS. Methods 2, 3, and 5 were used during this survey to measure NBS. Method 2, which is completed in the field and then verified using aerial photography, involves measuring the river's radius of curvature and dividing that value by the bankfull width. Method 3 is completed in the field and involves measuring the slope of pools in the river and the average slope of the river, then calculating the ratio of pool slope to average slope. Method 5 uses cross-section data to calculate the ratio of near-bank maximum depth to bankfull mean depth. Cross-sections previously collected for the EPA Housatonic River modeling study were used for Method 5.

The location of the thalweg was mapped in the field on aerial photos to provide another indication of NBS (Appendix C). A survey-grade geographic positioning system (GPS) unit was used to verify the length of bank segments and determine locations along the river. The GPS data were loaded into AutoCAD and converted to a spatially-referenced ArcView shapefile (NAD83 MA projection). The thalweg location and the existing cross-sections were used to assign an NBS value to each bank location throughout the study reaches.

The BEHI and NBS numbers for each of the 1,910 bank segments (shown in Appendix C) of Reaches 5A and 5B were converted to bank erosion rates using graphs of curves for the North Carolina Piedmont Region (North Carolina State University Stream Restoration Program 1989) and the South Central Colorado Region (USEPA 1989; Figures 4 and 5, respectively). It should be noted that, based on soil cohesion and vegetation type, it is expected that the South Central Colorado Region curve will over-predict bank erosion and the North Carolina Piedmont Region curve will under-predict bank erosion for the Housatonic River. To facilitate interpretation of the data, the field data were digitized, loaded into AutoCAD, and converted to a spatially-referenced ArcView shapefile (NAD83 MA projection) to show the bank erosion rates for Reaches 5A and 5B.

Stream: **Housatonic Example Bank** Location: **Example Bank for Report**

Station: Uptream of Holmes Road Observers: **DAB**

Date: **5-19-2009** Stream Type: **C4/5** Valley Type: **VIII**

**BEHI Score (Fig. 3-7)**

**Study Bank Height / Bankfull Height ( C )**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Study Bank Height** (ft) = | **16 (A)** | **Bankfull Height** (ft) = | **5 (B)** | ( A ) / ( B ) = | **3.2 (C)** | **9** |

**Root Depth / Study Bank Height ( E )**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Root Depth** (ft) = | **0.5 (D)** | **Study Bank Height** (ft) = | **16 (A)** | ( D ) / ( A ) = | **0.03125 (E)** | **9** |

**Weighted Root Density ( G )**

| | | | | |
|---|---|---|---|---|
| **Root Density** as **%** = | **25% (F)** | ( F ) x ( E ) = | **0.00781 (G)** | **9** |

**Bank Angle ( H )**

| | | |
|---|---|---|
| **Bank Angle** as *Degrees* = | **85 (H)** | **7** |

**Surface Protection ( I )**

| | | |
|---|---|---|
| **Surface Protection** as **%** = | **20% ( I )** | **7** |

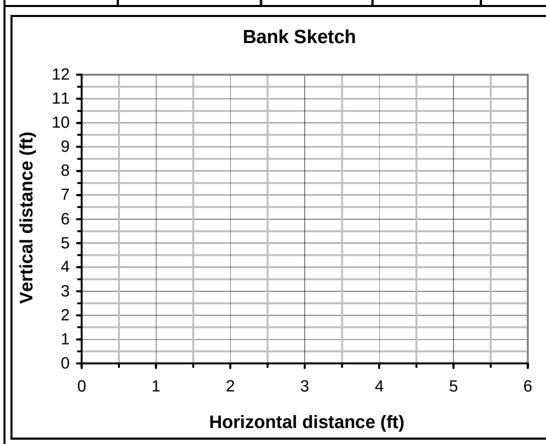
**Bank Material Adjustment:**

**Bedrock** (Overall Very Low BEHI)
**Boulders** (Overall Low BEHI)
**Cobble** (Subtract 10 points if uniform medium to large cobble)
**Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
**Sand** (Add 10 points)
**Silt/Clay** (no adjustment)

**Bank Material Adjustment**: **0**

**Stratification Adjustment**
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: **0**

| Very Low | Low | Moderate | High | Very High | Extreme | Adjective Rating and Total Score |
|---|---|---|---|---|---|---|
| 5 – 9.5 | 10 – 19.5 | 20 – 29.5 | 30 – 39.5 | 40 – 45 | 46 – 50 | **41** |



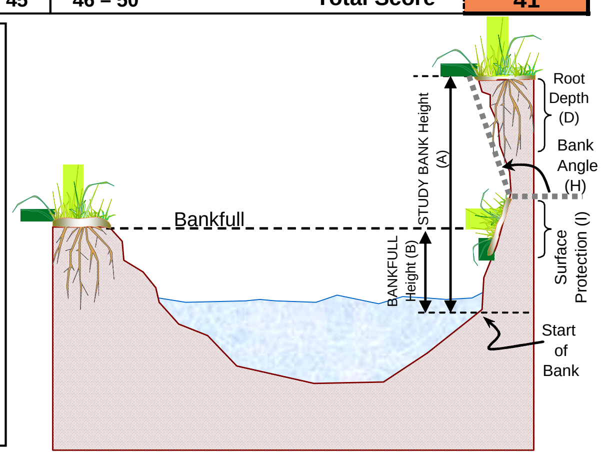




**Figure 2.** Example BEHI Form

## Estimating Near-Bank Stress ( NBS )

| | | |
|---|---|---|
| Stream: **Housatonic River** | Location: **Example** | |
| Station: | Stream Type: | Valley Type: |
| Observers: **DAB** | | Date: |

### Methods for Estimating Near-Bank Stress (NBS)

| | | |
|---|---|---|
| **(1)** Channel pattern, transverse bar or split channel/central bar creating NBS………. | Level I | Reconaissance |
| **(2)** Ratio of radius of curvature to bankfull width ( $R_c$ / $W_{bkf}$ )…………………………………………… | Level II | General prediction |
| **(3)** Ratio of pool slope to average water surface slope ( $S_p$ / S )……………………………………… | Level II | General prediction |
| **(4)** Ratio of pool slope to riffle slope ( $S_p$ / $S_{rif}$ )………………………………………………………… | Level II | General prediction |
| **(5)** Ratio of near-bank maximum depth to bankfull mean depth ( $d_{nb}$ / $d_{bkf}$ )………………………… | Level III | Detailed prediction |
| **(6)** Ratio of near-bank shear stress to bankfull shear stress ( $\tau_{nb}$ / $\tau_{bkf}$ )………………………… | Level III | Detailed prediction |
| **(7)** Velocity profiles / Isovels / Velocity gradient…………………………………………………… | Level IV | Validation |

**Level I**

**(1)**
Transverse and/or central bars-short and/or discontinuous………… ……………….…NBS = High / Very High
Extensive deposition (continuous, cross-channel)……………………………………………………NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow…………………………………NBS = Extreme

**Level II**

| | | | | |
|---|---|---|---|---|
| **(2)** | Radius of Curvature $R_c$ (ft) | Bankfull Width $W_{bkf}$ (ft) | *Ratio* $R_c$ / $W_{bkf}$ | Near-Bank Stress (NBS) |
| | | | | |

| | | | | |
|---|---|---|---|---|
| **(3)** | Pool Slope $S_p$ | Average Slope S | *Ratio* $S_p$ / S | Near-Bank Stress (NBS) |
| | | | | |

| | | | | |
|---|---|---|---|---|
| **(4)** | Pool Slope $S_p$ | Riffle Slope $S_{rif}$ | *Ratio* $S_p$ / $S_{rif}$ | Near-Bank Stress (NBS) |
| | | | | |

| |
|---|
| **Dominant Near-Bank Stress** |
| |

**Level III**

| | | | | |
|---|---|---|---|---|
| **(5)** | Near-Bank Max Depth $d_{nb}$ (ft) | Mean Depth $d_{bkf}$ (ft) | *Ratio* $d_{nb}$ / $d_{bkf}$ | Near-Bank Stress (NBS) |
| | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **(6)** | Near-Bank Max Depth $d_{nb}$ (ft) | Near-Bank Slope $S_{nb}$ | Near-Bank Shear Stress $\tau_{nb}$ ( lb/ft$^2$ ) | Mean Depth $d_{bkf}$ (ft) | Average Slope S | Bankfull Shear Stress $\tau_{bkf}$ ( lb/ft$^2$ ) | Ratio $\tau_{nb}$ / $\tau_{bkf}$ | Near-Bank Stress (NBS) |
| | | | | | | | | |

**Level IV**

| | | |
|---|---|---|
| **(7)** | Velocity Gradient ( ft / sec / ft ) | Near-Bank Stress (NBS) |
| | | |

### Converting Values to a Near-Bank Stress (NBS) Rating

| Near-Bank Stress (NBS) ratings | Method number | | | | | | |
|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
| **Very Low** | N / A | > 3.00 | < 0.20 | < 0.40 | < 1.00 | < 0.80 | < 0.50 |
| **Low** | N / A | 2.21 – 3.00 | 0.20 – 0.40 | 0.41 – 0.60 | 1.00 – 1.50 | 0.80 – 1.05 | 0.50 – 1.00 |
| **Moderate** | N / A | 2.01 – 2.20 | 0.41 – 0.60 | 0.61 – 0.80 | 1.51 – 1.80 | 1.06 – 1.14 | 1.01 – 1.60 |
| **High** | See | 1.81 – 2.00 | 0.61 – 0.80 | 0.81 – 1.00 | 1.81 – 2.50 | 1.15 – 1.19 | 1.61 – 2.00 |
| **Very High** | (1) | 1.50 – 1.80 | 0.81 – 1.00 | 1.01 – 1.20 | 2.51 – 3.00 | 1.20 – 1.60 | 2.01 – 2.40 |
| **Extreme** | Above | < 1.50 | > 1.00 | > 1.20 | > 3.00 | > 1.60 | > 2.40 |
| | **Overall Near-Bank Stress (NBS) rating** | | | | | | |

**Figure 3.** Example NBS Form

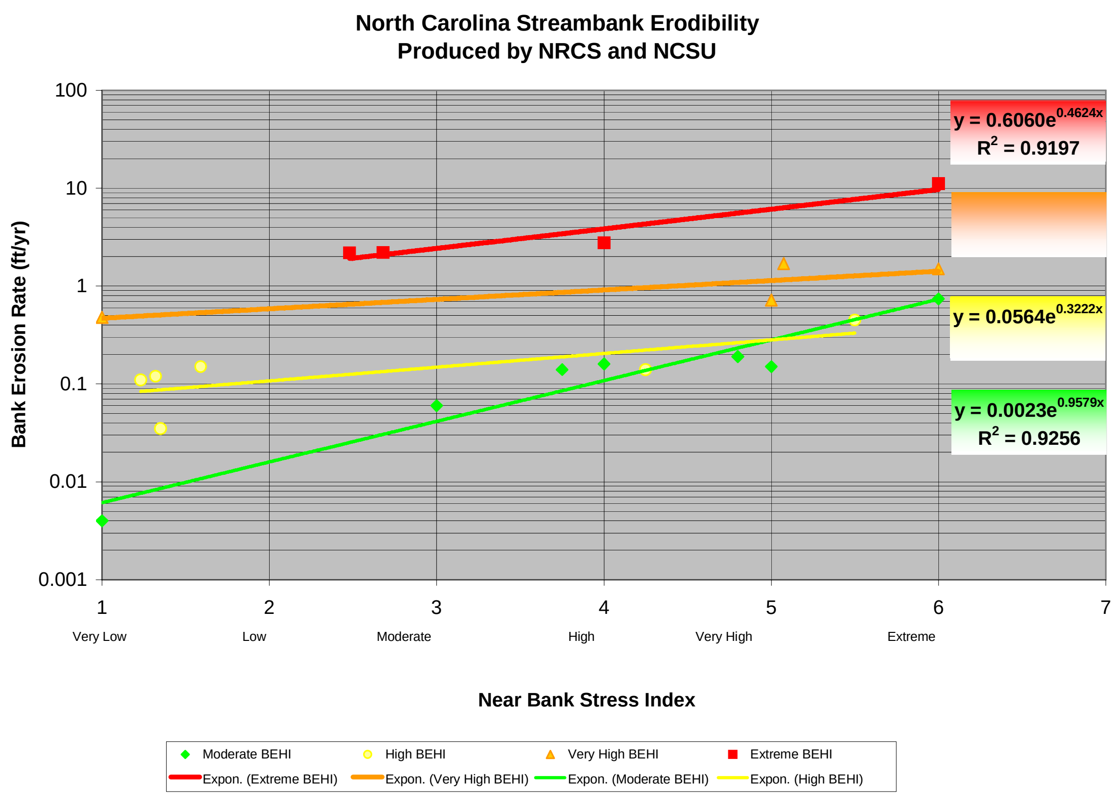



**Figure 4.** North Carolina Piedmont Region Bank Erosion Prediction Curve

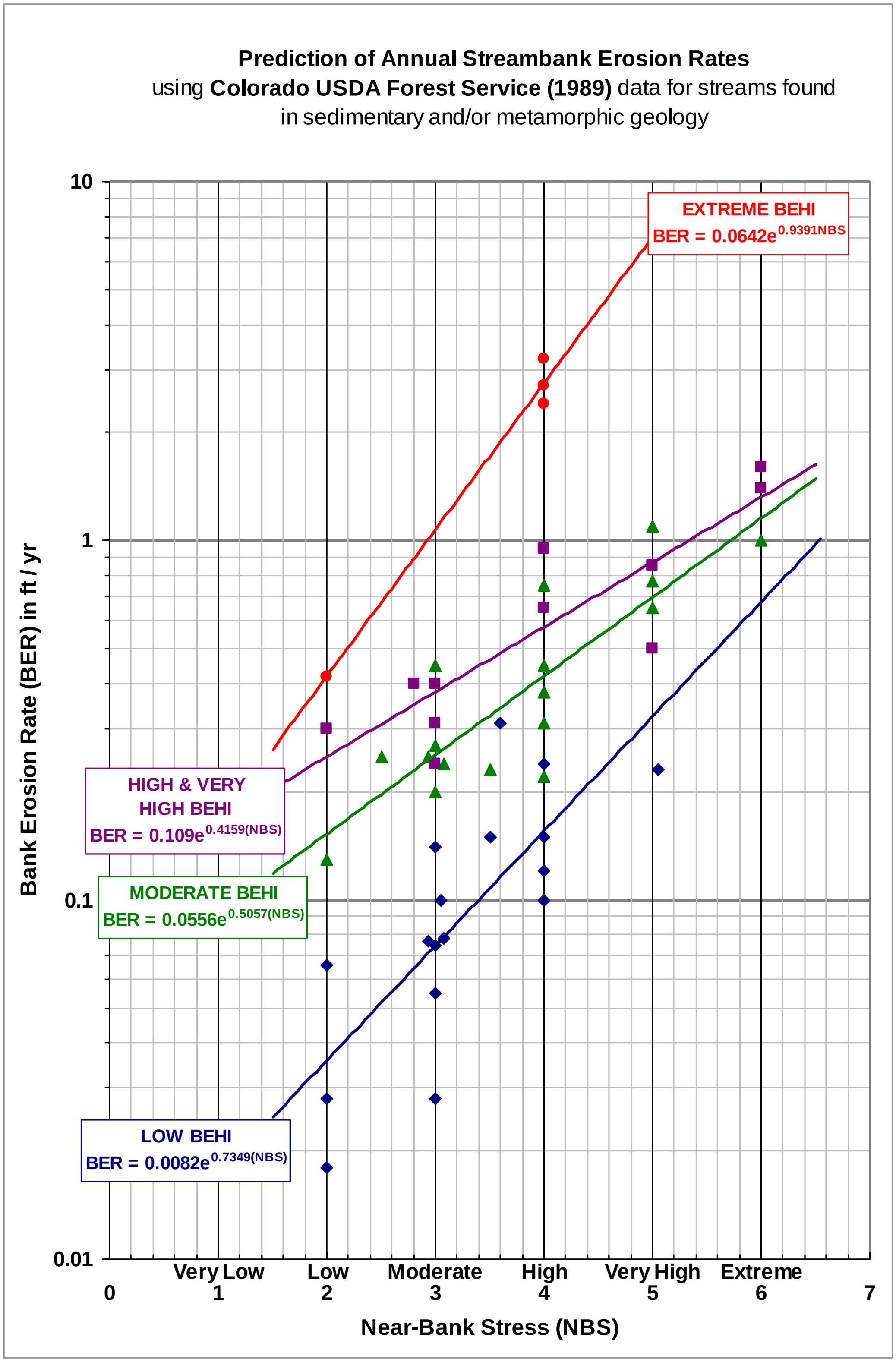



**Figure 5.** South Central Colorado Region Bank Erosion Prediction Curve

## 3.0 RESULTS

The average mean daily flow for the May 18 to May 22, 2009, survey period based on data from the East Branch of the Housatonic River US Geological Survey (USGS) gauge located at Coltsville, MA (upstream of the study area) was 103 cubic feet per second (cfs). This average was calculated from daily flow data downloaded from the gauge for the period of May 18 to May 22. This compared well with the long-term (72-year) average of 138 cfs for the month of May for the Coltsville station. The average flow for the survey period calculated from data downloaded from the USGS gage located near Great Barrington, MA (downstream of the study area) was 545 cfs. This compared well with the long-term (95-year) average of 676 cfs for the Great Barrington station. Flows during the study period were slightly below average but were representative.

The 1,910 bank segments inventoried ranged from 2 to 271 feet in length and had an average length of 43 feet.

The curves shown in Figures 4 and 5 were used to estimate yearly bank erosion based on BEHI and NBS values generated from the field survey. An average bank erosion rate of 0.32 feet/year was calculated for Reaches 5A and 5B. This is two orders of magnitude higher than the rates of 0.001-0.005 feet/year documented for stable streams in similar valley systems in North Carolina (unpublished data). Even when one considers that the North Carolina rivers probably have lower rates of bank erosion than rivers in the northeast, the data from the Housatonic clearly indicate that Reaches 5A and 5B are in a state of accelerated bank erosion. Qualitative surveys also indicate that upstream banks between areas previously restored by GE and USEPA up to the TJ Maxx Plaza on Merrill Road in Pittsfield are in a state of extreme erosion.

The BEHI and NBS numbers for the 1,910 bank segments were converted to sediment in tons/foot/year by multiplying bank erosion rates (North Carolina and Colorado) by the bank height and the length of bank assessed. The volume of material (cubic feet) lost from the streambank each year was converted to pounds based on a density of 124 pounds/cubic foot (lbs/cft).[1] The values were then normalized to reflect the weight of sediment eroding for each foot of streambank.

Figure 6 shows the bank erosion in tons/foot/year for Reaches 5A and 5B, which varies from almost 0 to 1.6 tons/foot/year with an average rate of about 0.2 tons/foot/year.

[1] Density estimated based on a particle density of 165 lbs/cft and bulk density of a sand soil of 105 lbs/cft (Jury and Horton 2004).

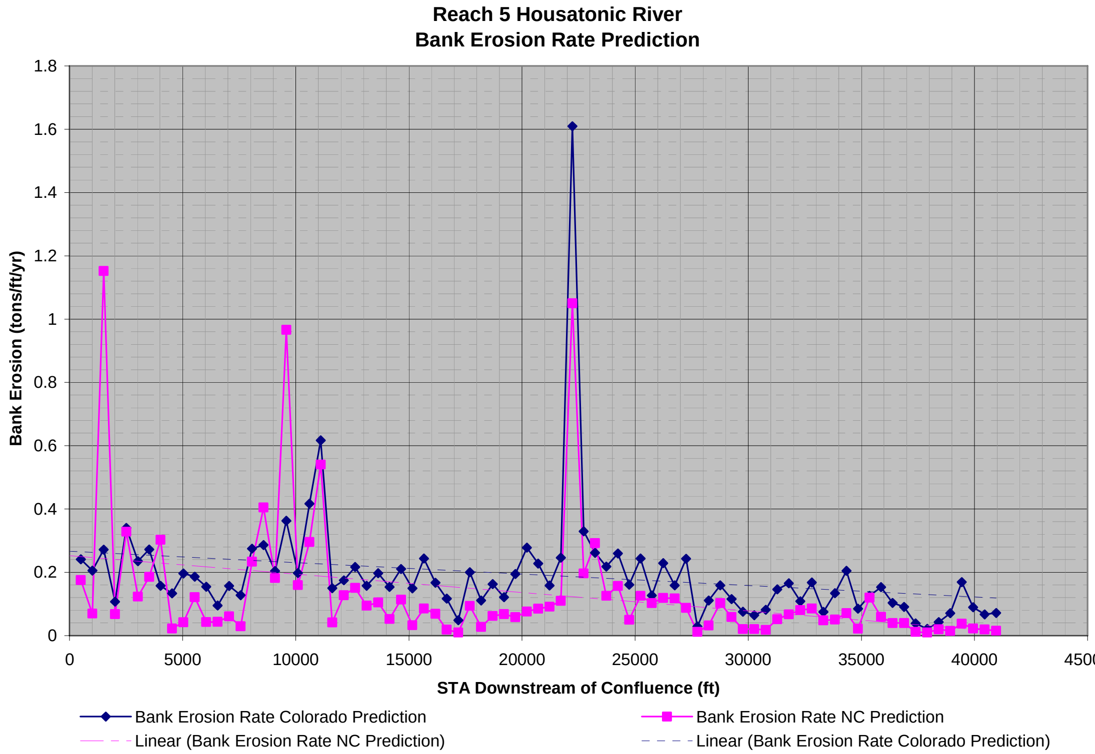



**Figure 6.** Bank Erosion Rate Predictions for Locations along Reaches 5A and 5B

The total bank erosion predicted from the 82,000 linear feet of streambank (41,000 feet of stream channel) surveyed was estimated to be about 8,500 tons/year using the South Central Colorado Region curve and 6,200 tons/year using the North Carolina Piedmont Region curve (Figure 7). The actual rate is likely between these two rates. The rates are based on a number of conditions, such as soil cohesion and vegetation, which are different depending on location. The conditions in Colorado lead to higher rates of erosion compared to the conditions in North Carolina. The conditions found along the Housatonic River are somewhere between the conditions found in North Carolina and Colorado, leading to the conclusion that erosion rates would be between those calculated.

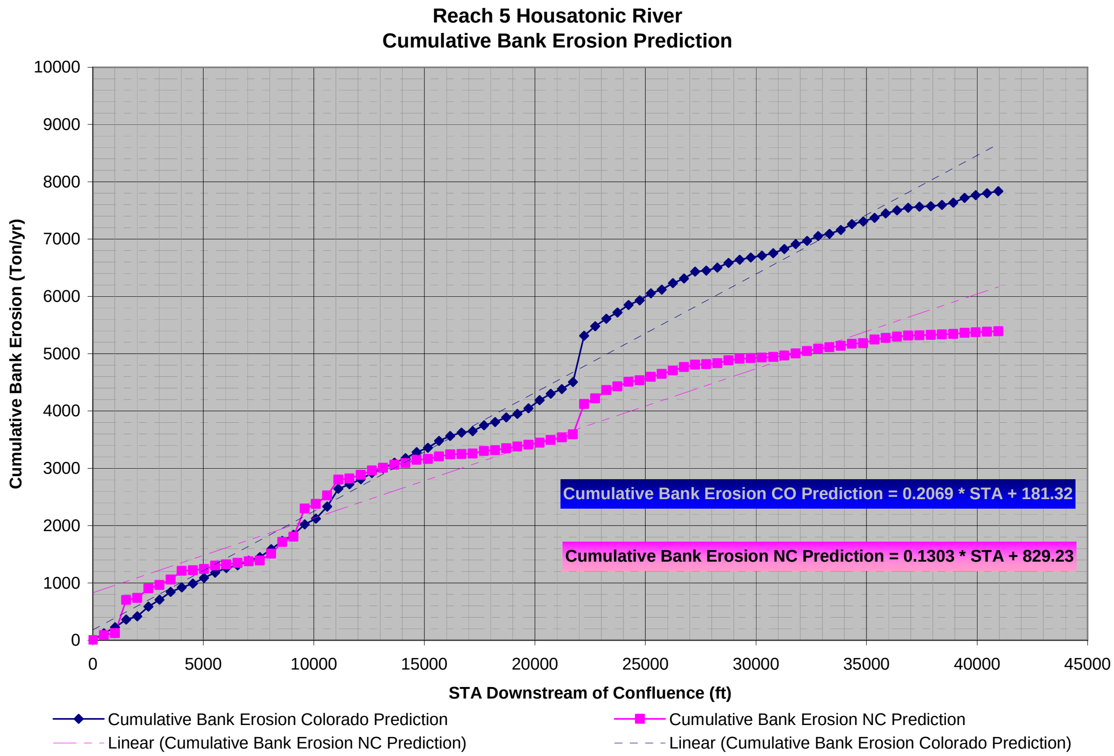



**Figure 7.** Cumulative Bank Erosion for Reaches 5A and 5B

Note: The straight, dashed "linear" lines represent the linear cumulative trend for total bank erosion. The slopes of each of these lines are the average bank erosion rates per unit length for each bank erosion prediction. These lines show that the two different predictions have two separate average bank erosion rates and the areas that graphically have a higher than average bank erosion rate (i.e., slope of the cumulative curve).

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The geographic information system (GIS) analysis supports the field data and observations. Reaches 5A and 5B have areas of very low bank erosion and areas of extreme accelerated bank erosion. The GIS analysis, however, shows that the areas of high bank erosion are generally out of phase with the plan form of the river. In alluvial systems, the areas of highest erosion are expected to occur in the lateral scour pools on the outside of the meander bends and in the lower third of the meander bend. On the reaches studied here, many of the extreme and very high bank erosion rates are located upstream of point bars on the inside banks. This is a sign of active channel migration and horizontal instability. The shapefile created for the GIS analysis can be mapped or displayed over aerial photography or other base map information (Figure 8). The shapefile has an associated database file containing data on the 1,910 segments.

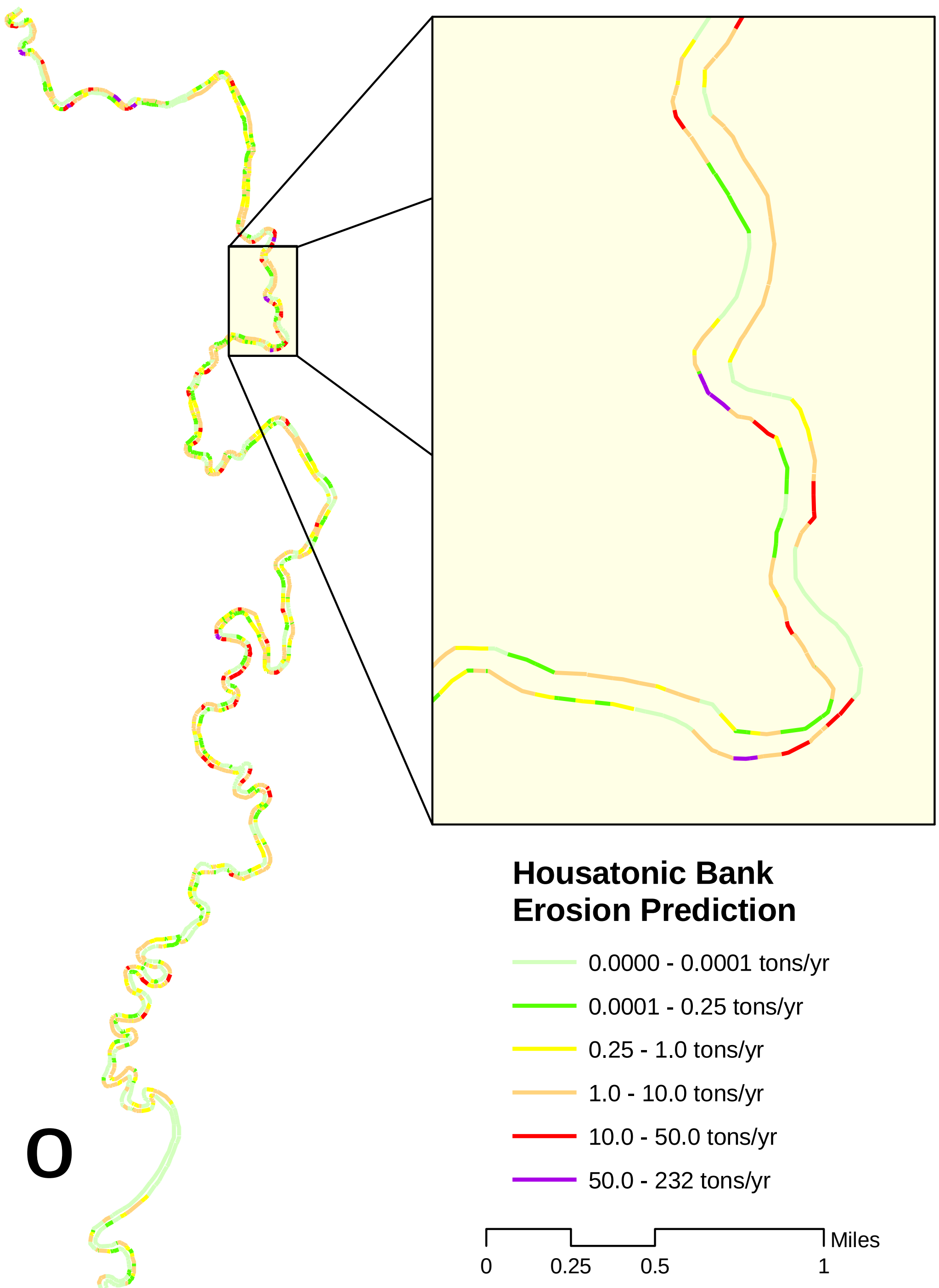


**Figure 8.** Reaches 5A and 5B Bank Erosion Prediction: Example GIS Shapefile Showing Bank Segments

## 4.0 SUMMARY

Streambank erosion rates for Reaches 5A and 5B of the Housatonic River were assessed in May 2009 during a period of average flow using a combination of the BEHI and NBS methods. BEHI provides an indication of streambank susceptibility to erosion, while NBS provides an indication of the erosive forces acting on the streambank. Together, these two factors provide a fairly good indication of streambank erosion. In total, the streambanks were divided into 1,910 segments based on their BEHI and NBS scores. Using quantitative studies from North Carolina and Colorado, the BEHI and NBS scores were converted to erosion rates that averaged 0.32 feet/year over the two reaches surveyed. Stable alluvial streams generally demonstrate erosion rates of 0.001 to 0.005 feet/year. Based on this comparison, Reaches 5A and 5B of the Housatonic River are in a state of accelerated bank erosion.

When combined with measurements of streambank height, the rates of erosion can be converted into a weight of sediment reaching the river. This works out to be approximately 0.16 tons/foot/year or approximately 7,300 tons/year for these two reaches. A GIS analysis revealed that many of the extreme and very high bank erosion rates were located upstream of point bars on the inside banks, a sign of active channel migration and horizontal instability.

## 5.0 LITERATURE CITED

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# APPENDIX A

Aerial Images


1/18


N
1 inch equals 200 feet


N
1 inch quals 200 feet


N
1 inch equals 200 feet


5/18


N
1 inch equals 200 feet


7/18


N
1 inch equals 200 feet
TRIB
432
430
431
BKF BENCH
DEBRIS DAM


9/18


10/18


11/18


12/18


N
1 inch equals 200 feet


N
1 inch equals 200 feet


N
1 inch equals 200 feet


N
1 inch equals 200 feet


N
1 inch equals 200 feet

# APPENDIX B

Representative Bank Photographs

Example of bank conditions with a Bank Erosion Hazard Index (BEHI) rating of very low

Example of bank conditions with a BEHI rating of low

Example of bank conditions with a BEHI rating of moderate

Example of bank conditions with a BEHI rating of high

Example of bank conditions with a BEHI rating of very high

Example of bank conditions with a BEHI rating of extreme

# APPENDIX C

CD Containing Two Shapefiles:
The thalweg and data for the 1,910 segments.

**REPOSITORY TARGET SHEET**

US EPA New England
Superfund Document Management System /
RCRA Document Management System
**Native Files Target Sheet**

SDMS Document ID #:517636

Site Name: GE HOUSATONIC RIVER

File Type(s) Attached (examples: Excel file or .jpg):
cpg, dbf,dwg, idx, shp and shx

Document Type this Target Sheet Represents:

| | | | | | |
|---|---|---|---|---|---|
| [ ] | Map | [ ] | Photograph | [ ] Graph/Chart | |
| [ ] | Video | [ ] | Compact Disc | [ x] Other (Specify below) | |

Description or Comments:
Various Housatonic Bank Erosion Prediction files from 07-25-09

**To view the attached files, open the "Attachment Panel"**
**by clicking on the paper clip - - at the bottom left of this window.**

** Please note to view attachments the software corresponding with the specified file type is necessary. **

For any additional assistance please contact the EPA New England Office of Site Remediation and Restoration Records and Information Center-
Telephone (617) 918 1440