Phase I Feasibility Analysis Report

Eastern Corridor Multi-Modal Projects
Segment II/III - Priority Part B Work
Little Miami River Geomorphic
Assessment

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Table of Contents

1.0 INTRODUCTION 1.1
1.1 SCOPE OF WORK 1.1
1.2 BACKGROUND INFORMATION 1.2
1.2.1 Location and Characteristics 1.2
1.2.2 River Designation 1.3

2.0 GEOMORPHIC ASSESSMENT OF THE LITTLE MIAMI RIVER 2.3
2.1 LITTLE MIAMI RIVER DESCRIPTION 2.3
2.1.1 Level I Assessment: Geomorphic Characterization 2.3
2.1.2 Level II Assessment: Morphological Description 2.4
Level III River Stability Prediction - 2.4
2.1.3 Stream Stability Indices 2.4

3.0 STREAMBANK EROSION ANALYSIS 3.9
3.1 STUDY BANKS 3.9
3.2 RIVER SUMMARY 3.11

4.0 CONCLUSIONS AND RECOMMENDATIONS 4.12
4.1 CONCLUSIONS 4.12
4.2 RECOMMENDATIONS 4.13

5.0 REFERENCES 5.16

6.0 APPENDICES 6.17
A DETAILED SITE MAP 6.17
B MORPHOLOGICAL DATA 6.17
C SEDIMENT DATA 6.17
D HISTORICAL MAPPING 6.17
E BANK ANALYSES 6.17

1.0 Introduction

The Eastern Corridor Multimodal Projects are a large-scale effort to create new modes and routes of transportation between Clermont and Hamilton Counties as well as increase the capacity of existing modes and routes of transportation. Segment II/III of the Eastern Corridor Projects extends from US 50 near Fairfax in Hamilton County to the Eastgate area of Clermont County. One of the key proposed improvements of this segment is the relocation of SR 32 with new parallel rail transit, which includes a multimodal clear span crossing of the Little Miami River.

The Eastern Corridor Tier 1 work documented historical meanders of the Little Miami River and the potential for future channel movement in the Horseshoe Bend area. The purpose of the geomorphic assessment is to better understand past, present, and potential future channel conditions in order to provide recommendations on suitable Little Miami River crossing locations. These recommendations will be considered in the Conceptual Alternatives Study (CAS) and the evaluation of alternatives to be advanced for further study. Stantec's geomorphic study consists of two phases, and focuses on a 2.5 mile section of the Little Miami River at the Horseshoe Bend from RM 4.5 to RM 7.0. The goal of the first phase is to identify reaches within the 2.5 mile study area that exhibit preferable stability characteristics based on qualitative soils, channel geometry, geomorphic, vegetation, and discernable channel characteristics and migration tendencies. This report documents the findings of Phase I (also referred to as the feasibility study), and includes the methodologies, results, conclusions and recommendations to be considered in the CAS evaluation. The second phase of the geomorphic assessment will be completed in the fall of 2009. The goal of Phase II is to validate predictive and qualitative assumptions and to identify implications for channel morphology and stability in the study reach.

1.1 SCOPE OF WORK

Stantec Consulting Services Inc. (Stantec) performed a geomorphologic assessment of the 2.5 mile section of the Little Miami River using methodologies developed by Dave Rosgen and outlined in Watershed Assessment of River Stability and Sediment Supply (WARSSS) (Rosgen, 2006). Physical characteristics of the river, including bed and bank stability, erosional and depositional features and patterns, utility impacts, and floodplain flood flow access, were the principle focuses of the study. Habitat stability, including the riffle-run-pool-glide bed structures, major lateral stream inflows, island complexes, and the vegetation integrity of the riparian corridor were also reviewed. The purpose of the habitat analysis is to compliment the physical stability analyses and is not intended for permitting, restoration, or as an environmental impact study.

The geomorphic study includes two phases as described above; only Phase I is discussed in this report. Phase I included the collection of existing, historical, and field data; analyses; and identification of reaches having preferred geomorphic stability characteristics for a clear-span bridge. Collected field data includes cross sections, a longitudinal profile, sediment samples, river bank profiles, soil samples, and photographs. The data also provides a baseline for comparison during Phase II of the geomorphic analyses.

1.2 BACKGROUND INFORMATION

1.2.1 Location and Characteristics

The Little Miami River (HUC 05090202) drains 1,755 square miles of southwestern Ohio as it runs approximately 100 miles from its headwaters in Clark County to its confluence with the Ohio River at Cincinnati in Hamilton County (Schiefer, 2002). The drainage area of the Little Miami River at the study reach is approximately 1,730 square miles (USGS Stream Stats).

The Little Miami River Watershed stretches across 5 physiographic regions and 11 counties within the Till Plains of Ohio. The Segment II/III study area lies in the Illinoian Till Plain in close proximity to the Outer Bluegrass Region. The Illinoian Till Plain is characterized by rolling ground moraines of older till generally lacking kames and eskers with many buried valleys. Modern valleys alternate between broad floodplains and bedrock gorges with overall moderately low relief. The soils are leached several feet and surficial material typically consists of silt-loam, high-lime Illinoian-age till with a loess cap overlying Ordovician- and Silurian-age carbonate rocks and calcareous shales. The physiographic characteristics of this portion of the watershed match the description for a Valley Type VIII. A Valley Type VIII is identified by multiple terraces spread across broad valleys with gentle down-valley slope. Soils form over alluvium from riverine and lacustrine deposition, which is responsible for the majority of valley landforms and high sediment supply. Slightly entrenched, meandering channels with riffle/pool bedforms are typical to this valley type (Rosgen, 1996).

The Segment II/III study area encompasses approximately 5.25 sq. mi. and includes the communities of Newtown and Shademore, a portion of Anderson Township, and the south edges of the communities of Fairfax and Mariemont.

The area is a mix of land use and disturbances, including residential, commercial and industrial development in Newtown, wooded stream corridor and agricultural land along the Little Miami River to the west and north of Newtown, and wooded uplands with developing residential areas to the south of Newtown and along existing SR 32 to Eastgate. Segment II/III contains a number of recreational and natural areas including a public golf course, ball/soccer fields and other parkland/greenspace, and the privately owned Horseshoe Bend preserve. The riparian buffer adjacent to the Little Miami River has been reduced in width, thinned of underbrush, or cleared in several areas, leading to bank instability and erosion (refer to Detailed Site Drawing in Appendix A) . Also occurring in the area is gravel mining and industrial development in the Ancor area to the east of Newtown, and active landfills along US 50 to the west of the Little Miami River and along existing SR 32 just east of Newtown. Landfill operations, specifically dump rock placement on the western river bank, also contributes to river instability. The Segment II/III area is also sensitive for cultural historic and archaeology resources, especially along the Little Miami River floodplain, and in and around Newtown.

Average annual precipitation for the watershed ranges from 38 to 43 inches, with higher precipitation to the south and approximately one-third becoming surface runoff. Average annual air temperature is 54º Fahrenheit. Average snowfall ranges from 20 to 30 inches per year (USGS, 1997).

1.2.2 River Designation

In 1968, the Little Miami River was the first river to be designated a State Scenic River by the State of Ohio. Portions of the river were chosen for national designation in 1968 with more added in 1973. It was the first of three Ohio rivers to receive both State and National Wild and Scenic Rivers designations. The National Wild and Scenic Rivers Act established the goal of "preserving certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations." (WSRA, 1968)

2.0 Geomorphic Assessment of the Little Miami River

Stantec divided the river into four reaches to analyze existing geomorphic conditions and describe channel influence variables. Reaches were separated based on river bank conditions, channel and floodplain morphology, and tributary and distributary influence. Reach 1 extended from approximately 1,800 feet upstream of the existing railroad bridge to approximately 3,100 feet downstream. Channel bank characteristics and flood prone width changes were evident in Reach 2, which extends approximately 3,800 ft downstream, ending where the landfill road turns to parallel the river. Reach 3 continues from this point to just upstream of the slough entrance at the Clear Creek confluence, approximately 1,700 feet. Reach 4 extends to the end of the study area, approximately 4,000 feet downstream of the Clear Creek slough inlet. Detailed Site Drawing A-1 presented in Appendix A shows the reach limits.

Stantec set and spatially located 12 permanent cross sections, 18 permanent bank study sites, and 9 scour chains in Ohio State Plan South Coordinates throughout the study area. Monitoring sites were distributed throughout the reaches. These sites will be resurveyed for final analyses in the fall of 2009 as part of Phase II. Detailed Site Drawing A-1 presented in Appendix A shows data collection points.

2.1 LITTLE MIAMI RIVER DESCRIPTION

2.1.1 Level I Assessment: Geomorphic Characterization

Broad level evaluations of channel slope, shape, and pattern provide delineative criteria for stream classification in the Rosgen Stream Classification System (Rosgen, 1996). The study reach of the Little Miami River exhibits a meandering, single-channel river pattern in plan view with moderate to high sinuosity. The channel is wide and shallow, overall, and is slightly entrenched with access to a broad, gently sloping, alluvial floodplain. The channel slope is well below the delineative criteria of 2%. Congruent with the low channel slope, riffle/pool bed features dominate the study reach. These characteristics are indicative of a C river type, with low channel slope (c-). A graphic of Rosgen's Stream Classification System can be viewed in Appendix B.

2.1.2 Level II Assessment: Morphological Description

A level II assessment is used to further classify and attain deeper insight into river channel states and characteristics by gathering detailed geomorphic field data. River channel dimensions and profiles are based on an elevation associated with the bankfull discharge. The most common and universally applicable definition provided by Dunne and Leopold (1978) is that "The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work results in the average morphological characteristics of channels." Bankfull stage is commonly thought of as the incipient point of flooding or elevation on the bank where flooding begins, but this is not always the case due to channel incision. The Little Miami River does have a number of bankfull indicators, or flat depositional, sandy surfaces, upon which field surveys were based.

Stantec collected and analyzed field data throughout the months of October and November of 2008 to provide further delineative criteria based on channel characteristics. Select morphological characteristics describing the study reach of the Little Miami River are presented in Table 1.

Table 1 Morphological Channel Characteristics	
Dimension and Sediment	
Entrenchment Ratio (ER)	12.8
Width/Depth Ratio (W/D)	40.4
D_{50} (mm) - Reach Average	10.0
Longitudinal Profile	
Slope (ft/ft)	0.00054
Plan-form	
Sinuosity (K)	1.36

Additional classification data is provided in WARSSS Worksheet 5-3 in Appendix B. Additional geomorphic data and particle size distributions obtained during field surveys are provided in Appendices B and C, respectively.

2.1.3 Level III River Stability Prediction - Stream Stability Indices

Riparian Vegetation

Reach 1 The woody vegetation riparian zone width is approximately 300 feet on the right bank; a slough / distributary, which begins approximately 1,100 feet downstream of the railroad bridge and reconnects with the main channel at the Horseshoe Bend, divides a lower riparian zone from the river bank. The wooded area on top of the bank has a relatively dense mix of mature, deciduous overstory, consisting mostly of Silver Maple, Eastern Cottonwood and Sycamore, with honeysuckle bushes and a combination of grasses, forbs, and other brush as understory. Downstream of the railroad bridge, open grass fields with some trees extend 400 to 1,200 feet from the river bank before ending near a railroad yard and industrial land uses. The lower riparian zone extends the length of the slough / distributary. The portion of this zone within Reach 1 ends near another small slough, approximately 2,750 feet downstream of the railroad bridge, which connects the larger slough / distributary with the main channel. The lower riparian zone has a well established population of mixed, deciduous trees evident in historical aerial photographs dating to 1938.

The left bank woody vegetation riparian zone is approximately 150 feet wide and consists of mixed, mature, deciduous overstory, consisting mostly of silver maple, eastern cottonwood and sycamore trees, with dense populations of honeysuckle bushes and various grasses and forbs of less dense understory. Beyond the woody vegetation riparian buffer, soybean, corn and sod fields extend thousands of feet.

Reach 2 The woody riparian zone along the left bank of Reach 2 remains approximately 150 feet wide approximately 600 feet downstream of the end of Reach 1 with a similar composition to the left bank of Reach 1. The remaining length of Reach 2 left bank is approximately 500 feet wide but has been selectively cleared and thinned of understory. The remaining understory is giant ragweed, which has a shallow rooting depth and low root density, with low percentage of grass cover. The composition of this zone continues downstream to the confluence with Clear Creek in Reach 4, but does vary is width. A number of large cottonwood trees along the left bank of Reach 2 bank have recently fallen into the river due to bank erosion.

The right bank of Reach 2 upstream of the slough / distributary confluence with the river is similar in density and composition to the lower zone of Reach 1. It ranges in width of approximately 500 to 900 feet. The right bank is the inside of a meander bend and is a depositional zone. The vegetation community is a good indicator of this fluvial process as the woody vegetation community close the river bank consists of younger willow species.

Downstream of the confluence of channels at the Horseshoe Bend, the composition of vegetation along the right bank changes significantly. The floodplain area is comprised almost entirely of giant ragweed with minimal grass ground cover. This vegetation community is approximately 200 feet wide upstream and increases to 600 feet wide at the apex of the bend and ends abruptly at a stand of trees lining a ditch. A corn field exists along the right bank to the end of the reach. Some willows populate portions of the bank from low flow water levels to the top of bank.

Reach 3 The left bank woody vegetation is dominated by mature willows close to the river and mature silver maple, eastern cottonwood, and sycamores along adjacent terraces. The average width is over 500 feet, bordered by thousands of feet of various grass and sod fields.

The right riparian zone through Reaches 3 and 4 consists of a narrow band of trees bordered by broad fields. Willows cover much of the bank. Atop the banks, mature sycamores dominate the 50 foot wide woody riparian zone. Beyond the woody vegetation zone, flat fields of various grasses, forbs, and bare earth extend from 200 to 1,200 feet from the river.

Reach 4 The left bank riparian zone narrows significantly, with the lower half having little to no woody vegetation buffer. A short portion at the end of the reach has a 200 foot wide stand of trees atop the bank. There are few trees growing below the top of bank. Several large trees have fallen into the river due to bank erosion. Sycamores are common in this segment. Beyond the tree line, flat sod fields extend thousands of feet.

Flow regime

The Little Miami River is a perennial stream with surface water persisting year long. River water comes primarily from storm runoff. Development in the immediate area and development throughout the watershed have played a role in altering the local flow regime. Large impoundments in the watershed upstream of the study area have significantly altered the Little Miami River's flow regime twice in the past 35 years. Caesar Creek was dammed to create Caesar Creek Lake in 1973 and East Fork Little Miami River was dammed in 1977 to create Harsha Lake. Aerial photographs indicate marked flow and deposition pattern changes at these times; reduced flood flows likely change the magnitude, duration, and frequency of bankfull discharge. This flow regime shift likely led to aggradation, sloughs / distributaries and allowed for growth of woody vegetation on the right bank entering Horseshoe Bend. A smaller impoundment was placed on Cowan Creek, a tributary to Todd's Fork in the eastern part of the watershed, in 1950.

Depositional Patterns, Tributaries and Distributaries

The study reach has many depositional features including point bars, mid-channel bars, side bars, and diagonal bars with some of these features extending as much as three times the channel width.

Reach 1 A slough / distributary begins approximately 1,100 feet downstream of the railroad bridge. During low flow conditions it is not accessed by the river and it holds long, stagnant pools of water with occasional gravel side bars. It is visible in the aerial photography from 1932. A bar feature exists at the entrance of the slough and continues downstream along the right bank of the river channel. The bed of the slough is composed of predominantly gravel which shifts to a sandier composition along the banks and on the floodplain and depositional zone between the slough and the river. The end of the slough has been historically dynamic. In 1932, the channels joined at the right-hand bend before Horseshoe Bend. Since then, the main channel has pushed south pulling away from the old alignment and the slough remained farther north. The island between the slough and the main channel has grown from 1,500 feet wide in 1932 to over 4,000 feet at the time this study.

Reach 2 The riffle section (R2_XS1) in this reach has a very high width to depth ratio of 124. This high width to depth ratio causes a reduction in stream power, causing sediment to fall out in this reach, also known as aggradation. The aggradation and instability is apparent by an observed gravel island in the middle of the active channel before Horseshoe Bend in Reach 2. The island is not discernible in 2004 aerial photography, although depositional processes are evident in this area. In 1990, one channel followed along the existing right alignment in a northwest direction. The channel appears to have widened and flowed in a more westerly direction with visible deposition in the island area in 2004. By 2007, the island and dual low flow alignments had formed. A submerged transverse bar connects the head of the island to a gravel bar feature along the right bank, visible only during lower flows. A long, wide, shallow riffle is present along the left low flow path. The right side loops around the island and is near half the width and slightly deeper than the left low flow path. The right alignment bends left along a large side bar to rejoin the left alignment and continue along the left's heading into the bend.

Currently, Horseshoe Bend has a large point bar on the inside of the meander bend, stretching approximately 1,500 feet of river length. The bar is composed predominantly of gravel near the low flow water surface with an increasing sand component up the slope to the bankfull elevation, where the particle distribution is almost entirely sand. A mid-channel, gravel bar is connected to the point bar by a thin strip of gravel near the upper third of the point bar. This depositional pattern is not evident in the 2007 aerial photography. Coinciding with the point and mid-channel bar development, a large sand bar has formed on the right bank downstream of the riffle at the entrance to the bend. The bar consists mostly of gravel near the active channel and on the upper third. The lower third and back of the bar is mostly sand.

Significant pattern changes and depositional feature changes in Reach 2 are first observed in 1950. At this time, flow at the entrance to the bend began shifting south and widening the active channel. This created mid-channel bars near the confluence with the unnamed tributary and slough / distributary. By 1968 the island is nearly 1,500 feet in length with transverse, high-flow channels. The island continued to build with the majority of flow shifting to the southern channel in the 1970's. By 1981 the northern channel was abandoned and vegetated between the river and the slough / distributary. The point bar at the Horseshoe Bend has consistently been a prominent feature extending into the active channel and has progressively moved downstream. The progression may be viewed in Appendix D.

Reach 3 Two side bars exist in Reach 3. As the point bar at Horseshoe Bend has moved south and west, the channel downstream has begun to move east, creating a gradual right-turn bend in Reach 3 with a corresponding depositional feature on the lower end. The deposition resembled a side bar that began forming in the mid 1960's. The bar has since grown and is displaying characteristics of a point bar. At the time of data collection, the bar extended downstream approximately three bankfull widths. The bar is composed mostly of gravel, with the percentage of sand increasing from front to back and from up- to downstream.

Reach 4 A submerged, transverse gravel bar connects the end of the bar in Reach 3 to the head of the next side bar on the opposite bank in Reach 4. The thalwag switches from the left 1/3 of the channel to the right 1/3 at this transition. The side bar on the left bank in Reach 4 is predominantly composed of gravel and is adjacent to the island between the slough that receives Clear Creek and connects to the Little Miami River. This sidebar is low and is frequently submerged.

The point bar on the right bank in Reach 4 has been relatively stable in its present form for approximately 40 years. It appears to be slowly extending and lengthening downstream, pushing the thalweg further to the left 1/3 of the channel. The point bar growth coupled with the narrow riparian buffer with little to no woody vegetation is likely causing high rates of bank erosion along study banks 2 and 3 (See Section 3.1 and Appendix E). The bar sediment size is mostly gravel and sand, fining in the downstream direction.

Meander Patterns

The Little Miami River has irregular meander patterns, a tortuous meander at the Horseshoe Bend and truncated meanders artificially confined by landuse, rip rap placement and infrastructure. Historical mapping and aerial photographs also show signs of unconfined and confined mender scrolls. The river has shown little meander movement in the last 30 years with the exception of Reach 2, which has seen significant changes in the recent past. Overall, river meander patterns from the last 140 years indicate dynamic conditions in the lower 2/3 of the study reach. The historical footprint of the river in the study area is approximately 450 acres. River lengths through the study area have differed by approximately 5,000 feet. According to historical data, maximum lengths occurred in the mid to late 1800's. The length dropped by approximately 3,000 feet by the turn of the century and another 1,000 ft by the middle of the 20^{th} century. These reductions in length may have contributed to river bed downcutting, or degradation. Since then, the river has gained approximately 1,500 ft. River stations have varied laterally as much as 3,500 feet.

Belt widths have ranged from1,300 to 5,000 feet and radii of curvatures have ranged from 375 (the existing Horseshoe Bend) to over 2,000 feet. Currently, the belt width through the study reach is approximately 4,000 feet with radii of curvature measured to be approximately 375, 740, 860, 1,030, and 2,130 feet. Meander movement through the study reach has been limited by the armoring of portions of the right bank in Reaches 2, 3, and 4. A 1,500 ft segment of right bank immediately downstream of Horseshoe Bend has been heavily armored with concrete rubble. This has stunted meander migration of this bend. Aerial photography shows bank erosion upstream of the armored portion in Reach 2 and erosion of study banks 9, 10, and 11. These erosion patterns coupled with the existing depositional patterns indicate a down valley migration. The river may experience an avulsion, a rapid shift in channel pattern, in the short term if the down valley migration continues to be impeded by bank armoring.

Side channel sloughs exist in each reach. Reach 1 has a slough / distributary in the right floodplain. This slough / distributary will not likely become the active river channel again due to the existing railroad bridge abutment just upstream of slough / distributary. The slough / distributary pattern appears to have remained stable for decades. However the slough / distributary length has nearly doubled in length over the past 70 years, extending into Reach 2. The slough / distributary receive an unnamed tributary and flows through a historic river alignment, or meander scroll, before joining the main channel at the Horseshoe Bend.

Historical aerial photographs show various other sloughs which have developed and faded through the study area. The slough in Reach 4 at the Clear Creek confluence appears to be a result of past channel migration to the west. Historical aerial photography shows that this slough is now less frequently accessed by the main channel and is filling with sediment and becoming more vegetated; field observations confirm this trend.

Debris and Channel Blockages

Debris and channel blockages are moderate to infrequent throughout the reach. Parts of automobiles and watercraft can be seen frequently, with most objects being floatable and small relative to the channel size. Human influences are also evident throughout the reach. Several active beaver lodges were observed along the river banks, but they likely have little to no influence on the channel processes. In each reach, large, fallen trees are seen frequently along the banks and infrequently within the middle one third of the channel. In general, these fallen trees have not had significant impacts to flow patterns. Two tree trunks extending from the outer bank in the Horseshoe Bend are affecting flow, as evidenced by local scour of the bank toe.

Degree of Channel Incision

The degree of channel incision can give insight to the sediment supply of the stream. It is determined using the Bank-Height Ratio (BHR). This is the lowest bank height divided by the maximum bankfull depth. The study reach has a BHR of 1.34, or moderately incised channel (Rosgen, 2006).

Degree of Channel Confinement

Channel confinement is determined from the Meander Width Ratio (MWR), which is calculated as belt width divided by the bankfull width. The MWR for the study reach is 11.9, which is high on the range of MWR for a C stream type, indicative of little to no channel confinement.

3.0 Streambank Erosion Analysis

3.1 STUDY BANKS

Eighteen different bank sites were assessed using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2006) throughout the study area to characterize bank stability. Banks were rated using the Bank Erodibility Hazard Index (BEHI) and Near Bank Stress (NBS) evaluations. In general, the BEHI procedure helps to predict erosion potential based on a number of variables including bank height, rooting depth, rooting density, surface protection, bank angle, bank stratification and soil composition. The NBS procedure evaluates the potential for increased shear stresses in the near bank region. For this study, Phase I is a predictive assessment of erosion rates and Phase II will validate those erosion rate predictions. Predicted bank erosion rates are presented in detail in Drawing E-1 in Appendix E.

Banks in Reach 1 were generally steep with high rooting depths and low rooting density. Study Banks 12, 13a, 14, 15, and 17 exhibited very low erosion potential, Study Bank 16 exhibits low erosion potential and Study Bank 13b exhibits very high erosion potential.

Study Banks 8, 9, 10, and 11 in Reach 2 have bare soil faces with low rooting depths and densities and low percentages of surface protection. Frequent bank stratification was observed on many of the banks in Reach 2. These banks have mostly moderate and high erosion potential. Study Bank 7 has a high percentage of surface protection from concrete rubble but has a high erosion potential due to very high shear stresses in the near bank.

The study banks in Reach 3 have high sand contents and material stratification. Rooting depth and density varies, but overall, this reach exhibits high erosion potential and the highest predicted erosion rate by reach.

Erosion potential in Reach 4 varies from very low to extreme. The upper portion of this reach has banks of high sand content with stratification and low rooting depth and the lower portion has extremely steep slopes and high banks with low root density and rooting depth. Some banks are stratified with gravel, sand and silt/clay. Large slope failures were observed at Study Banks 1 and 2 in Reach 4 during the time of data collection.

Table 2 gives BEHI and NBS ratings of each bank studied and predicted erosion rates.

Table 2 Bank Erodibility Factors				
Study Bank	**BEHI**	**NBS**	**Predicted Erosion Rate**	
			(in/yr)	**(ton/yr/ft)**
Reach 1				
17	Moderate	Low	0.2	0.01
16	High	Low	1.3	0.09
15	Moderate	Low	0.2	0.01
14	Moderate	Moderate	0.5	0.02
13b	Very High	Low	7.2	0.60
13a	Moderate	Moderate	0.5	0.03
12	Low	Low	0.1	0.01
Reach 2				
11	Very High	Low	8.4	0.42
10	Very High	Very Low	7.2	0.28
9	High	Very Low	1.3	0.04
8	High	Extreme	4.8	0.51
Reach 2/3				
7	Moderate	High	3.5	0.47
Reach 3				
6	High	Low	2.4	0.10
5	Very High	Low	8.4	0.58
Reach 4				
4	Very High	Low	7.2	0.42
3	High	Low	1.3	0.04
2	Extreme	Low	19.2	1.50
1	High	Low	1.8	0.08

Detailed graphs and summary data of each study bank are provided in Appendix E.

3.2 RIVER SUMMARY

Overall, bank erosion potential increased in the downstream direction. Figure E-1, found in Appendix E, illustrates the banks studied and predicted erosion rates throughout the study area.

4.0 Conclusions and Recommendations

4.1 CONCLUSIONS

Geomorphic study of the Little Miami River is a part of planning for Segment II/III of the Eastern Corridor Projects. Preliminary and predictive geomorphic assessments of a 2.5 mile stretch of the river, including four reaches (potential clear-span bridge crossing locations) was completed by Stantec. Phase I of the geomorphic study included the collection and analyses of existing, historical and field data and analyses including the classification and characterization of the physical stability of the river, insight into the geomorphic processes at work, and a baseline for comparison of data collected for Phase II and the completion of this study.

Dimension, pattern, and profile data indicates the Little Miami River is a C4c- river type according to the Rosgen Stream Classification System (Rosgen, 1996). The river has irregular, tortuous, and confined meander patterns with a high Meander Width Ratio (MWR). It is slightly entrenched with a moderate degree of channel incision. The channel has a flat slope (0.00054 feet/feet) with riffle, run, pool, and glide bed features. Bankfull channel dimensions include mean width and depth of 335.6 and 8.3 feet, respectively. Substrate analysis produced a reach average bed material, or D_{50}, of 10 mm.

Historical aerial photography analysis shows significant meander movement and depositional processes in Reaches 2, 3, and 4 over the past 140 years. Recent geomorphic activity in the past 30 years shows significant channel and depositional pattern shifts in Reach 2. The Horseshoe Bend shows characteristics of active deposition and down valley channel migration.

BEHI and NBS ratings indicate increasing erosion potential on banks from upstream to downstream. From the Horseshoe Bend to the bend in Reach 4, banks exhibit high, very high and extreme bank erosion potential and preliminary predicted values of bank erosion rates in tons per linear foot of bank per year.

Past reach length reductions, lateral meander and channel confinement and changes to the watershed hydrology may contribute to river instability. The construction of the Caesar Creek and East Fork Dams altered the hydrology and sediment supply of Little Miami River and may have caused river instability.

A reduction in stream length, possibly caused by human channel maintenance, dredging or channelization or a natural river avulsion at the turn of the twentieth century, may have led to increases in channel shear stresses, bed and bank erosion, degradation, and channel incision. Channel incision can result in a lower water table next to the river, limiting vegetation density and variability, which is evident in portions of each reach of the study area.

Lateral confinement which truncates meanders, can also lead to higher shear stress, higher bank instability and erosion, and increased sediment supply.

Caesar Creek and East Fork Dams construction likely caused a shift in bankfull discharge magnitude, duration, and frequency. This shift in the hydrology coupled with the instability and high sediment supply caused by reductions in reach length and increased lateral confinement likely caused aggradation. Field observations in the riffle upstream of the Horseshoe Bend are consistent with this assessment. The river has had C river type characteristics for a long period of time as seen in the historical aerial photography. However, instability and changes are causing the river to exhibit some characteristics of a D river type, a highly unstable river type in a Valley Type VIII.

4.2 RECOMMENDATIONS

Geomorphic Assessment – Phase I

Reach 1 exhibits favorable geomorphic stability characteristics for a clear-span bridge crossing. The river banks have mostly low and moderate BEHI and NBS ratings. Reach 1 has the lowest overall predicted erosion rate of the four river reaches. Historical aerial photography indicates this reach has had little channel movement in the past 100 years. The armored right bank upstream of the railroad bridge has constricted channel movement upstream of the bridge and the bridge and its abutments and piers have likely limited channel movement downstream. The age and relative stability of the railroad bridge also points to a desirable clear-span crossing location. A crossing in Reach 1 also would likely require the shortest clear span distance of the four alternatives. While Reach 1 has preferable geomorphic characteristics for a clear-span bridge crossing, the erosion potential and dynamic changes in the Horseshoe Bend area may impact this alignment where the apex of the bend is nearest to the existing rail line.

Reach 2 crossing exhibits the least favorable geomorphic characteristics for a clear-span bridge crossing. Reach 2 has experienced the most channel movement in the past and the Horseshoe Bend is likely progressing through a down valley migration. The upstream left river banks and the outside of the Horseshoe Bend have high and very high BEHI ratings and the Horseshoe Bend has extreme NBS rating due to the small radius of curvature to width ratio. Significant deposition is occurring upstream of the bend and at the point bar which further indicate instability.

It is likely the Horseshoe Bend will experience a river avulsion or significant down-valley migration during the design life of the clear span bridge (80 years). Specific erosion rates on Study Banks 8, 9, 10, and 11 will be measured in the fall of 2009. Erosion rates are closely tied to the frequency and magnitude of flood events on the Little Miami River which adds uncertainty to the complex analyses in determining river avulsion time frames. A more specific time frame for the river change may be defined as part of Phase II analyses and presented in the final report.

Reaches 3 and 4 have shown less channel migration than Reach 2 in the recent past, but both have seen historical meander movement; Reach 4 has historically moved more than Reach 3. Reach 3 shows channel stability based on historical aerial photography. However, because the Horseshoe Bend is likely to migrate down valley, or worse, experience an avulsion, Reach 3 is less preferable for a clear-span bridge crossing than Reach 1. Lower flooding zones on both sides of the river and Clear Creek slough may require a longer bridge span through Reaches 3 and 4.

Stantec's preliminary recommendation for a second, preferable clear-span bridge crossing location is at the Reach 3 / Reach 4 boundary, upstream of the Clear Creek – Little Miami River confluence. This crossing location appears to be far enough downstream of the Horseshoe Bend for the potential effects of the potential avulsion or down-valley migration to be minimized. This crossing location is also likely far enough upstream of the unstable and eroding Study Banks 1 and 2. However, siting a potential clear span bridge crossing at this location does have design implications as the span would need to be long enough to accommodate Clear Creek and its slough.

Geomorphic Assessment - Phase II

Phase II of Stantec's geomorphic assessment will be completed by fall of 2009. Additional tasks to be completed are (1) Additional Analysis & Monitoring, (2) Reach Re-surveys, (3) Sediment Transport Analyses, and (4) Final Stream Stability Report. Stantec will perform hydrologic analysis of USGS river gage data and will monitor winter and spring floods. Should over bank flooding occur, the stage along the detailed study reaches will be marked and surveyed and the flow patterns in the floodplain noted. Stantec will also re-survey the cross sections, longitudinal profiles, and study banks to note changes in the river morphology. Disposition of the scour chains will also be determined. Select sediment data will also be re-surveyed for comparative analyses. Stantec will also perform sediment transport competency and capacity analyses to further assess the Little Miami River's stability. These analyses will give a qualitative prediction on whether the Little Miami River has a tendency toward aggradation or degradation. The final report will contain the information obtained and analyses performed throughout the geomorphic assessment and their implication on the river crossing. Final recommendations for the bridge crossing locations and span distances will be presented in the report.

Analyses in this report will include:

- The final Rosgen classification of the river with the identification of bankfull stage and the flood frequency of this stage;
- The characterization and analyses of the 2008 and 2009 river flows to normal, historical river flows since the two flood control reservoirs were completed;
- Final BEHI and NBS analyses and rates of bank movement measured over one year and normalized to the river's average flows, evaluation of riffle and point bar samples, scour chains, pebble counts, profile and cross sections, and sediment transport competence and capacity to characterize the river as prone to aggregation or degradation;

- Further analyses and conclusions regarding channel evolution, down-valley migration, or river avulsion and prediction of these future river changes; and
- If over bank flooding is observed, Stantec will identify floodplain flow characteristics that may adversely or beneficially impact channel stability at the potential crossings.

Potential Restoration Opportunities

Stantec identified restoration opportunities along the Little Miami River during field reconnaissance visits in the fall of 2008.

Riparian Corridor Enhancement and Bank Stabilization

Several sections of the riparian corridor along the river could be enhanced. The left river bank upstream of the Horseshoe Bend (Study Banks 9, 10, and 11) and the left river bank in Reach 4 (Study Banks 1 and 2) would benefit most from riparian re-forestation and bank stabilization. The stabilization of Study Banks 9, 10, and 11 will not prevent the avulsion, but should be done in conjunction with in channel re-alignment. The stabilization of Study Banks 1 and 2 could enhance the overall stability of Reach 4.

Sewer Outfall Repair

The sewer outfall on the right bank just downstream of the Horseshoe Bend needs repair. The gabion baskets are failing and the concrete outfall channel is degraded. The gabion baskets and concrete channel should be removed and the outfall should be relocated. If left unattended the outfall could be significantly damaged.

Clear Creek

Clear Creek joins the Little Miami River in Reach 4 and is a degraded stream. Long segments of the stream have been channelized in conjunction with adjacent agricultural land uses. The stream is over-widened and entrenched. Stantec also observed significant and excessive algae blooms in Clear Creek, possibly from fertilizer application practices in the adjacent agricultural land use. Clear Creek would benefit from a Priority 1 or 2, full scale stream restoration. This restoration would benefit not only the stability of Clear Creek, but also the slough in Reach 4.

5.0 References

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6.0 Appendices

A DETAILED SITE MAP

Detailed Site Drawing A-1

B MORPHOLOGICAL DATA

Classification Form
Cross Sections
Longitudinal Profile

C SEDIMENT DATA

Pebble Counts
Bulk Sample - Point Bar Samples

D HISTORICAL MAPPING

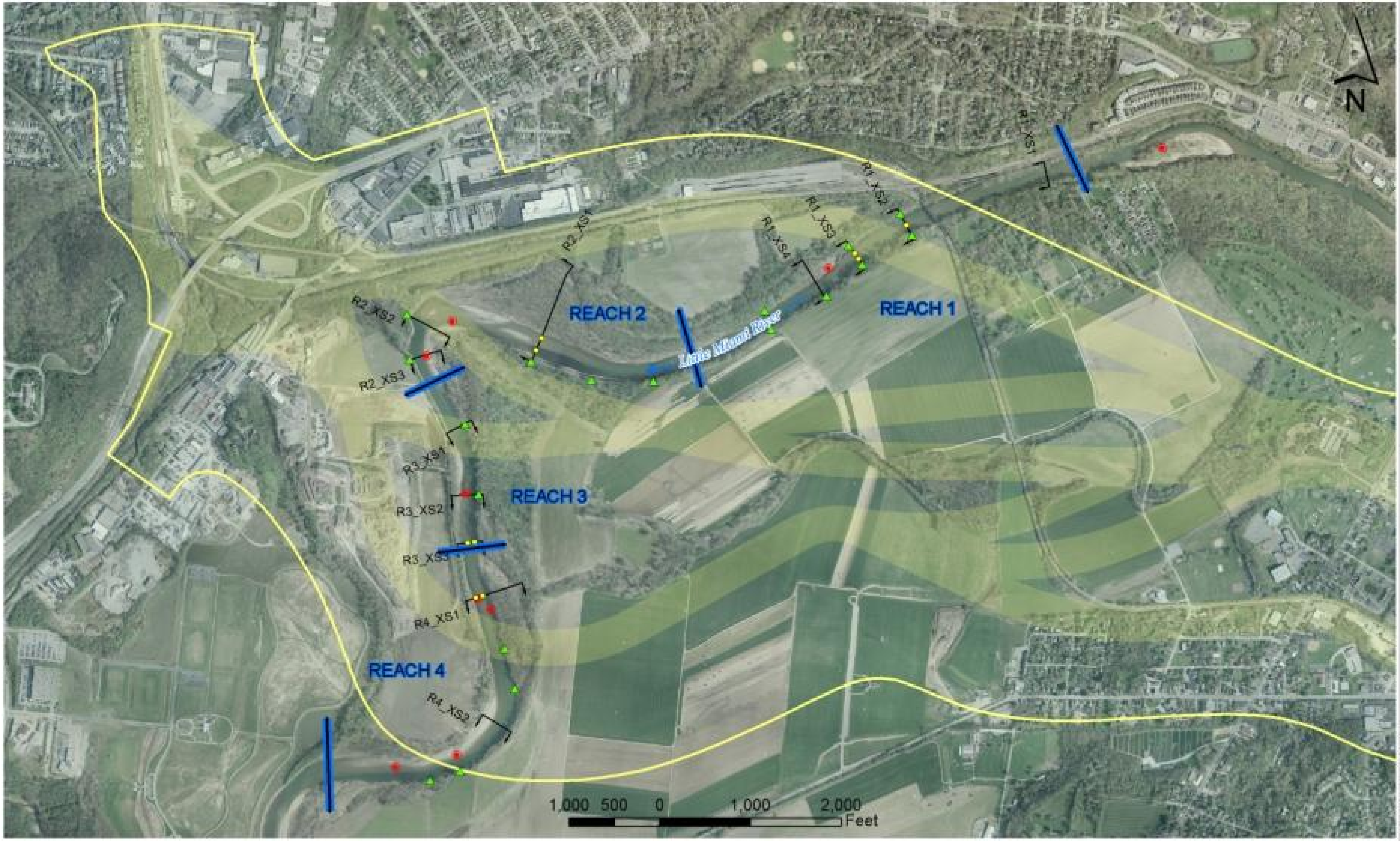
E BANK ANALYSES

Bank Erodibility Drawing E-1
Study Banks

Appendix A

Detailed Site Map

Detailed Site Drawing A-1



Legend

Study Area — Segment II/III Alternatives — Study Banks — Scour Chains — Sieve Analyses — Cross Sections

Stantec

Appendix A - Detailed Site Drawing

Entran
Little Miami River Riparian Crossings Analyses
Eastern Corridor Priority Part B - Segment II/III
Hamilton and Clermont Counties Ohio

SHEET

A - 1

Appendix B

Morphological Data

Classification Form

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**Little Miami River, Reach - RM 4.5 to RM 7.0**		
Basin:	**Little Miami River**	Drainage Area:	**1730** mi^2
Location:	**Eastern Corridor, Segment II/III**		
Observers:	**Scott Peyton, Tim Taylor**	Valley Type:	**VIII**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**336**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**8.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**2785**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**40.4**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**11.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**4300**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**12.8**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**10**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00054**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.36**	

Stream Type **C 4c-** (See **Figure 2-14**)

Cross Sections

RIVERMORPH CROSS SECTION SUMMARY

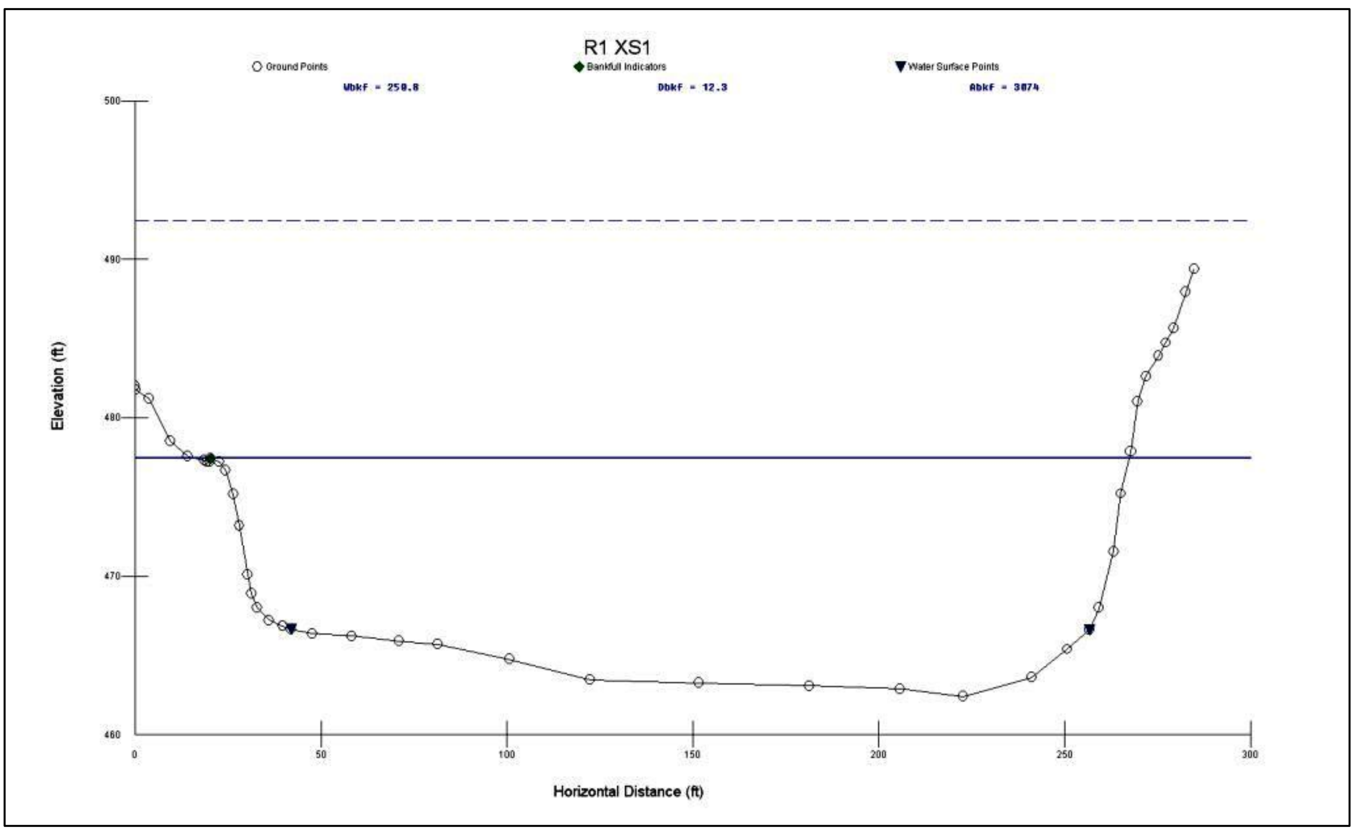
River Name: Little Miami River

Reach Name: RM 4.5 to RM 7.0

Cross Section: R1 XS1

Survey Date: 10/16/2008

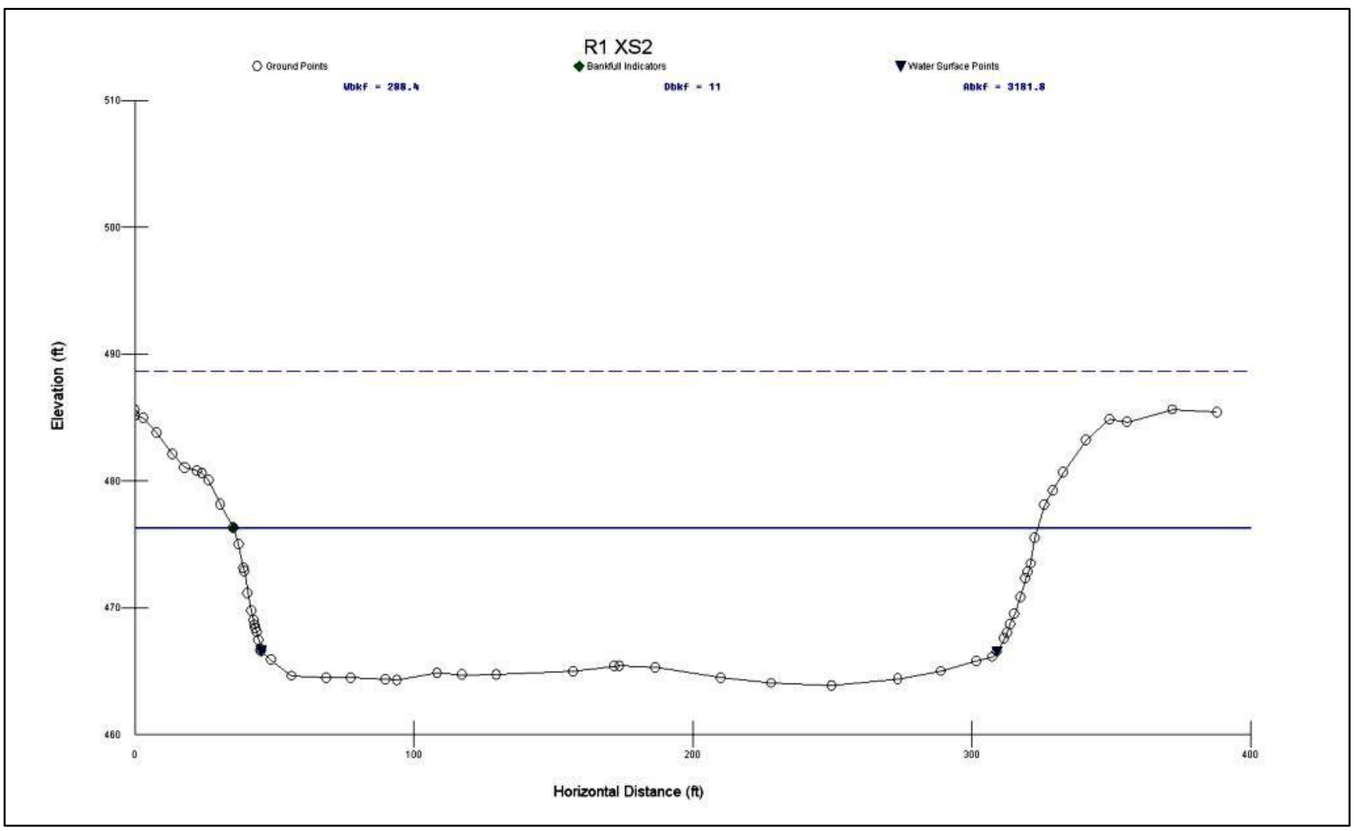
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	492.48	492.48	492.48
Bankfull Elevation (ft)	477.45	477.45	477.45
Floodprone Width (ft)	5000	-----	-----
Bankfull Width (ft)	250.84	128.34	122.5
Entrenchment Ratio	19.93	-----	-----
Mean Depth (ft)	12.25	11.11	13.46
Maximum Depth (ft)	15.03	14.13	15.03
Width/Depth Ratio	20.48	11.55	9.1
Bankfull Area (sq ft)	3074	1425.74	1648.25
Wetted Perimeter (ft)	260.16	146.6	141.82
Hydraulic Radius (ft)	11.82	9.73	11.62
Begin BKF Station	16.49	16.49	144.83
End BKF Station	267.33	144.83	267.33



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R1 XS2
Survey Date: 10/16/2008

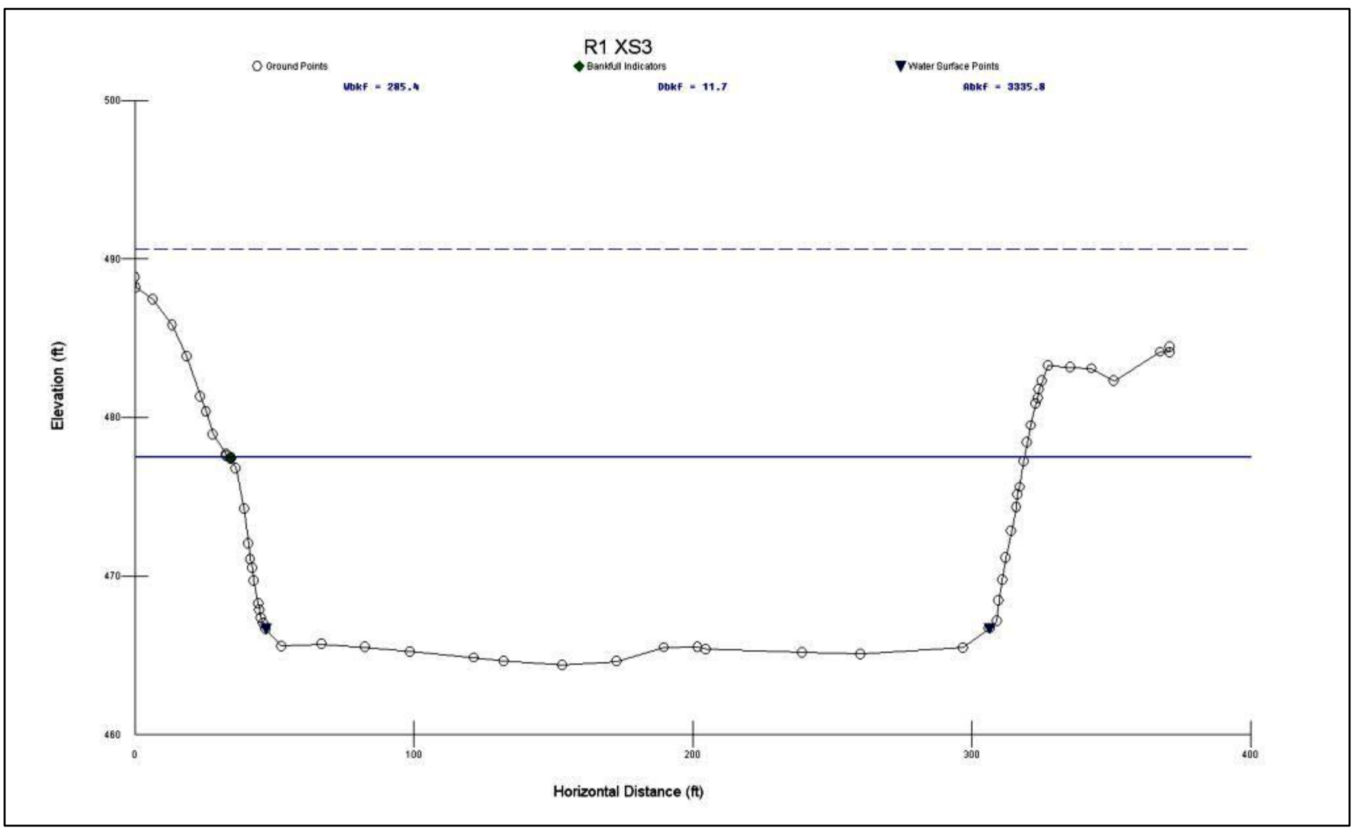
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	488.71	488.71	488.71
Bankfull Elevation (ft)	476.29	476.29	476.29
Floodprone Width (ft)	5000	-----	-----
Bankfull Width (ft)	288.44	144.22	144.22
Entrenchment Ratio	17.33	-----	-----
Mean Depth (ft)	11.03	11	11.06
Maximum Depth (ft)	12.42	11.99	12.42
Width/Depth Ratio	26.15	13.11	13.04
Bankfull Area (sq ft)	3181.83	1586.2	1595.62
Wetted Perimeter (ft)	296.06	159.41	158.48
Hydraulic Radius (ft)	10.75	9.95	10.07
Begin BKF Station	35.27	35.27	179.49
End BKF Station	323.71	179.49	323.71



RIVERMORPH CROSS SECTION SUMMARY

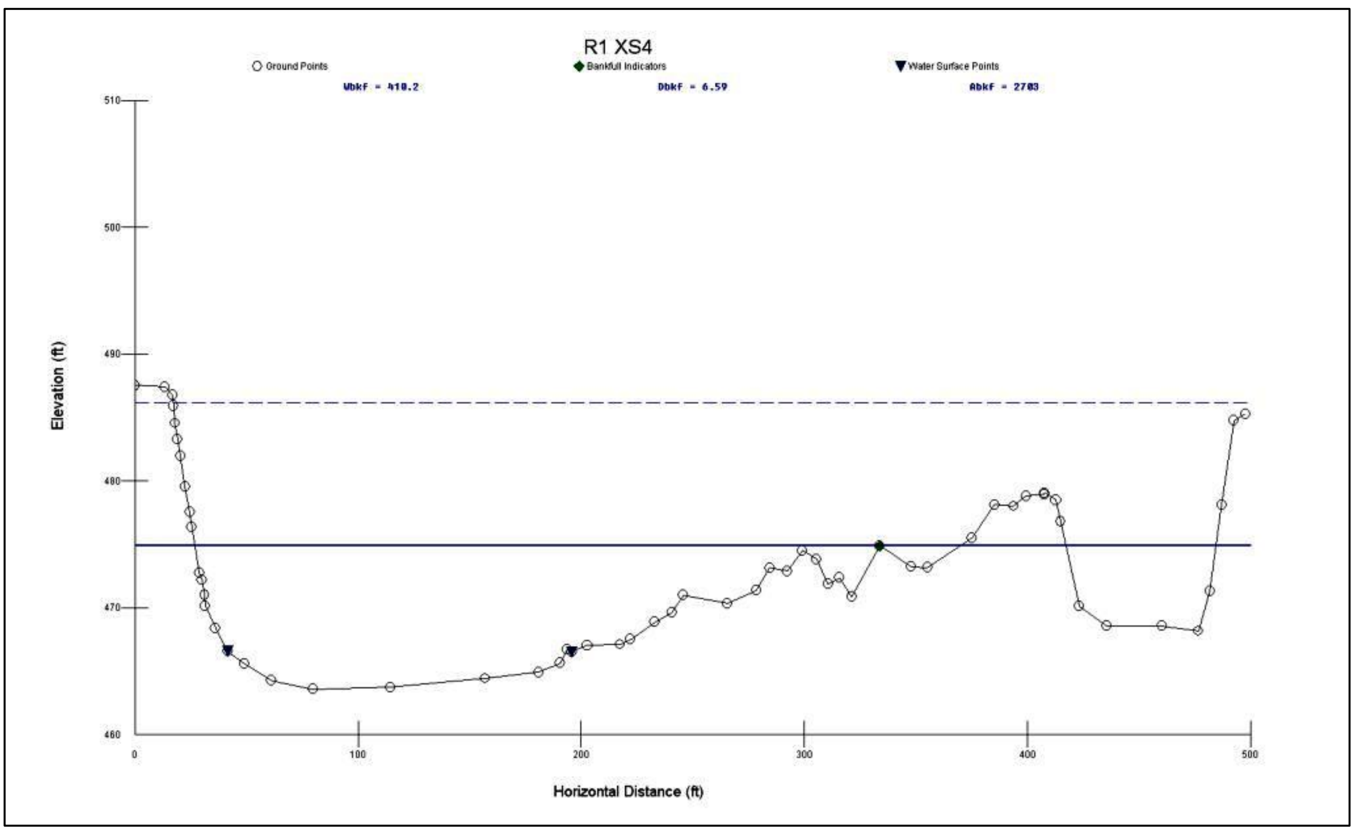
River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R1 XS3
Survey Date: 10/16/2008

Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	490.61	490.61	490.61
Bankfull Elevation (ft)	477.5	477.5	477.5
Floodprone Width (ft)	1000	-----	-----
Bankfull Width (ft)	285.37	142.81	142.56
Entrenchment Ratio	3.5	-----	-----
Mean Depth (ft)	11.69	11.74	11.64
Maximum Depth (ft)	13.11	13.11	12.69
Width/Depth Ratio	24.41	12.16	12.25
Bankfull Area (sq ft)	3335.8	1676.75	1659.05
Wetted Perimeter (ft)	294.74	160.13	159.98
Hydraulic Radius (ft)	11.32	10.47	10.37
Begin BKF Station	33.56	33.56	176.37
End BKF Station	318.93	176.37	318.93



RIVERMORPH CROSS SECTION SUMMARY
River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R1 XS4
Survey Date: 10/16/2008

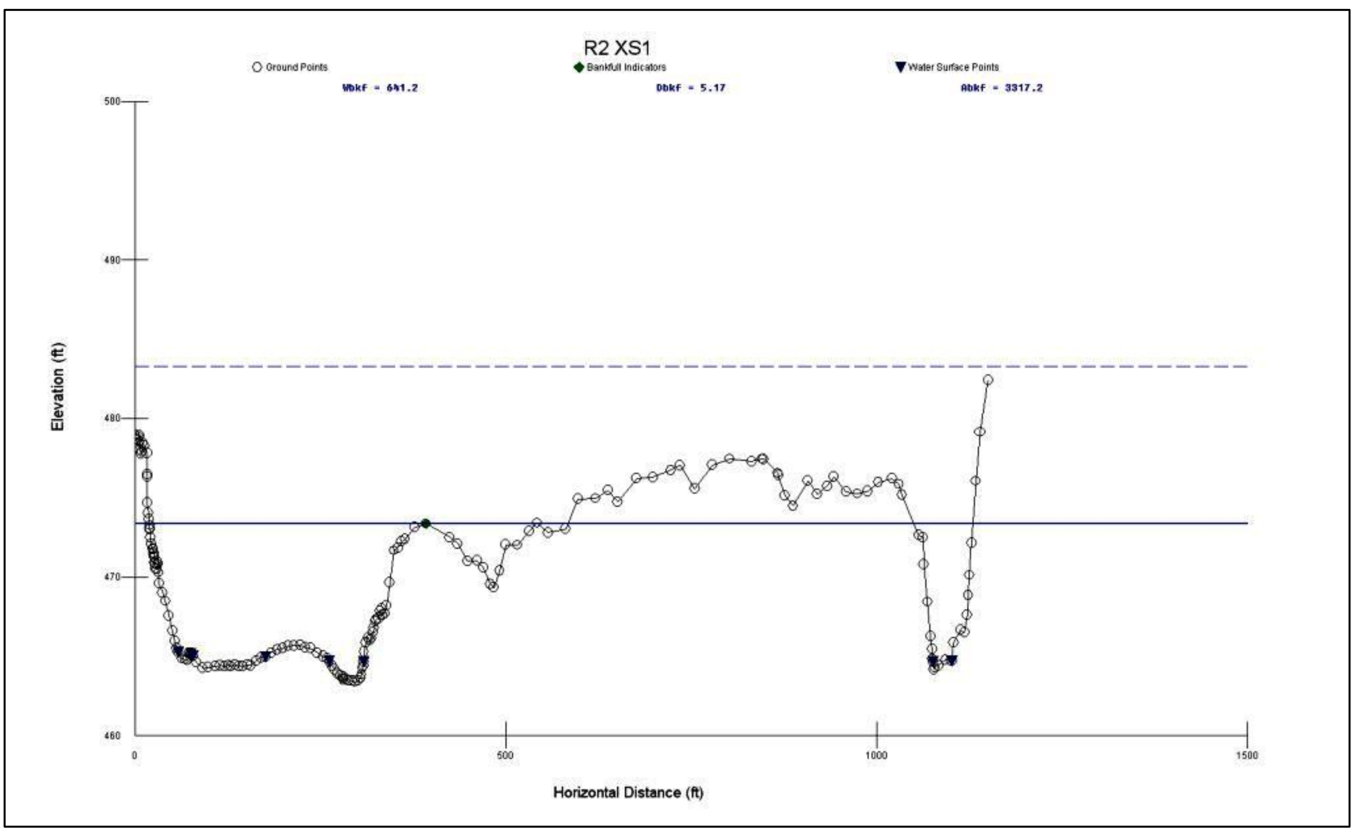
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	486.2	486.2	486.2
Bankfull Elevation (ft)	474.89	474.89	474.89
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	410.22	222.85	234.88
Entrenchment Ratio	4.88	-----	-----
Mean Depth (ft)	6.59	9.24	3.43
Maximum Depth (ft)	11.31	11.31	6.71
Width/Depth Ratio	62.25	24.12	68.48
Bankfull Area (sq ft)	2703.02	2059.47	643.56
Wetted Perimeter (ft)	420.11	230.42	197.72
Hydraulic Radius (ft)	6.43	8.94	3.25
Begin BKF Station	26.8	26.8	249.65
End BKF Station	484.53	249.65	484.53



RIVERMORPH CROSS SECTION SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Cross Section:	R2 XS1
Survey Date:	10/15/2008

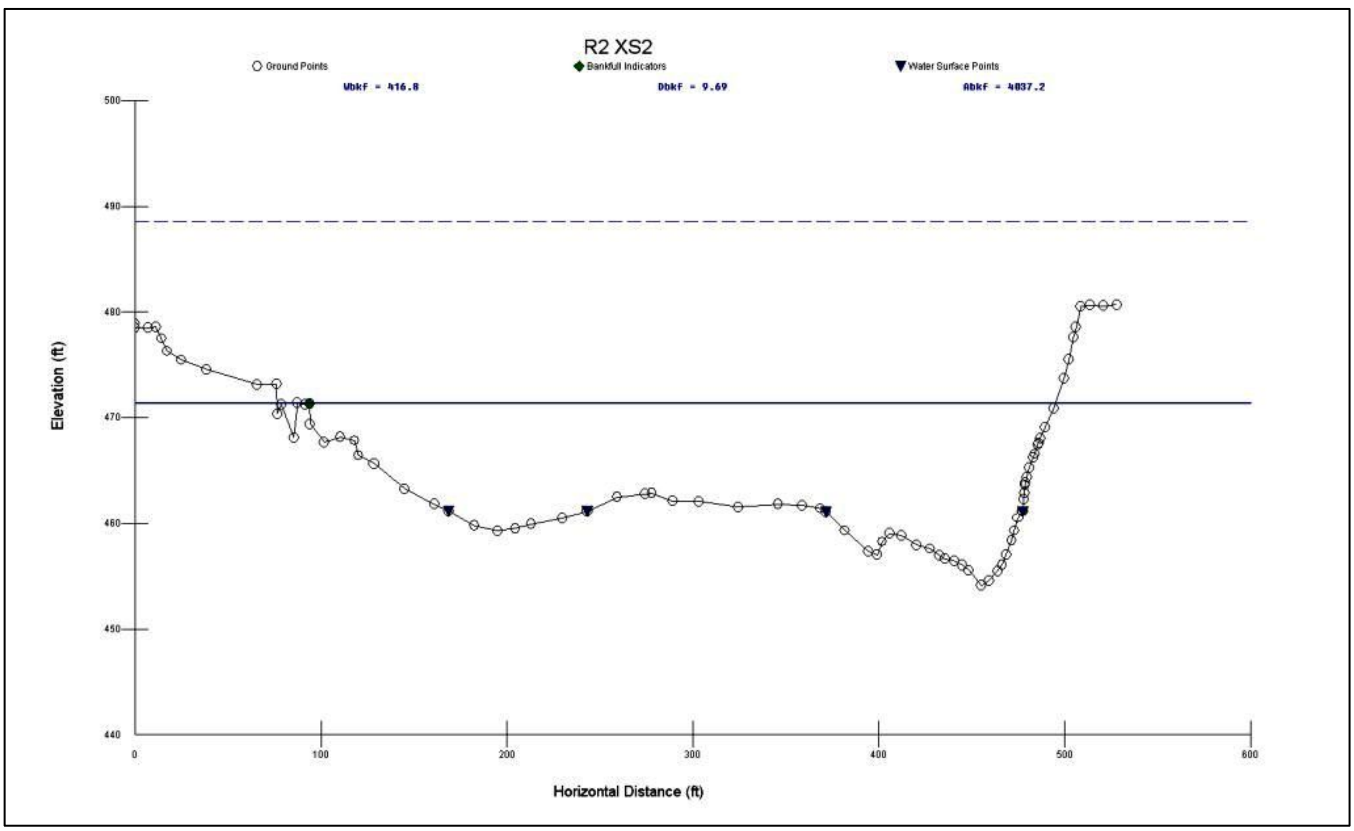
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	483.31	483.31	483.31
Bankfull Elevation (ft)	473.37	473.37	473.37
Floodprone Width (ft)	1600	-----	-----
Bankfull Width (ft)	641.25	297.3	812.89
Entrenchment Ratio	2.5	-----	-----
Mean Depth (ft)	5.17	8.08	2.66
Maximum Depth (ft)	9.94	9.94	9.2
Width/Depth Ratio	124.03	36.79	305.6
Bankfull Area (sq ft)	3317.17	2403.31	913.87
Wetted Perimeter (ft)	650.34	307.15	357.91
Hydraulic Radius (ft)	5.1	7.82	2.55
Begin BKF Station	19.26	19.26	316.56
End BKF Station	1129.45	316.56	1129.45



RIVERMORPH CROSS SECTION SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Cross Section:	R2 XS2
Survey Date:	10/15/2008

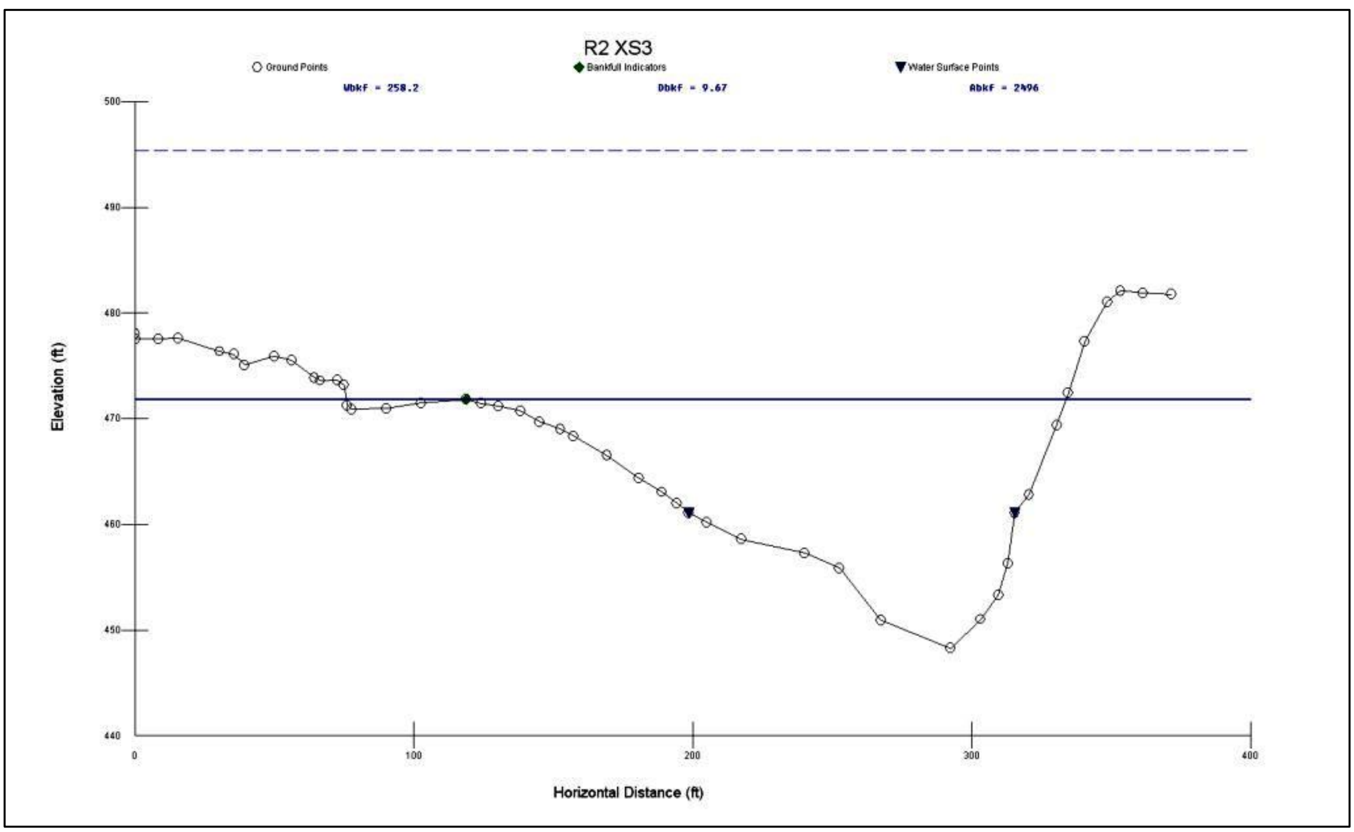
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	488.53	488.53	488.53
Bankfull Elevation (ft)	471.32	471.32	471.32
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	416.77	209.8	208.83
Entrenchment Ratio	4.8	-----	-----
Mean Depth (ft)	9.69	8.17	11.2
Maximum Depth (ft)	17.21	12.03	17.21
Width/Depth Ratio	43.01	25.68	18.65
Bankfull Area (sq ft)	4037.18	1698.32	2338.85
Wetted Perimeter (ft)	428.93	223.39	223.58
Hydraulic Radius (ft)	9.41	7.6	10.46
Begin BKF Station	76.4	76.4	286.2
End BKF Station	495.03	286.2	495.03



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R2 XS3
Survey Date: 10/15/2008

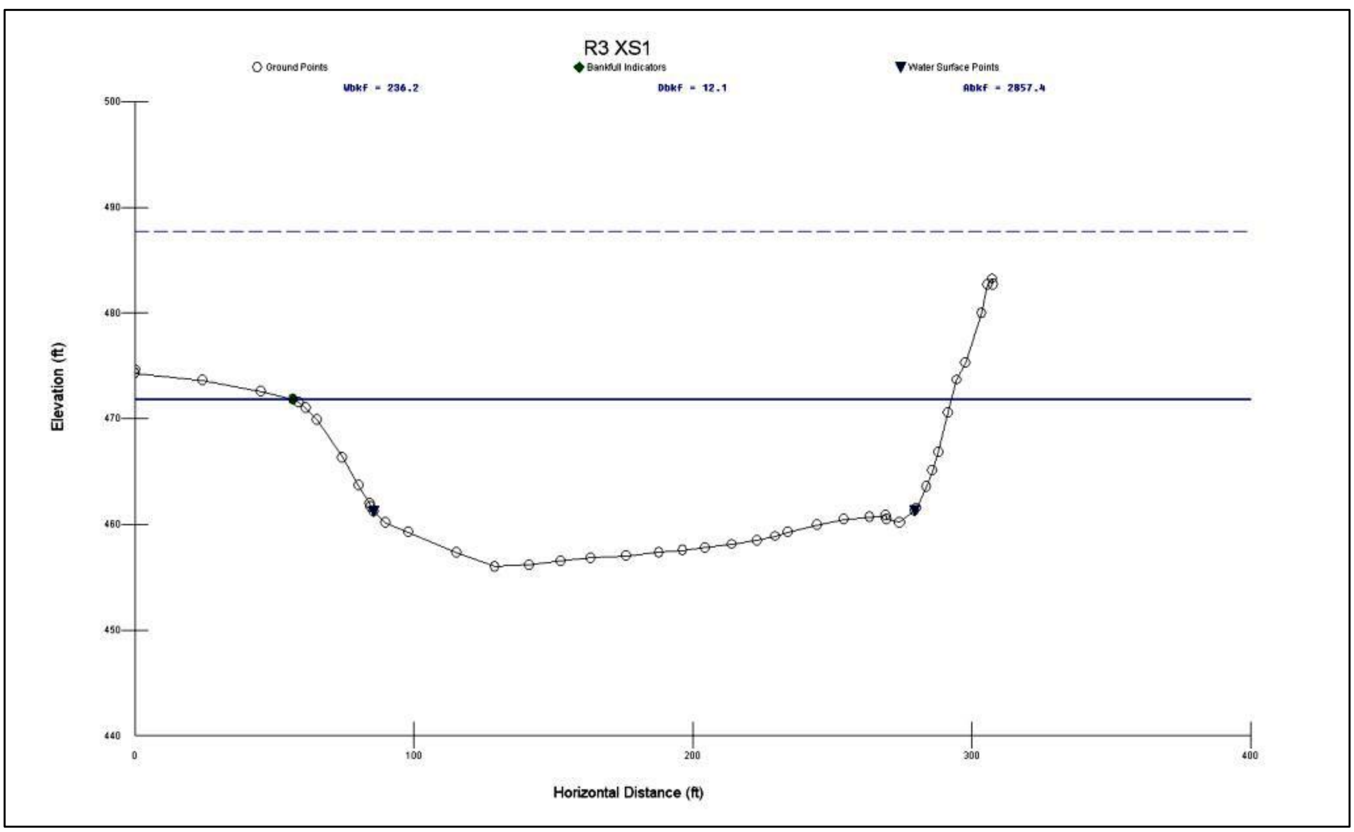
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	495.39	495.39	495.39
Bankfull Elevation (ft)	471.84	471.84	471.84
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	258.17	129.08	129.09
Entrenchment Ratio	7.75	-----	-----
Mean Depth (ft)	9.67	3.38	15.96
Maximum Depth (ft)	23.55	11.62	23.55
Width/Depth Ratio	26.7	38.19	8.09
Bankfull Area (sq ft)	2495.98	436.03	2059.95
Wetted Perimeter (ft)	268.47	141.98	149.72
Hydraulic Radius (ft)	9.3	3.07	13.76
Begin BKF Station	75.7	75.7	204.78
End BKF Station	333.87	204.78	333.87



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R3 XS1
Survey Date: 10/15/2008

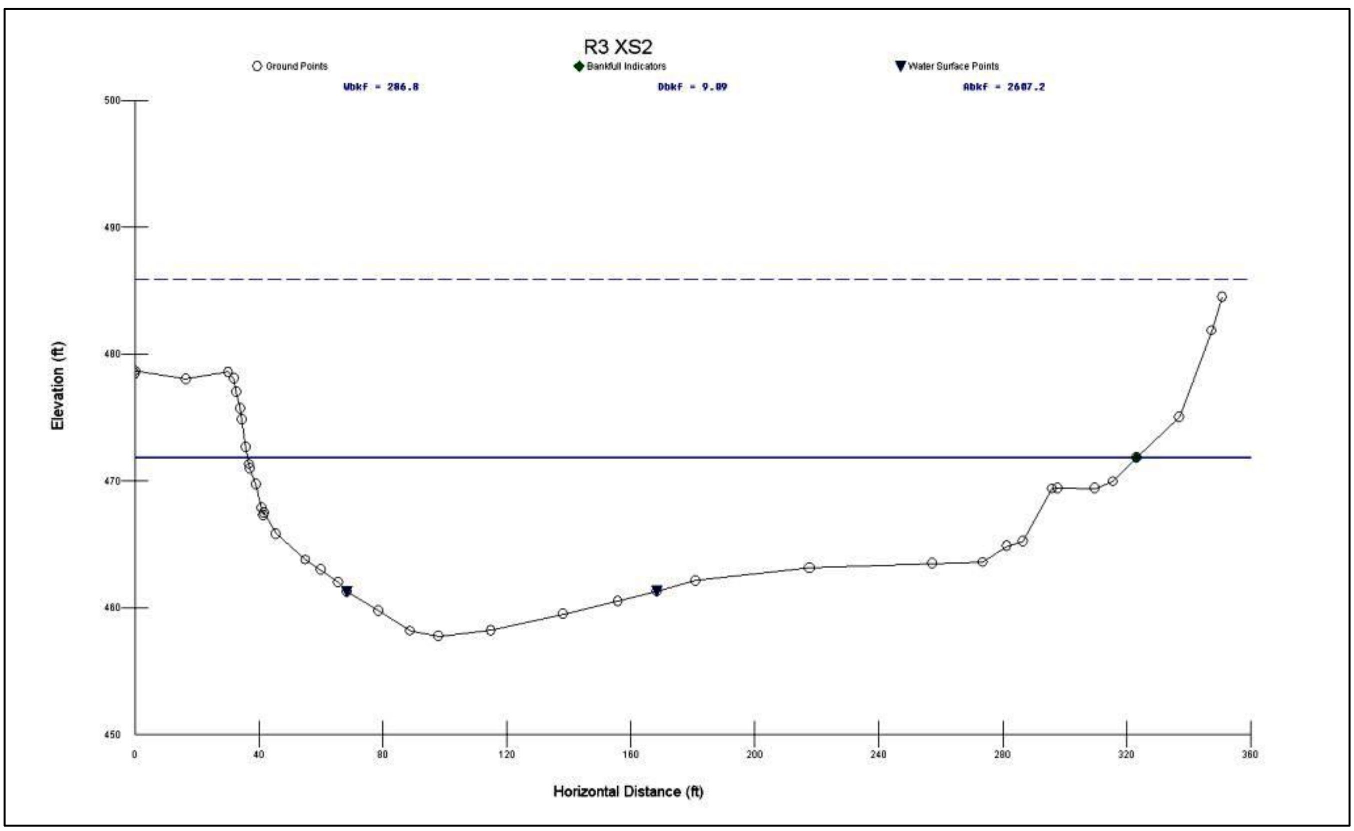
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	487.69	487.69	487.69
Bankfull Elevation (ft)	471.84	471.84	471.84
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	236.17	118.09	118.08
Entrenchment Ratio	8.47	-----	-----
Mean Depth (ft)	12.1	12.05	12.15
Maximum Depth (ft)	15.85	15.85	14.85
Width/Depth Ratio	19.52	9.8	9.72
Bankfull Area (sq ft)	2857.39	1422.62	1434.77
Wetted Perimeter (ft)	242.86	135.32	137.25
Hydraulic Radius (ft)	11.77	10.51	10.45
Begin BKF Station	56.6	56.6	174.69
End BKF Station	292.77	174.69	292.77



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R3 XS2
Survey Date: 10/15/2008

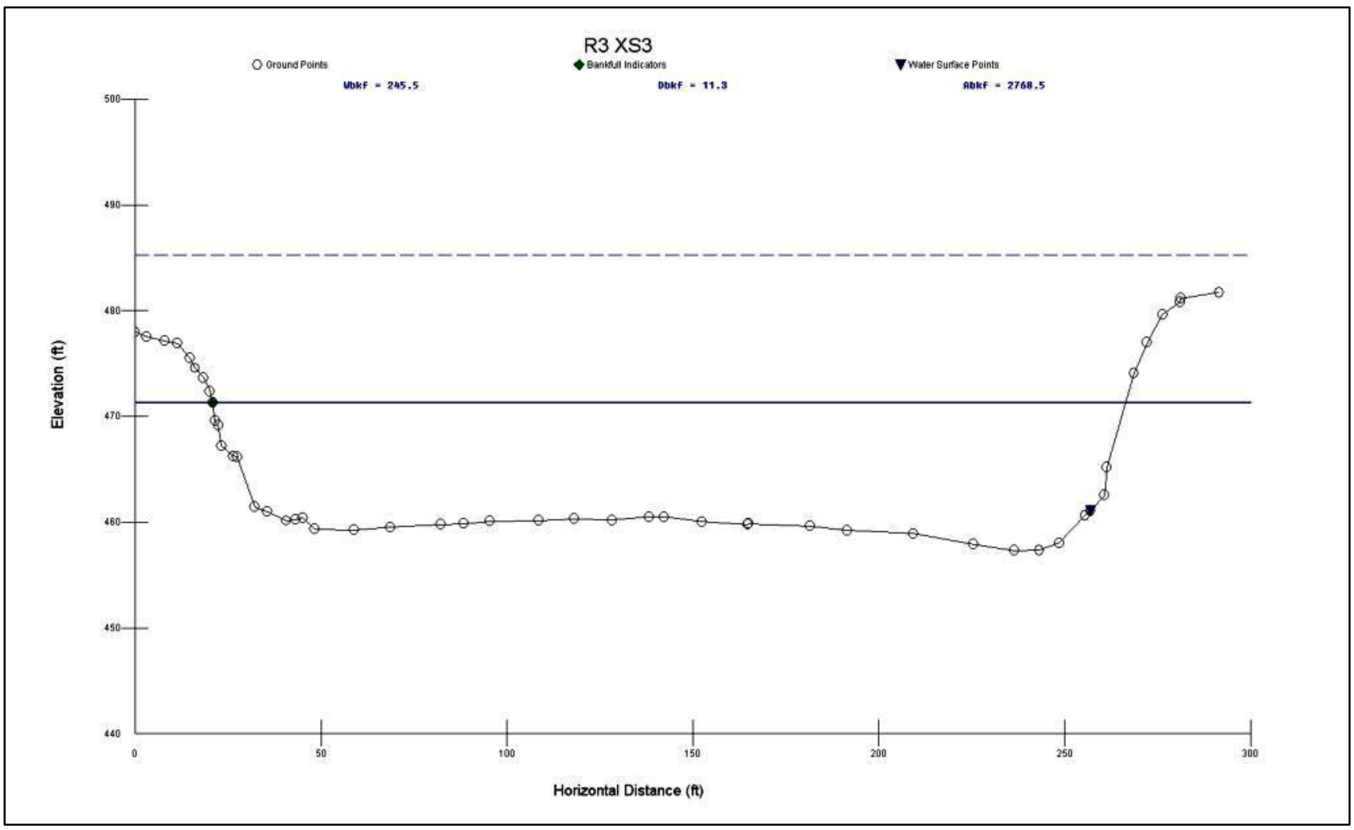
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	485.93	485.93	485.93
Bankfull Elevation (ft)	471.85	471.85	471.85
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	286.77	138.29	148.48
Entrenchment Ratio	6.97	-----	-----
Mean Depth (ft)	9.09	11.17	7.16
Maximum Depth (ft)	14.08	14.08	10.12
Width/Depth Ratio	31.55	12.38	20.74
Bankfull Area (sq ft)	2607.24	1544.02	1063.23
Wetted Perimeter (ft)	291.09	151.45	159.87
Hydraulic Radius (ft)	8.96	10.19	6.65
Begin BKF Station	36.39	36.39	174.68
End BKF Station	323.16	174.68	323.16



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R3 XS3
Survey Date: 10/14/2008

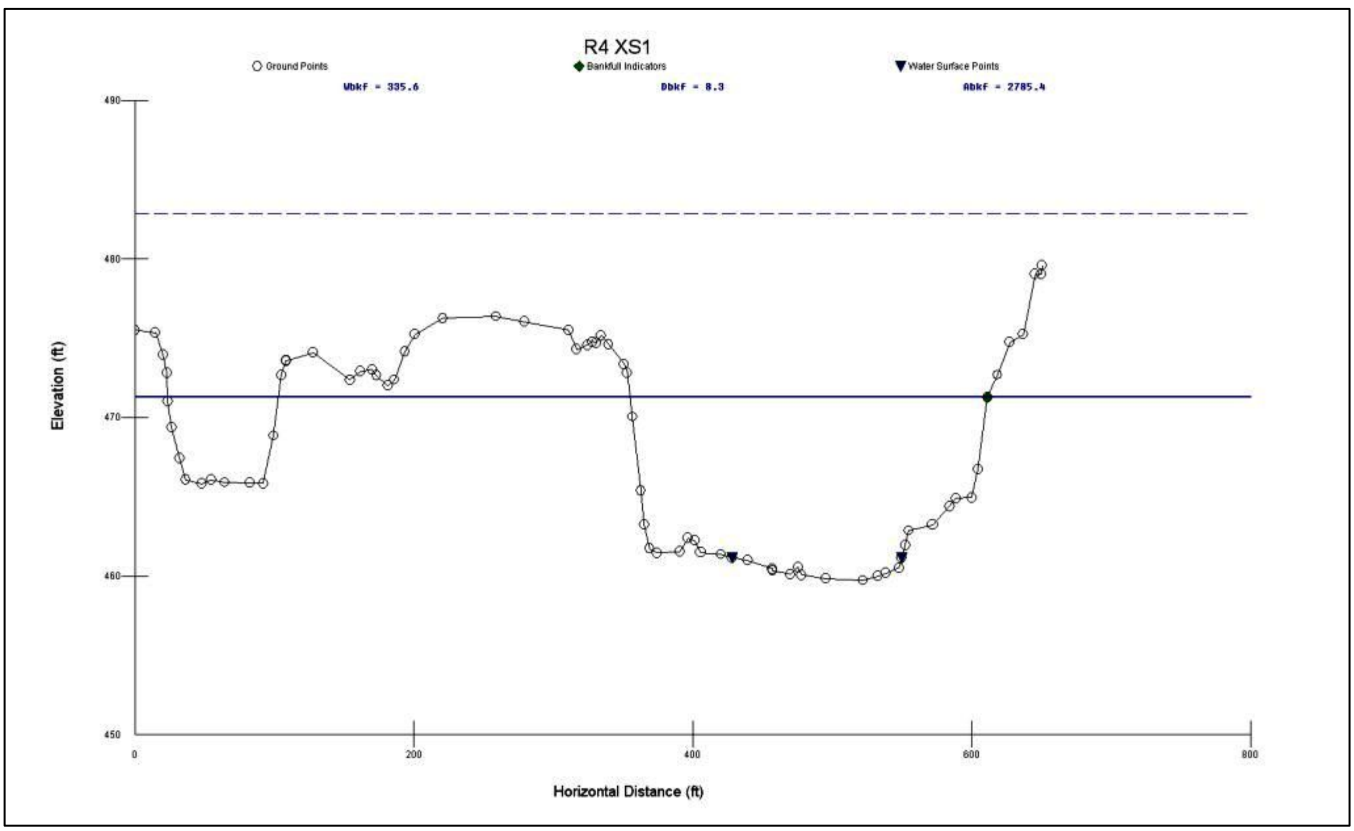
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	485.3	485.3	485.3
Bankfull Elevation (ft)	471.3	471.3	471.3
Floodprone Width (ft)	4100	-----	-----
Bankfull Width (ft)	245.52	122.6	122.92
Entrenchment Ratio	16.7	-----	-----
Mean Depth (ft)	11.28	10.75	11.8
Maximum Depth (ft)	14	12.05	14
Width/Depth Ratio	21.77	11.4	10.42
Bankfull Area (sq ft)	2768.46	1317.91	1450.55
Wetted Perimeter (ft)	256.43	138.47	139.72
Hydraulic Radius (ft)	10.8	9.52	10.38
Begin BKF Station	20.85	20.85	143.45
End BKF Station	266.37	143.45	266.37



RIVERMORPH CROSS SECTION SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R4 XS1
Survey Date: 10/14/2008

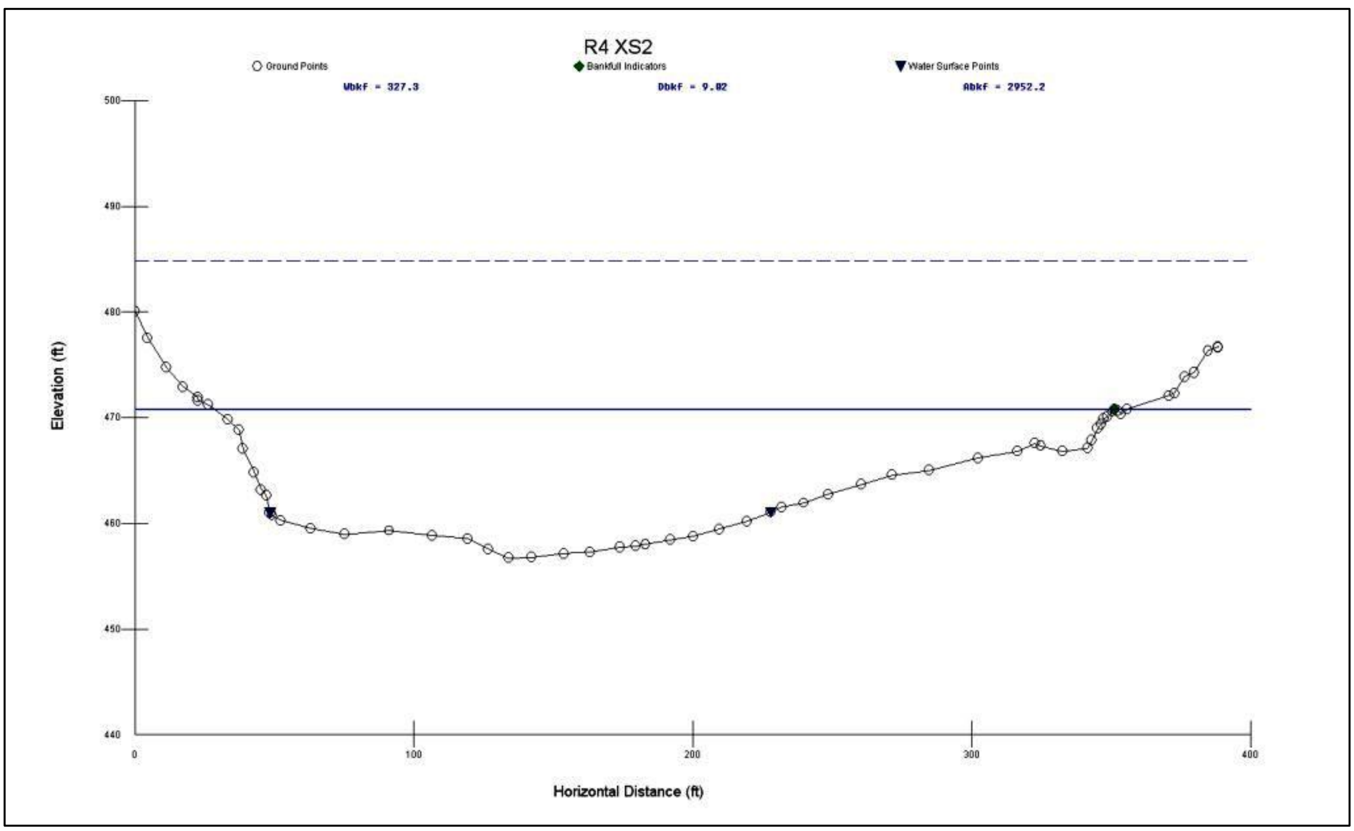
Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	482.86	482.86	482.86
Bankfull Elevation (ft)	471.3	471.3	471.3
Floodprone Width (ft)	4300	-----	-----
Bankfull Width (ft)	335.59	462.86	124.99
Entrenchment Ratio	12.81	-----	-----
Mean Depth (ft)	8.3	7.8	9.14
Maximum Depth (ft)	11.56	11.34	11.56
Width/Depth Ratio	40.43	59.34	13.68
Bankfull Area (sq ft)	2785.43	1643.41	1142.02
Wetted Perimeter (ft)	343.74	227.83	138.6
Hydraulic Radius (ft)	8.1	7.21	8.24
Begin BKF Station	23.36	23.36	486.22
End BKF Station	611.21	486.22	611.21



RIVERMORPH CROSS SECTION SUMMARY

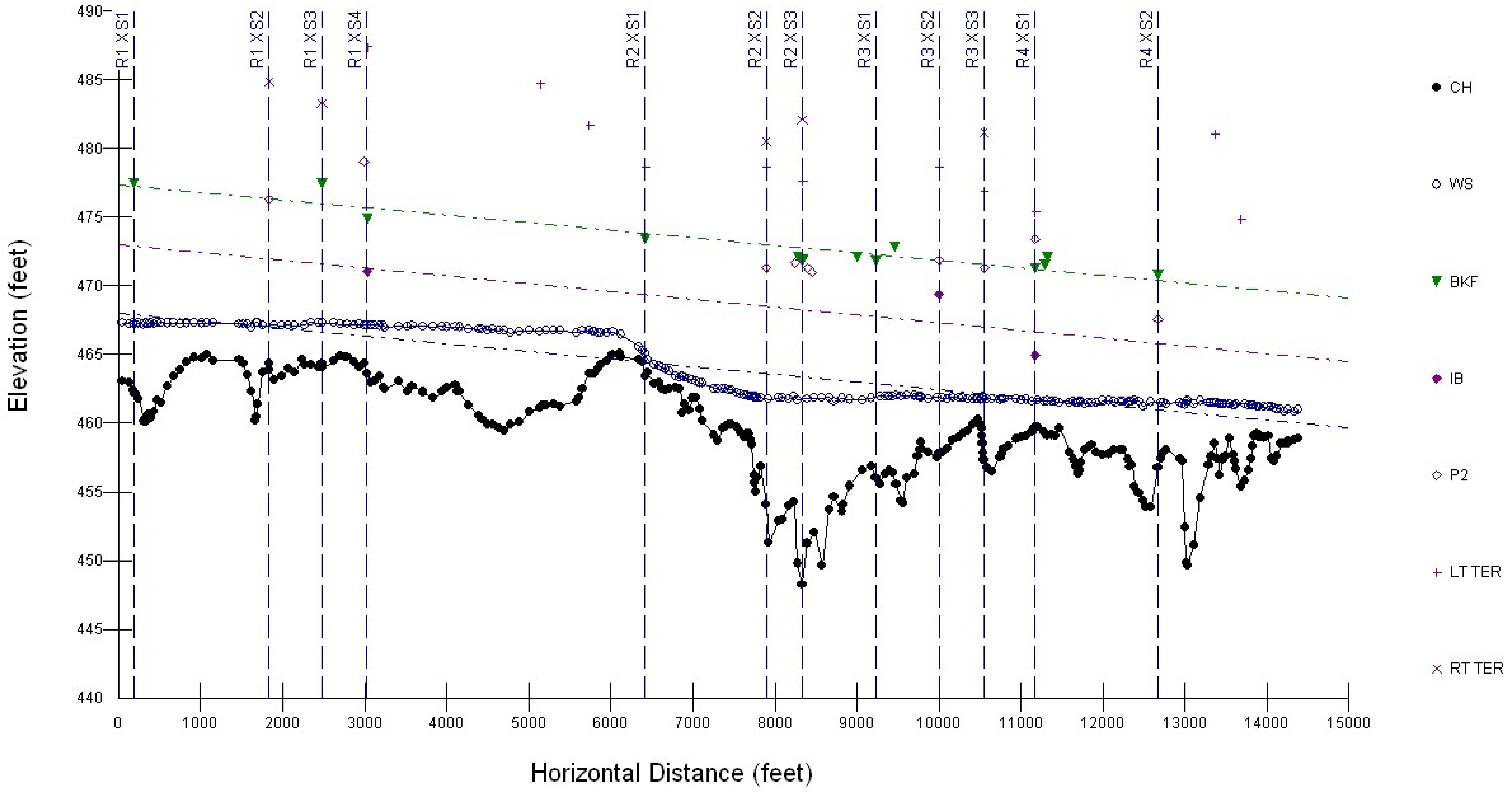
River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Cross Section: R4 XS2
Survey Date: 10/14/2008

Cross Sectional Geometry	Channel	Left	Right
Floodprone Elevation (ft)	484.84	484.84	484.84
Bankfull Elevation (ft)	470.78	470.78	470.78
Floodprone Width (ft)	2000	-----	-----
Bankfull Width (ft)	327.28	163.64	163.64
Entrenchment Ratio	6.11	-----	-----
Mean Depth (ft)	9.02	11.38	6.66
Maximum Depth (ft)	14.06	14.06	12.34
Width/Depth Ratio	36.28	14.38	24.57
Bankfull Area (sq ft)	2952.22	1862.8	1089.42
Wetted Perimeter (ft)	331.86	179.28	177.26
Hydraulic Radius (ft)	8.9	10.39	6.15
Begin BKF Station	28.42	28.42	192.06
End BKF Station	355.7	192.06	355.7



Longitudinal Profile Graph

Little Miami River Segment II/III - Longitudinal Profile



Appendix C

Sediment Data

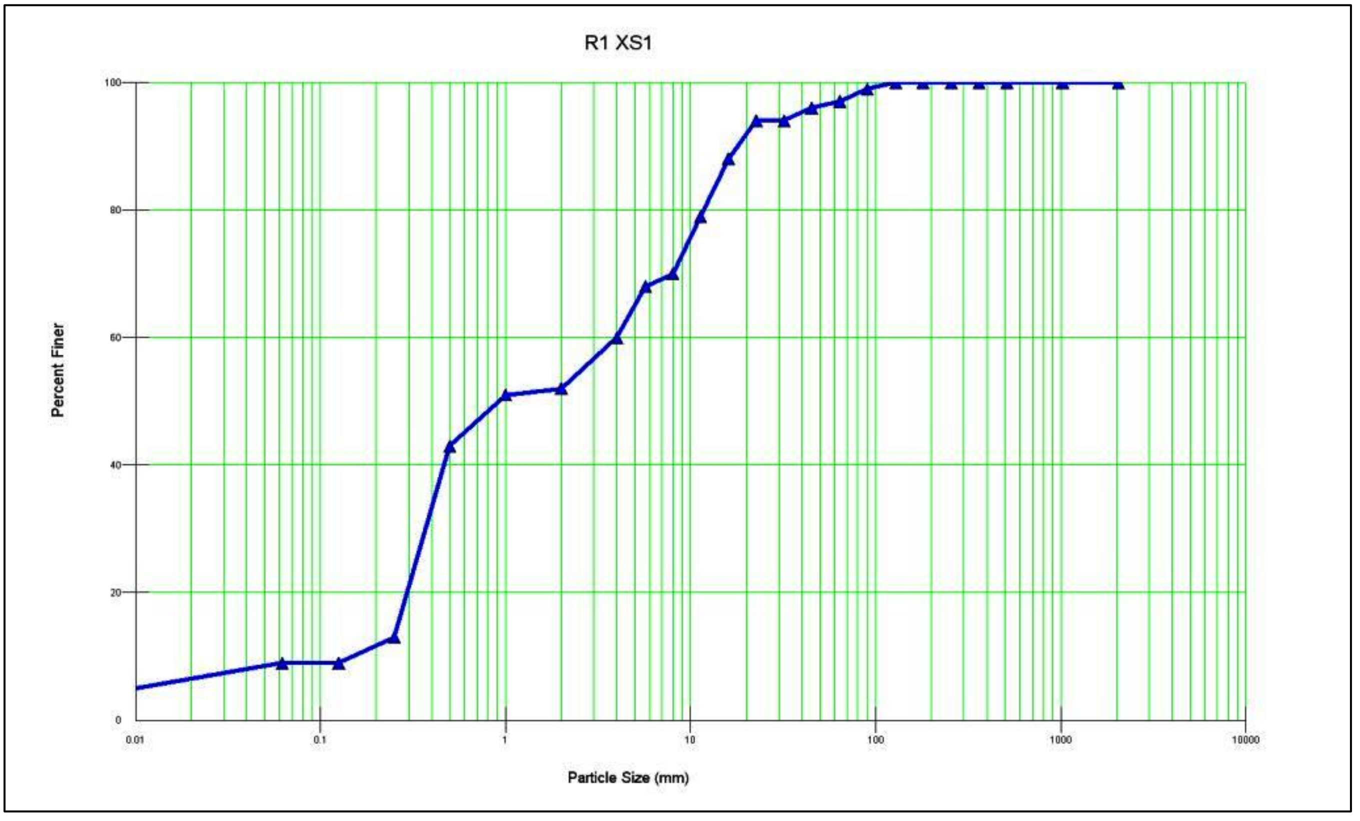
Pebble Count

RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R1 XS1
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	9	9.00	9.00
0.062 - 0.125	0	0.00	9.00
0.125 - 0.25	4	4.00	13.00
0.25 - 0.50	30	30.00	43.00
0.50 - 1.0	8	8.00	51.00
1.0 - 2.0	1	1.00	52.00
2.0 - 4.0	8	8.00	60.00
4.0 - 5.7	8	8.00	68.00
5.7 - 8.0	2	2.00	70.00
8.0 - 11.3	9	9.00	79.00
11.3 - 16.0	9	9.00	88.00
16.0 - 22.6	6	6.00	94.00
22.6 - 32.0	0	0.00	94.00
32 - 45	2	2.00	96.00
45 - 64	1	1.00	97.00
64 - 90	2	2.00	99.00
90 - 128	1	1.00	100.00
	100		

D16 (mm)	0.28
D35 (mm)	0.43
D50 (mm)	0.94
D84 (mm)	13.91
D95 (mm)	38.5
D100 (mm)	128
Silt/Clay (%)	9
Sand (%)	43
Gravel (%)	45
Cobble (%)	3
Boulder (%)	0
Bedrock (%)	0

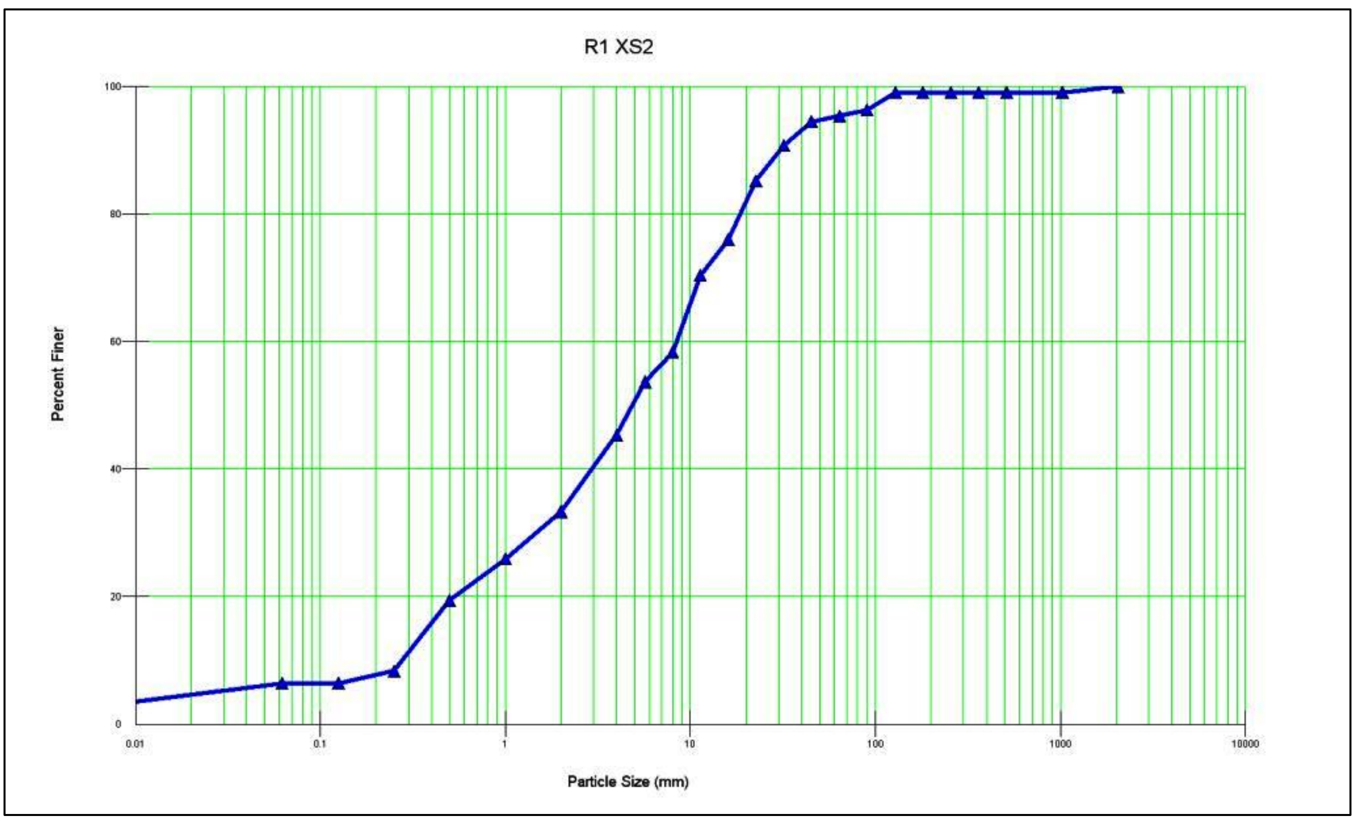


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R1 XS2
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	7	6.48	6.48
0.062 - 0.125	0	0.00	6.48
0.125 - 0.25	2	1.85	8.33
0.25 - 0.50	12	11.11	19.44
0.50 - 1.0	7	6.48	25.93
1.0 - 2.0	8	7.41	33.33
2.0 - 4.0	13	12.04	45.37
4.0 - 5.7	9	8.33	53.70
5.7 - 8.0	5	4.63	58.33
8.0 - 11.3	13	12.04	70.37
11.3 - 16.0	6	5.56	75.93
16.0 - 22.6	10	9.26	85.19
22.6 - 32.0	6	5.56	90.74
32 - 45	4	3.70	94.44
45 - 64	1	0.93	95.37
64 - 90	1	0.93	96.30
90 - 128	3	2.78	99.07
1024 - 2048	1	0.93	100.00
	100		

D16 (mm)	0.42
D35 (mm)	2.28
D50 (mm)	4.94
D84 (mm)	21.75
D95 (mm)	56.44
D100 (mm)	2047.89
Silt/Clay (%)	6.48
Sand (%)	26.85
Gravel (%)	62.04
Cobble (%)	3.7
Boulder (%)	0.93
Bedrock (%)	0

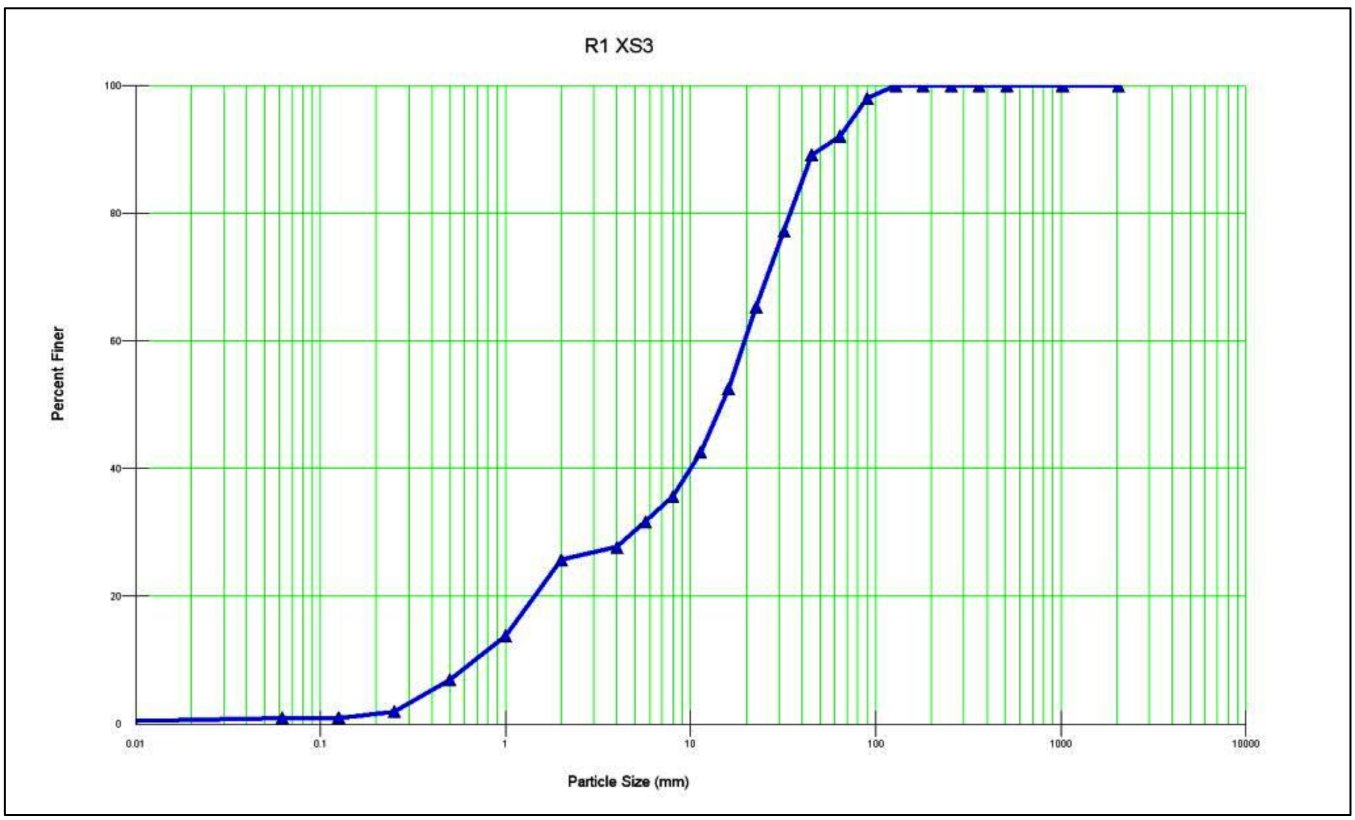


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R1 XS3
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	1	0.99	0.99
0.062 - 0.125	0	0.00	0.99
0.125 - 0.25	1	0.99	1.98
0.25 - 0.50	5	4.95	6.93
0.50 - 1.0	7	6.93	13.86
1.0 - 2.0	12	11.88	25.74
2.0 - 4.0	2	1.98	27.72
4.0 - 5.7	4	3.96	31.68
5.7 - 8.0	4	3.96	35.64
8.0 - 11.3	7	6.93	42.57
11.3 - 16.0	10	9.90	52.48
16.0 - 22.6	13	12.87	65.35
22.6 - 32.0	12	11.88	77.23
32 - 45	12	11.88	89.11
45 - 64	3	2.97	92.08
64 - 90	6	5.94	98.02
90 - 128	2	1.98	100.00
	100		

D16 (mm)	1.18
D35 (mm)	7.63
D50 (mm)	14.82
D84 (mm)	39.41
D95 (mm)	76.78
D100 (mm)	128
Silt/Clay (%)	0.99
Sand (%)	24.75
Gravel (%)	66.34
Cobble (%)	7.92
Boulder (%)	0
Bedrock (%)	0

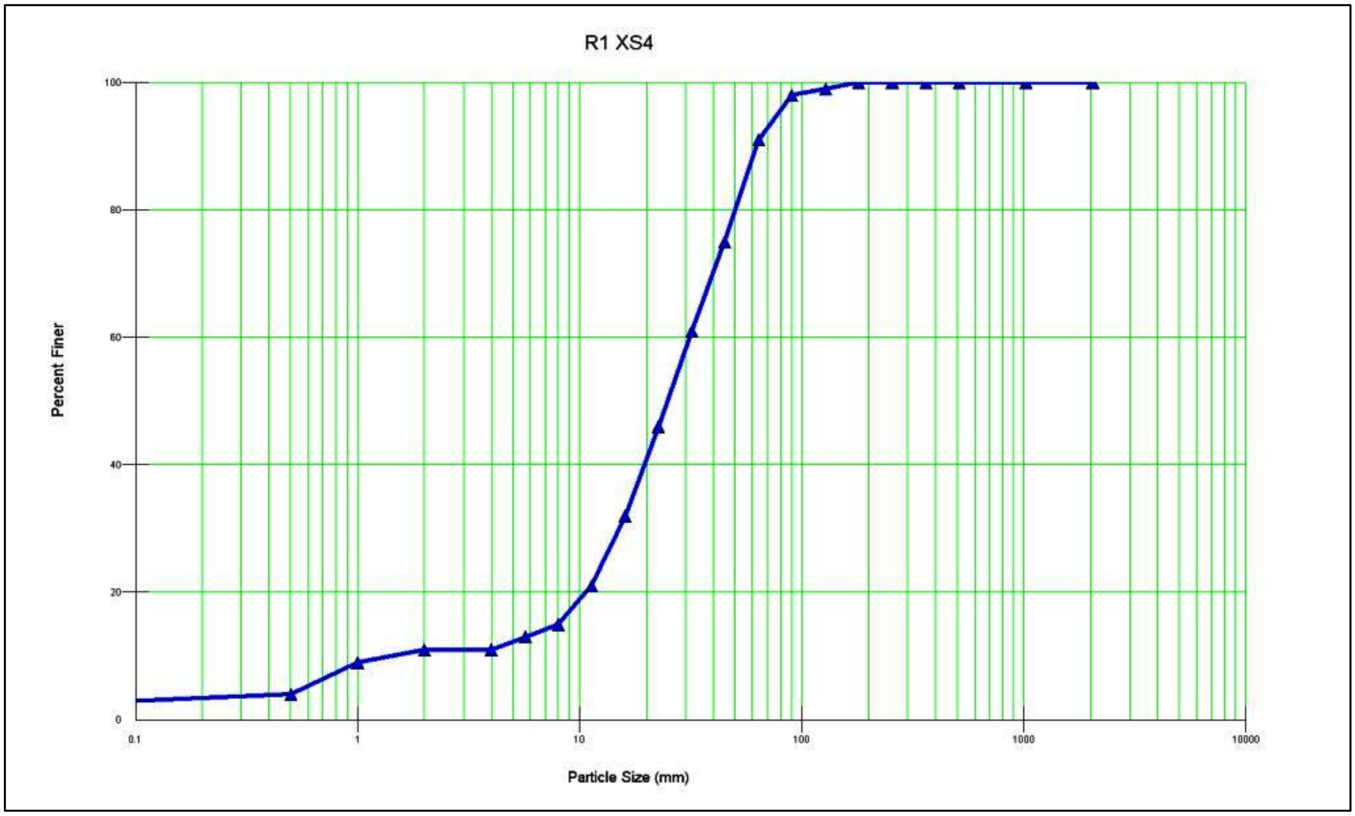


RIVERMORPH PARTICLE SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: R1 XS4
Survey Date: 11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	4	4.00	4.00
0.50 - 1.0	5	5.00	9.00
1.0 - 2.0	2	2.00	11.00
2.0 - 4.0	0	0.00	11.00
4.0 - 5.7	2	2.00	13.00
5.7 - 8.0	2	2.00	15.00
8.0 - 11.3	6	6.00	21.00
11.3 - 16.0	11	11.00	32.00
16.0 - 22.6	14	14.00	46.00
22.6 - 32.0	15	15.00	61.00
32 - 45	14	14.00	75.00
45 - 64	16	16.00	91.00
64 - 90	7	7.00	98.00
90 - 128	1	1.00	99.00
128 - 180	1	1.00	100.00
	100		

D16 (mm)	8.55
D35 (mm)	17.41
D50 (mm)	25.11
D84 (mm)	55.69
D95 (mm)	78.86
D100 (mm)	179.99
Silt/Clay (%)	0
Sand (%)	11
Gravel (%)	80
Cobble (%)	9
Boulder (%)	0
Bedrock (%)	0

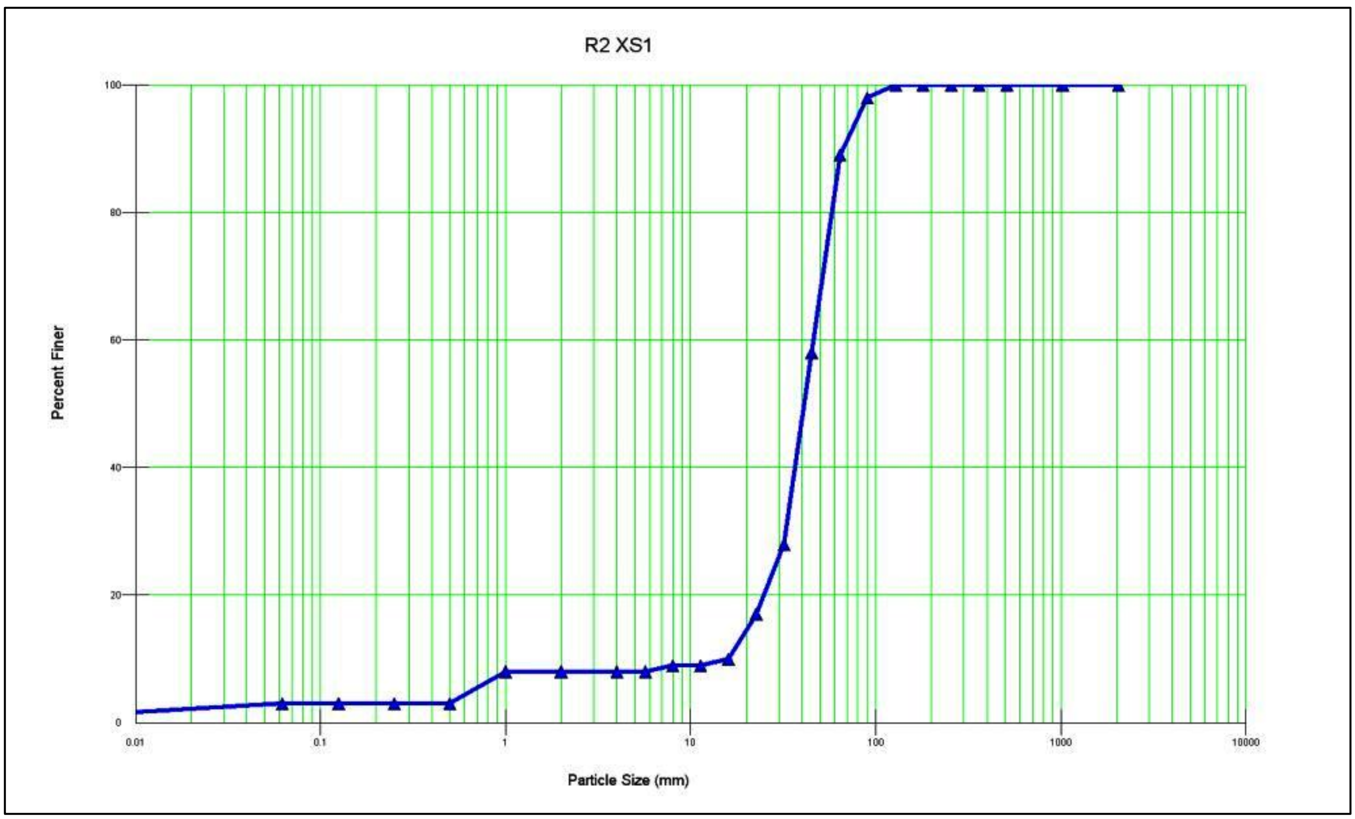


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R2 XS1
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	3	3.00	3.00
0.062 - 0.125	0	0.00	3.00
0.125 - 0.25	0	0.00	3.00
0.25 - 0.50	0	0.00	3.00
0.50 - 1.0	5	5.00	8.00
1.0 - 2.0	0	0.00	8.00
2.0 - 4.0	0	0.00	8.00
4.0 - 5.7	0	0.00	8.00
5.7 - 8.0	1	1.00	9.00
8.0 - 11.3	0	0.00	9.00
11.3 - 16.0	1	1.00	10.00
16.0 - 22.6	7	7.00	17.00
22.6 - 32.0	11	11.00	28.00
32 - 45	30	30.00	58.00
45 - 64	31	31.00	89.00
64 - 90	9	9.00	98.00
90 - 128	2	2.00	100.00
	100		

D16 (mm)	21.66
D35 (mm)	35.03
D50 (mm)	41.53
D84 (mm)	60.94
D95 (mm)	81.33
D100 (mm)	128
Silt/Clay (%)	3
Sand (%)	5
Gravel (%)	81
Cobble (%)	11
Boulder (%)	0
Bedrock (%)	0

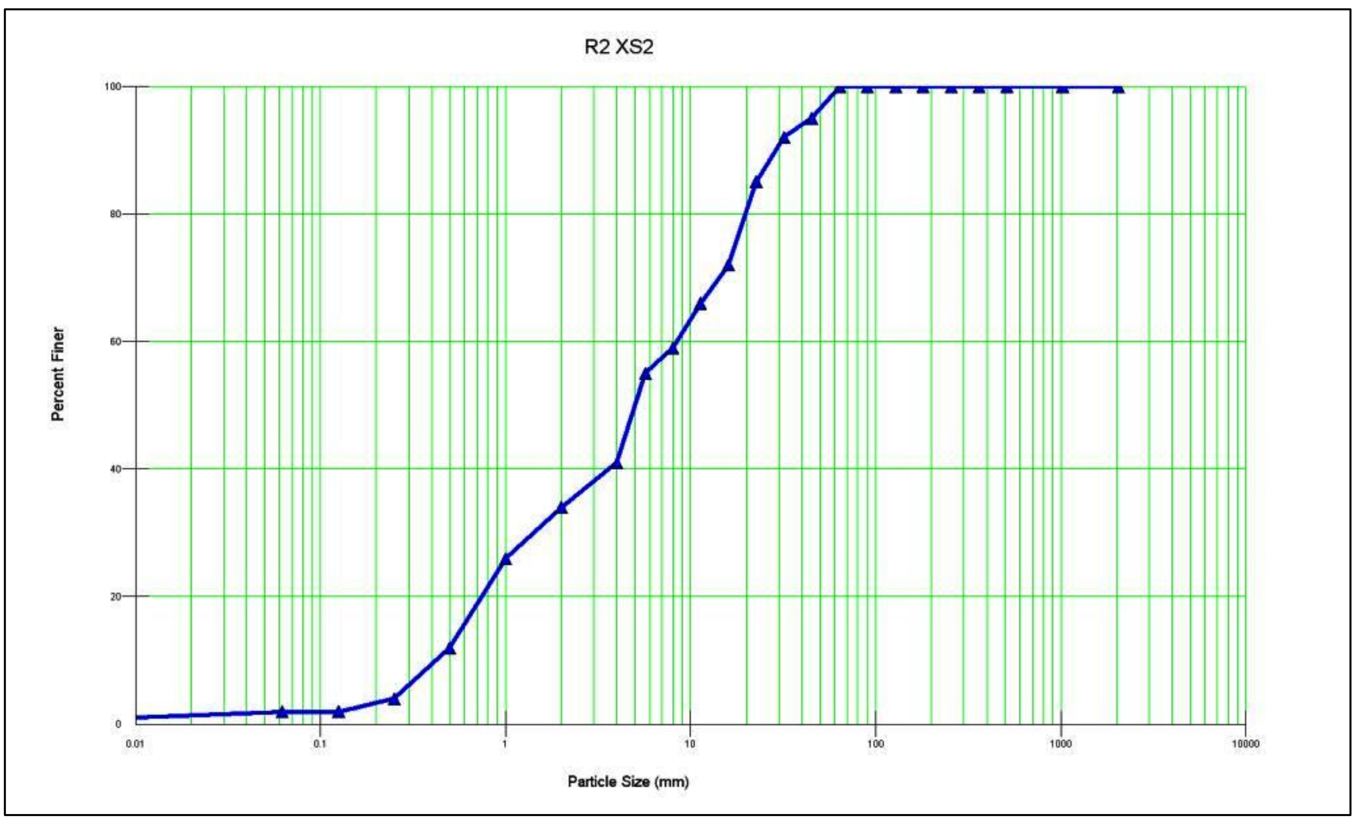


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R2 XS2
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	2	2.00	2.00
0.062 - 0.125	0	0.00	2.00
0.125 - 0.25	2	2.00	4.00
0.25 - 0.50	8	8.00	12.00
0.50 - 1.0	14	14.00	26.00
1.0 - 2.0	8	8.00	34.00
2.0 - 4.0	7	7.00	41.00
4.0 - 5.7	14	14.00	55.00
5.7 - 8.0	4	4.00	59.00
8.0 - 11.3	7	7.00	66.00
11.3 - 16.0	6	6.00	72.00
16.0 - 22.6	13	13.00	85.00
22.6 - 32.0	7	7.00	92.00
32 - 45	3	3.00	95.00
45 - 64	5	5.00	100.00
	100		

D16 (mm)	0.64
D35 (mm)	2.29
D50 (mm)	5.09
D84 (mm)	22.09
D95 (mm)	45
D100 (mm)	64
Silt/Clay (%)	2
Sand (%)	32
Gravel (%)	66
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

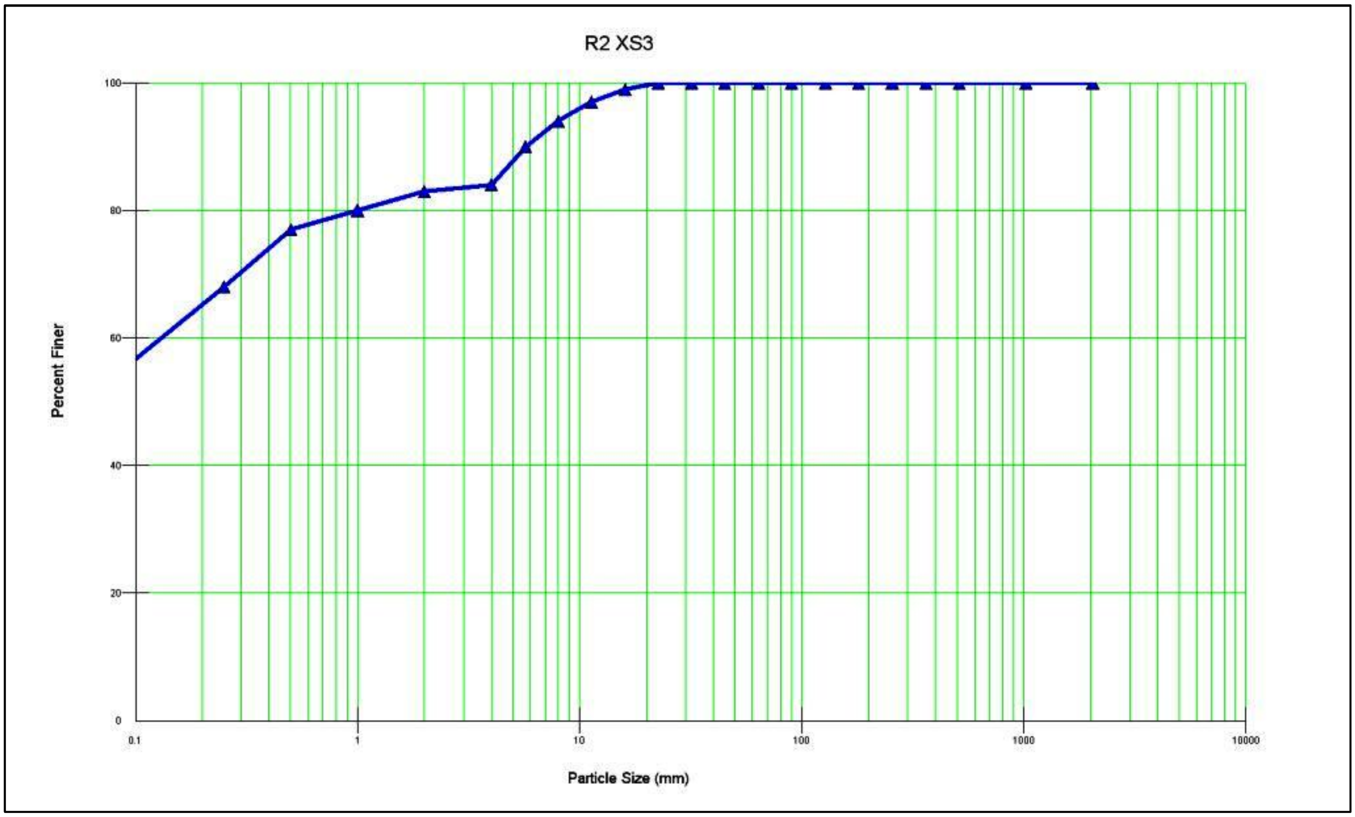


RIVERMORPH PARTICLE SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: R2 XS3
Survey Date: 11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	68	68.00	68.00
0.25 - 0.50	9	9.00	77.00
0.50 - 1.0	3	3.00	80.00
1.0 - 2.0	3	3.00	83.00
2.0 - 4.0	1	1.00	84.00
4.0 - 5.7	6	6.00	90.00
5.7 - 8.0	4	4.00	94.00
8.0 - 11.3	3	3.00	97.00
11.3 - 16.0	2	2.00	99.00
16.0 - 22.6	1	1.00	100.00
	100		

D16 (mm)	0.15
D35 (mm)	0.19
D50 (mm)	0.22
D84 (mm)	4
D95 (mm)	9.1
D100 (mm)	22.6
Silt/Clay (%)	0
Sand (%)	83
Gravel (%)	7
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

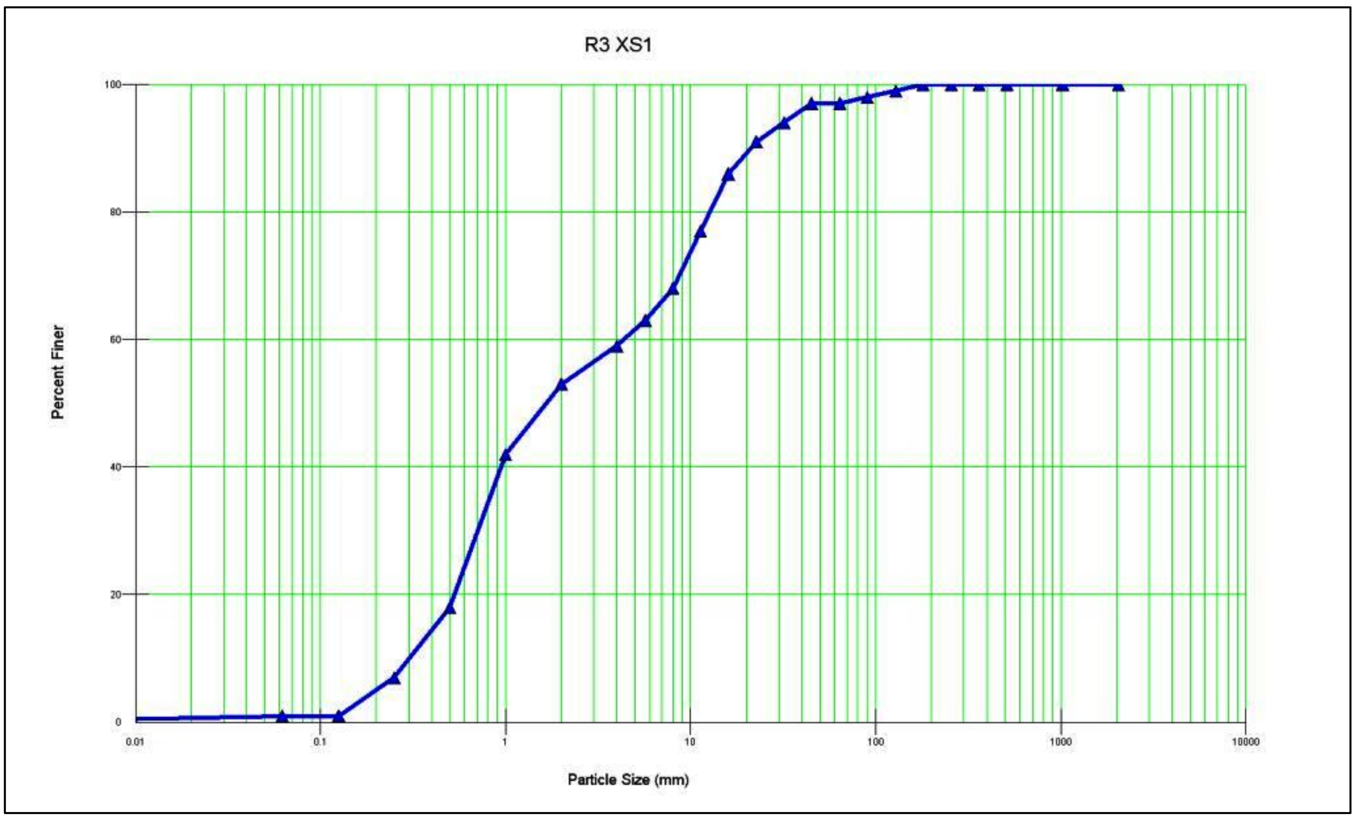


RIVERMORPH PARTICLE SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: R3 XS1
Survey Date: 11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	1	1.00	1.00
0.062 - 0.125	0	0.00	1.00
0.125 - 0.25	6	6.00	7.00
0.25 - 0.50	11	11.00	18.00
0.50 - 1.0	24	24.00	42.00
1.0 - 2.0	11	11.00	53.00
2.0 - 4.0	6	6.00	59.00
4.0 - 5.7	4	4.00	63.00
5.7 - 8.0	5	5.00	68.00
8.0 - 11.3	9	9.00	77.00
11.3 - 16.0	9	9.00	86.00
16.0 - 22.6	5	5.00	91.00
22.6 - 32.0	3	3.00	94.00
32 - 45	3	3.00	97.00
45 - 64	0	0.00	97.00
64 - 90	1	1.00	98.00
90 - 128	1	1.00	99.00
128 - 180	1	1.00	100.00
	100		

D16 (mm)	0.45
D35 (mm)	0.85
D50 (mm)	1.73
D84 (mm)	14.96
D95 (mm)	36.33
D100 (mm)	179.99
Silt/Clay (%)	1
Sand (%)	52
Gravel (%)	44
Cobble (%)	3
Boulder (%)	0
Bedrock (%)	0

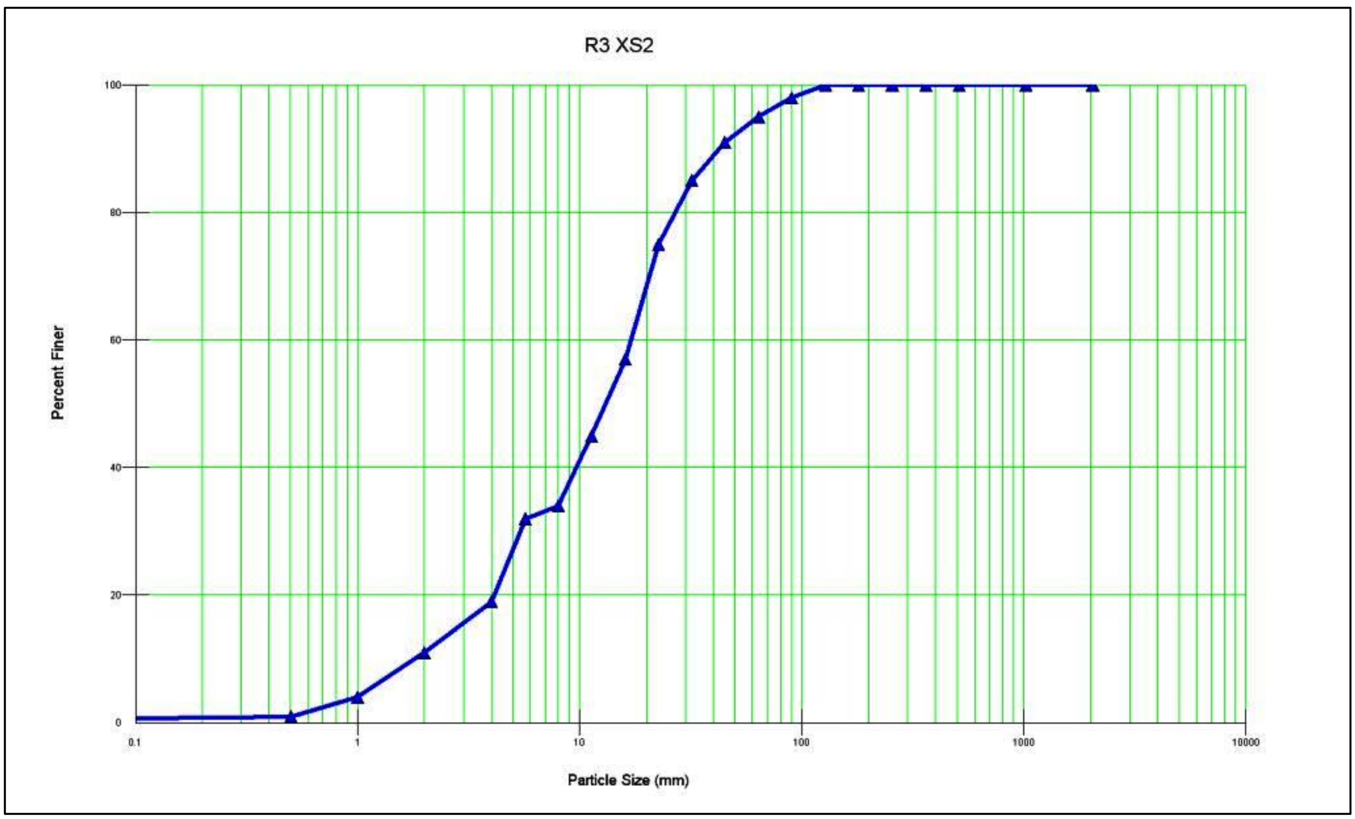


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R3 XS2
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	1	1.00	1.00
0.50 - 1.0	3	3.00	4.00
1.0 - 2.0	7	7.00	11.00
2.0 - 4.0	8	8.00	19.00
4.0 - 5.7	13	13.00	32.00
5.7 - 8.0	2	2.00	34.00
8.0 - 11.3	11	11.00	45.00
11.3 - 16.0	12	12.00	57.00
16.0 - 22.6	18	18.00	75.00
22.6 - 32.0	10	10.00	85.00
32 - 45	6	6.00	91.00
45 - 64	4	4.00	95.00
64 - 90	3	3.00	98.00
90 - 128	2	2.00	100.00
	100		

D16 (mm)	3.25
D35 (mm)	8.3
D50 (mm)	13.26
D84 (mm)	31.06
D95 (mm)	64
D100 (mm)	128
Silt/Clay (%)	0
Sand (%)	11
Gravel (%)	84
Cobble (%)	5
Boulder (%)	0
Bedrock (%)	0

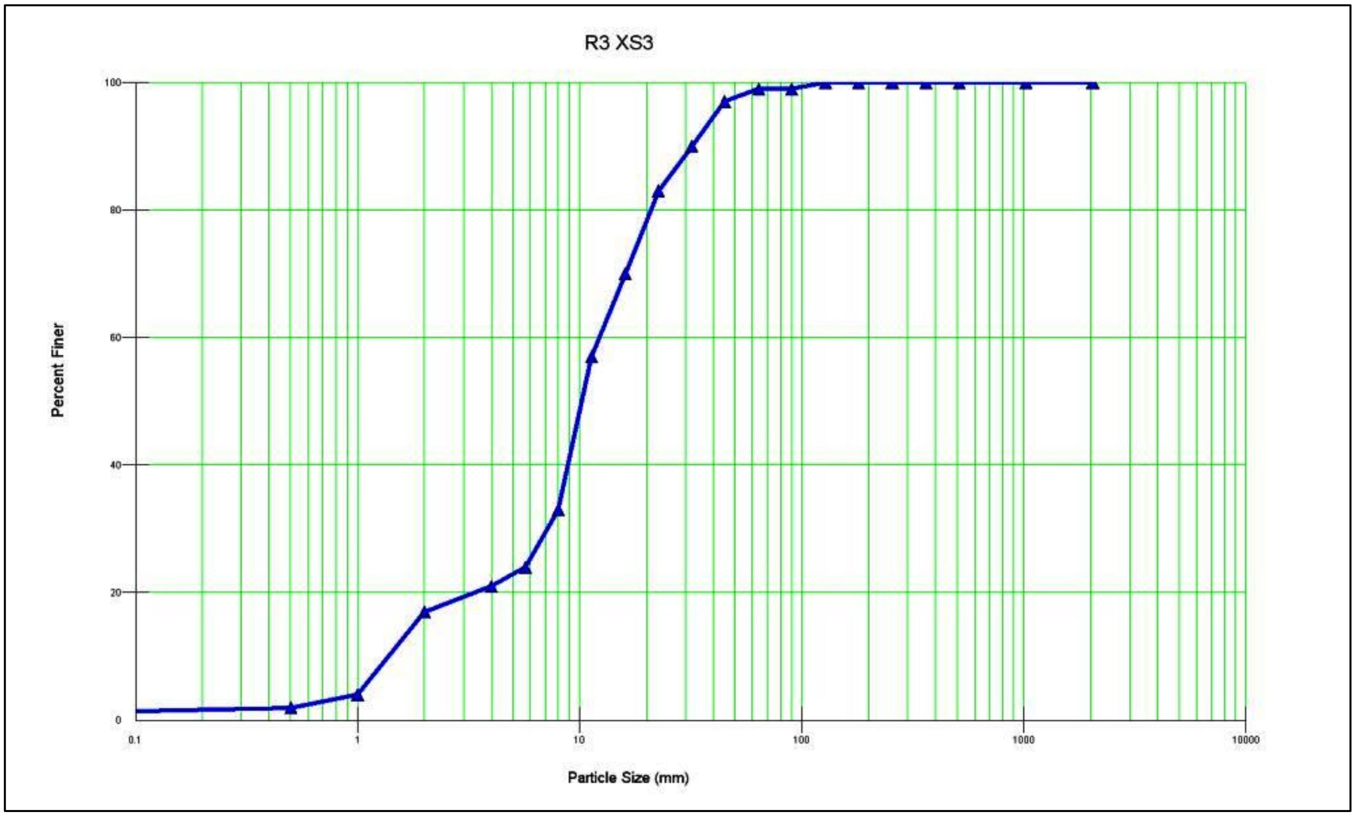


RIVERMORPH PARTICLE SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: R3 XS3
Survey Date: 11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	2	2.00	2.00
0.50 - 1.0	2	2.00	4.00
1.0 - 2.0	13	13.00	17.00
2.0 - 4.0	4	4.00	21.00
4.0 - 5.7	3	3.00	24.00
5.7 - 8.0	9	9.00	33.00
8.0 - 11.3	24	24.00	57.00
11.3 - 16.0	13	13.00	70.00
16.0 - 22.6	13	13.00	83.00
22.6 - 32.0	7	7.00	90.00
32 - 45	7	7.00	97.00
45 - 64	2	2.00	99.00
64 - 90	0	0.00	99.00
90 - 128	1	1.00	100.00
	100		

D16 (mm)	1.92
D35 (mm)	8.28
D50 (mm)	10.34
D84 (mm)	23.94
D95 (mm)	41.29
D100 (mm)	128
Silt/Clay (%)	0
Sand (%)	17
Gravel (%)	82
Cobble (%)	1
Boulder (%)	0
Bedrock (%)	0

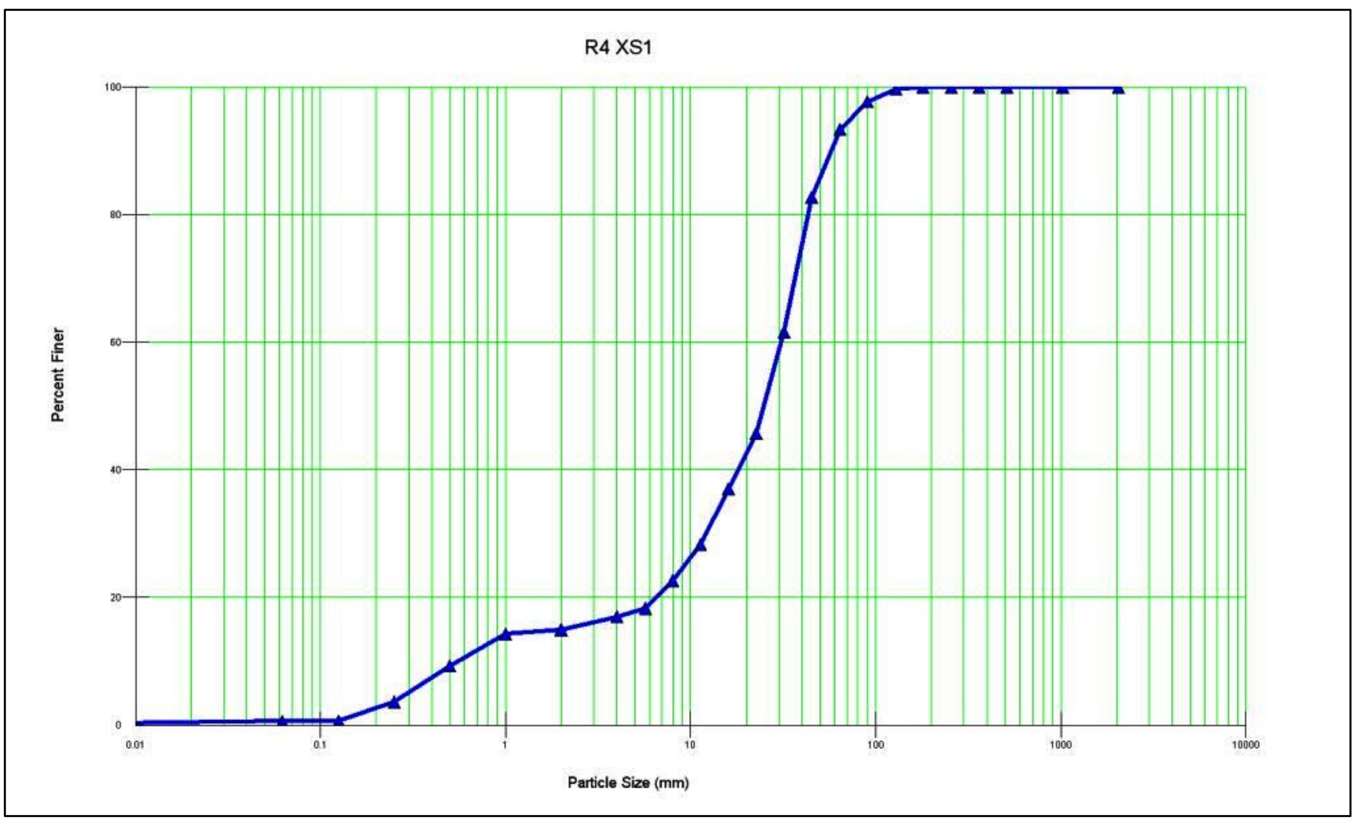


RIVERMORPH PARTICLE SUMMARY

River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: R4 XS1
Survey Date: 11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	2	0.67	0.67
0.062 - 0.125	0	0.00	0.67
0.125 - 0.25	9	3.00	3.67
0.25 - 0.50	17	5.67	9.33
0.50 - 1.0	15	5.00	14.33
1.0 - 2.0	2	0.67	15.00
2.0 - 4.0	6	2.00	17.00
4.0 - 5.7	4	1.33	18.33
5.7 - 8.0	13	4.33	22.67
8.0 - 11.3	17	5.67	28.33
11.3 - 16.0	26	8.67	37.00
16.0 - 22.6	26	8.67	45.67
22.6 - 32.0	48	16.00	61.67
32 - 45	63	21.00	82.67
45 - 64	32	10.67	93.33
64 - 90	13	4.33	97.67
90 - 128	6	2.00	99.67
128 - 180	1	0.33	100.00
	100		

D16 (mm)	3
D35 (mm)	14.92
D50 (mm)	25.14
D84 (mm)	47.37
D95 (mm)	74
D100 (mm)	179.98
Silt/Clay (%)	0.67
Sand (%)	14.33
Gravel (%)	78.33
Cobble (%)	6.67
Boulder (%)	0
Bedrock (%)	0

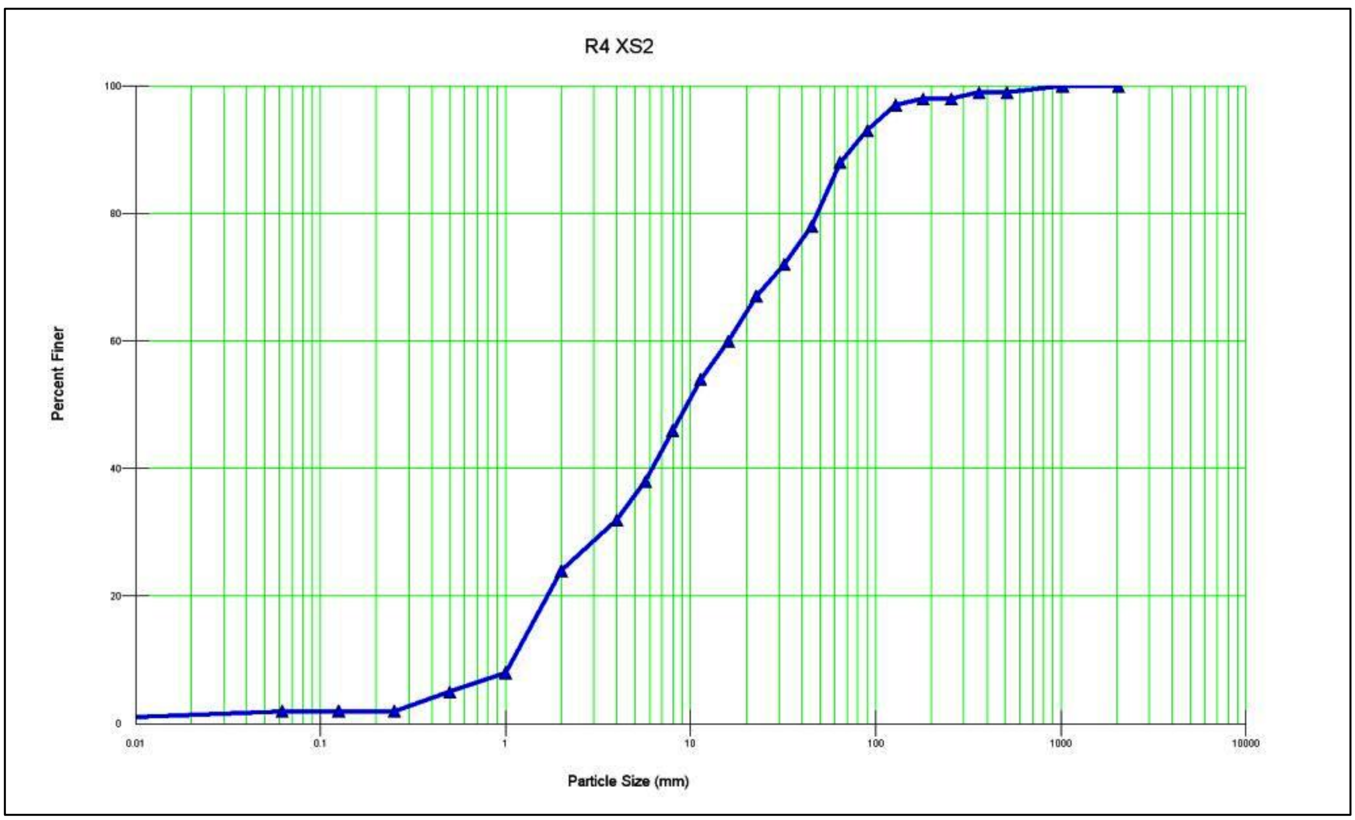


RIVERMORPH PARTICLE SUMMARY

River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	R4 XS2
Survey Date:	11/20/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	2	2.00	2.00
0.062 - 0.125	0	0.00	2.00
0.125 - 0.25	0	0.00	2.00
0.25 - 0.50	3	3.00	5.00
0.50 - 1.0	3	3.00	8.00
1.0 - 2.0	16	16.00	24.00
2.0 - 4.0	8	8.00	32.00
4.0 - 5.7	6	6.00	38.00
5.7 - 8.0	8	8.00	46.00
8.0 - 11.3	8	8.00	54.00
11.3 - 16.0	6	6.00	60.00
16.0 - 22.6	7	7.00	67.00
22.6 - 32.0	5	5.00	72.00
32 - 45	6	6.00	78.00
45 - 64	10	10.00	88.00
64 - 90	5	5.00	93.00
90 - 128	4	4.00	97.00
128 - 180	1	1.00	98.00
256 - 362	1	1.00	99.00
512 - 1024	1	1.00	100.00
	300		

D16 (mm)	1.5
D35 (mm)	4.85
D50 (mm)	9.65
D84 (mm)	56.4
D95 (mm)	109
D100 (mm)	1023.95
Silt/Clay (%)	2
Sand (%)	22
Gravel (%)	64
Cobble (%)	10
Boulder (%)	2
Bedrock (%)	0



Bulk Sample – Point Bar Samples

RIVERMORPH PARTICLE SUMMARY

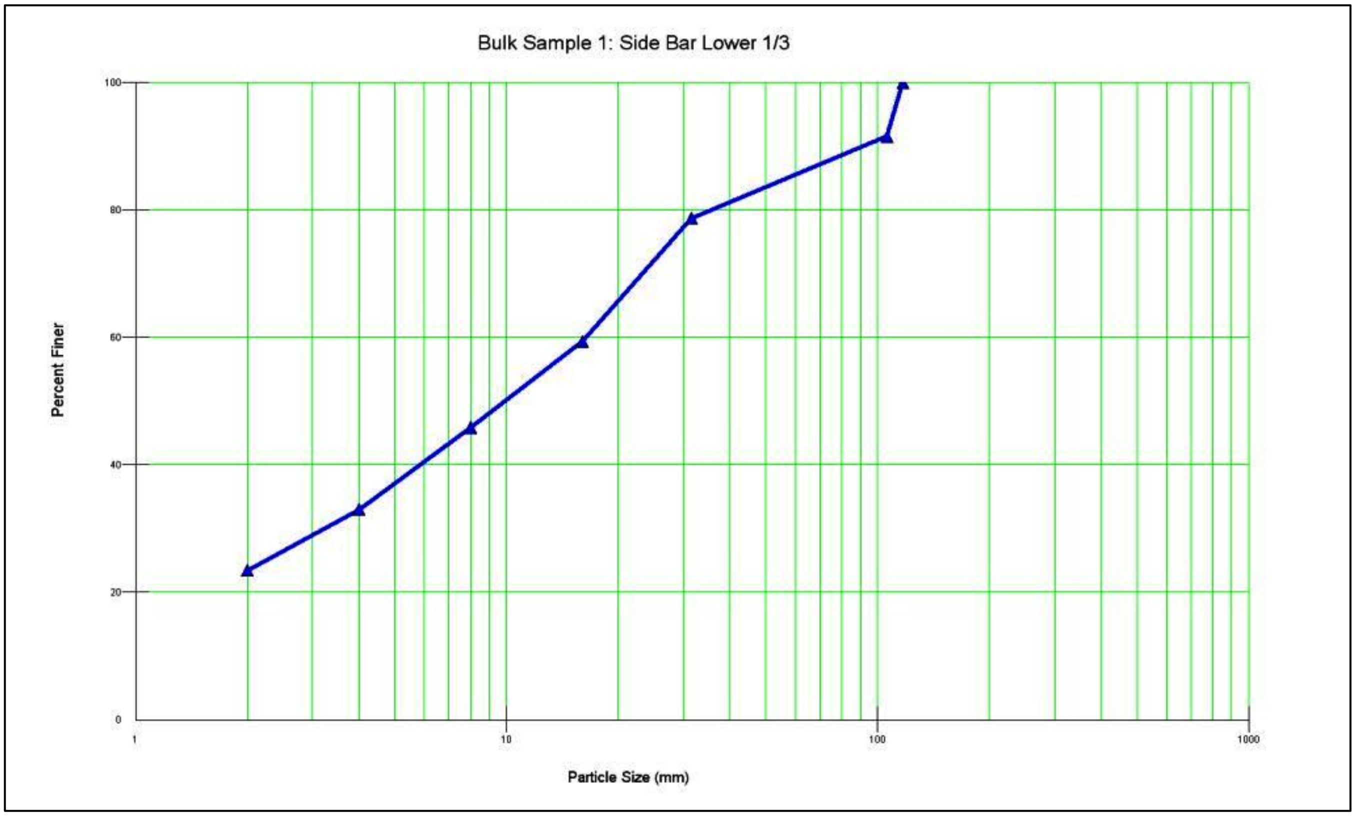
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 1 Side Bar Lower 1/3
Survey Date:	11/14/2008

SIEVE (mm)	NET WT
106	567
31.5	3855
16	5812
8	4054
4	3884
2	2863
PAN	7059
	30079

D16 (mm)	0
D35 (mm)	4.62
D50 (mm)	10.43
D84 (mm)	62.31
D95 (mm)	110.52
D100 (mm)	117
Silt/Clay (%)	0
Sand (%)	23.47
Gravel (%)	62.72
Cobble (%)	13.81
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	117	1928
Particle 2:	40	57



RIVERMORPH PARTICLE SUMMARY

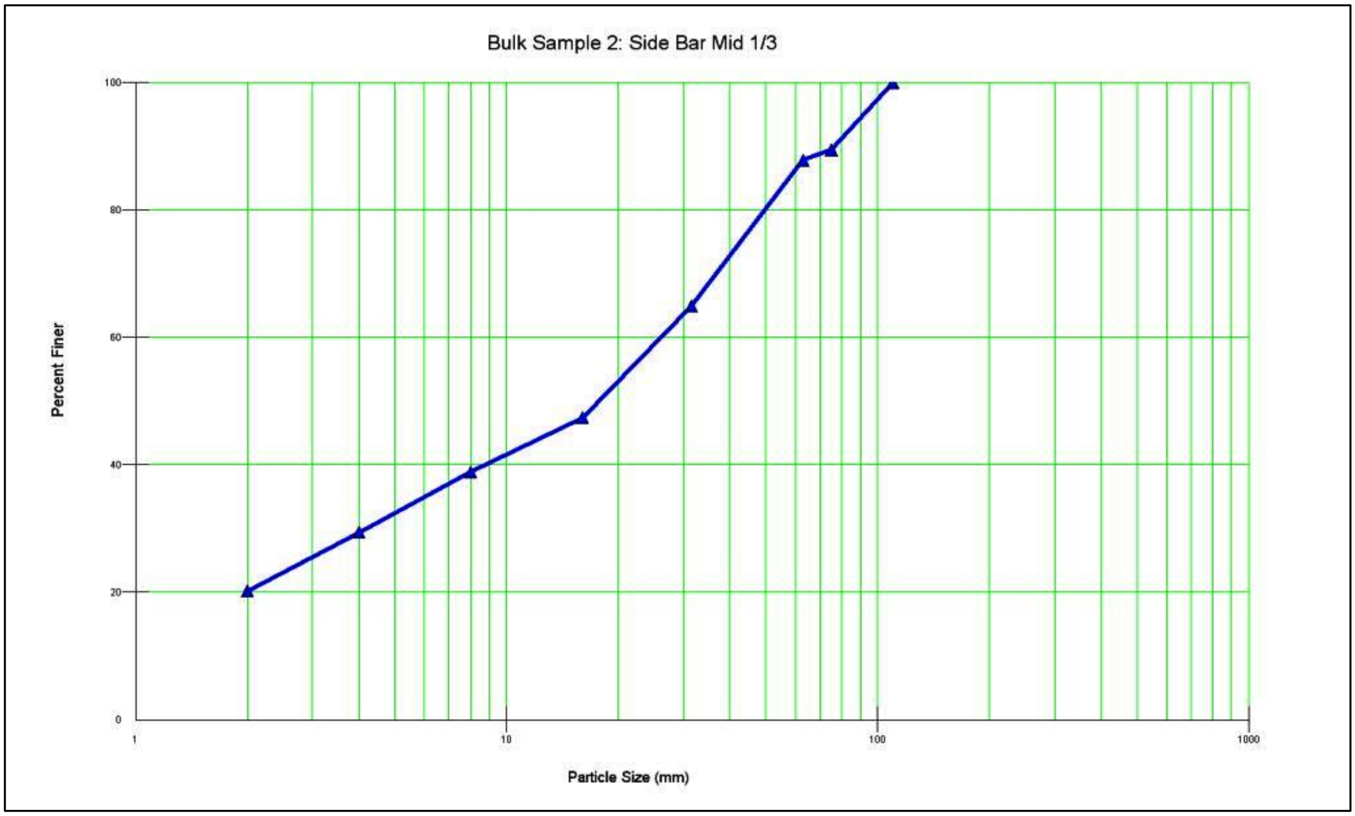
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 2 Side Bar Mid 1/3
Survey Date:	11/11/2008

SIEVE (mm)	NET WT
75	652
63	369
31.5	5273
16	4026
8	1956
4	2183
2	2126
PAN	4649
	23021

D16 (mm)	0
D35 (mm)	6.35
D50 (mm)	18.3
D84 (mm)	57.77
D95 (mm)	93.48
D100 (mm)	110
Silt/Clay (%)	0
Sand (%)	20.19
Gravel (%)	67.75
Cobble (%)	12.05
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	110	1418
Particle 2:	85	369



RIVERMORPH PARTICLE SUMMARY

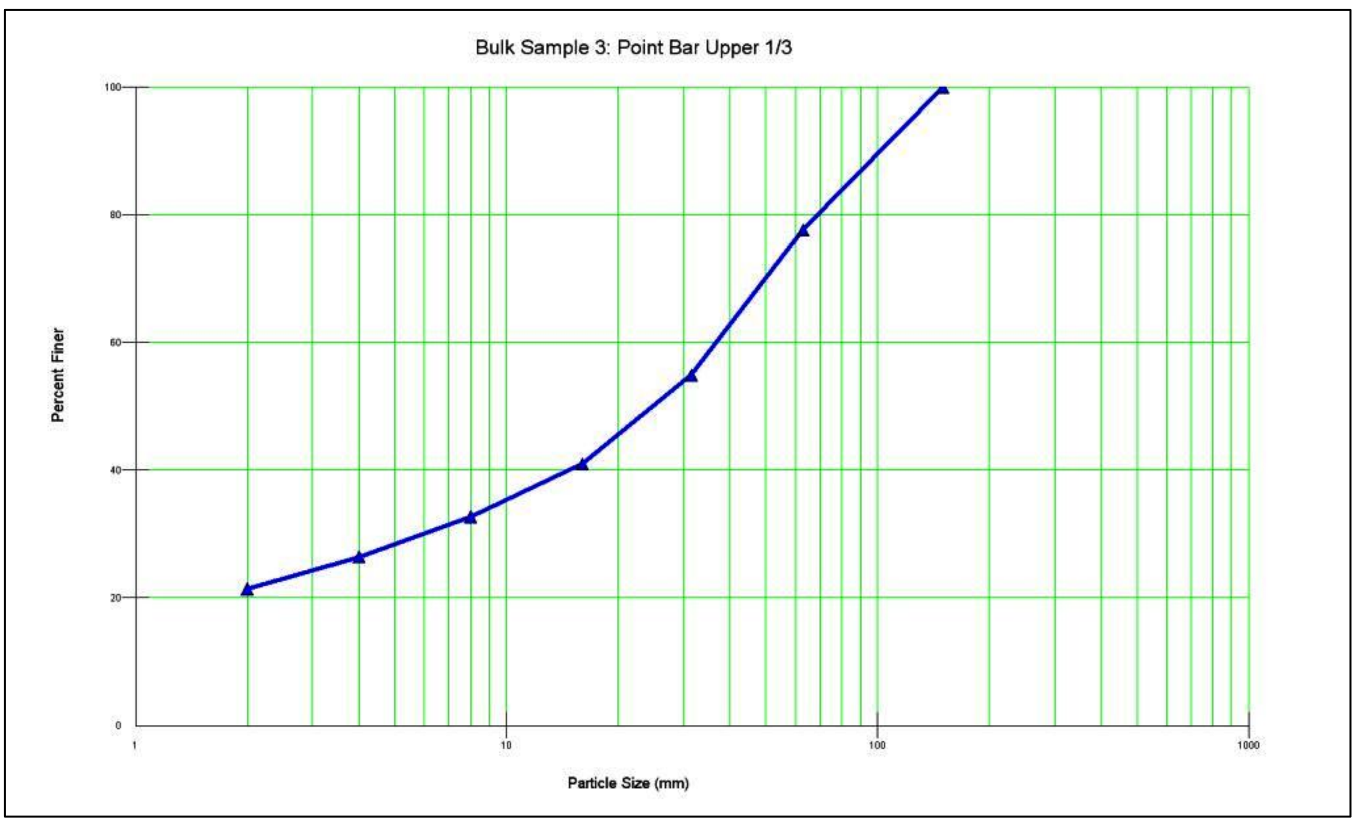
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 3 Point Bar Upper 1/3
Survey Date:	11/11/2008

SIEVE (mm)	NET WT
63	369
31.5	6946
16	4252
8	2523
4	1928
2	1531
PAN	6549
	30562

D16 (mm)	0
D35 (mm)	10.18
D50 (mm)	26.02
D84 (mm)	87.74
D95 (mm)	130.54
D100 (mm)	150
Silt/Clay (%)	0
Sand (%)	21.43
Gravel (%)	56.62
Cobble (%)	21.95
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	150	6237
Particle 2:	77	227



RIVERMORPH PARTICLE SUMMARY

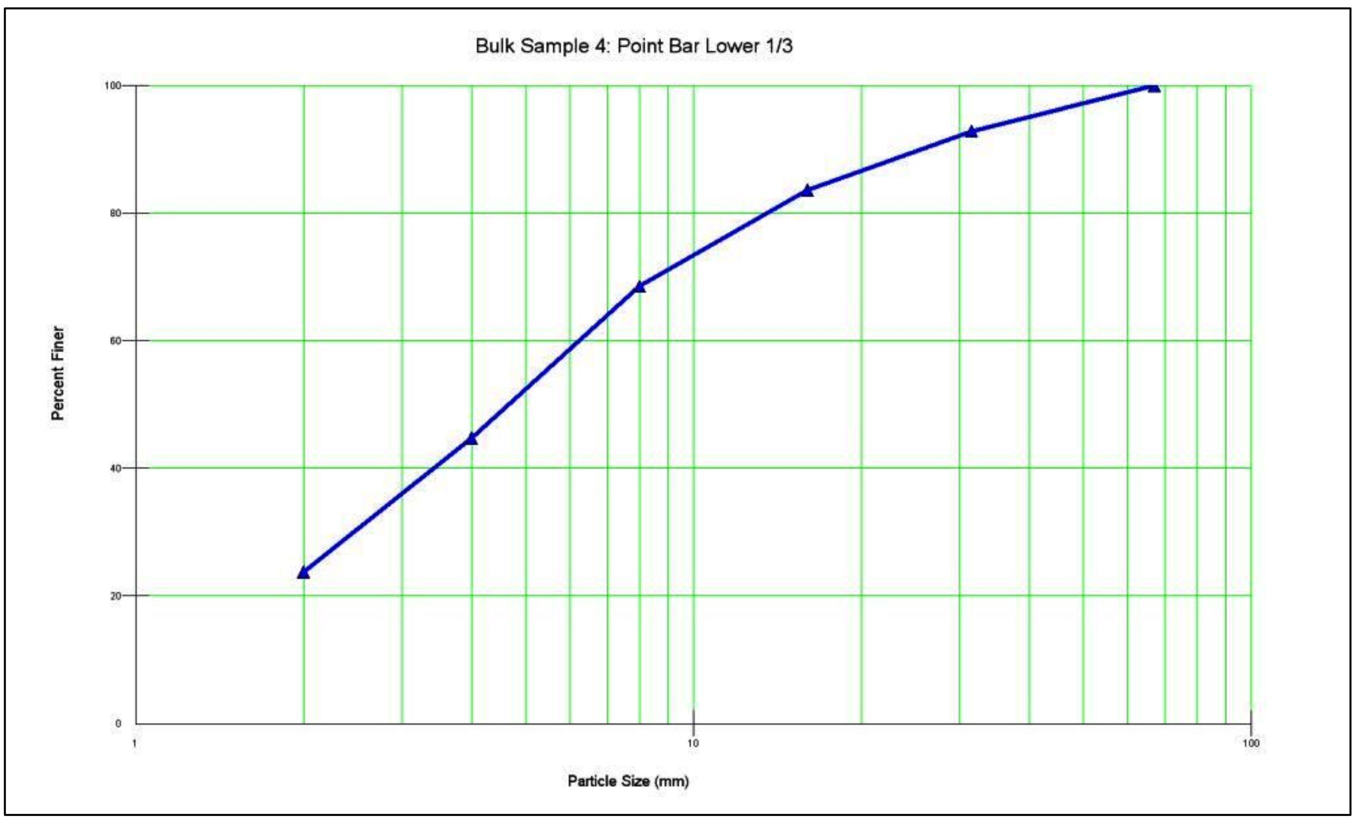
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 4 Point Bar lower 1/3
Survey Date:	11/11/2008

SIEVE (mm)	NET WT
31.5	283
16	1021
8	1673
4	2637
2	2325
PAN	2637
	11086.3

D16 (mm)	0
D35 (mm)	10.18
D50 (mm)	26.02
D84 (mm)	87.74
D95 (mm)	130.54
D100 (mm)	150
Silt/Clay (%)	0
Sand (%)	21.43
Gravel (%)	56.62
Cobble (%)	21.95
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	67	482
Particle 2:	40	28.3



RIVERMORPH PARTICLE SUMMARY

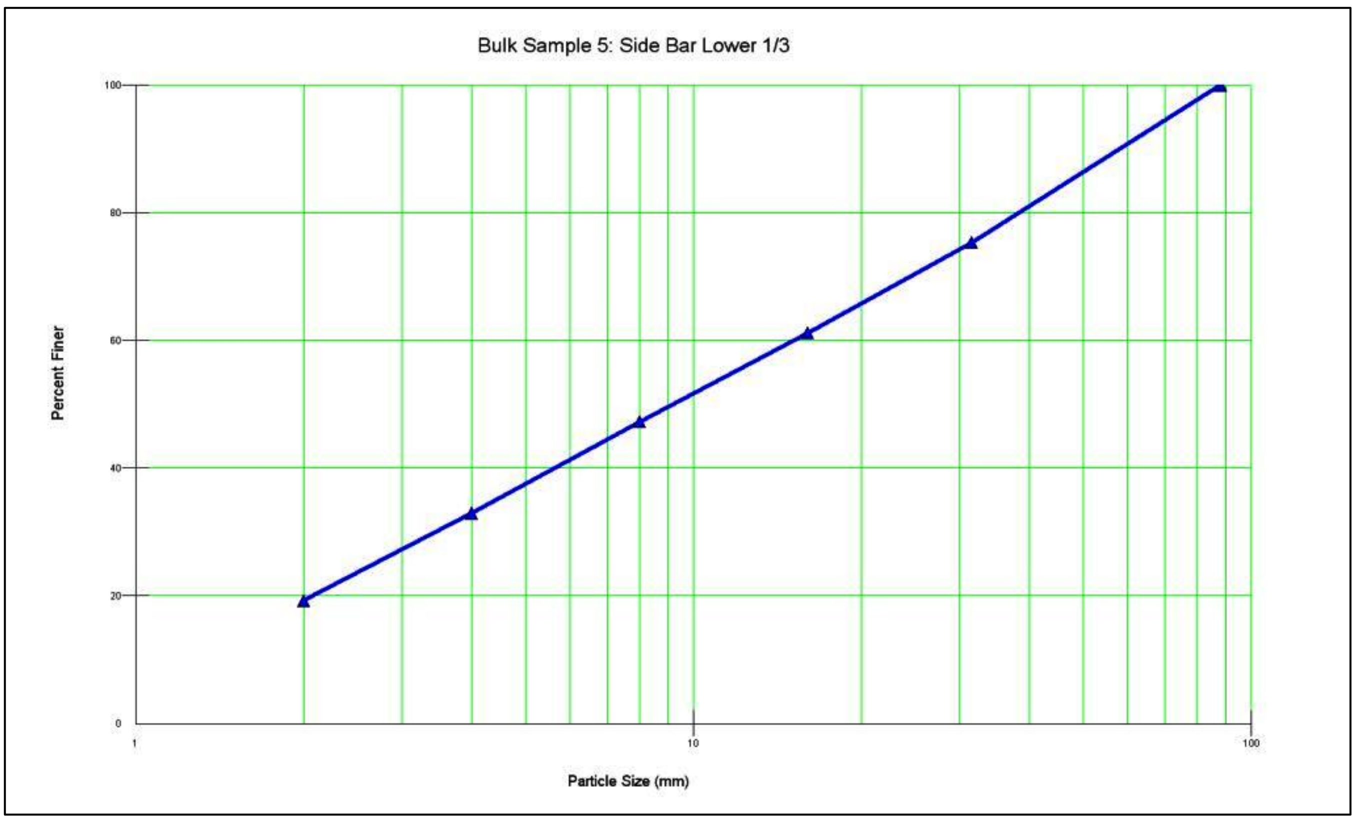
River Name: Little Miami River
Reach Name: RM 4.5 to RM 7.0
Sample Name: Bulk Sample 5 Side Bar lower 1/3
Survey Date: 11/10/2008

SIEVE (mm)	NET WT
31.5	2495
16	2608
8	2551
4	2637
2	2523
PAN	3544
	18399

D16 (mm)	0
D35 (mm)	4.57
D50 (mm)	9.55
D84 (mm)	51.33
D95 (mm)	76.54
D100 (mm)	88
Silt/Clay (%)	0
Sand (%)	19.26
Gravel (%)	73.1
Cobble (%)	7.64
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	88	1616
Particle 2:	64	425



RIVERMORPH PARTICLE SUMMARY

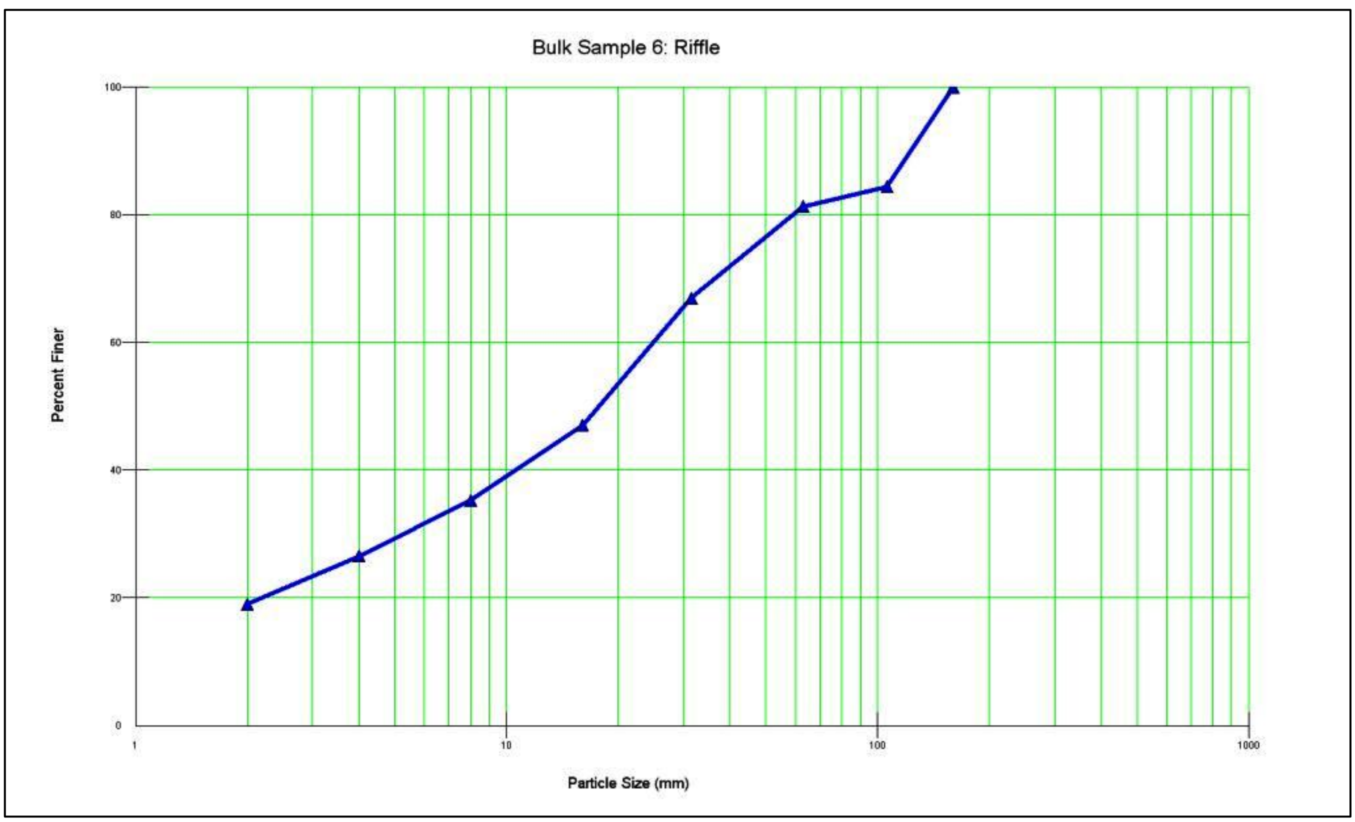
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 6 Riffle Composite
Survey Date:	11/11/2008

SIEVE (mm)	NET WT
106	794
63	1021
31.5	4763
16	6577
8	3884
4	2892
2	2495
PAN	6294
	33085

D16 (mm)	0
D35 (mm)	7.86
D50 (mm)	18.3
D84 (mm	100.33
D95 (mm)	142.68
D100 (mm)	160
Silt/Clay (%)	0
Sand (%)	19.02
Gravel (%)	62.39
Cobble (%)	18.59
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	160	3600
Particle 2:	85	765



RIVERMORPH PARTICLE SUMMARY

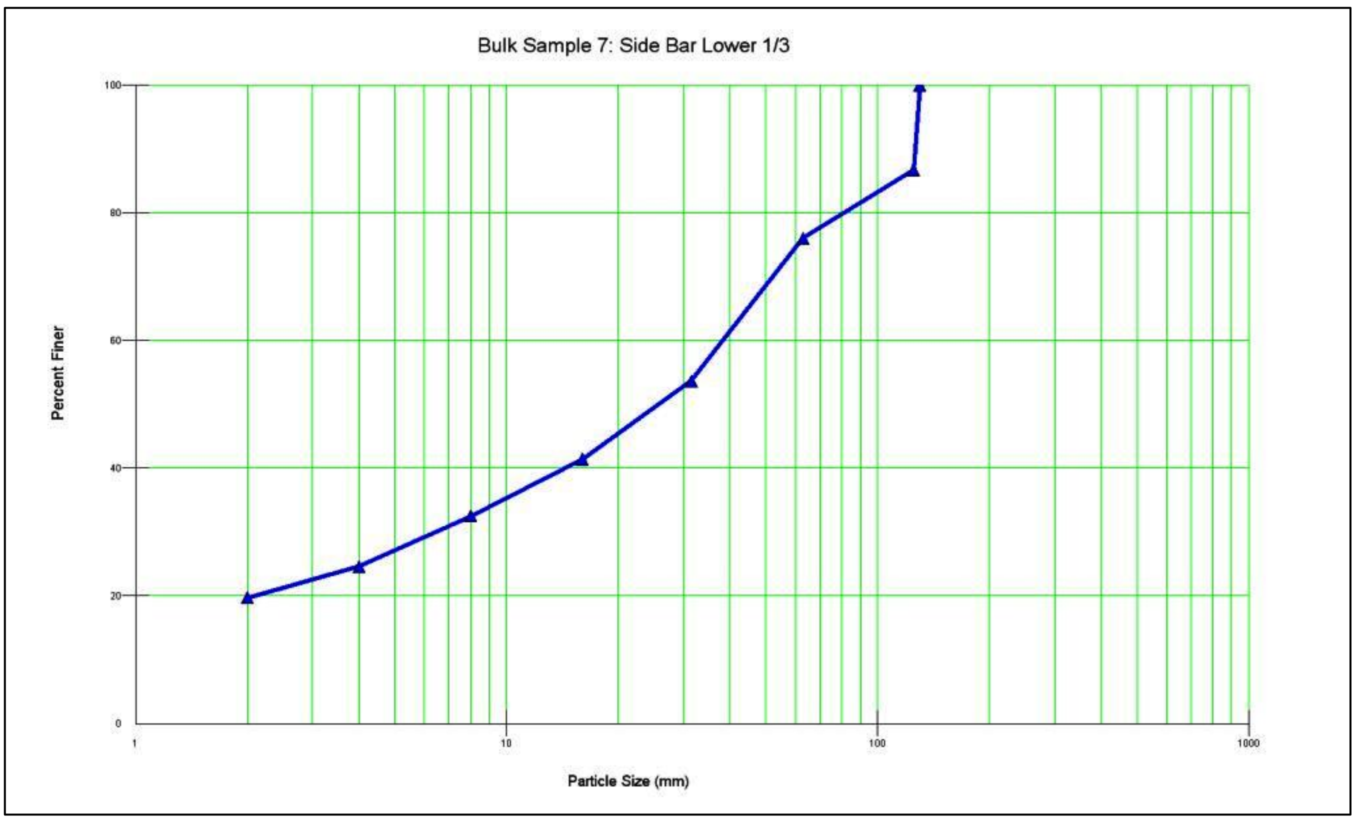
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 7 Side Bar Lower 1/3
Survey Date:	11/10/2008

SIEVE (mm)	NET WT
125	1304
63	3827
31.5	7966
16	4366
8	3175
4	2807
2	1758
PAN	7031
	35665

D16 (mm)	0
D35 (mm)	10.23
D50 (mm)	26.87
D84 (mm)	109.26
D95 (mm)	128.12
D100 (mm)	130
Silt/Clay (%)	0
Sand (%)	19.71
Gravel (%)	56.53
Cobble (%)	23.76
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	130	3289
Particle 2:	70	142



RIVERMORPH PARTICLE SUMMARY

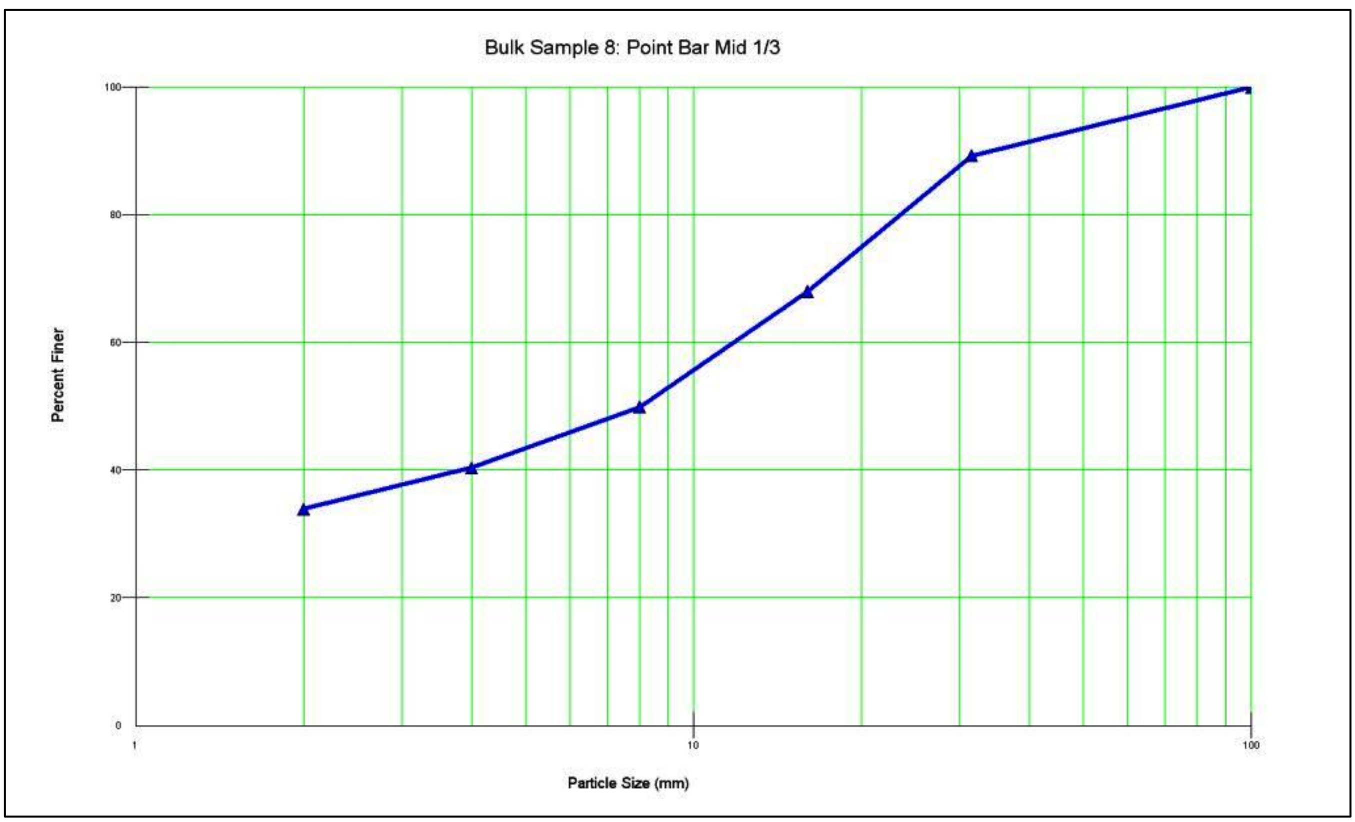
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 8 Point Bar Mid 1/3
Survey Date:	11/10/2008

SIEVE (mm)	NET WT
31.5	1871
16	5018
8	4281
4	2240
2	1531
PAN	8023
	23644

D16 (mm)	0
D35 (mm)	2.33
D50 (mm)	8.05
D84 (mm)	27.69
D95 (mm)	68.26
D100 (mm)	100
Silt/Clay (%)	0
Sand (%)	33.93
Gravel (%)	61.9
Cobble (%)	4.17
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	100	198
Particle 2:	60	482



RIVERMORPH PARTICLE SUMMARY

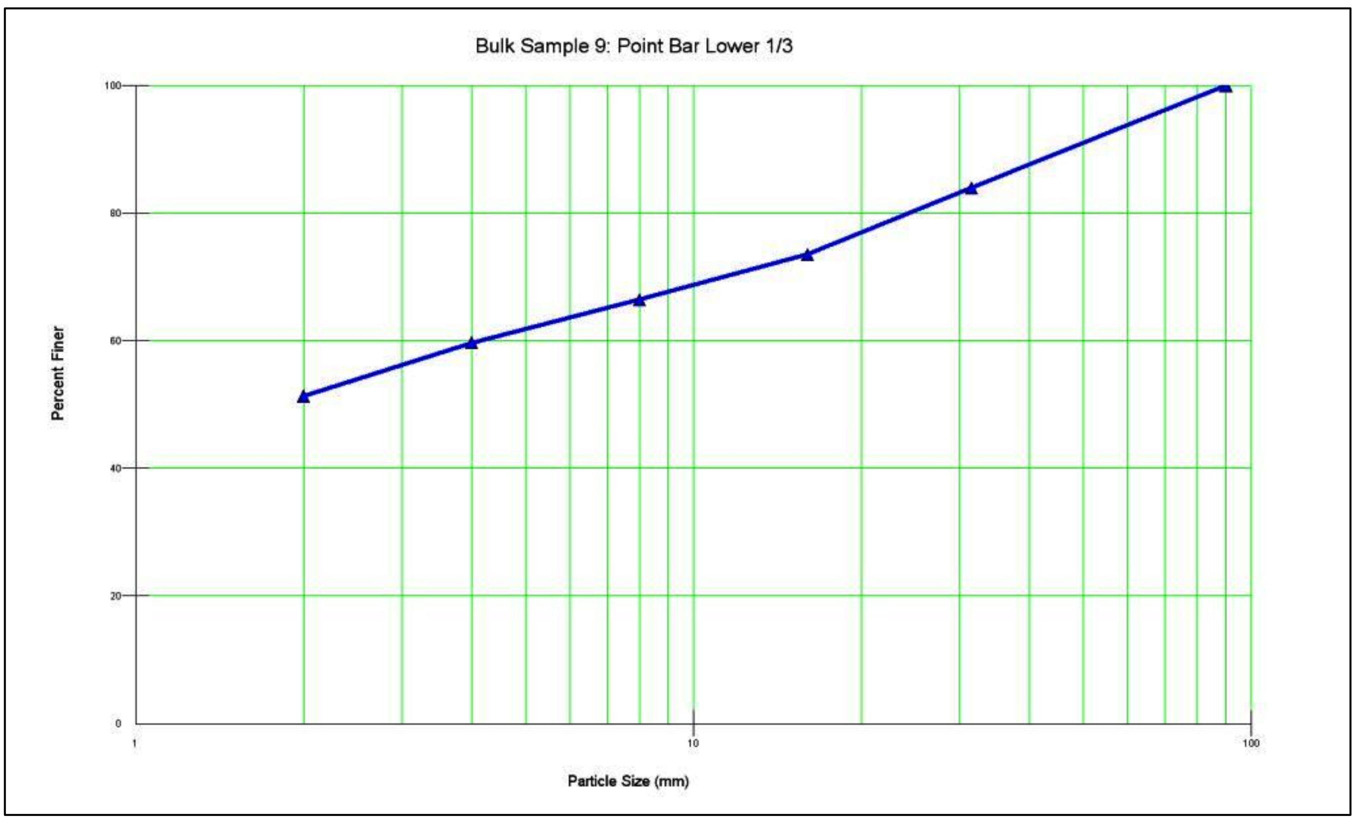
River Name:	Little Miami River
Reach Name:	RM 4.5 to RM 7.0
Sample Name:	Bulk Sample 9 Point Bar Lower 1/3
Survey Date:	11/10/2008

SIEVE (mm)	NET WT
31.5	1673
16	1871
8	1276
4	1219
2	1503
PAN	9242
	18003

D16 (mm)	0
D35 (mm)	0
D50 (mm)	0
D84 (mm)	31.73
D95 (mm)	71.79
D100 (mm)	90
Silt/Clay (%)	0
Sand (%)	51.34
Gravel (%)	43.45
Cobble (%)	5.22
Boulder (%)	0
Bedrock (%)	0

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	90	794
Particle 2:	79	425



Appendix D

Historical Mapping

Alignment Years

1938	1959
1948	1964

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Appendix D - 1
River Alignments Pre-Regulation

Stantec

STANTEC
CONSULTING
SERVICES INC.

11687 LEBANON RD
CINCINNATI, OH
45241-2012
513-842-8200

DRAWN BY	TJT	DATE	February, 2009	REVISED		SHEET
CHECKED BY	—	PROJ. NO.	174438122	1.	3.	1 OF 3
CHECKED BY	—	SCALE	*AS SHOWN*	2.	4.	

Appendix D - 2
River Alignments as Regulation Implemented

Alignment Years

- 1973
- 1975
- 1976
- 1977

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Stantec

STANTEC CONSULTING SERVICES INC.

11687 LEBANON RD
CINCINNATI, OH
45241-2012
513-842-8200

DRAWN BY	TJT	DATE	February, 2009	REVISED	SHEET
CHECKED BY	---	PROJ. NO.	174438122	1. 3.	1 OF 3
CHECKED BY	---	SCALE	***AS SHOWN***	2. 4.	

Alignment Years

- 1981
- 1990
- 2000
- 2008

Appendix D - 3
River Alignments with Regulation

Stantec

STANTEC CONSULTING SERVICES INC.
11687 LEBANON RD
CINCINNATI, OH
45241-2012
513-842-8200

DRAWN BY	TJT	DATE	February, 2009	REVISED		SHEET
CHECKED BY	—	PROJ. NO.	174438122	1.	3.	1 OF 3
CHECKED BY	—	SCALE	***AS SHOWN***	2.	4.	

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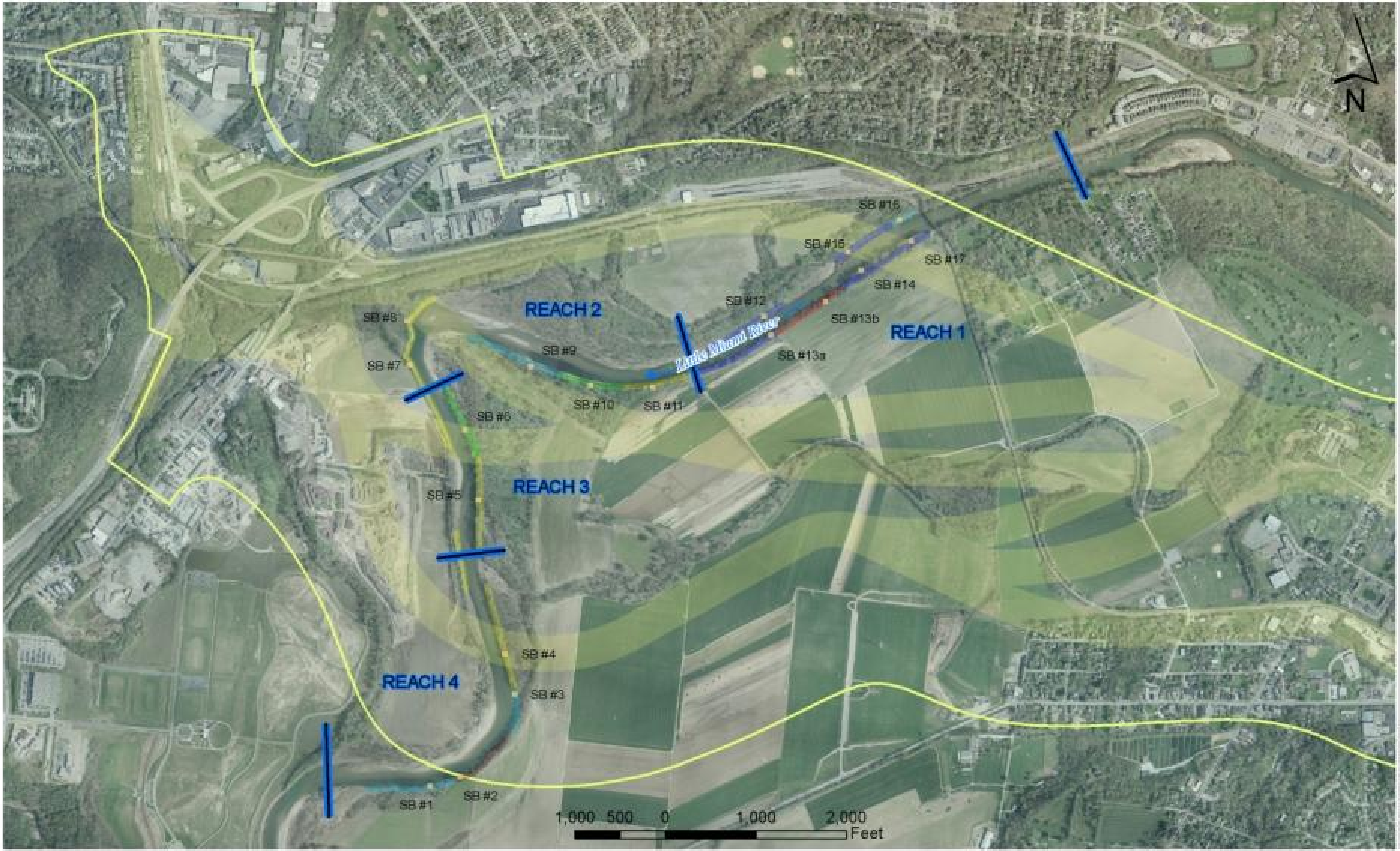
Appendix E

Bank Analyses

Bank Erodibility Drawing E-1



Legend

Study Area

Segment II/III Alternatives

Study Banks

Predicted Erosion (ton/yr/ft)

Very Low	Low	Moderate	High	Very High	Extreme
0.00 - 0.03	0.04 - 0.09	0.10 - 0.39	0.40 - 0.59	0.60 - 0.99	1.00 - 2.00

Stantec

Appendix E - Bank Erodibility Drawing

Entran
River Riparian Crossings Analyses
Easter Corridor Priority Part B Work
Hamilton and Clermont Counties Ohio

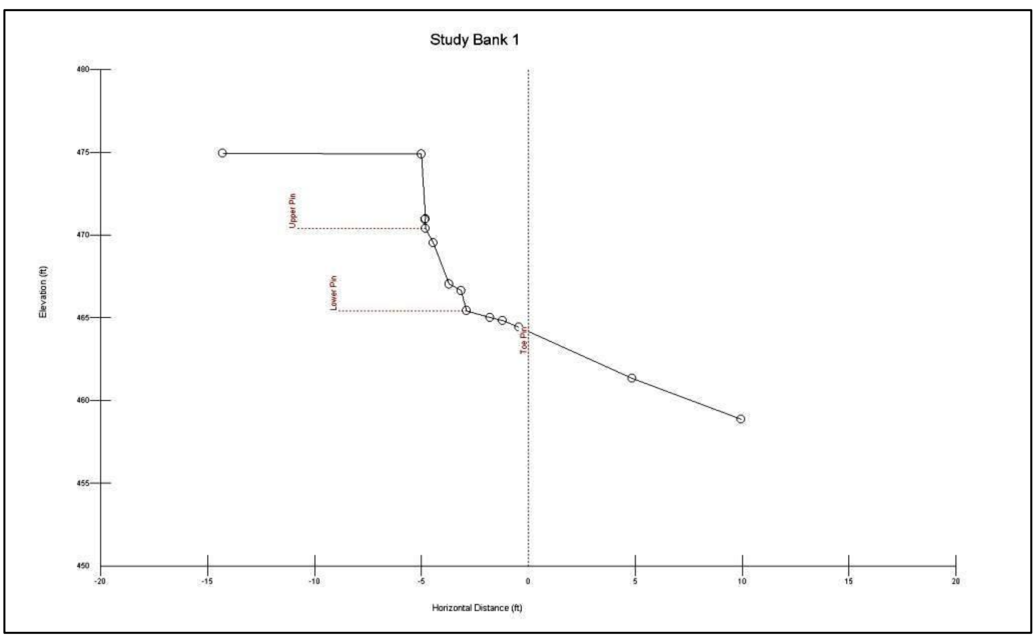
SHEET

E - 1

Study Banks

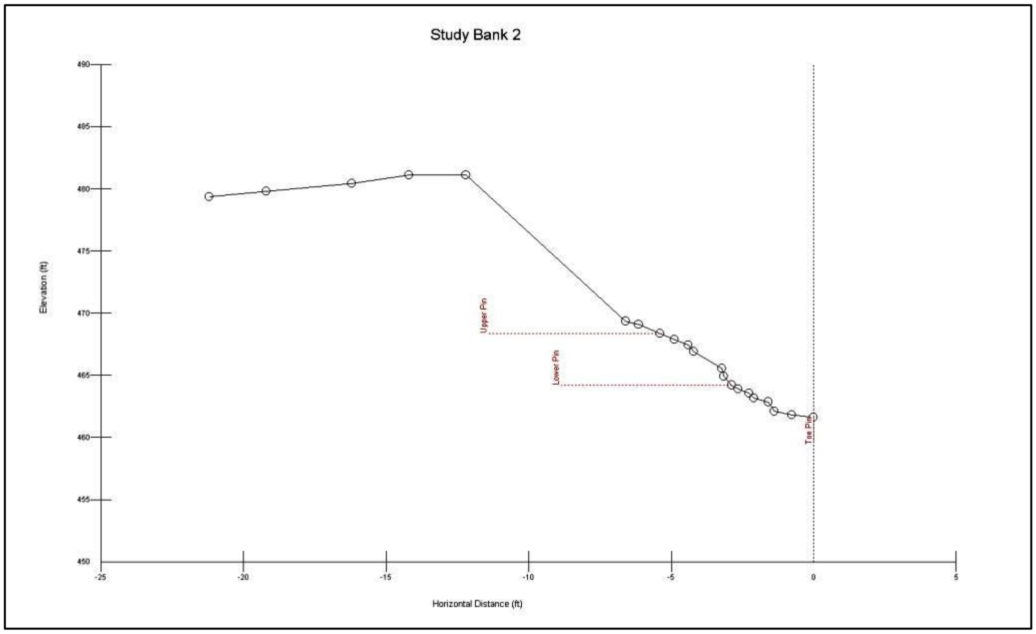
Study Bank 1


10.08.2008


Study Bank 1
480
475
470
465
460
455
450
Elevation (ft)
Upper Pin
Lower Pin
Toe Pin
-20
-15
-10
-5
0
5
10
15
20
Horizontal Distance (ft)

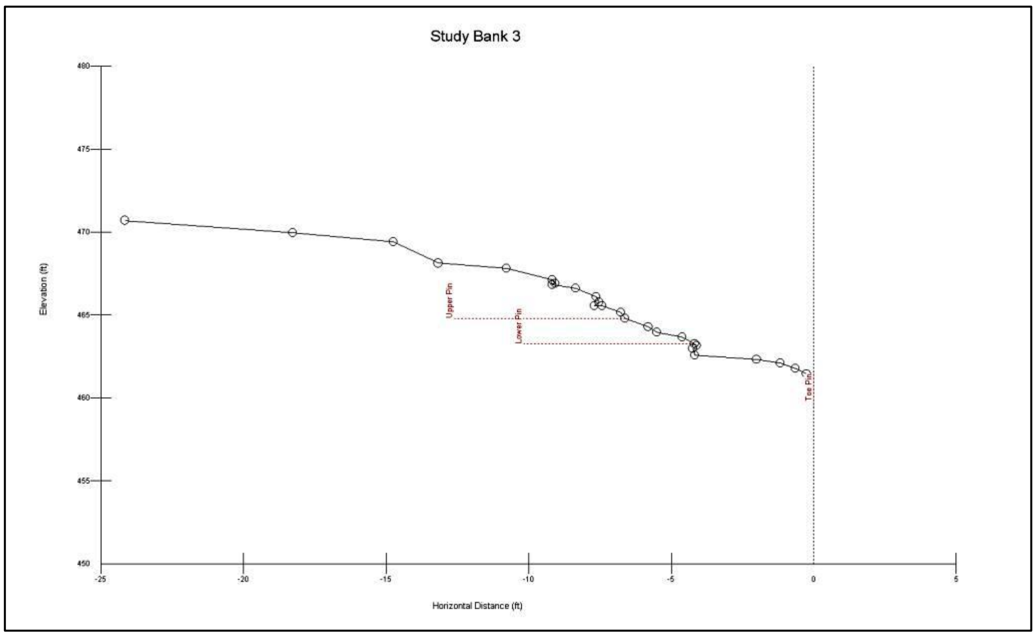
Study Bank 2


10.08.2008


Study Bank 2
490
485
480
475
470
465
460
455
450
Elevation (ft)
Upper Pin
Lower Pin
Toe Pin
-25
-20
-15
-10
-5
0
5
Horizontal Distance (ft)

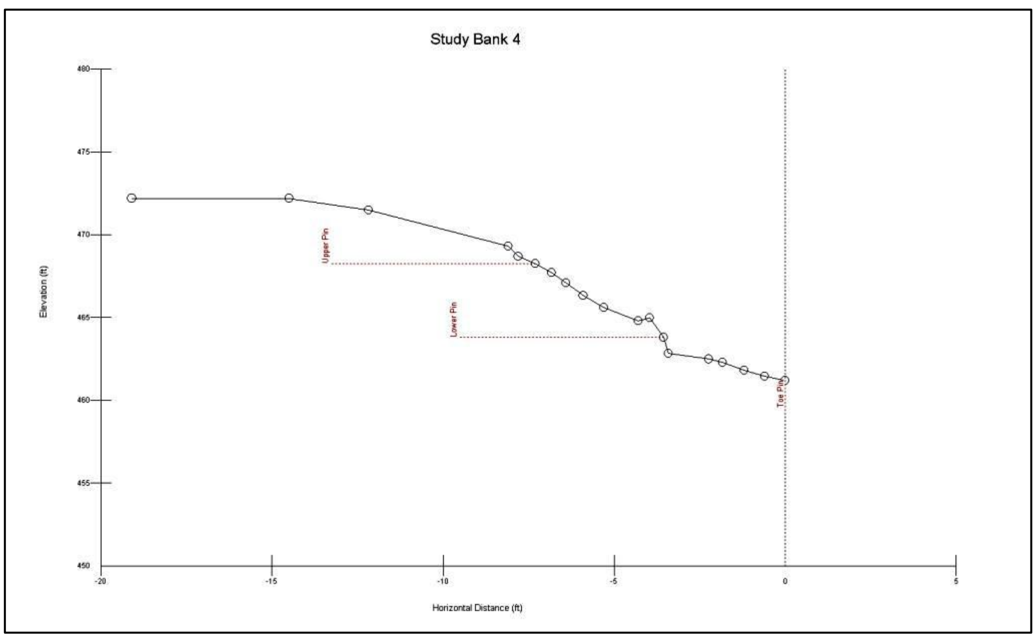
Study Bank 3


10.08.2008


Study Bank 3
Elevation (ft)
480
475
470
465
460
455
450
Upper Pin
Lower Pin
Toe Pin
-25
-20
-15
-10
-5
0
5
Horizontal Distance (ft)

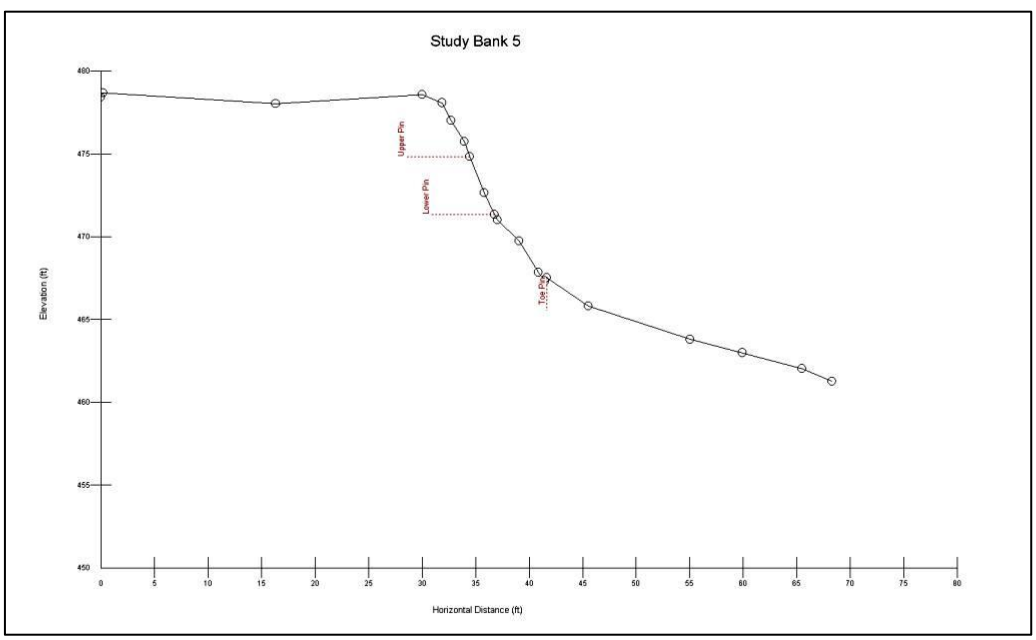
Study Bank 4


12.11.2008


Study Bank 4
480
475
470
465
460
455
450
Elevation (ft)
-20
-15
-10
-5
0
5
Horizontal Distance (ft)
Upper Pin
Lower Pin
Toe Pin

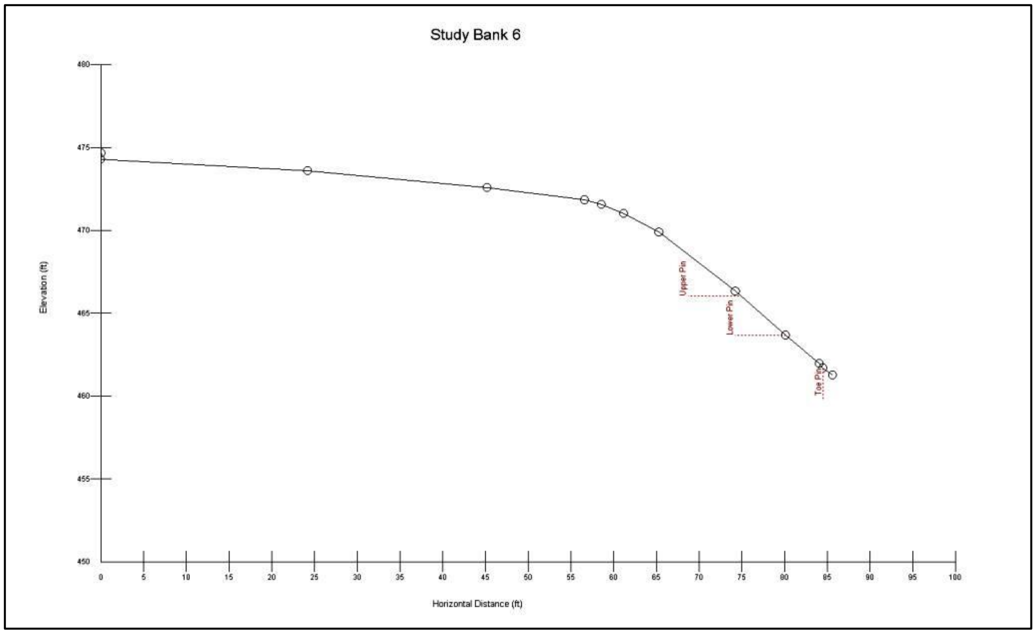
Study Bank 5


10.09.2008


Study Bank 5
Upper Pin
Lower Pin
Toe Pin
Elevation (ft)
480
475
470
465
460
455
450
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Horizontal Distance (ft)

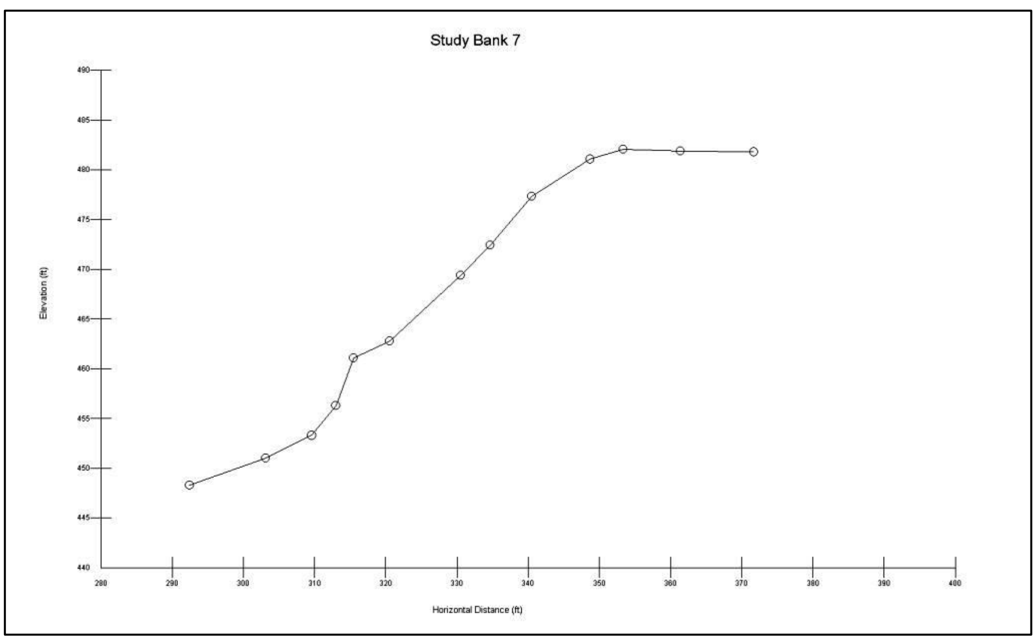
Study Bank 6


12.11.2008


Study Bank 6
Elevation (ft)
480
475
470
465
460
455
450
Horizontal Distance (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Upper Pin
Lower Pin
Toe Pin

Study Bank 7

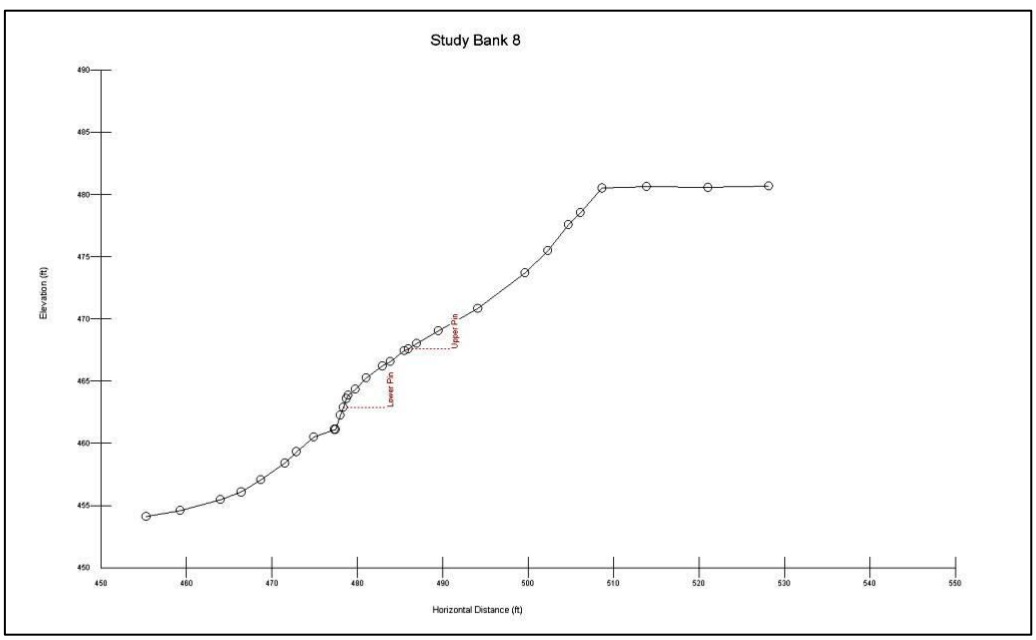
09/14/2008 12:51 AM



Study Bank 7
490
485
480
475
470
465
460
455
450
445
440
Elevation (ft)
280
290
300
310
320
330
340
350
360
370
380
390
400
Horizontal Distance (ft)

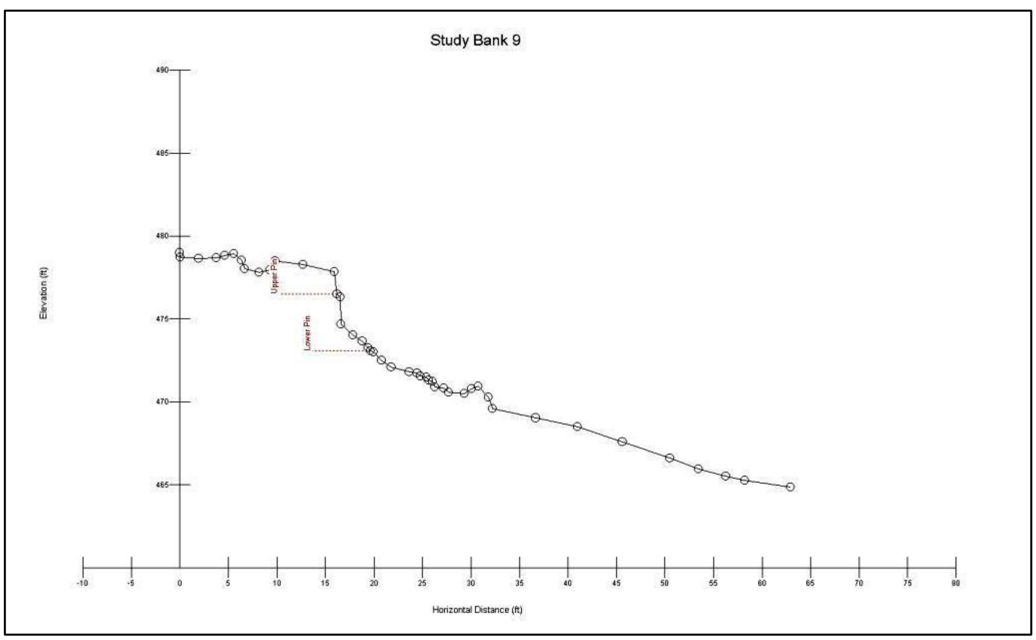
Study Bank 8


09/14/2008 06:30 PM

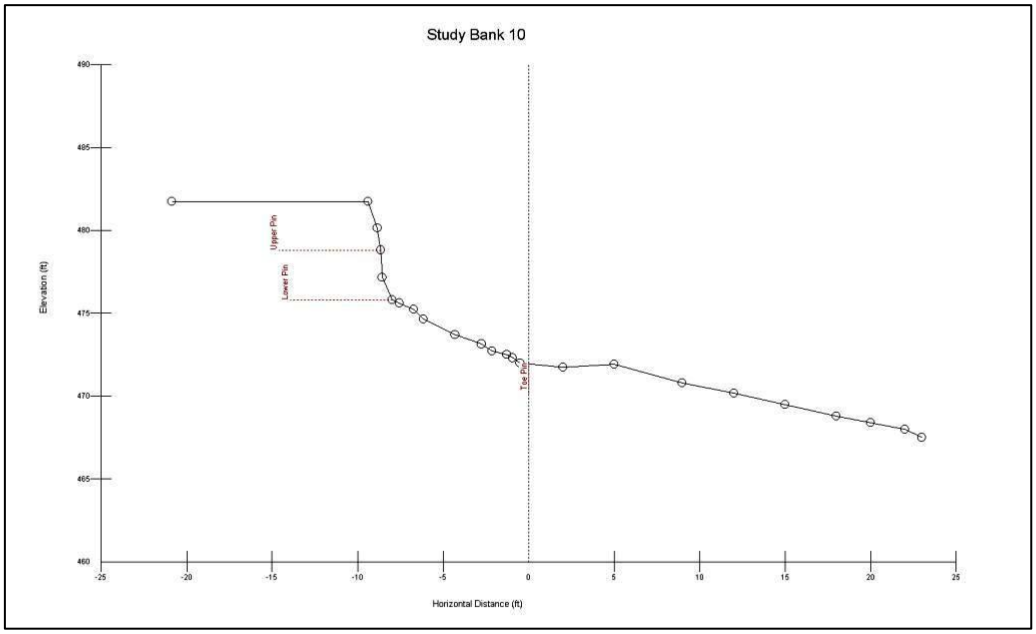

Study Bank 8
Elevation (ft)
490
485
480
475
470
465
460
455
450
Upper Pin
Lower Pin
450
460
470
480
490
500
510
520
530
540
550
Horizontal Distance (ft)

Study Bank 9

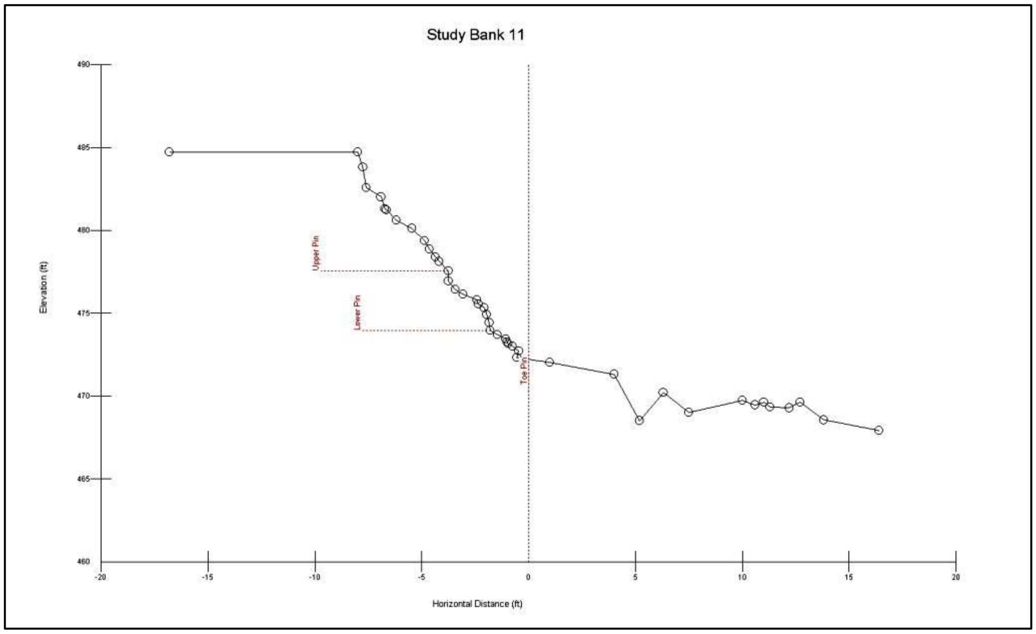

09/14/2008 04:18 PM


Study Bank 9
490
485
480
475
470
465
Elevation (ft)
Upper Pin
Lower Pin
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Horizontal Distance (ft)

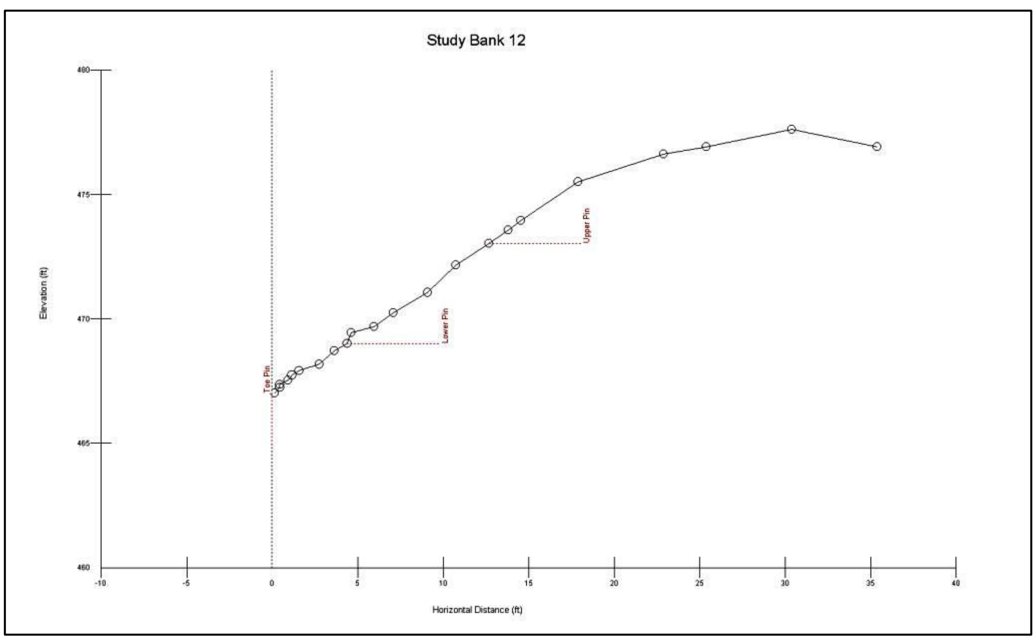
Study Bank 10



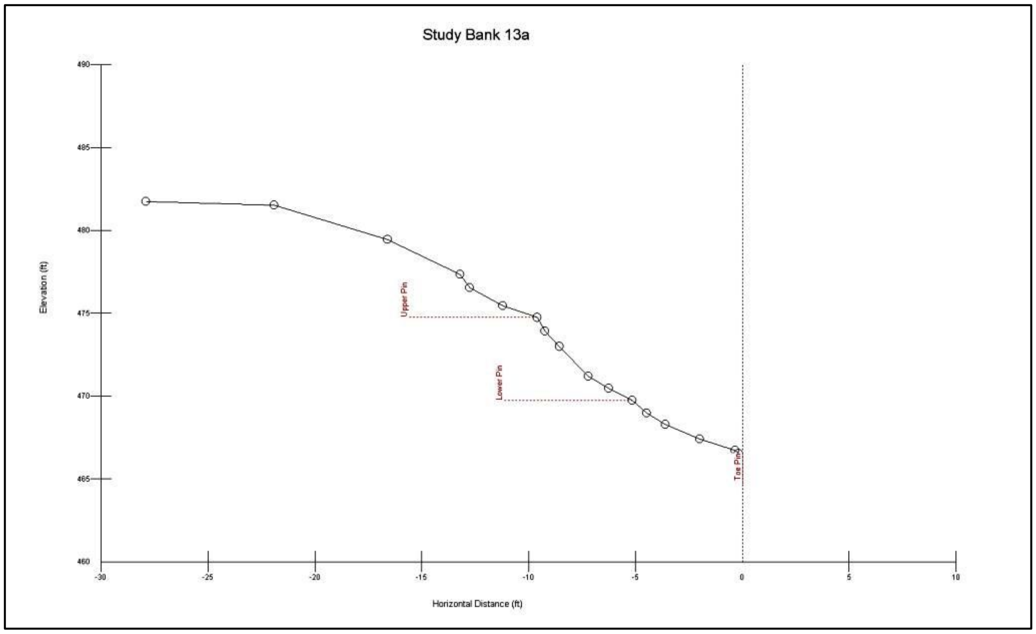
Study Bank 11



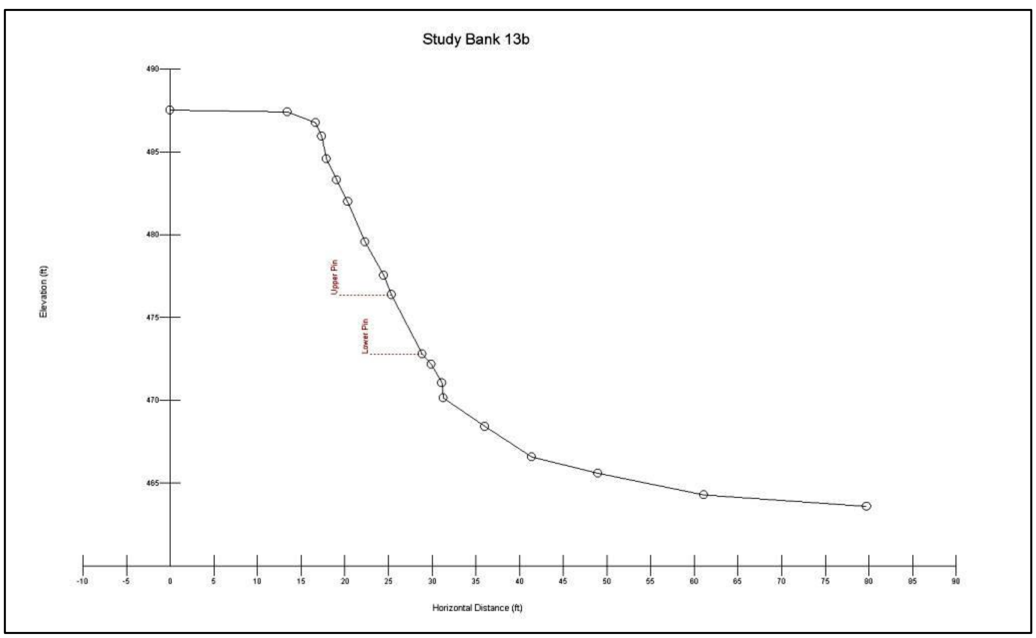
Study Bank 12



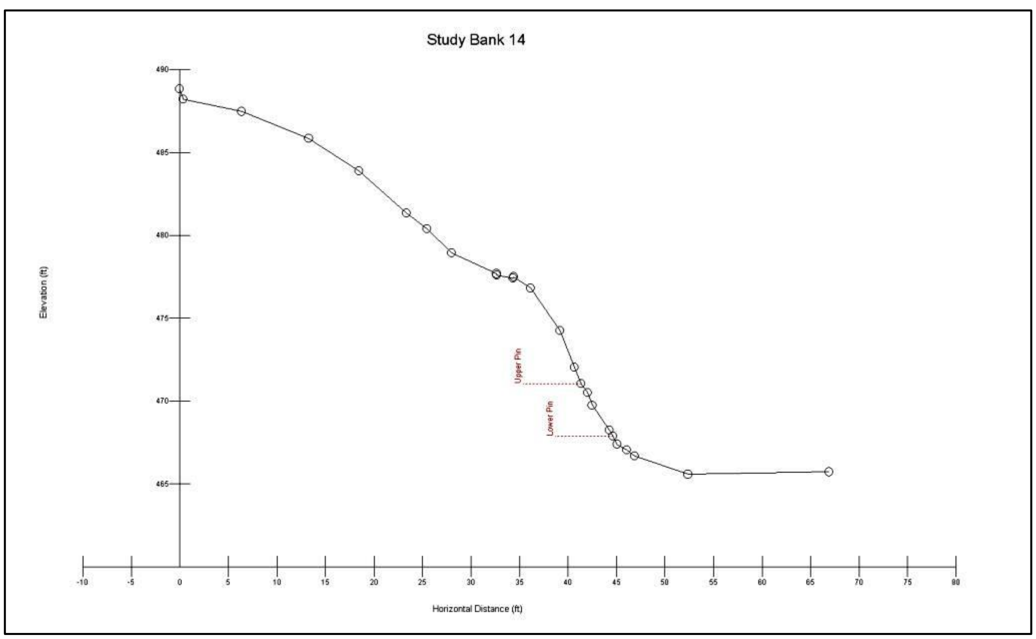
Study Bank 13a



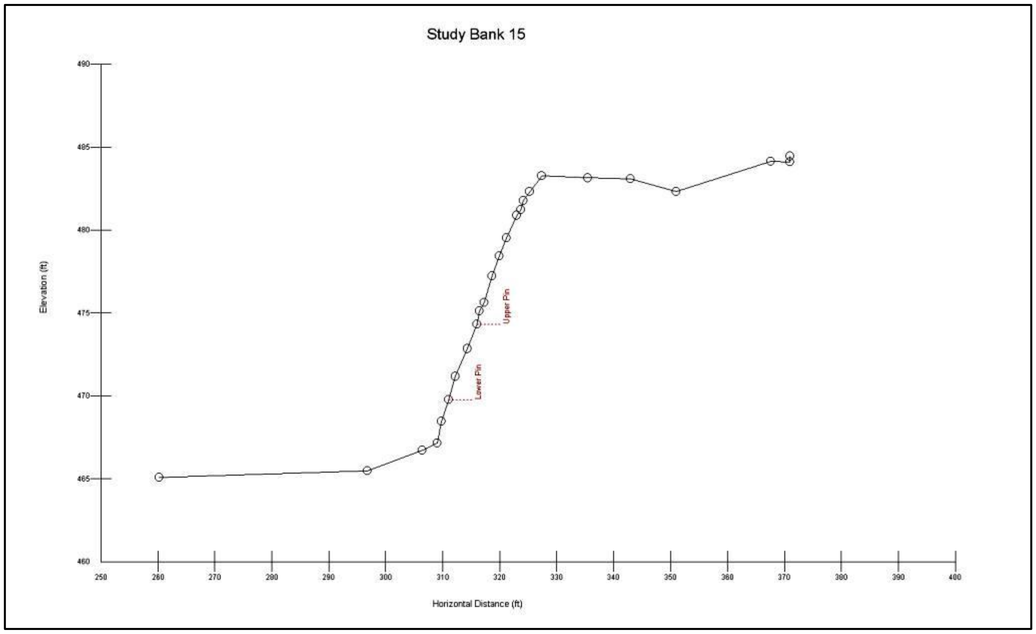
Study Bank 13b



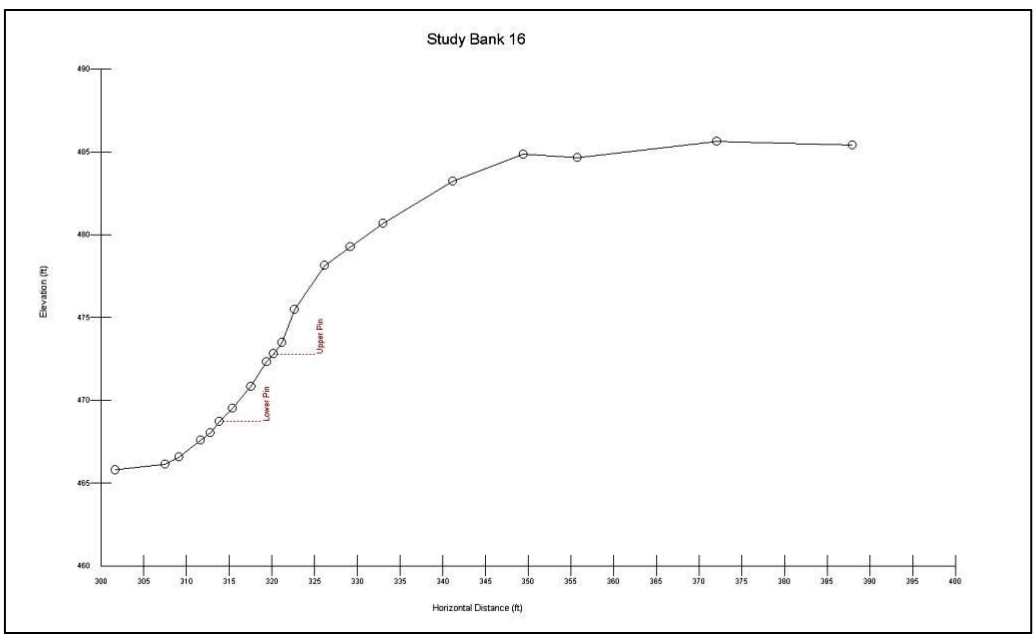
Study Bank 14



Study Bank 15



Study Bank 16



Study Bank 17