Atlantic Rim Coal Bed Methane and Natural Gas Project
Carbon County, Wyoming

April 6, 2010

Muddy Creek Monitoring Report - 2009

CDM

Executive Summary

This monitoring report presents data collected on upper Muddy Creek in the Atlantic Rim area in 2009. Camp, Dresser, and McKee, Inc., (CDM) is under contract with Anadarko to provide annual monitoring for geomorphology, aquatic habitat, and water quality on this project. The Atlantic Rim Coal Bed Methane and Natural Gas Project in Carbon County, Wyoming is a coal bed methane and natural gas project being developed on public and private land by Anadarko and other operators. A particular concern on upper Muddy Creek is the maintenance of populations of non-game, native fish species, particularly the roundtail chub, bluehead sucker, and flannelmouth sucker (BLM, 2007). The general goal of monitoring on upper Muddy Creek is to determine if activities associated with the Atlantic Rim Project have an impact on upper Muddy Creek that adversely affects the non-game, native fish population.

Monitoring objectives for upper Muddy Creek have been developed based on the performance goals in the Record of Decision (BLM, 2007) for the Atlantic Rim Coal Bed Methane and Natural Gas Project. The performance goal for sensitive fish species is to "maintain adequate water quality, water quantity, species distribution, and aquatic habitat components." To determine if the Atlantic Rim Project has adverse impacts on the sensitive fish populations in the stream, a multi-parameter approach that encompasses geomorphology, hydrology, habitat features and water quality has been recommended. All of these disciplines relate to sediment transport in the system, which is key to the health of the benthic macroinvertebrate populations and fish that feed on them. The objectives of this monitoring effort include:

- Measurement of sediment delivery from eroding streambanks.
- Measurement of habitat features and stream morphology.
- Measurement of in-stream sediment concentrations and other water quality parameters.

Monitoring in August 2009 occurred after a relatively high spring runoff. Water year 2009 was one of the higher precipitation years on record at the Divide Peak SNOTEL gage located south-east of Muddy Creek. Therefore, flows were certainly higher than normal during runoff along Muddy Creek in 2009, and ample evidence of the higher flows was seen in the field. Because natural gas related development is very limited in the Muddy Creek drainage at this time, the channel changes observed this year are attributed to the high precipitation and runoff.

Field work in August 2009 included a geomorphic and habitat measurements and water quality sampling. The six reference cross-sections (one at each site) were remeasured using a total station. Comparing the cross sections to those obtained in 2008, four reference cross-sections changed significantly and two remained relatively

unchanged. The patterns of fresh erosion and deposition documented at the reference cross-sections were observed at numerous locations along the stream. It is apparent that a large amount of sediment moved during runoff in Muddy Creek this year with sediment eroding, moving downstream, and depositing in other areas.

Bed measurements were taken using Wolman pebble count methods (Wolman, 1954) and embeddedness measurements (Sennatt et al, 2006). Pebble counts were similar to those obtained in the same locations as 2008. The condition of the riffles at the three upstream sites is similar to that of 2008 presumably because the bed material is coarse. However, at the three downstream sites, the bed material in the riffles is much smaller and the riffles are deteriorating and sometimes disappearing and reforming.

The embeddedness measurements are also similar to those collected in 2008. As in 2008, the pools are 100% embedded and the riffles are 0% embedded. To attain intermediate numbers areas just upstream or downstream of riffles were sampled, but the selection of these areas was targeted to obtaining a reasonable count and did not represent the condition of the stream well.

Erosion pins set in 2008 were remeasured this year. Although most of the erosion pins showed fairly small changes since 2008, the erosion pin at Rocky Crossing (just upstream of UMC3) showed significant bank retreat of 0.72 ft. This is a relatively low bank (about 3 ft. high) that is more susceptible to lateral movement than the higher banks typical of the monitoring sites.

Bank stability was evaluated using the Bank Erosion Hazard Index and Near Bank Stress metrics developed by Rosgen (1996). Ratings for 2009 were very similar to those obtained in 2008 and range from high to extreme. This indicates that the existing condition on Muddy Creek is highly erosive and produces large amounts of sediment.

Residual pool depths were measured at all sites and compared to 2008 depths. All pools showed some variation in residual depth compared to the previous year with depths being sometimes greater and sometimes less. Variations from the previous year were greatest at the downstream stations where riffles are unstable and pools are reforming with the changing bed conditions.

Water quality of upper Muddy Creek in August 2009 was very similar to that observed in 2008. Flows were significantly higher this year ranging from 4.64 to 5.66 cfs presumably due to the relatively wet summer of 2009. Common ions concentrations were similar to those of 2008, and total suspended sediment concentrations were also similar. Total selenium was less than 0.005 mg/L at all three sites, which is below the chronic aquatic life standard. The water quality does not appear to have changed significantly from 2008 in spite of the higher flows.

Contents

Section 1 Introduction 1-1

1.1 Background 1-1
1.2 Project Organization 1-2
1.3 Report Organization 1-2

Section 2 Geomorphic and Aquatic Habitat Monitoring 2-1

2.1 2009 Monitoring Event 2-1
2.2 Geomorphic Monitoring 2-1
2.2.1 Cross-sections 2-1
2.3 Bed Measurements 2-3
2.4 Bank Stability 2-5
2.4.1 Erosion Pins 2-5
2.4.2 Bank Erosion Hazard Index 2-7
2.4.3 Near Bank Stress 2-7
2.5 Residual Pool Depths 2-8

Section 3 Water Quality Sampling 3-1

3.1 Measurement Methods 3-1
3.2 Water Quality Sampling Results 3-1
3.3 Quality Assurance/Quality Control 3-3

Section 4 References 4-1

Appendices

Appendix A Monitoring Site Maps and Reference Section Photos - 2009
Appendix B Cross-sections, BEHI Calculations, and Bank Photos - 2009
Appendix C Cumulative Sediment Size Distribution Charts -2009
Appendix D Laboratory Data Sheets -2009

Tables

Table 2-1	D_{50} Values at Pebble Count Cross-sections for 2008 and 2009
Table 2-2	Average Embeddedness Values and Locations
Table 2-3	Locations and Protruding Lengths of Bank Erosion Pins for 2008 and 2009
Table 2-4	BEHI Ratings for 2008- 2009 and NBS Ratings
Table 2-5	Residual Pool Depths
Table 3-1	Field Parameters from August 2008 and 2009 Water Quality Sampling Upper Muddy Creek
Table 3-2	Common Ions, Selenium and TSS from August 2008 and 2009 Water Quality Sampling – Upper Muddy Creek

Figures

Figure 1-1	Altantic Rim Project Area
Figure 1-2	Upper Muddy Creek Roads
Figure 2-1	Upper Muddy Creek Monitoring Locations
Figure 2-2	Erosion and deposition features upstream of Cross-section 1 at Site UMC4.
Figure 2-3	Deteriorating riffle at UMC1, XS-1.

Section 1 Introduction

This monitoring report presents data developed or collected on Upper Muddy Creek in the Atlantic Rim area in 2009. Camp, Dresser, and McKee, Inc., (CDM) is under contract with Anadarko to provide annual monitoring for geomorphology, aquatic habitat, and water quality on this project. The Atlantic Rim Coal Bed Methane and Natural Gas Project in Carbon County, Wyoming is a coal bed methane and natural gas project being developed on public and private land by Anadarko and other operators (Figure 1-1). Development is occurring in a 270,080 acre area and requires construction of roads, pipelines, well pads, compressor stations and gas processing facilities, drilling up to 2,000 wells, and production of water (BLM, 2007). The portion of the Upper Muddy Creek drainage where development will take place is shown in Figure 1-2. As can be seen in this figure, there are almost 200 miles of existing four-wheel drive roads in the project area, which indicates the disturbed condition of the drainage in the baseline condition. At the time of the 2008 monitoring, only 3.4 miles of project related roads had been constructed in the upper Muddy Creek drainage, most of which are at some distance from Muddy Creek. Sedimentation impacts of oil and gas development at this time in the project area are therefore expected to be undetectable. In 2009 there was no new road building or new drilling in the Muddy Creek drainage.

A particular concern on Upper Muddy Creek is the maintenance of populations of non-game, native fish species, particularly the roundtail chub, bluehead sucker, and flannelmouth sucker (BLM, 2006). The general goal of monitoring on Upper Muddy Creek is to determine if activities associated with the Atlantic Rim Project have an impact on upper Muddy Creek that adversely affect the non-game, native fish population. The potential adverse effects caused by development will need to be compared to potential impacts due to other factors such as recreation and livestock grazing.

1.1 Background

The Atlantic Rim Coal Bed Methane and Natural Gas Project was proposed by Anadarko and other operators in 2001. The responsible agency for permitting the development is the Bureau of Land Management (BLM), which initiated scoping for an Environmental Impact Statement (EIS) in 2001. The Record of Decision (BLM, 2006) for the project was signed in 2007 and includes specific performance goals for the project. The performance goal for Muddy Creek sensitive fish is to "maintain adequate water quality, water quantity, species distribution, and aquatic habitat components." This is to be accomplished through use of Best Management Practices (BMPs), performance-based monitoring, and adaptive management. The monitoring program currently in place addresses activities that will take place on Upper Muddy Creek. The Muddy Creek Monitoring Plan (CDM, 2008a) describes the monitoring objectives developed by CDM for the Muddy Creek Working Group in 2008 to guide annual monitoring activities on the Upper Muddy Creek.

Executive Summary

This monitoring report presents data collected on upper Muddy Creek in the Atlantic Rim area in 2009. Camp, Dresser, and McKee, Inc., (CDM) is under contract with Anadarko to provide annual monitoring for geomorphology, aquatic habitat, and water quality on this project. The Atlantic Rim Coal Bed Methane and Natural Gas Project in Carbon County, Wyoming is a coal bed methane and natural gas project being developed on public and private land by Anadarko and other operators. A particular concern on upper Muddy Creek is the maintenance of populations of non-game, native fish species, particularly the roundtail chub, bluehead sucker, and flannelmouth sucker (BLM, 2007). The general goal of monitoring on upper Muddy Creek is to determine if activities associated with the Atlantic Rim Project have an impact on upper Muddy Creek that adversely affects the non-game, native fish population.

Monitoring objectives for upper Muddy Creek have been developed based on the performance goals in the Record of Decision (BLM, 2007) for the Atlantic Rim Coal Bed Methane and Natural Gas Project. The performance goal for sensitive fish species is to "maintain adequate water quality, water quantity, species distribution, and aquatic habitat components." To determine if the Atlantic Rim Project has adverse impacts on the sensitive fish populations in the stream, a multi-parameter approach that encompasses geomorphology, hydrology, habitat features and water quality has been recommended. All of these disciplines relate to sediment transport in the system, which is key to the health of the benthic macroinvertebrate populations and fish that feed on them. The objectives of this monitoring effort include:

- Measurement of sediment delivery from eroding streambanks.
- Measurement of habitat features and stream morphology.
- Measurement of in-stream sediment concentrations and other water quality parameters.

Monitoring in August 2009 occurred after a relatively high spring runoff. Water year 2009 was one of the higher precipitation years on record at the Divide Peak SNOTEL gage located south-east of Muddy Creek. Therefore, flows were certainly higher than normal during runoff along Muddy Creek in 2009, and ample evidence of the higher flows was seen in the field. Because natural gas related development is very limited in the Muddy Creek drainage at this time, the channel changes observed this year are attributed to the high precipitation and runoff.

Field work in August 2009 included a geomorphic and habitat measurements and water quality sampling. The six reference cross-sections (one at each site) were remeasured using a total station. Comparing the cross sections to those obtained in 2008, four reference cross-sections changed significantly and two remained relatively

unchanged. The patterns of fresh erosion and deposition documented at the reference cross-sections were observed at numerous locations along the stream. It is apparent that a large amount of sediment moved during runoff in Muddy Creek this year with sediment eroding, moving downstream, and depositing in other areas.

Bed measurements were taken using Wolman pebble count methods (Wolman, 1954) and embeddedness measurements (Sennatt et al, 2006). Pebble counts were similar to those obtained in the same locations as 2008. The condition of the riffles at the three upstream sites is similar to that of 2008 presumably because the bed material is coarse. However, at the three downstream sites, the bed material in the riffles is much smaller and the riffles are deteriorating and sometimes disappearing and reforming.

The embeddedness measurements are also similar to those collected in 2008. As in 2008, the pools are 100% embedded and the riffles are 0% embedded. To attain intermediate numbers areas just upstream or downstream of riffles were sampled, but the selection of these areas was targeted to obtaining a reasonable count and did not represent the condition of the stream well.

Erosion pins set in 2008 were remeasured this year. Although most of the erosion pins showed fairly small changes since 2008, the erosion pin at Rocky Crossing (just upstream of UMC3) showed significant bank retreat of 0.72 ft. This is a relatively low bank (about 3 ft. high) that is more susceptible to lateral movement than the higher banks typical of the monitoring sites.

Bank stability was evaluated using the Bank Erosion Hazard Index and Near Bank Stress metrics developed by Rosgen (1996). Ratings for 2009 were very similar to those obtained in 2008 and range from high to extreme. This indicates that the existing condition on Muddy Creek is highly erosive and produces large amounts of sediment.

Residual pool depths were measured at all sites and compared to 2008 depths. All pools showed some variation in residual depth compared to the previous year with depths being sometimes greater and sometimes less. Variations from the previous year were greatest at the downstream stations where riffles are unstable and pools are reforming with the changing bed conditions.

Water quality of upper Muddy Creek in August 2009 was very similar to that observed in 2008. Flows were significantly higher this year ranging from 4.64 to 5.66 cfs presumably due to the relatively wet summer of 2009. Common ions concentrations were similar to those of 2008, and total suspended sediment concentrations were also similar. Total selenium was less than 0.005 mg/L at all three sites, which is below the chronic aquatic life standard. The water quality does not appear to have changed significantly from 2008 in spite of the higher flows.

Initial monitoring activities for geomorphology, aquatic habitat and water quality were conducted by CDM between August 18 and 23, 2008. The results are summarized in the 2008 Muddy Creek Monitoring Report (CDM, 2008b).

Monitoring in August 2009 occurred after a relatively high spring runoff. Water year 2009 was one of the higher precipitation years on record at the Divide Creek SNOTEL site, which is a nearby precipitation gage with 28 years of record (http://www.wcc.nrcs.usda.gov/snotel/Wyoming/wyoming.html). The 2009 precipitation at this site was 42.2 inches and the mean for the period of record is 33.6 inches. April 2009 was the second wettest month in the entire period of record. Therefore, flows were certainly higher than normal during runoff along Muddy Creek in 2009, and ample evidence of the higher flows was seen in the field. Because natural gas related development is very limited in the Muddy Creek drainage at this time, the changes observed in the channel this year are attributed to the high precipitation and runoff that occurred in 2009.

1.2 Project Organization

Monitoring of Upper Muddy Creek is the responsibility of Anadarko and its consultant. Additional monitoring tasks are being conducted on the Upper Muddy Creek as well as on the Lower Muddy Creek and the Muddy Creek tributaries by various agencies. Water quality data is collected throughout the Muddy Creek drainage by the Little Snake River Conservation District (LSRCD) as it has been in the past. The LSRCD also measures flows at these stations. The Wyoming Game and Fish Department (WGFD) is continuing fish distribution and population studies in the drainage as well. The BLM as the lead agency for the Atlantic Rim Coal Bed Methane and Natural Gas Development Project coordinates the various monitoring efforts through the Muddy Creek Working Group.

1.3 Report Organization

This is the second annual report of monitoring activities conducted by Anadarko on the Atlantic Rim Coal Bed Methane and Natural Gas Project. Section 2 of this report presents the results of the geomorphic and aquatic habitat monitoring, and Section 3 presents the water quality monitoring results. Appendices A through D present the data developed or collected in 2009 as part of this assessment and monitoring effort.

The watershed assessment can be found in the 2008 Muddy Creek Monitoring Report (CDM, 2008b). Evaluation of most monitoring data will be conducted in future years after sufficient data have been collected to provide meaningful comparison.

Insert Figure 1-1

Insert Figure 1-2

Section 2 Geomorphic and Aquatic Habitat Monitoring

2.1 2009 Monitoring Event

Monitoring activities were conducted in Upper Muddy Creek during the period of August 4 through 6, 2009. The same six sites monitored during the 2008 monitoring activities were monitored during the 2009 event and work included geomorphic and aquatic habitat monitoring as well as water quality monitoring. The locations of the monitored sites are shown on Figure 2-1. Maps of each individual site are found in Appendix A.

Monitoring activities performed at each site are described in the Muddy Creek Monitoring Plan (CDM, 2008a). In summary, the following activities for geomorphic and aquatic habitat monitoring were performed:

- The monumented, reference cross-sections located during the 2008 monitoring activities were re-surveyed. Cross-section information was collected to allow measurement of channel changes over time.
- Banks selected for evaluation using the Bank Erosion Hazard Index (BEHI) (Rosgen, 1996) were evaluated and photographed.
- Wolman pebble counts and embeddedness measurements were performed at riffles and other areas with appropriate bed material conditions.
- The bank erosion pins were measured and compared to the previous year.
- Residual depths of pools were measured.

2.2 Geomorphic Monitoring

2.2.1 Cross-sections

The reference cross-section at each site was surveyed and compared to the previous year's survey. The remaining cross-sections were not surveyed during the 2009 field activities. The cross-sections surveyed during the 2008 field season are compared to the 2009 cross-sections in Appendix B. The significant changes in the sections are described here.

Section 4 at site UMC1 basically unchanged from the previous year. This may be due to coarse riffle at this section which remained stable during the high flow of 2009. At site UMC2, cross-section 5 shows significant change in the right bank where sloughing and/or deposition occurred in mid-bank and erosion occurred on the lower bank. There was no apparent vertical change in the bed. Cross-section 3 at site UMC3 shows considerable erosion occurred on the lower left bank.

Figure 2-1

Cross-section 3 at UMC4 shows a small amount of erosion in the lower left bank and soume sloughing in the upper right bank but the changes are relatively small. The thalweg elevation remains the same. At UMC5, cross-section 2 shows significant deposition on the lower left bank and an increase in the bed elevation by almost one foot. UMC6 cross-section 6 is essentially identical to its 2008 cross section. In summary, four reference cross-sections changed significantly from 2008 and two remained relatively unchanged.

The patterns of fresh erosion and deposition documented at the reference cross-sections were observed at numerous locations along the stream. It is apparent that a large amount of sediment moved during runoff in Muddy Creek this year with sediment eroding, moving downstream, and depositing in other areas. Figure 2-2 is an example of an area that shows fresh deposition on the left bank, erosion on the right bank as well as a presumed high water indicator on the far bank.

Figure 2-2. Erosion and deposition features upstream of Cross-section 1 at Site UMC4.

2.3 Bed Measurements

Wolman pebble counts (Wolman, 1954) and embeddedness measurements were performed at the same three locations measured during the 2008 field activities. Pebble counts were performed by measuring approximately 100 individual pebbles at each location with a gravelometer. At three locations (UMC1, XS-4; UMC4, XS-5;

and UMC5, XS-1), fewer pebbles were counted because the riffles were very small and the locations were not performing as riffles anymore. The pebbles were sorted into standard size classes and then a cumulative size distribution was plotted (Appendix C). Pebble counts were only performed at riffles because pool materials were generally sand and silt and not amenable to this measurement. Three pebble counts were performed at UMC1 at the same locations to the 2008 locations. Only two pebble counts were performed at UMC4 and UMC6 because the reaches only contained two riffles. One pebble count was performed at UMC5; although at this location, the riffle was limited in extent and clay was observed under the pebbles-sand mixture. Plots of the cumulative size distributions can be found in Appendix C. In Table 2-1, D_{50} (median diameter) values for all measured 2009 cross-sections are displayed and compared to the 2008 results.

Table 2-1: D_{50} Values at Pebble Count Cross-sections for 2008 and 2009.

Site	Cross-section and D_{50} range (mm) (2008/2009)		
UMC1	XS-1	XS-4	XS-6
	22.6-32/22.6-32	90-128/90-128	64-90/45-64
UMC2	XS-1	XS-3	XS-6
	32-45/32	22.6-32/11-16	8-11/8-11
UMC3	XS-1	XS-4	XS-6
	45-64/45	45-64/32	45-64/45
UMC4	XS-1	XS-5	
	22.6-32/11-16	11-16/11-16	
UMC5	XS-1		
	5.6-8/8		
UMC6	XS-1	XS-4	
	11-16/16-22.6	16-22.6/16-22.6	

At most sections, the 2009 median sizes are close to the 2008 median sizes. This suggests that there has been little change in riffle materials although the deterioration of riffles comprised of smaller materials was noted. The riffles in the upper three sites appeared to have maintained stability since last measured in 2008. This is attributed to the larger sizes of the riffle stone. However, at the downstream three stations, where bed materials are much smaller in the riffles, riffles were partially or wholly destroyed in the high flow. Thus, these downstream riffles appear to be

naturally unstable under high flow conditions. Figure 2-3 shows a deteriorating riffle at Site UMC6.

Figure 2-3. Deteriorating riffle at UMC1, XS-1.

The embeddedness measurement method followed the U.S. Geological Survey's National Water-Quality Assessment Program as described in Sennatt et al (2006). Embeddedness was measured by collecting 15 pebbles at each transect. The percent of the clast's height that was buried in silt was estimated. These percentages were then averaged to estimate embeddedness at that transect. At UMC2, UMC5, and UMC6, all areas were either clean gravel or larger clasts with no siltation or the bed was entirely silt. Therefore, embeddedness measurements were not taken at these sites. The results of embeddedness measurements are shown in Table 2-2. It is important to note that these measurements were largely taken in transitional zones between riffles and pools. Almost all of the pools throughout the study reach were 100% embedded and, likewise, almost all of the riffles were 0% embedded.

2.4 Bank Stability

2.4.1 Erosion Pins

Erosion Pins were installed near the monumented cross-section at each site during the 2008 field investigation. An erosion pin is a four-foot steel bar driven horizontally into the bank until a few inches protrude. Pins were placed in vertical sections of

Table 2-2: Average Embeddedness Values and Locations for 2008/2009.

UMC1	**30' below XS-1 Riffle**	**50' downstream of XS-2**	**Immediately below XS-5**
	32.0%/58.0%	52.7%/61%	52.7%/40.7%
UMC3	**Downstream of XS-1 Riffle**	**Upstream of XS-6**	
	38%/51.3%	31%/42%	
UMC4	**Upstream of XS-4 (1)**		
	44%		

(1) No measurement in 2008.

bank that are likely to erode (for example, outside of bends), and which are difficult to monitor using surveyed cross-sections.

The visible pins were measured during the 2009 field activities and were compared to the measurements taken in 2008. The measurements and differences are shown in Table 2-3 below. The measurements indicate that erosion is generally occurring at all compared locations ranging from 0.01 feet (Webber Drop right bank) to 0.72 feet (Rocky Crossing). At one location (UMC5, XS-3) there was a slight decrease in the measurement because of bank slumping. At two locations, UMC1 and UMC2, the pins were measured on the top and bottom of the pin because the pin was partially covered. The larger value was used in the interpretation. Two new pins (UMC5 and UMC6) were measured during this investigation and they will be re-measured during future monitoring activities.

Table 2-3: Locations and Protruding Lengths of Bank Erosion Pins for 2008 and 2009.

Site	Location	Length (ft)-Apr 2008	Length (ft)-Aug 2008	Length (ft)-Aug 2009	Difference
UMC1	XS-4, Right bank		0.33	0.30 top 0.42 bottom	0.09
UMC2	XS-5, Right bank		0.24	0.30 top 0.25 bottom	0.06
UMC3	XS-3, Right bank	0.22	0.27	0.35	0.13
UMC4	XS-3, Right bank		0.37	0.42	0.05
UMC5	XS-3, Right bank		0.38	0.35	-0.03
UMC5	XS-2, Right bank		?	0.33	
UMC6	XS-3, Right bank		?	0.33	
Webber drop	Left bank	0.44	Not visible	Not visible	
Webber drop	Right bank	0.31	0.24	0.25	0.01
Rocky Crossing	Left bank	0.43	0.51	1.23	0.72

Although most of the erosion pins showed fairly small changes since 2008, the erosion pin at Rocky Crossing (just upstream of UMC3) showed significant bank retreat.

This is a relatively low bank (about 3 ft. high) that is more susceptible to lateral movement than the higher banks typical of the monitoring sites.

2.4.2 Bank Erosion Hazard Index

Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) methods are presented in *Applied River Morphology* (Rosgen, 1996). BEHI looks at five indices of bank stability and assigns numeric values to the observed conditions. The index values are summed and subjected to adjustment for bank material type and stratification to arrive at a qualitative descriptor of bank stability. At each site, BEHI evaluations were performed on the more susceptible bank at each cross-section unless neither bank was applicable.

Many of the evaluated banks displayed characteristics not accounted for in the BEHI method. For instance, many banks displayed two or more distinct bank angles. Often, the bank would have a low angle near the water and then have a slope near vertical at the top. In these cases, an average bank angle weighted by the height of each section was used.

Appendix B contains the evaluation of BEHI at each evaluated bank and the corresponding photos. Table 2-4 shows BEHI and Near Bank Stress ratings for all the evaluated banks. The 2009 BEHI ratings range from "high" to "extreme", with most banks rating as "high" or "very high". These ratings indicate that most of the measured banks had a high potential for erosion. When compared to the 2008 ratings, the rating decreased in the following sites UMC1, XS-6; UMC2, XS1; UMC3, XS-3; UMC5, XS-3; and UMC6, XS-1 and XS-6 while the rating increased at sites UMC1, XS-4; UMC3, XS-5; and UMC5, XS-6.

2.4.3 Near Bank Stress

NBS evaluates the rate at which a bank is expected to supply sediment to a stream based on the local hydraulic conditions. Several options are available for estimating the effects of bank stress in the *Watershed Assessment of River Stability and Sediment Supply* website of EPA (http://www.epa.gov/WARSSS/monitor/method.htm). The method chosen in 2008 was the width to radius of curvature ratio. Because the planform of the stream did not change significantly in 2009, no change in the NBS ratings occurred. Therefore, the NBS evaluations calculated for the 2008 monitoring activities and are included in Table 2-4.

The comparison of 2009 to 2008 data reveal no trend in bank erosion changes with some banks changing to a more severe rating and some changing to a less severe rating but none changing more than one rating step. BEHI ratings are generally in the high to extreme range with only one moderate rating. This suggests that the baseline condition of this stream is one of considerable bank erosion.

Table 2-4: BEHI Rating for 2008 and 2009 and NBS Ratings

Site	Location	BEHI Rating (2008)	BEHI Rating (2009)	NBS Rating	Photo No. in Appendix B
UMC1	XS1, Left bank	High	High	Straight Reach	1
	XS1, Right bank	High		Straight Reach	NA
	XS2, Right bank	High	High	Extreme	2
	XS4, Right bank	High	Very high	Straight Reach	3
	XS6, Left bank	Moderate		Extreme	NA
	XS6, Right bank	Very High	High	Inside of bend	4
UMC2	XS1, Left bank	Very high	High	Extreme	5
	XS2, Right bank	High	High	Very high	6
	XS4, Left bank	High	High	Extreme	7
	XS5, Right bank	Very high	Very high	Moderate	8
	XS6, Right bank	Very high	Very high	Extreme	9
UMC3	XS1, Left bank	Very high	Very high	Moderate	10
	XS2, Right bank	High	High	Extreme	11
	XS3, Right bank	Very high	High	Straight Reach	12
	XS5, Left bank	High	Very high	Extreme	13
	XS6, Right bank	High	High	Very high	14
UMC4	XS1, Left bank	High	High	Low	15
	XS3, Right bank	High	High	Very low	16
	XS6, Right bank	Very high	Very high	Moderate	17
UMC5	XS1, Right bank	High	High	Straight Reach	18
	XS2, Right bank	High	High	Straight Reach	19
	Below XS3, Right bank	Very high	High	Low	20
	XS4, Left bank	High	High	Straight Reach	NA
	XS5, Right bank	High	High	Straight Reach	21
	XS6, Right bank	High	Very high	Very low	22
UMC6	XS1, Left bank	Extreme	Very high	NA	24
	XS3, Right bank	High	High	NA	23
	XS4, Right bank	Extreme	Extreme	Straight reach	25
	XS6, Left bank	Extreme	Very High	N/A	26

NA – Not available

Shading indicates reference section.

2.5 Residual Pool Depths

Residual pool depth refers to the depth of the pools remaining when water stops flowing, leaving water only in the pools. The depth was obtained by subtracting the elevation at the deepest point in a pool from the elevation of the riffle crest downstream of the pool. Measured depths may not always be maximum pool depths because turbid water prevented visual identification of the deepest pool location. Residual pool depths are shown in Table 2-5. New pools formed were observed

during the 2009 field activities and included in Table 2-5. All pools showed some variation in residual depth compared to the previous year with depths being sometimes greater and sometimes less. Variations from the previous year were greatest at the downstream stations where riffles are unstable and pools are reforming with the changing bed conditions.

Table 2-5. Summary of Residual Pool Depth Measurements for 2008 and 2009.

Site	Downstream Riffle Section	2008 Residual Pool Depth (ft)	2009 Residual Pool Depth (ft)
UMC-1	XS-3	1.9	2.2
UMC-1	XS-6	1.7	1.2
UMC-2	XS-3	0.9	0.7
UMC-2	XS-5	2.0	
UMC-2	55' downstream of XS-6	1.4	
UMC3	XS-2		2.2
UMC-3	XS-3	1.3	0.6
UMC-3	XS-6	2.4	1.9
UMC-4	XS-3	0.5	1.6
UMC-4	XS-5	1.7	2.4
UMC-5	XS-3	0.3	Not visible
UMC-5	XS-6	2.0	0.9
UMC6	XS-3		2.1
UMC6	XS-4		1.6
UMC6	XS-5		1.4
UMC6	XS-6		1.5
Average		1.5	1.6

Section 3 Water Quality Sampling

3.1 Measurement Methods

During the 2008 and 2009 site monitoring events, water quality samples were collected along with field measurements at three sites, UMC1, UMC3 and UMC6. These sites represent the upstream, middle and downstream portions of the project area on Upper Muddy Creek. As described in the Muddy Creek Monitoring Plan (CDM, 2008a), measurements were taken for discharge, pH, electrical conductivity, dissolved oxygen, temperature and turbidity. Discharge was measured with a Marsh-McBirney flow meter and field parameters were measured with a Hydrolab system.

Water quality samples were collected for common ions, total suspended solid (TSS), and dissolved selenium. Common ions and the metals sample were grab samples. The Muddy Creek Monitoring Plan (CDM, 2008a) called for depth integrated TSS sampling; however, the water depths were too shallow to permit sampling with the DH-48 sediment sampler. As an alternative, grab samples were collected at the center of the quartile flow sections and composited for the TSS sample. The field filtering apparatus used during the 2008 field activities proved to be inadequate to filter the metals sample; therefore, the selenium analysis was a total metals measurement. During the 2009 field activities, the analysis was performed for dissolved selenium as specified in the Muddy Creek Monitoring Plan (CDM, 2008a). There was also some uncertainty in the field measurements for electrical conductivity and turbidity; therefore, samples were collected for a laboratory measurement of these parameters.

Samples were delivered to Energy Laboratories in Helena, Montana in a chilled shipping container following chain-of-custody procedures on August 7, 2009.

3.2 Water Quality Sampling Results

Field measurements measured during the August 2008 and 2009 sampling event are summarized in Table 3-1.

Table 3-1. Field Parameters from August 2008 and 2009 Water Quality Sampling – Upper Muddy Creek.

Sample Site	Discharge (cfs) (2008/2009)	pH (2008/2009)	Temp. (°C) (2008/2009)	EC (mS) – Field (2008/2009)	EC (mS) - Lab	DO (mg/L) (2008/2009)	Turbidity* (2008/2009)	Turbidity* Lab (2009)
UMC1	2.29/5.66	7.77/8.23	14.4/20.85	0.548/0.740	0.556/0.664	7.32/8.74	14.9/121	16.0
UMC3	1.68/5.74	8.02/8.43	14.8/22.54	0.570/0.738	0.578/0.660	7.81/8.66	13.5/56	6.15
UMC6	1.46/4.64	8.02/8.05	22.6/18.03	0.607/0.763	0.616/0.688	7.5/7.92	14.8/36.6	6.88

* Nepholometric Turbidity Units (NTU)

Flow in the Upper Muddy Creek project area appeared to be continuous although the discharge decreased in the downstream direction. Flows in August were signifi-

cantly higher in 2009 than 2008 presumably due to the relatively wet summer of 2009. Field and laboratory electrical conductivities differed with the lab measurements preferred. Turbidity measurements collected in the field compared to laboratory measurements were considerably higher, which could be attributed to the difficulty calibrating the instrument in the field. Therefore, the lab measurements are considered more accurate. Dissolved oxygen values and pH values were similar between stations but slightly higher than measurements collected in 2008. The 2009 temperature readings were higher than the 2008 readings. The higher water temperature at UMC1 and UMC3 compared to UMC6 were probably due to the sampling days' weather conditions. The ambient temperatures on August 4 and 5 were considerably higher compared to August 6, 2009 ambient temperatures. The variation in water temperature with the previous year's data is also explained by daily air temperatures.

Table 3-2 presents the laboratory analytical data for 2008 and 2009, and Appendix D contains the laboratory data sheets for 2009. The 2008 laboratory data can be found in the 2008 Muddy Creek Monitoring Report (CDM, 2008b).

Table 3-2. Common Ions, Selenium and TSS from August 2008 Water Quality Sampling – Upper Muddy Creek.

Sample Site	UMC1		UMC3		UMC3-Dup		UMC6	
	2008	2009	2008	2009	2008	2009	2008	2009
Ca	61	76	60	71	61	72	58	73
Mg	17	25	19	26	19	26	19	27
K	3	4	3	4	3	4	4	4
Na	20	29	25	32	25	30	31	34
Alkalinity	150	170	150	160	150	160	150	160
Cl	5	6	6	6	6	6	7	7
SO_4	140	180	150	180	150	180	180	200
Dissolved Se	0.002[1]	<0.005	0.002[1]	<0.005	0.002[1]	<0.005	0.001[1]	<0.005
TSS	10	23	11	<10	<10	10	12	11

Notes:
[1] Samples were analyzed for total selenium.
Concentrations are in mg/L.

Common ions collected during the 2009 sampling activities were generally consistent between the three sampling sites. Common ion concentrations were insignificantly higher during the 2009 sampling event than during the 2008 sampling event. The dissolved selenium concentrations were less than 5 µg/L, which is below the chronic aquatic life standard of 5 µg/L. Total suspended solids (TSS) concentrations were in the range of 10 to 23 mg/L at the three sites and were somewhat higher at UMC1during the 2009 event than the 2008 sampling event. This may be attributed to the presence of cows in the stream during the 2009 sampling event at UMC1. In general, the water quality does not appear to have changed significantly from 2008 in spite of the higher flows.

3.3 Quality Assurance/Quality Control

Laboratory quality assurance/quality control (QA/QC) reports are included in Appendix D. All method blanks were below detection limits and all percent recoveries were within 20% of the control value.

A field duplicate sample was collected at site UMC3 and analysis results for this sample are presented in Table 3-2. All parameters had zero relative percent difference between the duplicate and natural sample except for calcium, sodium, and TSS. The natural sample for calcium was 71 mg/L while the duplicate was 72 mg/L with a percent difference of 1.4. The natural sample for sodium was 32 mg/L and the duplicate sample was 30 mg/L with a percent difference of 6.5. Percent difference between +/- 20 percent area considered acceptable. The natural TSS sample measured <10 mg/L and the duplicate was 10 mg/L. Because the measurements are near the detection limit, this relative percent difference is acceptable.

Section 4 References

Bureau of Land Management, 2007. Final Environmental Impact Statement for the Atlantic Rim Natural Gas Field Development Project, Carbon County, Wyoming. Rawlins Field Office, Rawlins, Wyoming.

CDM, 2008a. Muddy Creek Monitoring Plan, August.

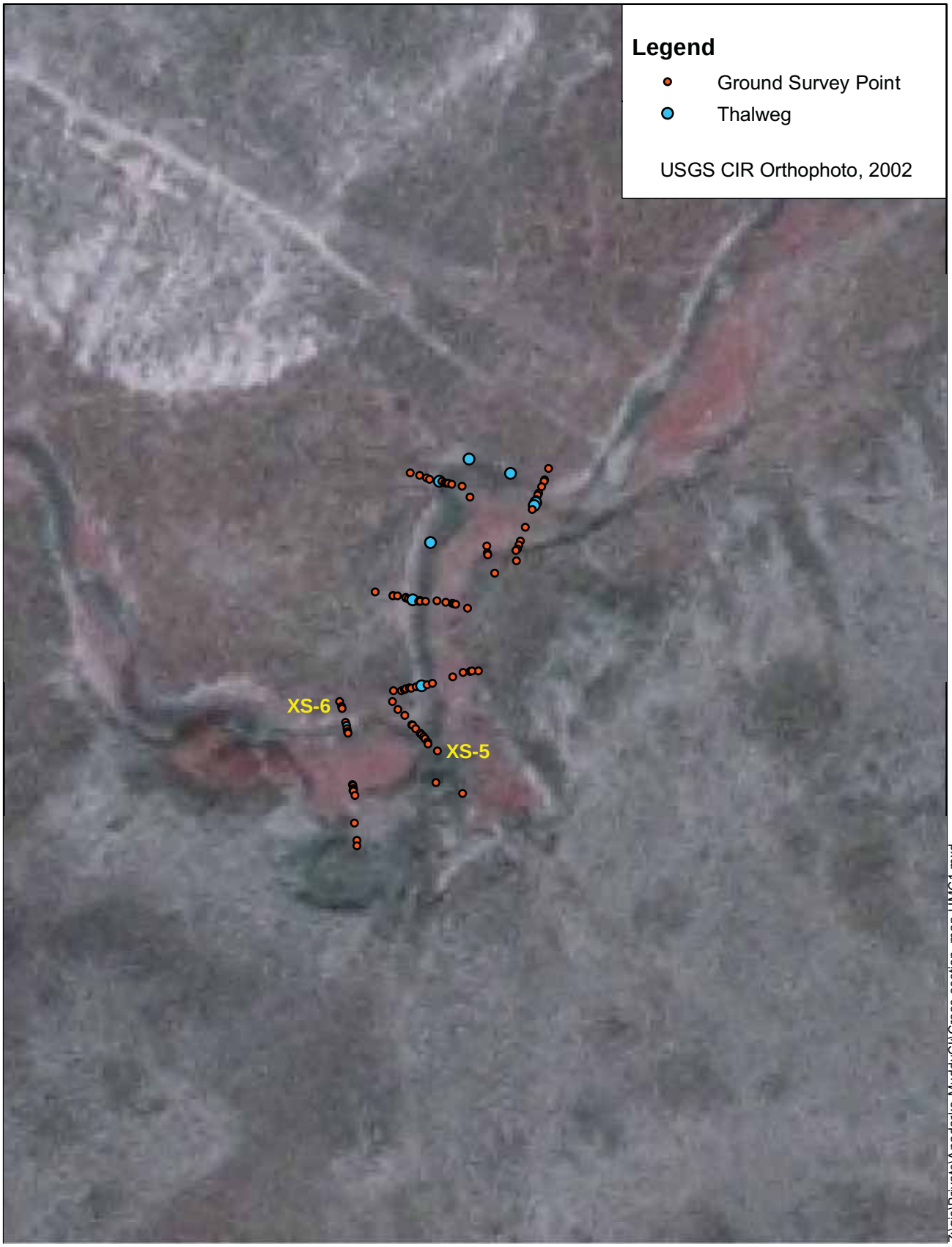
CDM, 2008b. Muddy Creek Monitoring Report – 2008, February. Rosgen D. L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Sennatt, K.M, N.L. Salant, C.E. Renshaw, F.J. Magilligan, 2006. Assessment of Methods for Measuring Embeddedness: Application to Sedimentation in Flow Regulated Streams. Journal of the American Water Resources Association (JAWRA) 42(6):1671-1682.

U.S. Department of Agriculture, Natural Resource Conservation Service, 2009. http://www.wcc.nrcs.usda.gov/snotel/Wyoming/wyoming.html.U.S. Geological Survey, 2002. Color infrared orthophotos of Wyoming available at http://wgiac2.state.wy.us/html/aboutDOQQ2002.asp

Wolman, M.G., 1954. A Method for Sampling Coarse River Bed Material. Transactions of the American Geophysical Union 35(6): 951-956.

Appendix A

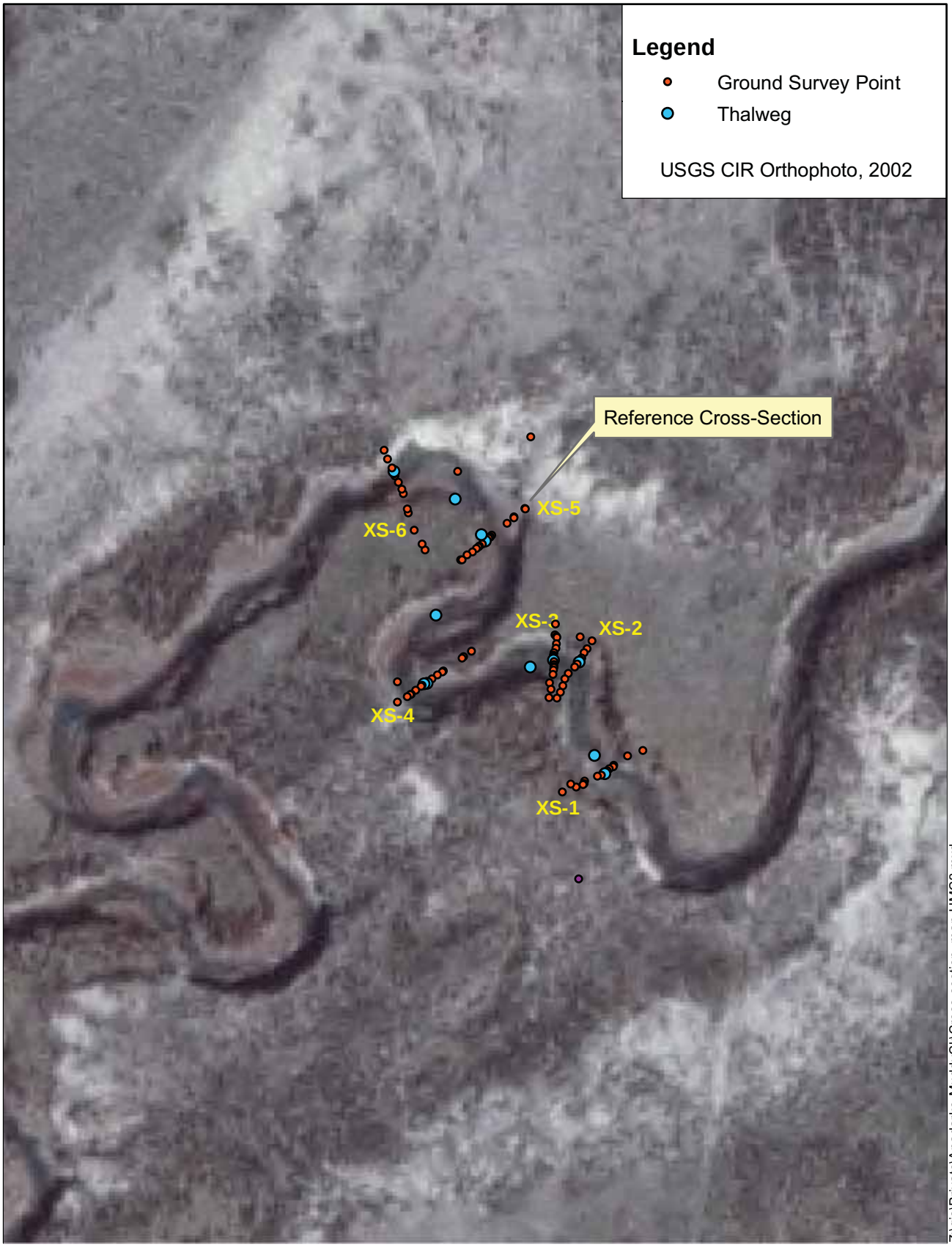


Monitoring Site UMC-1
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

0 50 100 200 300 400 Feet

CDM



Monitoring Site UMC-2
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

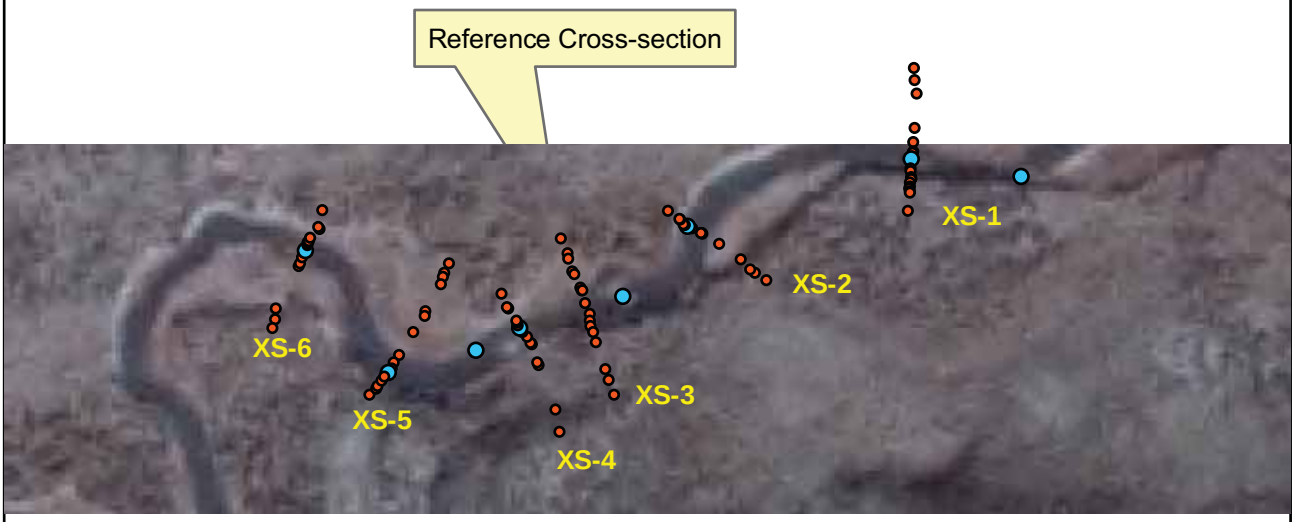
0 50 100 200 300 400 Feet

CDM

Legend

- Ground Survey Point
- Thalweg

USGS CIR Orthophoto, 2002



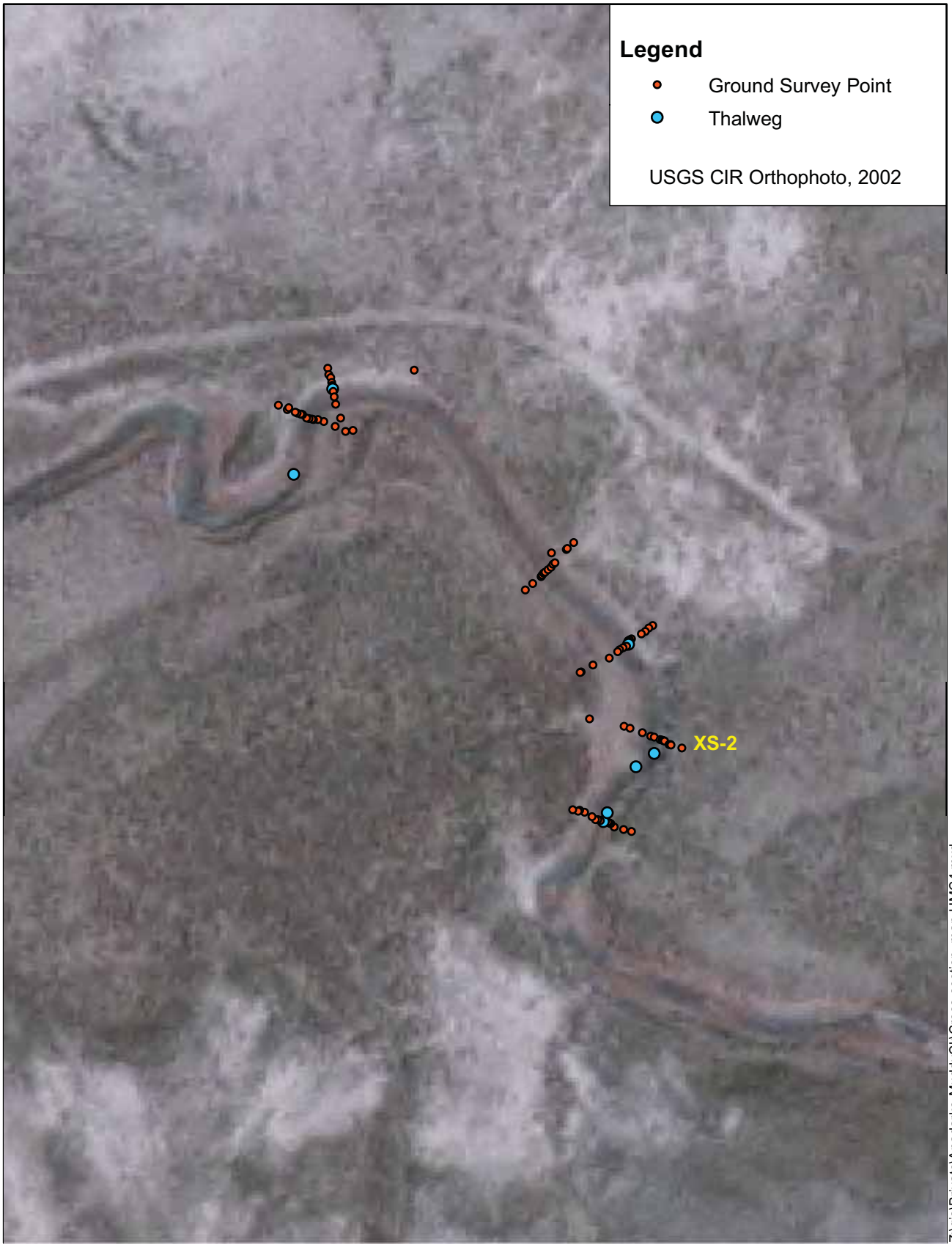
Z:\gis\Private\Anadarko-MuddyCk\Cross-section_map-UMC3.mxd

Monitoring Site UMC-3
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

0 50 100 200 300 400 Feet

CDM



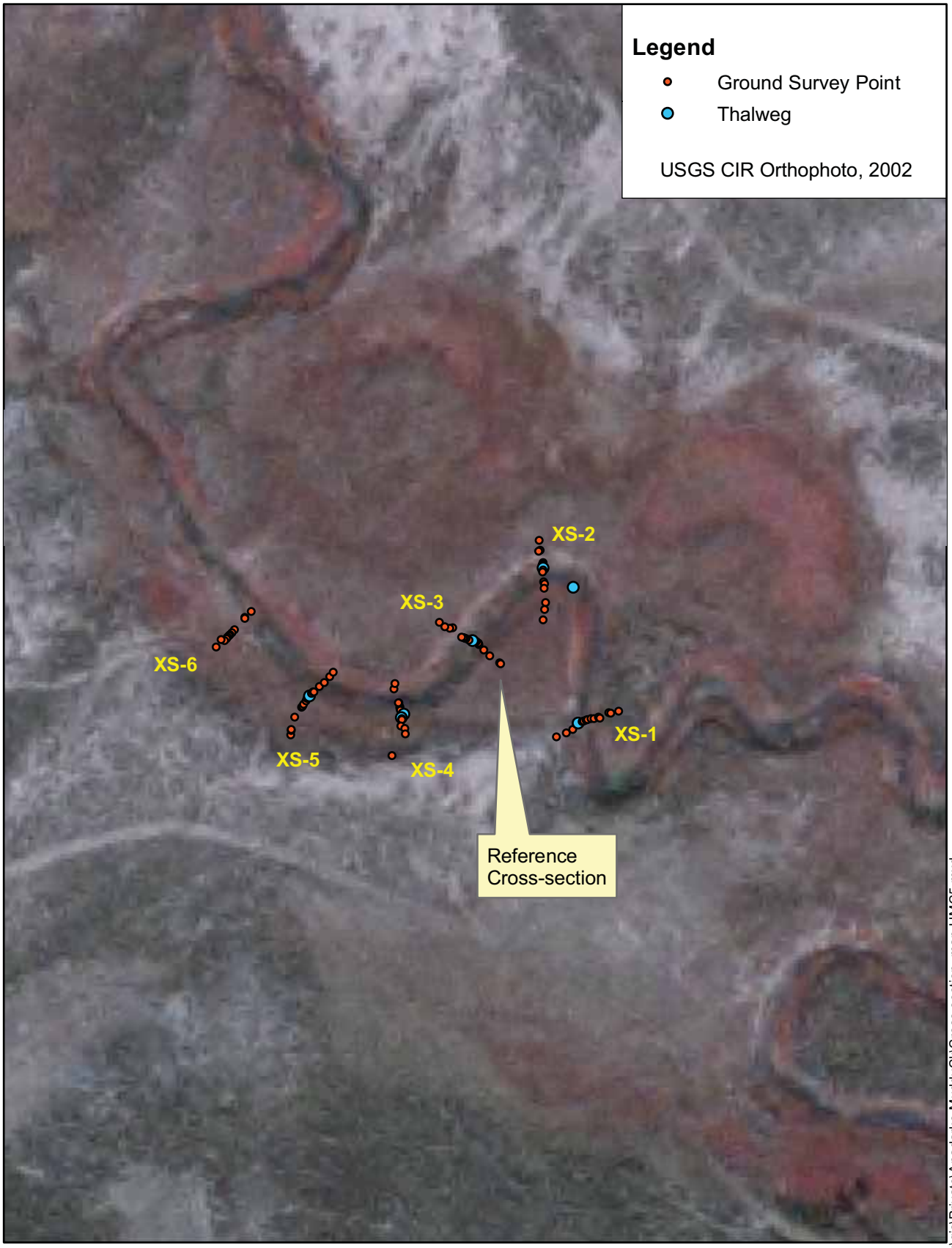
Z:\gis\Private\Anadarko-MuddyCk\Cross-section_map-UMC4.mxd

Monitoring Site UMC-4
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

0 50 100 200 300 400 Feet

CDM



Monitoring Site UMC-5
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

0 50 100 200 300 400 Feet

CDM

Z:\gis\Private\Anadarko-MuddyCk\Cross-section_map-UMC5.mxd

Cross Section UMC-6
Plan View
Upper Muddy Creek
Atlantic Rim Project
Carbon County, Wyoming

N

0 50 100 200 300 400 Feet

CDM

Z:\gis\Private\Anadarko-MuddyCk\Cross-section_map-UMC6.mxd

REFERENCE CROSS-SECTION PHOTOS-2009

UMC1, XS-4, View Upstream

UMC1, XS-4, View Downstream

UMC1 XS-4

UMC2, XS-5, Right Bank

UMC2, XS-5, View Upstream

UMC2, XS-5, View Downstream

REFERENCE CROSS-SECTION PHOTOS-2009

UMC3, XS-3, View Upstream

UMC3, XS-3, View Downstream

UMC3, XS-3 Right Bank

UMC4, XS-3 Right Bank

UMC4, XS-3, View Upstream

UMC4, XS-3, View Downstream

REFERENCE CROSS-SECTION PHOTOS-2009

UMC5, XS-3, View Upstream

UMC5, XS-3, View Downstream

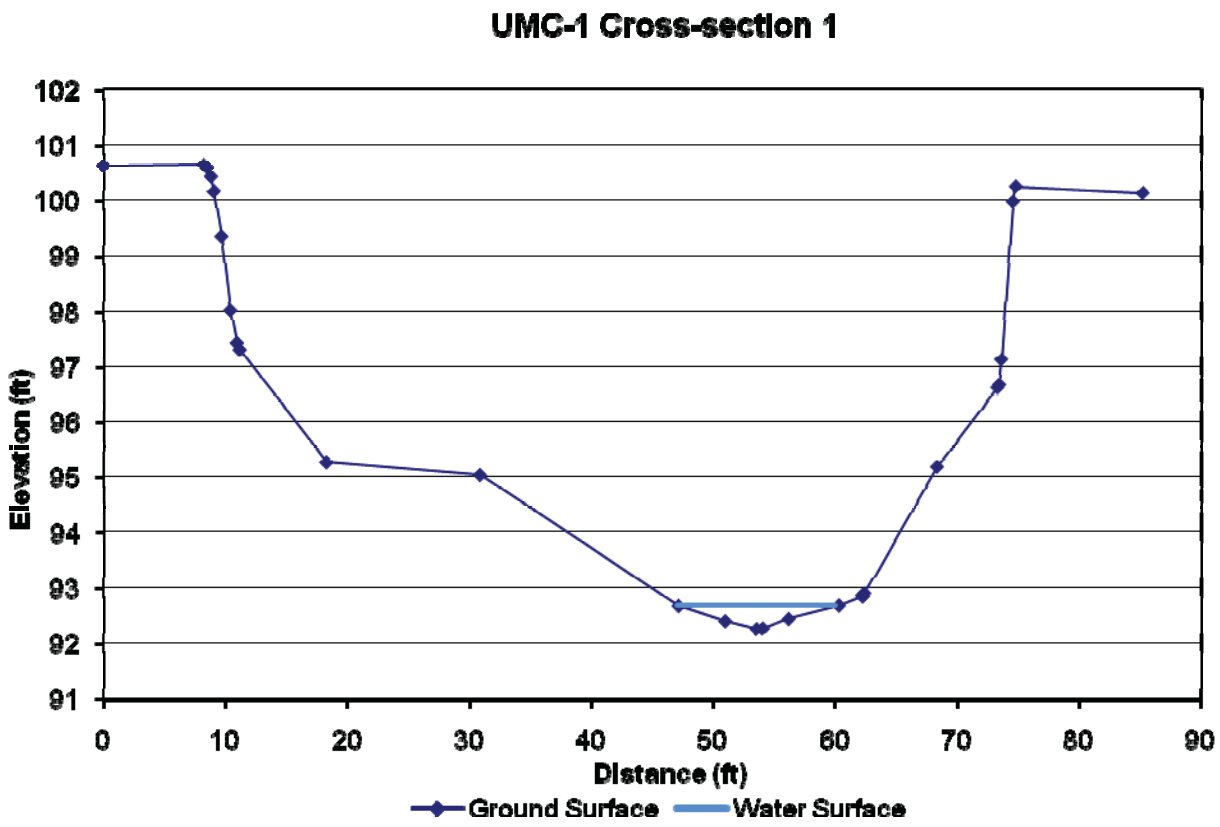
UMC5, XS-3, Right Bank

UMC6, XS-3, Right Bank

UMC6, XS-3, View Upstream

UMC6, XS-3, View Downstream

Appendix B

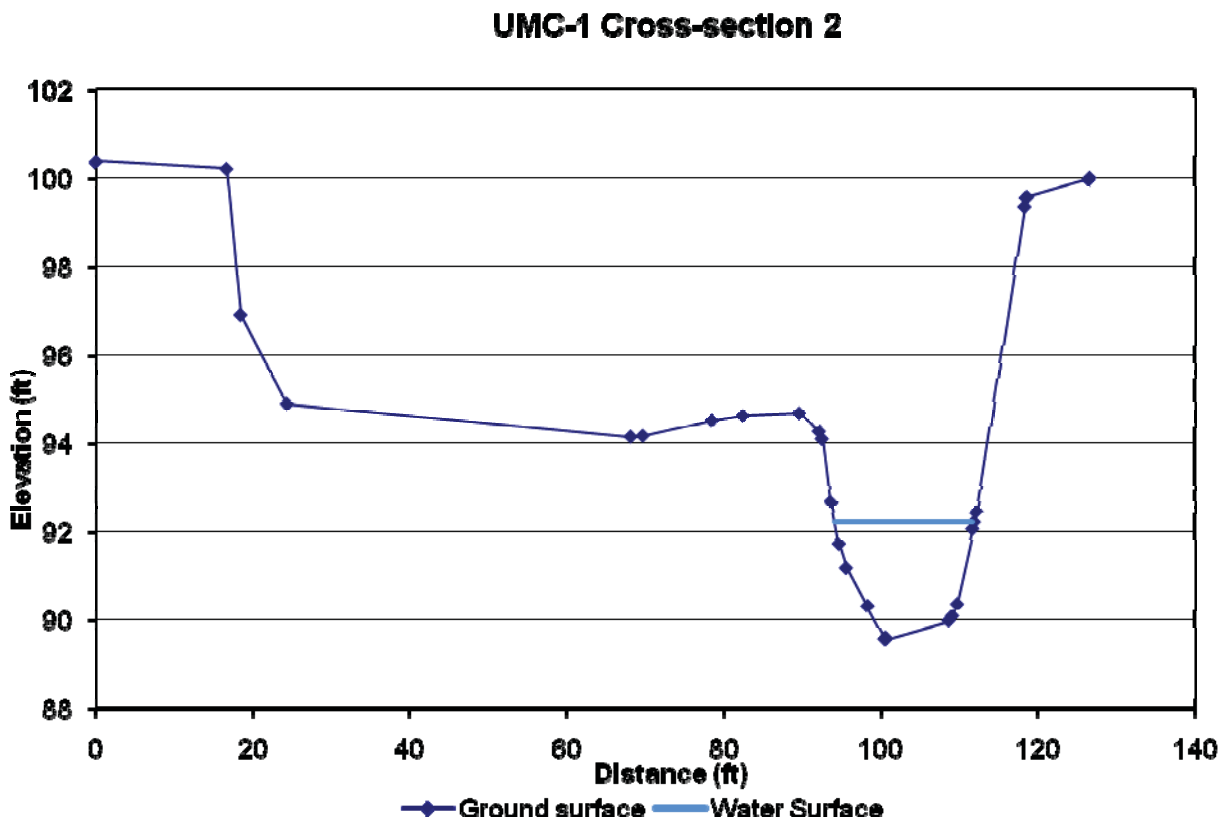


Note: Cross section was surveyed during the 2008 field activites.

UMC1, Cross-section 1, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2.5	8.6
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	58	3.8
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	39.4
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 1. UMC1, XS-1, Left Bank

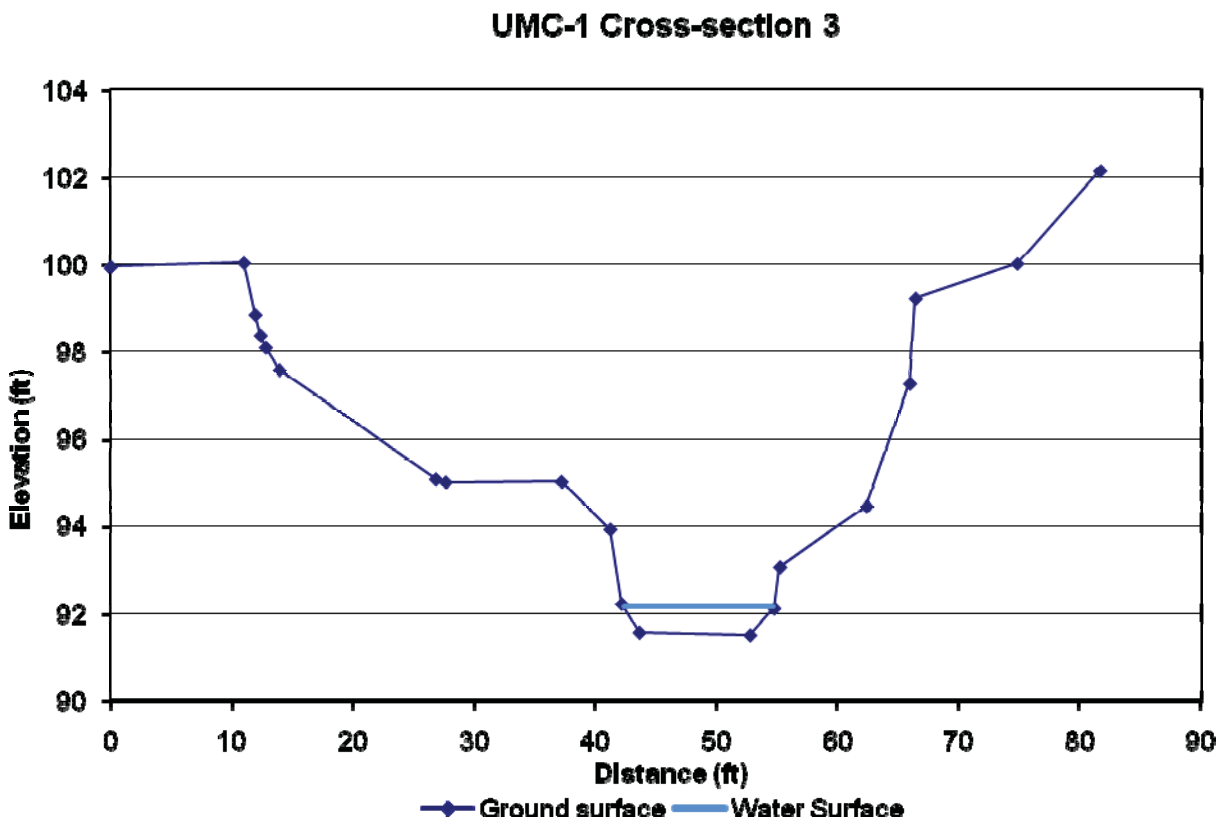


Note: Cross section was surveyed during the 2008 field activites.

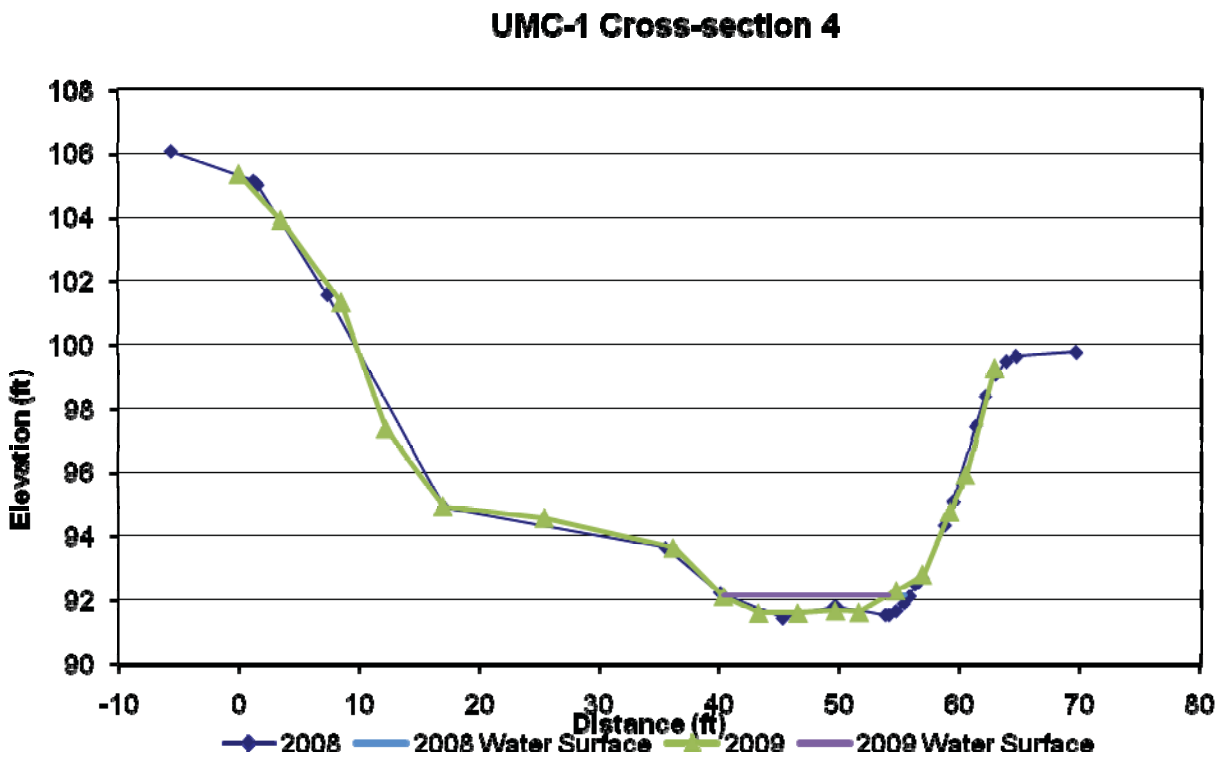
UMC1, Cross-section 2, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	1.7	6.2
Root Depth/Bank ht	0.2	6.5
Root Density	<5%	10
Bank Angle	64	4.3
Surface Protection	26%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	37.0
BEHI Rating	--	**High**
Radius of Curvature	23	--
Bankfull Width	90.3	--
Rc/W	0.255	--
NBS Rating	--	**Extreme**

Photo 2. UMC1, XS-2, Right Bank



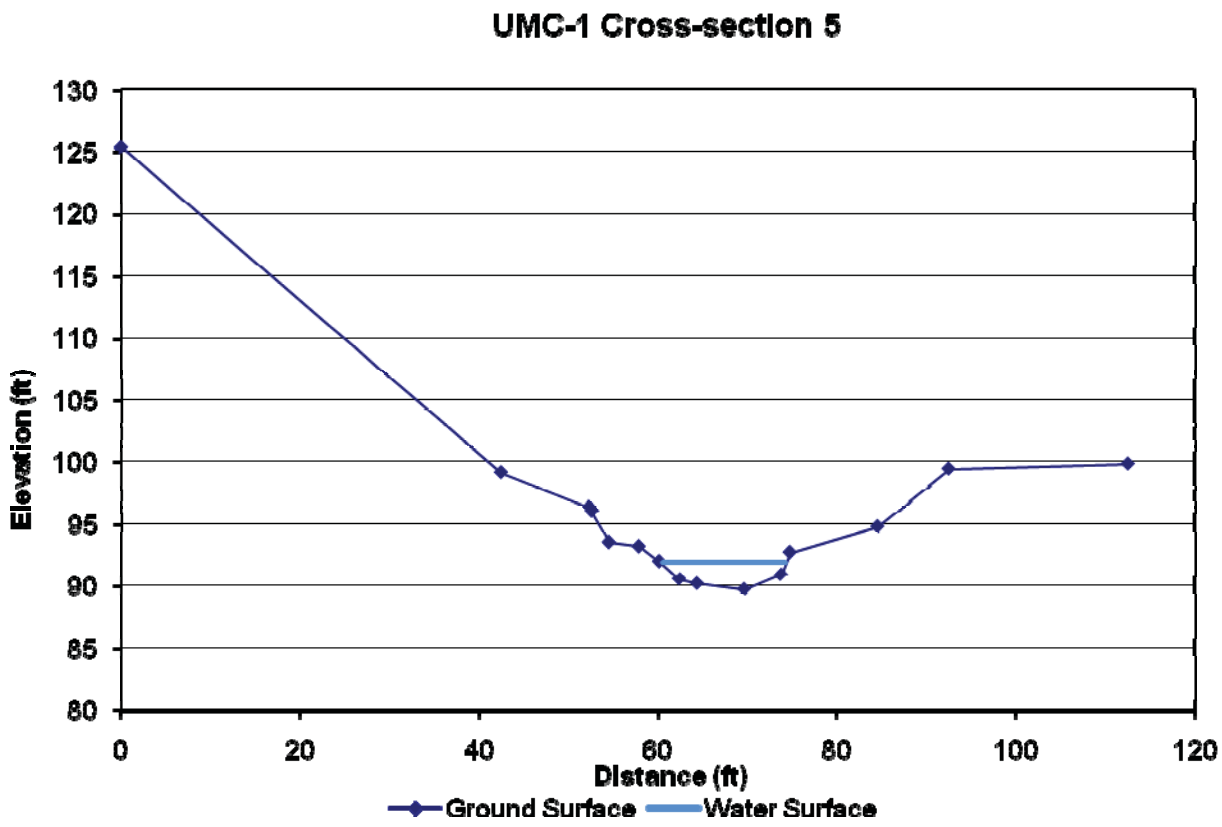
Note: Cross section was surveyed during the 2008 field activites.



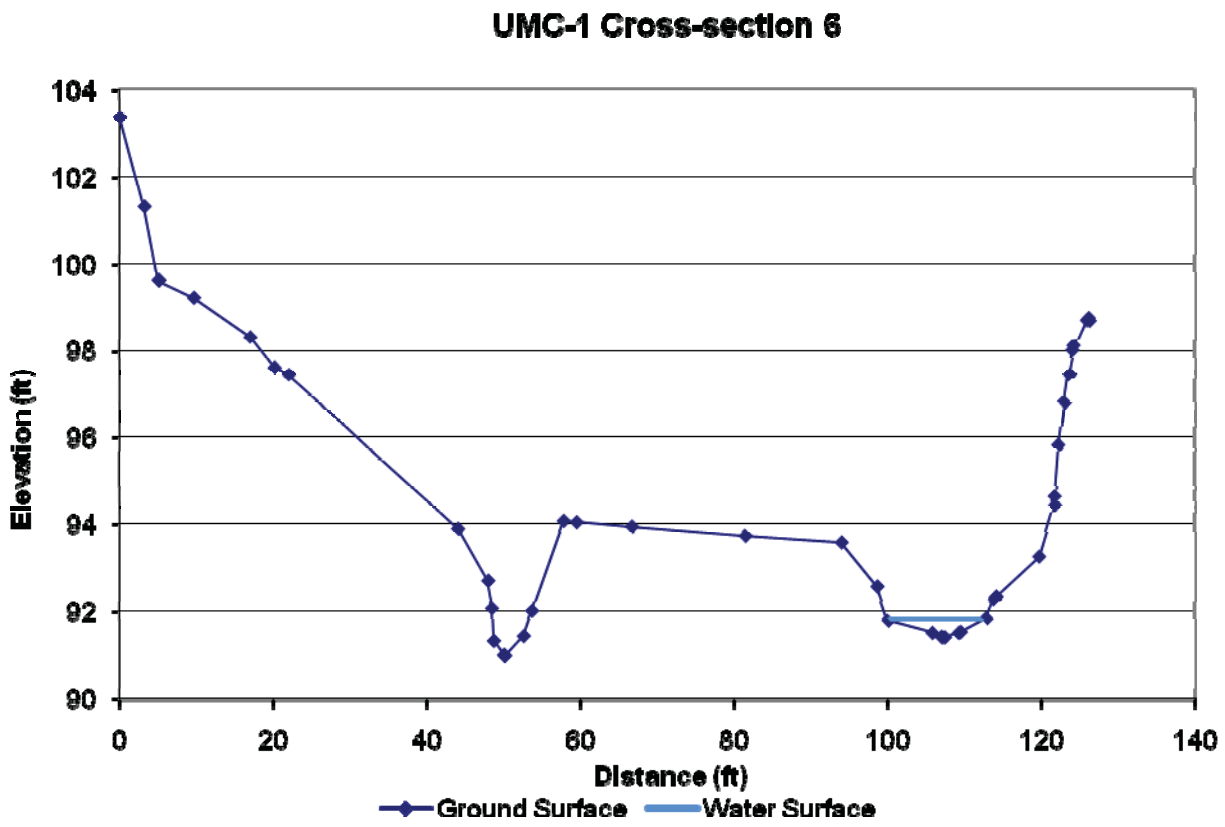
UMC1, Cross-section 4, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.8	9
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	72	5.1
Surface Protection	3.6%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	41.1
BEHI Rating	--	**Very High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 3. UMC1, XS-4, Right Bank



Note: Cross section was surveyed during the 2008 field activites.

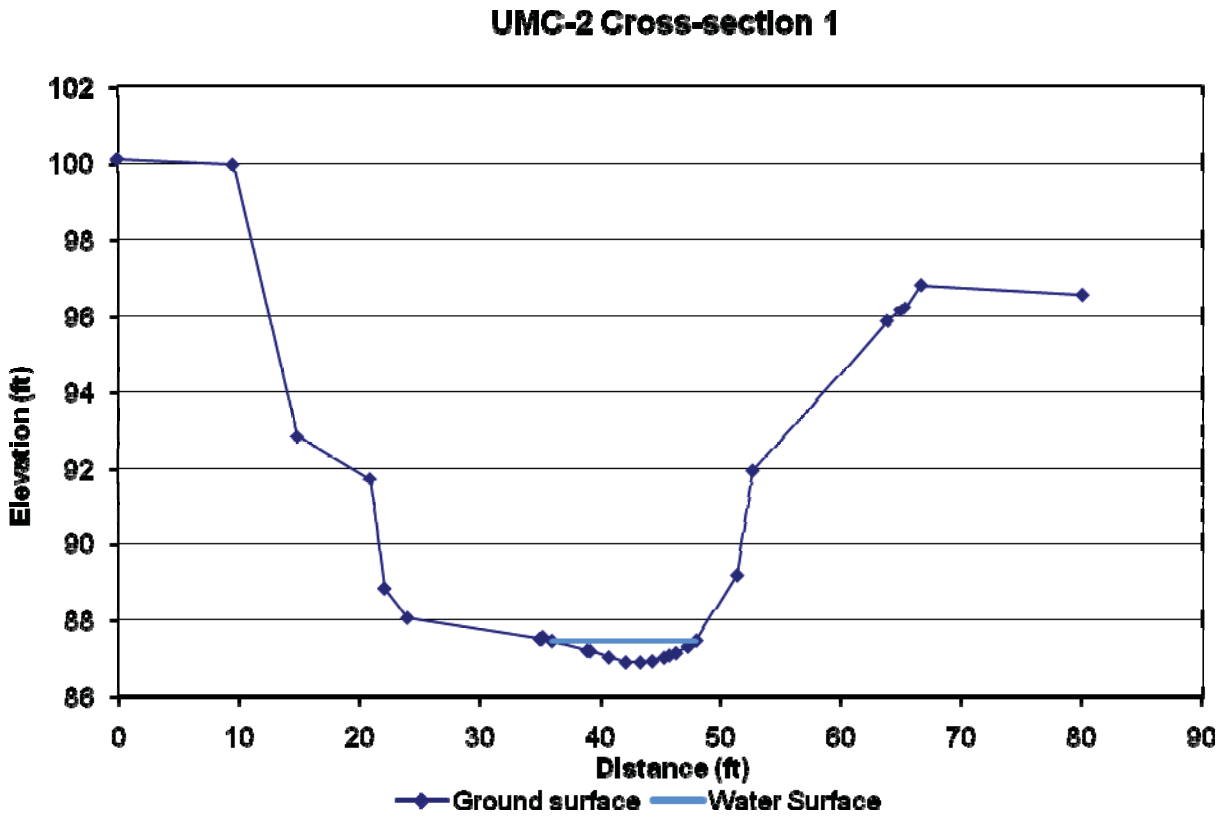


Note: Cross section was surveyed during the 2008 field activites.

UMC1, Cross-section 6, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	4	1.6
Root Depth/Bank ht	0.4	5
Root Density	<5%	10
Bank Angle	80	5.9
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	32.5
BEHI Rating	--	**High**
Radius of Curvature	Inside of bank	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 4: UMC1, XS-6, Right Bank

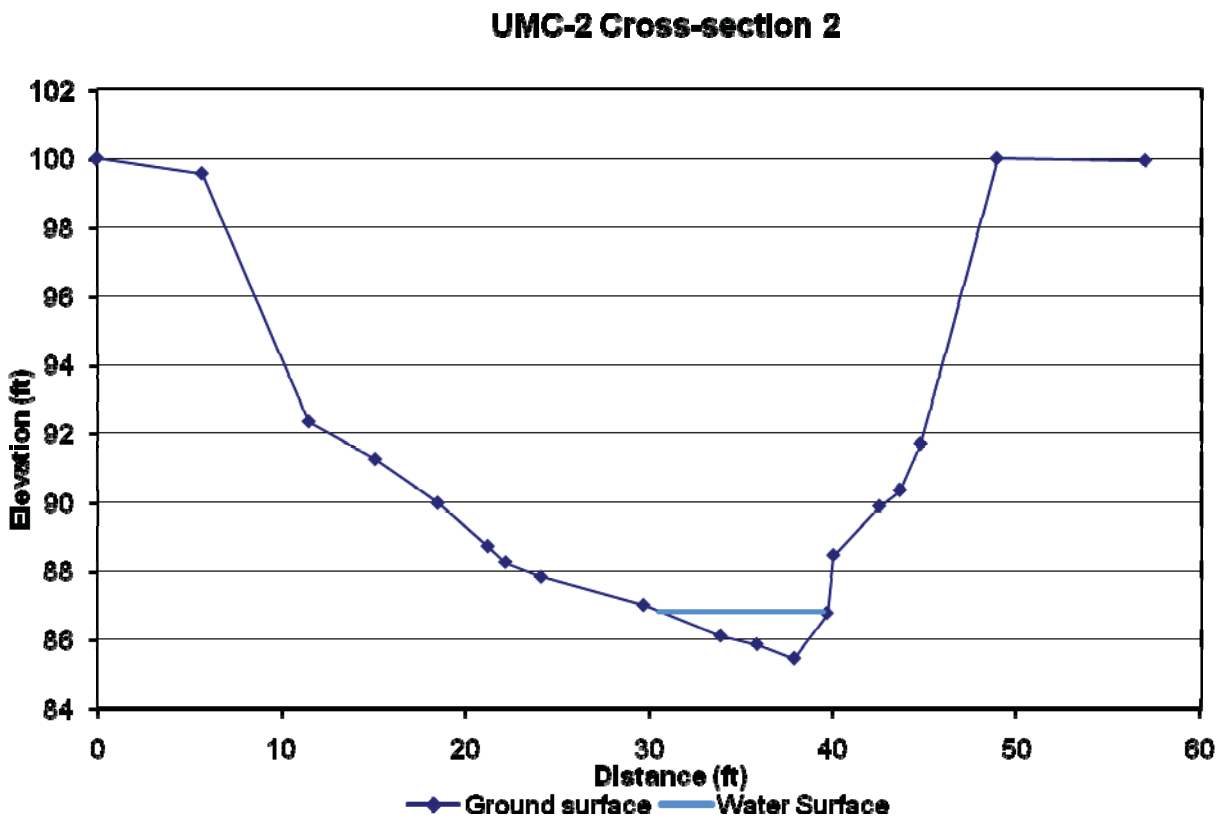


Note: Cross section was surveyed during the 2008 field activites.

UMC2, Cross-section 1, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2	7.9
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	73	5.2
Surface Protection	18.75%	6.5
Bank Material	Silt	0
Stratification	None	0
Index sum	--	32.9
BEHI Rating	--	**High**
Radius of Curvature	47	--
Bankfull Width	32	--
Rc/W	1.5	--
NBS Rating	--	**Extreme**

Photo 5: UMC2, XS-1, Left Bank

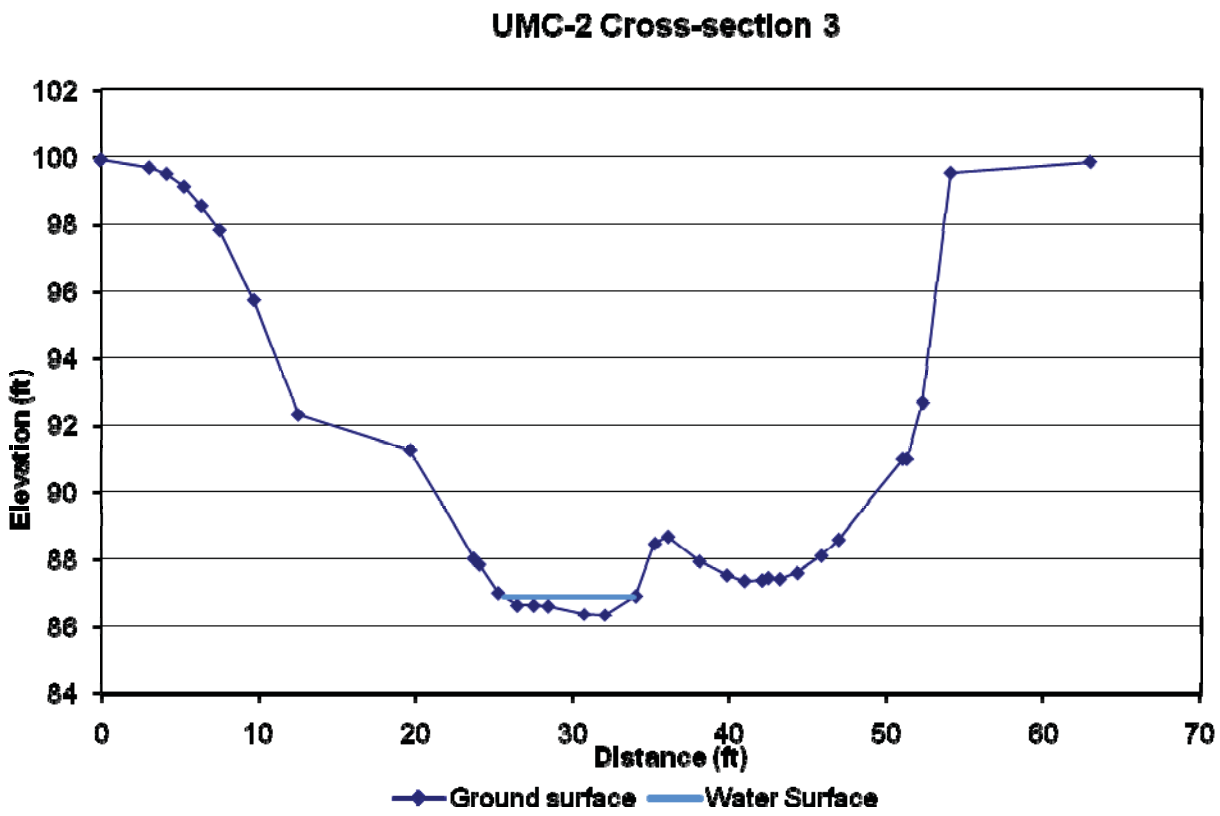


Note: Cross section was surveyed during the 2008 field activites.

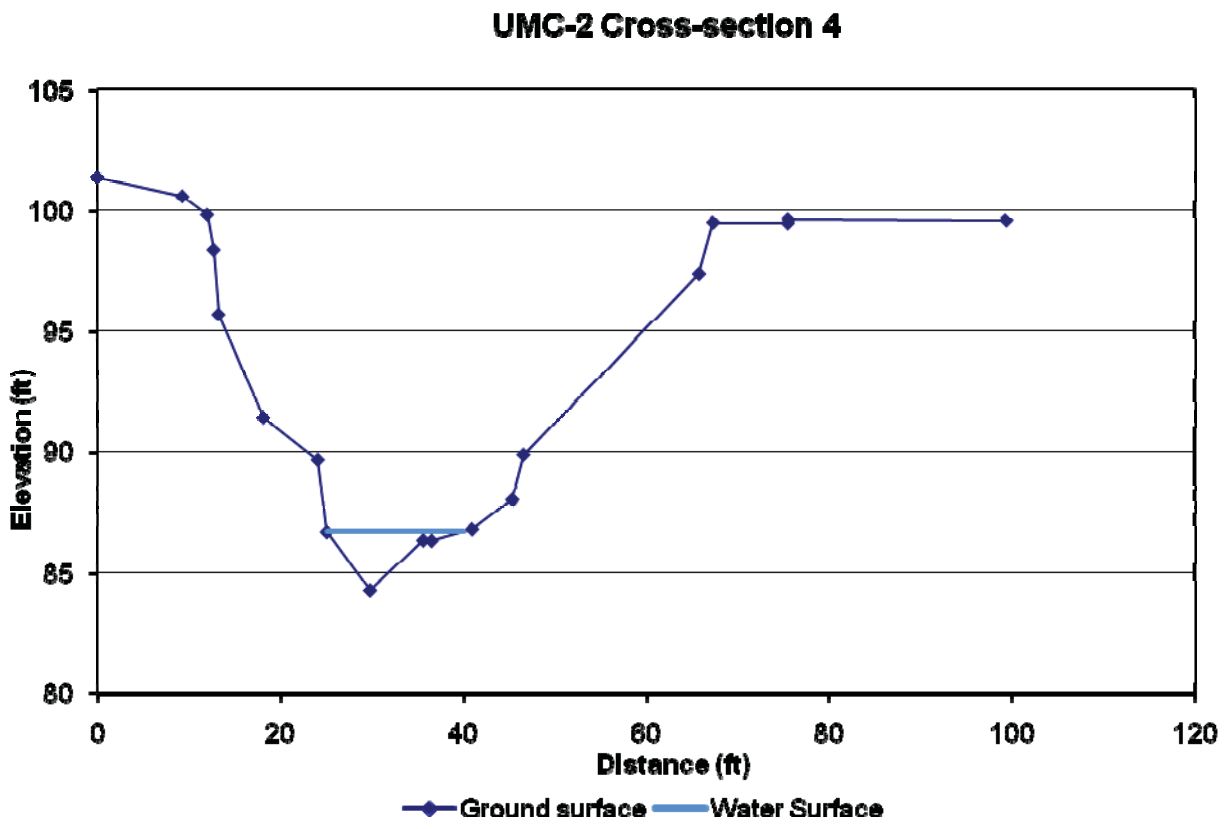
UMC2, Cross-section 2, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.14	8
Root Depth/Bank ht	0.3	5.9
Root Density	<5%	10
Bank Angle	70	4.9
Surface Protection	10%	9
Bank Material	Silt	0
Stratification	None	0
Index sum	--	37.8
BEHI Rating	--	**High**
Radius of Curvature	37	--
Bankfull Width	24	--
Rc/W	1.5	--
NBS Rating	--	**Very High**

Photo 6. UMC2, XS-2, Right Bank.



Note: Cross section was surveyed during the 2008 field activites.

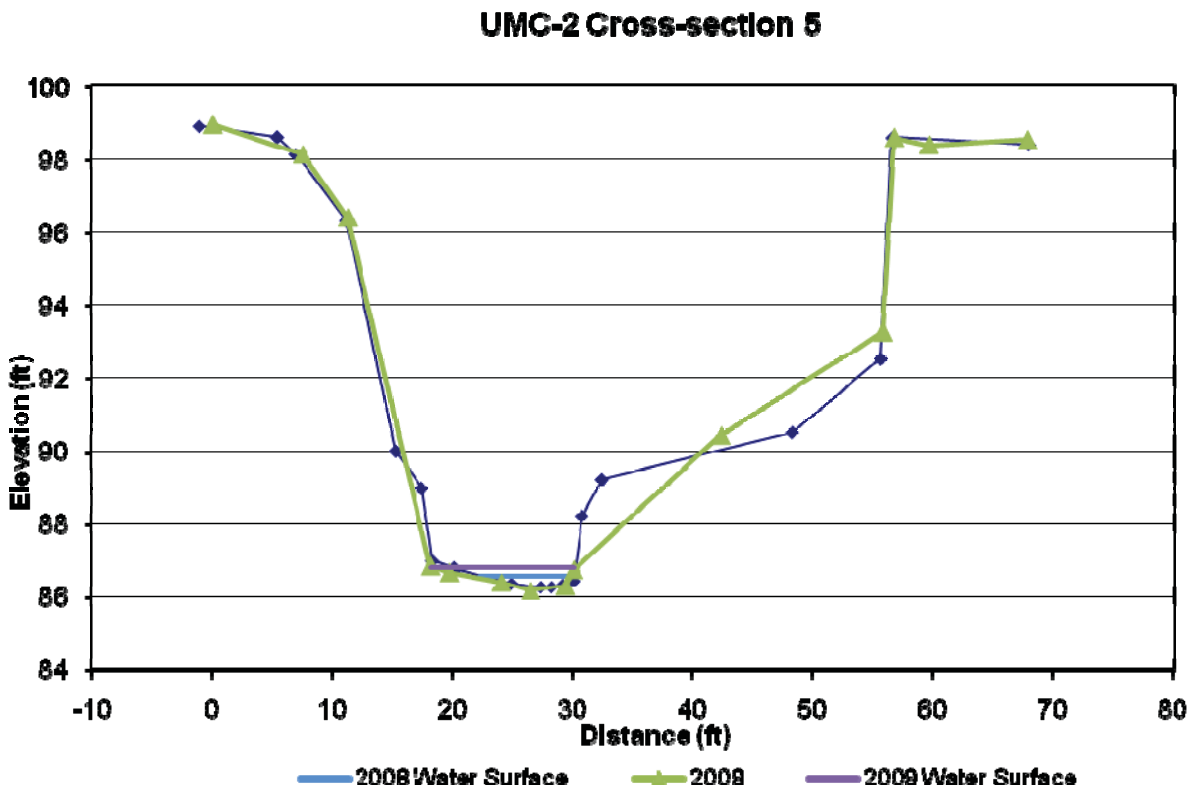


Note: Cross section was surveyed during the 2008 field activites.

UMC2, Cross-section 4, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2.1	8
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	53	3.7
Surface Protection	5%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	38.7
BEHI Rating	--	**High**
Radius of Curvature	32	--
Bankfull Width	23	--
Rc/W	1.4	--
NBS Rating	--	**Extreme**

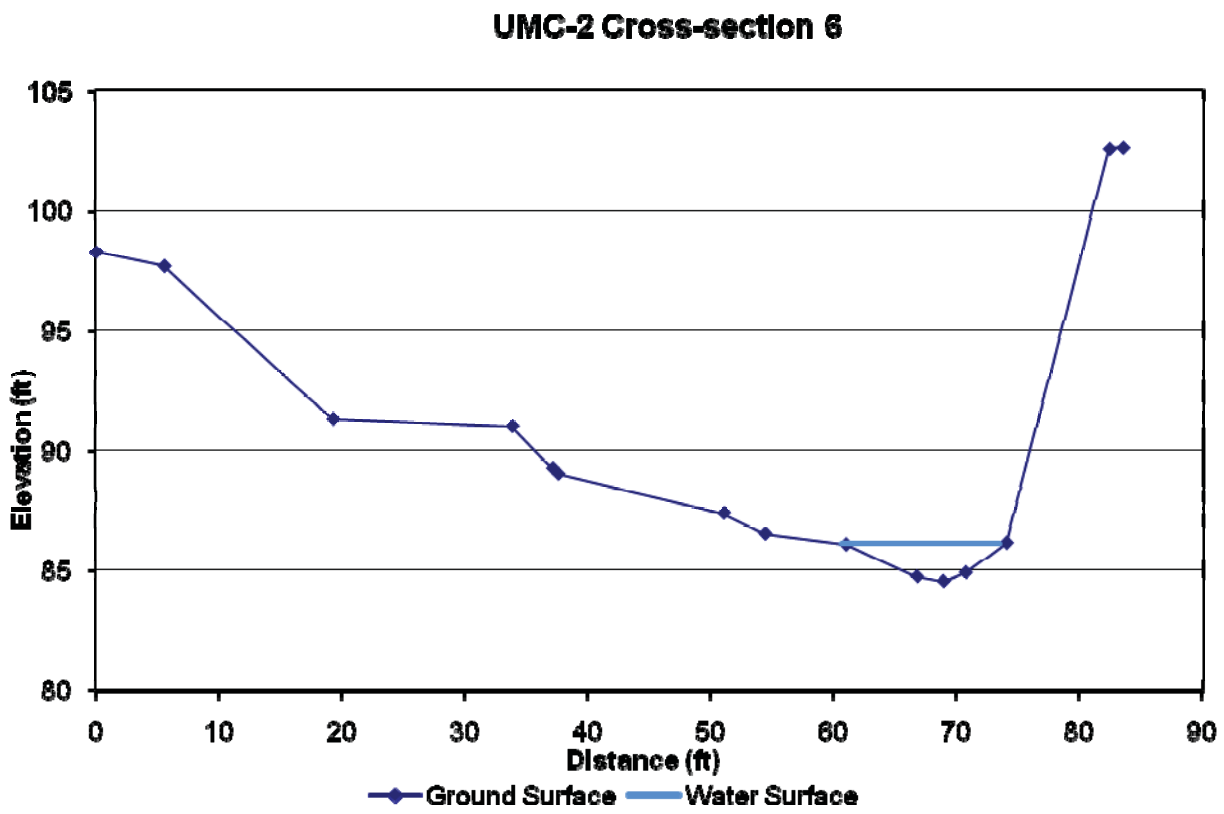
Photo 7. UMC, XS-4, Left Bank.



UMC2, Cross-section 5, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.56	8.65
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	75	5.4
Surface Protection	<5%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	42.6
BEHI Rating	--	**Very High**
Radius of Curvature	73	--
Bankfull Width	33	--
Rc/W	2.2	--
NBS Rating	--	**Moderate**

Photo 8: UMC2, XS-5, Right Bank

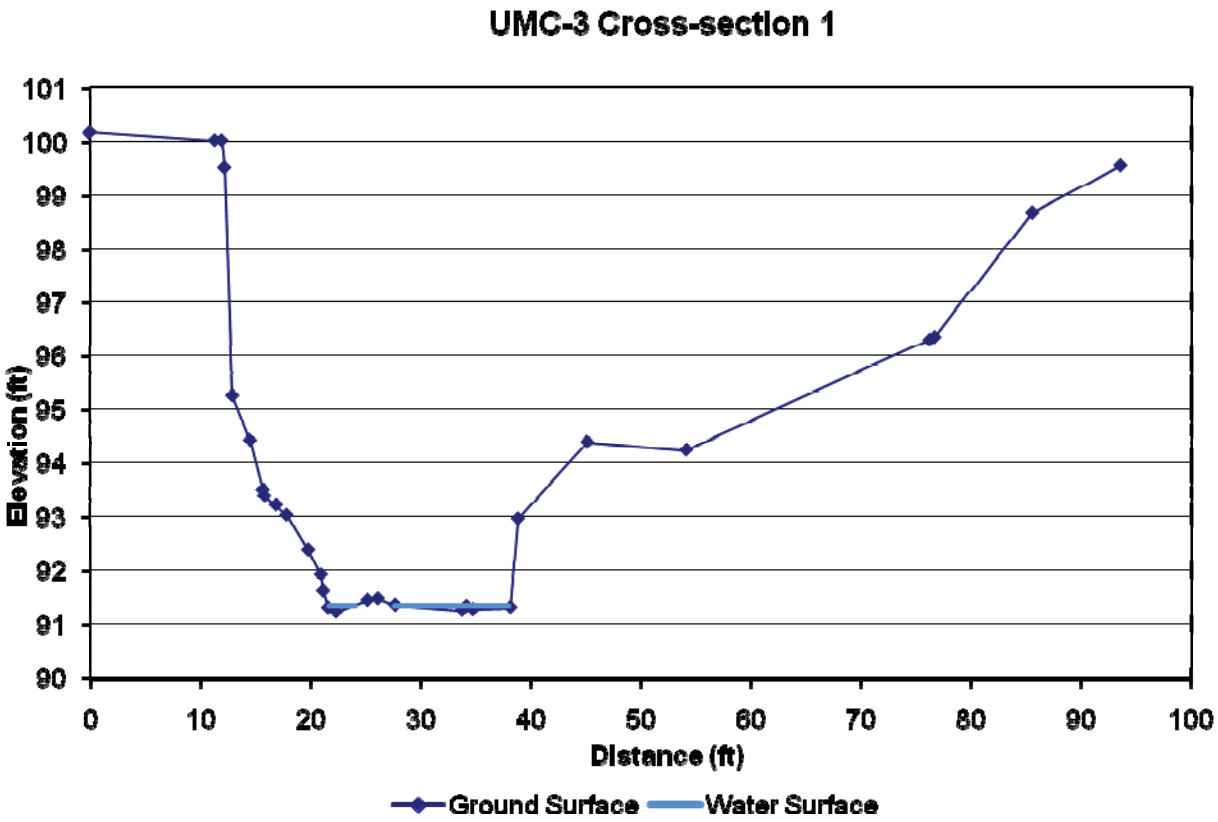


Note: Cross section was surveyed during the 2008 field activites.

UMC2, Cross-section 6, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	5.7	10
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	60	3.9
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	42.4
BEHI Rating	--	**Very High**
Radius of Curvature	45	--
Bankfull Width	37	--
Rc/W	1.2	--
NBS Rating	--	**Extreme**

Photo 9: UMC2, XS-6, Right Bank

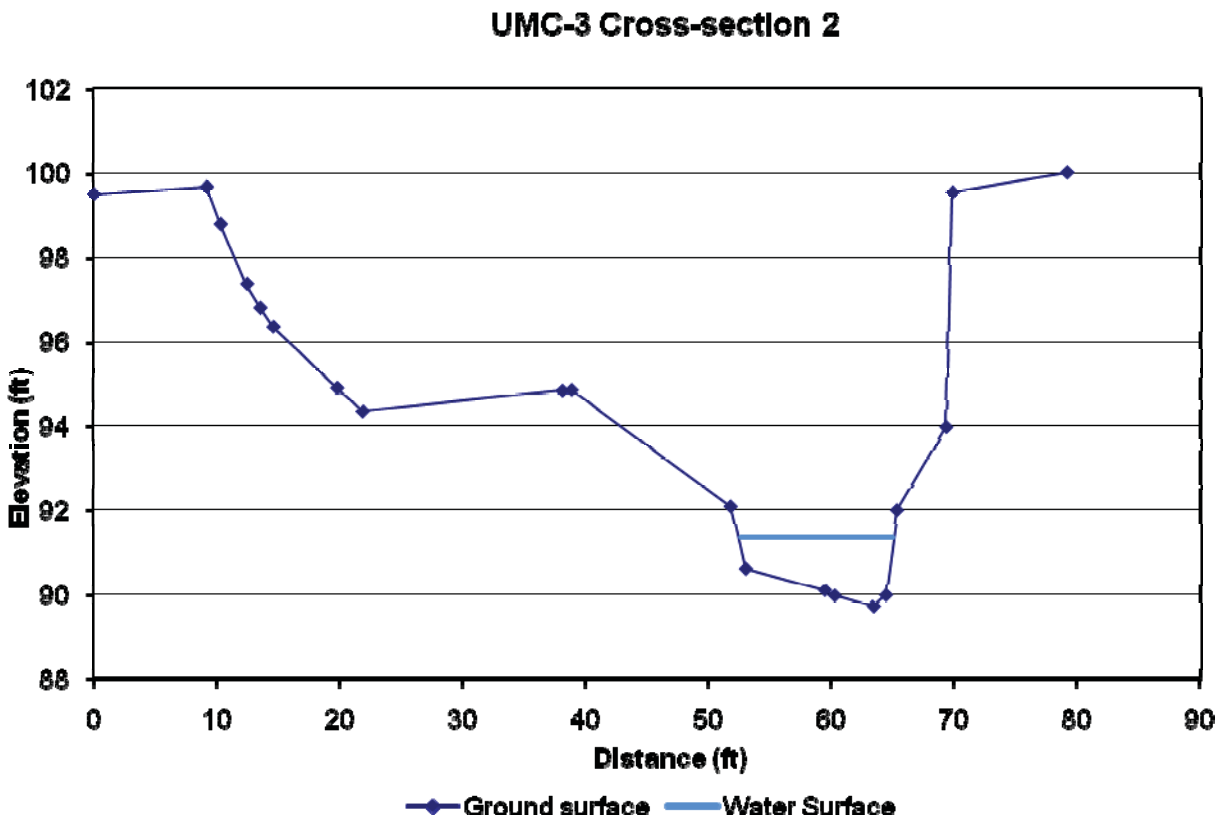


Note: Cross section was surveyed during the 2008 field activites.

UMC3, Cross-section 1, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2.8	9
Root Depth/Bank ht	0.3	9.5
Root Density	<5%	10
Bank Angle	76	5.5
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	1 ft Weak Layer	0
Index sum	--	44
BEHI Rating	--	**Very High**
Radius of Curvature	86	--
Bankfull Width	42	--
Rc/W	2.1	--
NBS Rating	--	**Moderate**

Photo 10: UMC3, XS-1, Left Bank

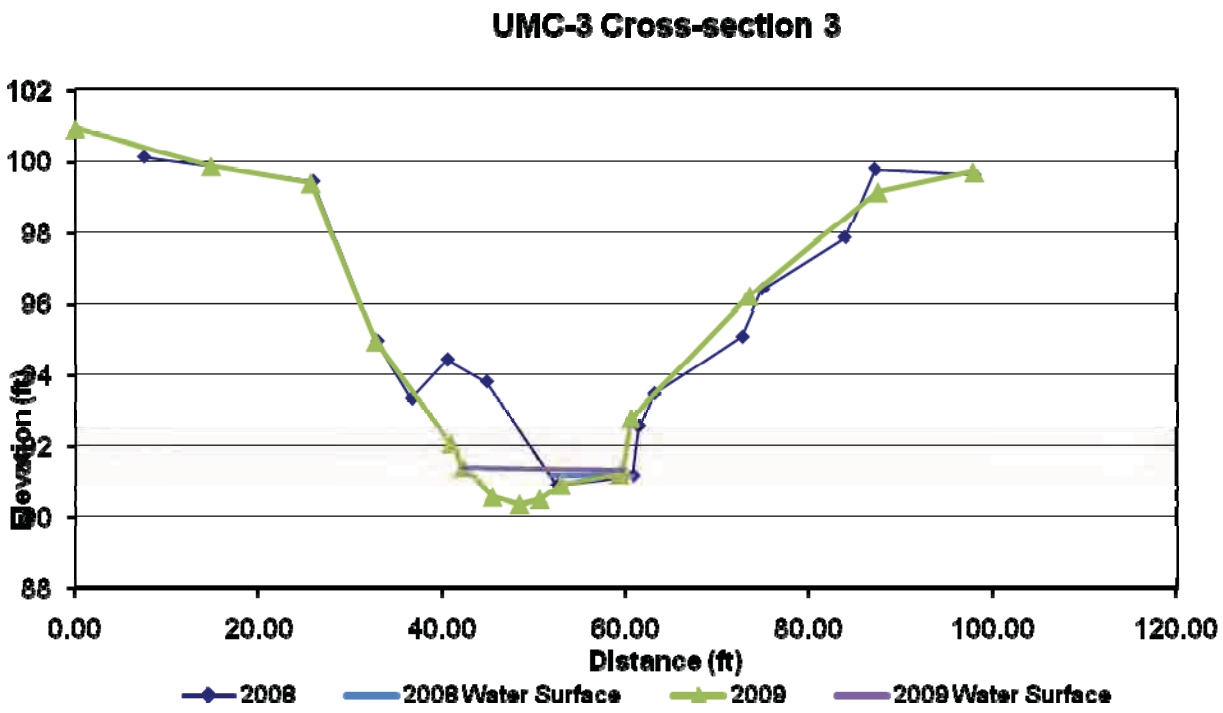


Note: Cross section was surveyed during the 2008 field activites.

UMC3, Cross-section 2, Right banl

Category	Value	Index
Bank ht/Bankfull Depth	2.1	8.
Root Depth/Bank ht	0.7	3
Root Density	<5%	10
Bank Angle	70	4.9
Surface Protection	21.4%	7
Bank Material	Silt	0
Stratification	None	0
Index sum	--	32.9
BEHI Rating	--	**High**
Radius of Curvature	53	--
Bankfull Width	50	--
Rc/W	1.1	--
NBS Rating	--	**Extreme**

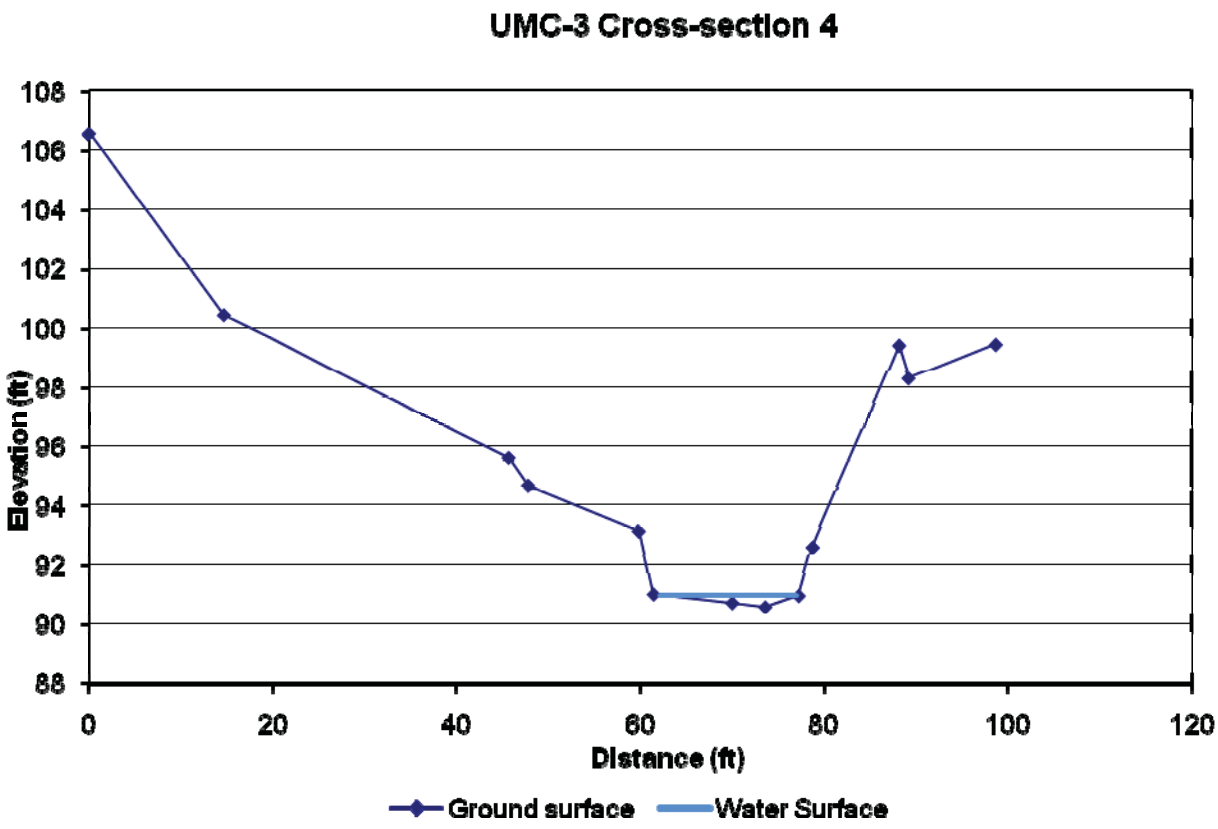
Photo 11: UMC3, XS-2, Right Bank



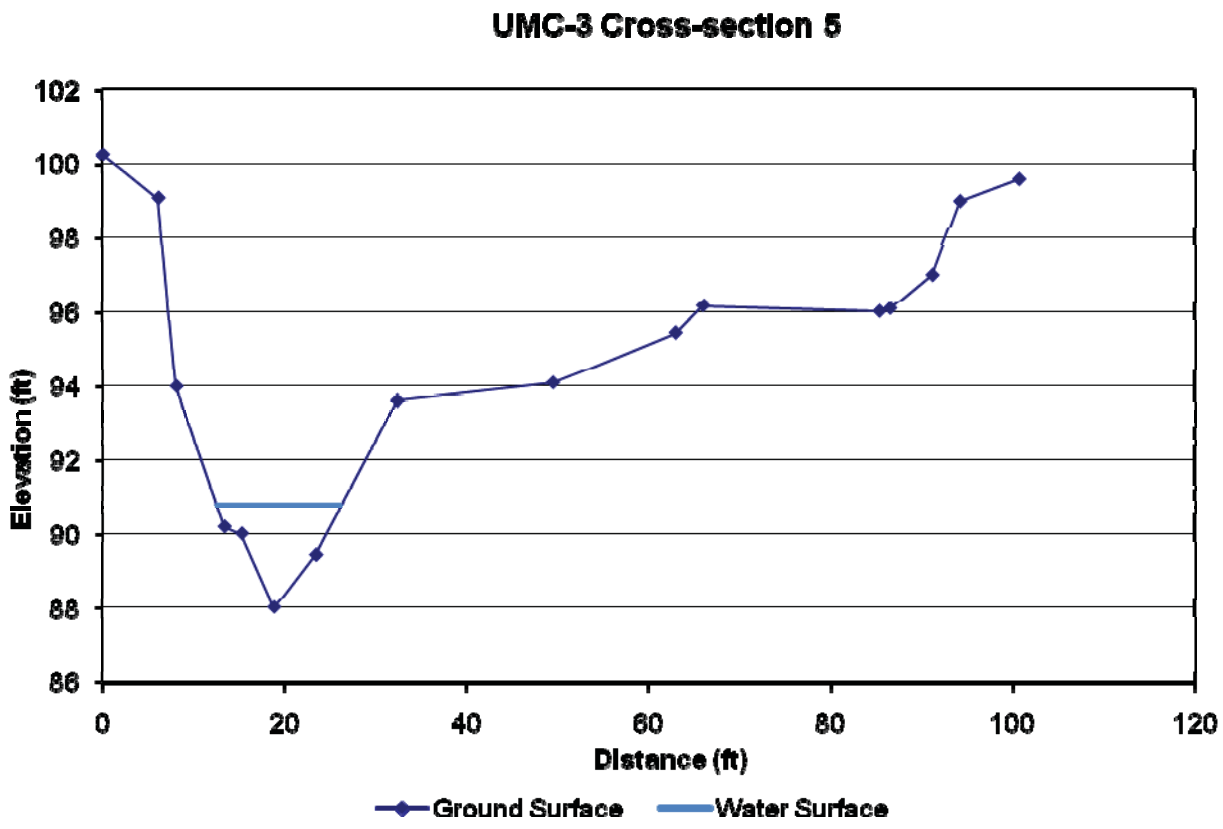
UMC3, Cross-section 3, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	1.9	7.4
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	67.5	4.65
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	39.05
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 12: UMC3, XS-3, Right Bank



Note: Cross section was surveyed during the 2008 field activites.

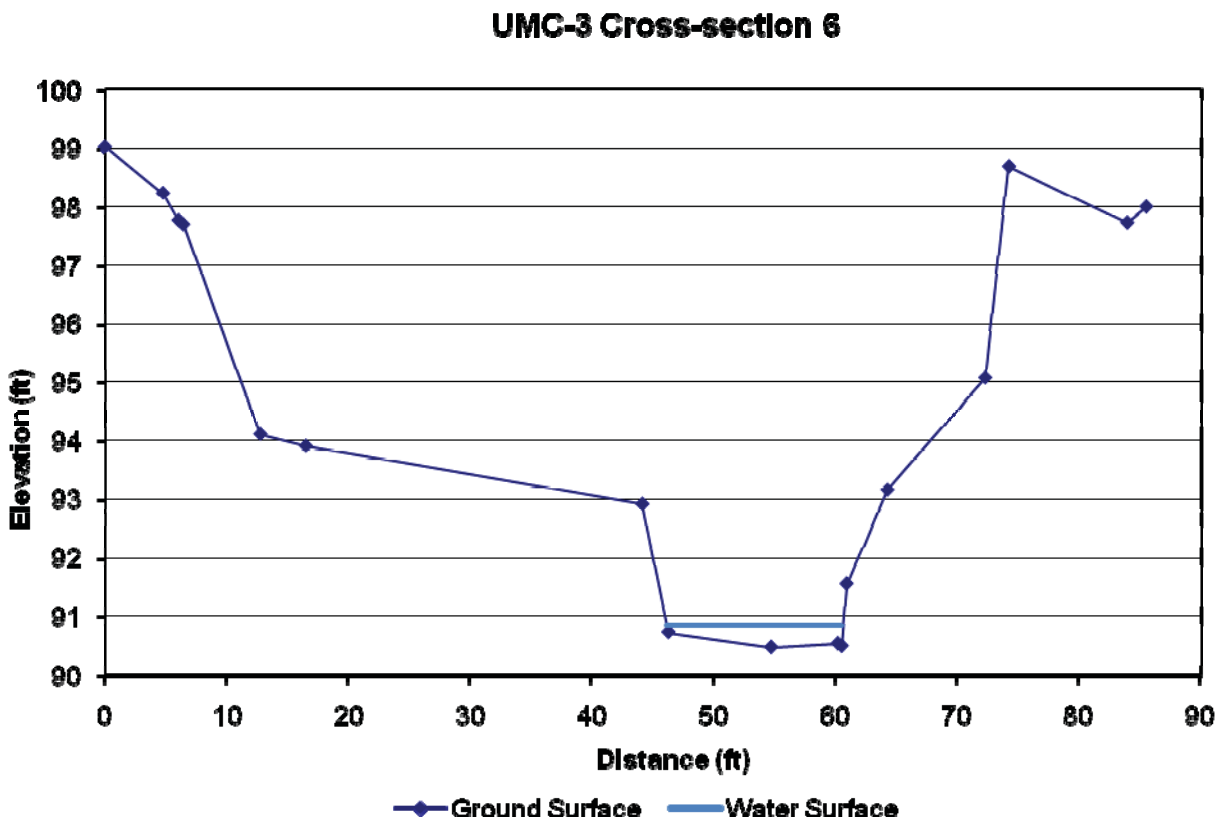


Note: Cross section was surveyed during the 2008 field activites.

UMC3, Cross-section 5, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2.3	8.33
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	70	4.9
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	40.23
BEHI Rating	--	**Very High**
Radius of Curvature	48	--
Bankfull Width	41	--
Rc/W	1.2	--
NBS Rating	--	**Extreme**

Photo 13: UMC3, XS-5, Left Bank

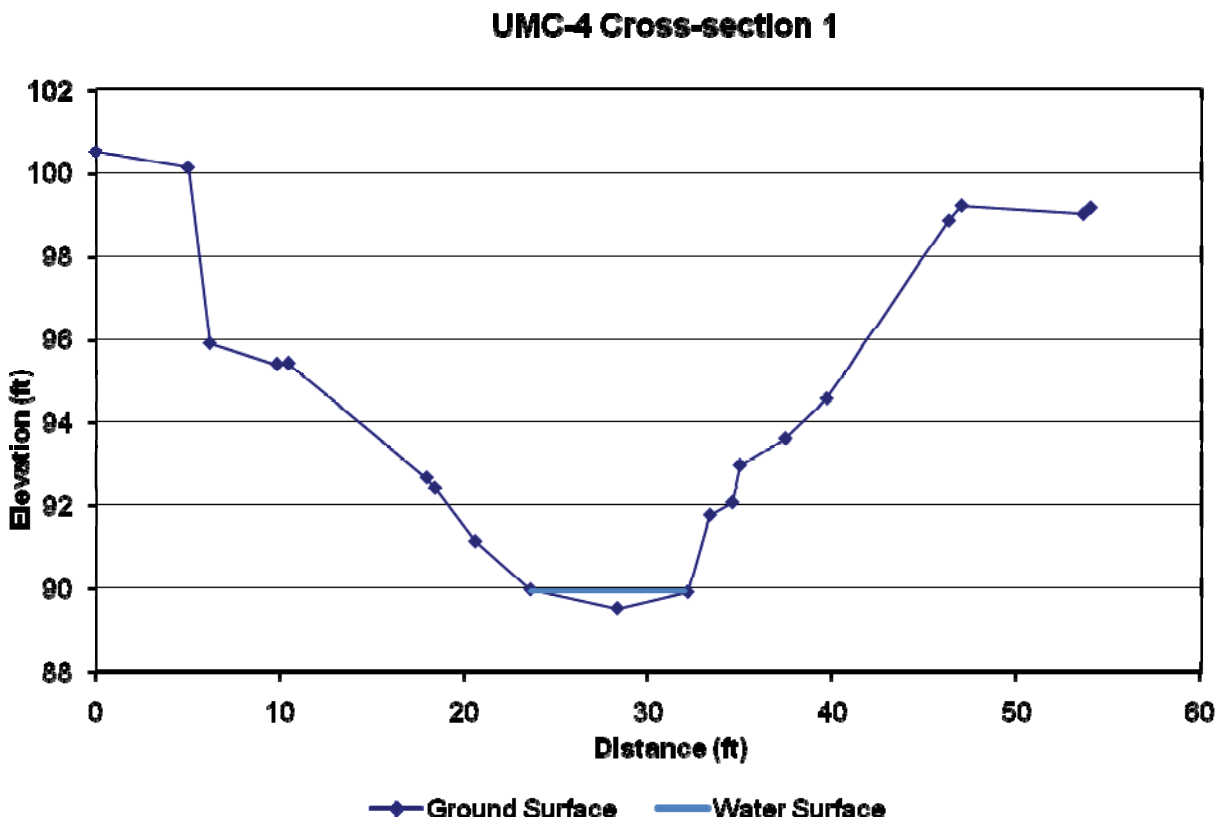


Note: Cross section was surveyed during the 2008 field activites.

UMC3, Cross-section 6, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.83	10
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	46	3.2
Surface Protection	44%	4.79
Bank Material	Silt	0
Stratification	Weak Layer present	0
Index sum	--	38
BEHI Rating	--	**High**
Radius of Curvature	96	--
Bankfull Width	56	--
Rc/W	1.7	--
NBS Rating	--	**Very High**

Photo 14: UMC3, XS-6, Right Bank

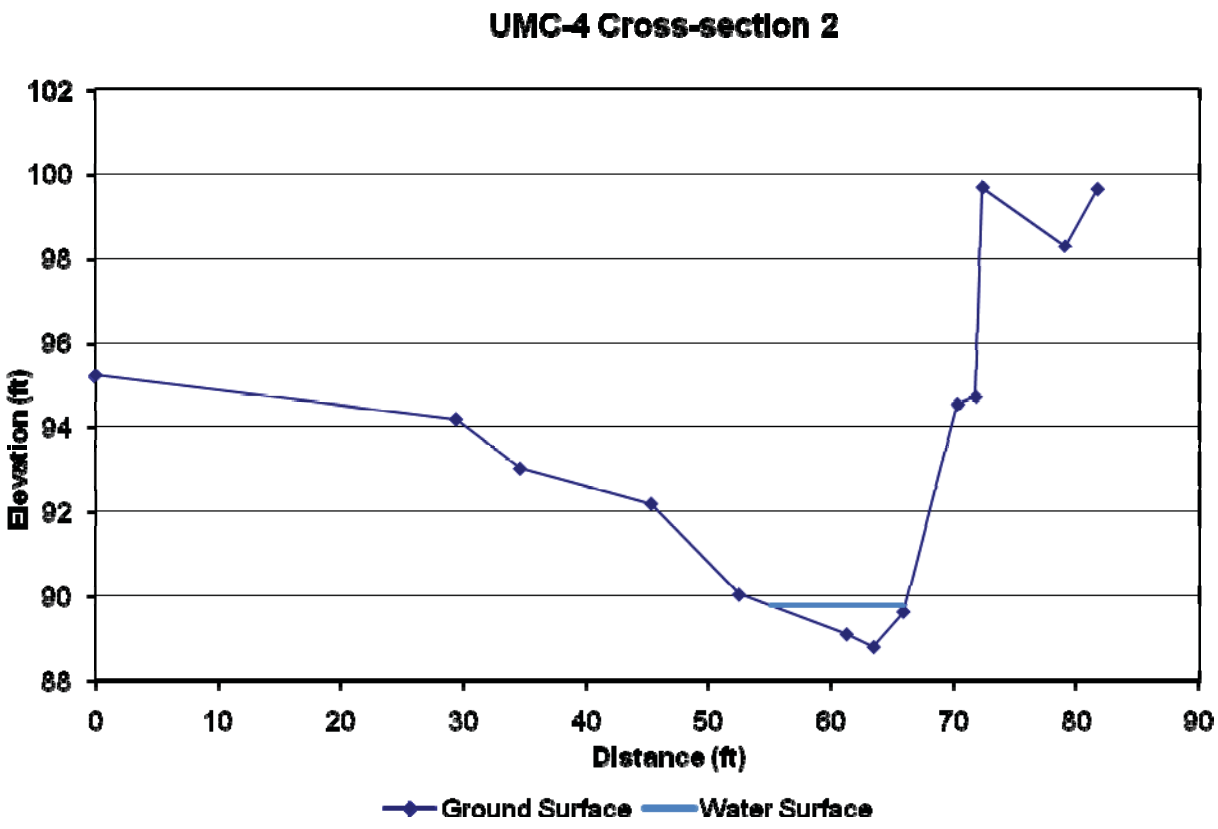


Note: Cross section was surveyed during the 2008 field activites.

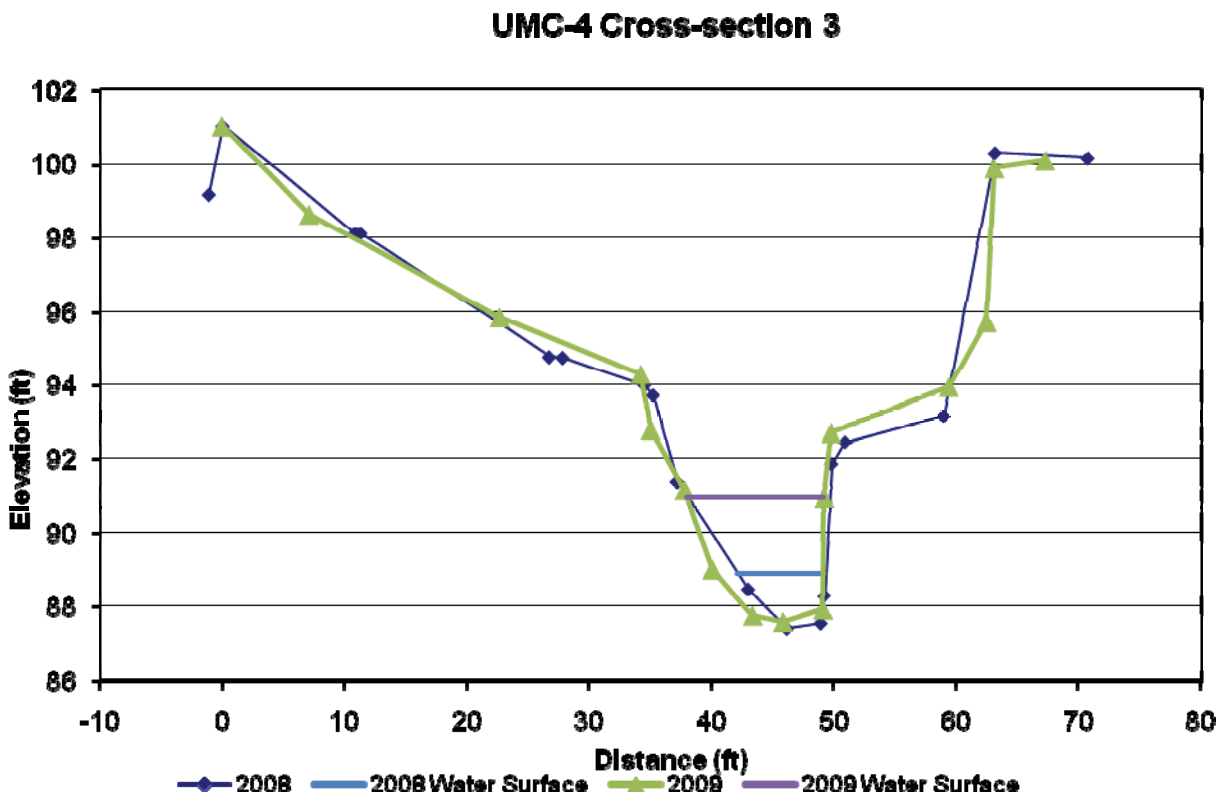
UMC4, Cross-section 1, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	3.0	10
Root Depth/Bank ht	0.3	5.9
Root Density	<5%	10
Bank Angle	53	3.55
Surface Protection	43%	4.87
Bank Material	Silt	0
Stratification	None	0
Index sum	--	34.32
BEHI Rating	--	**High**
Radius of Curvature	57	--
Bankfull Width	22	--
Rc/W	2.6	--
NBS Rating	--	**Low**

Photo 15: UMC4, XS-1, Left Bank



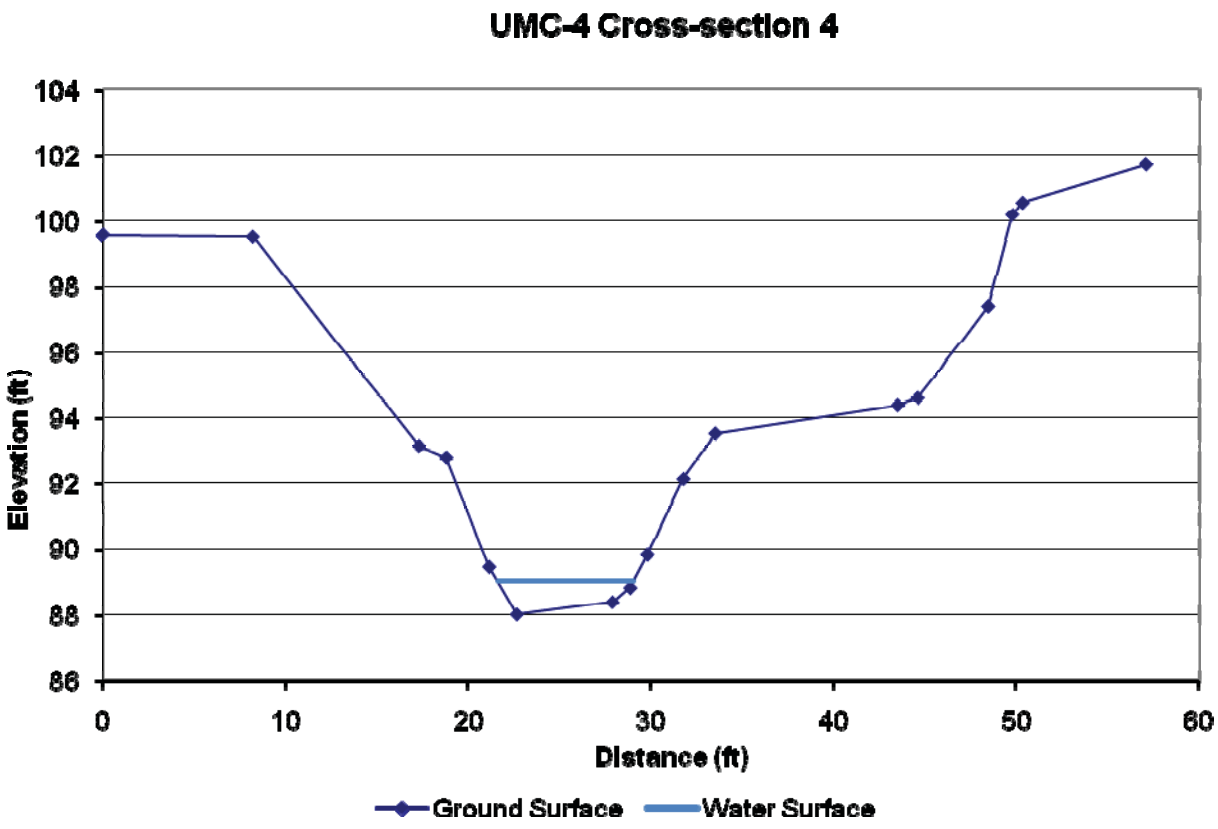
Note: Cross section was surveyed during the 2008 field activites.



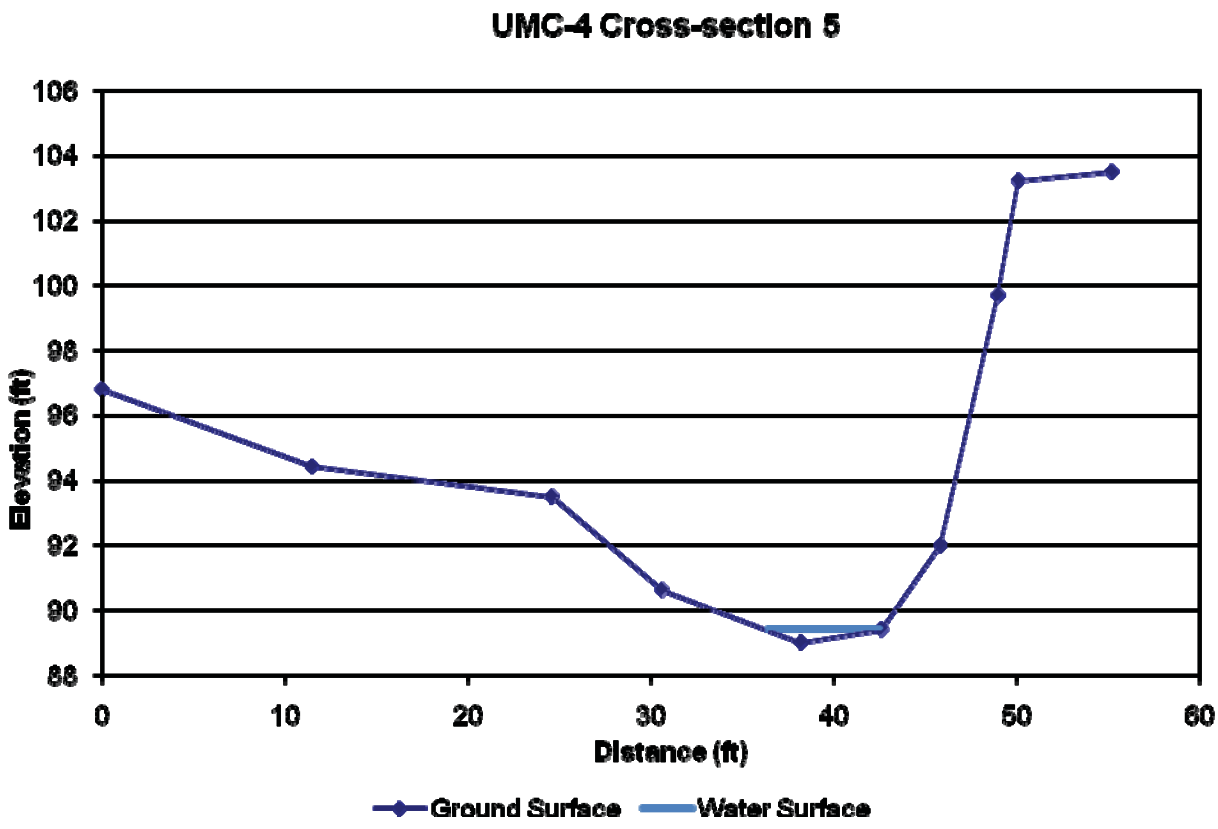
UMC4, Cross-section 3, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.4	8.43
Root Depth/Bank ht	0.3	5.9
Root Density	<5%	10
Bank Angle	74	5.3
Surface Protection	17.5%	7.56
Bank Material	Silt	0
Stratification	None	0
Index sum	--	37.2
BEHI Rating	--	**High**
Radius of Curvature	121	--
Bankfull Width	26	--
Rc/W	4.7	--
NBS Rating	--	**Very Low**

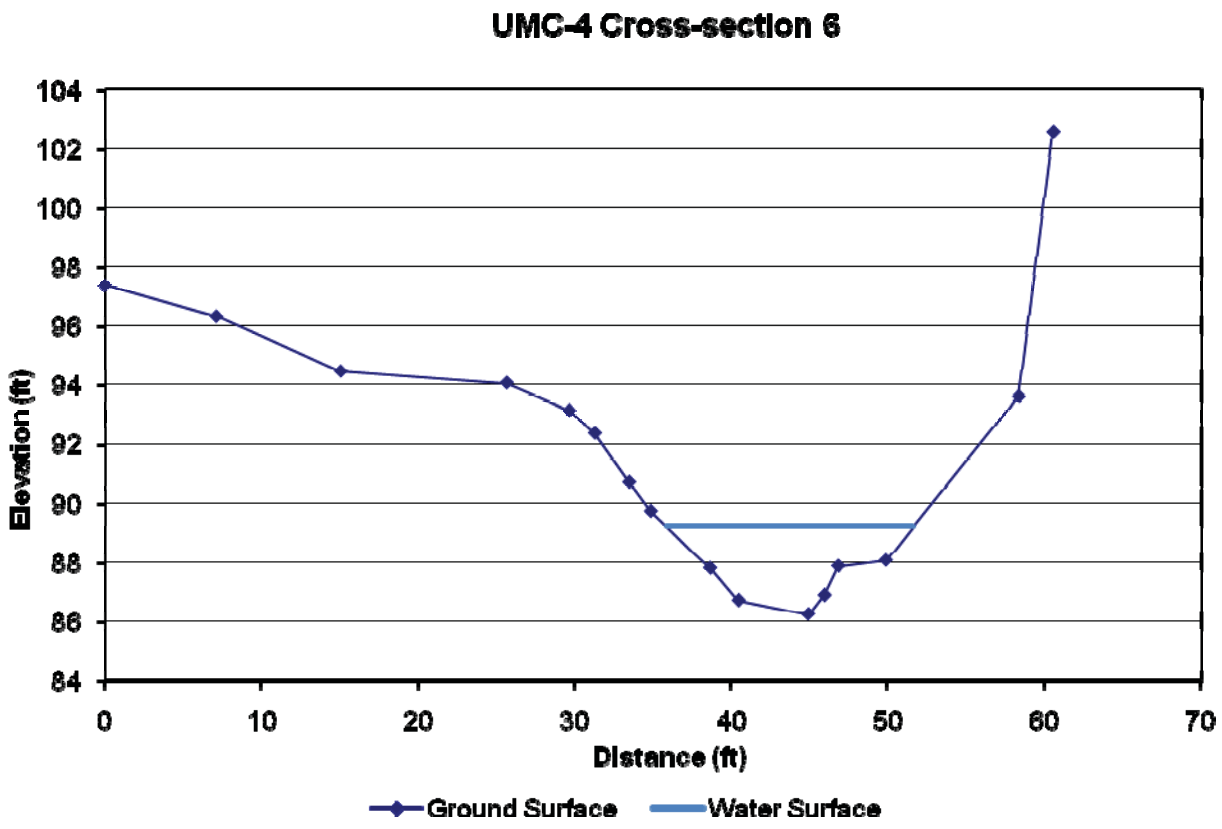
Photo 16: UMC4, XS-3, Right bank



Note: Cross section was surveyed during the 2008 field activites.



Note: Cross section was surveyed during the 2008 field activites.

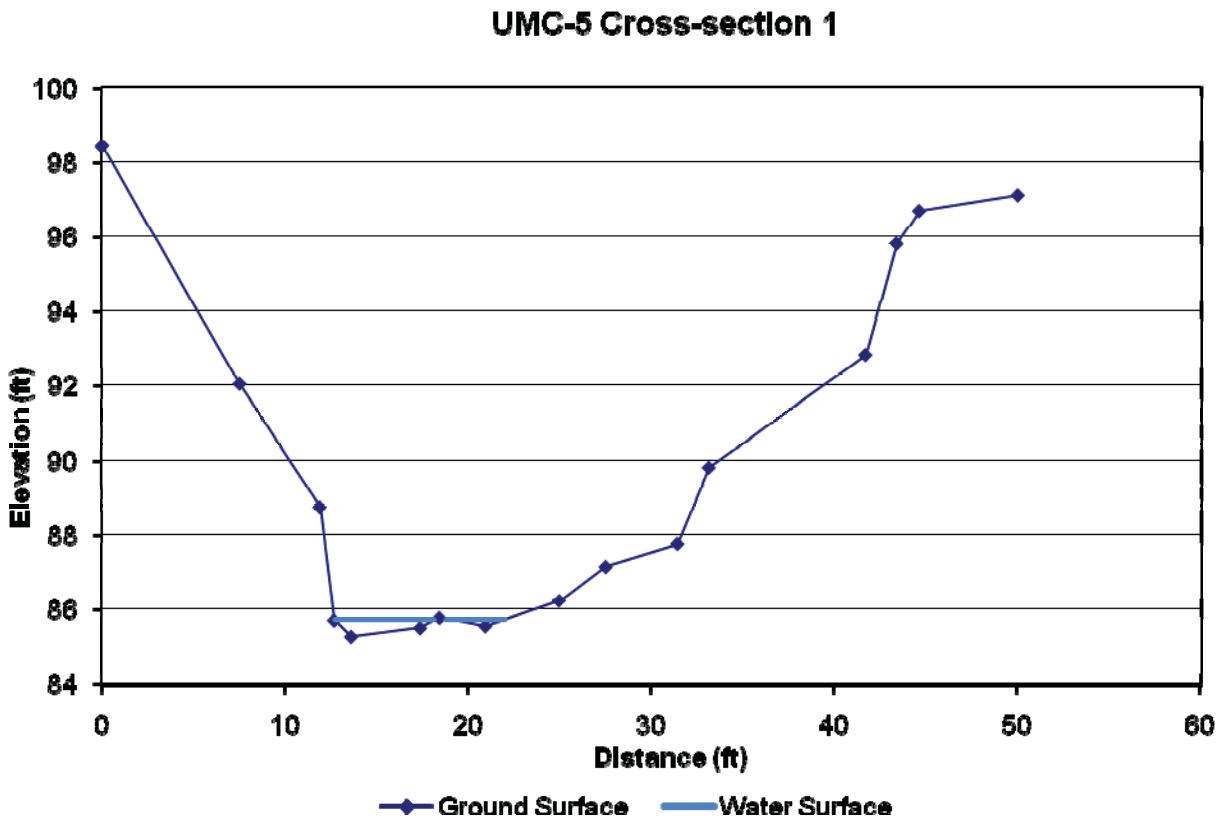


Note: Cross section was surveyed during the 2008 field activites.

UMC4, Cross-section 6, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.1	8.0
Root Depth/Bank ht	0.2	7
Root Density	<5%	10
Bank Angle	71.25	4.67
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	40.17
BEHI Rating	--	**Very High**
Radius of Curvature	43	--
Bankfull Width	21	--
Rc/W	2.1	--
NBS Rating	--	**Moderate**

Photo 17: UMC4, XS-6, Right Bank

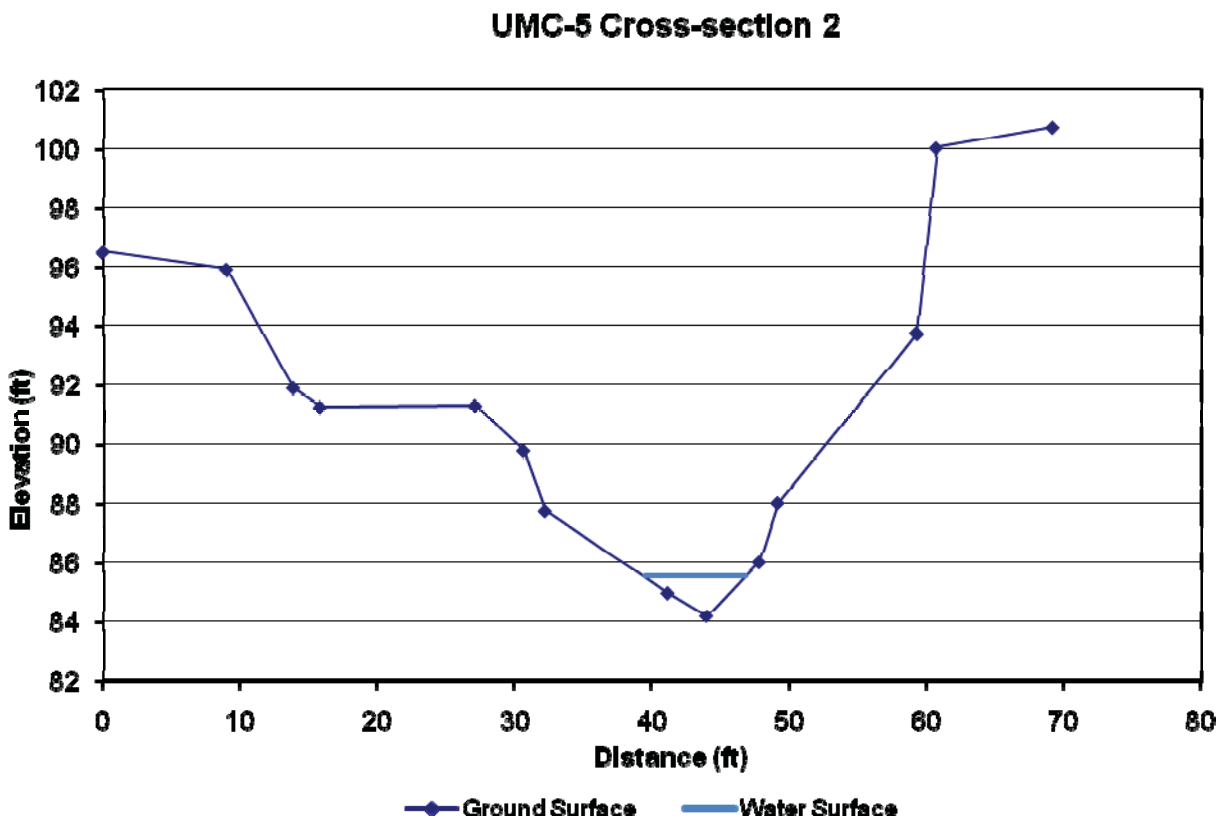


Note: Cross section was surveyed during the 2008 field activites.

UMC5, Cross-section 1, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	3.0	10
Root Depth/Bank ht	0.3	5.9
Root Density	<5%	10
Bank Angle	42	3.0
Surface Protection	30%	5.9
Bank Material	Silt	0
Stratification	None	0
Index sum	--	34.8
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 18: UMC5, XS-1, Right Bank

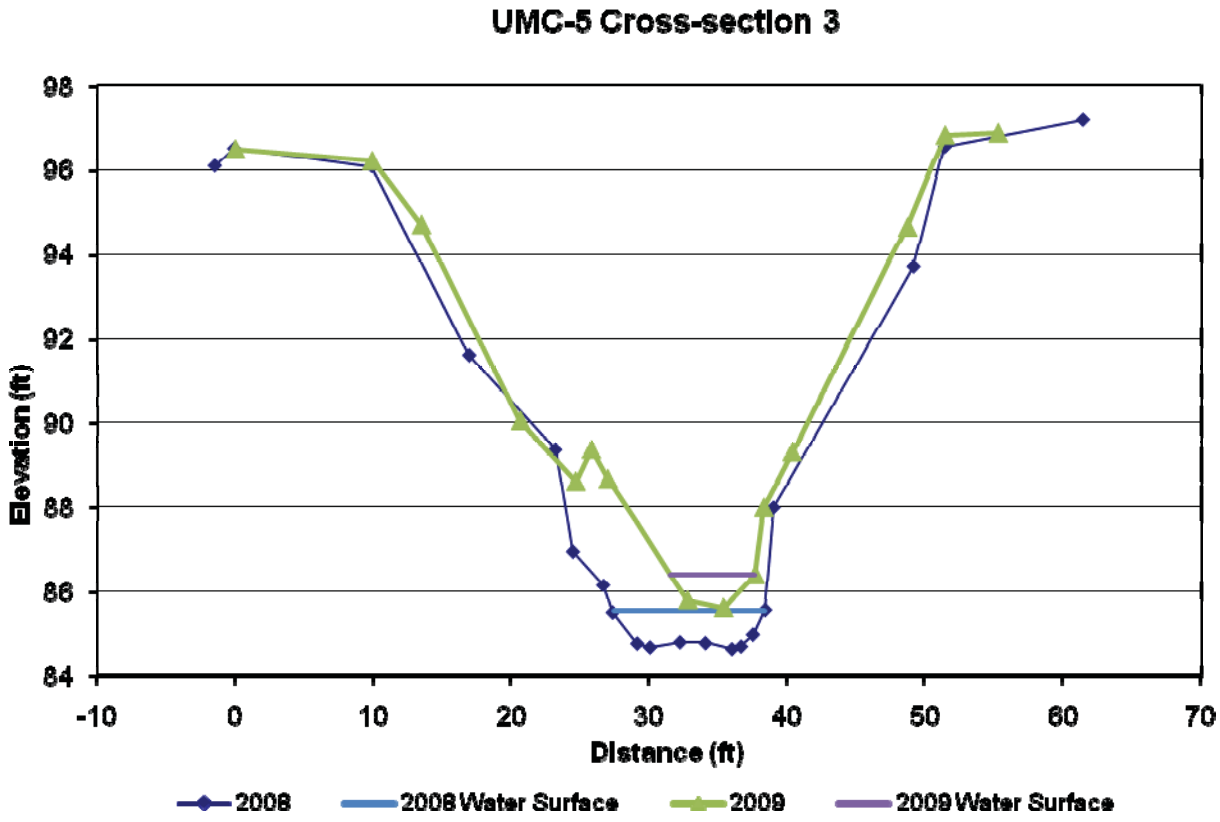


Note: Cross section was surveyed during the 2008 field activites.

UMC5, Cross-section 2, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	4.2	10
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	52	3.5
Surface Protection	20%	7.2
Bank Material	Silt	0
Stratification	None	0
Index sum	--	39.2
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

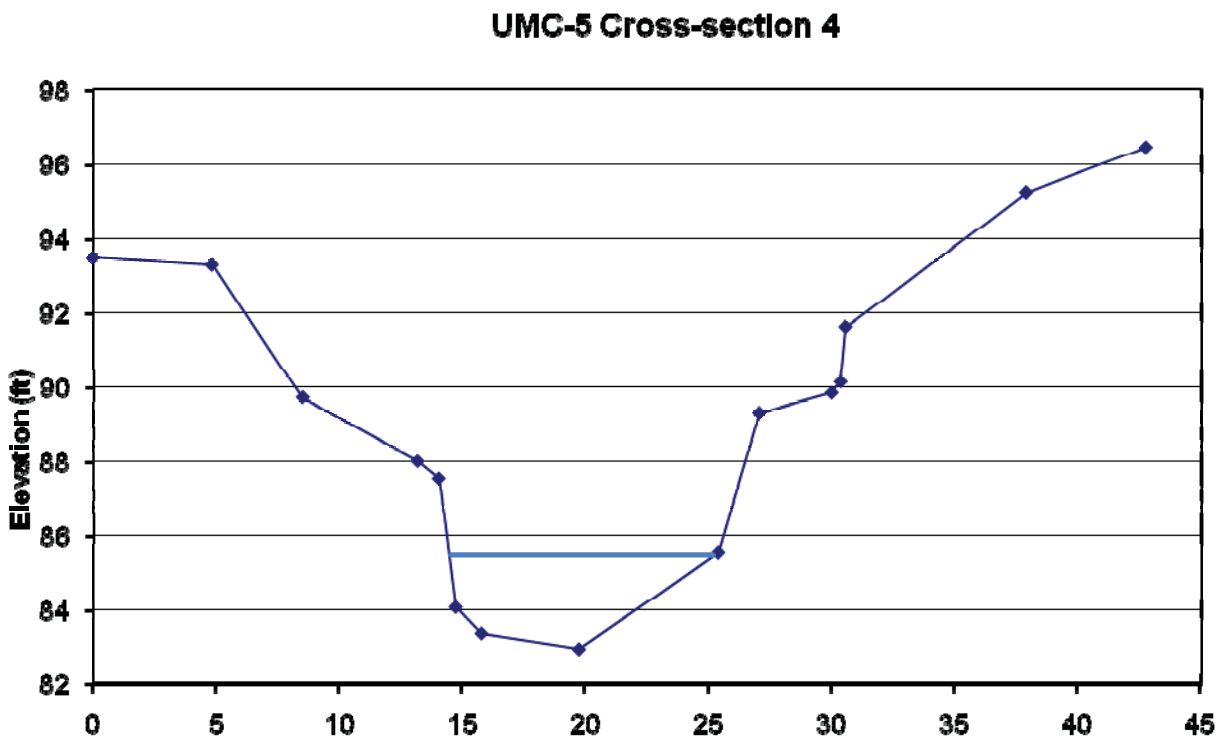
Photo 19: UMC5, XS-2, Right Bank



UMC5, Cross-section 3, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.7	8.85
Root Depth/Bank ht	0.2	7.4
Root Density	<5%	10
Bank Angle	66	4.5
Surface Protection	20%	7.2
Bank Material	Silt	0
Stratification	None	0
Index sum	--	37.95
BEHI Rating	--	**High**
Radius of Curvature	43	--
Bankfull Width	16	--
Rc/W	2.8	--
NBS Rating	--	**Low**

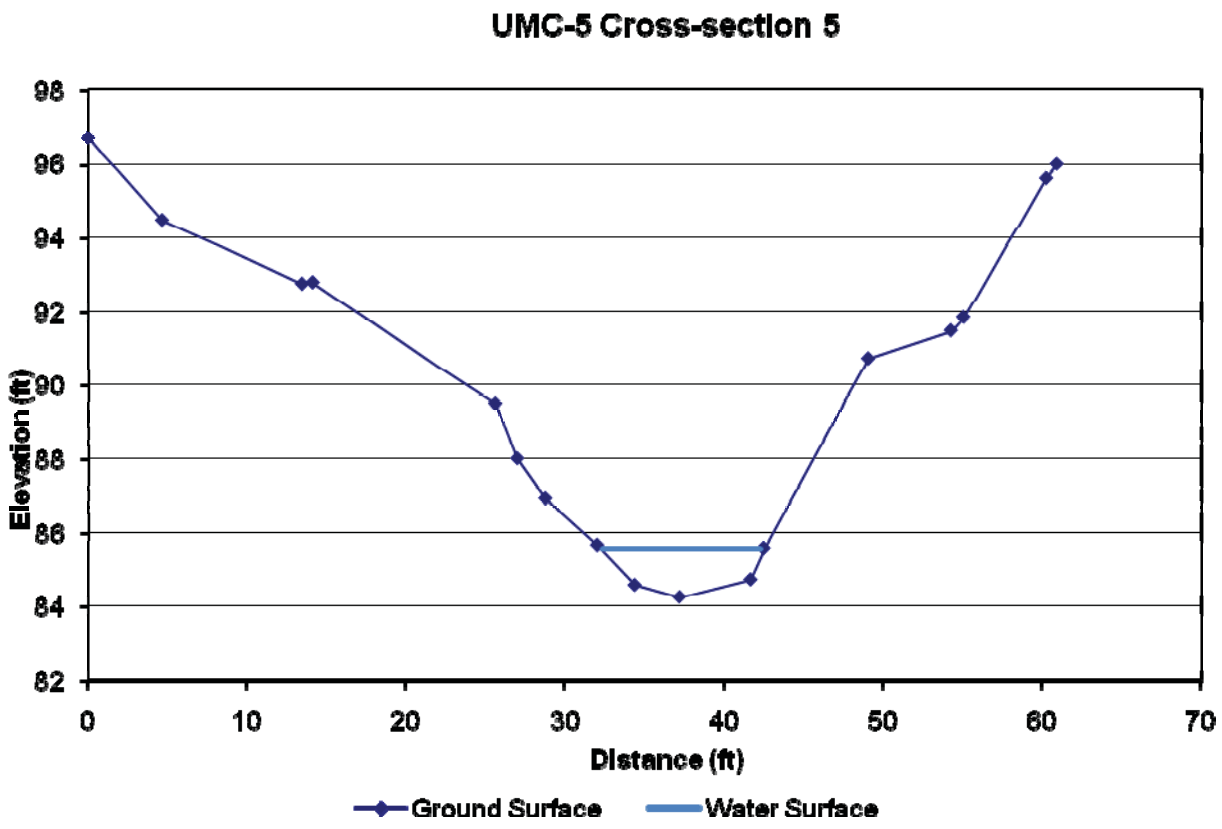
Photo 20: UMC5, XS-3, Right Bank



Note: Cross section was surveyed during the 2008 field activites.

UMC5, Cross-section 4, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	2.3	8.33
Root Depth/Bank ht	0.3	5.9
Root Density	<5%	10
Bank Angle	60	3.9
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	38.13
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

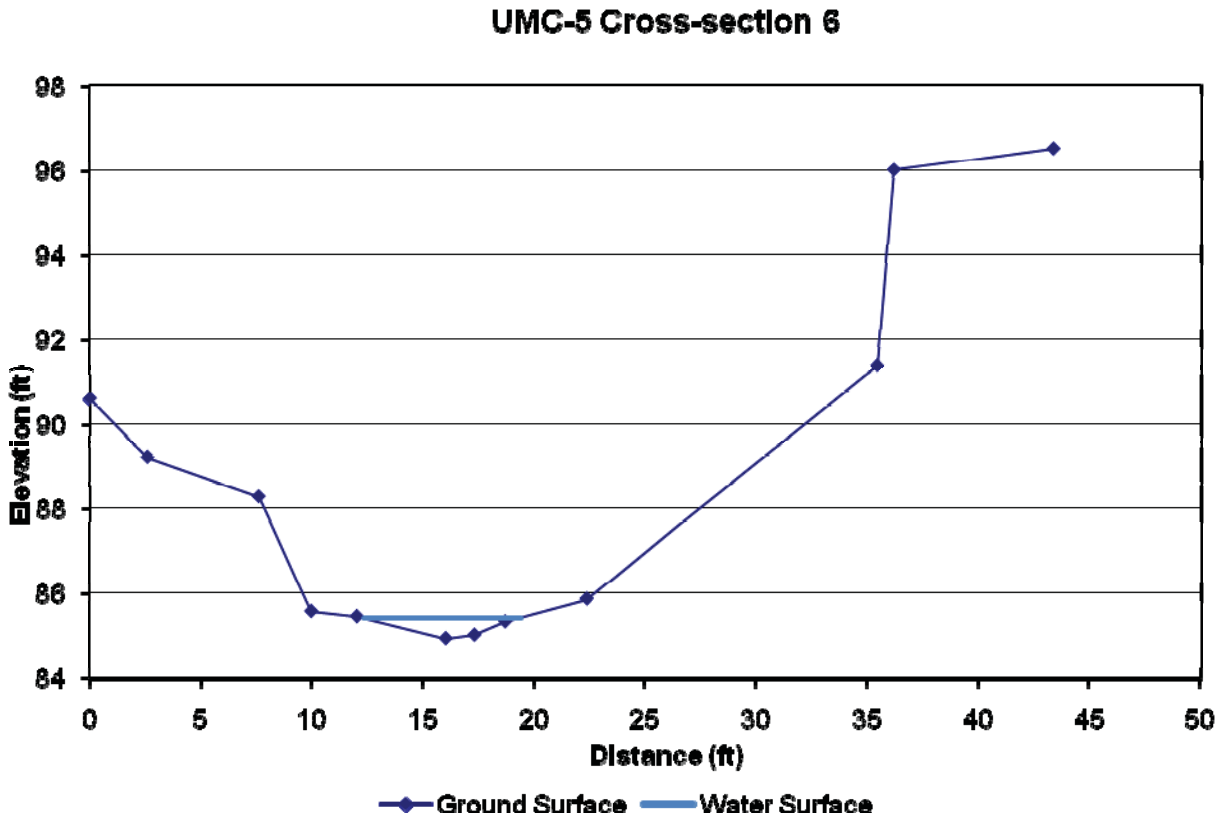


Note: Cross section was surveyed during the 2008 field activites.

UMC5, Cross-section 5, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	2.36	8.23
Root Depth/Bank ht	0.2	7.5
Root Density	<5%	10
Bank Angle	41	2.97
Surface Protection	45%	4.7
Bank Material	Silt	0
Stratification	None	0
Index sum	--	33.4
BEHI Rating	--	**High**
Radius of Curvature	Straight	--
Bankfull Width	--	--
NBS Rating	--	**N/A**

Photo 21: UMC5, XS-5, Right Bank

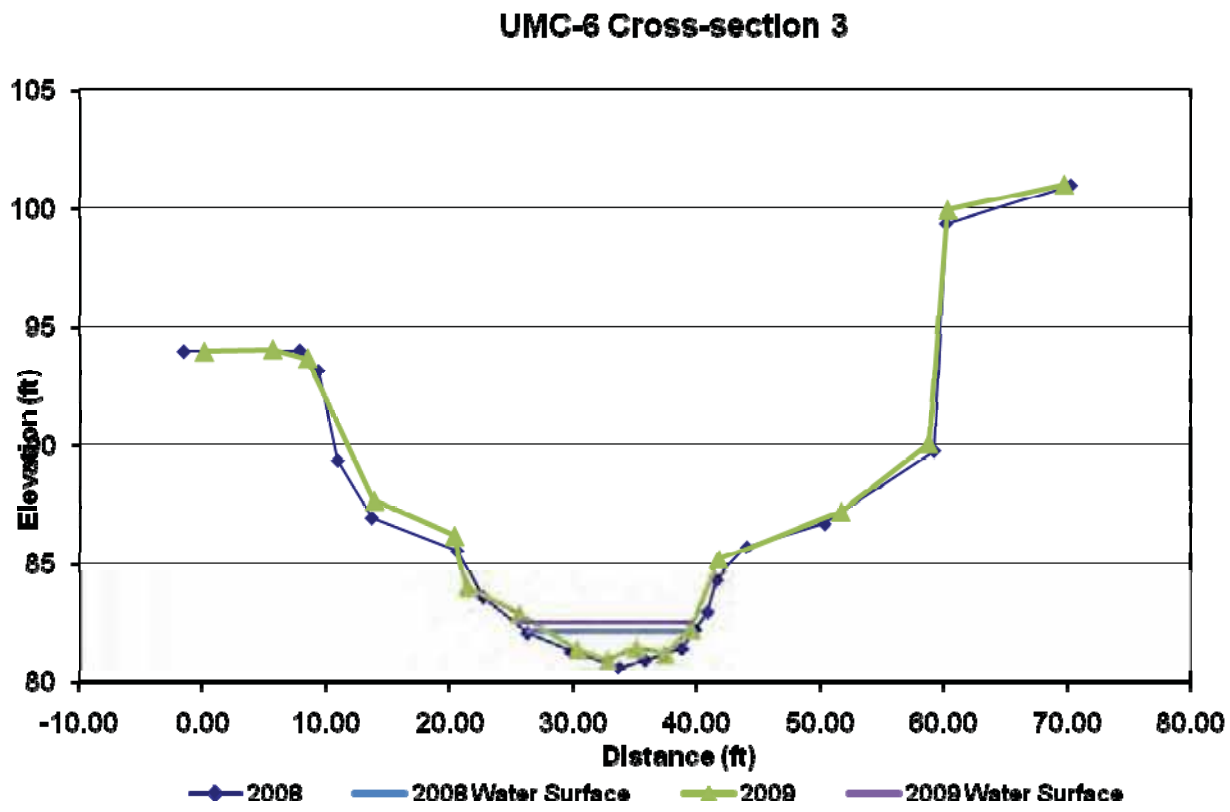


Note: Cross section was surveyed during the 2008 field activites.

UMC5, Cross-section 6, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	3.14	10
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	60	3.9
Surface Protection	16%	7.76
Bank Material	Silt	0
Stratification	None	0
Index sum	--	40.16
BEHI Rating	--	**Very High**
Radius of Curvature	91	--
Bankfull Width	21	--
Rc/W	4.4	--
NBS Rating	--	**Very Low**

Photo 22: UMC5, XS-6, Right Bank



Note: Cross section was surveyed during the 2008 field activites.

UMC6, Cross-section 3, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	4.2	10
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	62	4.1
Surface Protection	19%	6.1
Bank Material	Silt	0
Stratification	None	0
Index sum	--	38.7
BEHI Rating	--	High

Photo 23 UMC6, XS-3, Right Bank

UMC6, Cross-section 1, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	3.9	10
Root Depth/Bank ht	0.1	8.5
Root Density	<5%	10
Bank Angle	85	6.84
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	45.34
BEHI Rating	--	**Very High**

Photo 24: UMC6, XS-1, Left Bank

UMC6, Cross-section 4, Right bank

Category	Value	Index
Bank ht/Bankfull Depth	3.1	10
Root Depth/Bank ht	0.05	10
Root Density	<5%	10
Bank Angle	77	5.6
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	45.6
BEHI Rating	--	**Extreme**

Photo 25: UMC6, XS-4, Right Bank

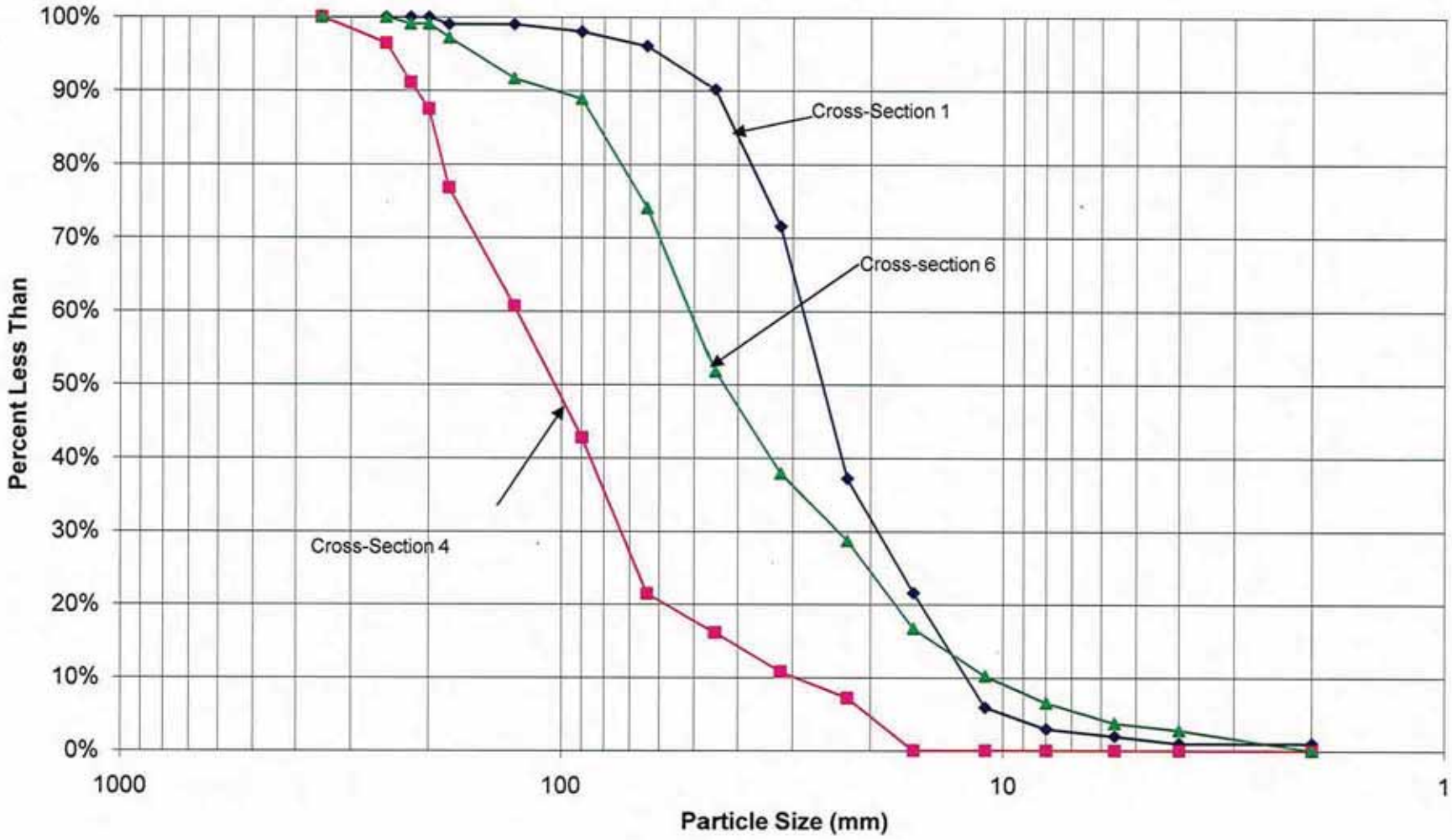
UMC6, Cross-section 6, Left bank

Category	Value	Index
Bank ht/Bankfull Depth	4.0	10
Root Depth/Bank ht	0.17	7.7
Root Density	<5%	10
Bank Angle	83.5	6.25
Surface Protection	0%	10
Bank Material	Silt	0
Stratification	None	0
Index sum	--	43.95
BEHI Rating	--	**Very High**

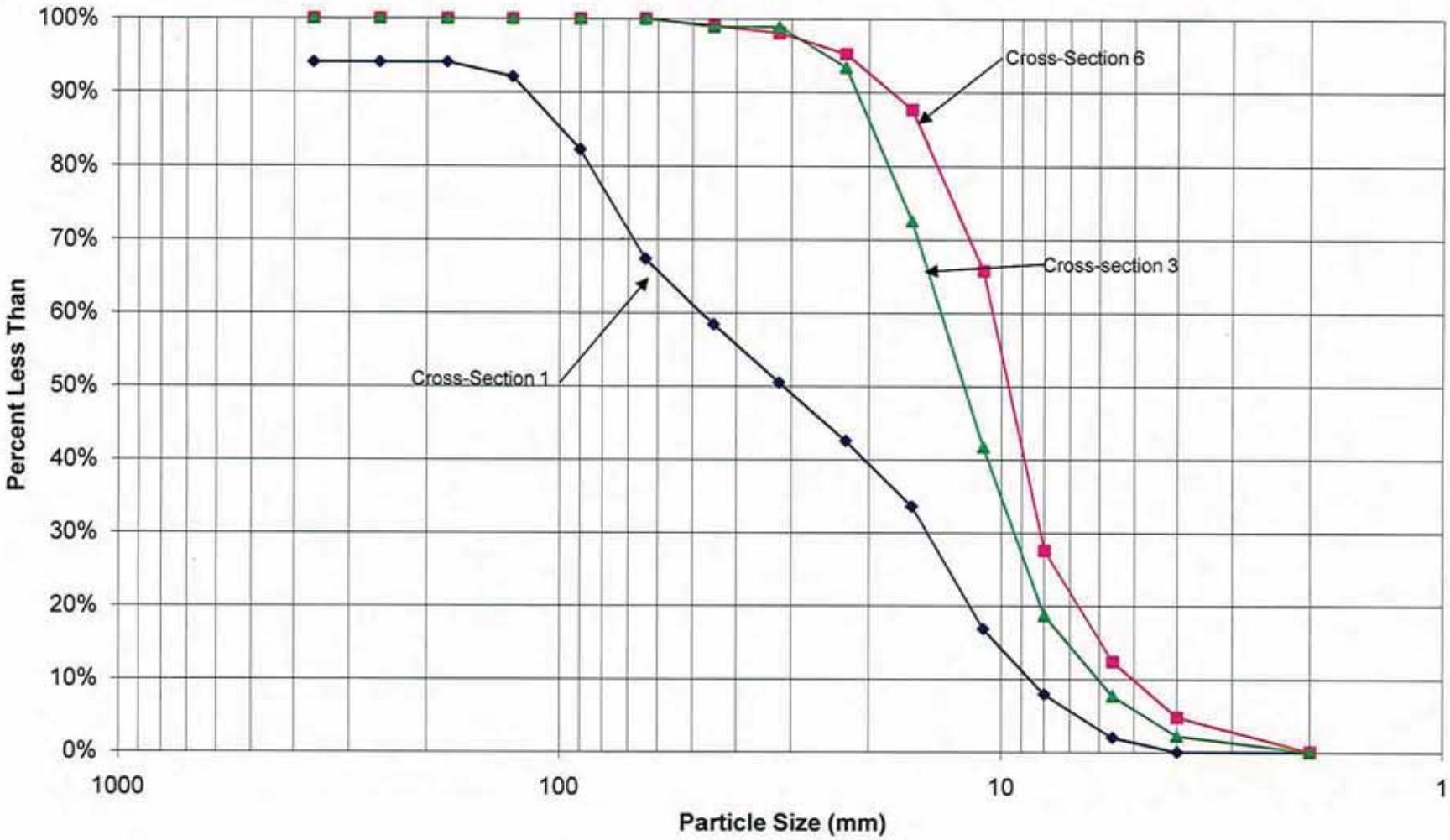
Photo 26: UMC6, XS-6, Left Bank

Appendix C

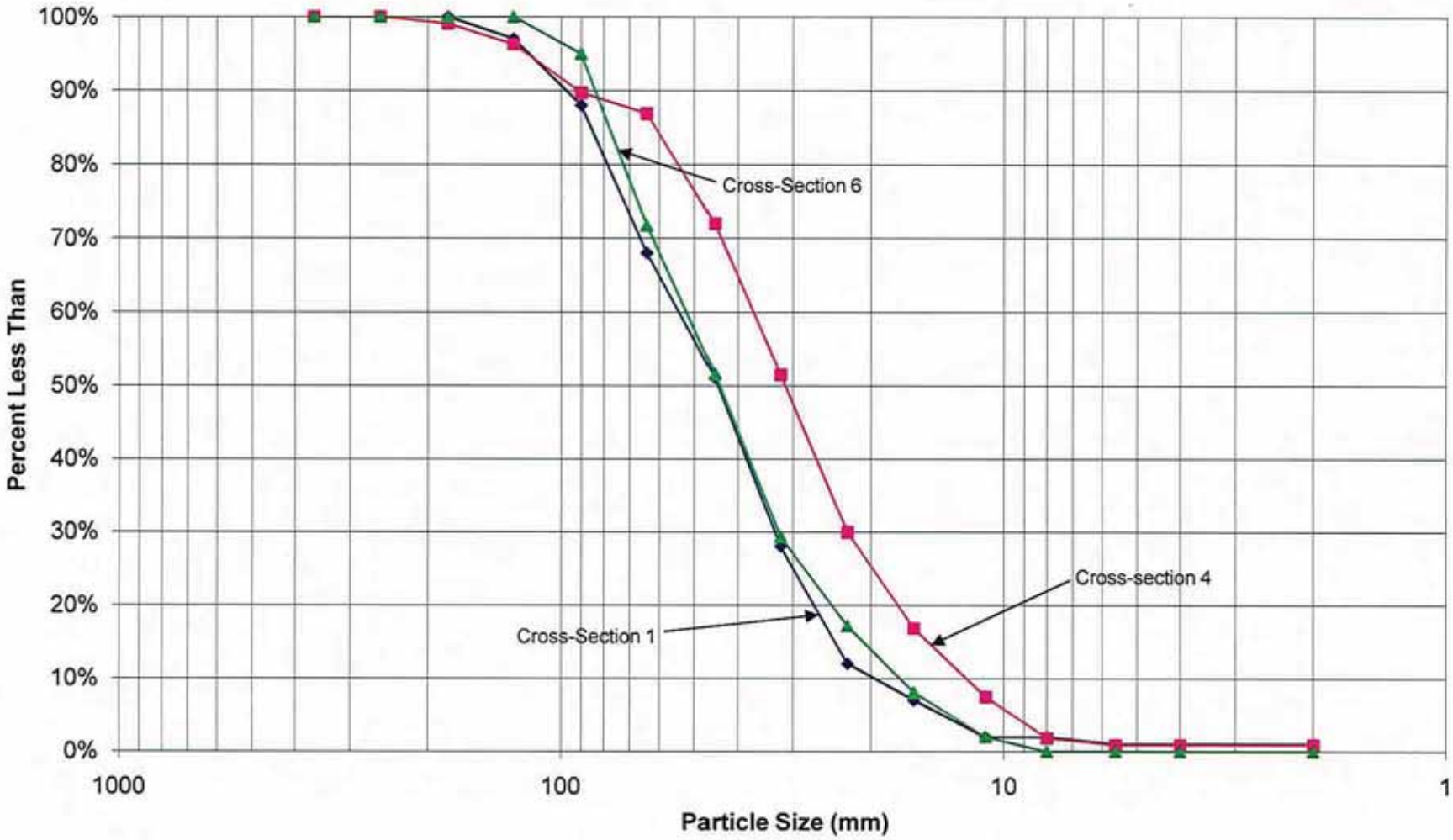
UMC-1 -2009
Pebble Count Cumulative Size Distributions
Upper Muddy Creek, Carbon County, Wyoming



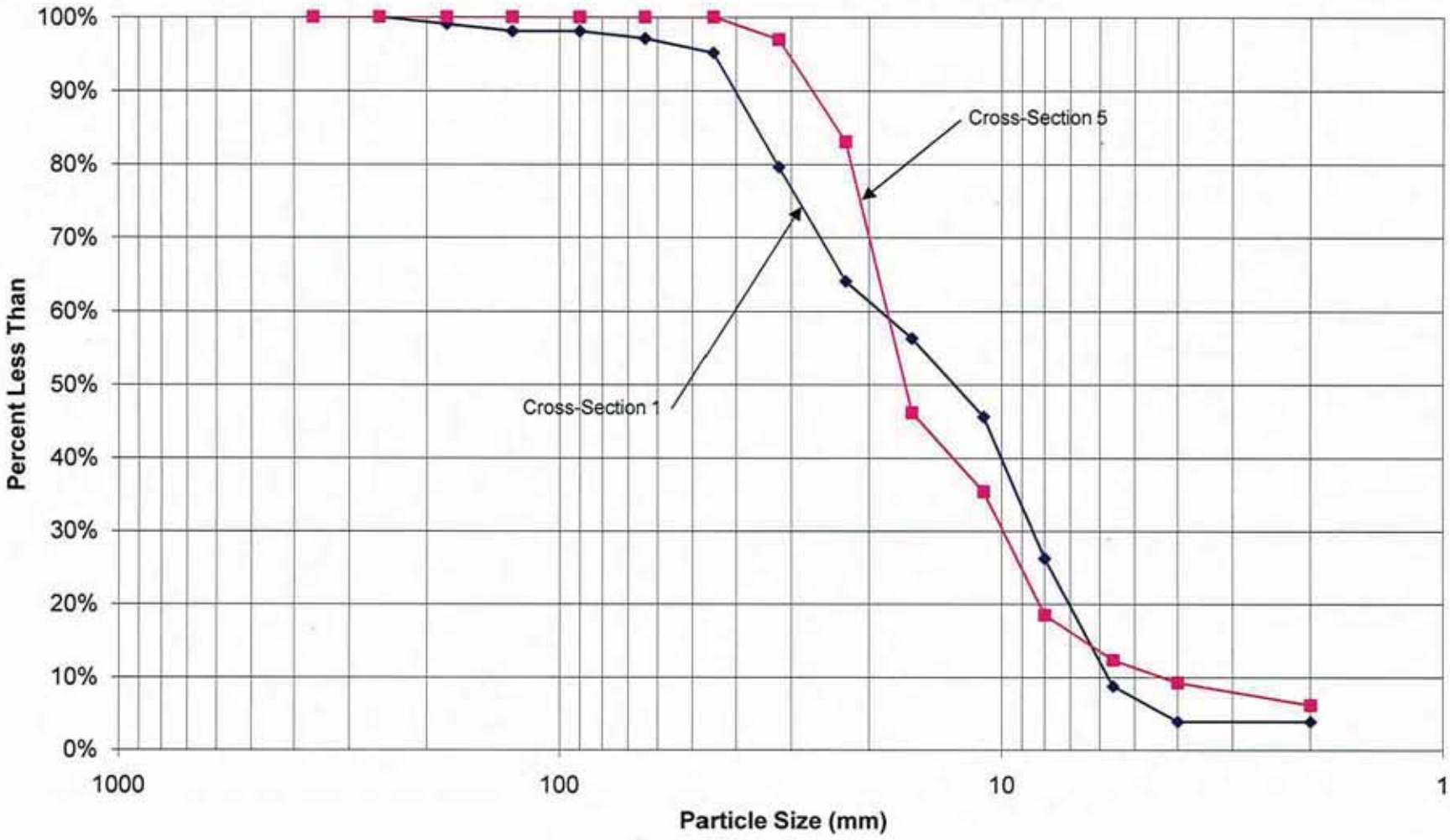
UMC-2 - 2009
Pebble Count Cumulative Size Distributions
Upper Muddy Creek, Carbon County,Wyoming



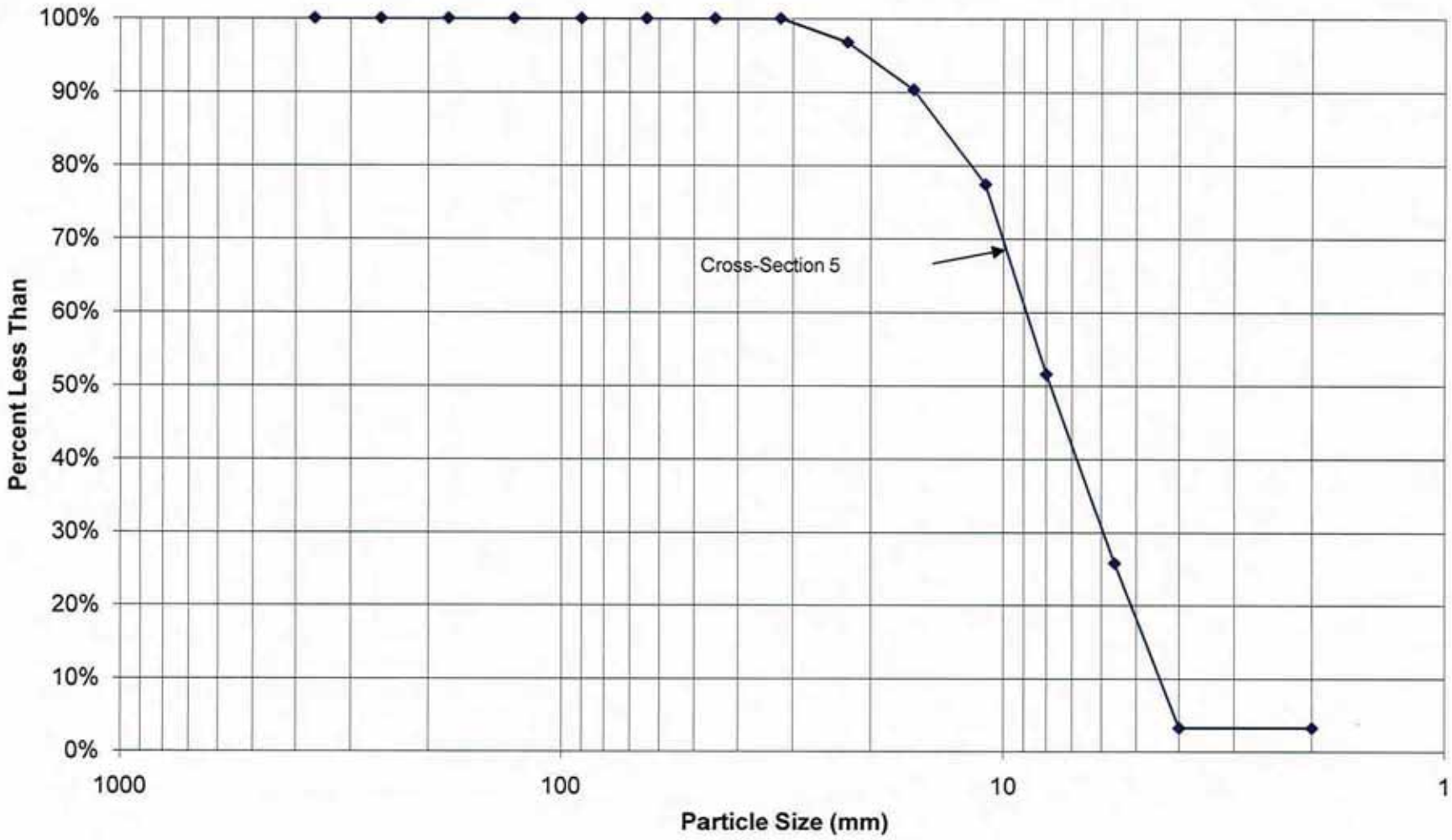
UMC-3 - 2009
Pebble Count Cumulative Size Distributions
Upper Muddy Creek, Carbon County, Wyoming



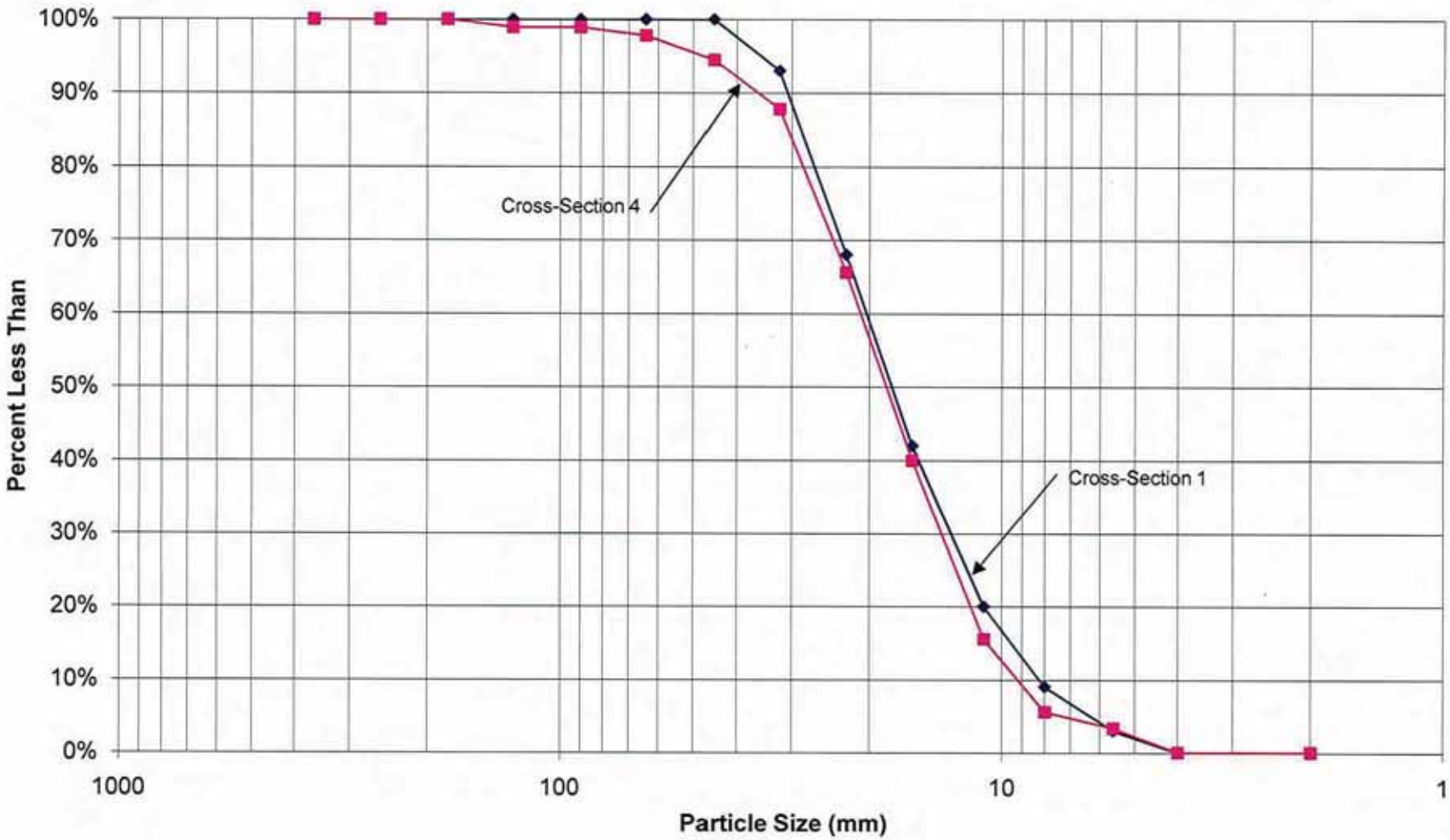
UMC-4 - 2009
Pebble Count Cumulative Size Distributions
Upper Muddy Creek, Carbon County, Wyoming



UMC-5 -2009
Pebble Count Cumulative Size Distributions
Upper Muddy Creek, Carbon County, Wyoming



UMC-6 - 2009
Pebble Count cumulative Size Distributions
Upper Muddy Creek, Carbon County, Wyoming



Appendix D

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

ANALYTICAL SUMMARY REPORT

September 14, 2009

Bill Butcher
Camp Dresser and McKee Inc
50 W 14th St Ste 200
Helena, MT 59601

Workorder No.: H09080092

Project Name: Anadarko-Muddy Creek

Energy Laboratories Inc received the following 5 samples for Camp Dresser and McKee Inc on 8/7/2009 for analysis.

Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
H09080092-001	UMC-3D	08/05/09 14:50	08/07/09	Aqueous	Metals by ICP/ICPMS, Dissolved Alkalinity Conductivity Anions by Ion Chromatography Solids, Total Suspended Turbidity
H09080092-002	UMC-3	08/05/09 14:40	08/07/09	Aqueous	Metals by ICP/ICPMS, Dissolved Alkalinity Conductivity Anions by Ion Chromatography Solids, Total Suspended
H09080092-003	UMC-1	08/04/09 16:00	08/07/09	Aqueous	Metals by ICP/ICPMS, Dissolved Alkalinity Conductivity Anions by Ion Chromatography Solids, Total Suspended Turbidity
H09080092-004	UMC-6	08/06/09 13:00	08/07/09	Aqueous	Same As Above
H09080092-005	UMC-6B	08/06/09 13:00	08/07/09	Aqueous	Metals by ICP/ICPMS, Dissolved Alkalinity Conductivity Anions by Ion Chromatography

BRANCH LABORATORY LOCATIONS
eli-b - Energy Laboratories, Inc. - Billings, MT, EPA # MT00005
eli-c - Energy Laboratories, Inc. - Casper, WY, EPA# WY00002
eli-g - Energy Laboratories, Inc. - Gillette, WY, EPA# WY00006
eli-h - Energy Laboratories, Inc. - Helena, MT, EPA# MT00945
eli-r - Energy Laboratories, Inc. - Rapid City, SD, EPA# SD00012
eli-t - Energy Laboratories, Inc. - College Station, TX, EPA# TX01520

SUBCONTRACTING ANALYSIS
Subcontracting of sample analyses to an outside laboratory may be required. If so, ENERGY LABORATORIES, INC. will utilize its branch laboratories or qualified contract laboratories for this service. Any such laboratories are indicated within the Laboratory Analytical Report.

SAMPLE TEMPERATURE COMPLIANCE: 4°C (±2°C)
Temperature of samples received may not be considered properly preserved by accepted standards. Samples that are hand delivered immediately after collection shall be considered acceptable if there is evidence that the chilling process has begun.

ELI appreciates the opportunity to provide you with this analytical service. For additional information, including certifications, and analytical services visit our web page www.energylab.com.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

ANALYTICAL SUMMARY REPORT

Report Approved By: Amanda Blackburn

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

CLIENT: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Sample Delivery Group: H09080092

Date: *14-Sep-09*

CASE NARRATIVE

Turbidity was not logged into the work order for sample UMC-1 at the time of sample receipt due to laboratory error. Turbidity was analyzed on 9/10/09 past hold per client request. There is no charge for Turbidity analysis on UMC-1. Abb 9/14/09

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Lab ID: H09080092-003
Client Sample ID: UMC-1

Report Date: 09/07/09
Collection Date: 08/04/09 16:00
DateReceived: 08/07/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
Conductivity	664	umhos/cm		1		A2510 B	08/10/09 10:27 / hm
Turbidity	16.0	NTU	H	0.01		E180.1	09/10/09 11:30 / hm
Solids, Total Suspended TSS @ 105 C	23	mg/L		10		A2540 D	08/10/09 08:55 / JG
INORGANICS							
Alkalinity, Total as CaCO3	170	mg/L		4		A2320 B	08/10/09 12:48 / JG
Chloride	6	mg/L		1		E300.0	08/10/09 21:48 / hm
Sulfate	180	mg/L		1		E300.0	08/10/09 21:48 / hm
METALS, DISSOLVED							
Calcium	76	mg/L		1		E200.7	08/12/09 12:57 / eli-b
Magnesium	25	mg/L		1		E200.7	08/12/09 12:57 / eli-b
Potassium	4	mg/L		1		E200.7	08/12/09 12:57 / eli-b
Selenium	ND	mg/L		0.005		E200.8	08/12/09 22:45 / eli-b
Sodium	29	mg/L		1		E200.7	08/12/09 12:57 / eli-b

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
H - Analysis performed past recommended holding time.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Lab ID: H09080092-002
Client Sample ID: UMC-3

Report Date: 09/07/09
Collection Date: 08/05/09 14:40
DateReceived: 08/07/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
Solids, Total Suspended TSS @ 105 C	ND	mg/L		10		A2540 D	08/10/09 08:55 / JG
INORGANICS							
Alkalinity, Total as CaCO3	160	mg/L		4		A2320 B	08/10/09 12:35 / JG
Chloride	6	mg/L		1		E300.0	08/10/09 21:32 / hm
Sulfate	180	mg/L		1		E300.0	08/10/09 21:32 / hm
METALS, DISSOLVED							
Calcium	71	mg/L		1		E200.7	08/12/09 12:53 / eli-b
Magnesium	26	mg/L		1		E200.7	08/12/09 12:53 / eli-b
Potassium	4	mg/L		1		E200.7	08/12/09 12:53 / eli-b
Selenium	ND	mg/L		0.005		E200.8	08/12/09 22:41 / eli-b
Sodium	32	mg/L		1		E200.7	08/12/09 12:53 / eli-b

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Lab ID: H09080092-001
Client Sample ID: UMC-3D

Report Date: 09/07/09
Collection Date: 08/05/09 14:50
DateReceived: 08/07/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
Conductivity	660	umhos/cm		1		A2510 B	08/10/09 08:13 / JG
Turbidity	6.15	NTU		0.01		E180.1	08/07/09 13:42 / hm
Solids, Total Suspended TSS @ 105 C	10	mg/L		10		A2540 D	08/10/09 08:54 / JG
INORGANICS							
Alkalinity, Total as CaCO3	160	mg/L		4		A2320 B	08/10/09 11:54 / JG
Chloride	6	mg/L		1		E300.0	08/10/09 21:15 / hm
Sulfate	180	mg/L		1		E300.0	08/10/09 21:15 / hm
METALS, DISSOLVED							
Calcium	72	mg/L		1		E200.7	08/12/09 12:49 / eli-b
Magnesium	26	mg/L		1		E200.7	08/12/09 12:49 / eli-b
Potassium	4	mg/L		1		E200.7	08/12/09 12:49 / eli-b
Selenium	ND	mg/L		0.005		E200.8	08/12/09 22:09 / eli-b
Sodium	30	mg/L		1		E200.7	08/12/09 12:49 / eli-b

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Lab ID: H09080092-004
Client Sample ID: UMC-6

Report Date: 09/07/09
Collection Date: 08/06/09 13:00
DateReceived: 08/07/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
Conductivity	688	umhos/cm		1		A2510 B	08/10/09 08:15 / JG
Turbidity	6.88	NTU		0.01		E180.1	08/07/09 13:44 / hm
Solids, Total Suspended TSS @ 105 C	11	mg/L		10		A2540 D	08/10/09 08:57 / JG
INORGANICS							
Alkalinity, Total as CaCO3	160	mg/L		4		A2320 B	08/10/09 12:59 / JG
Chloride	7	mg/L		1		E300.0	08/10/09 22:37 / hm
Sulfate	200	mg/L		1		E300.0	08/10/09 22:37 / hm
METALS, DISSOLVED							
Calcium	73	mg/L		1		E200.7	08/12/09 13:01 / eli-b
Magnesium	27	mg/L		1		E200.7	08/12/09 13:01 / eli-b
Potassium	4	mg/L		1		E200.7	08/12/09 13:01 / eli-b
Selenium	ND	mg/L		0.005		E200.8	08/12/09 22:49 / eli-b
Sodium	34	mg/L		1		E200.7	08/12/09 13:01 / eli-b

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek
Lab ID: H09080092-005
Client Sample ID: UMC-6B

Report Date: 09/07/09
Collection Date: 08/06/09 13:00
DateReceived: 08/07/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
INORGANICS							
Alkalinity, Total as CaCO3	ND	mg/L		4		A2320 B	08/10/09 13:02 / JG
Chloride	ND	mg/L		1		E300.0	08/10/09 22:54 / hm
Sulfate	ND	mg/L		1		E300.0	08/10/09 22:54 / hm
METALS, DISSOLVED							
Calcium	ND	mg/L		1		E200.7	08/12/09 13:05 / eli-b
Magnesium	ND	mg/L		1		E200.7	08/12/09 13:05 / eli-b
Potassium	ND	mg/L		1		E200.7	08/12/09 13:05 / eli-b
Selenium	ND	mg/L		0.005		E200.8	08/12/09 22:54 / eli-b
Sodium	ND	mg/L		1		E200.7	08/12/09 13:05 / eli-b

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

QA/QC Summary Report

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek

Report Date: 09/07/09
Work Order: H09080092

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A2320 B									Analytical Run: TITTR_090810A	
Sample ID: CCV1_090810A		Continuing Calibration Verification Standard							08/10/09 13:42	
Alkalinity, Total as CaCO3		1000	mg/L	4.0	**104**	90	110			
Method: A2320 B									Batch: 090810A-ALK-W	
Sample ID: MBLK1_090810A		Method Blank				Run: TITTR_090810A			08/10/09 11:00	
Alkalinity, Total as CaCO3		2	mg/L	1						
Sample ID: LCS1_090810A		Laboratory Control Sample				Run: TITTR_090810A			08/10/09 11:04	
Alkalinity, Total as CaCO3		580	mg/L	4.0	**96**	90	110			
Sample ID: H09080092-001ADUP		Sample Duplicate				Run: TITTR_090810A			08/10/09 11:58	
Alkalinity, Total as CaCO3		160	mg/L	4.0				**0.6**	20	
Sample ID: H09080092-005AMS		Sample Matrix Spike				Run: TITTR_090810A			08/10/09 13:14	
Alkalinity, Total as CaCO3		590	mg/L	4.0	**98**	90	110			
Sample ID: H09080092-005AMSD		Sample Matrix Spike Duplicate				Run: TITTR_090810A			08/10/09 13:22	
Alkalinity, Total as CaCO3		580	mg/L	4.0	**97**	90	110	**1**	20	
Method: A2510 B									Analytical Run: COND_090810A	
Sample ID: CCV1_090810A		Continuing Calibration Verification Standard							08/10/09 08:23	
Conductivity		722	umhos/cm	1.0	**101**	90	110			
Method: A2510 B									Analytical Run: COND_090810B	
Sample ID: CCV1_090810A		Continuing Calibration Verification Standard							08/10/09 10:29	
Conductivity		721	umhos/cm	1.0	**100**	90	110			
Method: A2510 B									Batch: 090810A-COND-PROBE-W	
Sample ID: LCS1_090810A		Laboratory Control Sample				Run: COND_090810A			08/10/09 08:10	
Conductivity		1410	umhos/cm	1.0	**100**	90	110			
Sample ID: H09080092-004ADUP		Sample Duplicate				Run: COND_090810A			08/10/09 08:16	
Conductivity		688	umhos/cm	1.0				**0.1**	10	
Sample ID: H09080092-003ADUP		Sample Duplicate				Run: COND_090810B			08/10/09 10:27	
Conductivity		664	umhos/cm	1.0				**0**	10	
Method: A2540 D									Batch: 090810A-SLDS-TSS-W	
Sample ID: MBLK1_090810A		Method Blank				Run: SOLIDS_090810A			08/10/09 08:53	
Solids, Total Suspended TSS @ 105 C		ND	mg/L	1						
Sample ID: LCS1_090810A		Laboratory Control Sample				Run: SOLIDS_090810A			08/10/09 08:54	
Solids, Total Suspended TSS @ 105 C		1810	mg/L	10	**90**	70	130			
Sample ID: H09080092-003ADUP		Sample Duplicate				Run: SOLIDS_090810A			08/10/09 08:56	
Solids, Total Suspended TSS @ 105 C		23.0	mg/L	10					10	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

QA/QC Summary Report

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek

Report Date: 09/07/09
Work Order: H09080092

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E180.1									Analytical Run: TURBIDITY_090807A	
Sample ID: CCV1_090807A		Continuing Calibration Verification Standard							08/07/09 13:45	
Turbidity		0.997	NTU	0.010	**100**	90	110			
Method: E180.1									Batch: 090807A-TURB-W	
Sample ID: MBLK1_090807A		Method Blank				Run: TURBIDITY_090807A			08/07/09 13:36	
Turbidity		ND	NTU							
Sample ID: LCS1_090807A		Laboratory Control Sample				Run: TURBIDITY_090807A			08/07/09 13:37	
Turbidity		9.89	NTU	0.010	**99**	90	110			
Sample ID: H09080092-004ADUP		Sample Duplicate				Run: TURBIDITY_090807A			08/07/09 13:45	
Turbidity		7.00	NTU	0.010				**1.7**	20	
Method: E180.1								ical Run: HACH 2100N TURBIDIMETER_090910A		
Sample ID: CCV1_090910A		Continuing Calibration Verification Standard							09/10/09 11:30	
Turbidity		20.3	NTU	0.010	**102**	90	110			
Method: E180.1									Batch: 090910A-TURB-W	
Sample ID: LCS1_090910A		Laboratory Control Sample				Run: HACH 2100N TURBIDIMETER			09/10/09 11:30	
Turbidity		100	NTU	0.010	**100**	90	110			
Sample ID: MBLK1_090910A		Method Blank				Run: HACH 2100N TURBIDIMETER			09/10/09 11:30	
Turbidity		0.06	NTU							
Sample ID: H09080092-003ADUP		Sample Duplicate				Run: HACH 2100N TURBIDIMETER			09/10/09 11:30	
Turbidity		16.8	NTU	0.010				**4.9**	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

QA/QC Summary Report

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek

Report Date: 09/07/09
Work Order: H09080092

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Analytical Run: SUB-B134258	
Sample ID: ICV	5	Continuing Calibration Verification Standard							08/12/09 11:33	
Calcium		24.4	mg/L	1.0	**98**	95	105			
Magnesium		24.8	mg/L	1.0	**99**	95	105			
Manganese		2.50	mg/L	0.010	**100**	95	105			
Potassium		25.5	mg/L	1.0	**102**	95	105			
Sodium		25.3	mg/L	1.0	**101**	95	105			
Method: E200.7									Batch: B_R134258	
Sample ID: MB-TJADIS090812A	5	Method Blank				Run: SUB-B134258			08/12/09 12:00	
Calcium		ND	mg/L	0.04						
Magnesium		ND	mg/L	0.06						
Manganese		0.0008	mg/L	0.0003						
Potassium		0.06	mg/L	0.05						
Sodium		ND	mg/L	0.02						
Sample ID: LFB-TJADIS090812A	5	Laboratory Fortified Blank				Run: SUB-B134258			08/12/09 12:03	
Calcium		49.4	mg/L	1.0	**99**	85	115			
Magnesium		49.9	mg/L	1.0	**100**	85	115			
Manganese		4.98	mg/L	0.010	**100**	85	115			
Potassium		49.2	mg/L	1.0	**98**	85	115			
Sodium		48.9	mg/L	1.0	**98**	85	115			
Sample ID: B09080932-005BMS2	5	Sample Matrix Spike				Run: SUB-B134258			08/12/09 13:09	
Calcium		50.8	mg/L	1.0	**101**	70	130			
Magnesium		50.7	mg/L	1.0	**101**	70	130			
Manganese		5.03	mg/L	0.010	**101**	70	130			
Potassium		51.4	mg/L	1.0	**103**	70	130			
Sodium		51.6	mg/L	1.0	**103**	70	130			
Sample ID: B09080932-005BMSD2	5	Sample Matrix Spike Duplicate				Run: SUB-B134258			08/12/09 13:12	
Calcium		52.0	mg/L	1.0	**104**	70	130	**2.2**	20	
Magnesium		51.9	mg/L	1.0	**104**	70	130	**2.4**	20	
Manganese		5.14	mg/L	0.010	**103**	70	130	**2.1**	20	
Potassium		51.4	mg/L	1.0	**103**	70	130	**0**	20	
Sodium		52.2	mg/L	1.0	**104**	70	130	**1.2**	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

QA/QC Summary Report

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek

Report Date: 09/07/09
Work Order: H09080092

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Analytical Run: SUB-B134242	
Sample ID: QCS - 090602A,09060		Initial Calibration Verification Standard							08/12/09 18:24	
Selenium		0.049	mg/L	0.0050	**98**	90	110			
Method: E200.8									Batch: B_R134242	
Sample ID: LRB		Method Blank				Run: SUB-B134242			08/12/09 10:39	
Selenium		ND	mg/L	0.0002						
Sample ID: LFB		Laboratory Fortified Blank				Run: SUB-B134242			08/12/09 10:43	
Selenium		0.047	mg/L	0.0050	**94**	85	115			
Sample ID: B09080960-001AMS		Sample Matrix Spike				Run: SUB-B134242			08/12/09 21:33	
Selenium		0.051	mg/L	0.0050	**101**	70	130			
Sample ID: B09080960-001AMSD		Sample Matrix Spike Duplicate				Run: SUB-B134242			08/12/09 21:37	
Selenium		0.051	mg/L	0.0050	**102**	70	130	**1.2**	20	
Sample ID: B09080932-001BMS		Sample Matrix Spike				Run: SUB-B134242			08/12/09 22:29	
Selenium		0.0527	mg/L	0.0050	**102**	70	130			
Sample ID: B09080932-001BMSD		Sample Matrix Spike Duplicate				Run: SUB-B134242			08/12/09 22:33	
Selenium		0.0513	mg/L	0.0050	**99**	70	130	**2.7**	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@energylab.com

QA/QC Summary Report

Client: Camp Dresser and McKee Inc
Project: Anadarko-Muddy Creek

Report Date: 09/07/09
Work Order: H09080092

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E300.0									Analytical Run: IC101-H_090810A	
Sample ID: ICV	2	Initial Calibration Verification Standard								08/10/09 13:19
Chloride		2.5	mg/L	1.0	**100**	90	110			
Sulfate		9.9	mg/L	1.0	**99**	90	110			
Sample ID: CCV	2	Continuing Calibration Verification Standard								08/10/09 18:15
Chloride		24	mg/L	1.0	**94**	90	110			
Sulfate		50	mg/L	1.0	**99**	90	110			
Sample ID: CCV	2	Continuing Calibration Verification Standard								08/10/09 22:05
Chloride		23	mg/L	1.0	**94**	90	110			
Sulfate		50	mg/L	1.0	**101**	90	110			
Method: E300.0										Batch: R55741
Sample ID: LCS	2	Laboratory Control Sample				Run: IC101-H_090810A				08/10/09 13:35
Chloride		86	mg/L	1.0	**98**	90	110			
Sulfate		28	mg/L	1.0	**97**	90	110			
Sample ID: LFB	2	Laboratory Fortified Blank				Run: IC101-H_090810A				08/10/09 13:52
Chloride		4.7	mg/L	1.0	**94**	90	110			
Sulfate		9.5	mg/L	1.0	**92**	90	110			
Sample ID: MBLK	2	Method Blank				Run: IC101-H_090810A				08/10/09 14:08
Chloride		ND	mg/L	0.05						
Sulfate		0.3	mg/L	0.1						
Sample ID: H09080050-002A MS	2	Sample Matrix Spike				Run: IC101-H_090810A				08/10/09 20:26
Chloride		50	mg/L	1.0	**101**	90	110			
Sulfate		99	mg/L	1.0	**101**	90	110			
Sample ID: H09080050-002A MSD	2	Sample Matrix Spike Duplicate				Run: IC101-H_090810A				08/10/09 20:42
Chloride		50	mg/L	1.0	**101**	90	110	**0.3**	20	
Sulfate		99	mg/L	1.0	**102**	90	110	**0.2**	20	
Sample ID: H09080098-002A MS	2	Sample Matrix Spike				Run: IC101-H_090810A				08/11/09 00:16
Chloride		28	mg/L	1.0	**96**	90	110			
Sulfate		110	mg/L	1.0	**103**	90	110			
Sample ID: H09080098-002A MSD	2	Sample Matrix Spike Duplicate				Run: IC101-H_090810A				08/11/09 00:32
Chloride		28	mg/L	1.0	**96**	90	110	**0.2**	20	
Sulfate		110	mg/L	1.0	**104**	90	110	**0.3**	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. • P.O. Box 5688 • 3161 East Lyndale Ave. • Helena, MT 59604
877-472-0711 • 406-442-0711 • 406-442-0712 fax • helena@energylab.com

Energy Laboratories Inc
Workorder Receipt Checklist

H09080092

Camp Dresser and McKee Inc

Login completed by: Wanda Johnson
Date and Time Received: 8/7/2009 10:40 AM

Reviewed by: BL2000\wjohnson
Received by: rlt

Reviewed Date: 8/10/2009 6:53:00 PM
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☐	No ☑	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☐	No ☑	
Container/Temp Blank temperature:	3.3°C		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☑	No ☐	Not Applicable ☐

Contact and Corrective Action Comments:

Client contacted about sample UMC-6B which was not listed on Chain Of Custody as to if we were to analyze and what parameters. As per Karin Mainhousen we are to analyze UMC-6B for common Ions (Ca,Mg,K,Na) Sulfate ,Chloride,Dis. And Selenium. UMC -3 Raw no sample date or time on bottle, UMC-6 1 Raw no sample date or time. UMC6 bottles state 12.50 for time of collection and Chain Of Custody states 13.00 s/b what is on COC per K. Mainhzuser.MT 9/8/09 spoke with K Mainhauzen analyze the Turbidity even though past time. Wj

Chain of Custody and Analytical Request Record

ENERGY LABORATORIES

Page ____ of ____

PLEASE PRINT- Provide as much information as possible.

Company Name:	Project Name, PWS, Permit, Etc.	Sample Origin	EPA/State Compliance:
CDM	Anadarko - Muddy Creek.	State: WY	Yes ☐ No ☐
Report Mail Address:	**Contact Name:** Phone/Fax:	Email:	Sampler: (Please Print)
50 W. 14th Str. Helena, MT 59601	Bill Bucher 406-441-1413		
Invoice Address:	**Invoice Contact & Phone:**	Purchase Order:	Quote/Bottle Order:
same	Bill Bucher 406-441-1413		

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

- ☐ DW
- ☐ GSA
- ☐ POTW/WWTP
- ☐ State: _____
- ☐ Other: _____
- ☐ A2LA
- ☐ EDD/EDT (Electronic Data) Format: _____
- ☐ LEVEL IV
- ☐ NELAC

Number of Containers
Sample Type: A Air W Water S Soils/Solids V Vegetation B Bioassay O Other

ANALYSIS REQUESTED

SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX	Common Ions Ca, Mg, Na, K,	Alkalinity	Sulfate	Chloride	dis. Se	TSS	Turbidity -	Sp. Conductance	SEE ATTACHED	Normal Turnaround (TAT)
1 UMC-3D	8/5/09	1450	H2O	X	X	X	X	X	X	X	X		
2 UMC-3	8/5/09	1440	"	X	X	X	X	X	X				
3 UMC-1	8/4/09	1600	"	X	X	X	X	X	X				
4 UMC-6	8/6/09	1300	H2O	X	X	X	X	X	X	X	X		
5													
6													
7													
8													
9													
10													

RUSH

Contact ELI prior to **RUSH** sample submittal for charges and scheduling – See Instruction Page

Comments:

Turbidity & Conductivity on UMC-1 even tho PAST HOLD per K. Mainhardt

Shipped by: hand

Cooler ID(s):

Receipt Temp 3.3 °C

On Ice: Yes No

Custody Seal Y N

Bottles/Coolers B C

Intact Y N

Signature Match Y N

LABORATORY USE ONLY H09080092

Custody Record MUST be Signed

Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
[signature]	8/7/09 1040	K. Mainhardt			
Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
			Received by Laboratory: Roxanne Jones	Date/Time: 8.7.09 10:40	Signature: [signature]

Sample Disposal: Return to Client: _____ Lab Disposal: _____

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.

Visit our web site at www.energylab.com for additional information, downloadable fee schedule, forms, and links.