U.S. Fish & Wildlife Service

Watts Branch, Washington, D.C.

Natural Resources Conservation Service Stream Stabilization Monitoring Report

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WATTS BRANCH, WASHINGTON, DISTRICT OF COLUMBIA NATURAL RESOURCES CONSERVATION SERVICE STREAM STABILIZATION MONITORING REPORT

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CBFO-S05-04

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I. INTRODUCTION

The District of Columbia (D.C.), Department of Health, Environmental Health Administration (DOH) and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Service) entered into a partnership agreement (Agreement 51410-1902-0172) to assess and restore streams in Washington, D.C. for the public and Service trust resources. Under this partnership agreement, the Service prepared a watershed and stream assessments of Watts Branch (Eng 2002).

As part of the Watts Branch watershed and stream assessment, the Service conducted monitoring of the Natural Resources Conservation Service (NRCS) stream stabilization project. The project reach is approximately 2,000 linear feet, and begins at 63rd Street and ends at 58th Street (Figure 1). The primary objective of the project was to reduce stream channel erosion by stabilizing stream banks and providing grade control. Stabilization techniques included repairing or replacing failing gabion revetments, installing imbricated rip-rap and boulder revetments, and installing rock vanes, cross vanes, and j-hooks in the stream channel. The project was completed in 2001 and the Service monitored post construction conditions for three years.

The objective of this monitoring is to document stream channel adjustments, over time, within the NRCS project reach. The Service could not assess the success of the project, because the Service did not assess the baseline conditions prior to the stabilization project. However, the Service can assess the effectiveness of the structures used to stabilize the stream.

This report presents the methods used to monitor the stream stabilization project, the findings of the stream monitoring, and discusses the results and effectiveness of the structures used to stabilize the stream. The importance of monitoring stabilization projects is to evaluate the stream stabilization techniques, and to allow DOH and other designers to select the most effective technique(s) for future projects. Monitoring will also allow DOH to identify the need for any potential repair/maintenance, prior to minor problems becoming more significant and expensive.

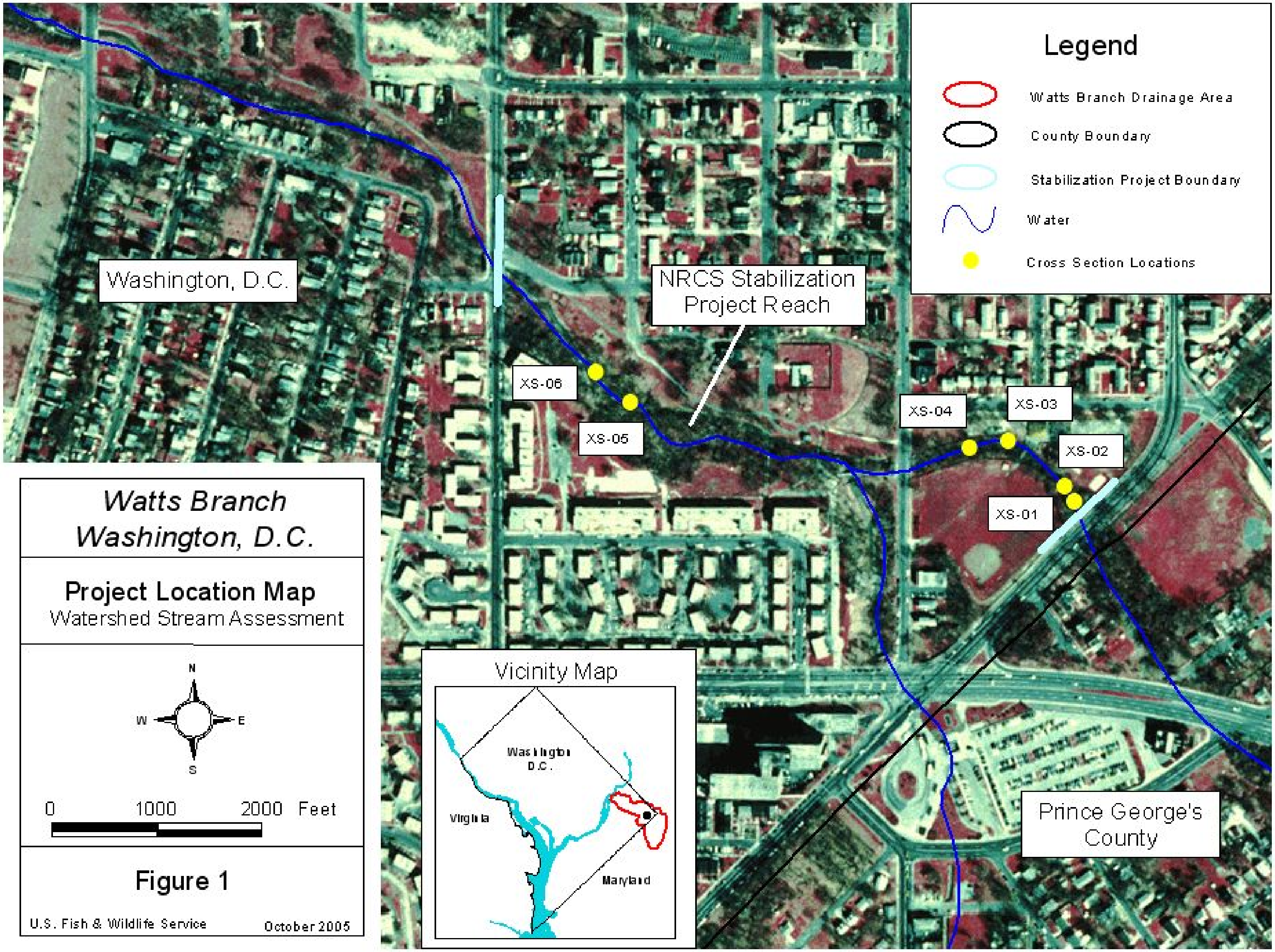
II. METHODOLOGY

This section presents the process the Service used to document vertical and lateral stream channel adjustments. This information is a general work plan, and is not a stepwise instruction manual. Detailed cross section and longitudinal profile survey procedures are presented in the manual *Stream channel reference sites: An illustrated guide to field technique* (Harrelson et al. 1994).

The Service installed six monumented cross sections in 2001, and resurveyed the cross sections in 2003 and 2004, to monitor lateral channel adjustment and scour development (Figure 1). The Service selected locations for the cross sections that would represent the various stream conditions in the project reach, including various bank revetments and grade control structures.

The Service assessed lateral adjustments and scour development by overlaying the annual cross section plots. The Service also visually assessed unmonitored stream banks for indicators of lateral channel adjustments, such as exposed banks, slumping bank, or undercut revetments.

The Service conducted longitudinal profile surveys in 2001, 2003 and 2004, to document vertical change and scour development in the channel bed, within the NRCS stabilization project reach.



Watts Branch
Washington, D.C.

Project Location Map
Watershed Stream Assessment

Figure 1

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The Service assessed vertical adjustments (*i.e*., changes in facet features and slopes) and scour development by overlaying the annual longitudinal profile surveys.

III. RESULTS

This section presents the findings of the stabilization monitoring study. The Service separately presents the cross section, longitudinal profile, and the stabilization evaluation results.

A. Cross Section Results

The Service surveyed six cross sections and overlaid the annual plots to document vertical and lateral channel adjustments (Figures 2a, b, and c). Each plot contains the three years of survey data. The Service determined differences in channel characteristics by comparing each year of survey data with the previous year of survey data. The Service looked at the total change in channel characteristics by summing the annual differences (Table 1).

Total changes in bankfull width ranged from a 1.97-foot decrease to a 2.89-foot increase in width. Total changes in bankfull depth ranged from a 0.10-foot decrease to a 0.23-foot increase in depth. Total changes in bankfull area ranged from a 1.63-square foot decrease to a 9.65-square foot increase in area. Total changes in entrenchment ratio ranged from a 0.05 decrease to a 0.21 increase in entrenchment. Total changes in width/depth ratio ranged from a 2.5 decrease to a 0.81 increase in width/depth.

B. Longitudinal Profile Results

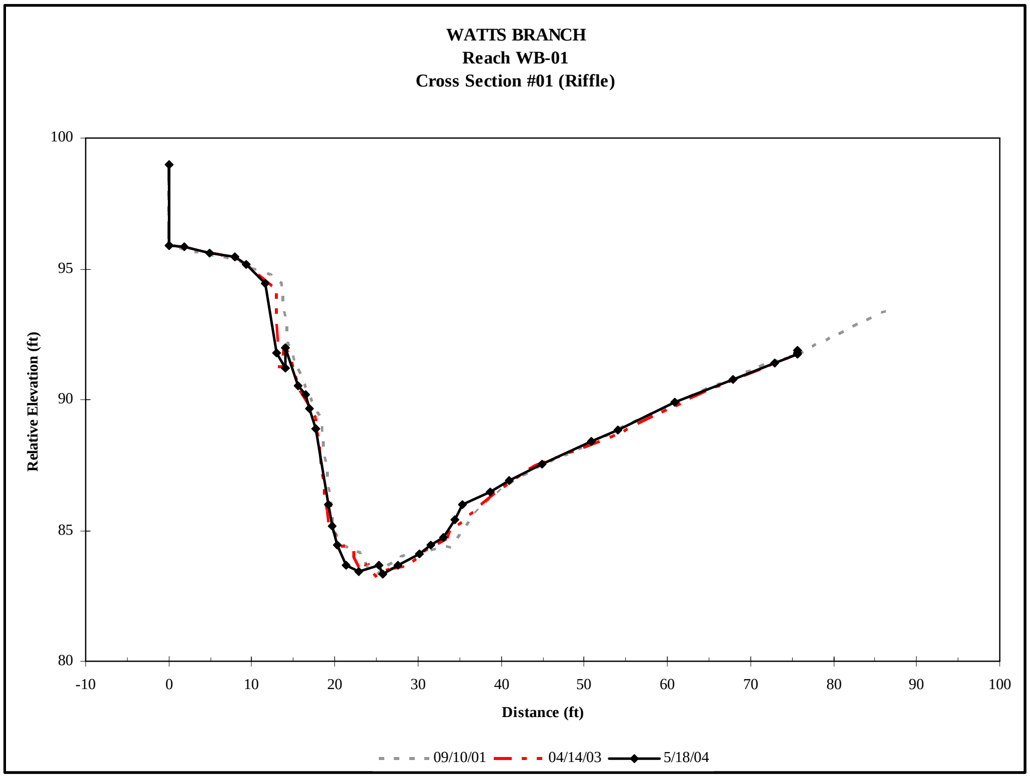
The Service conducted three longitudinal profile surveys and overlaid the thalweg profiles to document vertical channel adjustments. The Service separately compared the two latter thalweg profiles (*i.e*., 2003 and 2004 surveys) with the 2001 thalweg profile.

1. <u>2001 and 2003 Longitudinal Profile Overlay</u>

For the 2001 and 2003 longitudinal profile overlay, the Service observed approximately 20 percent degradation and approximately 19 percent aggradation (Figure 3a). In general, the upper section (station 00+00 to 07+00) and middle section (station 07+00 to 16+25) of the reach were stable, with areas of localized scour, ranging from 0.09 feet to 1.62 feet, and localized aggradation, ranging from 0.06 feet to 0.58 feet. Overall, the lower section of the reach (station 16+25 to 19+75) was aggrading, with the bed rising from 0.10 feet to 1.38 feet. The Service also observed aggradation in the pools, including those downstream of constructed grade control structures, which typically maintain pool depths of two to four times the riffle bankfull depth.

The Service measured a significant scour enlargement at the confluence of the Watts Branch main stem and unnamed tributary (station 07+60 to 08+60). NRCS installed a cross vane on the tributary at the confluence of the two streams. The maximum scour depth (*i.e*., 1.0 feet) has remained the same; however the maximum depth is now more uniform throughout the pool, extending 30 feet farther upstream, and 24 feet farther downstream.

Figure 2a. Cross Section Overlay Plots



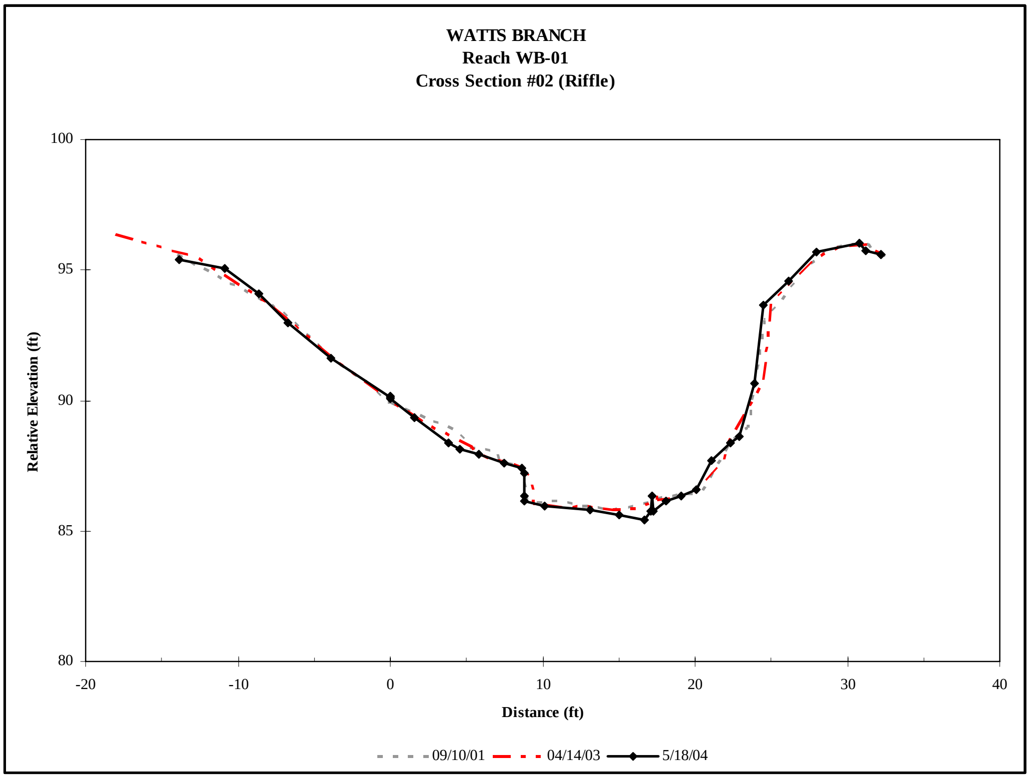
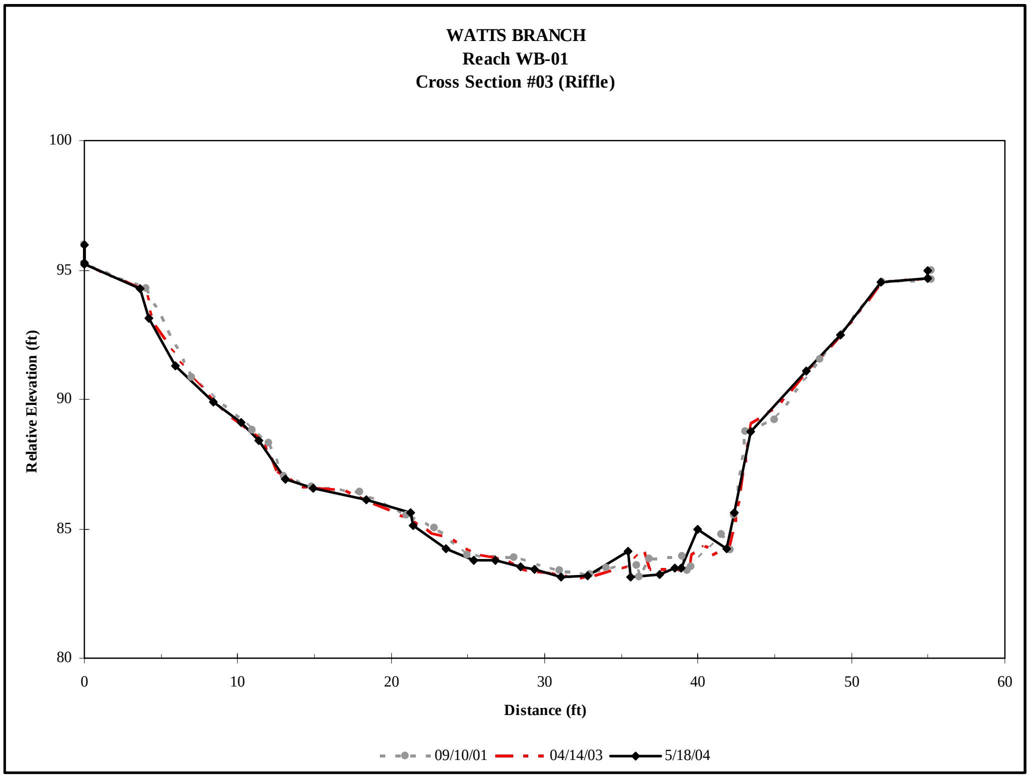


Figure 2b. Cross Section Overlay Plots



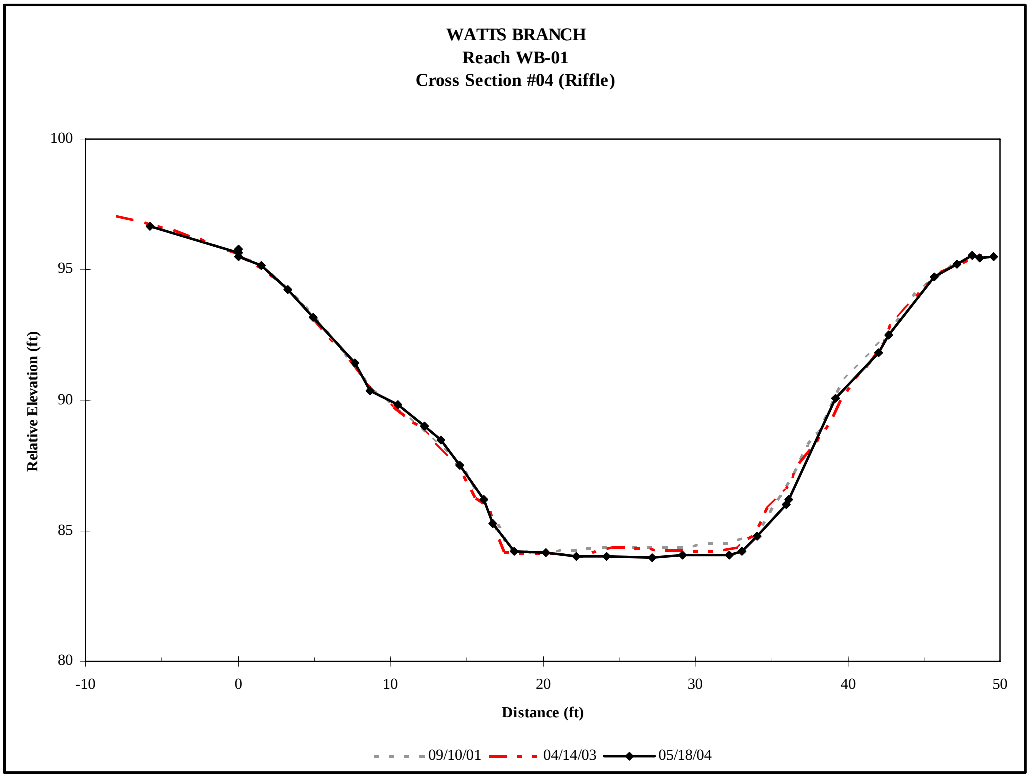
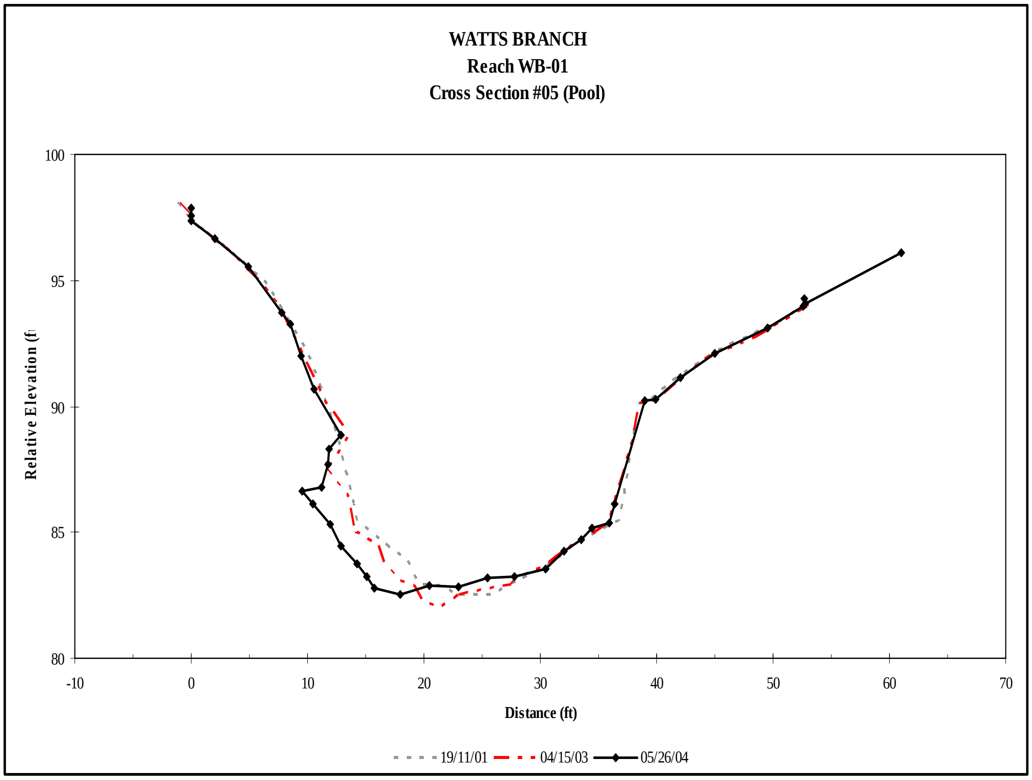


Figure 2c. Cross Section Overlay Plots



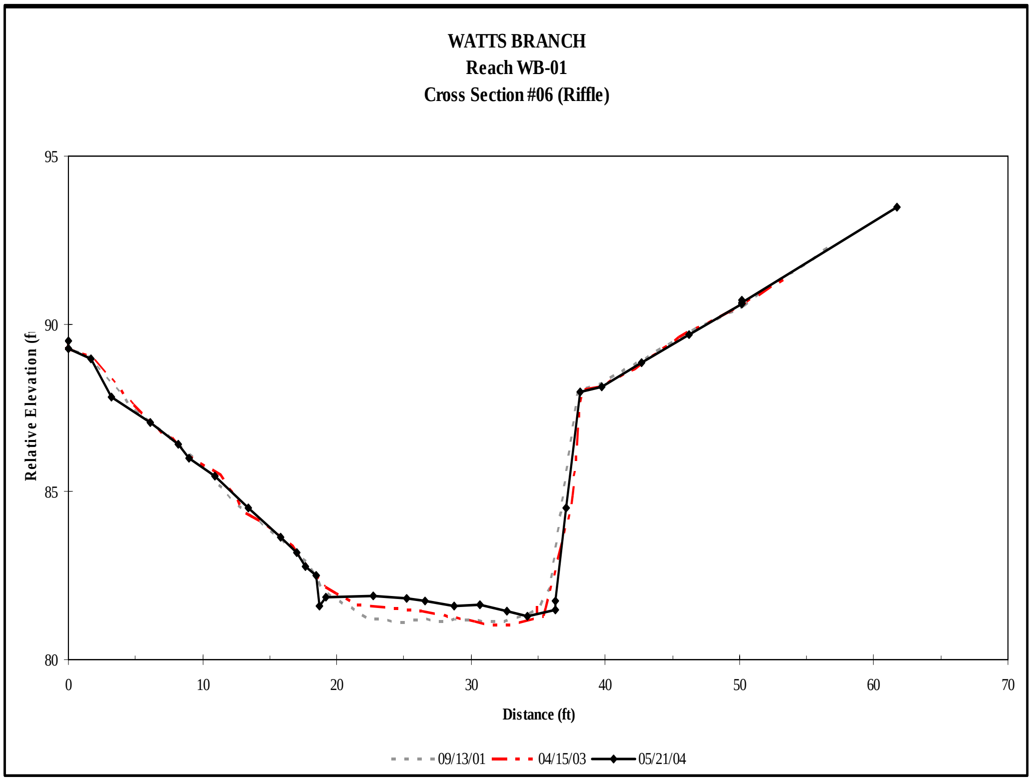
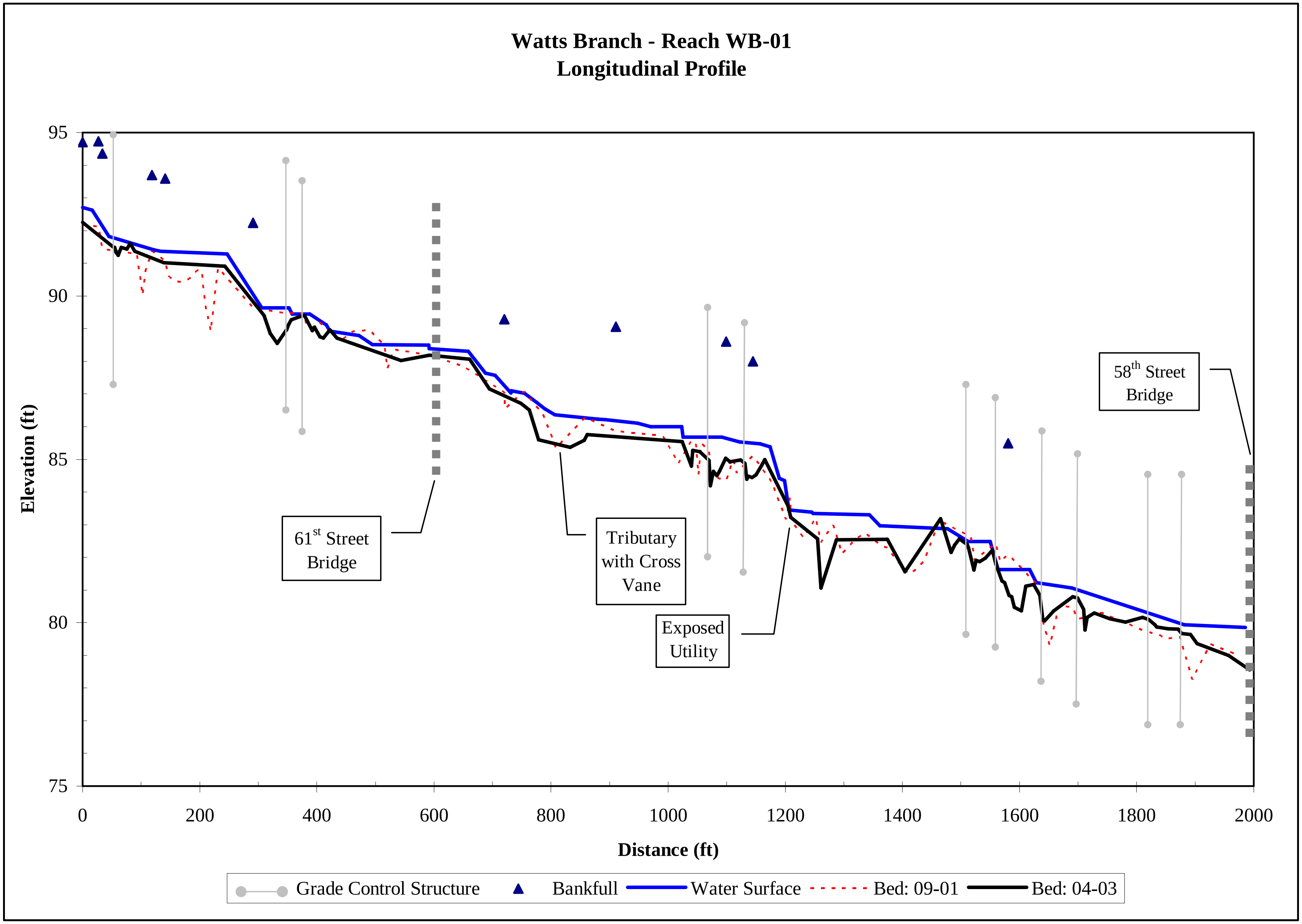


Table 1. Summary of Cross Sections Dimensions

Cross Section		2001	2003 Data	2003 Change*	2004 Data	2004 Change*	Total Change
XS #01	Width (ft)	18.08	17.80	-0.28	16.11	-1.69	-1.97
	Depth (ft)	1.60	1.52	-0.08	1.83	0.31	0.23
	Area (ft^2)	28.85	27.06	-1.79	29.53	2.47	0.68
	Maximum Depth (ft)	2.58	2.54	-0.04	2.67	0.13	0.09
	Wetted Perimeter (ft)	19.49	19.31	-0.18	17.78	-1.53	-1.71
	Hydraulic Radius (ft)	1.48	1.40	-0.08	1.66	0.26	0.18
	Entrenchment Ratio	1.85	1.76	-0.09	2.06	0.30	0.21
	Width/Depth Ratio	11.30	11.71	0.41	8.80	-2.91	-2.50
XS #02	Width (ft)	17.54	18.11	0.57	18.55	0.44	1.01
	Depth (ft)	1.77	1.87	0.10	1.73	-0.14	-0.04
	Area (ft^2)	31.05	33.90	2.85	32.14	-1.76	1.09
	Maximum Depth (ft)	2.65	2.74	0.09	2.95	0.21	0.30
	Wetted Perimeter (ft)	19.89	20.55	0.66	21.75	1.20	1.86
	Hydraulic Radius (ft)	1.56	1.65	0.09	1.48	-0.17	-0.08
	Entrenchment Ratio	1.42	1.54	0.12	1.50	-0.04	0.08
	Width/Depth Ratio	9.91	9.68	-0.23	10.72	1.04	0.81
XS #03	Width (ft)	21.40	21.24	-0.16	21.05	-0.19	-0.35
	Depth (ft)	1.56	1.55	-0.01	1.79	0.24	0.23
	Area (ft^2)	33.41	33.01	-0.40	37.71	4.70	4.30
	Maximum Depth (ft)	2.38	2.28	-0.10	2.48	0.20	0.10
	Wetted Perimeter (ft)	24.41	23.80	-0.61	24.65	0.85	0.24
	Hydraulic Radius (ft)	1.37	1.39	0.02	1.53	0.14	0.16
	Entrenchment Ratio	1.45	1.45	0	1.52	0.07	0.07
	Width/Depth Ratio	13.72	13.70	-0.01	11.76	-1.94	-1.96
XS #04	Width (ft)	20.00	19.78	-0.22	20.04	0.26	0.04
	Depth (ft)	1.83	1.78	-0.05	1.87	0.09	0.04
	Area (ft^2)	36.56	35.15	-1.41	37.43	2.28	0.87
	Maximum Depth (ft)	2.25	2.23	-0.02	2.22	-0.01	-0.03
	Wetted Perimeter (ft)	21.75	21.59	-0.16	21.50	-0.09	-0.25
	Hydraulic Radius (ft)	1.68	1.63	-0.05	1.74	0.11	0.06
	Entrenchment Ratio	1.26	1.30	0.04	1.21	-0.09	-0.05
	Width/Depth Ratio	10.93	11.11	0.18	10.72	-0.40	-0.21
XS #05	Width (ft)	23.06	22.70	-0.36	25.95	3.25	2.89
	Depth (ft)	2.33	2.55	0.22	2.44	-0.11	0.11
	Area (ft^2)	53.79	57.92	4.13	63.44	5.52	9.65
	Maximum Depth (ft)	3.61	4.07	0.46	3.61	-0.46	0.00
	Wetted Perimeter (ft)	25.04	25.33	0.29	27.79	2.46	2.75
	Hydraulic Radius (ft)	2.15	2.29	0.14	2.28	-0.01	0.13
	Entrenchment Ratio	1.13	1.17	0.04	1.09	-0.08	-0.04
	Width/Depth Ratio	9.90	8.90	-1.00	10.64	1.73	0.74
XS #06	Width (ft)	23.36	24.09	0.73	23.70	-0.39	0.34
	Depth (ft)	2.50	2.38	-0.12	2.40	0.02	-0.10
	Area (ft^2)	58.44	57.22	-1.22	56.81	-0.41	-1.63
	Maximum Depth (ft)	3.28	3.34	0.06	3.23	-0.11	-0.05
	Wetted Perimeter (ft)	25.82	27.26	1.44	27.29	0.03	1.47
	Hydraulic Radius (ft)	2.26	2.10	-0.16	2.08	-0.02	-0.18
	Entrenchment Ratio	1.41	1.39	-0.02	1.47	0.08	0.06
	Width/Depth Ratio	9.34	10.12	0.78	9.88	-0.25	0.53

Note: *Change**: *Change compared to survey from previous year*

Figure 3a. Longitudinal Profile Overlay Plot for 2001 and 2003 Surveys



2. <u>2001 and 2004 Longitudinal Profile Overlay</u>

For the 2001 and 2004 longitudinal profile overlay, the Service observed approximately 46 percent degradation and approximately 19 percent aggradation (Figure 3b). The majority of the degradation was in the upper and middle sections of the reach, with the degradation ranging from 0.05 feet to 2.08 feet. The majority of the aggradation occurred in the lower section, with the aggradation ranging from 0.14 feet to 0.74 feet. The aggradation in the lower section of the 2004 survey was similar to the aggradation the Service observed in 2003 survey, with the exception of some minor scour development.

C. Stabilization Effectiveness Results

The Service presents enlargements of the longitudinal profile near the rock vanes, cross vanes, and j-hook structures to observe the influence these structures have on the streambed (Figures 4a, b, and c). The Service overlaid all three years of survey data for each profile enlargement.

In general, vertical adjustments at grade control structures reflected the overall adjustments observed in the upper, middle, and lower sections of the study reaches. For the 2001 and 2003 longitudinal profile overlay, the Service observed scour near the grade control structures, in the upper and middle sections, ranging from 0.09 feet to 1.62 feet. The Service also observed minor areas of aggradation in these sections. The Service observed significant aggradation at the grade control structures in the lower section, ranging from 0.10 feet to 1.38 feet.

For the 2001 and 2004 longitudinal profile overlay, the Service continued to observe scour near the grade control structures, in the upper and middle sections, ranging from 0.09 feet to 2.08 feet. The Service continued to observe minor areas of aggradation in these sections, and significant aggradation at grade control structures, in the lower section, ranging from 0.13 feet to 0.64 feet.

III. DISCUSSION

In this section, the Service discusses the findings of the stabilization monitoring study. The Service separately discusses cross section results, longitudinal profile results, and the stabilization structures.

A. Cross Section Discussion

The Service measured and observed no significant vertical or lateral channel adjustments, based on the cross section data and visual assessment of the study reach. Overall, the stream channel is currently stable with only localized areas of erosion. One of the reasons for the lack of lateral adjustments is that over 60 percent of the banks are protected by bank revetments (*e.g.*, gabion baskets, imbricated rip rap, rip rap, and concrete block revetment). However, one of the objectives of the NRCS project was to repair/replace the failing revetments and this routine maintenance/replacement of bank revetments indicates that these types of revetments are still prone to failure, particularly to undermining from toe erosion.

Figure 3b. Longitudinal Profile Overlay Plot for 2001 and 2004 Surveys

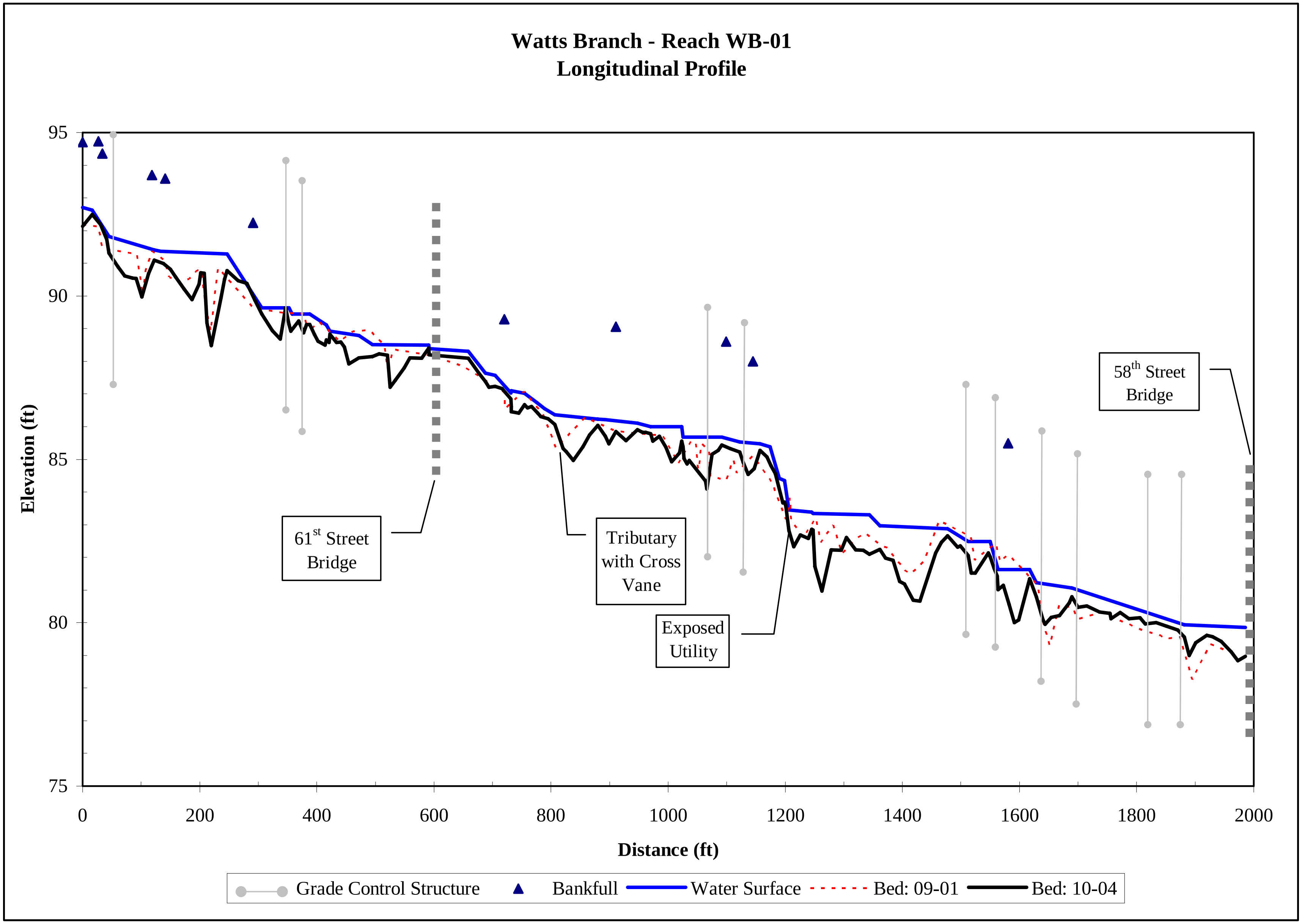
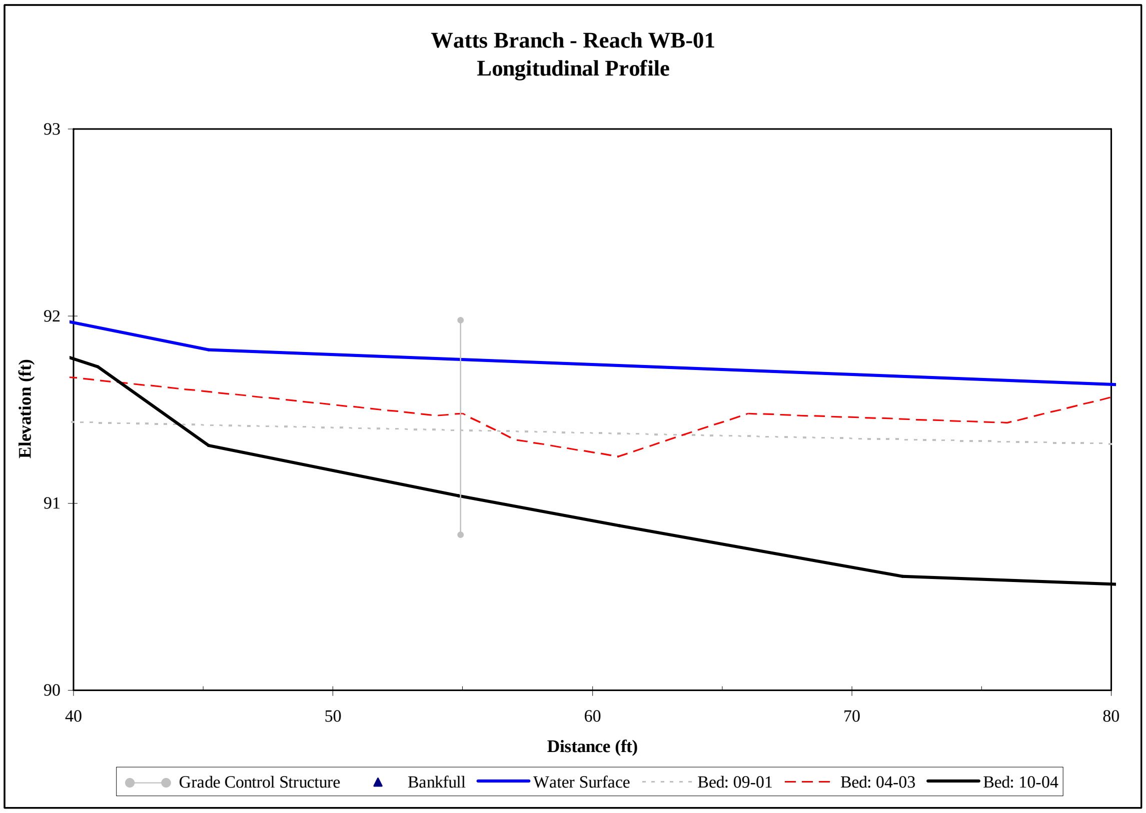


Figure 4a. Longitudinal Profile Enlargement Plots



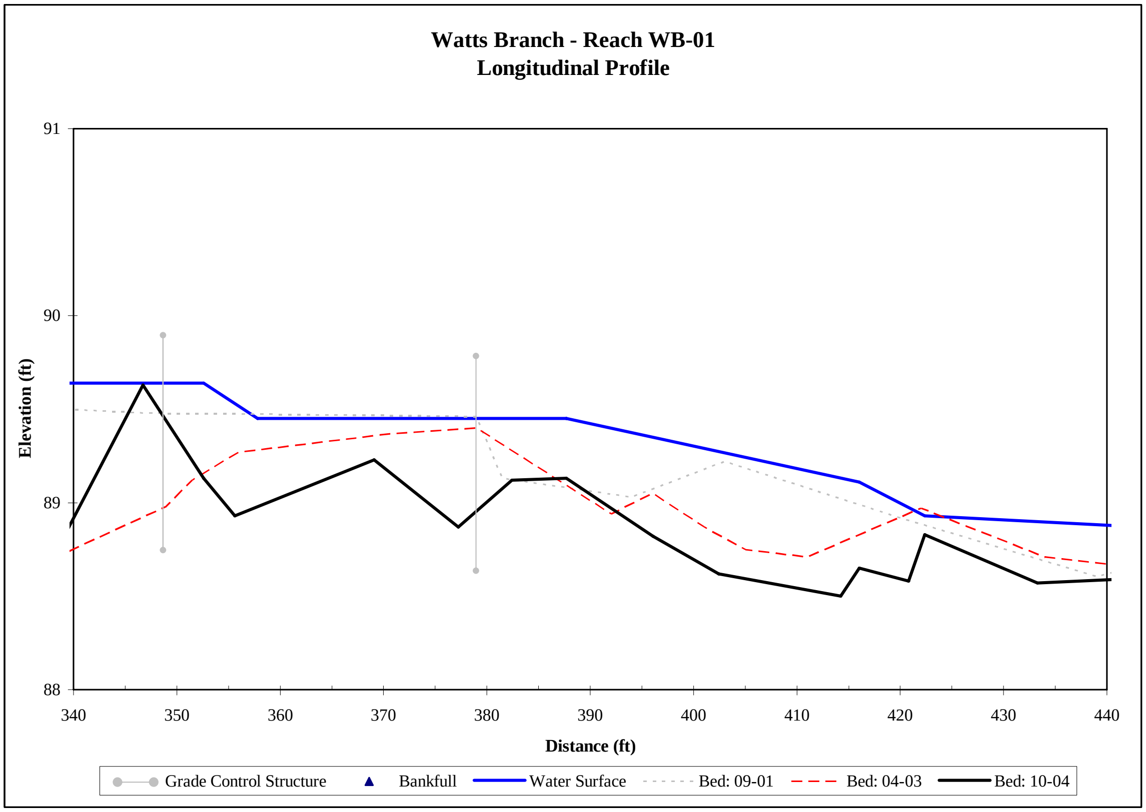
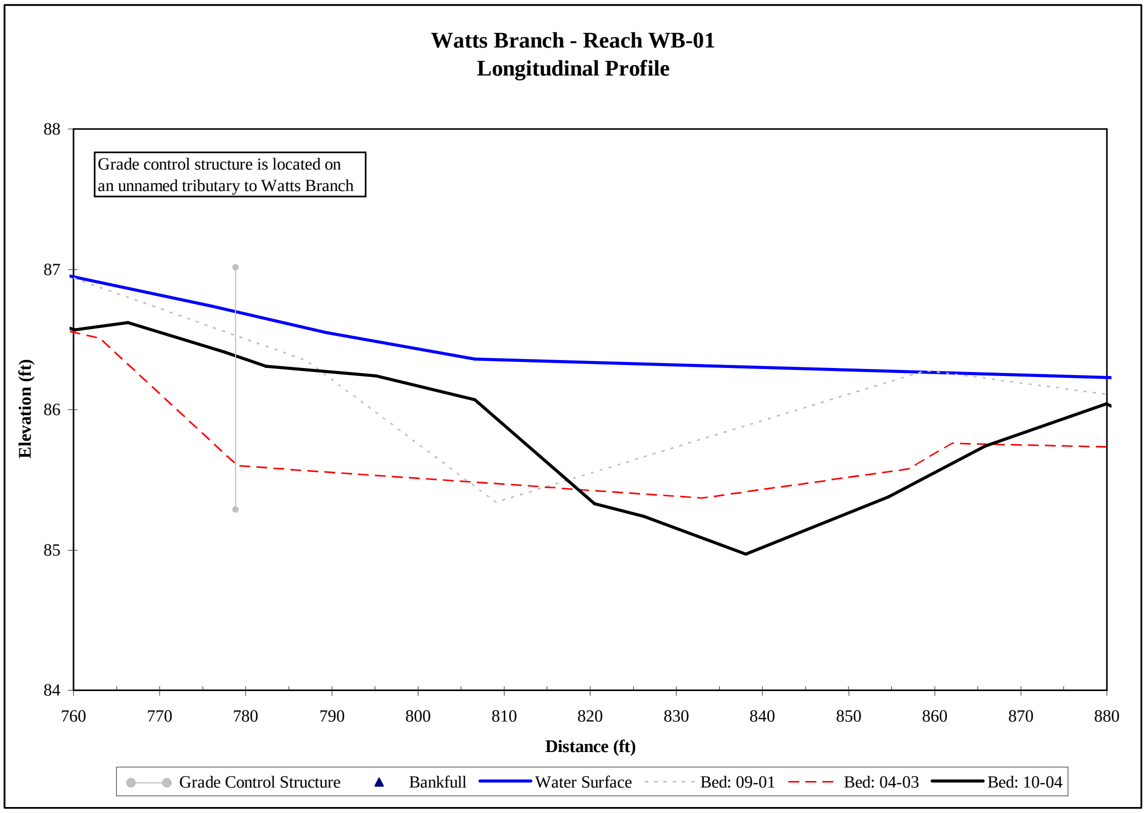


Figure 4b. Longitudinal Profile Enlargement Plots



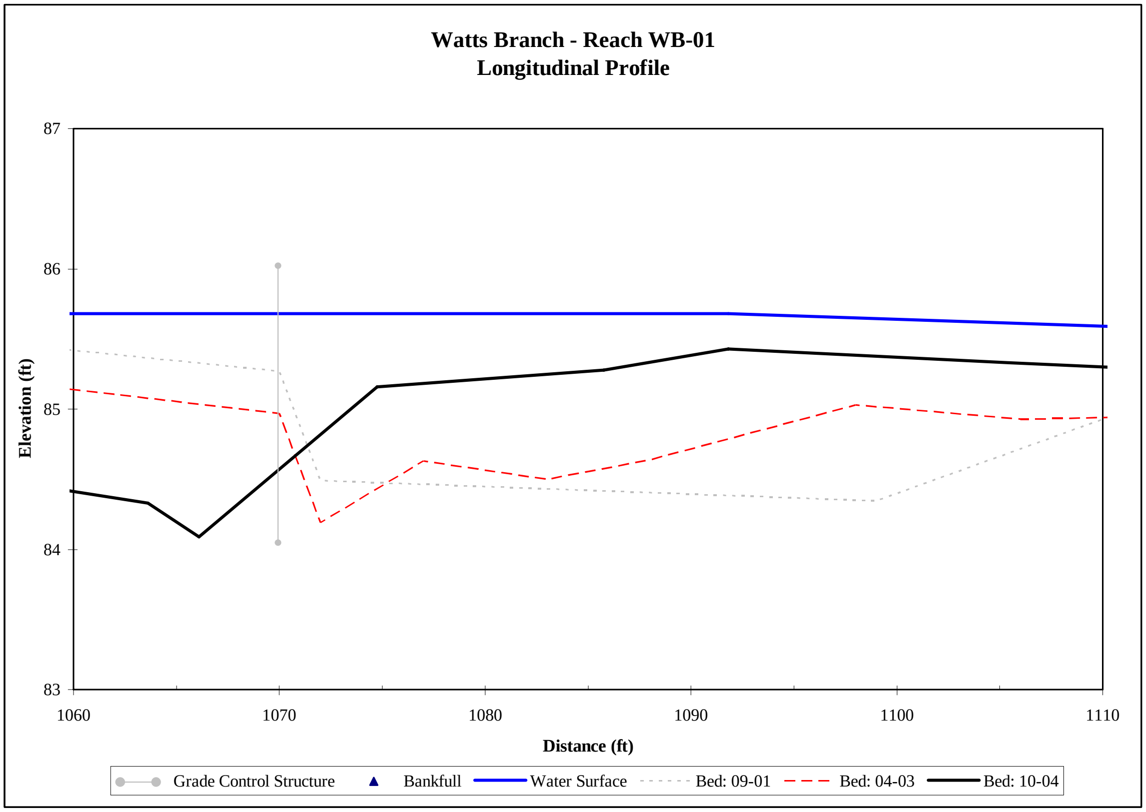
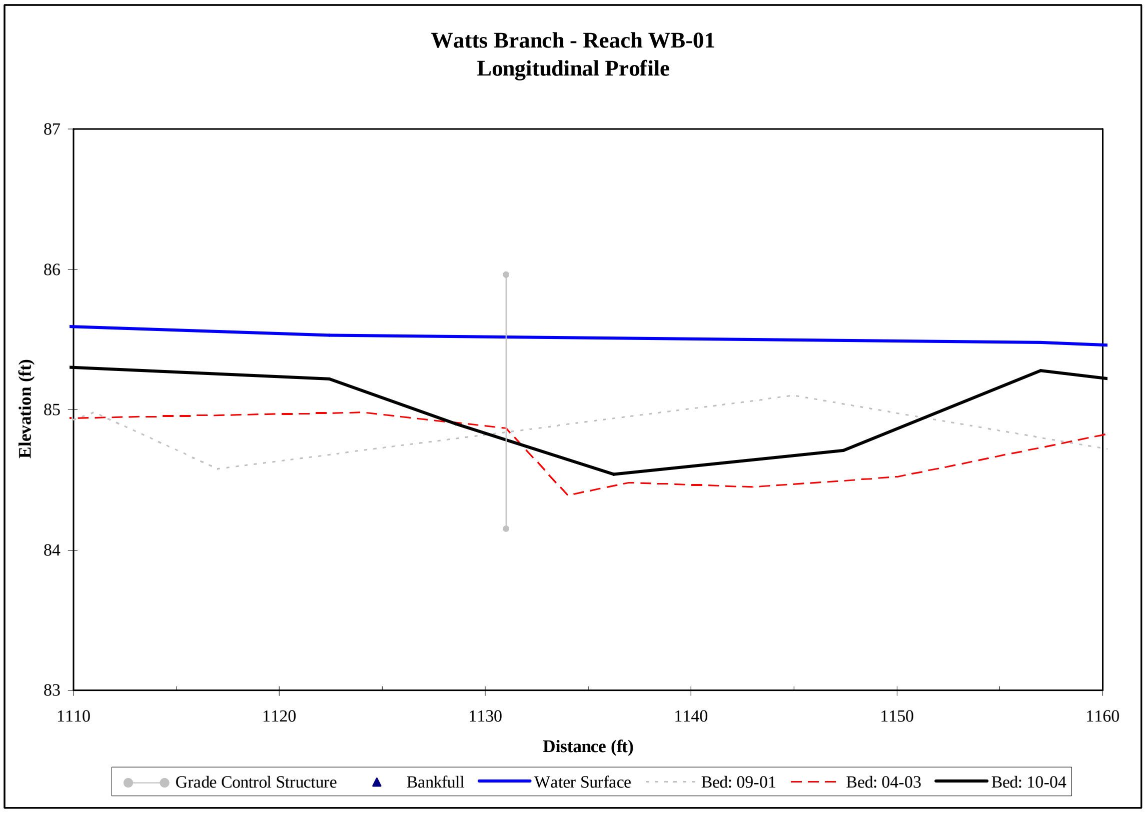


Figure 4c. Longitudinal Profile Enlargement Plots



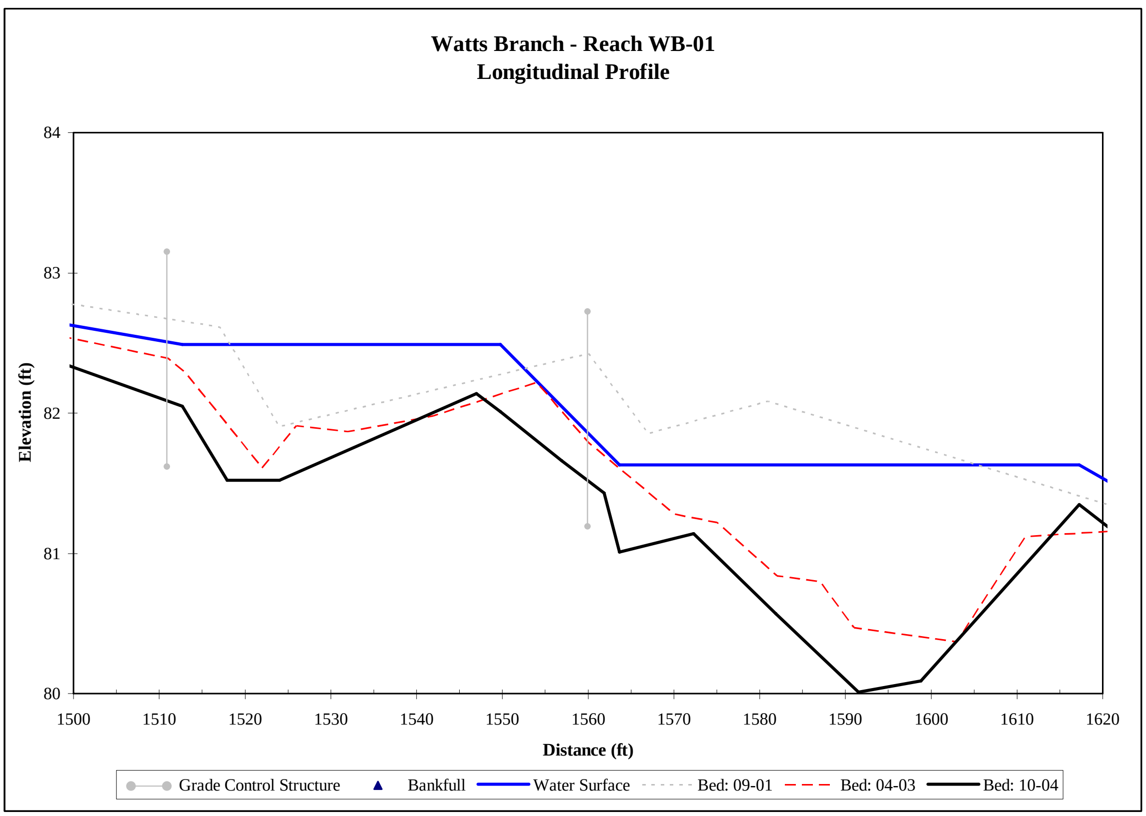
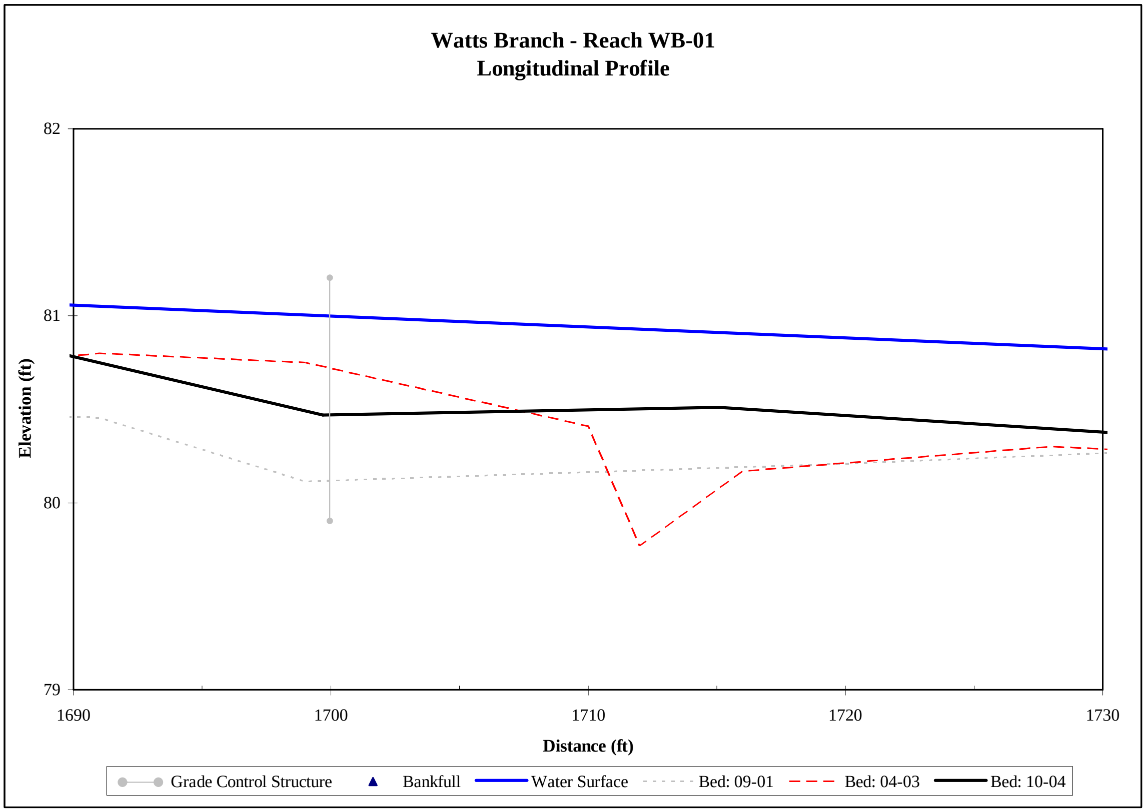
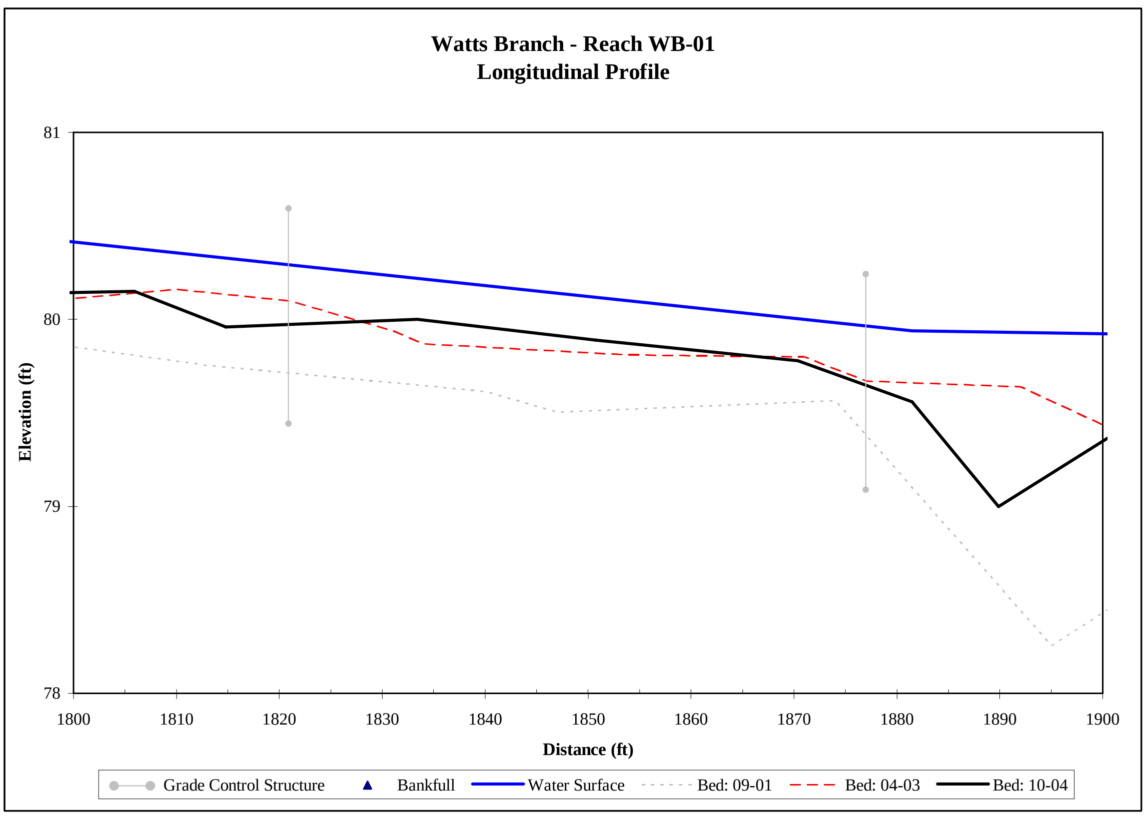


Figure 4d. Longitudinal Profile Enlargement Plots





The Service anticipated little lateral adjustment for cross sections 01 and 06, because the banks prone to erosion are stabilized by imbricated rip rap. The only significant change was a 1.97-foot decrease in bankfull width for cross section 01, because of the development of a bankfull bench. The bench and the current bankfull depth will not affect the ability of the imbricated rip rap to protect the bank.

The right bank of cross section 02 has a very high erosion potential, because of the high bank, shallow root depth, low root density, and low surface protection. High banks can be more susceptible to erosion, because more of the bank is exposed to erosional forces. Shallow root depths and low root densities are less able to secure the bank and prevent bank scour and rotational bank failure. However, the Service measured no significant changes in channel dimensions for cross section 02. The lack of actual bank erosion is due to the low near bank shear stress, as the stream flow is directed away from the right bank. However, there still is a significant potential for erosion, because of the entrenched channel conditions. The Service will discuss its potential erosion concerns with an entrenched channel later in this section. There were also no significant changes for cross section 04, due to the low near bank shear stress and vegetated banks.

Although imbricated rip rap was used to stabilize cross sections 03 and 05, these cross sections had the largest change in bankfull cross-section area. The cross-section area change for cross section 03 is the result of a scour pool from the j-hook structure located at the cross section. Scour pools, downstream of j-hook structures, are a designed function of these structures. Cross section 05 had the largest change in bankfull cross-section area (*i.e.*, 9.65 square feet). Several factors contributed to the lateral erosion at cross section 05, including a high bank erosion potential and a moderate near bank shear stress. The high bank erosion potential is the result of a high bank and low root density. The moderate near bank shear stress is the result of more stream flow directed towards the bank. Another factor contributing to the lateral erosion is that upstream of the cross section, the left bank is stabilized with imbricated rip rap, which accelerates stream flows across the unprotected bank at the cross section.

For all the cross sections, the Service calculated little change in the entrenchment ratio, which ranged from moderately entrenched (*i.e.*, cross sections 01-03 and 06) to entrenched (*i.e.*, cross sections 04 and 05). Entrenched streams contain high stream flows, which increases the potential for bank erosion because the stream does not have access to a floodplain for attenuation of shear stresses. The extensive bank revetments further increase the bank erosion potential by accelerating high flows along the hardened banks, which may cause toe erosion and result in undermining of the revetments. Unprotected banks are also at risk of increased erosion from the accelerated high flows.

The Service calculated little change in width/depth ratios, with the exception of cross sections 01 and 03. The decrease in width/depth ratios, for cross sections 01 and 03, resulted from a decrease in bankfull width and an increase in mean depth. The width/depth ratios were lower than what is expected for a stable reference stream (*i.e.*, B or C Rosgen stream type) in a similar landscape, but close to the range of width/depth ratios considering the natural variability of stream characteristics. The combination of the low width/depth and high entrenchment ratios, present through much of the stream can increases channel shear stress and erosion, which can result in scoured and less defined bed features.

B. Longitudinal Profile Discussion

1. <u>2001 and 2003 Longitudinal Profile Discussion</u>

The Service compared the 2001 and 2003 thalweg profiles and found the stream channel to be stable, with only minor, localized, vertical adjustments. There was some scouring in the upper and middle section of the project area and aggradation in the lower section. The localized erosion in the upper and middle sections, at that time, did not affect the function of the bank revetments or grade control structures. The aggradation in the lower section has filled in some of the grade control structures rendering them nonfunctional; however, this condition was not affecting channel stability.

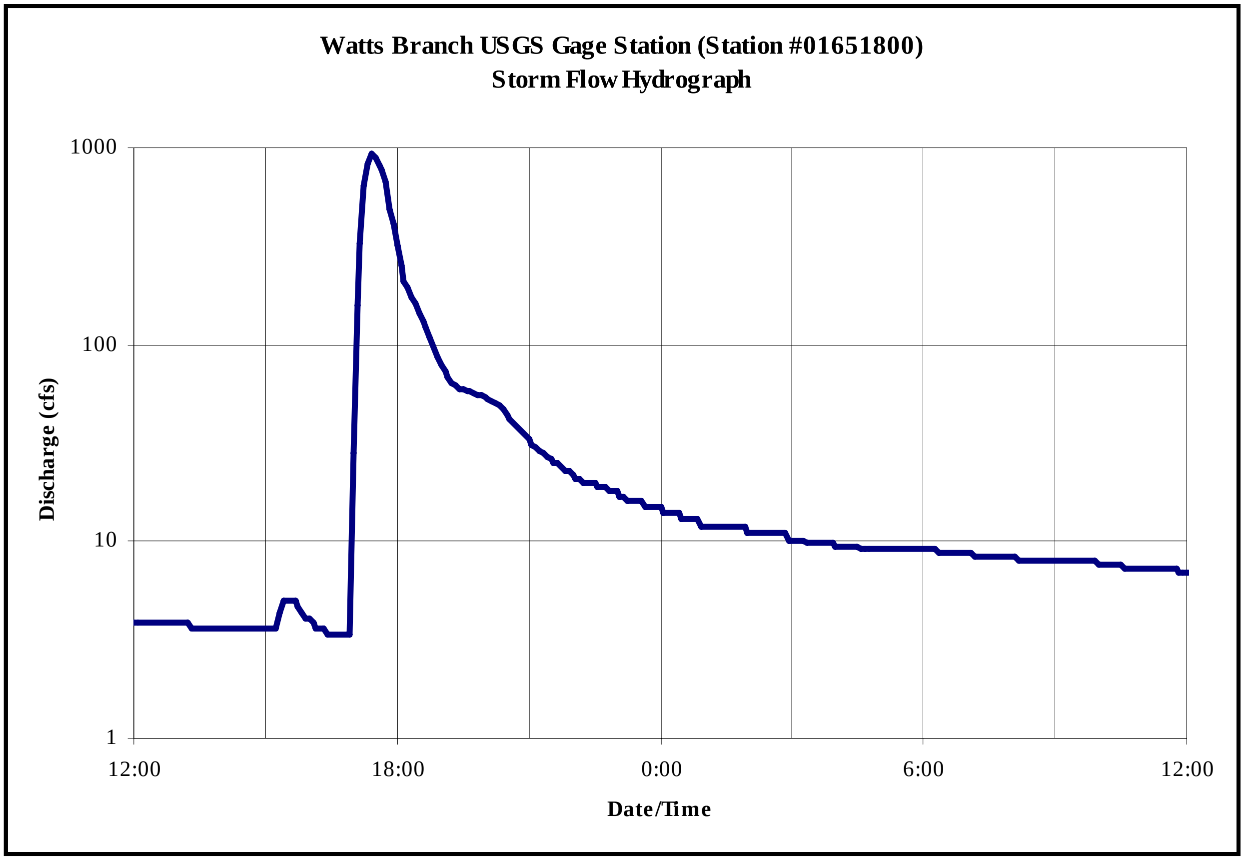
A potential reason for the minimal streambed adjustments could be attributed to lower than average mean annual discharges for the pervious years. The Service reviewed the flow data from the Watts Branch gage station (Station #01651800), operated by the U.S. Geological Survey. The mean annual discharges for the pervious years, 3.50 cubic feet per second (cfs) for 2001 and 2.73 cfs for 2002, were lower than the mean annual discharge of 4.57 cfs for the period of record. Although there was a significant flood event in 2001 (*i.e.*, 1,470 cfs), this peak discharge occurred prior to the initial longitudinal survey. The peak discharge for 2002 was only 413 cfs, well below the mean peak discharge for the period of record of 1,012 cfs. The lower discharges reduce stream sediment transport loads, thus influencing the streambed adjustment capability.

In addition, pools in Watts Branch may be prone to accumulating sediment, because of the flashiness of the hydrograph. The slope of the rising limb of the Watts Branch hydrograph is steep and the duration of the peak is short, and the recession limb is extended with a shallow slope (Figure 5). The peak of the hydrograph typically performs most of the sediment transport and maintenance of the channel dimensions. However, the recession limb of the Watts Branch hydrograph appears to perform more sediment transport, because of the short duration of the peak and the increased duration of the recession limb. Pools may fill in under these conditions, because the duration of the peak is insufficient to maintain pool depths. In addition, the lower sediment transport capacity during the recession limb may result in sediment accumulating in pools.

<u>Scouring Areas</u>

In the upper and middle sections of the study reach, the Service measured increased scour depths in existing scour pools, or newly formed scour pools downstream of grade control features/structures (*i.e.*, riffles, cross vanes, and construction debris). Riffles are natural grade control features characterized by steeper slopes, shallower depths, and coarser bed materials than other stream facet features (*e.g.*, runs, pools, and glides). Scour pools typically develop downstream of riffles because of the accelerated stream flows down the steep gradient of the riffles. The Service measured greater scour downstream of steeper riffles, as observed at stations 03+32 feet and 12+61 feet of the 2003 longitudinal profile (Figure 3a).

Figure 5. Typical Hydrograph for Watts Branch



Scour pools also typically develop downstream of constructed grade control structures (*e.g.*, cross vanes and j-hooks) because the structures are designed to redirect stream flows away from the edges of the channel and into the center of the channel. These scour pools are generally two to five times the riffle bankfull depth; a potential range of 3.74 to 7.48 feet based on Watts Branch bankfull depth. The Service measures scour pools depths, downstream of natural riffles, ranging from 2.82 to 6.17 feet for the 2003 longitudinal profile. The Service measured scour pools depths, downstream of constructed grade control structures, ranging from 2.36 to 4.91 for the 2003 longitudinal profile. The shallow depths for some of the scour pools, such as at stations 00+81 (*i.e.*, 2.36 feet) and 03+96 feet (*i.e.*, 3.11 feet), could be a result of sediment in filling from construction activities during the stabilization project. The shallow pool depths may indicate the potential for future enlargement of the scour pools.

Aggradation Areas

The Service measured aggradation in the lower section of the reach. The primary reasons for the aggradation are a lower reach average slope and backwater conditions from the 58th Street bridge. These conditions decrease stream velocities, which decrease the sediment transport competency of the stream and results in aggradation.

2. <u>2001 and 2004 Longitudinal Profile Discussion</u>

The Service also compared the 2001 and 2004 thalweg profiles and found the stream channel to be currently stable, with areas of increased bed scour, and similar aggradation to the 2003 profile. Although there was increased bed scour in the upper and middle sections of the project area, the localized erosion should not affect the function of the bank revetments or grade control structures. The grade control structures in the lower section remain nonfunctional, because of the reach-wide aggradation. Currently, this condition does not affect channel stability.

A potential reason for the increased streambed adjustments, in the upper and middle sections, is the higher than average discharges for 2003. The 2003 mean annual discharge was 7.65 cfs, which is well above the mean annual discharge for the period of record (*i.e*., 4.57 cfs). In addition, the 2003 peak discharge (*i.e*., 1000 cfs) was close to the mean peak discharge for the period of record. The increase in discharge was supported by the higher than average precipitation for the previous year (Figure 6). The Service acquired total monthly precipitation data from the National Oceanic and Atmospheric Administration weather station at the Baltimore – Washington International Airport. The total annual precipitation for 2003 was 61.96 inches, which is 1.48 times higher than the average precipitation for this area (*i.e*., 41.86 inches). The increase in mean annual discharge may explain some of the vertical adjustments, because the higher and more frequent flows increase sediment transport competency, which can result in changes in the stream channel.

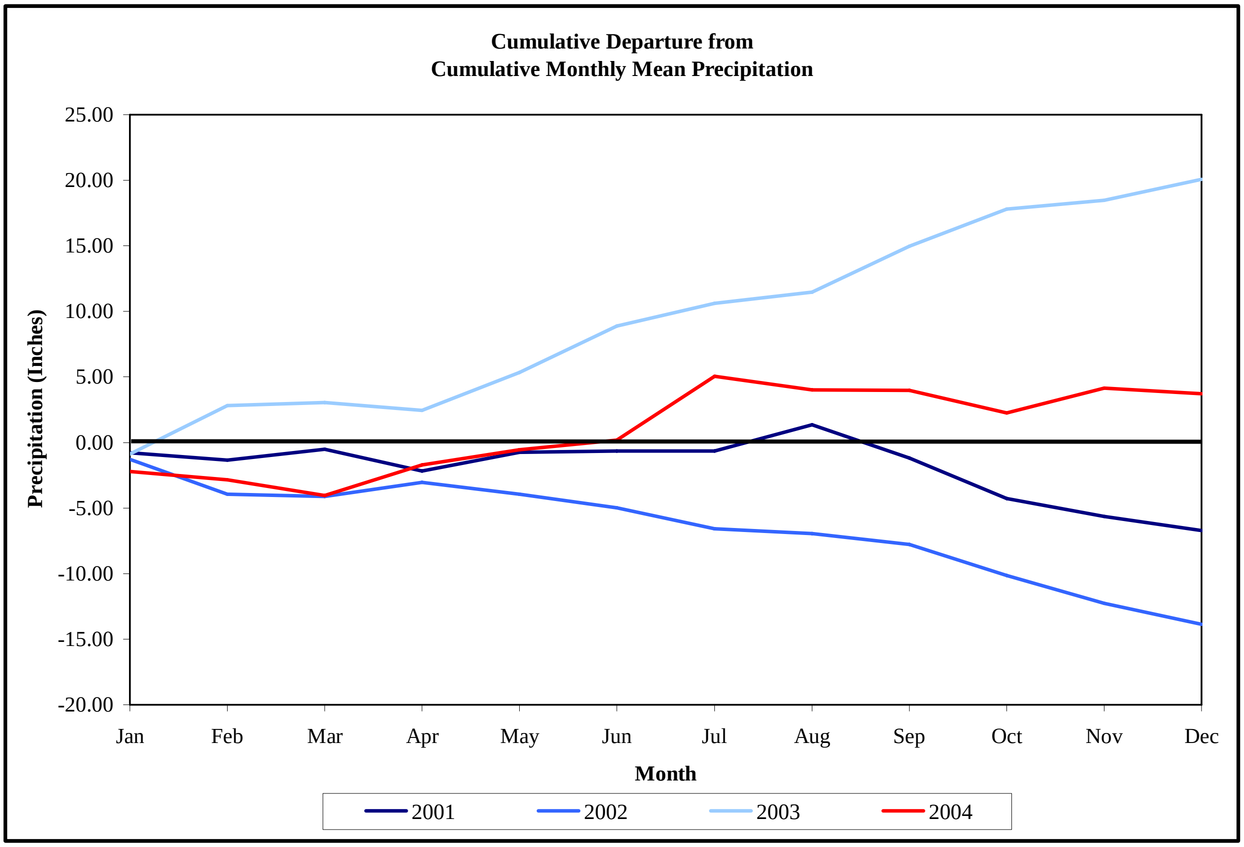
Another potential reason is the entrenched stream conditions at Watts Branch. Streams typically use floodplains to dissipate the erosional forces from higher stream flows. Streams also dissipate erosional forces laterally by using the stream's meander pattern and/or vertically using pools to attenuate the erosion forces. The lack of an active floodplain or meander pattern at Watts Branch promotes vertical dissipate of energy in the streambed. In addition, the stream may attempt to attenuate erosional forces through lateral erosion and attempt to recreate a meander pattern, where possible (*e.g*., increased potential for bank erosion).

The extensive bank revetments can also be a reason for the increased streambed adjustments. As previously discussed, the bank revetments accelerate storm flows along the hardened bank, which promotes erosion, particularly at the toe of the bank.

<u>Scouring Areas</u>

The Service anticipated increased scour depths, especially downstream of the constructed grade control structures, because some of the pools were shallower than the typical two to five times bankfull depth. The Service noted, for the previous year, that the pool depths at stations 00+81 and 03+96 were shallower than the typical two riffle bankfull depths. For 2004, the Service found that these scour pools had increased to 3.87 and 3.40 feet, an increase in depth of 1.51 and 0.29 feet, respectively.

Figure 6. Monthly Precipitation Departure from Baltimore – Washington International Airport



The Service measured scour pool depths, downstream of natural riffles, ranging from 3.38 to 6.25 feet. The Service measured scour pools depths at five of the existing grade control structures ranging from 3.40 to 5.34 feet. Despite the increase in pool depths, there is still the potential for further enlargement of some pool depths.

Aggradation Areas

The Service continued to measure aggradation in the lower section of the reach, similar in extent and depth to the previous years. Although aggradation in the lower section was similar to the previous year, future increases in sediment contributions from upstream may increase the depth and extent of the aggradation in this section. The reasons for the aggradation remain the same as discussed for the previous year, in the 2001 and 2004 Longitudinal Profile Discussion section, under the Aggradation Areas.

C. Stabilization Effectiveness Discussion

In general, the bank revetments and the constructed grade control structures are currently providing vertical and lateral stability to the stream, based on the longitudinal profiles and the cross section surveys. The bank revetments appear to be functioning and in good condition.

However, some of the grade control structures may not be operating at their full potential, based on the minor changes in bed elevation upstream of the structures and the shallow scour development. The changes in elevation should not affect the functions of the structures, assuming the structures were properly constructed with footer rocks.

Bank Revetments

NRCS installed a variety of bank revetments to stabilize the stream banks, including imbricated rip rap and gabion baskets. These bank revetments provide lateral stability by physically hardening the bank to inhibit bank erosion. In general, the Service believes that the various bank revetments are effectively stabilizing the stream banks. However, the Service has several concerns regarding the long-term effectiveness of the stabilization structures. As discussed previously, these types of bank revetments support conditions that make them prone to toe erosion.

In addition, the accelerated storm flows along the bank revetments and entrenched stream channel make the unprotected banks vulnerable to bank erosion, as seen at cross section 05. Approximately 1,500 linear feet of stream bank is unprotected, most of which has a potential to erode. Bank revetments, such as gabion baskets, also have a limited life expectancy and require routine maintenance and replacement.

Grade Control Structures

NRCS installed rock vanes, cross vanes, and j-hook to provide vertical and lateral stability in the stream channel. Cross vanes provide vertical stability by establishing a local bed elevation and physically preventing bed degradation. In general, the grade control structures in the upper and middle sections of the reach had minor decreases in bed elevation upstream of the grade control structures, ranging from no significant changes to 1.14 feet. The elevation changes are typically associated with scour from existing riffles, other constructed grade control structures, or outfall structures, upstream of the impact structures. The largest change, at station 10+70, was associated with scour from an outfall approximately 30 feet upstream of the cross vane. The Service would recommend inspections of the grade control structure downstream of the outfall to confirm that the outfall will not affect the structure. The structures in the lower section are nonfunctioning because of the wide spread aggradation in this section.

Cross vanes also provide lateral stability by redirecting stream flows from the stream banks to the center of the stream channel. The lack of scour may indicate that the structures are not providing the maximum bank protection, by diverting flow away from the banks and redirecting it to the center of the stream channel.

VI. RECOMMENDATIONS

The Service has one procedural recommendation based on the field survey and analysis. The Service observed minor shifts in the riffle and pool stationing. These shifts may be the result of the method used by the Service to determine stationing. The Service recommends the installation of stationing benchmarks along the study reach, especially at grade control structures. This will allow surveyors to better align their longitudinal profile surveys, especially for the overlay plots.

The Service also recommends inspections of the grade control structure at station 10+70. This structure had the largest decrease in bed elevation, potentially because of the scour from an outfall upstream of the structure. Inspections may be necessary to ensure that the scour does not compromise the structure. A minimum requirement for the inspections should include a physical inspection of the structure to determine if the scour is undermining the grade control structure.

V. CONCLUSION

The objective of the NRCS project appears to be stream stabilization, and the project currently has successfully stabilized the stream. However, the Service also believes that the channel still has a high erosion potential because it is entrenched and has poor access to an adequate floodplain. Stormflows are contained within the channel, resulting in elevated channel stress. This stress will likely pose a problem to unprotected banks farther downstream. This stress may also undermine existing bank revetments, as observed in other sections of Watts Branch. The Service believes that the stream has poor aquatic habitat for a wide variety of reasons, including poor habitat diversity and water quality concerns.

As an alternative to stream stabilization, the Service believes that a natural channel design approach could address many of the channel stability and poor habitat issues. Natural channel design uses stream characteristics (*i.e.*, channel dimension, stream pattern, and longitudinal profile) from a stable reference stream to develop restoration design criteria for the impaired stream. Natural channel design is able to achieve long-term stream stability by allowing the stream to attenuate its erosional forces along the stream pattern and/or in the longitudinal profile. Aquatic habitat improvements are achieved by restoring appropriate facet feature characteristics (*e.g.*, facet feature depths and spacing) to the stream.

In addition, natural channel design typically costs less than traditional stream stabilization because stabilization projects typically require extensive bank revetments and routine maintenance, repair, or replacement. Natural channel design uses fewer structures and less material to attain channel stability. Natural channel design is also less expensive because its structures provide long-term stability, and do not require routine maintenance, repair, or replacement.

It is important to note that the Service does not know the specific objectives of the NRCS stabilization project and their project objectives may not have included the concerns presented by the Service. In addition, the Service does not know the specific constraints of the project, so NRCS may not have been able to address the issues presented by the Service.

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