Grave Creek Restoration Project
Phase 1 and Phase 2 Monitoring Report

Grave Creek Phase 1

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June 2011

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1.0 Introduction

1.1 Project Background

The Kootenai River Network, Inc. (KRN) with funding provided by the Montana Department of Environmental Quality (MDEQ) retained River Design Group, Inc. (RDG) to complete a Quality Assurance Project Plan and Sampling and Analysis Plan (QAPP-SAP) for lower Grave Creek in the Tobacco River Watershed Total Maximum Daily Load (TMDL) Planning Area. The QAPP-SAP detailed sampling activities to be performed to evaluate trends and progress in meeting lower Grave Creek TMDL goals, as presented in the *Grave Creek Watershed Water Quality and Habitat Restoration Plan and Sediment Total Maximum Daily Load* (MDEQ, 2005). This report summarizes the monitoring results.

Implementation of restoration activities in lower Grave Creek began in 2002 under a joint venture initiated by the Montana Department of Fish, Wildlife & Parks (MFWP), Kootenai River Network, Inc., U.S. Fish and Wildlife Service (FWS), and private landowners. Two phases of restoration work have been implemented in 2002 (Phase 1) and 2004 (Phase 2). Restoration re-established a cobble and gravel dominated, meandering, riffle-pool stream type and focused on increasing habitat complexity and facilitating recovery of riparian and floodplain vegetation. Combined, the Phase 1 and Phase 2 projects included approximately 7,800 ft or 1.5 miles of Grave Creek.

1.2 Watershed Description

The Grave Creek watershed is located in northwest Montana southwest of the town of Eureka, Montana. Draining a watershed area of approximately 74.2 mi^2, with elevations ranging from 2,700 ft at the confluence with Fortine Creek, to over 7,500 ft at the watershed divide, approximately 91% of the land base is managed by the Kootenai National Forest. Grave Creek is tributary to the Tobacco River, a major tributary to the Kootenai River west of Eureka. Grave Creek supports a largely native assemblage of fish comprised of ten species within four families. Classified as a bull trout core area (Montana Bull Trout Scientific Group, 1996b), Grave Creek is the major bull trout spawning tributary to Lake Koocanusa (USFS, 2000). Threats to resident and migratory life forms include, among others, residential development and agricultural land uses.

1.3 Problem Definition

The Montana 303(d) list identifies the main stem of Grave Creek from Foundation Creek downstream to the confluence of Grave Creek and Fortine Creek as impaired (MDEQ, 2005). Table 1-1 provides a summary of the impairment information from both the 1996 and 2004 303(d) lists.

Table 1-1. List of beneficial use impairments for Grave Creek based on the 1996 and 2004 303(d) lists.

Listed Stream and Number	List	Probable Causes	Probable Sources	Beneficial Uses Not Fully Supported
Grave Creek (MT76D004-6)	1996	Flow Alteration Other Habitat Alterations Siltation	Agriculture Silviculture	Aquatic Life Coldwater Fish
	2004	Bank Erosion Dewatering Fish Habitat Degradation Flow Alteration Other Habitat Alterations Siltation	Agriculture Grazing-related sources Silviculture Logging/road construction Dam Construction Flow Regulation/Mod Hydromodification	Aquatic Life Coldwater Fish Recreation

Lower Grave Creek has been subjected to a long period of residential encroachment, removal of riparian vegetation, overgrazing, physical channelization of the stream corridor, and dewatering. Prior to restoration actions, the cumulative effects of these actions included a substantial reduction in floodplain and streamside vegetation, and impaired channel morphology and aquatic habitat conditions. Due to these conditions, erosion rates were accelerated resulting in excessive sediment delivery to the channel. Primary aquatic habitat limiting factors in lower Grave Creek were related to the distribution of deep pool habitats. Adult holding habitats that are essential for fish during fall spawning migrations were extremely limited in lower Grave Creek due to poor pool development, insufficient large woody debris, and homogenous riffle habitat. Degraded riparian conditions along a majority of the project area contributed to elevated water temperatures, limited woody debris recruitment, and inadequate instream cover for bull trout and westslope cutthroat trout. As described in Section 4.0 of the Grave Creek TMDL, past and recent investigations indicated the main stem is impaired for sediment and aquatic habitat.

As defined by Montana State Law (75-5-703(7) & (9)), MDEQ is required to evaluate progress toward meeting TMDL goals and satisfying water quality standards associated with beneficial use support. Implementation monitoring is therefore necessary to assess progress toward meeting the targets developed in the Grave Creek TMDL. This report summarizes the monitoring results and progress towards meeting targets developed for lower Grave Creek by evaluating a variety of indicators for Grave Creek below the GLID, as summarized in Section 5.4.1.1 of the TMDL. Specifically, this report evaluates the following Type 1 Targets: 1) pool frequency; and 2) percent surface fines in riffles. Type II Targets evaluated in this report include: 1) width-to-depth ratio; 2) percent surface fines in riffles. Supplemental indicators were also measured and include large woody debris, channel sinuosity, and meander geometry relationships (Table 1-2). Vegetation parameters are also evaluated in this report. Although not included in the TMDL, vegetation parameters were developed during floodplain and riparian restoration activities within Phase 1 and 2 and are being used to evaluate floodplain and riparian plant community development and function.

Table 1-2. Summary of data collected in 2010 and their relation to the Grave Creek TMDL.

Parameter	Target Type	TMDL and Parameter Objectives[2]
Geomorphic Channel Monitoring		
Longitudinal Profile	Type I	Determine bankfull slope. Identify riffle, run, pool, and glide habitat types.
Cross-Sections	Type II	Establish channel dimensions.
Planform Analysis	Supplemental	Determine meander geometry and channel sinuosity.
Pebble Count	Type I	Determine channel bed particle size distribution and percent fines in riffles.
Photo Points	Supplemental	Supplemental data to support channel monitoring.
Large Woody Debris Inventory	Supplemental	Quantify availability of large wood as an indicator of channel stability, energy dissipation, sediment storage.
Sediment Reduction Analysis		
Bank Erosion Inventory	Supplemental	Evaluate bank erosion hazard and quantify bank-derived sediments.
Aquatic Habitat Monitoring		
Longitudinal Profile	Type 1	Evaluate pool frequency, residual pool volumes and maximum pool depths.
Large Woody Debris Inventory	Supplemental	Quantify availability of large wood for aquatic habitat.
Vegetation Monitoring[1]		
Aerial Photo Interpretation	N/A	Evaluate post-restoration floodplain plant community development.
Containerized Plant Survival	N/A	Evaluate effectiveness of containerized plantings and plant community development.
Streambank Woody Vegetation Cover	N/A	Evaluate effectiveness of streambank bioengineering treatments in reducing bank erosion.
Floodplain Vegetation Transects	N/A	Evaluate depositional and erosional processes on constructed floodplains and how they relate to plant community development.
Browse Evaluation	N/A	Evaluate effectiveness of exclosure fencing at promoting understory plant community development.

[1]Vegetation parameters were not included in the Grave Creek TMDL.

[2]Sampling methods are provided in Appendix E.

2.0 Grave Creek Phase 1 Results

This section provides the 2001 existing conditions survey data and the 2010 post-restoration survey data for Grave Creek Phase 1. Phase 1 was completed in 2002.

Sampling index and vicinity maps of the Phase 1 project area are included in Figure 2-1 and Figure 2-2. Figures 2-1 and 2-2 also include the location of the surveyed channel length, cross-sections, pebble count sites, and photo points.

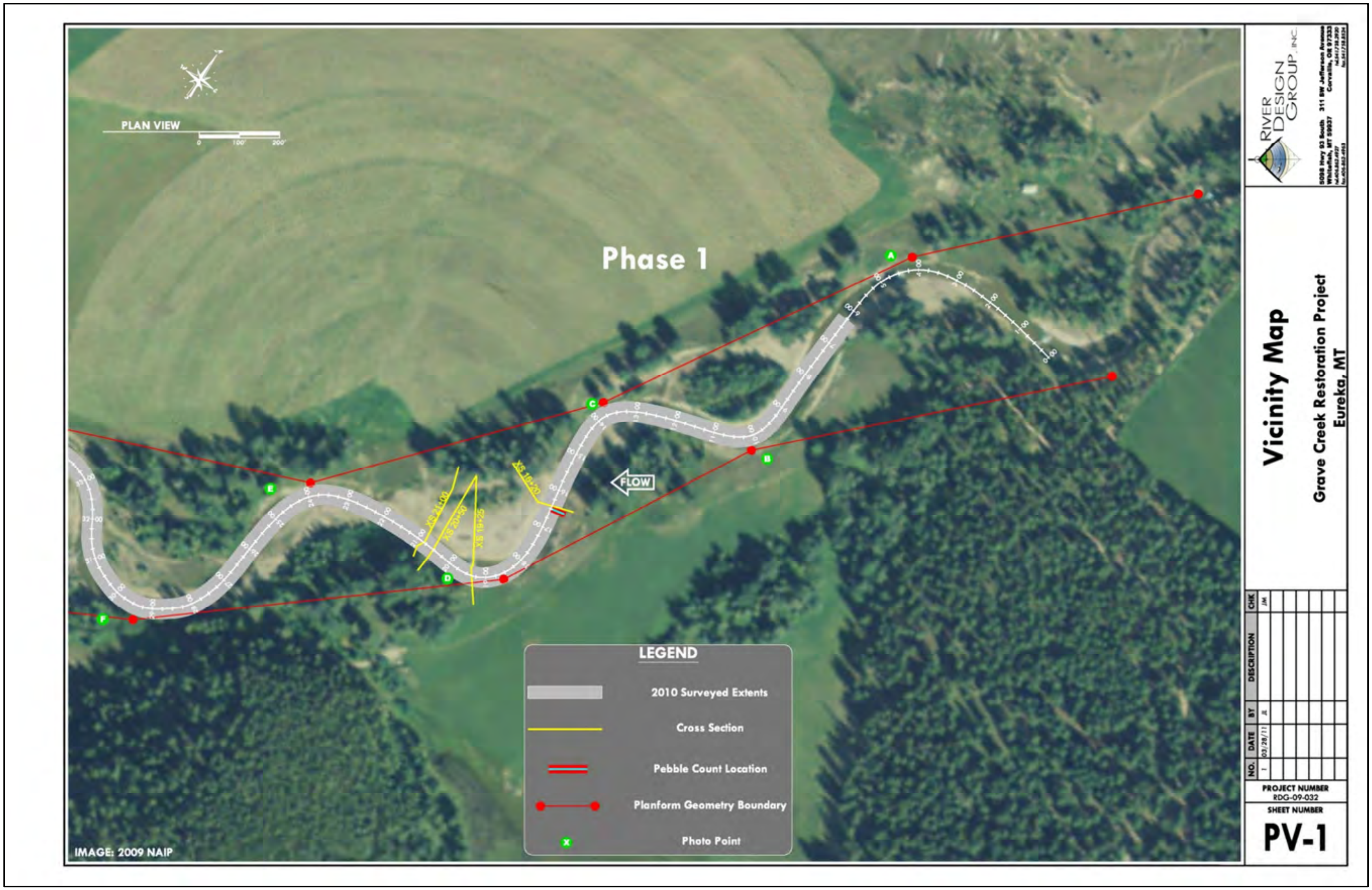

Figure 2-1. Vicinity and sampling index map for upper Phase 1.

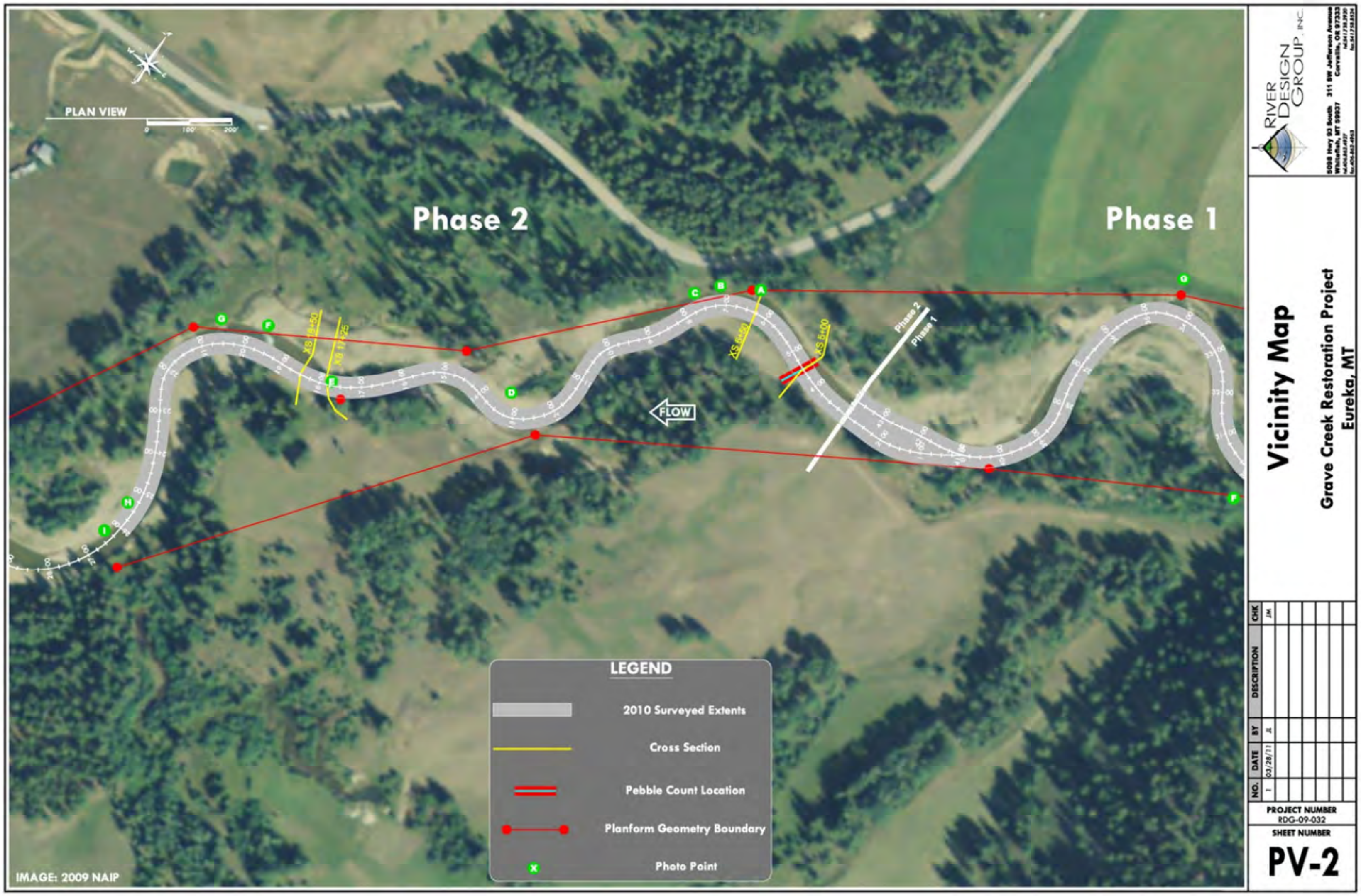

Figure 2-2. Vicinity and sampling index map for lower Phase 1.

2.1 Geomorphic Data Summary

This section summarizes the results of the geomorphic surveys completed in the Phase 1 project area. The pre and post-restoration longitudinal profiles are presented in Figure 2-3. Approximately 2,700 ft of the Phase 1 channel was surveyed. Surveyed features include channel thalweg elevations, water surface elevations, and bankfull floodplain elevations, stratified by channel habitat unit type (e.g. pool, riffle, run and glide). These data are presented in Table 2-1 and are reported for actual values and dimensionless ratios.

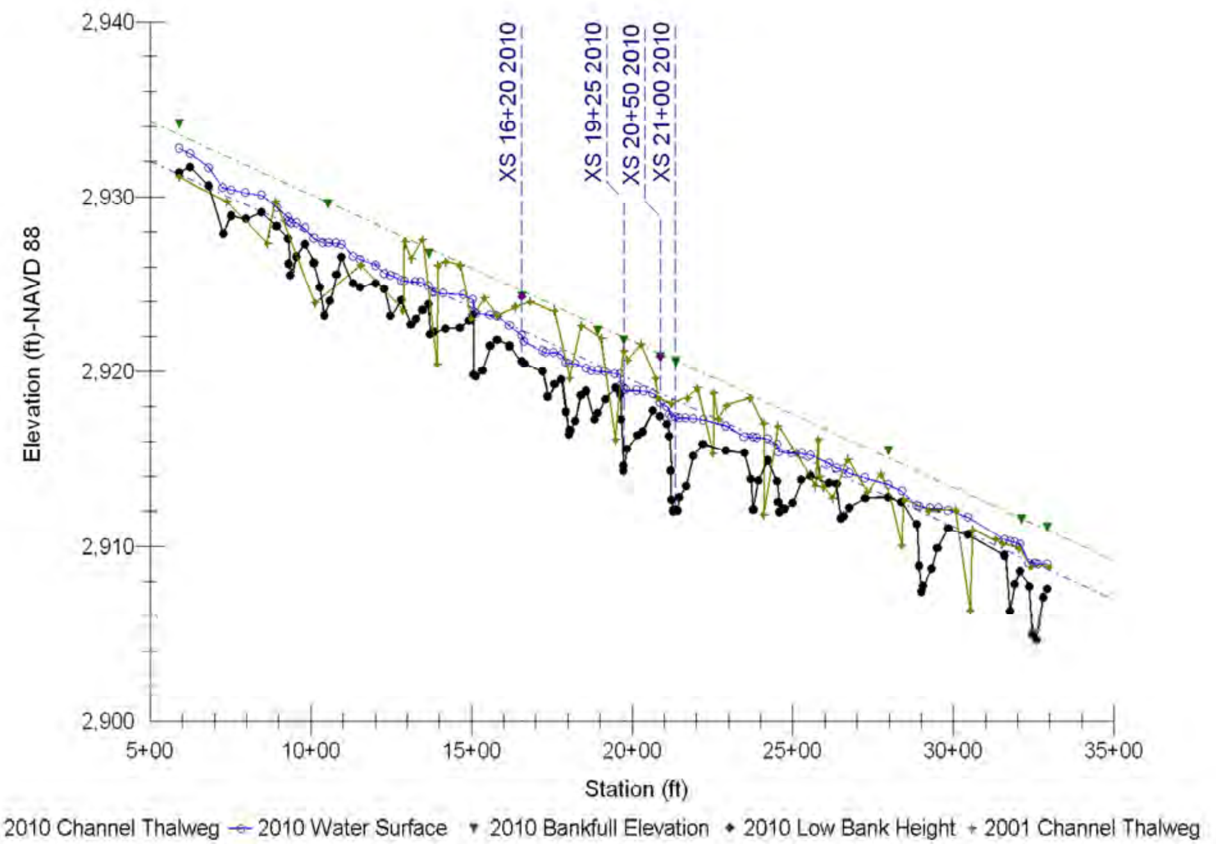

Figure 2-3. Longitudinal profile of Phase 1 displaying pre and post-restoration channel thalweg, water surface, and bankfull floodplain elevations.

The restoration project reduced the energy gradient by approximately 92.4% with the increased channel length and sinuosity. The data related to pool habitats indicate increased frequency and length of pool features. A 300% increase in pool habitat was noted and a corresponding decrease in the availability of riffle habitat. Maximum depths for all channel units increased throughout the project area.

Table 2-1. Phase 1 channel profile data for pre-restoration and post-restoration conditions and percent change.

Metric	2001 Mean	2010 Mean	Percent Change
Bankfull Slope (ft/ft)	0.1100	0.0084	-92.4
S Riffle (ft/ft)	0.0145	0.0109	-24.8
S Pool (ft/ft)	0.0045	0.0009	-80.0
S Run (ft/ft)	0.1900	0.0060	-96.8
S Glide (ft/ft)	N/A	0.0040	N/A
Pool - Pool (ft)	670	179	-73.3
Pool Length (ft)	42.1	70.8	68.2
No. of Pools	4	16	300
Riffle Length (ft)	494	111	-77.5
Dmax Riffle (ft)	2.0	3.2	60.0
Dmax Pool (ft)	4.3	6.3	46.5
Dmax Run (ft)	3.5	4.9	40.0
Dmax Glide (ft)	N/A	4.1	N/A
Low Bank Ht (ft)	3.2	3.7	15.6

Figure 2-4. Photos of Phase 1 in 2004 (left) and 2009 (right). A log cross vane built to maintain vertical grade control at the pool tailout is visible in the photos.

The channel planform geometry analysis for Phase 1 is presented in Table 2-2. The lateral extents of the channel migration zones are denoted in Figures 2-1 and 2-2. The reconstructed channel alignment occupies the same channel migration zone as the pre-restoration channel. The design re-activated approximately eight meander sequences in the Phase 1 project area. Conversion of the existing braided planform to a meandering, single-threaded pattern, increased channel sinuosity by 20%.

Table 2-2. Planform geometry summary table for Phase 1.

	Meander Wave Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity
Pre-Restoration	850	330	145	1.15
Post-Restoration	770	316	158	1.38
Percent Change	-9.4	-4.2	9.0	20.0

Four channel cross-sections were surveyed to characterize pre-restoration conditions and were replicated during the 2010 post-restoration survey. Table 2-3 includes a comparison of the pre-restoration and post-construction cross-section metrics. Percent change is reported for two pool and two riffle cross-sections. Post-restoration channel dimensions related to pools and riffles demonstrate considerable change from pre-restoration conditions. The data indicate reductions in channel widths and increases in mean and maximum depths for both pool and riffle cross-sections. A corresponding decrease in channel width to depth ratio reflects the transition to a narrower, deeper dominant channel.

Table 2-3. Cross-section dimensions for riffle (n=2) and pool (n=2) cross-sections and percent change for Phase 1. Values are based on the bankfull elevation.

Metric	2001	2010	Percent Change
Floodprone Width (ft)[1]	338	308	-8.9
Riffle Area (ft^2)	195	145	-25.6
Max Riffle Depth (ft)	3.3	3.6	9.1
Mean Riffle Depth (ft)	1.3	2.3	76.9
Riffle Width (ft)	154	63.2	-59.0
Entrenchment Ratio[1]	2.2	4.9	123
Width/Depth Ratio[1]	168	28.0	-83.3
Pool Area (ft^2)	196	220	12.2
Max Pool Depth (ft)	3.1	8.0	158
Mean Pool Depth (ft)	1.0	3.1	210
Pool Width (ft)	201	75.1	-62.6

[1]Parameter reflects riffle cross-sections only.

Figure 2-5 displays the 2001 and 2010 riffle cross-section at Station 16+20. The solid line represents the 2010 bankfull elevation and the dashed line indicates the floodprone elevation. The graph demonstrates the wide, shallow riffle that existed in 2001 as well as the narrower, lower width to depth ratio post-restoration channel.

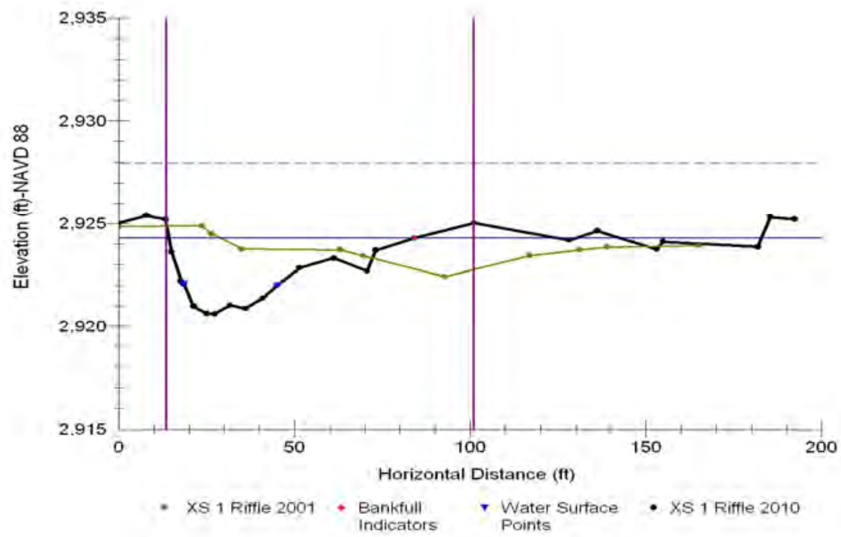

Figure 2-5. Riffle cross-section at Station 16+20 displaying pre and post-restoration conditions.

Table 2-4 includes a comparison of select morphological variables for cross section 16+20 in 2001 and 2010. The post-restoration floodprone width is similar in extent to the pre-restoration width; however the active channel width has been reduced by over 50%. Both mean and maximum depths have increased while bankfull area has decreased by 32%. Channel width to depth ratio decreased from 103 to 36.7 and the entrenchment ratio increased to 4.3, reflecting the improved channel-floodplain hydrologic connectivity relative to pre-restoration conditions.

Table 2-4. Riffle cross-section at Station 16+20, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	310	300	-3.2
Bankfull Width (ft)	141	69.8	-50.5
Entrenchment Ratio	2.2	4.3	95.5
Mean Depth (ft)	1.4	1.9	35.7
Maximum Depth (ft)	2.5	3.7	48.0
Width/Depth Ratio	103	36.7	-64.4
Bankfull Area (ft^2)	194	132	-32.0
Wetted Perimeter (ft)	143	71.0	-50.3
Hydraulic Radius (ft)	1.4	1.9	35.7

Figure 2-6 contains photographs of the riffle feature at Station 16+20 for pre and post-restoration conditions. The 2001 channel condition was characterized by extensive mid-channel and transverse bar deposits, braiding and high bank erosion conditions. The 2010 photograph depicts the lower width to depth ratio, dominant channel, absence of mid-channel depositional features and improved streambank stability.

Figure 2-6. Photos of the riffle cross-section at Station 16+20 ft in 2001 (left) and 2010 (right).

Figure 2-7 displays the 2001 and 2010 pool cross-section at Station 19+25. The graph shows a laterally extensive, high width to depth ratio, multiple channel riffle that existed at the site in 2001. Also shown is the narrow, deep pool that was constructed and the adjacent point bar and floodplain surface.

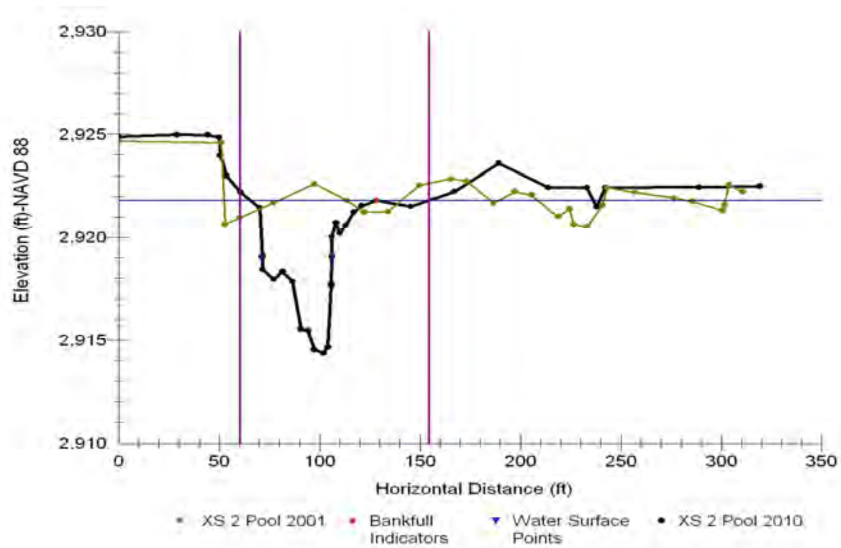

Figure 2-7. Pool cross-section at Station 19+25 ft, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data for cross section 19+25 are summarized in Table 2-5. Conversion from a braided riffle condition to a dominant channel has reduced the active channel width from 237 ft to approximately 90 ft. Mean and maximum channel depths increased by 188% and 257%, respectively. The channel width to depth ratio has been reduced from 285 to 38.7. Bankfull channel cross-sectional area remains within 3% of the pre-restoration condition.

Table 2-5. Pool cross-section at Station 19+25, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	N/A	N/A	N/A
Bankfull Width (ft)	237	88.6	-62.6
Entrenchment Ratio	N/A	N/A	N/A
Mean Depth (ft)	0.8	2.3	188
Maximum Depth (ft)	2.1	7.5	257
Width/Depth Ratio	285	38.7	-86.4
Bankfull Area (ft^2)	198	203	2.5
Wetted Perimeter (ft)	239	95.6	-60.0
Hydraulic Radius (ft)	0.8	2.1	163

Figure 2-8 contains photographs of the cross-section location at Station 19+25 for pre and post-restoration conditions. A braided channel form was present in the 2001 pre-restoration photograph and a mid-channel bar results in flow divergence. The depositional feature consists of sand and gravel size particles and occupies a large portion of the cross-sectional area. The 2010 photograph displays the constructed pool feature and the adjacent point bar with colonizing willows and riparian shrubs.

Figure 2-8. Photos of the pool cross-section at Station 19+25 ft in 2001 (left) and 2010 (right).

Figure 2-9 presents the 2001 and 2010 channel conditions for the riffle cross-section at Station 20+20. The graph shows a laterally extensive, multiple channel riffle that existed at the site in 2001. Overlaid is the single-thread riffle feature of the post-restoration design. Also shown is the constructed floodplain surface that previously existed as part of the active channel.

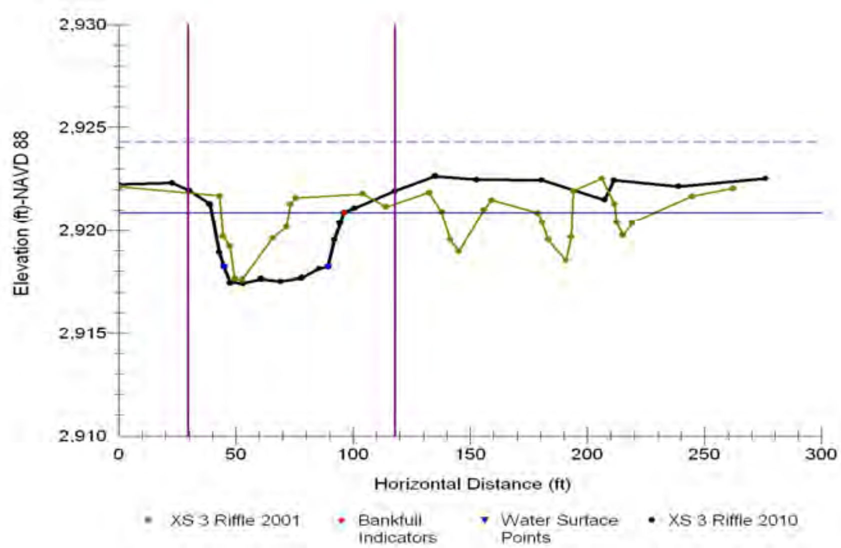

Figure 2-9. Riffle cross-section at Station 20+50, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data are summarized in Table 2-6. The active channel width has decreased from 166 ft in 2001 to 57 ft in 2010, a 66% change. The mean depth has increased 133%. Conversion from the braided channel condition has reduced the width to depth ratio from 142 to 20.3 and has resulted in a 155% increase in the entrenchment ratio. The bankfull channel area has remained within 20% of the 2001 existing conditions.

Table 2-6. Riffle cross-section at Station 20+50, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	365	315	-13.7
Bankfull Width (ft)	166	56.5	-66.0
Entrenchment Ratio	2.2	5.6	155
Mean Depth (ft)	1.2	2.8	133
Maximum Depth (ft)	4.1	3.4	-17.1
Width/Depth Ratio	142	20.3	-85.7
Bankfull Area (Sq ft)	195	157	-19.5
Wetted Perimeter (ft)	171	57.8	-66.2
Hydraulic Radius (ft)	1.1	2.7	145

Figure 2-10 contains photographs of the riffle feature at Station 20+20 for pre and post-restoration conditions. A multi-threaded channel exists in 2001, characterized by mid-channel and transverse bar deposits. These depositional features lacked stabilizing vegetation due to frequent bed scour and deposition. The 2010 post-restoration photograph reflects the single-threaded riffle feature and the adjacent point bar floodplain constructed in 2002.

Figure 2-10. Photos of the riffle cross-section at station 20+50 ft in 2001 (left) and 2010 (right).

Figure 2-11 displays the 2001 and 2010 channel conditions at Station 21+00. Similar to the site at Station 20+50, a laterally extensive, multi-threaded riffle characterized the channel in 2001. Three mid-channel bars are evident from the survey data. During the restoration process, the shallow multi-channel riffle feature was converted to a dominant channel and pool habitat feature in this location. Also shown is the constructed floodplain surface including floodplain swales that serve to hold moisture and facilitate the establishment of riparian vegetation.

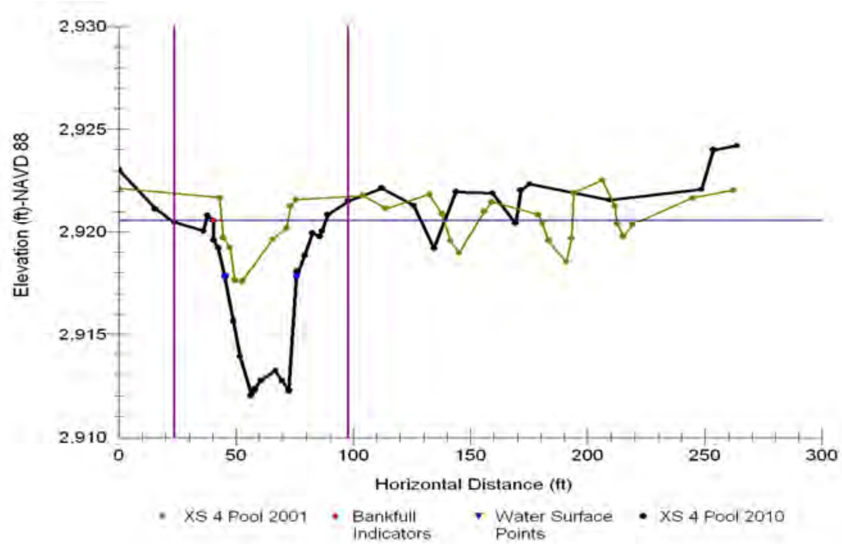

Figure 2-11. Pool cross-section at station 21+00 ft, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data for cross section are compared in Table 2-7. The active channel width has decreased from 166 ft to 61.7 ft through the consolidation of multiple channels into one dominant channel. The mean and maximum depths have increased 217% and 107%, respectively. The width to depth ratio has decreased from 141 to 16.1. The bankfull channel area has remained within 21.5% of the 2001 conditions.

Table 2-7. Pool cross-section at station 21+00 ft, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	N/A	N/A	N/A
Bankfull Width (ft)	166	61.7	-62.8
Entrenchment Ratio	N/A	N/A	N/A
Mean Depth (ft)	1.2	3.8	217
Maximum Depth (ft)	4.1	8.5	107
Width/Depth Ratio	141	16.1	-88.6
Bankfull Area (ft^2)	195	237	21.5
Wetted Perimeter (ft)	171	68.6	-59.9
Hydraulic Radius (ft)	1.1	3.5	218

Figure 2-12 contains photographs of the pool feature at Station 21+00 for pre and post-restoration conditions. The presence of an un-vegetated, mid-channel gravel bar in the 2001 photograph suggests recent bed scour and deposition. The expansive depositional feature occupies a large portion of the channel cross-sectional area. The 2010 post-restoration photograph shows the dominant pool feature and the adjacent floodplain surface. The Phase 1 fencing exclosure is visible in the upper right.

Figure 2-12. Photos of the pool cross-section at Station 21+00 in 2001 (left) and 2010 (right).

Channel substrate particle size distribution was evaluated at the riffle feature at Station 16+20 or both the pre-restoration and post-restoration conditions. Figure 2-13 and Table 2-8 include the results.

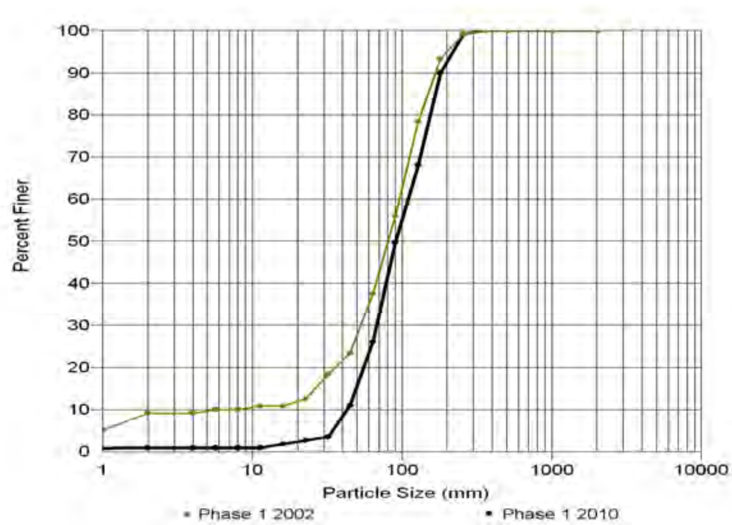

Figure 2-13. Riffle substrate particle size distribution for pre and post-restoration conditions within Phase 1.

Results of the particle size distribution analysis indicate a coarsening trend for all size classes except the D_{100}. The coarsening trend may be attributed to a reduction in fine sediments contributed to the channel from bed and streambank erosion.

Table 2-8. Riffle substrate particle size (mm) distribution within Phase 1.

Percentile	2002	2010	Percent Change
D_{16}	28	51	82.1
D_{35}	61	74	21.3
D_{50}	82	91	11.0
D_{84}	148	166	12.2
D_{95}	202	222	9.9
D_{100}	362	362	0.0

Table 2-9 contains the results of the large woody debris assessment for both the pre and post-restoration conditions. Qualifying single pieces were at least 3.0 meters in length and 0.1 meter in diameter. Aggregates were defined as two or more singles either in contact or functioning as an array. All wood within the bankfull channel was inventoried. Qualifying pieces were tallied as rootfans or stems. Results indicate increased frequency of both singles and aggregates for all categories compared to the post-restoration condition. An increase of approximately 30% was observed for single pieces of qualifying wood over pre-restoration conditions. Additionally, results indicate a 450% increase in qualifying wood pieces incorporated into aggregates and a 650% increase in the number of individual rootfans. The number of aggregates per 100 meters has increased 267% compared to pre-restoration conditions.

Table 2-9. Large woody debris summary data for the 2001 and 2010 monitoring data in Phase 1.

Reach ID	No. of Pieces as Singles	No. of Pieces in Aggregates	No. of Rootfans	No. of Singles /100 meters	No. of Aggregates /100 meters
Phase 1 2001	51	37	24	4.6	0.6
Phase 1 2010	66	203	180	5.9	2.2
Percent Change	29.4	449	650	28.3	267

2.2 Sediment Reduction Analysis

Table 2-10 contains the results of the sediment reduction analysis completed for the pre and post-restoration bank conditions within Phase 1. In general, streambanks were more unstable in 2001 due to the lack of woody riparian vegetation and high near-bank stress ratings. The 2001 bank conditions averaged an adjective rating of moderate-high and low-moderate in 2010. The average BEHI numerical rating decreased 26.9% following restoration. Restoration techniques utilizing large wood and vegetated soil lifts have increased bank stability and reduced the erosion hazard. Average bank height remained similar to the pre-restoration conditions. Predicted bank erosion is estimated to have been reduced from 275 tons per year to 187 tons per year, a 32% reduction in bank-derived sediment within Phase 1.

Table 2-10. Sediment reduction analysis for Phase 1: pre-restoration and post-restoration Bank Erosion Hazard Index (BEHI) evaluation.

Bank Condition	Average BEHI Adjective Rating	Average BEHI Numerical Rating	Average Bank Height (ft)	Cumulative BEHI Bank Length (ft)	Average Predicted Bank Erosion (ft/yr)	Predicted Bank Erosion (tons/yr)
Pre-Restoration	Moderate-High	30.8	3.5	5,180	0.28	275
Post-Restoration	Low-Moderate	22.5	3.4	5,205	0.22	187
Percent Change	n/a	-26.9	-2.9	0.5	-21.4	-32.0

2.3 Aquatic Habitat

An evaluation of available aquatic habitat was completed for the pre and post-restoration conditions in Phase 1. Pool habitats were identified and evaluated during the 2001 and 2010 monitoring surveys. Figure 2-14 displays the longitudinal distribution of pool habitat features prior to restoration in 2001. Figure 2-15 displays the longitudinal distribution of pool habitat features eight years following construction in 2010.

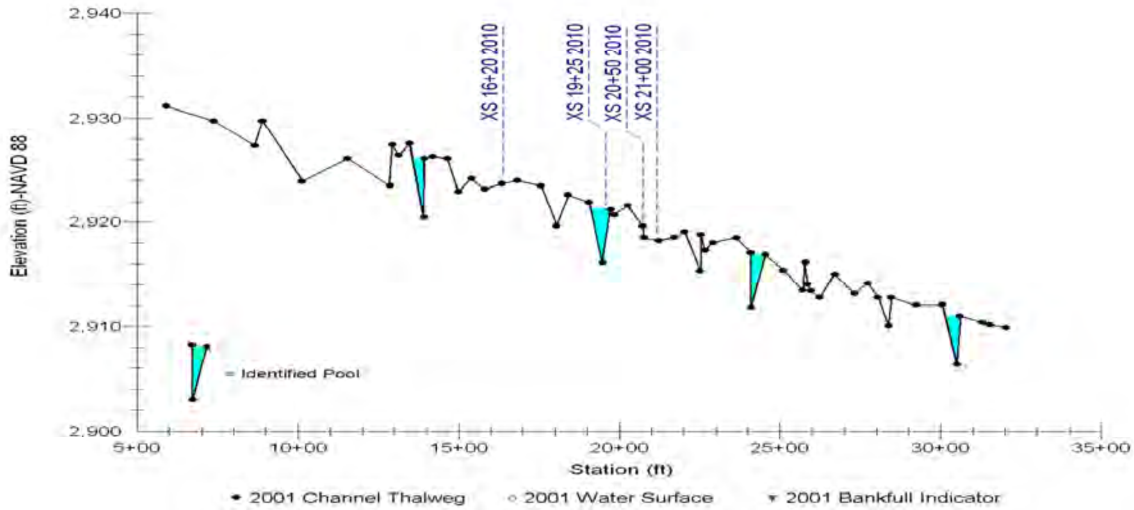

Figure 2-14. Longitudinal profile displaying the pre-restoration distribution of pool habitat units in Phase 1.

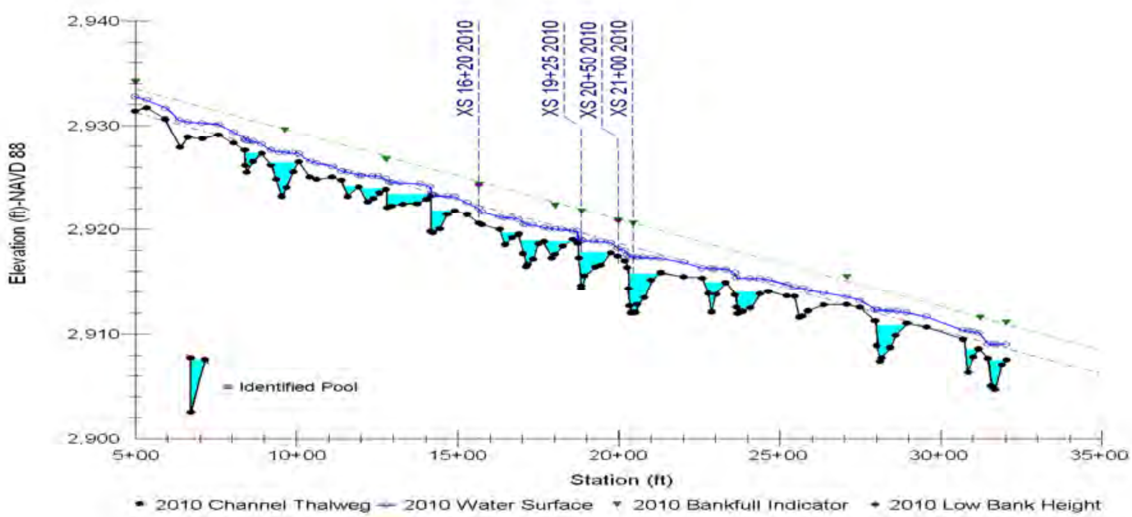

Figure 2-15. Longitudinal profile displaying the post-restoration distribution of pool habitat units in Phase 1.

Table 2-11 includes the results of the aquatic habitat evaluation. The number of pools increased from four identified in 2001 to 16 identified in 2010, a 300% increase. The pool spacing averaged 552 ft in 2001 and 179 ft in 2010. Average residual pool volume in Reach 1 increase136% compared to 2001 pre-restoration conditions.

Table 2-11. Aquatic habitat summary data for the 2001 and 2010 monitoring data. Minimum-Maximum (Average).

Reach ID	Number of Pools	Pool Spacing (ft)	Maximum Bankfull Pool Depths (ft)	Discrete Residual Pool Volume (ft^3)	Cumulative Residual Pool Volume (ft^3)
Phase 1 2001	4	461-633 (552)	6.3-7.5 (6.7)	17,067-25,410 (19,541)	78,164
Phase 1 2010	16	78.8-329 (179)	4.9-8.7 (6.3)	1,714-12,882 (6,230)	99,674
Percent Change	300	-67.6[1]	-6.0[1]	-68.1[1]	27.5

[1] Percent change is reported for the average values.

3.0 Grave Creek Phase 2 Results

This section provides the results of the Grave Creek Phase 2 restoration activities on Grave Creek. Phase 2 was completed in 2004. Subsequent maintenance and revegetation activities occurred in select areas of the Phase 2 project area in 2006 and 2008.

Sampling index and vicinity maps of the Phase 2 project area are included in Figure 3-1 and Figure 3-2. The surveyed channel length, cross-section, pebble count, and photo point locations are provided.

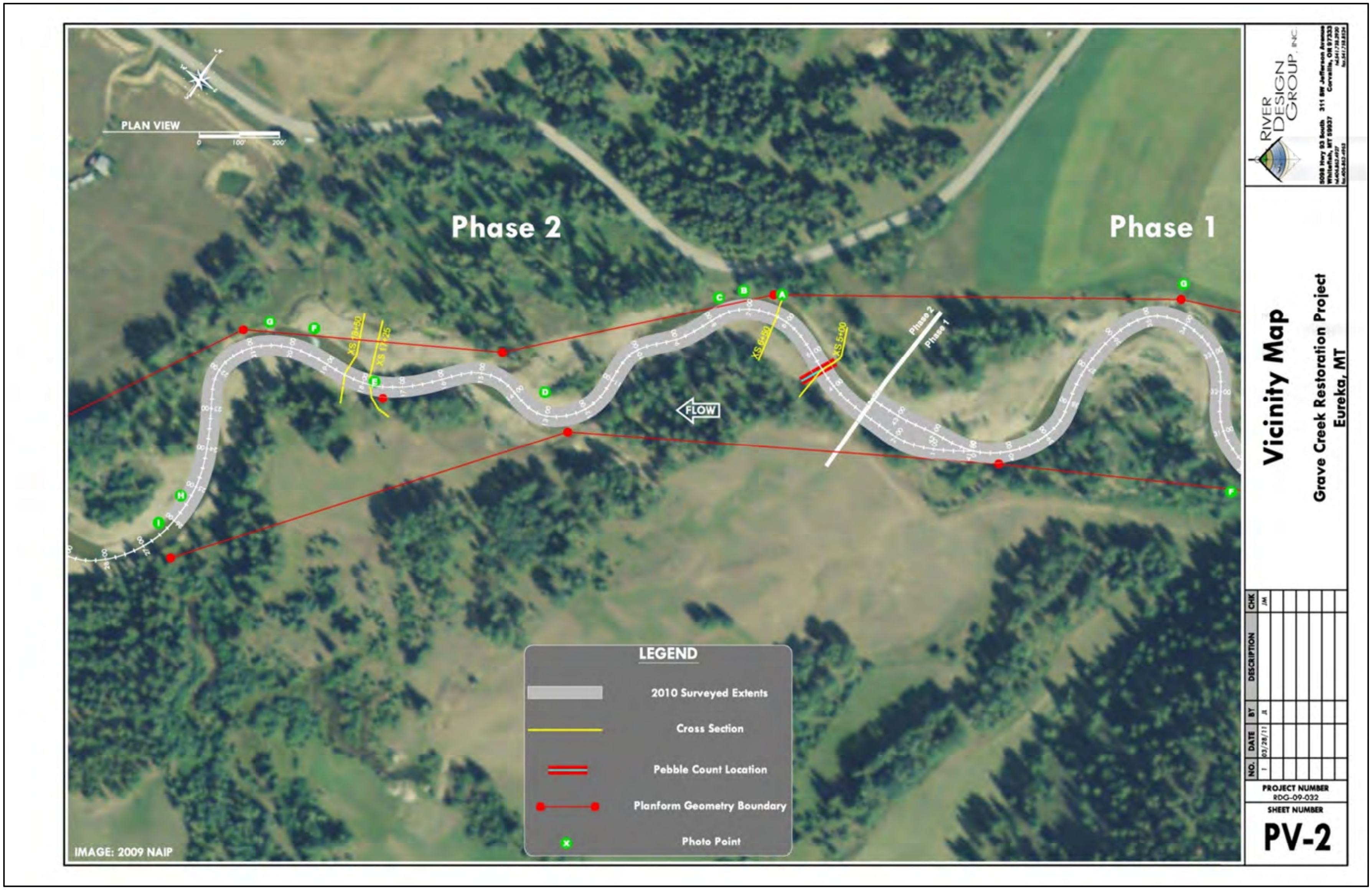

Figure 3-1. Vicinity and sampling index map for upper Phase 2.

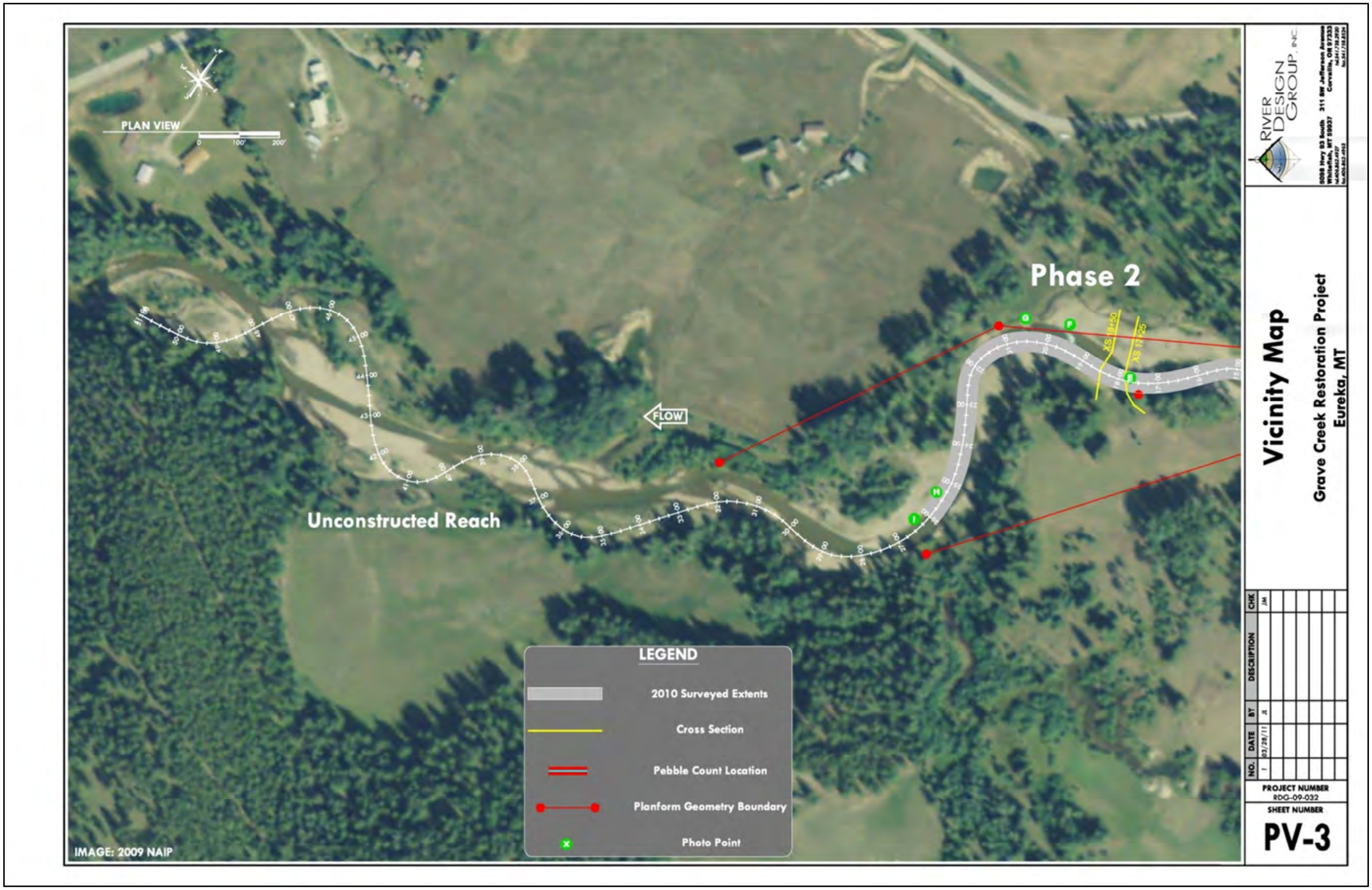

Figure 3-2. Vicinity and sampling index map for lower Phase 2.

3.1 Geomorphic Data Summary

The following section summarizes the results of the geomorphic surveys completed in the Phase 2 project area. The pre and post-restoration longitudinal profiles are presented in Figure 3-3. Approximately 2,600 ft of the Phase 2 channel was surveyed. Surveyed features include channel thalweg elevations, water surface elevations, and bankfull floodplain elevations, stratified by channel habitat unit type (e.g. pool, riffle, run and glide). The data are presented in Table 3-1 and are reported for actual values and dimensionless ratios.

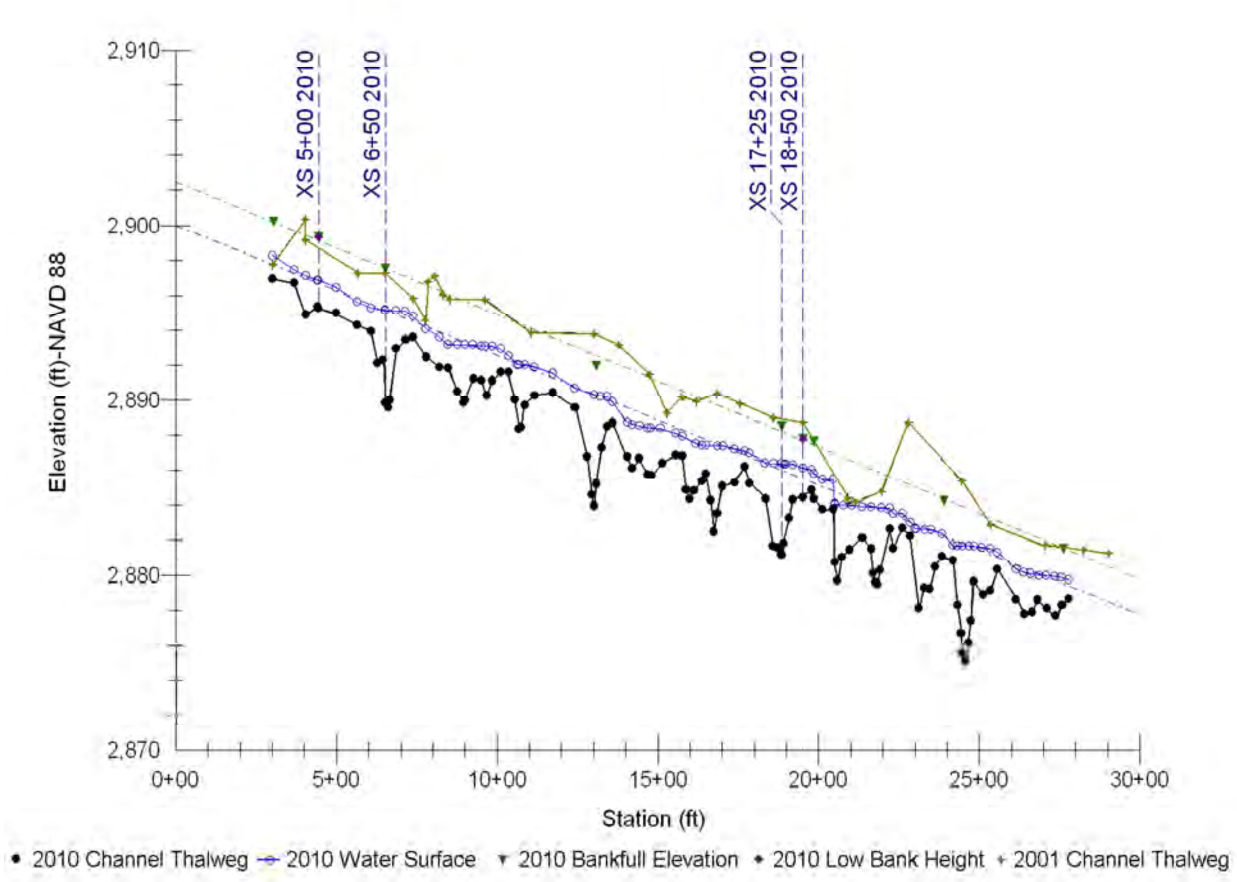

Figure 3-3. Longitudinal profile of Phase 2 displaying pre and post-restoration channel thalweg, water surface, and bankfull floodplain elevations.

The restoration project reduced the energy gradient by approximately 93.1% by increasing channel length and sinuosity. The data related to pool habitats indicate increased frequency and lengthening of pool features. A 333% increase in the number of pools was noted and a corresponding decrease in the availability of riffle habitat. Maximum depths for all channel habitat units increased throughout the project area. Results are presented in Table 3-1.

Table 3-1. Phase 2 channel profile data for pre-restoration and post-restoration conditions and percent change.

Metric	2001 Mean	2010 Mean	Percent Change
Bankfull Slope (ft/ft)	0.1100	0.0076	-93.1
S Riffle (ft/ft)	0.0145	0.0121	-16.6
S Pool (ft/ft)	0.0045	0.0008	-82.2
S Run (ft/ft)	0.1900	0.0058	-96.9
S Glide (ft/ft)	N/A	N/A	N/A
Pool - Pool (ft)	725	208	-71.3
Pool Length (ft)	136	117	-14.0
No. of Pools	3	13	333.3
Riffle Length (ft)	543	104	-80.8
Dmax Riffle (ft)	2.0	3.4	70.0
Dmax Pool (ft)	4.3	6.9	60.5
Dmax Run (ft)	3.5	5.2	48.6
Dmax Glide (ft)	N/A	N/A	N/A
Low Bank Ht (ft)	3.2	3.6	12.5

The longitudinal spacing of pools decreased from 725 ft in 2001 to 208 ft in 2010. A 333% increase in the number of pools was observed with a decrease in the longitudinal distribution of riffle habitat types. Maximum depths for all channel units increased throughout the project area.

Figure 3-4. Photos of Phase 2 in 2004 (left) and 2010 (right).

The channel planform geometry analysis for Phase 2 is presented in Table 3-2. The lateral extents of the channel migration zones are denoted in Figures 3-1 and 3-2. Restoration activities reactivated numerous abandoned meanders in Reach 2, increasing channel sinuosity from 1.06 to 1.18, representing an 11.3% percent increase. Meander reactivation reduced the average meander wave length from 1,350 ft to 697 ft, a 48.4% reduction. The post-restoration meander belt width has remained similar to the 2001 conditions, averaging 282 ft in the Phase 2 project area.

Table 3-2. Planform geometry summary table for Phase 2 (July 2010).

	Meander Wave Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity
Pre-Restoration	1,350	287	180	1.06
Post-Restoration	697	282	175	1.18
Percent Change	-48.4	-1.7	-2.8	11.3

Four channel cross-sections were surveyed to characterize the existing condition and were replicated during the post-restoration survey. Table 3-3 includes a comparison of the existing and post-construction cross-section metrics. Percent change is reported for two pool and two riffle cross-sections. Post-restoration channel dimensions related to pools and riffles demonstrate considerable change from pre-restoration conditions. The riffle data indicate a slight reduction in floodprone width and a greater reduction in active channel width, 5.1% and 70.1% respectively. Maximum riffle depth decreased by 15.9% and mean riffle depth increased by 56.3%. Riffle cross-sectional area decreased 54.7%.

Table 3-3. Cross-section dimensions for riffle (n=2) and pool (n=2) cross-sections and percent change for Phase 2.

Metric	2001	2010	Percent Change
Floodprone Width (ft) [1]	253	240	-5.1
Riffle Area (Sq ft)	311	141	-54.7
Max Riffle Depth (ft)	4.4	3.7	-15.9
Mean Riffle Depth (ft)	1.6	2.5	56.3
Riffle Width (ft)	188	56.2	-70.1
Entrenchment Ratio[1]	1.4	4.3	207
Width/Depth Ratio[1]	118	20.7	-82.5
Pool Area (Sq ft)	337	248	-26.4
Max Pool Depth (ft)	4.8	8.0	66.7
Mean Pool Depth (ft)	2.1	3.8	81.0
Pool Width (ft)	158	67.7	-57.2

[1]Parameter reflects riffle cross-sections only.

Constructed pools are approximately 57% narrower than pre-restoration pool widths and 81% deeper, on average. Accordingly, average bankfull pool area is 26% less than pre-restoration pool area. The average width to depth ratio has been reduced from 118 to 20.7 and demonstrates the transition to a narrower, deeper primary channel.

Cross-sections demonstrating the pre and post-restoration channel dimensions in Phase 2 are reported in the following section. Figure 3-5 displays the 2001 and 2010 riffle cross-section at Station 5+00. The solid line represents the 2010 bankfull elevation and the dashed line indicates the floodprone elevation.

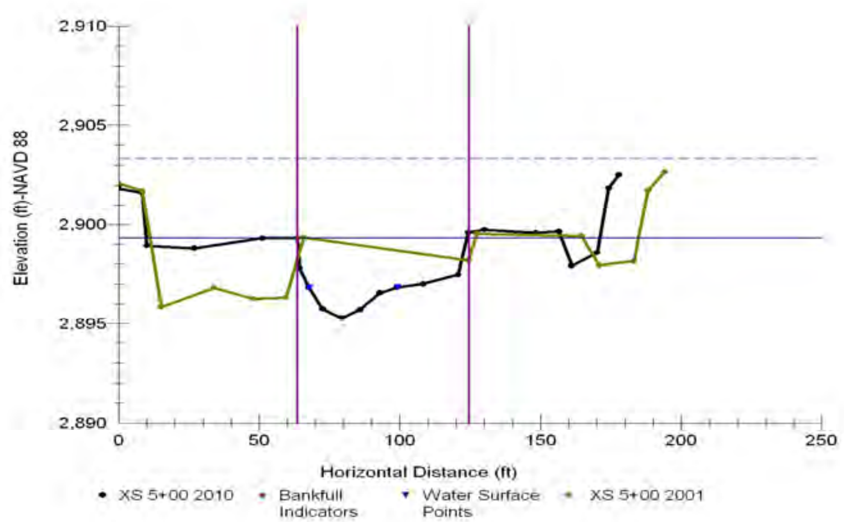

Figure 3-5. Riffle cross-section at Station 5+00, displaying pre and post-restoration conditions.

Table 3-6 includes a comparison of select morphological variables for the 2001 and 2010 data sets. The post-restoration floodprone width has increased 11.1% and the active channel width has been reduced by over 65%. Both mean and maximum depths have increased by 108% and 8.1%, respectively, while bankfull area decreased by 30%. Channel width to depth ratio has decreased from 131 to 22.5 and the entrenchment ratio has increased to 4.3, reflecting the improved channel-floodplain hydrologic connectivity relative to pre-restoration conditions.

Table 3-4. Riffle cross-section at Station 5+00, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	207	230	11.1
Bankfull Width (ft)	174	60.3	-65.3
Entrenchment Ratio	1.2	3.8	217
Mean Depth (ft)	1.3	2.7	108
Maximum Depth (ft)	3.7	4.0	8.1
Width/Depth Ratio	131	22.5	-82.8
Bankfull Area (Sq ft)	232	162	-30.2
Wetted Perimeter (ft)	177	62.1	-64.9
Hydraulic Radius (ft)	1.3	2.6	100

Figure 3-6 contains photographs of the riffle feature at Station 5+00 for pre and post-restoration conditions. The 2001 channel condition was characterized by extensive mid-channel and transverse bar deposits, braiding, and high bank erosion conditions. The 2010 photograph depicts a single-thread channel and the absence of depositional mid-channel depositional features and improved streambank stability.

Figure 3-6. Photos of the riffle cross-section at Station 5+20 in 2001 (left) and 2010 (right).

Figure 3-7 displays the 2001 and 2010 pool cross-section at Station 6+50. The graph shows a laterally extensive, shallow, high width to depth ratio channel in 2001. Also displayed is the narrow, deep pool that was constructed and the adjacent point bar and floodplain surface.

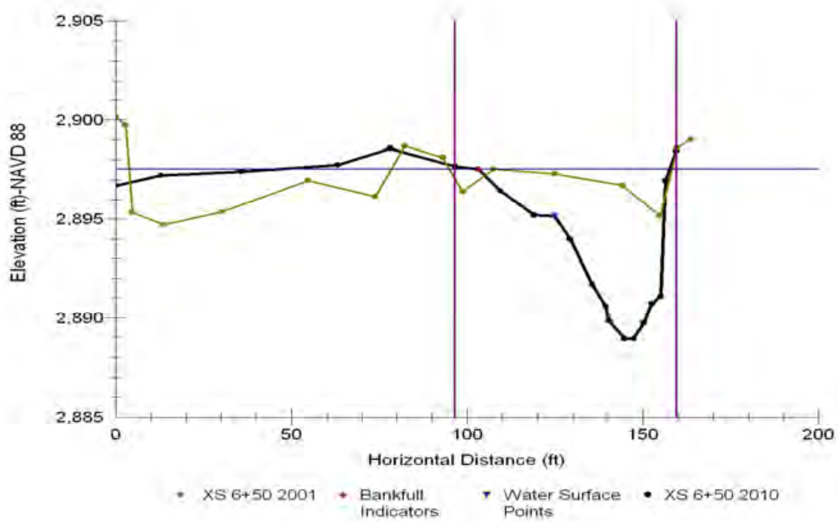

Figure 3-7. Pool cross-section at Station 6+50, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data are presented in Table 3-5. Conversion from a braided riffle condition to a dominant channel has reduced the active channel width from 155 ft in 2001 to approximately 54.5 ft in 2010. Mean and maximum channel depths increased 110% and 121%, respectively. Channel width to depth ratio has decreased from 76.3 to 13.0. Bankfull channel cross-sectional area decreased 27.3% compared to 2001 conditions.

Table 3-5. Pool cross-section at Station 6+50, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	N/A	N/A	N/A
Bankfull Width (ft)	155	54.5	-64.8
Entrenchment Ratio	N/A	N/A	N/A
Mean Depth (ft)	2.0	4.2	110
Maximum Depth (ft)	3.9	8.6	121
Width/Depth Ratio	76.3	13.0	-83.0
Bankfull Area (ft^2)	315	229	-27.3
Wetted Perimeter (ft)	159	60.9	-61.7
Hydraulic Radius (ft)	2.0	3.8	90.0

Figure 3-8 contains photographs of the cross-section location at Station 6+50 for pre and post-restoration conditions. A braided channel form is present in the 2001 photograph, characterized by sediment loading, high width to depth ratios, and streambank instability. The depositional features consisted of sand, gravel and small cobble size particles and serve to reduce channel cross-sectional area and pool development. The 2010 photograph displays the constructed pool feature and the adjacent point bar.

Figure 3-8. Photos of the pool cross-section at Station 6+50 in 2001 (left) and 2010 (right).

Figure 3-9 presents the 2001 and 2010 channel conditions for the riffle cross-section at Station 17+25. The graph reflects a shallow, high width to depth ratio, multi-channel riffle feature in 2001 and the post-restoration channel morphology in 2010. Side channel habitat was enhanced during construction and is visible on the right side of the graph.

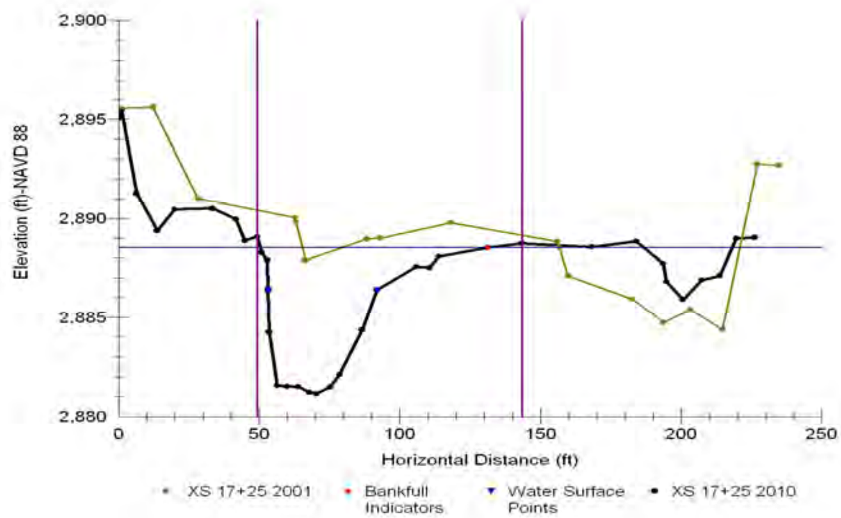

Figure 3-9. Pool cross-section at Station 17+25, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data are compared in Table 3-6. The active channel width has been reduced by approximately 50% relative to the 2001 conditions. Mean and maximum depths have increased by 50.0% and 29.8%, respectively. Conversion from a braided channel condition has reduced the width to depth ratio from 71.5 to 24.5.

Table 3-6. Pool cross-section at Station 17+25, summary data and percent change from 2001 to 2010.

Metric	2001	2010	Percent Change
Floodprone Width (ft)	N/A	N/A	N/A
Bankfull Width (ft)	160	80.8	-49.5
Entrenchment Ratio	N/A	N/A	N/A
Mean Depth (ft)	2.2	3.3	50.0
Maximum Depth (ft)	5.7	7.4	29.8
Width/Depth Ratio	71.5	24.5	-65.7
Bankfull Area (ft^2)	359	267	-25.6
Wetted Perimeter (ft)	163	85.9	-47.3
Hydraulic Radius (ft)	2.2	3.1	40.9

Figure 3-10 contains photographs of the cross-section location at Station 17+25 for the pre and post-restoration conditions. A multiple channel condition characterized by mid-channel and transverse bar deposits characterized the morphology in 2001. The 2010 post-restoration photograph shows the constructed pool feature, large wood habitat structure, and the improved channel geometry that functions to consolidate base flows.

Figure 3-10. Photos of the pool cross-section at Station 17+25, in 2001 (left) and 2010 (right).

Figure 3-11 displays the 2001 and 2010 channel conditions at Station 18+50. An extensive mid-channel bar is evident in the 2001 channel reflecting the high width to depth ratio condition and depositional channel regime. The restoration project converted the multi-channel geometry to a dominant channel with secondary side channels on the active floodplain surface.

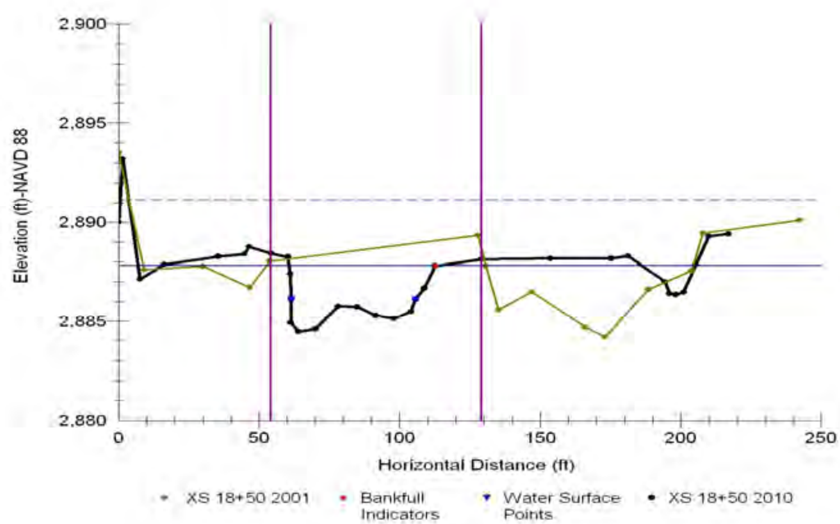

Figure 3-11. Riffle cross-section at Station 18+50, displaying pre and post-restoration conditions.

The pre-restoration and post-restoration data are compared in Table 3-7. The 2010 floodprone width remained unchanged compared to 2001 and averaged 250 ft. The bankfull channel width decreased from 201 ft to 52.1 ft through consolidation of multiple channels into one dominant channel. Mean depth has increased 21.1% and maximum depth decreased 35.3%. The width to depth ratio decreased from 104 in 2001 to 22.6 in 2010. Channel cross-sectional area is 70% less than the 2001 pre-restoration conditions.

Table 3-7. Riffle cross-section at Station 18+50, summary data and percent change from 2001 to 2010.			
Metric	2001	2010	Percent Change
Floodprone Width (ft)	250	250	0.0
Bankfull Width (ft)	201	52.1	-74.1
Entrenchment Ratio	1.2	4.8	300
Mean Depth (ft)	1.9	2.3	21.1
Maximum Depth (ft)	5.1	3.3	-35.3
Width/Depth Ratio	104	22.6	-78.3
Bankfull Area (ft^2)	390	120	-69.2
Wetted Perimeter (ft)	203	55.2	-72.8
Hydraulic Radius (ft)	1.9	2.2	15.8

Figure 3-12 contains photographs of a riffle channel unit at Station 18+50 ft for the pre and post-restoration conditions. Recent deposition is evident in the 2001 photograph. This depositional feature occupies a large percentage of the channel cross-sectional area. The 2010 post-restoration photograph shows the dominant channel and adjacent floodplain surfaces.

Figure 3-12. Photos of the riffle cross-section at station 18+50 ft, in 2001 (left) and 2010 (right).

Channel substrate particle size distribution was evaluated at the riffle feature at Station 5+00 for both the pre-restoration and post-restoration conditions. Figure 3-13 and Table 3-8 include the results.

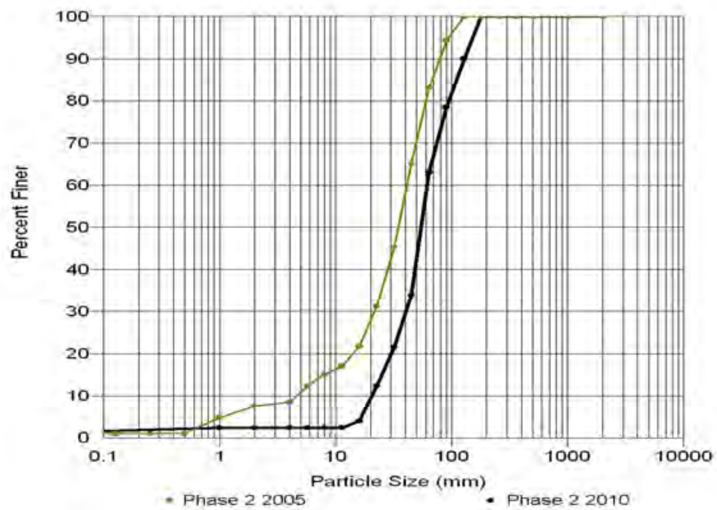

Figure 3-13. Riffle substrate particle size distribution for pre and post-restoration conditions within Phase 2.

Results of the particle size distribution analysis indicate a coarsening trend for all size classes. The coarsening trend may be attributed to a reduction in fine sediments contributed to the channel from bed and streambank erosion.

Table 3-8. Riffle substrate particle size distribution within Phase 2.

Percentile	2002	2010	Percent Change
D_{16}	10	26	160
D_{35}	25	46	84.0
D_{50}	35	56	60.0
D_{84}	66	108	63.6
D_{95}	94	154	63.8
D_{100}	128	180	40.6

Table 3-9 contains the results of the large wood evaluation for both the pre and post-restoration conditions. Results indicate increased frequency of large wood for all categories for the post-restoration condition. Number of single pieces increased 65% relative to 2001 pre-restoration conditions. Results indicate a 6,700% increase in qualifying wood pieces incorporated into aggregates and a 911% increase in the number of individual rootfans. The number of aggregates per 100 meters increased 3,000% following restoration.

Table 3-9. Large woody debris summary data for the 2001 and 2010 monitoring data in Phase 2.

Reach ID	No. of Pieces as Singles	No. of Pieces in Aggregates	No. of Rootfans	No. of Singles /100 meters	No. of Aggregates /100 meters
Phase 2 2001	20	6	18	2.6	0.1
Phase 2 2010	33	413	182	4.3	3.1
Percent Change	65.0	6,783	911	65.4	3,000

3.2 Sediment Reduction Analysis

Table 3-10 contains the results of the sediment reduction analysis completed for the pre and post-restoration bank conditions within Phase 2. In general, streambanks were more unstable in 2001 due to the lack of woody riparian vegetation and altered channel morphology. The 2001 bank conditions averaged an adjective rating of high and low-moderate in 2010. The average BEHI numerical rating decreased 38.5% following restoration. Restoration techniques utilizing large wood and vegetated soil lifts have increased bank stability and reduced the erosion hazard. Average bank height remained within 15% of the pre-restoration conditions and the cumulative length of contributing banks decreased 31.5%. Predicted bank erosion is estimated to have been reduced from 219 tons per year to 86.1 tons per year, a 60.7% reduction in bank-derived sediment within Phase 2.

Table 3-10. Sediment reduction analysis for Phase 2: pre-restoration and post-restoration Bank Erosion Hazard Index (BEHI) evaluation.

Bank Condition	Average BEHI Adjective Rating	Average BEHI Numerical Rating	Average Bank Height (ft)	Cumulative BEHI Bank Length (ft)	Average Predicted Bank Erosion (ft/yr)	Predicted Bank Erosion (tons/yr)
Pre-Restoration	High	36.9	4.1	3,475	0.32	219
Post-Restoration	Low-Moderate	22.7	3.5	2,380	0.22	86.1
Percent Change	n/a	-38.5	-14.6	-31.5	-31.3	-60.7

3.3 Aquatic Habitat

An evaluation of available aquatic habitat was completed for the pre and post-restoration conditions in Phase 2. Pool habitats were identified and evaluated during the 2001 and 2010 monitoring surveys. Figure 3-14 displays the longitudinal distribution of pool habitat features prior to restoration in 2001. Figure 3-15 displays the longitudinal distribution of pool habitat features six years following construction in 2010.

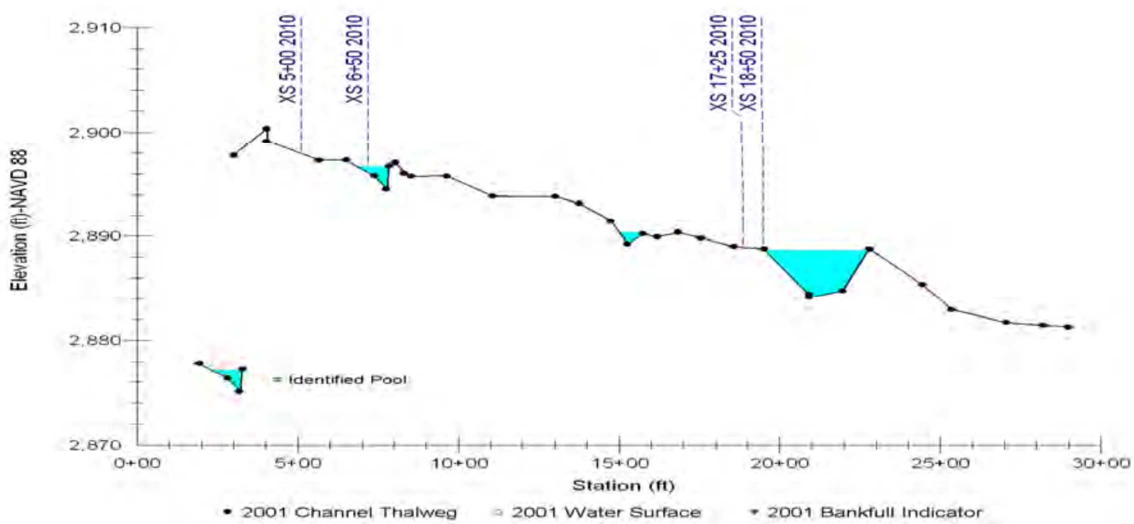

Figure 3-14. Longitudinal profile displaying the pre-restoration distribution of pool habitat units in Phase 2.

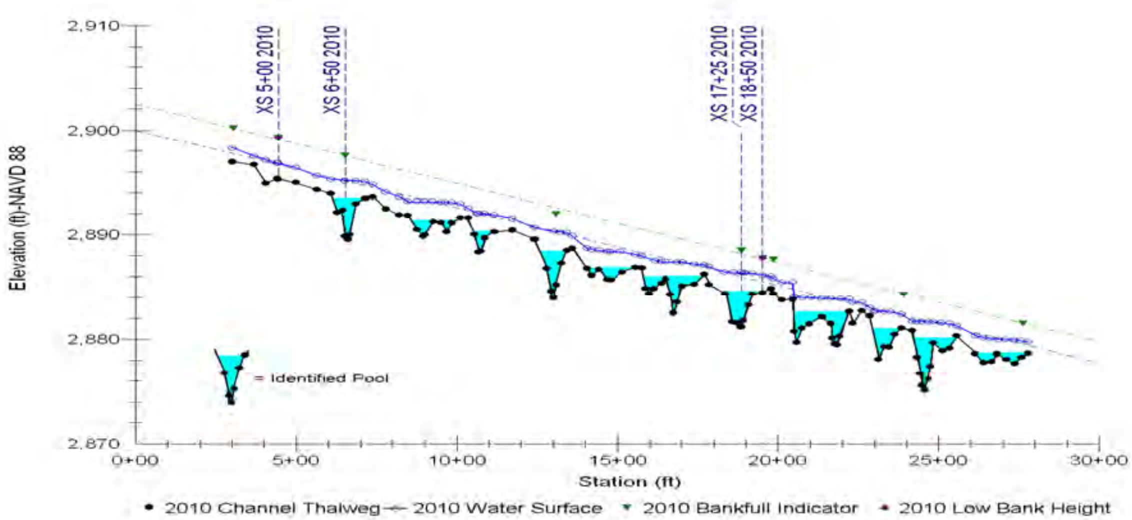

Figure 3-15. Longitudinal profiles displaying the post-restoration distribution of pool habitat units in Phase 2.

Table 3-11 includes the results of the aquatic habitat evaluation. The number of pools increased from three in 2001 to 13 in 2010, an increase of 333%. Pool spacing averaged

633 ft in 2001 and 208 ft in 2010. Average maximum pool depth and residual pool volume increased 116% and 235%, respectively, compared to 2001 conditions.

Table 3-11. Aquatic habitat summary data for the 2001 and 2010 Monitoring data. Minimum-Maximum (Average).

Reach ID	Number of Pools	Pool Spacing (ft)	Maximum Bankfull Pool Depths (ft)	Discrete Residual Pool Volume (ft^3)	Cumulative Residual Pool Volume (ft^3)
Phase 2 2001	3	570-756 (663)	2.2-4.7 (3.2)	4,819-52,052 (23,643)	70,928
Phase 2 2010	13	141-279 (208)	4.3-8.9 (6.9)	3,841-24,469 (10,654)	127,847
Percent Change	333	-68.6[1]	116[1]	-54.9[1]	80.2

[1] Percent change is reported for the average values.

4.0 Vegetation Monitoring

This section describes the results of 2010 vegetation monitoring within the Grave Creek project reach and compares those results with previous year's data and pre-project data. The following vegetation sampling was completed to document trends in floodplain and streambank plant community establishment and revegetation treatment effectiveness:

- Aerial photo mapping of plant community relative abundance pre- and post-restoration;
- Containerized plant survival;
- Percent cover of woody vegetation on treated streambanks;
- Floodplain transects to document riparian plant community successional processes; and
- Effects of browse on plant communities.

4.1 Aerial photo interpretation of plant community relative abundance

Pre-project vegetation community mapping was done by interpreting pre-project aerial photos (1990) and where available, ground photos taken prior to implementing the project. Post-project mapping was done by delineating existing vegetation communities on 2005 aerial photos. The constructed channel alignment was overlaid on this photo to support vegetation community delineation. Vegetation communities were ground-truthed in August 2010. Figure 4-1 shows the results of pre-project vegetation community mapping. Figure 4-2 shows the results of post-project vegetation community mapping. Table 4-1 provides a description of the vegetation communities mapped in the project reach. Table 4-2 shows the change in acreage of each vegetation community between 1990 and 2010.

Table 4-1. Grave Creek project reach mapped vegetation communities.

Vegetation Community	Description[1]
Alder	Communities dominated by alder. These communities occur most often in low elevation areas and swales along the back edges of point bar surfaces. These surfaces likely developed during large flood events. These communities are early/mid seral but may persist for a long time before being replaced by willows, cottonwoods or conifers. At the Grave Creek site, this may represent a late-seral or climax community in low elevation areas of the floodplain that are subject to less frequent disturbance.
Colonizing Woody Vegetation	Communities consisting of cottonwood and willow seedlings. These communities occur on point bar features, concentrated within and around swales and in other areas subject to frequent disturbance and consisting of relatively recent deposition. These are early successional communities. The more protected portions of these communities will grow and mature overtime into Pole Black Cottonwood communities.
Herbaceous -- Grass Dominated	Herbaceous communities dominated by various grass species. These communities are static and occur in areas adjacent to working agricultural lands. These communities have been fenced and excluded from cattle and other agricultural related activities. Over time, these communities should develop into seral or climax communities as shrubs and spruce begin to colonize the understory.

Vegetation Community	Description[1]
Main Channel	No vegetation communities are present within the main channel. This is included as mapped area because it represents a large portion of the project reach that
Mature Black Cottonwood/ Engelmann Spruce	Communities consisting of both mature black cottonwood and mature Engelmann spruce. Varying age classes of cottonwood and spruce are present as well as Douglas fir seedlings and saplings, western larch saplings, mature alder, birch and dogwood. These communities represent late seral stages that in the absence of disturbance should develop into mature Engelmann spruce stands.
Mature Black Cottonwood	Communities dominated by mature black cottonwood. This community type was used for pre-project mapping where understory vegetation was not discernable from aerial or ground photos. These communities likely represent a mix of mid to late seral stages.
Mature Black Cottonwood/ Herbaceous	Communities dominated by mature black cottonwood in the overstory with an understory consisting of only herbaceous species. These are seral communities that may develop more diverse understory communities in the absence of disturbance and eventually develop into late successional stage cottonwood or climax spruce communities.
Mature Black Cottonwood/ Shrub	Communities dominated by mature black cottonwood in the overstory with a diverse dense shrub and herbaceous understory. These communities are found at bankfull elevation or low terraces along the channel. These communities represent a relatively undisturbed mid-seral stage of plant community succession at the site. Over time and in the absence of disturbance the cottonwoods will be replaced by a later successional stage dominated by conifer species such as spruce.
Mature Black Cottonwood/ Young Engelmann Spruce	Communities dominated by mature black cottonwood in the overstory and by Engelmann spruce seedlings and saplings in the understory. These communities are mid to late seral communities that will likely shift to mature Engelmann spruce communities over time.
Mature Engelmann Spruce	Communities dominated by mature Englemenn spruce. Other species of conifers, shrubs and herbaceous species are also present in varying amounts. These communities are found along low elevation terraces along the channel and in sites further from the main channel. This community likely represents the potential climax riparian community for the Grave Creek project reach.
Older Colonizing Woody Vegetation	These communities are dominated by cottonwood and willow seedlings greater than two years in age. Other shrub species and herbaceous species are also present in these communities. This community is found along areas of point bars above bankfull elevation or further from the channel where soil is more developed and disturbance is less frequent compared with the surfaces where the Colonizing Woody Vegetation community is found. This community represents an
Pole Black Cottonwood	These communities support a young age class of cottonwoods. These communities occur primarily on bare alluvial substrate immediately along the channel and continue to be subject to frequent disturbance. Very few species other than cottonwood occur in most of these

Vegetation Community	Description[1]
	communities. This community represents an early seral (pioneer) stage of succession. Over time and in the absence of disturbance these stands will mature and develop a diverse understory of shrubs and herbaceous species as soils develop.
Pole Black Cottonwood/ Engelmann Spruce	These communities support a young age class of cottonwoods with some Engelmann spruce present. These communities are found in similar locations as the Pole Black Cottonwood communities. These communities are likely in transition and succession will depend on the type, frequency, and duration of disturbance. These communities have the potential to support mature black cottonwood communities and may eventually shift to Engelmann spruce communities over time.
Willow	These communities support a variety of willow species. This is a minor community in the project reach occurring immediately along the channel where bioengineering has been installed, in small low elevation areas along the channel, and in a few small off-channel areas where seeps and springs are abundant. These are likely early seral communities that will continue to develop into various late seral willow communities over time.
Young Engelmann Spruce	These communities are dominated by sapling sized Engelmann spruce. These communities occur on older point bar surfaces. These communities represent early seral/pioneer plant communities that in the absence of disturbance may develop into mature climax Engelmann spruce communities over time

[1] Successional information provided in this table is based on descriptions found in Hansen et al. (1995).

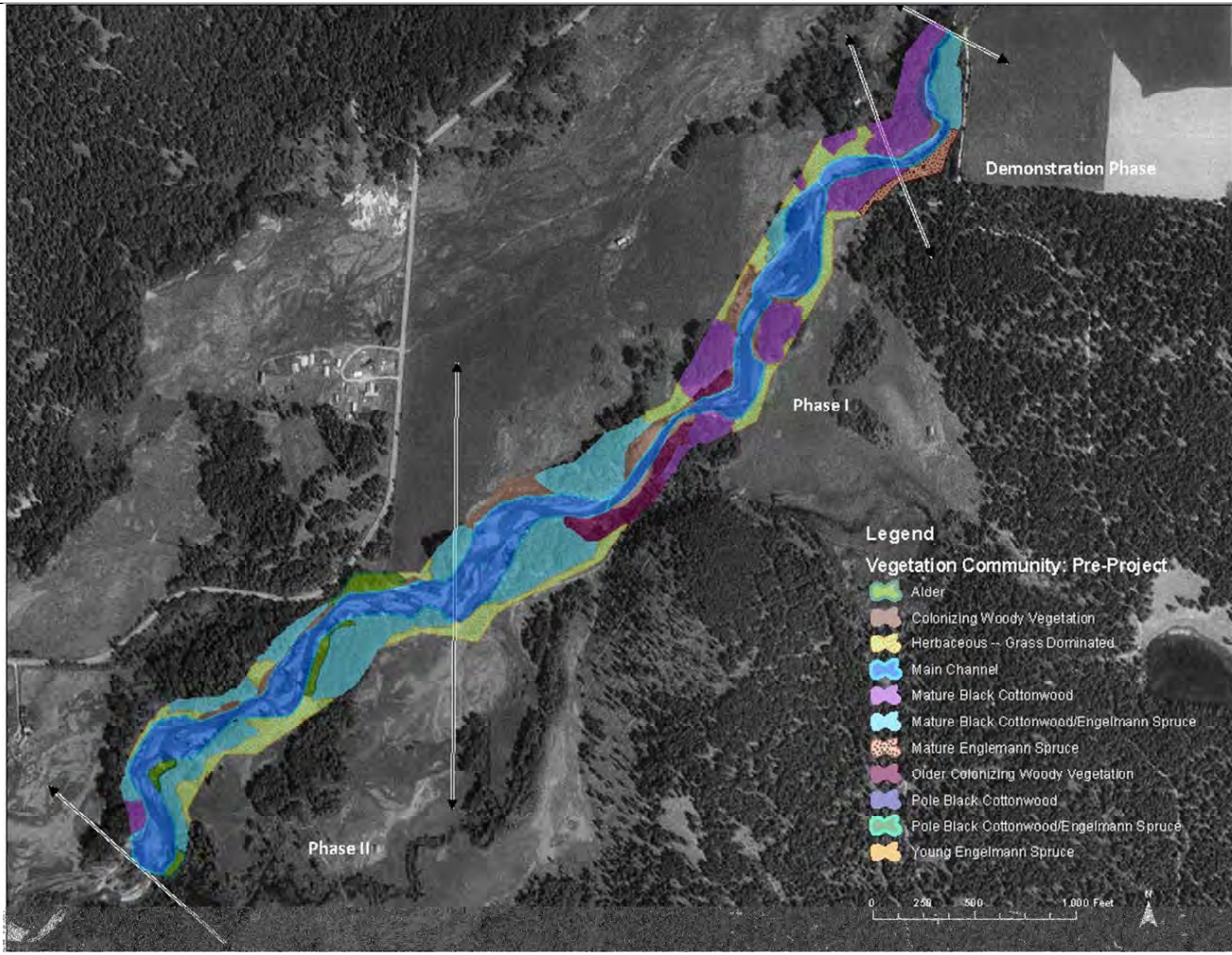

Figure 4-1. Riparian vegetation communities present within the Grave Creek project area prior to restoration (photo date 1999).

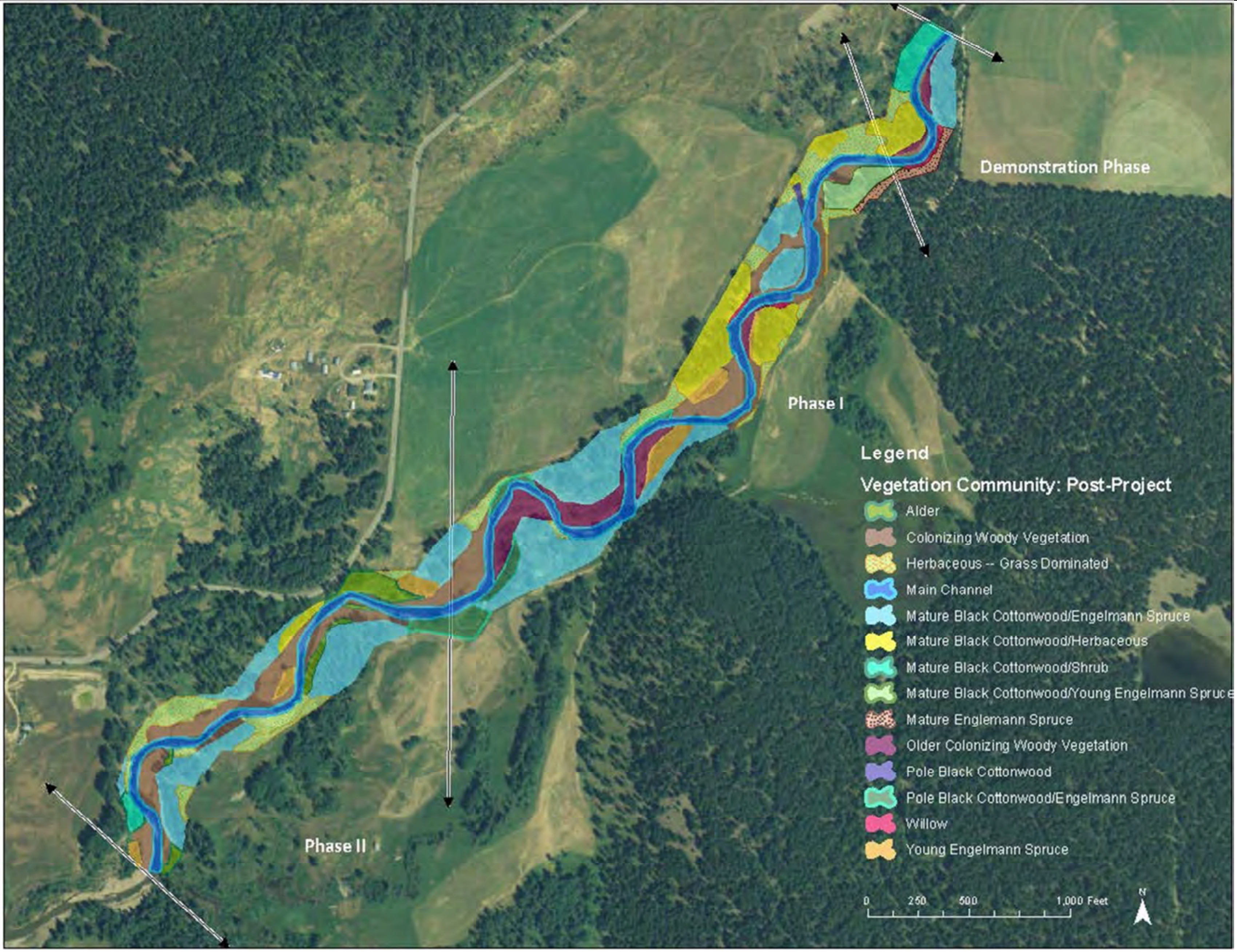

Figure 4-2. Riparian vegetation communities within the Grave Creek project area post restoration (mapped in summer 2010).

Table 4-2. Comparison of vegetation communities within the Grave Creek Restoration project area before and after restoration.

Vegetation Community	Acres	
	Pre-project	**Post-project**
Alder	1.4	1.6
Colonizing Woody Vegetation	3.1	8.9
Herbaceous -- Grass Dominated	6.5	5.5
Main Channel	17.6	7.0
Mature Black Cottonwood/Engelmann Spruce	12.8	14.2
Mature Black Cottonwood	7.5	0.0
Mature Black Cottonwood/Herbaceous		4.8
Mature Black Cottonwood/Shrub		1.2
Mature Black Cottonwood/Young Engelmann Spruce		1.0
Mature Engelmann Spruce	0.8	0.6
Older Colonizing Woody Vegetation	1.9	3.4
Pole Black Cottonwood	0.2	0.1
Pole Black Cottonwood/Engelmann Spruce	0.0	1.7
Willow	0.0	0.3
Young Engelmann Spruce	0.0	1.6
TOTAL	**51.8**	**51.8**

The greatest change in the project reach post restoration is the amount of area that was mapped as Main Channel. Prior to restoration the channel was braided and unstable. Restoration actions converted the channel to one consisting of a primary main channel. This is indicated by a change in acreage from 17.6 to 7.0 acres post-restoration for the Main Channel category. The surfaces created by restoring the channel to one primary channel instead of multiple channels are being colonized by early successional woody vegetation. This is indicated by the increase or appearance of a number of early successional vegetation communities post-project including: Colonizing Woody Vegetation, Older Colonizing Woody Vegetation and Young Englemann Spruce. Other shifts in vegetation communities are expected as plant community succession continues at the site. For example, the increase in acres occupied by Mature Black Cottonwood/Englemann Spruce indicates that mature cottonwood stands present pre-project are transitioning to later successional stands dominated by Englemann spruce.

4.2 Container Plant Survival

In 2010 container plant survival monitoring was conducted in two topographically different areas; bankfull benches along outer meanders (Planting Areas) and swales within constructed point bar features (Planting Swales). Container plant survival was also monitored in these locations in 2007, 2008 and 2009. Monitoring methods and results of previous data collection are discussed in detail in two documents, *Grave Creek Riparian Revegetation and Monitoring Plan* (2008 Revegetation Plan) (Geum Environmental 2008) and *Grave Creek 2008 As-Built and 2009 Monitoring Report* (2009 Monitoring Report) (Geum Environmental 2009).

4.2.1 Riparian Planting Areas

Plants were installed in the Planting Areas in 2005. These planting units are located along outsides of meander bends. Overall survival is moderate ranging from 37% to 61% (Table 4-3). Figure 4-3 shows the location of Planting Area Monitoring Plots in the project area. Figure 4-4 compares conditions within Planting Area Monitoring Plot 4 in 2008 and 2010.

Table 4-3. Comparison of container plant survival in Riparian Planting Areas between 2007 and 2010.

Plot	2007	2008	2009	2010
Planting Area Monitoring Plot 1 (PA-MP 1)	77%	82%	60%	37%
Planting Area Monitoring Plot 2 (PA-MP 2)	96%	77%	60%	56%
Planting Area Monitoring Plot 3 (PA-MP 3)	86%	79%	71%	N/A
Planting Area Monitoring Plot 4 (PA-MP 4)	85%	59%	61%	61%

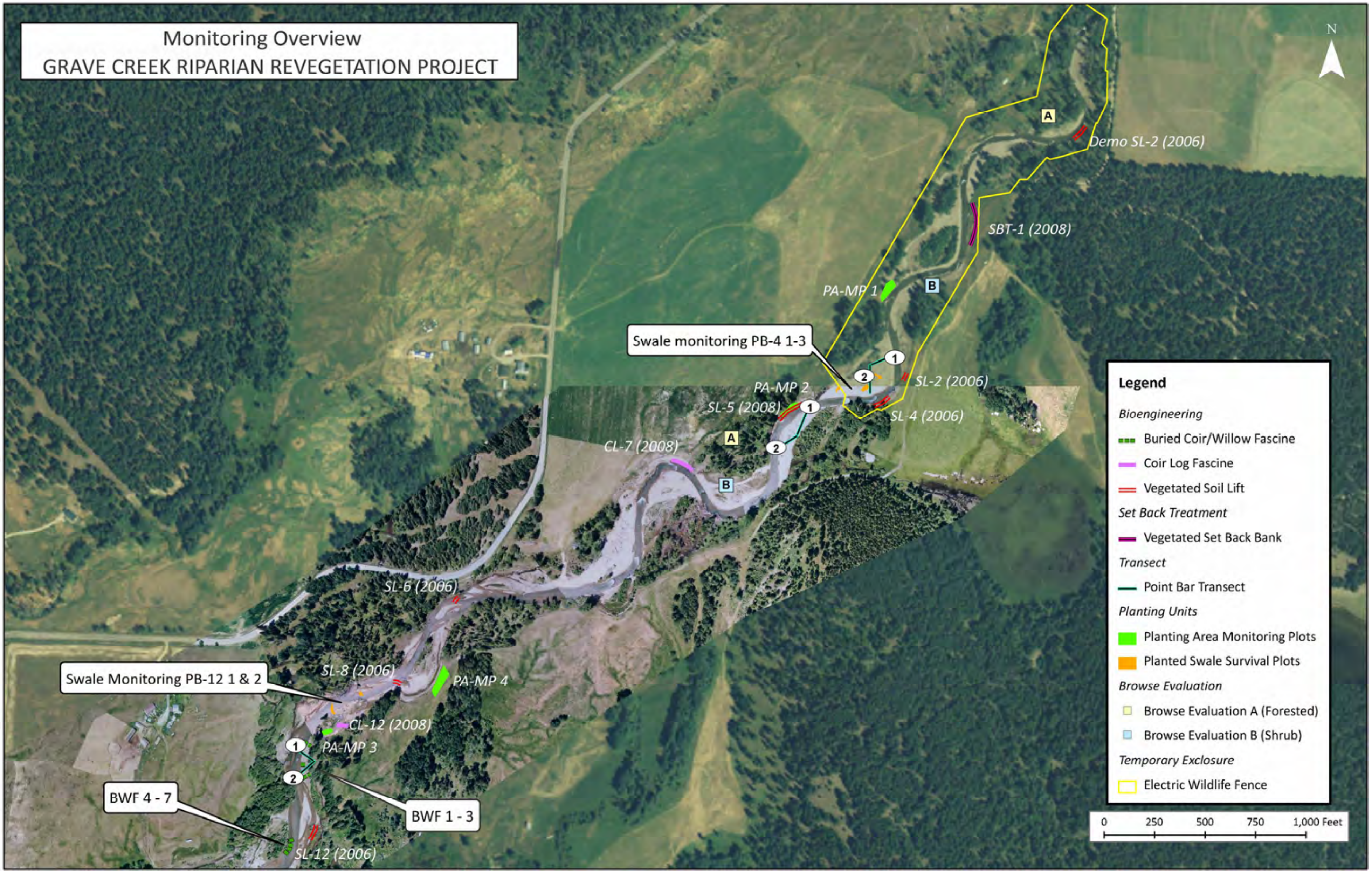

Figure 4-3. Overview of Grave Creek vegetation monitoring locations.

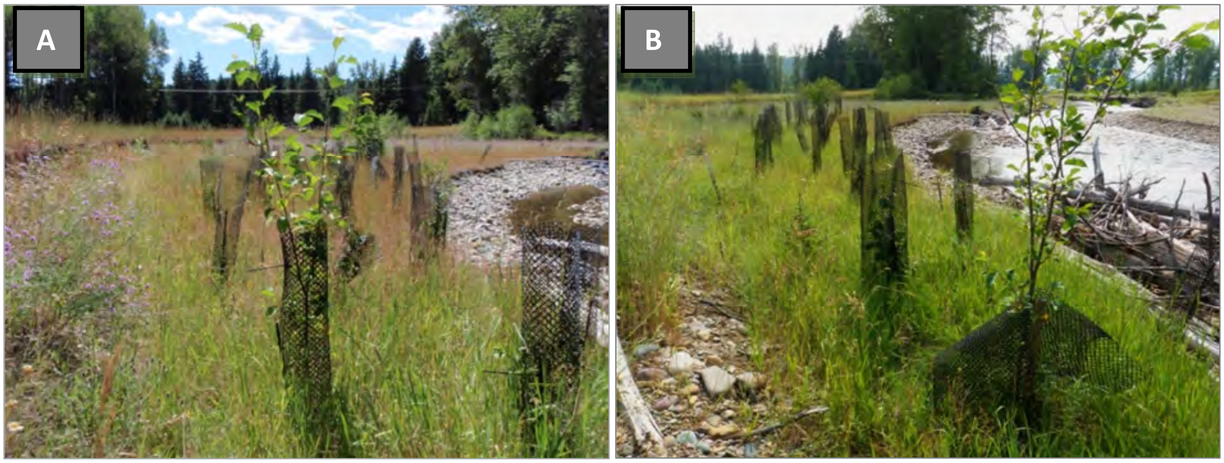

Figure 4-4. Photographs of Riparian Planting Area Monitoring Plot 4 in 2008 (A) and 2010 (B).

4.2.2 Swale Planting Areas

Swale Planting Areas consist of swales excavated into constructed point bar features. Swales were planted and seeded with woody species. Swales were constructed to provide microsites where vegetation can establish; therefore, natural recruitment of woody vegetation is also common in these features. In order to monitor the effectiveness of swale treatments, all woody plants present within each monitored Swale Planting Area were recorded. Table 4-4 provides a comparison of woody plant species found within each monitored swale in 2009 and 2010. Figure 4-3 shows the locations of Swale Planting Area monitoring plots. Container plants installed within swales in 2008 include black cottonwood, red-osier dogwood, bebb willow, sandbar willow. Most other species recorded have either recruited naturally or germinated from seed applied during 2008. Shrub species included in the 2008 seed mix were red-osier dogwood, water birch and common chokecherry. Other shrub species were installed in a select number of swales during the initial revegetation effort in 2005. Shrubs that were not planted or seeded in 2008 are from either 2005 planting or natural recruitment.

An electric wildlife fence was installed in the project reach in 2008 (Figure 4-3). Survival of installed shrubs is similar inside and outside of the fenced area; however, plants located within the fenced area are taller and more vigorous compared with those outside the fence. The number and diversity of species recorded in Swale Planting Areas contained within the electric wildlife fence has increased compared to the plots located outside the fence (Table 4-4). Figure 4-5 shows a comparison of planted swales located in Phase I of the project reach inside the fence and outside the fence in 2009 and 2010. Cottonwood seedlings are abundant and some have grown to three feet making it difficult to distinguish between those that were planted and those that have naturally recruited.

Table 4-4. Comparison of shrub species recorded within swales in Point Bar Planting Areas in 2009 and 2010.

	2009		2010	
Plot	**Species**	**Number of Alive Plants**	**Species**	**Number of Alive Plants**
PB 4 Plot 1 Inside Fence	bebb willow	3	bebb willow	2
	sandbar willow	1	sandbar willow	1
	red-osier dogwood	3	red-osier dogwood	4
	black cottonwood	2	black cottonwood	0
	Drummond willow	2	Drummond willow	2
	willow species	1	willow species	3
	hawthorne	2	hawthorne	2
PB 4 Plot 2 Inside Fence	bebb willow	2	bebb willow	3
	sandbar willow	3	sandbar willow	7
	red-osier dogwood	3	red-osier dogwood	3
	black cottonwood	1	black cottonwood	2
	common chokecherry	4	common chokecherry	4
	willow species	4	willow species	4
	hawthorne	1	hawthorne	1
	snowberry	1	snowberry	1
			alder	1
PB 4 Plot 3 Outside Fence	Drummond willow	5		
	bebb willow	2		
	willow species	3	willow species	10
	red-osier dogwood	7	red-osier dogwood	7
	hawthorne	1	hawthorne	2
			red raspberry	1
			cottonwood	2
PB 12 Plot 1 Outside	bebb willow	1	bebb willow	1
	red-osier dogwood	3	red-osier dogwood	3
PB 12 Plot 2 Outside	sandbar willow	1	sandbar willow	1
	bebb willow	2	bebb willow	2
	red-osier dogwood	1	red-osier dogwood	1

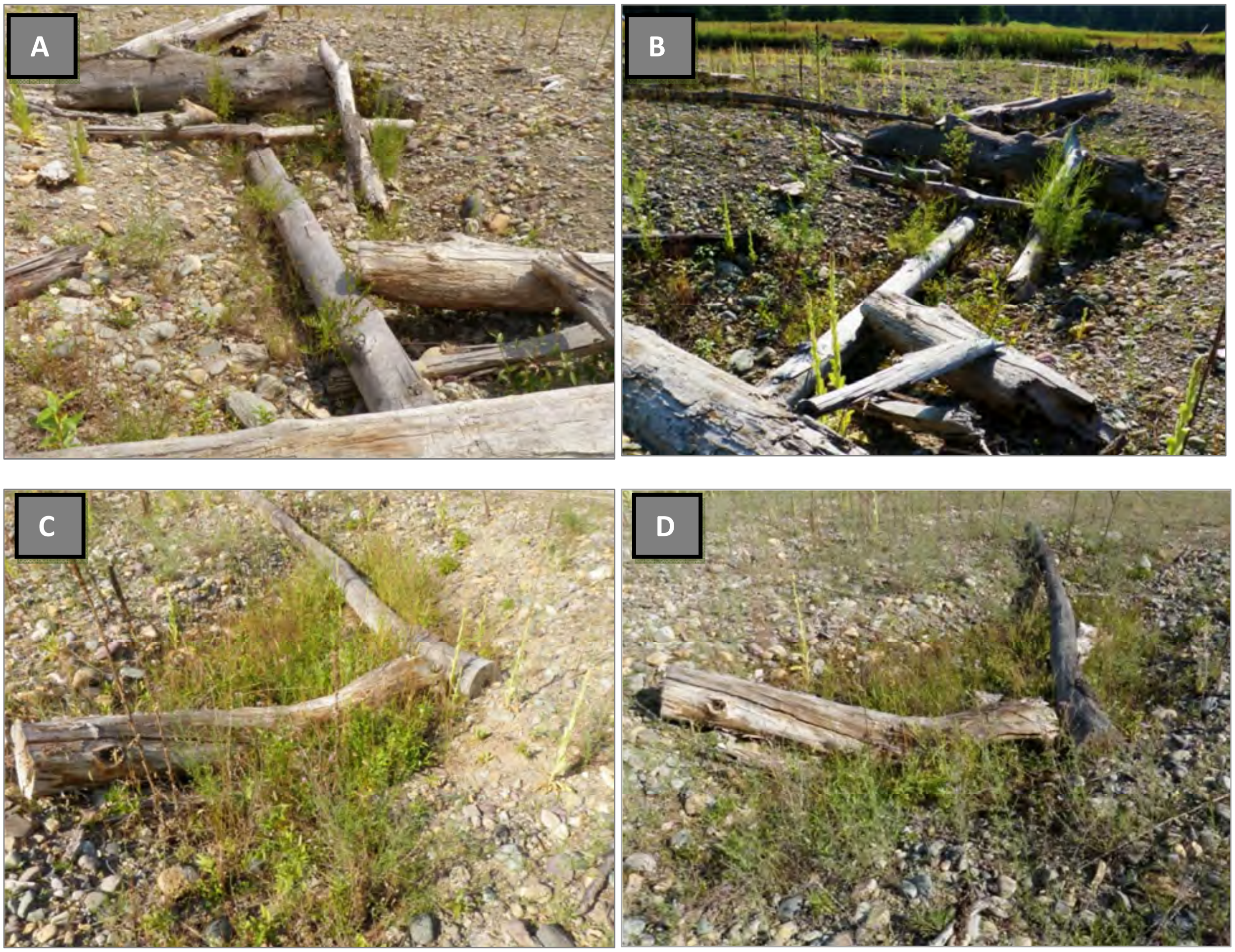

Figure 4-5. Photographs show the difference between a planted swale located inside and outside the electric wildlife fence as well as comparing swale conditions in 2008 and 2010. Photographs A and B are of Point Bar 4 Plot 2 inside fence (photo A 2008 and B 2010). Photographs C and D are of Point Bar 4 Plot 3 outside fence (Photos C 2008 and D 2010).

4.3 Percent cover of woody vegetation on treated streambanks

Cover of woody species on bioengineering structures was recorded for seven structures in 2010 (Table 4-5 and 4-6, Figure 4-3). Data were collected in five foot increments along the face of the structures. Data collected at each structure included percent cover of woody species, percent of structure browsed, and average height of new growth of woody species. Tables 4-5 and 4-6 provide a summary of data collected in 2010 and compares that data with previous year's data where possible. Figure 4-3 shows the locations of monitored structures.

In general, bioengineering structures have remained stable since 2006. As shown in Tables 4-5 and 4-6 most of the structures have greater than 60% cover of woody vegetation. Figures 4-6 through 4-12 show each of the monitored soil lifts in 2008 or 2009 and in 2010.

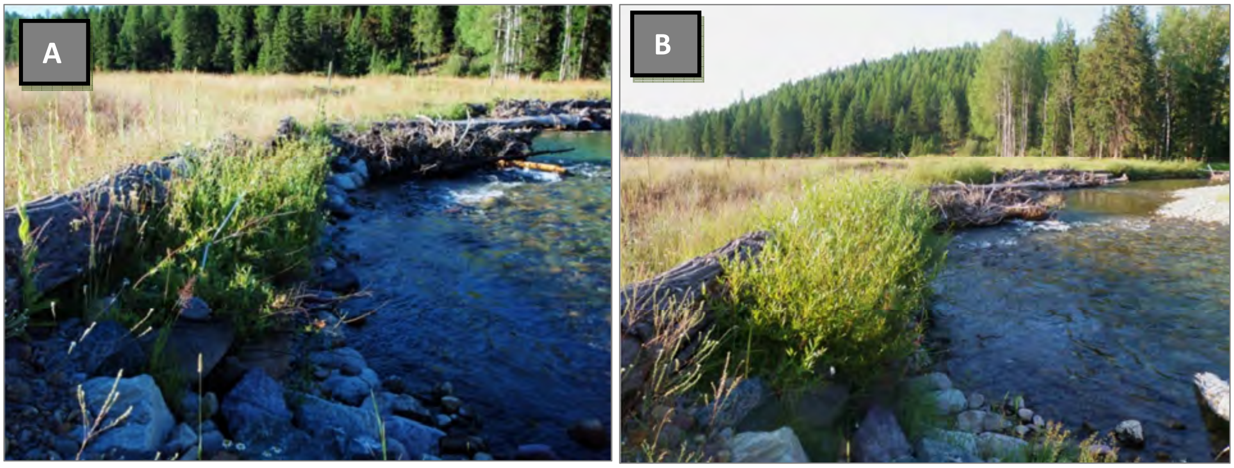

Figure 4-6. Photographs of Soil Lift 2 (2006) in 2008 (A) and 2010 (B) during the fourth growing season.

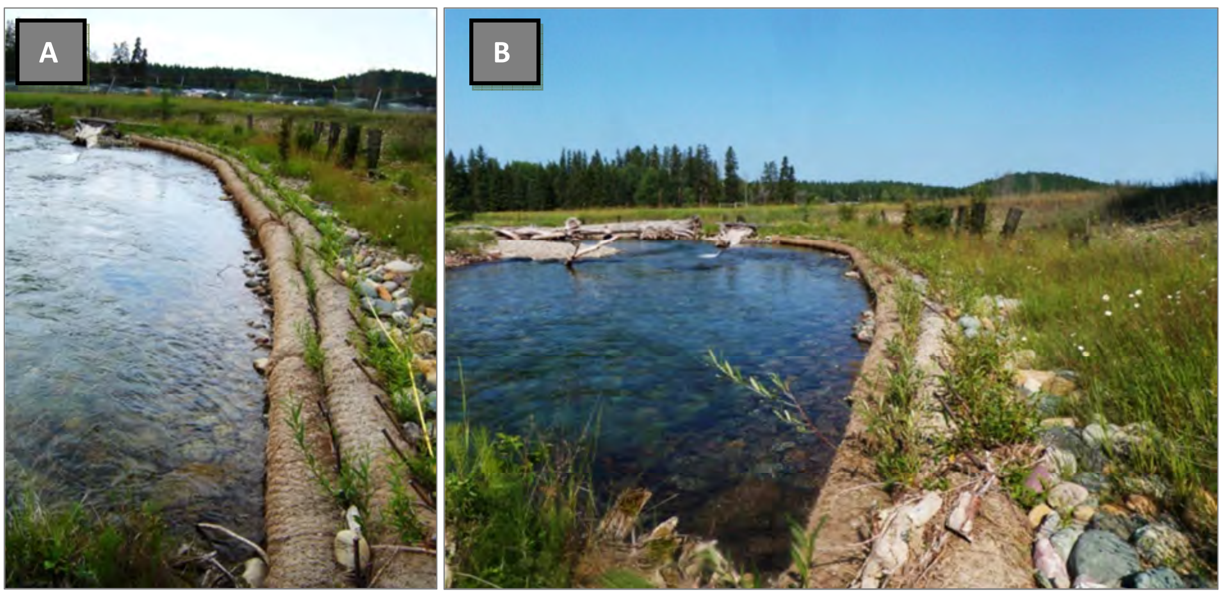

Figure 4-7. Photographs of Coir Log 7 (installed in 2008) in 2009 (A) and 2010 (B).

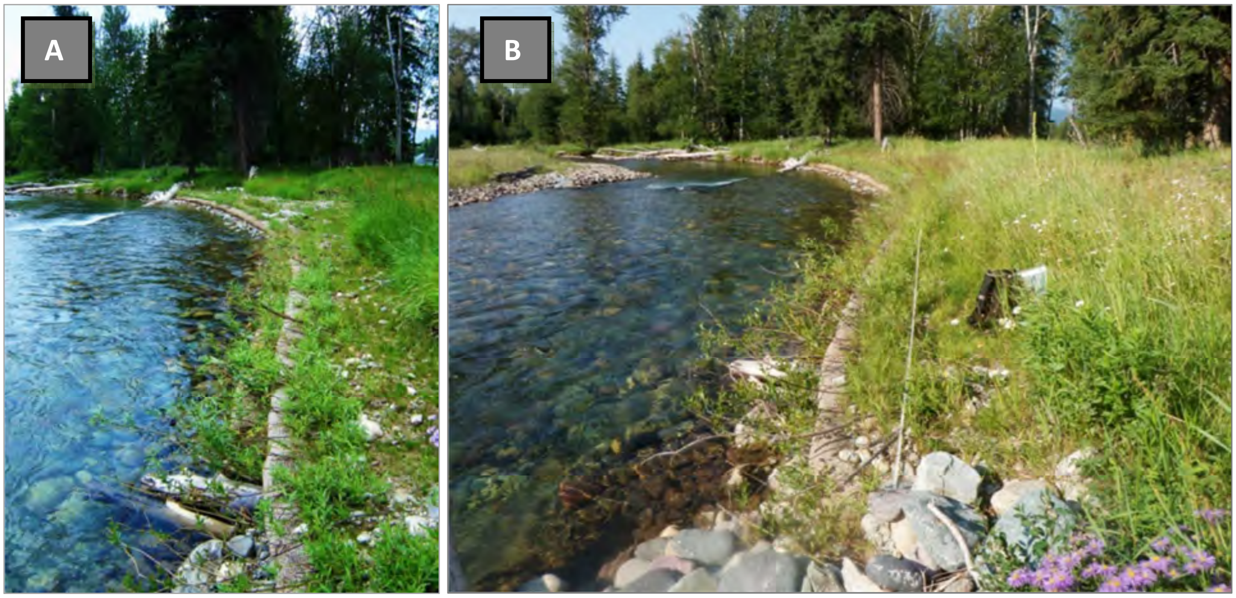

Figure 4-8. Photographs of Soil Lift 5 (installed in 2008) in 2009 (A) and 2010 (B).

Figure 4-9. Photographs of Soil Lift 12 (installed in 2006) in 2008 (A) and 2010 (B).

Figure 4-10. Photographs of Soil Lift 3 (installed in 2008) in 2009 (A) and in 2010 (B).

Figure 4-11. Photographs of Soil Lift 10 (installed in 2008) in 2009 (A) and in 2010 (B).

Figure 4-12. Photographs of Coir Log 12 (installed in 2008) in 2009 (A) and in 2010 (B).

Table 4-5. Summary of soil lift monitoring data for 2008, 2009 and 2010.

	SL-3 (2008)		SL-5 (2008)				SL-2 (2006)						SL-10 (2008)			SL-12(2006)					
Year	**2010**		**2009**		**2010**		**2008**		**2009**		**2010**		**2010**			**2008**		**2009**		**2010**	
Layer	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**3**	**1**	**2**	**1**	**2**	**1**	**2**
Metric[1]																					
Average percent cover willow	81	77	52	57	62	42	40	54	75	88	65	89	65	33	0	33	31	29	57	76	66
Average percent browsed	N/A	N/A	10	25	N/A	N/A	5	41	0	0	N/A	N/A	N/A	N/A	N/A	12	33	8	3	N/A	N/A
Average shoot height (inches)	38	30	12	10	15	5	13	10	26	31	29	29	36	16	0	10	9	18	24	66	20

Table 4-6. Summary of coir log monitoring data for 2009 and 2010.

	CL-7 (2008)				CL-12 (2008)	
Monitoring Year	**2009**		**2010**		**2009**	**2010**
Layer	**1**	**2**	**1**	**2**	**All**	**All**
Metric						
Average percent cover woody vegetation	9	28	17	46	46	22
Average percent browsed	0	10	17	55	98	80
Average shoot height (inches)	10	14	10	10	14	8

4.4 Transects to measure plant community establishment on constructed floodplains

Two constructed point bars were monitored in August 2010 (Figure 4-3). Data collected at each site are provided in Tables D-1 through D-8 in Appendix D. Many of the swales constructed in 2005 support a variety of grasses, forbs, and shrubs and provide the highest and most diverse concentration of vegetation on the point bars.

The number of shrubs along transects and the extent of transects with shrubs has increased between 2008 and 2010. Much of the increase is a result of cottonwood seedlings that have colonized and persisted along transects (Figure 4-13). Some cottonwood seedlings have grown to three feet, especially in areas where they have colonized in woody debris pile microsites (Figure 4-13). In addition to cottonwood seedlings, spruce, dogwood and alder seedlings are colonizing the point bar surfaces. Some transects intercept constructed swale features. Vegetation within swales is expanding and filling in the swales (Figure 4-14).

Point bar surfaces appear to support floodplain building processes such as scour and deposition and recruitment of woody species (Figure 4-15). Overall cover of weeds, woody debris, grasses and forbs recorded in 2010 remains similar to 2009 conditions, but their distribution along the transect has shifted slightly (Tables D-1 through D-8 in Appendix D).

Figure 4-13. Photographs of cottonwood seedlings of various age classes growing in microsites created by large woody debris placed on floodplain surfaces.

Figure 4-14. Photograph of vegetation in swale on Point Bar 4.

Figure 4-15. Photograph of flood deposited debris on constructed point bar surface.

4.5 Browse evaluation inside and outside wildlife exclosure

Paired monitoring points (one inside of the fence perimeter and one outside of the fence perimeter) were established to evaluate the effectiveness of the electric wildlife fence installed in August 2008 (Figure 4-3). Paired points were established in two distinct vegetation types thought to represent desired vegetation communities along Grave Creek in the project area. One set of points was established within mature cottonwood areas (forested) and the second set of points was established in wetter, shrub dominated areas (shrub). Data collected at each site are provided in Table D-9 in Appendix D. At each point, a series of panoramic photographs were taken and cardinal directions recorded at each photo location. At each monitoring point, percent cover of shrubs was recorded as well as general observations of browse and natural recruitment.

Forested plots consist of mature cottonwood trees and an understory dominated by pasture grasses with some inclusions of understory shrubs such as dogwood, alderleaf buckthorn, rose, snowberry, and alder. Each forested evaluation point includes both open and closed canopy areas to evaluate regeneration and plant community succession. Shrub evaluation points consist of willows, cottonwood, alder, birch, and raspberry. These points are located at lower elevations near the channel and are frequently inundated by overbank flows.

Plots located within the electric fence show signs of release from browse as indicated by the absence of browse on current year's growth and the presence of previously browsed older stems. Willow stands have expanded and percent cover has increased from 30 to 50 percent. Plants in plots located outside of the electric fence continue to show signs of moderate to severe browse as indicated by the presence of browse on current and older growth. Figure 4-16 compares shrubs within the browse evaluation point located within the fenced area prior to fence installation and two growing seasons after fence installation. Willow height, percent cover and distribution has increased. Figure 4-17 compares shrubs within the browse evaluation point located outside the fenced area in 2009 and 2010. Figure 4-18 compares the difference in shrub growth form for shrubs within the fenced and outside of the fenced area.

Figure 4-16. Photographs of vegetation in Browse Evaluation Plot B Inside Fence (shrub) in July 2008 (A) prior to fence installation and in August 2010 (B) two growing seasons after fence installation.

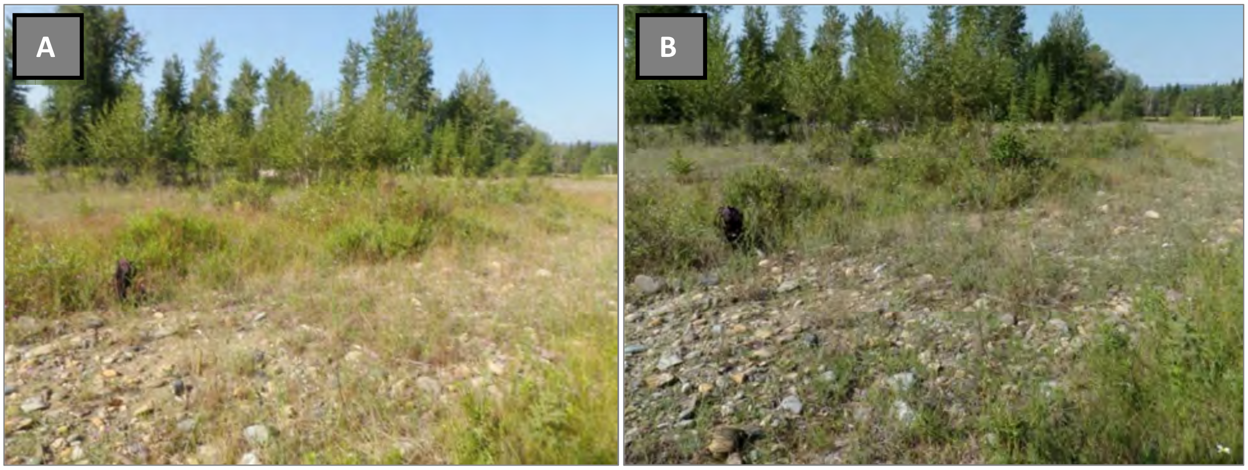

Figure 4-17. Photographs of vegetation in Browse Evaluation Plot B Outside Fence in July 2009 (A) and in August 2010 (B).

Figure 4-18. Photograph of a forested plot outside the fence (A) and a forested plot inside the fence (B). Inset photograph is of browse on shrub within the forested plot outside of the exclosure fence.

5.0 Discussion

As described in the Grave Creek TMDL, lower Grave Creek is a dynamic alluvial environment subject to extreme rain-on-snow driven runoff events that can deliver large quantities of sediment to the lower reaches. The aerial photo record indicates that Grave Creek responded to large flood events and other disturbances by braiding, followed by a period of vegetation recovery that converted the system back to a predominantly single threaded, meandering stream type with active secondary channels. Because of the natural background sediment loading and natural disturbance regimes, the TMDL recognized that it may not be possible to satisfy some of the Type I and Type II targets. The TMDL also acknowledged that natural disturbance pulses can be a positive influence on the system by creating and maintaining habitat features such as pools and large woody debris that are critical components to supporting the life history stages of the focal fish species.

Geomorphic monitoring results indicate that Grave Creek is trending towards the desired future condition and maintaining the average channel cross-section, planform, and longitudinal profile dimensions. The channel and floodplain are operating under a natural range of variability that includes ranges for most measured geomorphic variables including channel width to depth ratio, pool frequency and residual pool volume, sinuosity, and other metrics including percent fines and meaner geometry relationships. The addition of large wood, primarily in the form of aggregates, has increased channel and floodplain roughness and created complex aquatic habitat conditions, areas for fine and coarse sediment deposition, and stable surfaces that now support a wide range of desired plant communities in various successional stages. Over time, as floodplain and streambank vegetation matures, the added stability provided by deep rooted woody vegetation should facilitate natural channel processes including lateral channel migration.

Structural components used in the restoration project varied between phases. The primary purpose of the structures was to prevent excessive erosion until vegetation communities mature and balance erosive forces under a more natural rate compared to pre-restoration conditions. Structural components included the use of more hardened approaches including j-hook vanes and cross vanes in the Phase 1 project area. Based on monitoring, these structures were modified or eliminated in Phase 2 and replaced with softer bioengineering techniques to achieve streambank restoration objectives, and alternative grade control structures such as roughened riffles to provide vertical channel stability and floodplain connection. Future phases on lower Grave Creek should minimize the use of large rock-based structures and encourage the use of wood and bioengineering based designs to achieve project objectives. In the long-term, creating conditions that will allow natural processes to establish and maintain a diverse mosaic of floodplain plant communities will be necessary to balance erosion rates in lower Grave Creek, accepting that erosion will occur in some areas at greater rates than others.

The following sections summarize the monitoring results compared to the established TMDL Type I, Type II, and supplemental indicator targets.

5.1 Type I Indicators

Effectiveness monitoring results and the Grave Creek TMDL Type I target values are listed in Table 5-1. Relevant Type I targets include pool frequency per mile and percent surface fines less than two millimeters in riffle features.

Table 5-1. Summary of Phase 1 and Phase 2 monitoring data compared to established TMDL type 1 target values.

Target Parameter	Phase 1	Phase 2	Phase 1 and 2	TMDL Target
Pool Frequency (pools/mile)	23.1	27.1	25.1	12-29
Percent Fines <2mm in Riffles	0.8	2.3	1.6	<20%

Monitoring results indicate that pool frequency in Phase 1 is 23.1 pools per mile and 27.1 pools per mile in Phase 2. This equates to an average value of 25.1 pools per mile for both project phases. The Type I target range for pool frequency is 12-29 pools per mile. Pool frequency in both phases meets TMDL Type I indicator targets.

The Type I target value for surface fines less than two millimeters in riffle features is less than 20%. Post-restoration particle size analyses demonstrate that the sampled riffles in Phase 1 reflect less than 1% surface fines, while the sampled riffles in Phase 2 reflect 2.3% fines less than two millimeters. Riffle features in both phases meet TMDL Type I indicator targets.

5.2 Type II Indicators

Effectiveness monitoring results and the Grave Creek TMDL Type II target values are listed in Table 5-2. Relevant Type II targets include percent surface fines less than 6.35 millimeters in riffle features and bankfull channel width to depth ratios of less than or equal to 27.

Table 5.2. Summary of Phase 1 and Phase 2 monitoring data compared to established TMDL type 2 target values.

Target Parameter	Phase 1	Phase 2	Phase 1 and 2	TMDL Target
Percent Fines <6.35mm in Riffles	0.8	2.3	1.6	≤15%
Width to Depth Ratio	16.1-38.7 (28.0 Ave) (28.5 Median)	13.0-24.5 (20.6 Ave) (22.5 Median)	13.0-38.7 (24.3 Ave) (25.9 Median)	≤27

The Type II target value for surface fines less than 6.35 millimeters in riffles is less than or equal to 15%. Post-restoration particle size analyses demonstrate that the sampled riffles in Phase 1 reflect less than 0.8% surface fines, while the sampled riffles in Phase 2 reflect less than 2.3% surface fines less than 6.35 millimeters. Riffle features in both phases meet TMDL Type II indicator targets.

The average width to depth ratio in Phase 1 is 27.9 and ranges from 16.1 to 38.7. The average width to depth ratio in Phase 2 is 20.7 and ranges from 13.0 to 24.5. The TMDL

Type II target range for width to depth ratio is less than or equal to 27. All sampled cross-sections in Phase 2 meet the TMDL Type II indicator targets. The average width to depth ratio value of the sampled cross-sections in Phase 1 slightly exceeds the TMDL Type II indicator value. However, when the sampled cross-section width to depth values are averaged for both phases of restoration (24.3), the Type II indicator target is met.

5.3 Supplemental Indicators

The Grave Creek effectiveness monitoring data and the TMDL Supplemental Target values are listed in Table 5-3. Relevant supplemental targets include meander length ratio, channel sinuosity, large woody debris, residual pool depth, and percent sediment reduction.

Table 5-3. Summary of Phase 1 and Phase 2 monitoring data compared to established TMDL supplemental target values.

Target Parameter	Phase 1	Phase 2	Phase 1 and 2	TMDL Target
Meander Length Ratio	10.1-14.2 (12.2)	7.3-16.5 (11.0)	11.6	13.8-19.2
Sinuosity	1.36	1.20	1.28	1.2-1.6
Large Woody Debris (no. single pieces/mile)	95.2	68.7	82.0	104-210
Large Woody Debris (no. pieces in aggregates/mile)	501	860	681	146-294
Residual Pool Depth (ft)	1.1-3.9 (2.4)	1.0-5.3 (3.0)	2.7	≥3.0
Sediment Reduction (%)	-32	-63	47.5	≥63

Effectiveness monitoring results indicate that the average meander length ratios in Phase 1 and Phase 2 are 12.2 and 11.0, respectively. The supplemental target range is 13.8 to 19.2. Both restoration phases do not meet established TMDL targets (see Section 5.4).

Channel sinuosity in the Phase 1 and Phase 2 project areas is 1.35 and 1.20, respectively, for an average value of 1.28. The TMDL supplemental target range for channel sinuosity is 1.2 to 1.6. Both phases of restoration meet the established TMDL target values for channel sinuosity.

The number of single pieces of large woody debris per mile in the Phase 1 and Phase 2 project areas is 95.2 and 68.7, respectively, for an average value of 82.0. The supplemental target range for single pieces of large woody debris per mile is 146-294. Neither phase of restoration meet the established TMDL target values for single pieces of large woody debris per mile (see Section 5.4).

The number of pieces of large woody debris in aggregates per mile in the Phase 1 and Phase 2 is 501 and 860, respectively, for an average value of 681. The supplemental target range for number of pieces in aggregates per mile is 146-294. Both phases of restoration meet the established TMDL target values for number of pieces in aggregates per mile.

Effectiveness monitoring results indicate that residual pool depth ranged from 1.1-3.9 ft and averaged 2.4 ft in the Phase 1 project area. In Phase 2, residual pool depth ranged from 1.0 to 5.3 ft and averaged 3.0 ft. The supplemental target value for residual pool depth is greater than or equal to 3.0 ft. The Phase 1 project area does not meet the established TMDL target value for residual pool depth, whereas the Phase 2 project area does meet the established TMDL target value.

Effectiveness monitoring results for the Phase 1 and Phase 2 project areas indicated a 32% and 47.5% decrease in bank-derived sediments inputs to the channel, respectively. The TMDL supplemental target value for bank-derived sediment reduction is greater than or equal to 63%. The Phase 1 project area does not meet the established target whereas the Phase 2 project area meets the established target value.

5.4 Vegetation

Vegetation monitoring data indicate that the site is trending towards the desired future condition. The desired future condition for the riparian and floodplain environment within the Grave Creek project reach is a dynamic, succession driven mosaic of plant communities capable of supporting a wide range of floodplain ecosystem functions (Geum Environmental 2008). This desired future condition is necessary long-term to achieve project objectives and TMDL targets. As described in Section 4, vegetation communities mapped in 2010 represent a wide range of desired plant communities in various successional stages. This indicates that the river and floodplain processes necessary to achieve the desired future condition are in place in the project reach.

Overall, revegetation treatments are supporting project objectives and creating conditions necessary to achieve the desired future condition. Some factors have contributed to and will continue to limit the success of some treatments. Containerized plant survival is relatively poor for outside meander planting units. A number of environmental factors; including erosion of banks, browse, drought and well-drained soils, have made not only survival but also growth of planted shrubs and trees challenging. Percent cover of woody vegetation is low on some constructed streambanks, but averages 60 percent cover overall. This is considered at or above natural levels for woody vegetation cover on streambanks (Geum Environmental, unpublished data).

6.0 References

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APPENDIX A

GRAVE CREEK RESTORATION PROJECT PHASE 1 AND 2

SEDIMENT REDUCTION ANALYSIS

JULY 2010

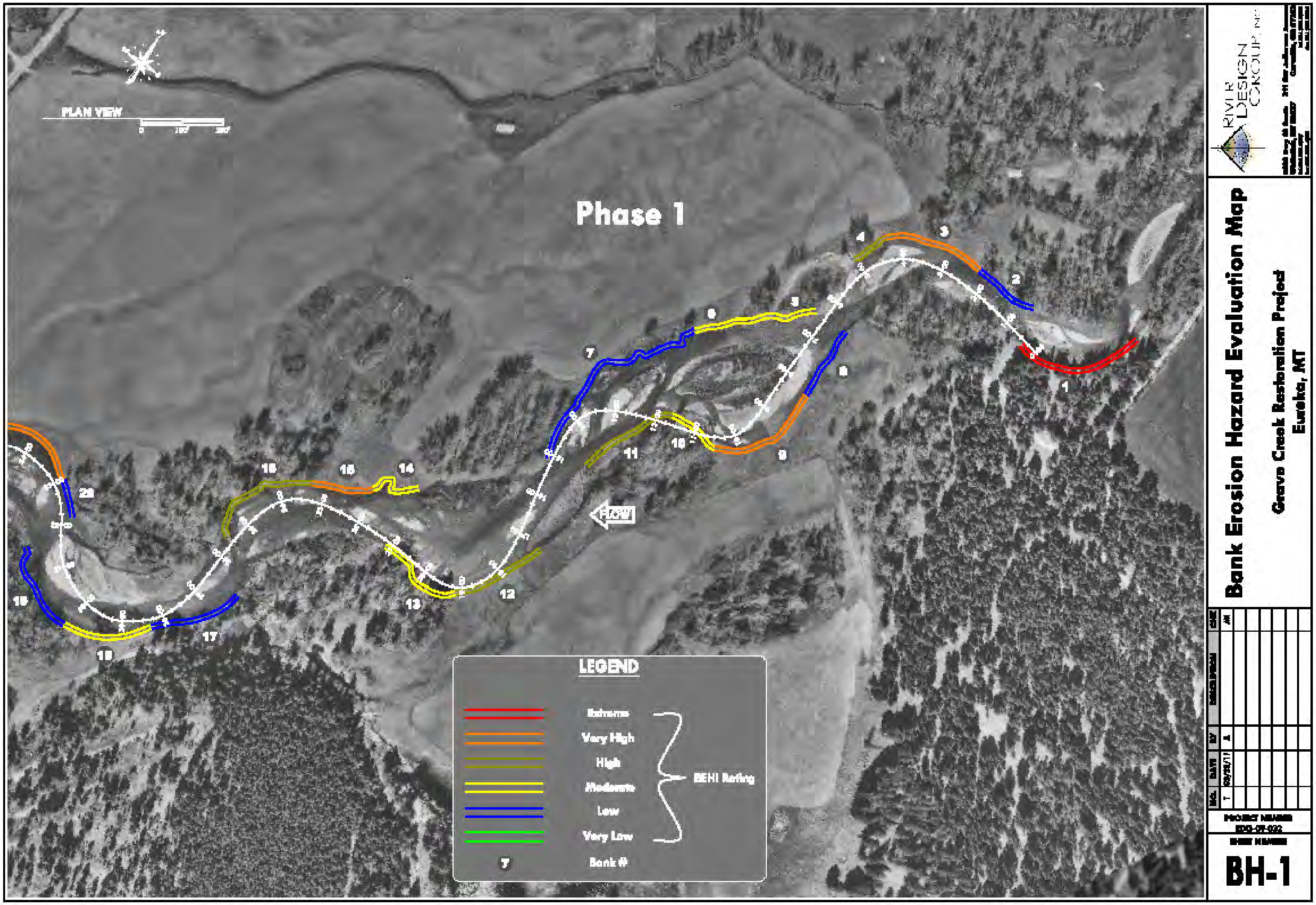

Figure A-1. Distribution of the bank erosion hazard in upper Phase 1 before restoration.

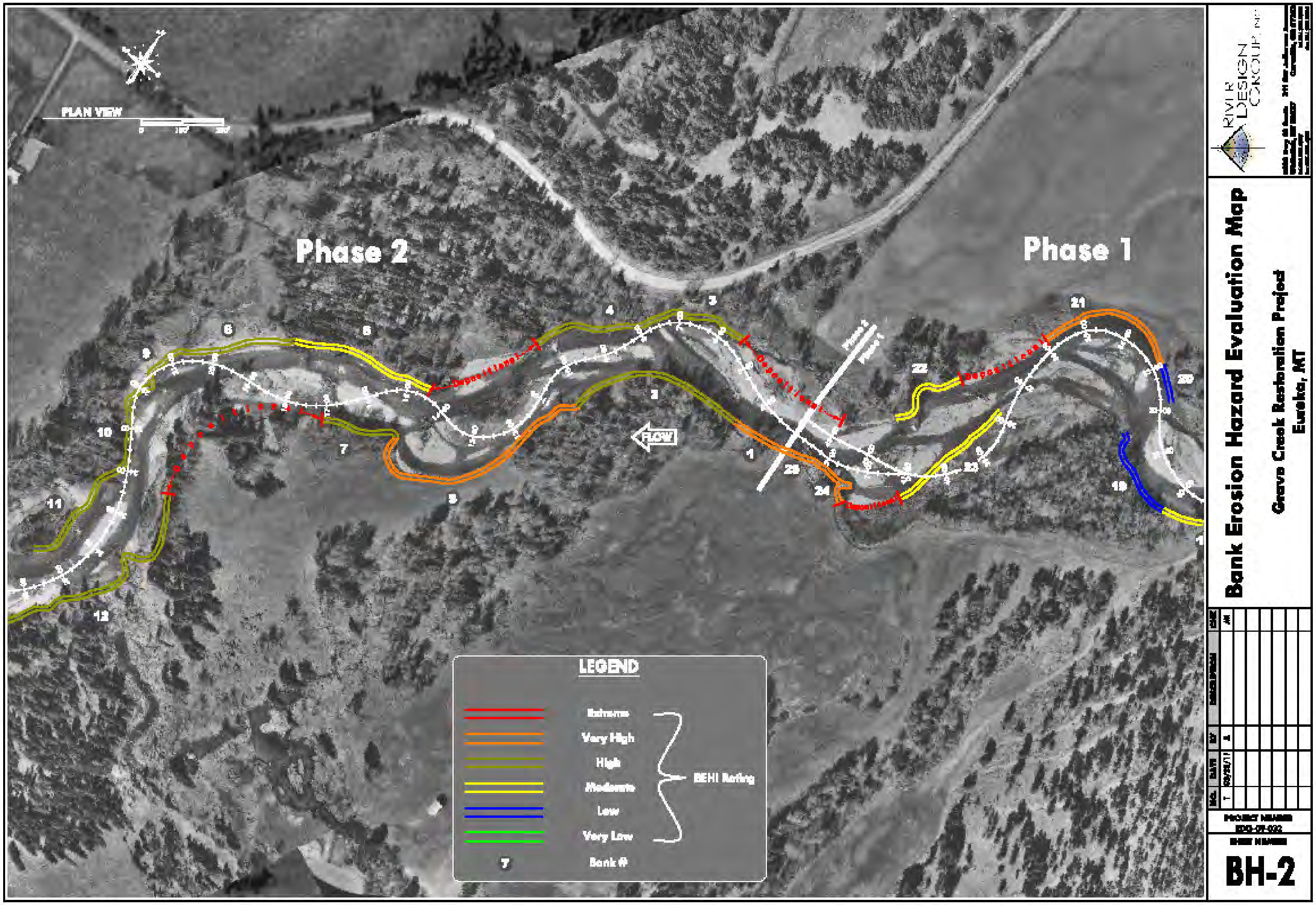

Figure A-2. Distribution of the bank erosion hazard in lower Phase 1 before restoration.

Phase 1 Bank Erosion Hazard Index (BEHI) Evaluation for 2001 (Pre-Restoration)

Table A-1. Grave Creek Phase 1: Average pre-restoration BEHI bank conditions and estimated erosion rates for 2001.[1]

Bank No.	BEHI Adjective Rating	BEHI Numerical Rating	Bank Height (ft)	Bank Length (ft)	Estimated Bank Erosion (ft/yr)	Estimated Bank Erosion (tons/yr)
1	Extreme	46.3	10.0	350	0.47	79.2
2	Low	19.6	3.5	150	0.17	4.3
3	Very High	42.0	3.0	280	0.39	15.8
4	High	31.5	2.8	110	0.31	4.6
5	Moderate	24.4	2.0	200	0.23	4.4
6	Moderate	29.2	3.2	100	0.23	3.6
7	Low	19.2	2.0	460	0.17	7.5
8	Low	19.9	3.2	190	0.17	5.0
9	Very High	40.6	3.2	250	0.39	15.0
10	Moderate	23.8	3.5	140	0.23	5.4
11	High	33.0	3.3	200	0.31	9.8
12	High	38.7	3.0	220	0.31	9.8
13	Moderate	29.5	3.2	200	0.23	7.1
14	Moderate	29.3	2.5	120	0.23	3.3
15	Very High	42.6	2.8	160	0.39	8.4
16	High	31.1	2.8	300	0.31	12.5
17	Low	15.8	2.8	160	0.17	3.7
18	Moderate	26.1	5.5	200	0.23	5.5
19	Low	19.9	2.5	200	0.17	4.1
20	Low	19.8	3.0	100	0.17	2.5
21	Very High	42.3	3.0	380	0.39	21.4
22	Moderate	29.8	3.0	190	0.23	6.3
23	Moderate	28.7	2.0	250	0.23	5.5
24	Very High	45.5	6.0	120	0.39	13.5
25	Very High	40.3	6.0	150	0.39	16.9
Total						275

[1]Predicted erosion rates based on Middle Blackfoot River measured erosion (MT DEQ 2007).

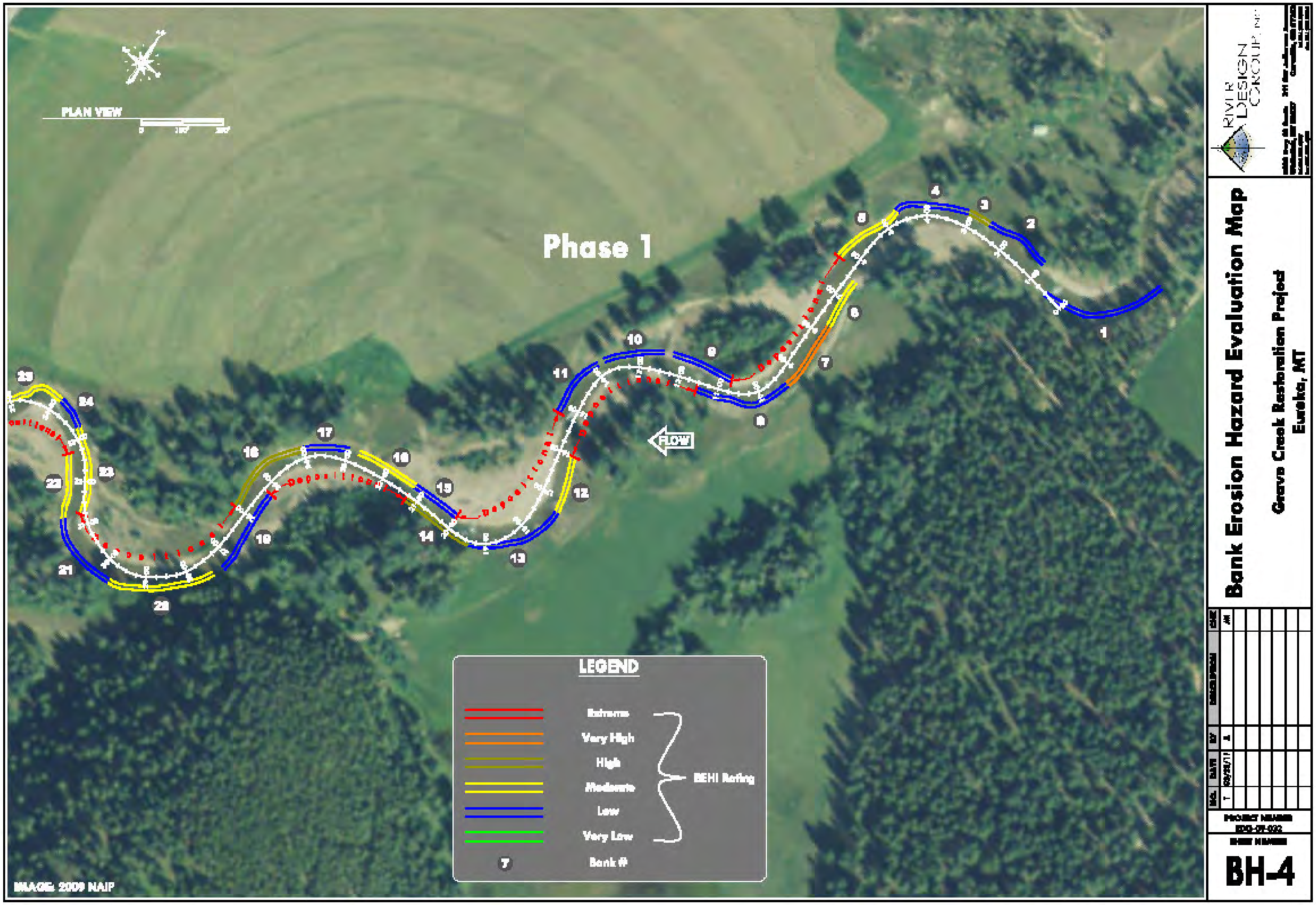

Figure A-3. Distribution of the bank erosion hazard in upper Phase 1 after restoration.

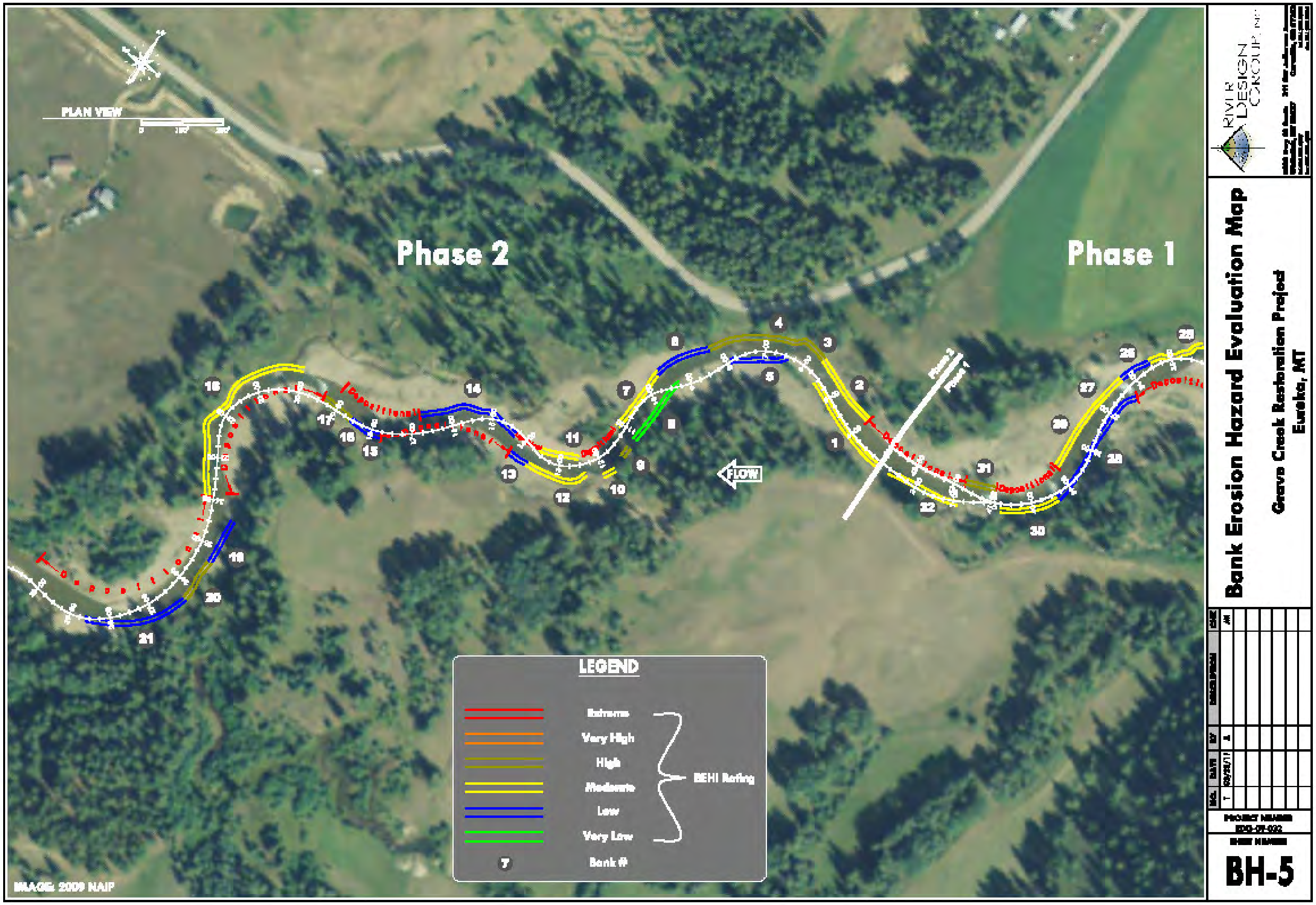

Figure A-4. Distribution of the bank erosion hazard in lower Phase 1 after restoration.

Phase 1 Bank Erosion Hazard Index (BEHI) Evaluation for 2010 (Post-Restoration)

Table A-2. Grave Creek Phase 1: Average post-restoration BEHI bank conditions and estimated erosion rates for 2010.

Bank No.	BEHI Adjective Rating	BEHI Numerical Rating	Bank Height (ft)	Bank Length (ft)	Estimated Erosion Rate[1] (ft/yr)	Estimated Bank Erosion (tons/yr)
1	Low	12.3	3.5	300	0.17	8.6
2	Low	19.6	3.5	160	0.17	4.6
3	High	33.6	3.5	50	0.31	2.6
4	Low	18.0	3.0	190	0.17	4.7
5	Moderate	22.6	2.8	170	0.23	5.3
6	Moderate	25.2	3.3	120	0.23	4.4
7	Very High	45.6	5.5	180	0.39	18.6
8	Low	19.5	3.5	210	0.17	6.0
9	Low	13.3	2.8	160	0.17	3.7
10	Low	15.8	3.2	150	0.17	4.3
11	Low	19.6	3.5	140	0.17	4.0
12	Moderate	25.1	3.7	175	0.23	7.2
13	Low	16.3	3.7	200	0.17	6.1
14	High	33.7	4.0	175	0.31	10.4
15	Low	19.2	3.0	110	0.17	2.7
16	Moderate	21.9	3.0	190	0.23	6.3
17	Low	13.5	3.0	120	0.17	3.0
18	High	34.8	3.0	215	0.31	9.6
19	Low	17.2	2.0	210	0.17	3.4
20	Moderate	27.5	3.7	240	0.23	9.8
21	Low	17.5	3.5	135	0.17	3.9
22	Moderate	22.0	3.0	145	0.23	4.8
23	Moderate	22.3	3.0	170	0.23	4.3
24	Low	14.1	3.6	75	0.17	2.2
25	Moderate	20.4	4.0	160	0.23	7.1
26	Low	13.1	3.0	80	0.17	2.0
27	Moderate	22.8	3.1	120	0.23	4.1
28	Low	19.2	2.8	305	0.17	7.0
29	Moderate	29.9	3.7	150	0.23	6.2
30	Moderate	27.5	4.0	140	0.23	6.2
31	High	34.6	5.0	85	0.31	6.3
32	Moderate	21.7	4.0	175	0.23	7.8
Total						187

Table A-3. Grave Creek Phase 1: Pre-restoration and post-restoration BEHI bank conditions and percent change.

Bank Condition	Average BEHI Adjective Rating	Average BEHI Numerical Rating	Average Bank Height (ft)	Cumulative BEHI Bank Length (ft)	Average Predicted Bank Erosion (ft/yr)	Predicted Bank Erosion (tons/yr)
Pre-Restoration	Moderate-High	30.8	3.5	5,180	0.28	275
Post-Restoration	Low-Moderate	22.5	3.4	5,205	0.22	187
Percent Change	One Category	-26.9	-2.9	0.5	-21.4	-32.0

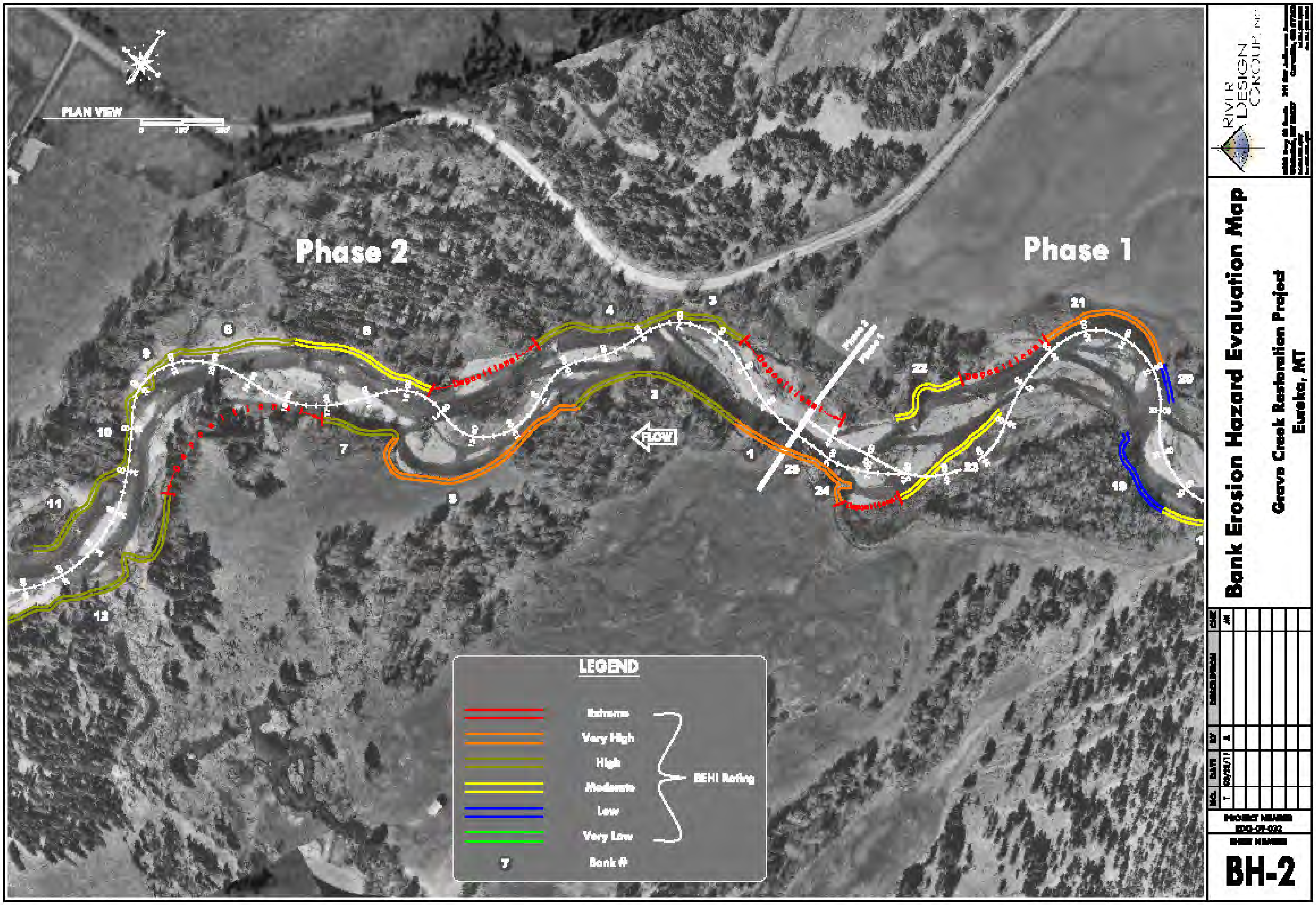

Figure A-5. Distribution of the bank erosion hazard in upper Phase 2 before restoration.

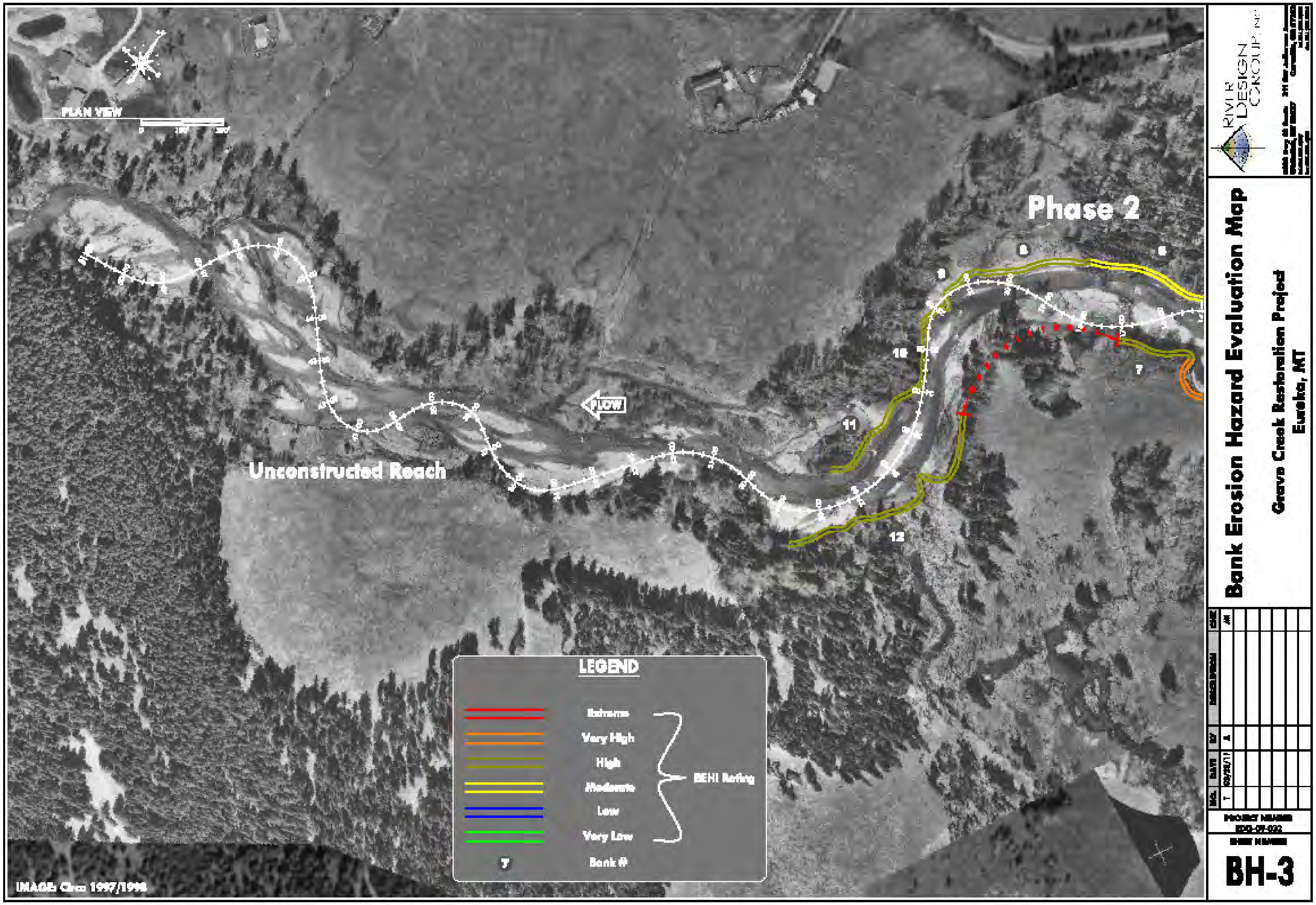

Figure A-6. Distribution of the bank erosion hazard in Lower Phase 2 before restoration.

Phase 2 Bank Erosion Hazard Index (BEHI) Estimation for 2001 (Pre-Restoration)

Table A-4. Grave Creek Phase 2: Average pre-restoration BEHI bank conditions and estimated erosion rates for 2001.[1]

Bank No.	BEHI Adjective Rating	BEHI Numerical Rating	Bank Height (ft)	Bank Length (ft)	Estimated Bank Erosion (ft/yr)	Estimated Bank Erosion (tons/yr)
1	Very High	41.4	5.0	125	0.39	11.7
2	High	35.4	4.5	450	0.31	30.2
3	High	38.9	4.8	200	0.31	14.3
4	High	38.5	5.3	300	0.31	23.7
5	Very High	41.2	4.7	400	0.39	35.3
6	Moderate	29.8	2.8	300	0.23	9.3
7	High	37.6	2.5	275	0.31	10.3
8	High	37.3	2.8	275	0.31	11.5
9	High	38.4	4.5	150	0.31	10.1
10	High	32.3	4.8	200	0.31	14.3
11	High	36.3	4.0	350	0.31	20.9
12	High	35.3	4.0	450	0.31	26.9
Total						219

[1]Predicted erosion rates based on Middle Blackfoot River measured erosion (MT DEQ 2007).

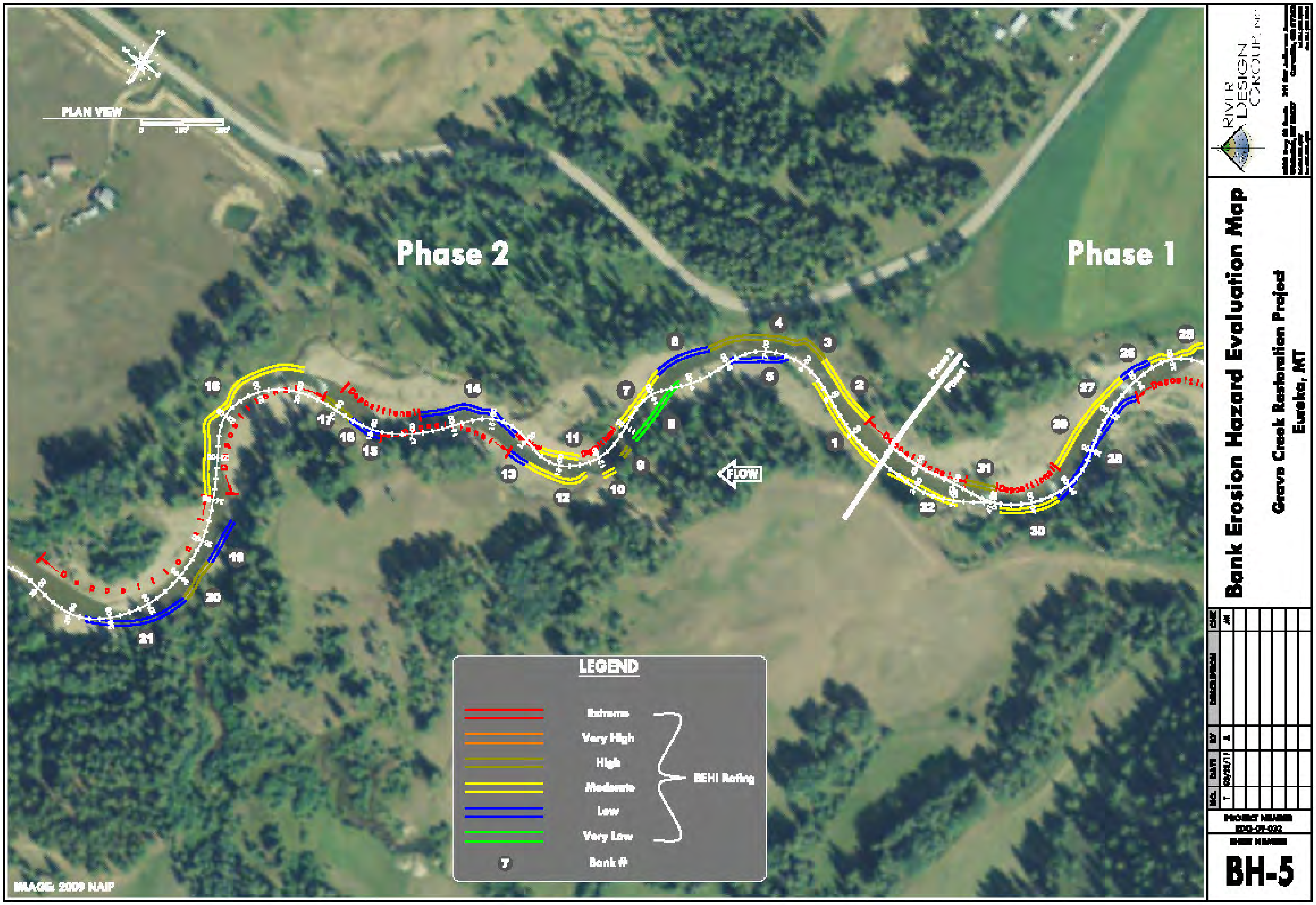

Figure A-7. Distribution of the bank erosion hazard in upper Phase 2 after restoration.

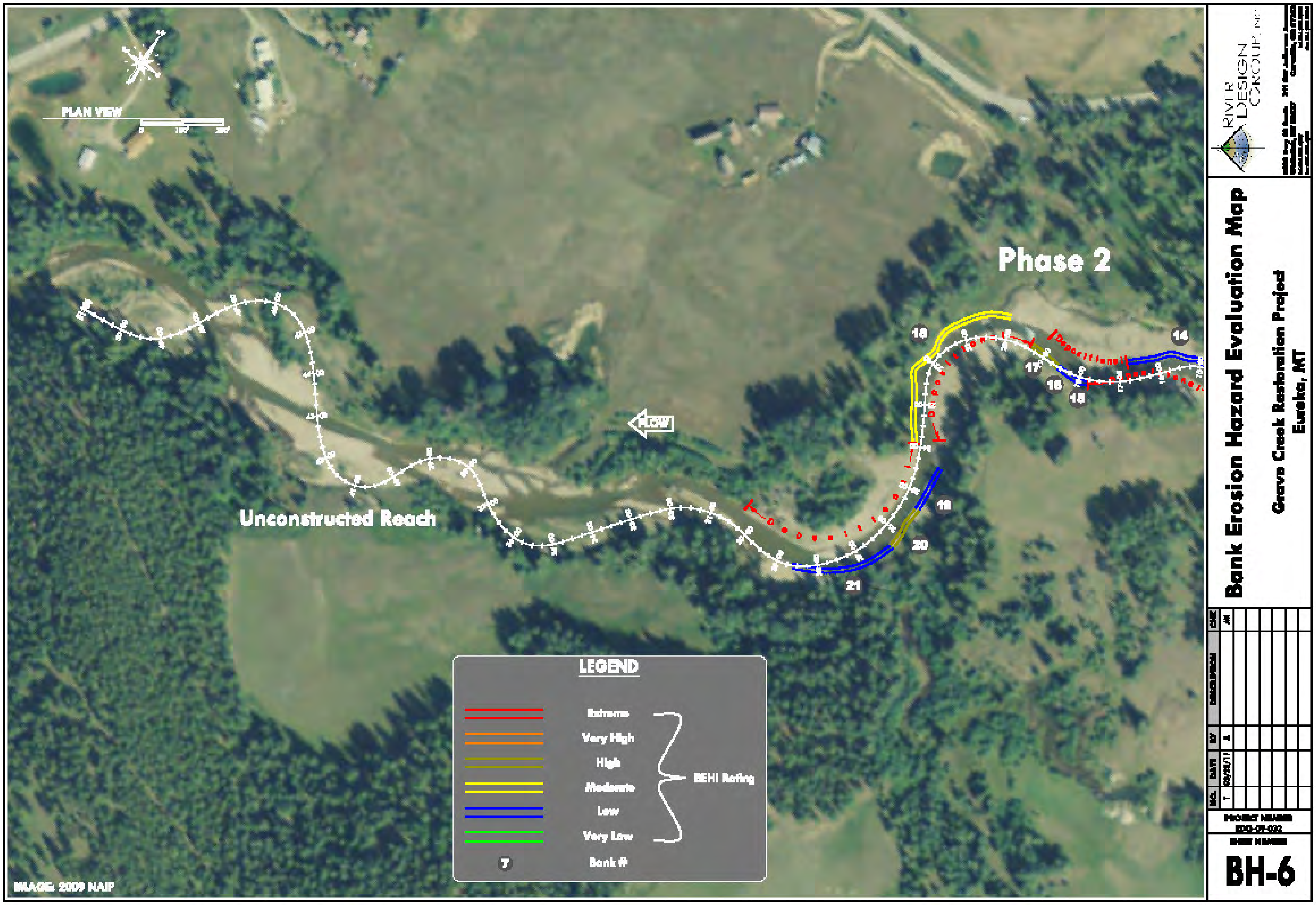

Figure A-8. Distribution of the bank erosion hazard in Lower Phase 2 after restoration.

Phase 2 Bank Erosion Hazard Index (BEHI) Estimation for 2010 (Post-Restoration)

Table A-5. Grave Creek Phase 2: Average post-restoration BEHI bank conditions and estimated erosion rates for 2010.

Bank No.	BEHI Adjective Rating	BEHI Numerical Rating	Bank Height (ft)	Bank Length (ft)	Estimated Erosion Rate[1] (ft/yr)	Estimated Bank Erosion (tons/yr)
1	Moderate	25.7	3.4	155	0.23	5.8
2	Moderate	21.9	2.5	175	0.23	4.9
3	High	30.6	3.3	25	0.31	1.2
4	High	38.5	5.0	140	0.31	10.5
5	Low	14.9	2.7	100	0.17	2.2
6	Low	13.8	4.5	155	0.17	5.7
7	Moderate	24.6	3.0	120	0.23	4.0
8	Very Low	10.0	2.7	150	0.10	2.0
9	High	35.9	3.5	20	0.31	1.0
10	Moderate	23.5	4.0	20	0.23	1.0
11	Moderate	28.8	3.4	175	0.23	6.6
12	Moderate	29.9	3.7	200	0.23	8.2
13	Low	19.1	3.8	30	0.17	1.0
14	Low	10.8	3.4	210	0.17	5.9
15	Low	13.9	3.0	45	0.17	1.1
16	Low	19.8	3.0	25	0.17	0.6
17	High	39.7	4.0	70	0.31	4.2
18	Moderate	23.1	4.0	125	0.23	5.5
19	Low	12.4	4.0	100	0.17	3.3
20	High	30.0	3.0	100	0.31	4.5
21	Low	10.5	3.5	240	0.17	6.9
Total						86.1

Table A-6. Grave Creek Phase 2: Pre-restoration and post-restoration BEHI bank conditions and percent change.

Bank Condition	Average BEHI Adjective Rating	Average BEHI Numerical Rating	Average Bank Height (ft)	Cumulative BEHI Bank Length (ft)	Average Predicted Bank Erosion (ft/yr)	Predicted Bank Erosion (tons/yr)
Pre-Restoration	High	36.9	4.1	3,475	0.32	219
Post-Restoration	Low-Moderate	22.7	3.5	2,380	0.22	86.1
Percent Change	One Category (+)	-38.5	-14.6	-31.5	-31.3	-60.7

APPENDIX B

GRAVE CREEK RESTORATION PROJECT
PHASE 1 AND 2

PHOTO POINTS

JULY 2010

Phase 1 (2001-2010)

Photo Point A

Figure B-1. Photo Point A; view upstream from the right bank in 2001 (left) and in 2010 (right) at station 5+00 ft.

Figure B-2. Photo Point A; view downstream from the right bank in 2001 (left) and in 2010 (right) at station 5+00 ft.

Photo Point B

Figure B-1. Photo Point B; view upstream from the left bank in 2001 (left) and in 2010 (right) at station 10+20 ft.

Figure B-2. Photo Point B; view downstream from the left bank in 2001 (left) and in 2010 (right) at station 10+20 ft.

Photo Point C

Figure B-3. Photo Point C; view upstream from the right bank in 2001 (left) and in 2010 (right) at station 14+50 ft.

Figure B-4. Photo Point C; view downstream from the right bank in 2001 (left) and in 2010 (right) at station 14+50 ft.

Photo Point D

Figure B-5. Photo Point D; view upstream from the left bank in 2001 (left) and in 2010 (right) at station 20+00 ft.

Figure B-6. Photo Point D; view downstream from the left bank in 2001 (left) and in 2010 (right) at station 20+00 ft.

Photo Point E

Figure B-7. Photo Point E; view upstream from the right bank in 2001 (left) and in 2010 (right) at station 25+00 ft.

Figure B-8. Photo Point E; view downstream from the right bank in 2001 (left) and in 2010 (right) at station 25+00 ft.

Photo Point F

Figure B-9. Photo Point F; view upstream from the left bank in 2001 (left) and in 2010 (right) at station 29+50 ft.

Figure B-10. Photo Point F; view downstream from the left bank in 2001 (left) and in 2010 (right) at station 29+50 ft.

Photo Point G


Figure B-13. Photo Point G; view upstream from the right bank in 2001 (left) and in 2010 (right) at station 34+40 ft.


Figure B-11. Photo Point G; view downstream from the right bank in 2001 (left) and in 2010 (right) at station 34+40 ft.

Photo Point H

Figure B-12. Photo Point H; view upstream from the left bank in 2001 (left) and in 2010 (right) at station 40+50 ft.

Phase 2 (2001-2010)

Photo Point A

Figure B-13. Photo Point A; view downstream from the right bank in 2004 (left) and in 2010 (right) at station 6+40 ft.

Photo Point B

Figure B-14. Photo Point B; view upstream from the right bank in 2004 (left) and in 2010 (right) at station 7+00 ft.

Photo Point C

Figure B-15. Photo Point C; view downstream from the right bank in 2004 (left) and in 2010 (right) at station 7+40 ft.

Photo Point D

Figure B-16. Photo Point D; view downstream from the right bank in 2004 (left) and in 2010 (right) at station 13+75 ft.

Photo Point E

Figure B-17. Photo Point E; view upstream from the left bank in 2004 (left) and in 2010 (right) at station 17+00ft.

Photo Point F

Figure B-18. Photo Point F; view upstream from the right bank in 2004 (left) and in 2010 (right) at station 19+75 ft.

Photo Point G

Figure B-19. Photo Point G; view downstream from the right bank in 2004 (left) and in 2010 (right) at station 20+35 ft.

Photo Point H

Figure B-20. Photo Point H; view downstream from the right bank in 2004 (left) and in 2010 (right) at station 24+75 ft.

Photo Point I

Figure B-21. Photo Point I; view upstream from the right bank in 2004 (left) and in 2010 (right) at station 25+55 ft.

APPENDIX C

GRAVE CREEK RESTORATION PROJECT
PHASE 1 AND 2

SURVEY DATA

JULY 2010

PHASE 1 SURVEY DATA

JULY 2010

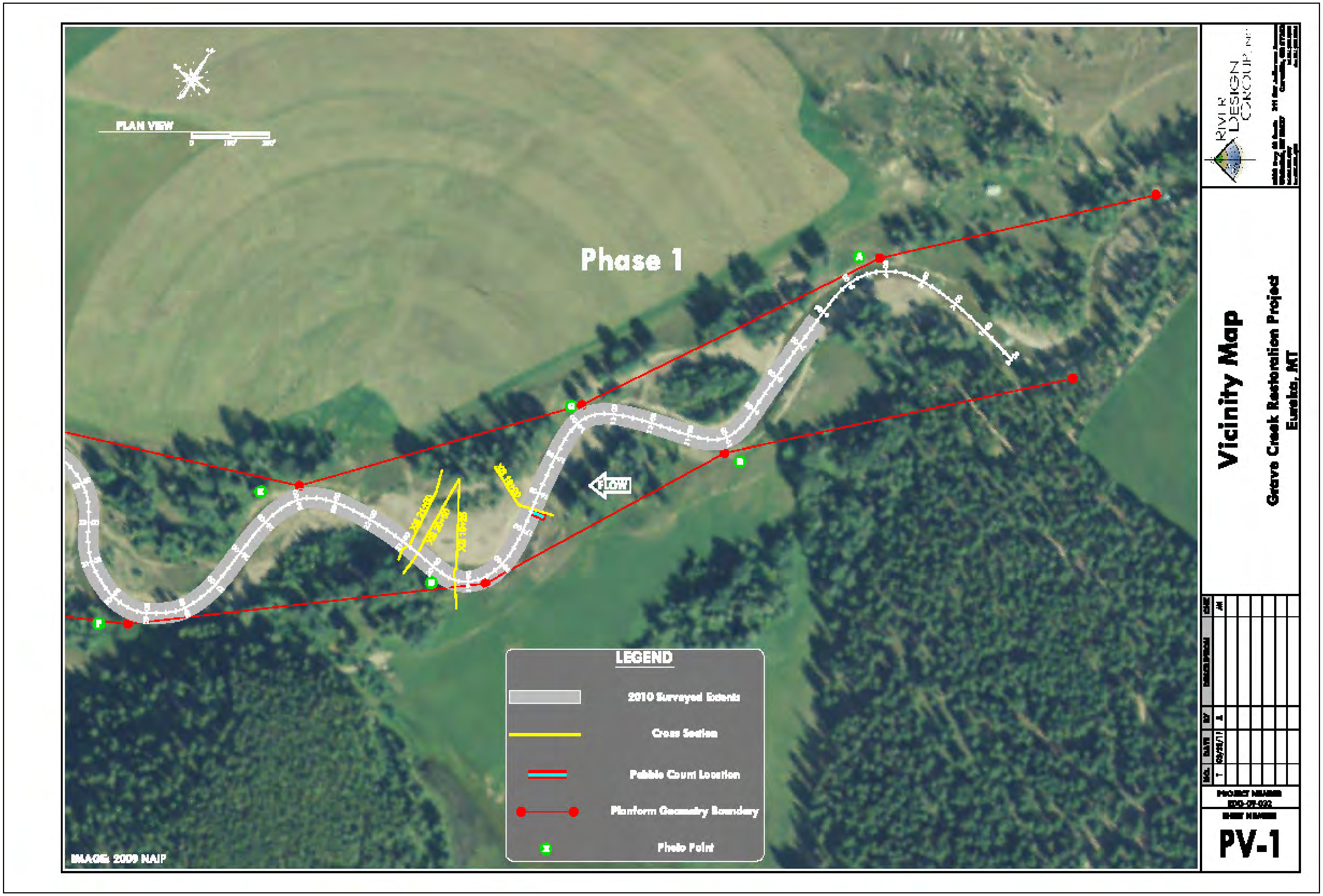

Figure C-1. Vicinity and sampling index map for upper Phase 1.

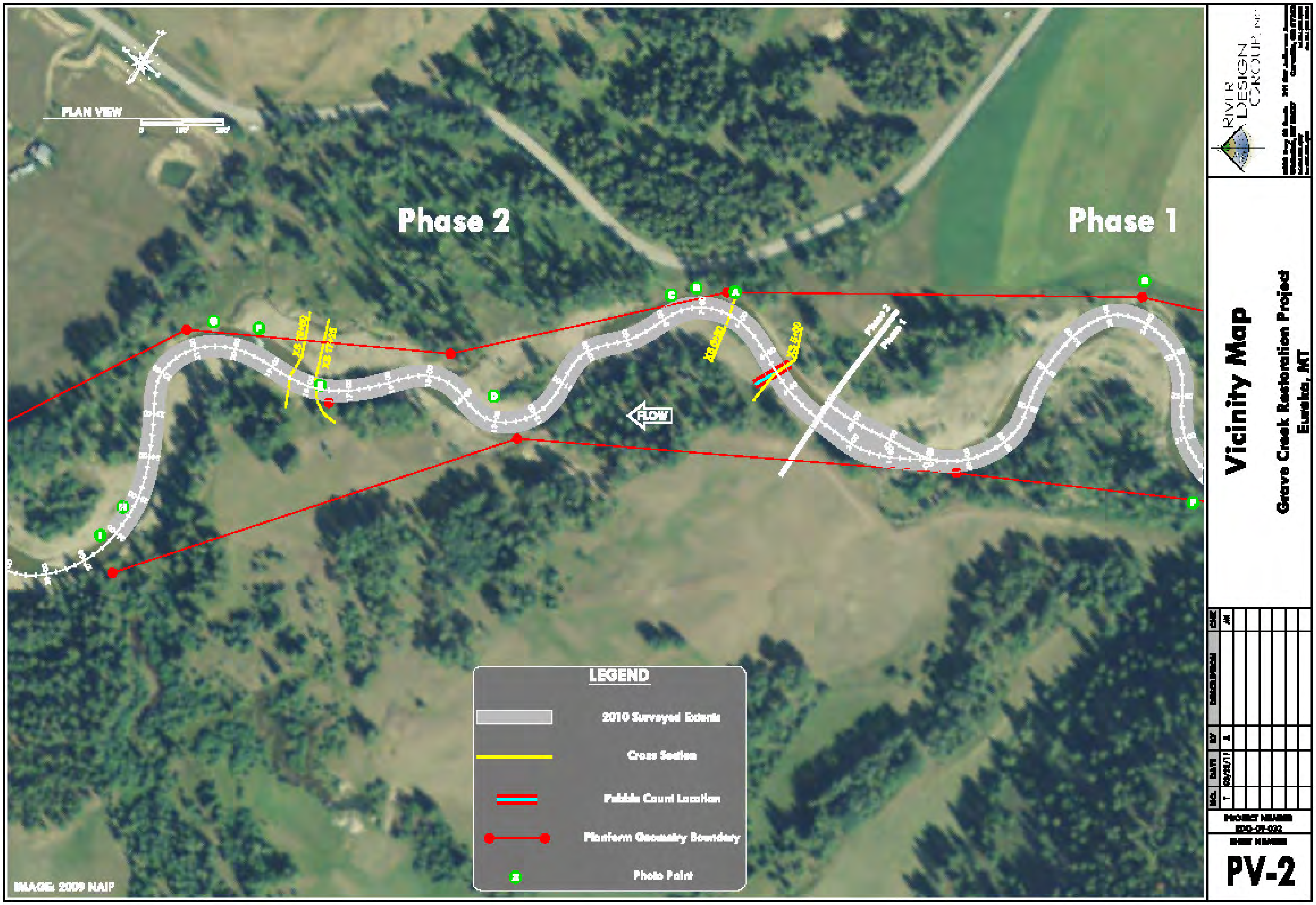

Figure C-2. Vicinity and sampling index map for lower Phase 1.

Survey Planview

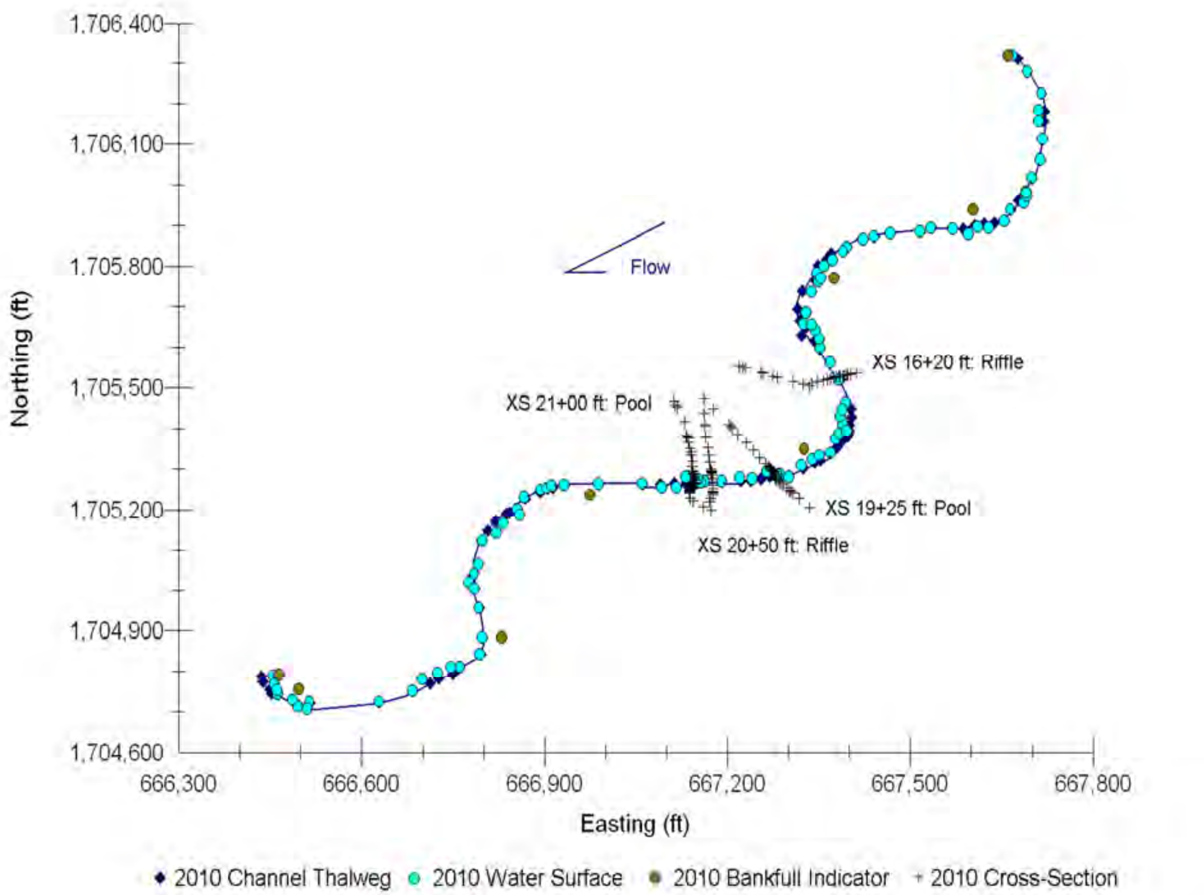

Figure C-3. Planview of surveyed points in the phase 1 project area.

Longitudinal Profile

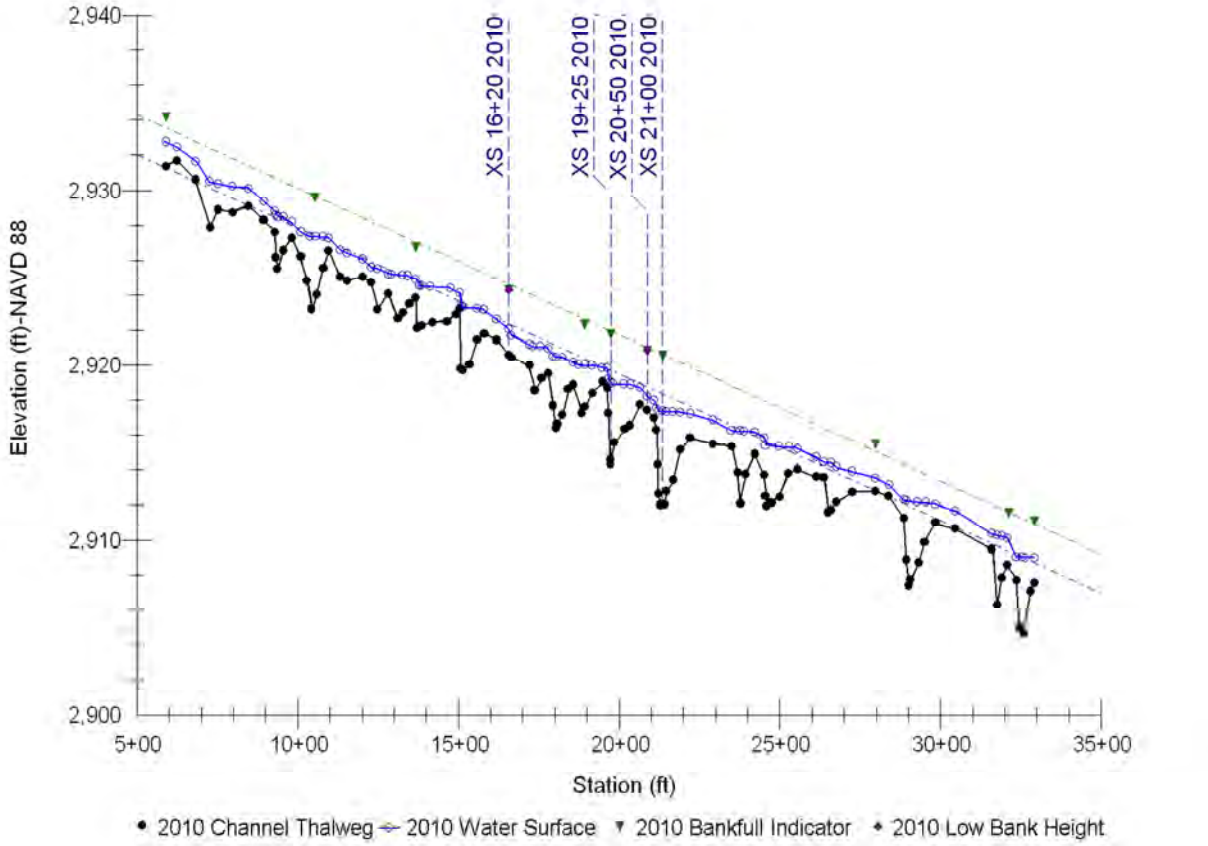

Figure C-4. Longitudinal profile of the Phase 1 project area.

Longitudinal Profile Dimensions

Table C-1. Longitudinal profile dimensions for Phase 1 (July 2010).

Metric	Minimum	Mean	Maximum
Bankfull Slope (ft/ft)		0.0084	
Water Surface Slope (ft/ft)		0.0084	
Riffle Slope (ft/ft)	0.0075	0.0109	0.0143
Pool Slope (ft/ft)	0.0004	0.0009	0.0013
Run Slope (ft/ft)	0.0025	0.0060	0.0100
Glide Slope (ft/ft)	0.0029	0.0040	0.0056
Pool - Pool (ft)	78.8	179	329
Pool Length (ft)	42.8	70.8	122
Riffle Length (ft)	51.4	111	177
Dmax Riffle (ft)	2.1	3.2	4.1
Dmax Pool (ft)	4.9	6.3	8.7
Dmax Run (ft)	4.2	4.9	5.7
Dmax Glide (ft)	3.6	4.1	5.4
Low Bank Ht (ft)	3.5	3.7	3.9

Figure C-5. Photos of Phase 1 in 2010.

Planform Geometry

Table C-2. Planform geometry summary table of Phase 1 (July 2010).

Meander Location (ft)	Meander Wave Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)
-1+00	760	230	150
4+05	880	340	188
10+10	820	240	125
13+75	700	260	163
18+75	740	340	125
23+90	900	290	188
29+10	640	400	188
34+30	720	430	138
Minimum	640	230	125
Mean	770	316	158
Maximum	900	430	188
Standard Deviation	90.1	73.9	27.5
Coefficient of Variance	0.12	0.23	0.17
Sinuosity	1.38		

Cross-Section Dimensions

Table C-2. Cross-section dimensions for riffle (n=2) and pool (n=2) cross-sections within Phase 1 (2010).

Metric	Minimum	Mean	Maximum
Floodprone Width (ft)	300	308	315
Riffle Area (Sq ft)	132	145	157
Max Riffle Depth (ft)	3.4	3.6	3.7
Mean Riffle Depth (ft)	1.9	2.3	2.8
Riffle Width (ft)	56.5	63.2	69.8
Entrenchment Ratio	4.3	4.9	5.6
Width/Depth Ratio	20.3	28.5	36.7
Pool Area (Sq ft)	203	220	237
Max Pool Depth (ft)	7.5	8.0	8.5
Mean Pool Depth (ft)	2.3	3.1	3.8
Pool Width (ft)	61.7	75.1	88.6

Riffle Cross-Sections: Station 16+20 ft. and 20+50 ft.

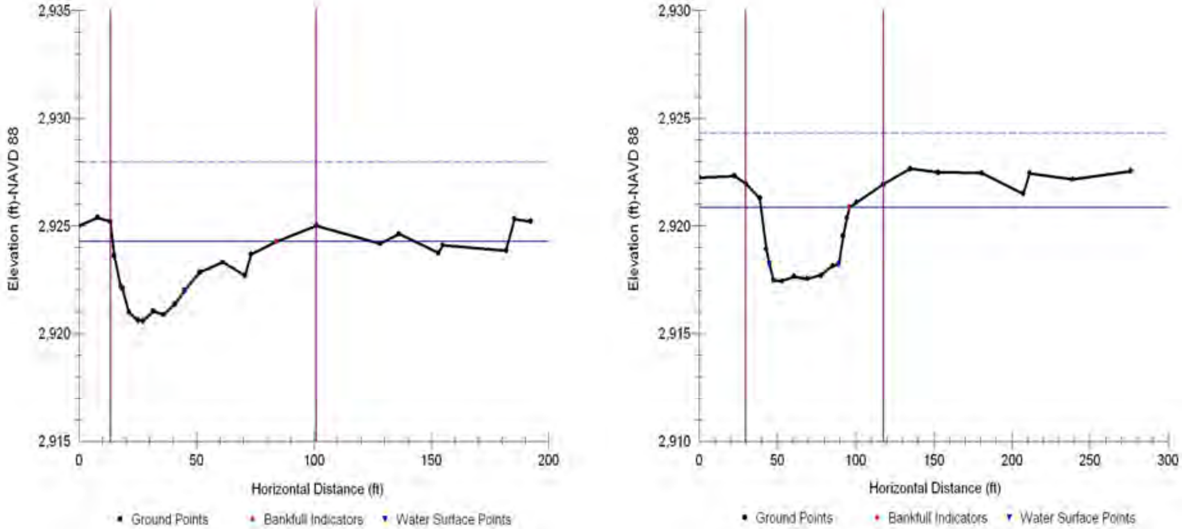

Figure C-6. Riffle cross-sections at station 16+20 ft. (left) and 20+50 ft. (right).

Table C-3. Riffle cross-section summary data at stations 16+20 ft and 20+50 ft.

Metric	Sta. 16+20 ft	Sta. 20+50 ft.
Floodprone Width (ft)	300	315
Bankfull Width (ft)	69.8	56.5
Entrenchment Ratio	4.3	5.6
Mean Depth (ft)	1.9	2.8
Maximum Depth (ft)	3.7	3.4
Width/Depth Ratio	36.7	20.3
Bankfull Area (sq ft)	132	157
Wetted Perimeter (ft)	71.0	57.8
Hydraulic Radius (ft)	1.9	2.7

Figure C-7. Photos of the riffle cross-sections at station 16+20 ft (left) and 20+50 ft (right).

Pool Cross-Sections: Station 19+25 ft. and 21+00 ft.

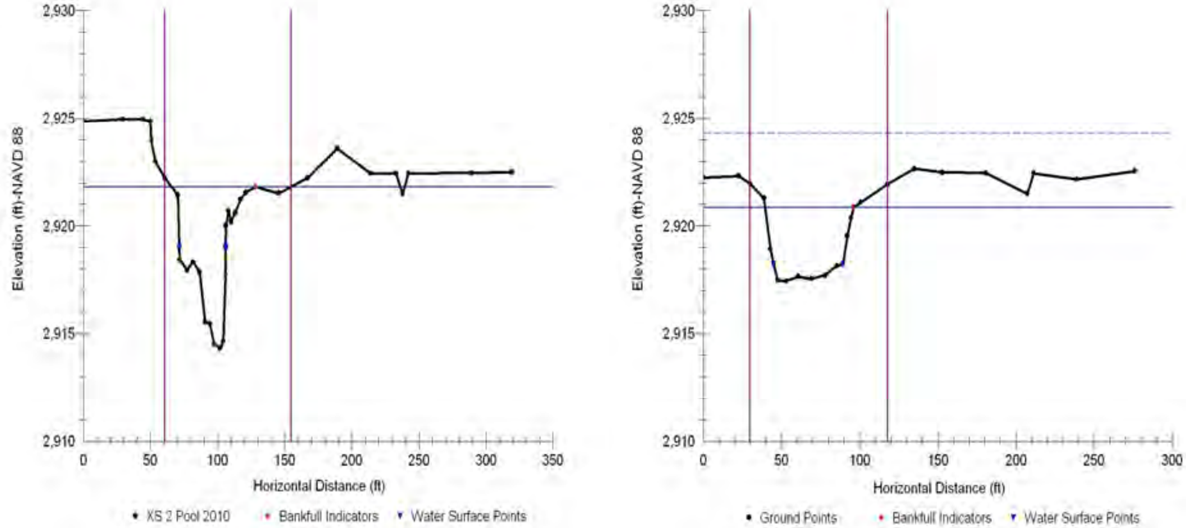

Figure C-8. Pool cross-sections at station 19+25 ft. (left) and 21+00 ft. (right).

Table C-4. Pool cross-section summary data at stations 19+25 ft. and 21+00 ft.

Metric	Sta. 19+25 ft.	Sta. 21+00 ft.
Floodprone Width (ft)	N/A	N/A
Bankfull Width (ft)	88.6	61.7
Entrenchment Ratio	N/A	N/A
Mean Depth (ft)	2.3	3.8
Maximum Depth (ft)	7.5	8.5
Width/Depth Ratio	38.7	16.1
Bankfull Area (sq ft)	203	237
Wetted Perimeter (ft)	95.6	68.6
Hydraulic Radius (ft)	2.1	3.5

Figure C-9. Photos of the pool cross-sections at station 19+25 ft. (left) and 21+00 ft. (right).

Substrate Particle Size Distribution

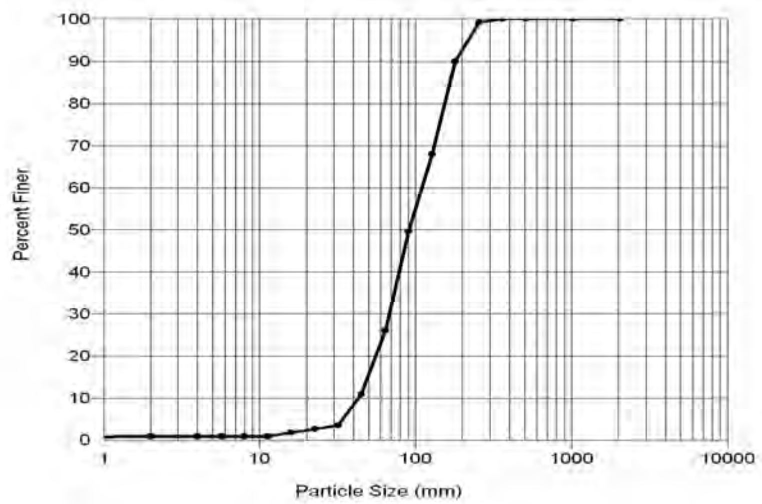

Figure C-10. Riffle substrate particle size distribution within Phase 1.

Table C-5. Riffle substrate particle size distribution within Phase 1.

Percentile	Millimeters	Inches
D_{16}	51	2.0
D_{35}	74	2.9
D_{50}	91	3.6
D_{84}	166	6.5
D_{95}	222	8.7
D_{100}	362	14.3

Large Woody Debris

Table C-6. Characterization of large wood found within Phase 2.

R1R4 Variable Outputs	Singles	Aggregates	Rootfans
Total Number (count)	66	24	36 / 144[1]
Number / 100 Meters	5.9	2.2	3.2 / 16.1[2]
Mean Diameter of Single Pieces (ft)	1.3		
Mean Length of Single Pieces (ft)	30.1		
Total Volume of Single Pieces (ft^3)	4,091		
Percent Submerged Volume of Single Pieces (%).	35		
Number of Pieces in Aggregates	347[3]		144

[1] Total number of rootwads occurring as singles / or in aggregates.
[2] Number of rootwads occurring as single pieces / or in aggregates, per 100 meters.
[3] Represents the number of single pieces identified in aggregates.

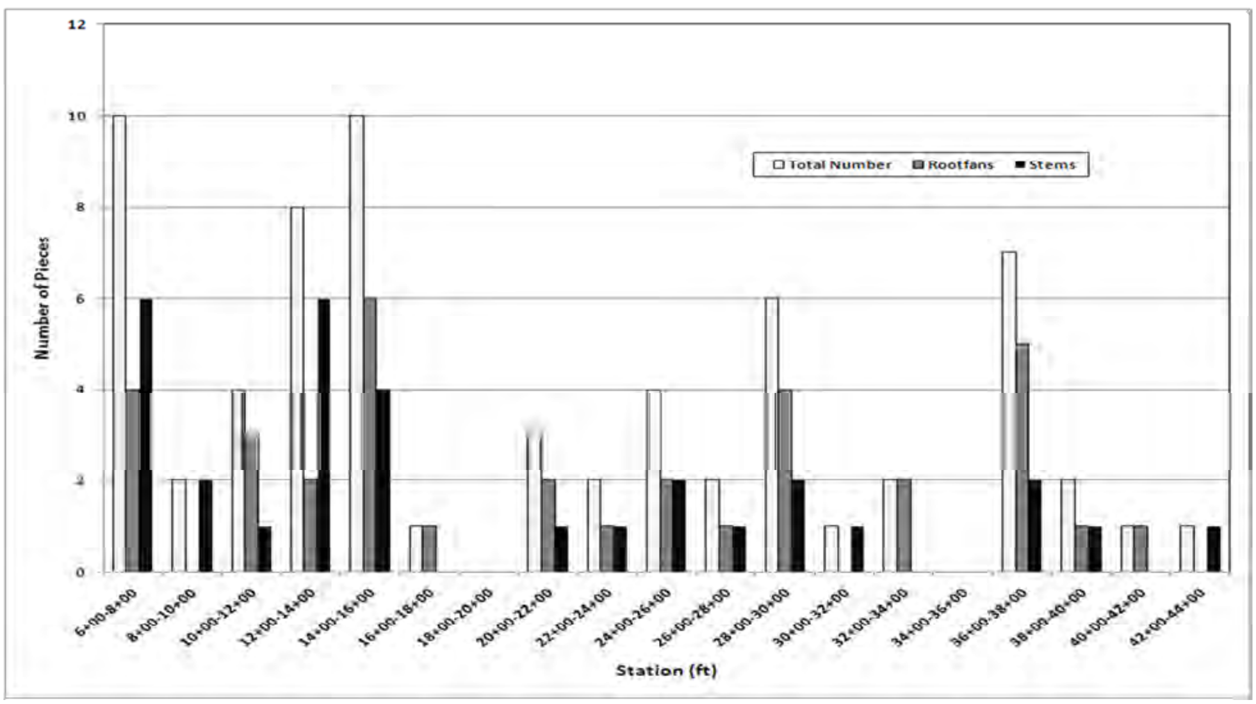

Figure C-11. Number of qualifying pieces identified as singles within Phase 1.

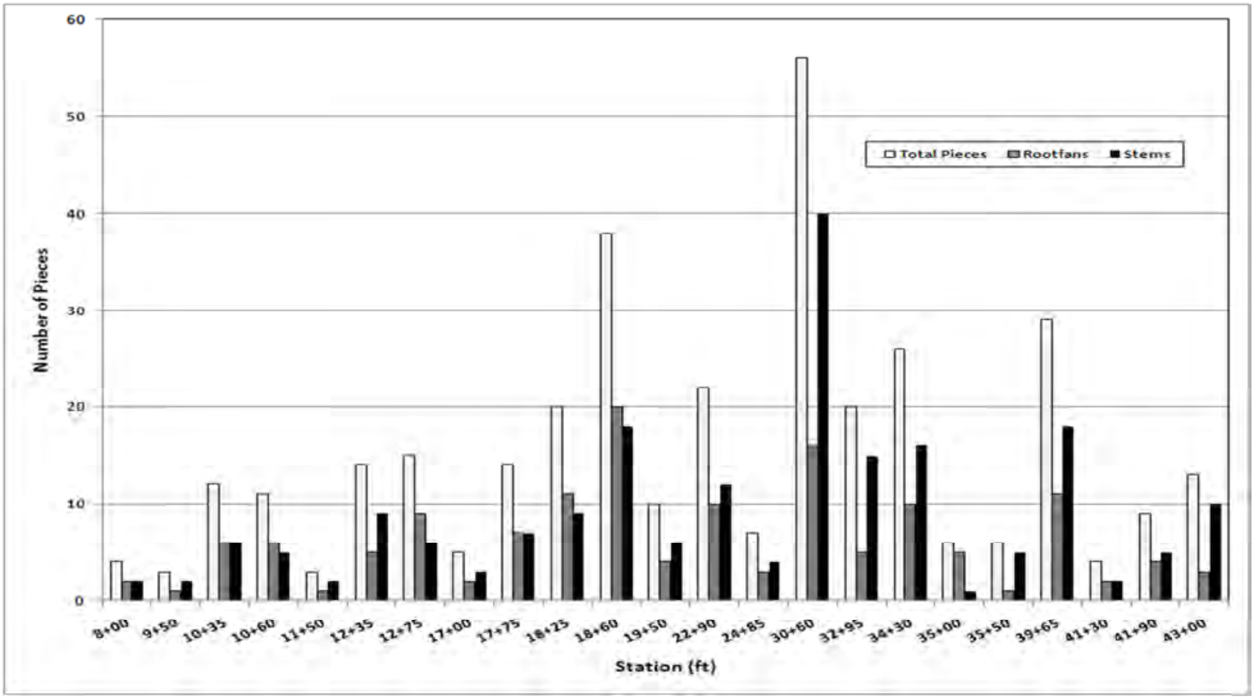

Figure C-12. Number of qualifying pieces identified in aggregates within Phase 1.

Aquatic Habitat

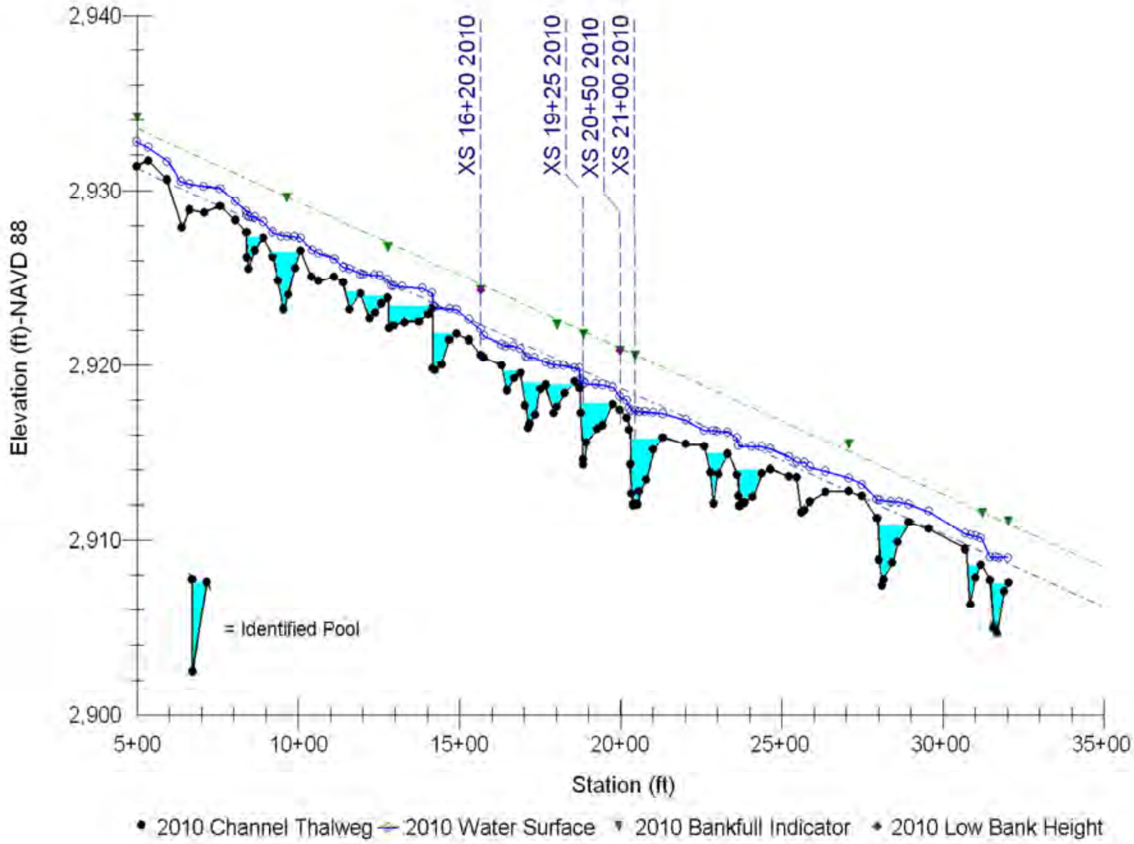

Figure C-3. Longitudinal profile identifying pool habitats in Phase 1.

Table C-5. Aquatic habitat summary data for Phase 1.

Reach ID	Number of Pools	Pool Frequency (ft)	Maximum Pool Depths (ft)	Discrete Residual Pool Volume (ft^3)	Cumulative Residual Pool Volume (ft^3)
Phase 1 2010	16	78.8-329 (179)	4.9-8.7 (6.3)	3,949-29,680 (14,353)	229,653

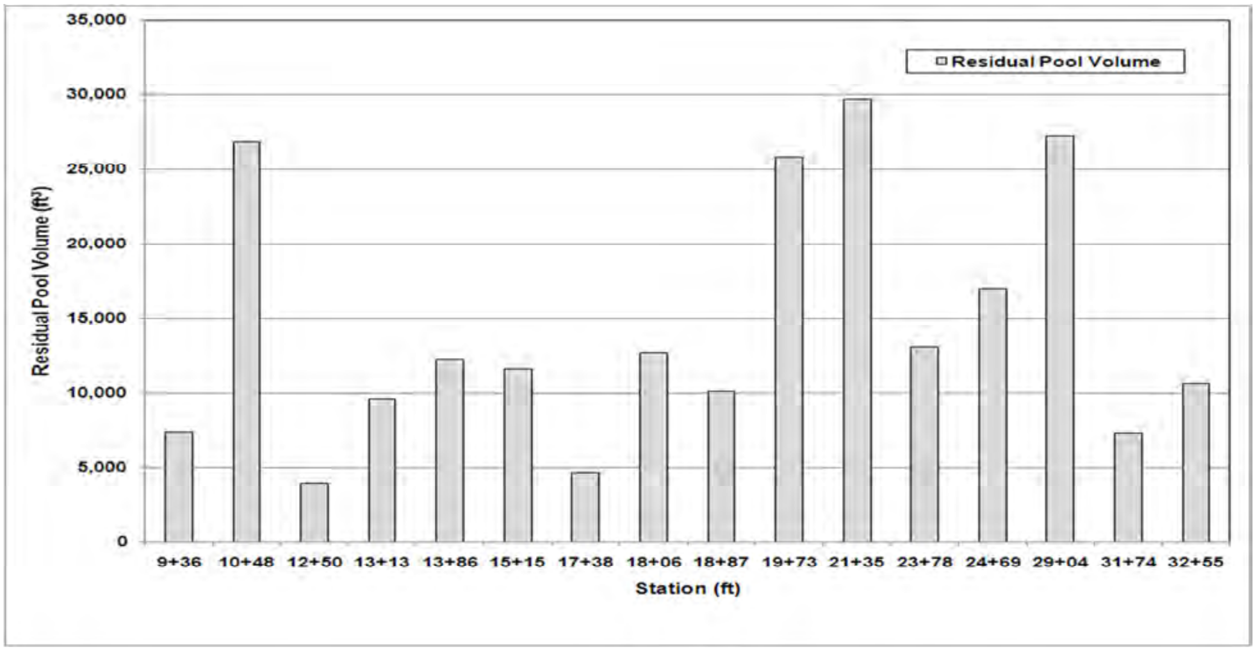

Figure C-14. Residual pool volume in discrete pools within Phase 1.

PHASE 2 SURVEY DATA

JULY 2010

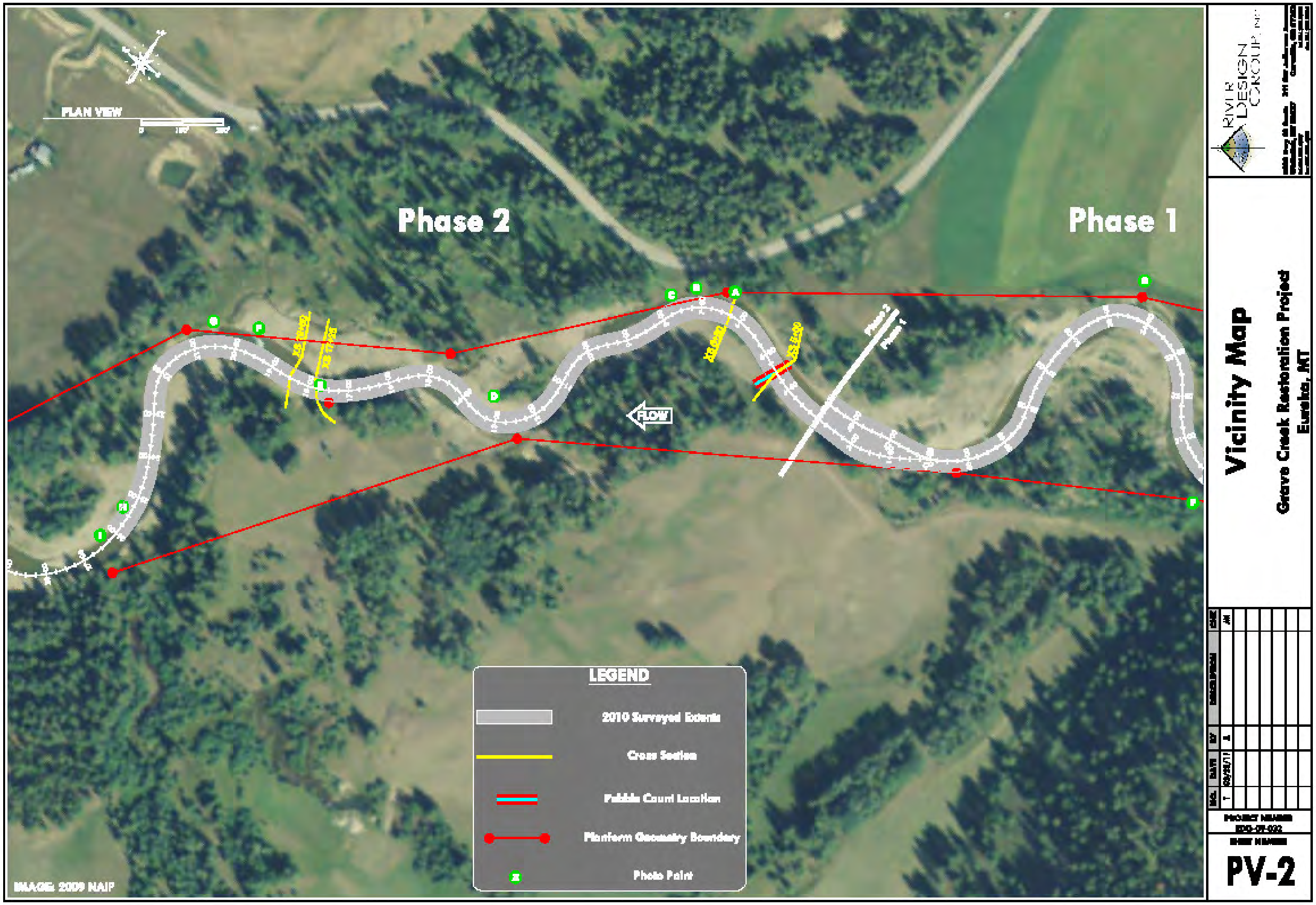

Figure C-15. Vicinity and sampling index map for upper Phase 2.

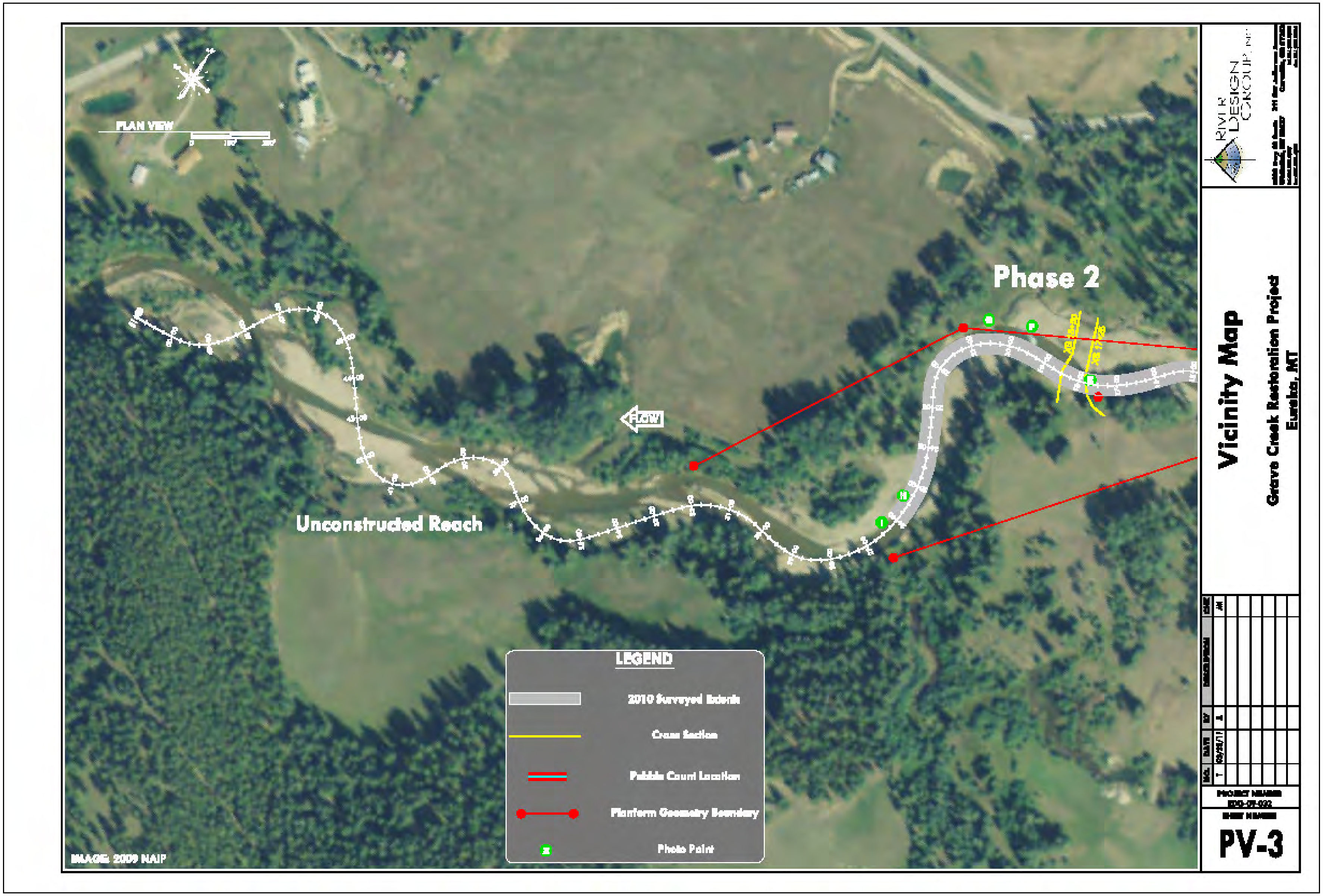

Figure C-4. Vicinity and sampling index map for lower Phase 2.

Survey Planview

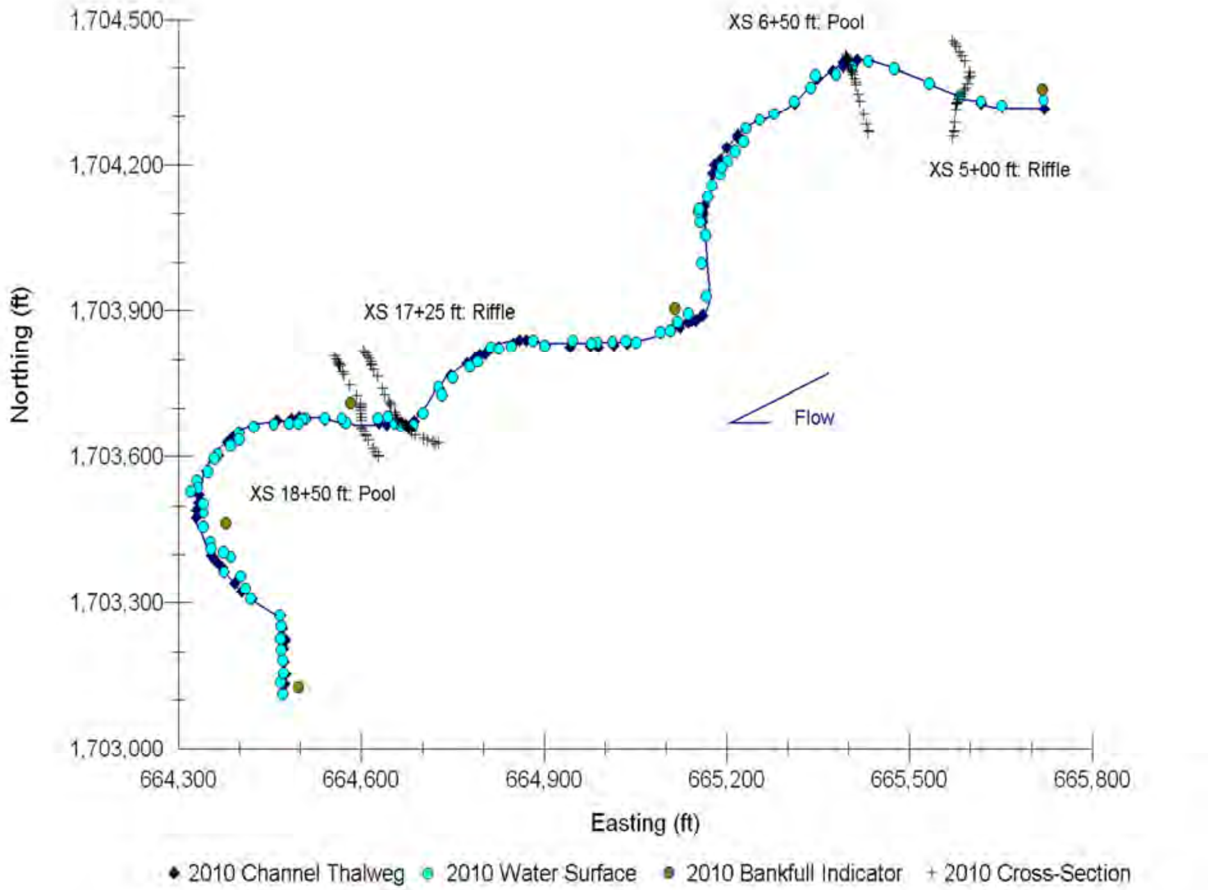

Figure C-17. Planview of surveyed points in the Phase 2 project area.

Longitudinal Profile

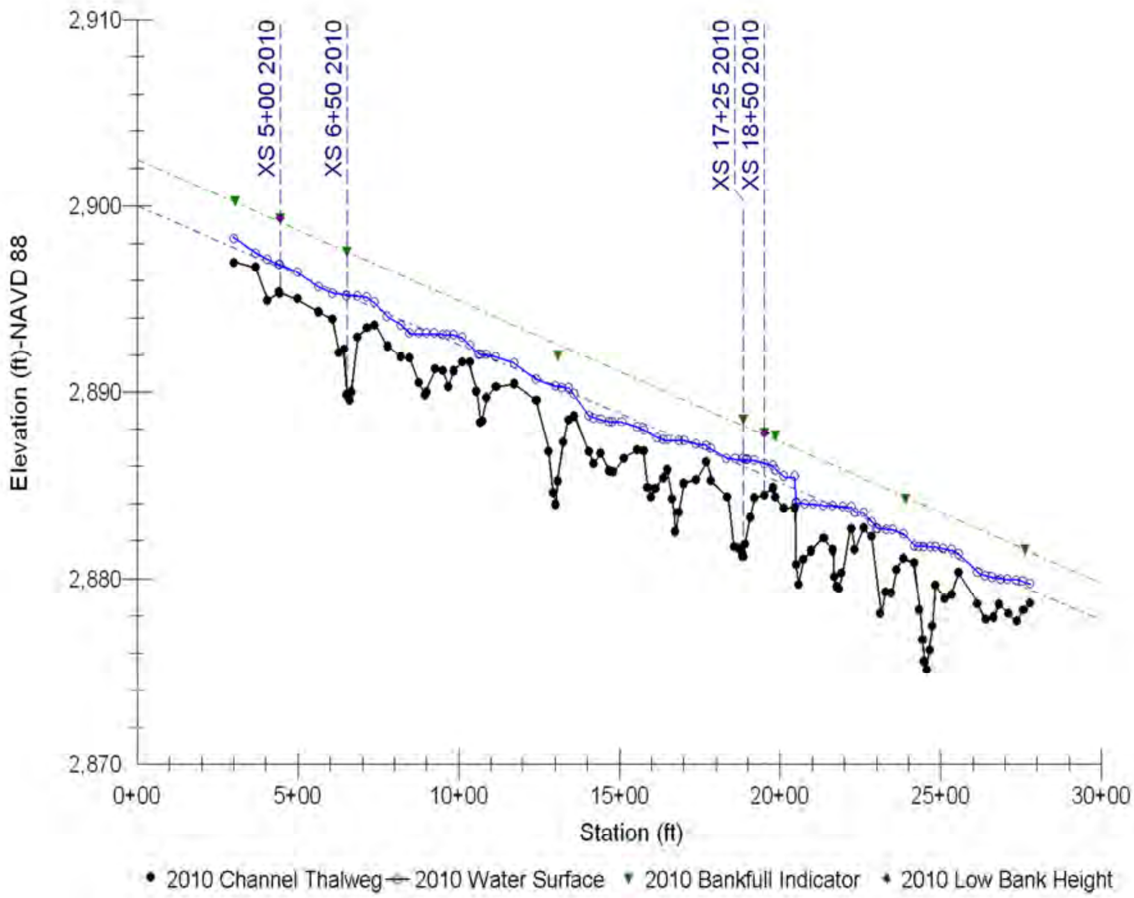

Figure C-18. Longitudinal profile of the Phase 2 project area.

Longitudinal Profile Dimensions

Table C-8. Longitudinal profile dimensions for Phase 2 (July 2010).

Metric	Minimum	Mean	Maximum
Bankfull Slope (ft/ft)		0.0076	
Water Surface Slope (ft/ft)		0.0074	
Riffle Slope (ft/ft)	0.0091	0.0121	0.0154
Pool Slope (ft/ft)	0.0005	0.0008	0.0016
Run Slope (ft/ft)	0.0032	0.0058	0.0071
Glide Slope (ft/ft)	0.0030	0.0041	0.0064
Pool - Pool (ft)	141	208	279
Pool Length (ft)	77.4	117	169
Riffle Length (ft)	49.2	104	302
Dmax Riffle (ft)	2.9	3.4	3.9
Dmax Pool (ft)	4.3	6.9	8.9
Dmax Run (ft)	3.9	5.2	6.0
Dmax Glide (ft)	3.4	4.0	5.1
Low Bank Ht (ft)	3.4	3.6	4.1

Figure C-5. Photos of Phase 2 in 2010.

Planform Geometry

Table C-9. Planform geometry summary table for Phase 2(July 2010).

Meander Location (ft)	Meander Wave Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)
6+50	1040	370	200
12+50	680	240	125
14+70	460	160	125
17+00	540	160	237
21+00	700	360	150
26+50	760	400	240
Minimum	460	160	125
Mean	697	282	180
Maximum	1040	400	240
Standard Deviation	201	109	53
Coefficient of Variance	0.29	0.39	0.30
Sinuosity	1.18		

Cross-Section Dimensions

Table C-6. Cross-section dimensions for riffle (n=2) and pool (n=2) cross-sections in Phase 2 (July 2010).

Metric	Minimum	Mean	Maximum
Floodprone Width (ft)	230	240	250
Riffle Area (Sq ft)	120	141	162
Max Riffle Depth (ft)	3.3	3.7	4.0
Mean Riffle Depth (ft)	2.3	2.5	2.7
Riffle Width (ft)	52.1	56.2	60.3
Entrenchment Ratio	3.8	4.3	4.8
Width/Depth Ratio	22.5	22.6	22.6
Pool Area (Sq ft)	229	248	267
Max Pool Depth (ft)	7.4	8.0	8.6
Mean Pool Depth (ft)	3.3	3.8	4.2
Pool Width (ft)	54.5	67.7	80.8

Riffle Cross-Sections: Station 5+00 ft: and 18+50 ft.

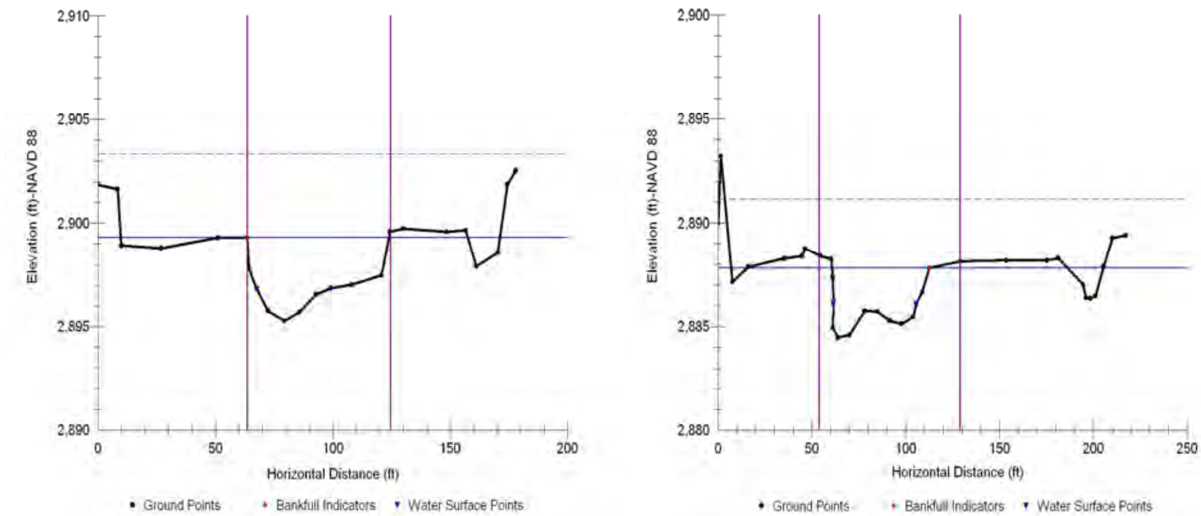

Figure C-6. Riffle cross-sections at station 5+00 ft. (left) and 18+50 ft. (right).

Table C-11. Riffle cross-section summary data for station 5+00 ft and 18+50 ft.

Metric	Sta. 5+00 ft	Sta. 18+50 ft.
Floodprone Width (ft)	230	250
Bankfull Width (ft)	60.3	52.1
Entrenchment Ratio	3.8	4.8
Mean Depth (ft)	2.7	2.3
Maximum Depth (ft)	4.0	3.3
Width/Depth Ratio	22.5	22.6
Bankfull Area (sq ft)	162	120
Wetted Perimeter (ft)	62.1	55.2
Hydraulic Radius (ft)	2.6	2.2

Figure C-7. Photos of the riffle cross-sections at station 5+00 ft. (left) and 18+50 ft. (right).

Pool Cross-Sections: Station 6+50 ft. and 17+25 ft.

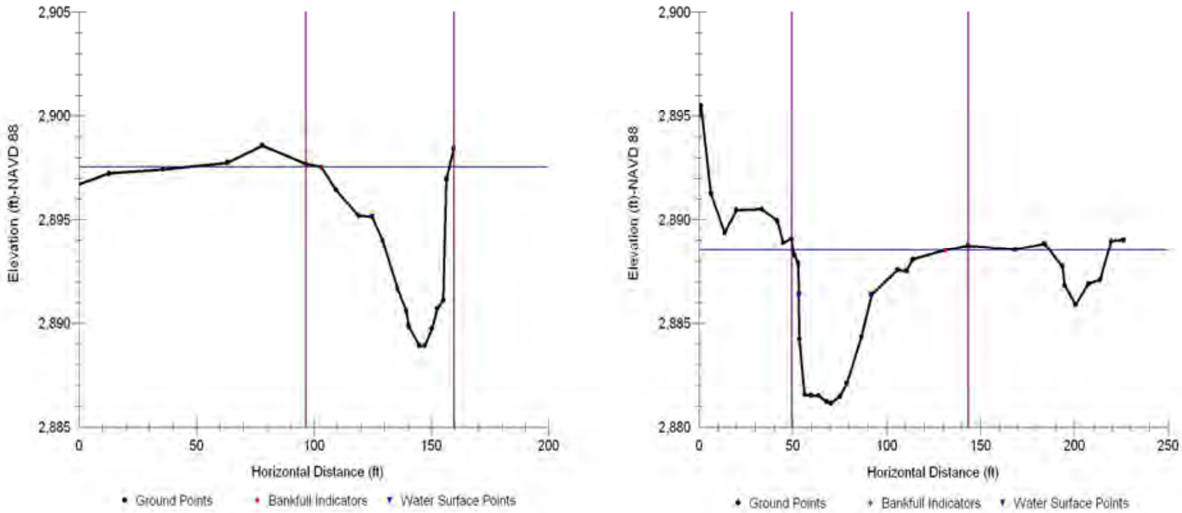

Figure C-8. Pool cross-sections at station 6+50 ft. (left) and 17+25 ft. (right).

Table C-12. Pool cross-section summary data at stations 6+50 ft and 17+25 ft.

Metric	Sta. 6+50 ft	Sta. 17+25 ft.
Floodprone Width (ft)	N/A	N/A
Bankfull Width (ft)	54.5	80.8
Entrenchment Ratio	N/A	N/A
Mean Depth (ft)	4.2	3.3
Maximum Depth (ft)	8.6	7.4
Width/Depth Ratio	13.0	24.5
Bankfull Area (sq ft)	229	267
Wetted Perimeter (ft)	60.9	85.9
Hydraulic Radius (ft)	3.8	3.1

Figure C-23. Photos of the pool cross-sections at station 6+50 ft. (left) and 17+25 ft. (right).

Substrate Particle Size Distribution

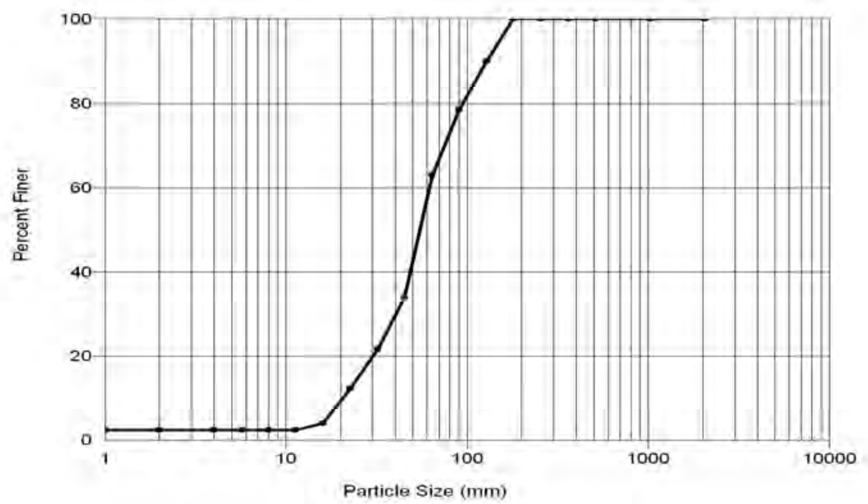

Figure C-9. Riffle substrate particle size distribution within Phase 2.

Table C-7. Riffle substrate particle size distribution within Phase 2.

Percentile	Millimeters	Inches
D_{16}	26	1.0
D_{35}	46	1.8
D_{50}	56	2.2
D_{84}	108	4.3
D_{95}	154	6.1
D_{100}	180	7.1

Large Woody Debris

Table C-14. Characterization of large wood found within Phase 2.

R1R4 Variable Outputs	Singles	Aggregates	Rootfans
Total Number (count)	33	24	15 / 167[1]
Number / 100 Meters	4.3	3.1	1.9 / 21.6[2]
Mean Diameter of Single Pieces (ft)	1.2		
Mean Length of Single Pieces (ft)	33.4		
Total Volume of Single Pieces (ft^3)	1,902		
Percent Submerged Volume of Single Pieces (%).	23		
Number of Pieces in Aggregates	413[3]		167

[1] Total number of rootwads occurring as singles / or in aggregates.
[2] Number of rootwads occurring as single pieces / or in aggregates, per 100 meters.
[3] Represents the number of single pieces identified in aggregates.

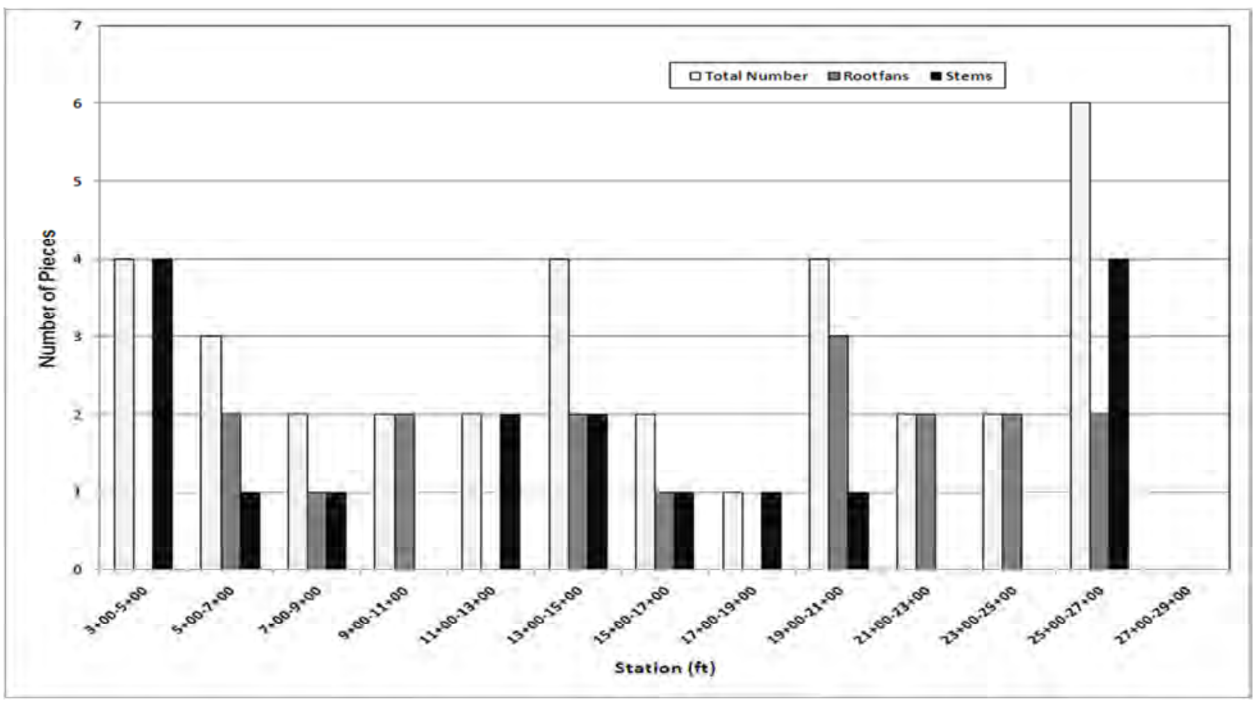

Figure C-10. Number of qualifying pieces identified as singles within Phase 1.

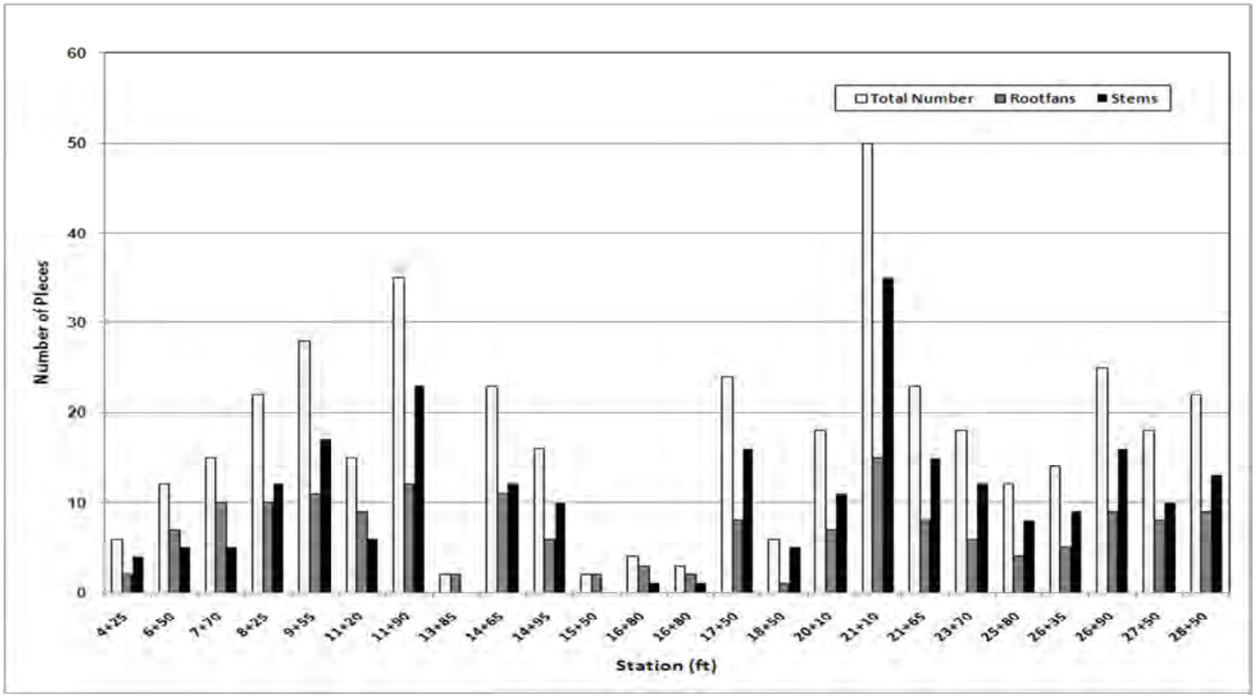

Figure C-11. Number of qualifying pieces identified in aggregates within Phase 1.

Aquatic Habitat

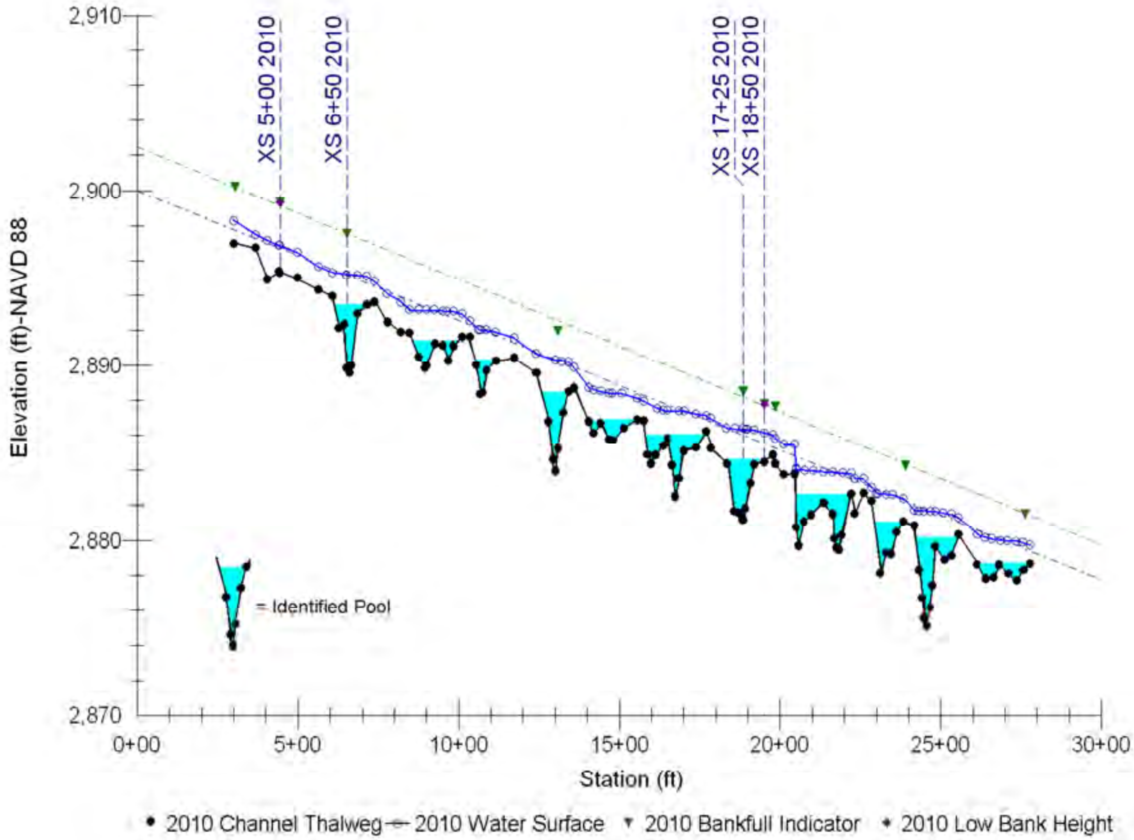

Figure C-12. Longitudinal profile identifying pool habitats in Phase 2.

Table C-8. Aquatic habitat summary data for Phase 2.

Reach ID	Number of Pools	Pool Frequency (ft)	Maximum Pool Depths (ft)	Discrete Residual Pool Volume (ft^3)	Cumulative Residual Pool Volume (ft^3)
Phase 2 2010	13	141-279 (208)	4.3-8.9 (6.9)	8,247-52,540 (22,877)	274,519

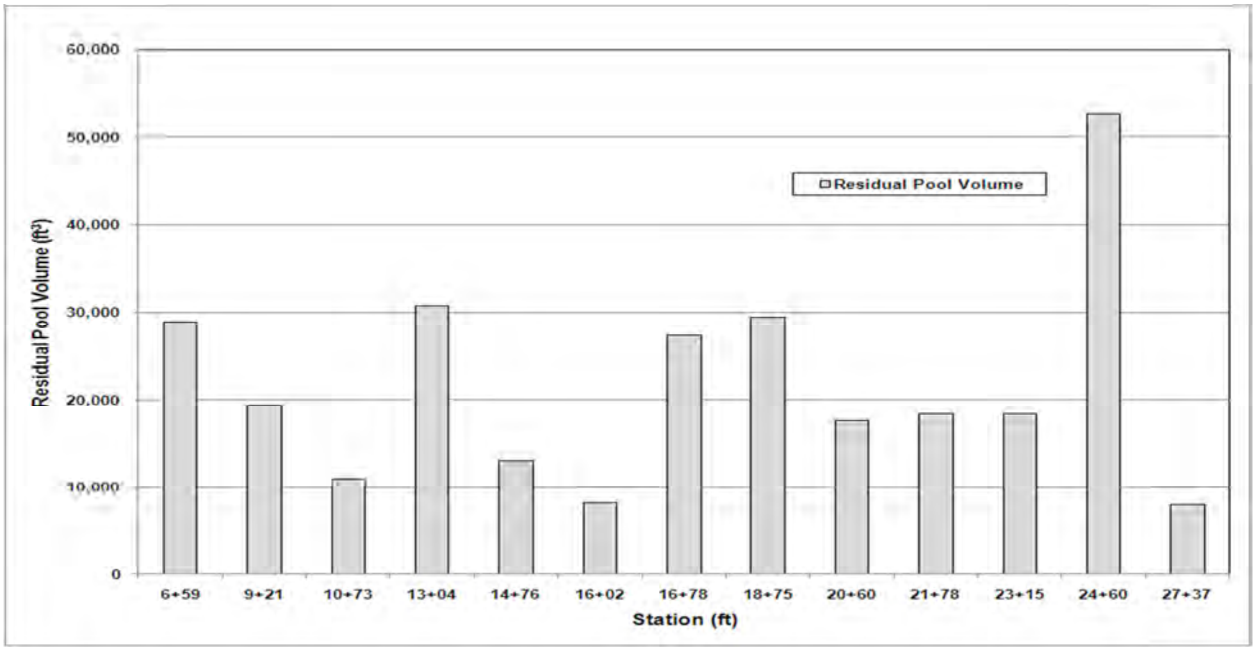

Figure C-28. Residual pool volume in discrete pools within Phase 2.

APPENDIX D

GRAVE CREEK RESTORATION PROJECT
PHASE 1 AND 2

VEGETATION DATA

JULY 2010

Table D-1. Point Bar 13 Transect 1 Monitoring Results 2007

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
Point Bar 13 Transect 1 Direction: 302 degrees	**Metric**																
	LWD # <4	0	0	0	0	0	0	0	0	1	0	0	0	0			
	LWD # >4	0	0	0	0	6	1	3	4	0	0	0	0	0			
	LWD Percent	<1	<1	<1	0	30	5	20	40	5	0	0	0	<1			
	Percent cover weeds	0	<1	<1	0	0	<1	1	10	5	<1	<1	0	0			
	Percent cover grasses and forbs	0	0	<1	1	<1	<1	<1	5	1	0	<1	0	0			
	Number of shrubs/trees	0	0	0	0	10+	50+	20+	5+	50+	50+	50+	<5	0			
	Substrate	< 0.5 with some 00.5 - 2	<00.5 with some 00.5 - 2, silt loam with some organic matter	<2 with some 2-4, silt loam with OM	2-6 with pathches of FD sand		4-6 with patches of FD sand and some >2	4-6 with some 6-8	OM and sand	2-4 with some <2 and sand patches	2-4 with patches of sand	4-6 with patches of sand	2-4 with some 4-6 and sand below	2-4 with some 4-6 and sand below			
	Deposition type and percent	leaves 75	leaves 1		leaves 15		leaves 5	leaves 20	sand 30	sand 10	sand 1	sand 5	OM <1	OM <1			
					OM <1		sand 5	sand 5	OM 5	OM 1	leaves 4	leaves 1	sand <1	sand <1			
									leaves 15	leaves 1							
	Other Notes	Leaf deposition from mature cottonwood directly above transect.		OM = organic matter	FD = flood deposited	Shrubs from 40-end are tiny cottonwood seedlings unless otherwise noted.			Swale								

Table D-2. Point Bar 4 Transect 1 Monitoring Results 2007

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
	Metric																
Point Bar 4 Transect 1 Direction: 68 degrees to 1st T post left of wooden gate post	**LWD # <4**	1	0	0	0	0	3	0	0	0	0						
	LWD # >4	6	1	4	1	6	0	5	0	5	0						
	LWD Percent	40	15	15	20	40	30	50	0	75	20						
	Percent cover weeds	10	20	1	1	1	1	1	1	0	<1						
	Percent cover grasses and forbs	40	5	5	1	<1	<1	<1	0	<1	<1						
	Number of shrubs/trees	0	0	2	0	0	0	0	0	0	0						
	Substrate	OM with some 6-10	1-4 with sand and OM underneath	1-4 with silt loam	1-6 with sand below	1-6 with few 10, sand underneath	1-6 with sand underneath	1-6 with some 10	1-6 with some 10, sandy beneath	1-6 with sand	0.25-2 with some 4-6						
	Deposition type and percent	leaves 10	leaves 20	leaves 30	leaves 10	leaves 5	leaves 20	leaves 10	leaves 1	leaves 70	OM 5						
		OM 2						OM 1		fine sediment 30							
	Other Notes							Swale is located at 73-91 feet; fine sand and OM deposited at streamside edge of swale; fine sediment includes small wood and other organics				100 feet and beyond is under ice					

Table D-3. Point Bar 13 Transect 1 Monitoring Results 2008

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
	Metric																
	LWD # <4	0	0	0	0	1	1	1	1	2	0	0	0	0			
	LWD # >4	0	0	0	0	5	2	3	5	0	0	0	0	0			
	LWD Percent	<1	<1	<1	0	30	10	20	40	5	<1	<1	0	0			
	Percent cover weeds	<1	1	<1	1	1	<1	5	10	5	<1	<1	0	0			
	Percent cover grasses and forbs	1	5	1	5	1	<1	5	20	5	<1	1	<1	<1			
Point Bar 13 Transect 1 Direction: 302 degrees	**Number of shrubs/trees**	3/2	0/4	0/0	1/>20	0/>50	0/>100	0/>100	0/>20	0/>200	0/>200	0/>100	0/0	0/>50			
	Substrate	<0.5, some 0.5-2	<0.5 and 0.5-2 w/some OM	<0.5-2, silt	2-4, some 4-6, few 8	2-6, sand	4-6, sand, some 2-4	4-6, some 8, sand	sand	2-4, sand	2-4, some 4-6, sand	2-4, some 4-6, few 8	2-4,4-6, some 8	2-4 some 4-6, sand			
	Deposition type and percent	leaves 20		leaves <1	leaves 20	leaves 1	sand 1	sand 5	sand 90	OM 10		OM<1					
					sand 10	OM<1			om10	leaves1		sand 1					
	Other Notes	All trees are cottonwood, if more than 5 seedlings were present they were put in categories of >5,>10,>20, etc.															
		Swale at 70 to 77 feet															
		Cottonwood recruits stop at 105' then start again at 120 feet															
		Water's edge at 128 feet															
		OM is organic matter															

Table D-4. Point Bar 4 Transect 1 Monitoring Results 2008

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
	Metric																
Point Bar 4 Transect 1 Direction: 68 degrees	**LWD # <4**	8	4	6	1	3	3	3	3	4	0	0	0	0	0	0	0
	LWD # >4	4	3	4	1	6	0	5	5	2	0	0	0	3	0	0	0
	LWD Percent	40	10	20	5	40	30	50	50	30	20	0	0	20	0	0	0
	Percent cover weeds	10	20	30	20	1	1	1	1	1	<1	<1	0	0	0	0	0
	Percent cover grasses and forbs	50	15	20	5	1	1	5	1	1	1	<1	0	0	0	0	0
	Number of shrubs/trees	1/0	0/0	3/0	0/0	0/0	1/0	0/8	4/4	5/4	1/4	0/<20	0/0	0/0	0/0	0/0	0/0
	Substrate	OM, 6-10	1-4, sand	1-4	1-6, sand	1-6, few 10, sand	1-6 few 8, sand	1-6 some 10, sand	1-4	1-6, silt-loam	0.5-2, some 4-6, sand	0.25-6, silt	0.25-6, some10	0.25-2, some4-6, silt	1-6, some 10, sand	1-6, some 10, sand	1-6, some 10
	Deposition type and percent	leaves 30	leaves 5	leaves 20	leaves 20	leaves 5	leaves 10	leaves 10	leaves 10	leaves 10	OM 10			OM<1		leaves <1	
		OM 20						OM 1	OM 10	OM 20							
	Other Notes	Weeds include toadflax, knapweed, oxeye daisy, houndstounge.															
		Swale starts 73'.															
		Shrubs inside swale include wood's rose, willow, red-osier dogwood, snowberry. Cottonwood seedlings around edges. Mint in bottom.															
		159 water's edge.															

Table D-5. Point Bar 4 Transect 1 Monitoring Results 2009

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
	Metric																
Point Bar 4 Transect 1 Direction: 68 degrees	**LWD # <4**	6	7	4	2	3	1	3	4	5	10	1	20	>20	0	0	
	LWD # >4	4	3	8	1	6	5	6	4	7	6	0	3	6	2	0	
	LWD percent	30	15	30	5	40	20	20	20	50	40	<1	10	60	1	0	
	Percent cover weeds	10	20	30	20	5	1	5	10	1	10	0	0	0	0	0	
	Percent cover grasses and forbs	50	15	15	1	1	1	5	10	20	20	1	0	<1	0	<1	
	Number shrubs/trees	2	0	2	0	0	1	0	3	7	8	0	0	0	0	0	
	Number cottonwood seedlings	0	2	2	1	3	3	>10	20	6	>20	>20	0	3	6	0	
	Substrate	OM, 2-4, 6-10	OM, 1-4	OM 1-4, 4-6	<1, 1-6	<1, 1-6, few 8	1-6, few 8	1-6, 8-10	sand, 1-6, few 8	silt, OM, few 8-10	sand, OM, 2-8	sand 2-4, some 8	sand 2-6, some 8	sand, 1-4	<1, 1-4, few 6-8	2-6, some 8-10	
	Deposition type and percent	OM 50	OM 20	OM 10	OM <5	OM <5	OM <5	OM <5	OM 10	OM 10	OM 10	sand 20	sand 1	sand 10	sand 1		
													OM 5	OM 5			
	Other Notes	Cottonwood seedlings surround the edges of the swales															
		Weeds include: oxeye daisy, houndstongue, knapweed, Canada thistle, yellow toadflax, reed canarygrass															
		Sedge species in swale															
		OM is organic matter and includes leaves and other litter															
		Shrub species include: red-osier dogwood, American red raspberry, willow, wood's rose, snowberry															

Table D-6. Point Bar 13 Transect 1 Monitoring Results 2009

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
Point Bar 13 Transect 1 Direction: 302 degrees	Metric																
	LWD # <4	5	3	1	1	1	7	2	2	1	2	0	0	0			
	LWD # >4	0	0	0	0	7	2	5	8	2	0	0	0	0			
	LWD percent	1	<1	<1	1	30	10	20	40	5	<1	<1	0	0			
	Percent cover weeds	<1	1	1	5	1	1	5	5	5	<1	<1	<1	<1			
	Percent cover grasses and forbs	1	5	<1	10	5	1	10	40	1	1	5	<1	<1			
	Number shrubs/trees	4	0	0	0	0	0	1	1	0	1	2	0	0			
	Number cottonwood seedlings	7	0	0	>50	>50	>75	>75	>100	>200	>200	>200	7	>50			
	Substrate	OM, <1, 2-4	<1,2-4, OM	silt, <1, 2-4, some 6	OM, sand, 2-4, 6-8	sand, OM, <1, 2-6, some 10	OM, sand, 2-4, 6-8	silt, 4-6, some 10	sand 2-4	sand, <1, 2-4	<1, 2-4, some 6	sand 2-4, some 8-10	2-6, some 10	2-4, few 10, some 6-8			
	Deposition type and percent	OM 5	OM 1	OM 1	OM 20	sand 20	OM 5	OM 1	sand 40	sand 10	0	0	0	sand 1			
					sand 10	OM 10		sand 5	OM 5								
	Other Notes	Swale at 67 feet has lots of sand deposition															
		Abundant cottonwood seedlings surviving form previous year. Cottonwood seedlings stop at 110 feet and begin again at 120 feet; the bare area is where water flows over the point bar															
		Weeds include oxeye daisy, knapweed, Canada thistle, reed canarygrass															
		Forbs include large leaf avens, Canada goldenrod, yarrow, clover															
		Shrubs include currant, red-osier dogwood, American red raspberry, western serviceberry, wood's rose, thimble berry															

Table D-7. Point Bar 13 Transect 1 Monitoring Results 2010

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
Point Bar 13 Transect 1 Direction: 302 degrees	**Metric**																
	LWD # <4	T	T	T	T	0	4	2	0	2	3	1	0	0			
	LWD # >4	0	0	0	0	7	1	5	8	0	0	0	0	0			
	LWD Percent	T	T	T	T	40	5	30	40	5	T	T	0	0			
	Percent cover weeds	T	P	T	5	P	T	P	5	5	T	T	T	T			
	Percent cover grasses and forbs	T	T	T	5	5	T	10	30	5	P	T	T	T			
	Number of shrubs/trees	2	0	0	1	3	6	2	1	2	4	0	1	0			
	Number of cottonwood seedlings	6	5	6	>20	>75	>100	>100	>100	>100	>100	>100	3	>20			
	Substrate	<.5, .5 -2	<.5, .5 -2, OM	2-4, silt, OM	sand, <.5-1, some 6-8	patch of sand, <.5-10	silt, OM, 2-4, 6-8	silt, sand, OM, <.5-2, 4-6	sand, silt, <.5-2, 4-6	sand, silt, OM, <.5-2, 2-4	<.5-2, 4-6, some 8	silt, <.5 -2, 2-8	<.5 -8	silt, 2-8			
	Deposition type and percent	LVS/litter 30	litter P	litter T	litter 5	litter 5	lvs/litter 10	litter 5	litter P	litter 10	litter T	litter 5	litter T	litter T			
	Other Notes	Swale at 67-78.															
		110-120 is in flow zone photo 19 and 20.															
		Weeds include knapweed, oxeye daisy, houndstongue, Canada thistle.															
		Reed canarygrass clump at 40-50.															
		Spruce, dogwood and alder seedlings colonizing.															
		Cottonwood seedlings of varying age classes carpet most of the transect.															

Table D-8. Point Bar 4 Transect 1 Monitoring Results 2010

	Transect Distance (ft)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160
Point Bar 4 Transect 1 Direction: 68 degrees	**Metric**																
	LWD # <4	5	4	4	0	1	3	3	1	5	4	1	4	3	0	0	
	LWD # >4	3	1	5	4	6	4	5	7	4	3	0	4	5	1	0	
	LWD percent	40	5	20	5	10	5	30	30	40	20	T	20	30	P	0	
	Percent cover weeds	5	30	20	10	10	P	5	10	P	P	0	0	0	T	T	
	Percent cover grasses and forbs	60	20	5	T	T	T	T	P	5	60	T	T	T	T	T	
	Number shrubs/trees	1	0	2	0	0	0	0	3	8	4	0	0	2	0	0	
	Number cottonwood seedlings	0	1	1	1	2	3	>10	>20	>10	>20	>10	1	>10	5	0	
	Substrate	OM, 6-10	2-6	2-10	<.5-6	<.5-6	<.5-6	<.5-10	<.5-10	silt, some 10, <.5-4	silt, 4-6	silt, 2-6, few 8	silt, 2-6	silt, sand, 2-4	silt, sand, <.5-4, some 8-10	2-10	
	Deposition type and percent	lvs 10	lvs 5	lvs 10	lvs 5	lvs P	lvs P	lvs P	lvs P	lvs P	OM P	OM T	lvs T	OM P	litter T	0	
		OM 20								OM P			OM T	LVS P			
	Other Notes	Some of the cottonwood seedlings are 2-3 years old															
		Swale plants include rose, dogwood, sandbar willow, willow species are all growing and not browsed; they are beginning to fill in the swale															
		Swale bottom has mix of grasses and mint, cottonwood seedlings surround the edges															
		Cottonwood seedlings have grown to 3 feet on this point bar -- especially in areas where they are protected by debris piles															
		Cottonwood seedlings are growing in new sediment deposits and woody debris piles															

Table D-9. Browse evaluation data 2009 and 2010

Browse Evaluation Plot	2009				2010		
	Scientific Name	Common Name	Cover		Scientific Name	Common Name	Cover
Plot A Outside	*Cornus sericea*	red-osier dogwood	T		*Cornus sericea*	red-osier dogwood	T
	Populus balsamifera	black cottonwood	1		*Populus balsamifera*	black cottonwood (mature)	1
	Rosa woodsii	Wood's rose	P		*Rosa woodsii*	wood's rose	P
	Rubus idaeus	American red raspberry	T		*Rubus idaeus*	American red raspberry	T
					Rhamnus alnifolia	alderleaf buckthorn	T
					Symphoricarpos spp	snowberry species	T
Plot A Inside	*Cornus sericea*	red-osier dogwood	1		*Cornus sericea*	red-osier dogwood	1
	Populus balsamifera	black cottonwood (seedling)	T		*Populus balsamifera*	black cottonwood (seedling)	T
	Populus balsamifera	black cottonwood (mature)	3		*Populus balsamifera*	black cottonwood (mature)	3
	Rhamnus alnifolia	alderleaf buckthorn	2		*Rhamnus alnifolia*	alderleaf buckthorn	2
	Rosa woodsii	Wood's rose	3		*Rosa woodsii*	wood's rose	3
	Symphoricarpos spp	snowberry species	5		*Symphoricarpos spp*	snowberry species	5
					Prunus virginiana	common chokecherry	T
Plot B Outside	*Alnus incana*	alder	T		*Alnus incana*	alder	T
	Betula occidentalis	water birch	T		*Betual occidentalis*	water birch	T
	Cornus sericea	red-osier dogwood	T		Cornus sericea	red-osier dogwood	0
	Picea engelmannii	Engelmann spruce	P		*Picea engelmannii*	Engelmann spruce	T
	Populus balsamifera	black cottonwood	3		*Populus balsamifera*	black cottonwood (mature)	3
	Salix spp	willow species	1		*Salix spp*	willow species	1
					Pseudotsuga menziesii	Douglas fir	T
					Ribes spp	currant species	T
Plot B Inside	*Alnus incana*	alder	P		*Alnus incana*	alder	P
	Amelanchier alnifolia	Western serviceberry	T		*Amelanchier alnifolia*	Western serviceberry	T
	Cornus sericea	red-osier dogwood	P		*Cornus sericea*	red-osier dogwood	T
	Picea engelmannii	Engelmann spruce	T		*Picea engelmannii*	Engelmann spruce	T
	Populus balsamifera	black cottonwood	T		*Populus balsamifera*	black cottonwood	T
	Ribes spp	currant species	T		*Ribes spp*	currant species	T
	Rosa woodsii	Wood's rose	1		*Rosa woodsii*	wood's rose	1
	Rubus idaeus	American red raspberry	P		*Rubus ideaus*	American red raspberry	P
	Salix spp	willow species	3		*Salix spp*	willow species	5
	Symphoricarpos spp	snowberry species	P		Symphoricarpos spp	snowberry species	0
					Lonicera involucrata	twinberry honeysuckle	T

APPENDIX E

GRAVE CREEK RESTORATION PROJECT
PHASE 1 AND 2

SAMPLING METHODS

JULY 2010

Sampling Methods Requirements

Channel Surveys

Channel surveys were completed with a Leica survey grade GPS. Manufacturer suggested standard operating procedures were followed in operating the survey instrument. Channel surveys followed techniques outlined in Harrelson et al. 1994. Post-restoration channel cross-section locations were selected based on representativeness and pre-restoration cross-section locations.

Pools are defined as habitat features with residual depths greater than zero. Residual pool depth is the difference between the maximum pool depth and the downstream riffle crest depth. For this effort only pools with residual depths of 1.0 ft or greater were included in the analysis. The residual pool length extends from the riffle crest upstream to the head of the pool. Residual pool width equates to the wetted pool width at the time of survey.

Pebble counts were completed at one riffle cross-section in each reach following the Wolman protocol (1954). Particles were selected within the bankfull limits of the active channel including the upper bank profile (i.e. bank face).

Large woody debris was enumerated throughout the project area. Qualifying single pieces were at least 3.0 meters in length and 0.1 meter in diameter. Aggregates were defined as two or more singles either in contact or functioning as an array. All wood within the bankfull channel was inventoried. Qualifying pieces were tallied as rootfans or stems. Percent change in the following metrics are computed and reported.

Channel cross-section metrics

- Bankfull width
- Floodprone width (riffles)
- Entrenchment ratio
- Mean and maximum depths
- Width-to-depth ratios
- Bankfull cross-sectional area
- Wetted perimeter
- Hydraulic radius
- Energy gradient or average water surface slope

Longitudinal profile metrics

- Average slope (reach)
- Riffle, pool, run and glide facet slopes
- Pool to pool spacing
- Pool length
- Maximum depths of riffle, run, pool and glide habitat features
- Residual Pool Depth

Planform metrics
- Sinuosity
- Meander length
- Meander belt width
- Radius of curvature

Photo Points
Photo points have been established at all monitoring sites according to techniques outlined in Hall (2002). During each monitoring visit, photos were taken from monumented photo point locations in addition to other locations. Photo number, numbered photo point location, and direction were noted in the field notes.

BEHI Assessment
RDG has assessed sediment load reductions resulting from the restoration project using methodologies outlined in Watershed Assessment of River Stability and Sediment Supply (WARSS). Specifically, the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model was used to predict pre and post bank erosion rates within the project area. The application evaluates the pre and post construction bank characteristics and flow distribution along the river reach and maps BEHI and NBS risk ratings commensurate with streambank and channel changes. Annual pre construction bank erosion rates were estimated and then multiplied by the bank height and by a corresponding bank length of similar condition, providing an estimate of cubic yards and tons of sediment per year delivered to the project area. An identical analysis was completed following construction to demonstrate the post construction BEHI and NBS ratings and associated sediment loading estimates along the entire project reach.

The BANCS model used two bank erosion estimation tools.

1. The Bank Erosion Hazard Index (BEHI), and
2. Estimation of near-bank stress (NBS).

BEHI and NBS was used to evaluate streambank erosion potential. The BEHI procedure integrates multiple factors which have a direct impact on streambank stability, including the following parameters:

- Ratio of streambank height to bankfull stage,
- Ratio of riparian vegetation rooting depth to streambank height,
- Degree of rooting density,
- Composition of streambank materials,
- Streambank angle,
- Bank material stratigraphy, and
- Bank surface protection afforded by woody debris and vegetation.

The BEHI index incorporated these seven variables into a numerical reach score that was used to rank streambank erosion potential on a scale ranging from very low to extreme for the post restoration condition. Aerial photo interpretation and the 1999 ground based photo library was used to predict pre-restoration BEHI and NBS condition classes in the Phase 1 and Phase 2 project areas. Bank sites were rated from very low to extreme bank erodibility condition based on the above mentioned parameters and the rating matrix provided in Table 2-2.

Table 2-2. BEHI score and rating matrix (Rosgen, 2001).

Parameter		Very Low	Low	Moderate	High	Very High	Extreme
Bank Height Ratio	Value	1.0 – 1.1	1.11 – 1.19	1.2 – 1.5	1.6 – 2.0	2.1 – 2.8	> 2.8
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Root Depth Ratio	Value	1.0 – 0.9	0.89 – 0.5	0.49 – 0.3	0.29 – 0.15	0.14 – 0.05	<0.05
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Weighted Root Density	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 5	<5
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Bank Angle	Value	0 – 20	21 – 60	61 – 80	81 – 90	91 – 119	>119
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Surface Protection	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 10	<10
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10

The combination of the BEHI and NBS ratings was used in the BANCS model to derive annual streambank erosion rates. Erosion rates were predicted using established models from streams formed in sedimentary geology. NBS and BEHI ratings were converted to total annual streambank erosion rates. By measuring bank heights and stream lengths for associated BEHI and NBS values, the total erosion rate was converted to annual sediment supply in tons/year. This task was completed for both the pre and post restoration project area conditions to demonstrate actual sediment reduction (in tons/year).

Vegetation Sampling

Vegetation monitoring documents trends in floodplain and streambank plant community establishment, and determining effectiveness of revegetation treatments. Vegetation data collection and analysis includes:

- Aerial photo mapping of plant community relative abundance pre- and post-restoration;
- Containerized plant survival (2 plots per reach);
- Percent cover of woody vegetation on treated streambanks (2 treatments per reach);
- Floodplain transects to document riparian plant community successional processes (1 floodplain transect per reach); and

- Effects of browse on plant communities (2 monitoring plots per reach).

Aerial photo interpretation of plant community relative abundance
To compare pre-restoration vegetation communities with post-restoration vegetation communities, distinct plant communities were mapped as polygons in GIS using pre-restoration (1990s) and post-restoration (2005) aerial photos. Plant communities were mapped according to habitat and community types described in Hansen et al. (1995). The minimum mapping unit was 0.5 acres.

Containerized plant survival monitoring
Nine permanent monitoring plots were established at the project site to monitor survival of containerized plants installed during restoration. Four plots (two within Phase 1 and two within Phase 2) were selected for sampling and are shown on Figure 1-2. Monitoring plots include entire planting units and therefore vary in size. Plots located on outer meander bends are marked with rebar, survey cap and flagging on the upstream corner of the plot furthest from the channel. Plots located on floodplain surfaces included planted swale features and are delineated by the swale perimeter. All plots were recorded using GPS.

All plants within the plot are sampled by beginning at one corner of the plot and tallying each plant by species. For each plant, a status of either “dead” or “alive” is recorded. Dead plants are recorded by species where possible, otherwise “dead unknown” is recorded. Qualitative observations of growth and vigor of both living plants and naturally recruited species are also recorded.

Photographs are also recorded at each plot. For outer meander plots, a photograph is taken from the marked corner of the plot looking downstream and across the plot. For floodplain swale plots, a photograph is taken from the edge of the swale closest to the channel looking across the swale planting unit.

Percent cover of woody vegetation on treated streambanks
Percent canopy cover of woody vegetation on treated streambanks (streambanks where bioengineering treatments were installed) was recorded along belt transects. Four treated banks of variable length, two in Phase 1 and two in Phase 2, were selected for sampling and are shown on Figure 1-2. Transects will be established parallel to the treated bank from the upstream to the downstream end. The total canopy cover of all woody species was recorded along the transect in five-foot linear increments. The transect belt width includes the distance from the toe of the bank treatment horizontally to the top of bank.

Photographs of each treated bank were taken looking downstream along the treated bank from the upstream end of the treatment.

Transects to measure plant community establishment on constructed floodplains
Floodplain transects were established to evaluate plant community distribution relative to geomorphic features and channel elevations and to evaluate floodplain processes

and plant community succession on restored features. Belt transects were established at two locations in the Phase 1 and Phase 2 project areas. Transects extended the width of the floodplain, which varies within the project area. Transects were sampled from left edge of floodplain to right edge of floodplain; and transect ends were recorded with GPS and marked with rebar, survey cap and flagging. The azimuth of each transect was recorded, and transects were surveyed with a laser level and stadia rod. Elevations were recorded by transect distance at breaks in plant communities, elevation breaks or other distinguishing features.

Horizontal stations and GPS locations were recorded at each plant community break along the transect. Between the starting and ending stations for each plant community, the percent cover of dominant species was recorded within a 20 ft belt width. Specific data was collected along the portion of the transect extending through point bar surfaces. These point bar surfaces include the portion of the inside meander extending from the edge of the baseflow water surface elevation to the edge of the meander belt width. On these surfaces, swales and other micro topography features were constructed and woody debris was placed to create conditions that would promote natural plant community recruitment and succession. In addition, these areas were planted with shrubs and seeded with herbaceous species. To evaluate effectiveness of these treatments, the following data was collected in ten-foot by ten-foot increments along the transects: percent cover of woody debris, percent cover of naturally recruited woody vegetation, percent cover of grasses and non-weedy/non-invasive forbs, percent cover of fine sediment deposition and percent cover of weeds/invasive species. Photos were taken at each plant community transition and at each point bar sampling increment.

<u>Browse evaluation inside and outside wildlife exclosure</u>

Browse by deer and elk was identified as one factor limiting revegetation within the restoration project. In summer 2008, an electric deer and elk exclosure was constructed to control wildlife access to the upper portion of the project reach. To evaluate the effectiveness of the fence and the continued effects of browse pressure on establishing and existing riparian plant communities, two paired monitoring points, one within the exclosure and one outside of the exclosure, were established and monitored in July 2009. Paired points were established in two distinct vegetation types representing desired vegetation communities in the project area. One set of points was established within mature cottonwood areas (forested) and the second set of points was established in wetter, shrub dominated areas (shrub). Both paired points were sampled and are shown on Figure 1-2.

At each point, two photo locations were established and marked with rebar, survey cap and flagging. A series of panoramic photographs were taken at each photo location. Percent cover of shrub species was recorded at each point. General observations of browse and natural recruitment of vegetation was also recorded at each point.

All data generated will be provided to DEQ according to the DEQ approved Sampling and Analysis Plan. RDG will coordinate with the DEQ project managers to ensure the databases are compatible with the requirements of ongoing sediment and modeling efforts in the basin.

2.3 Instrument Calibration, Testing, Inspection, and Maintenance

All field instruments and sampling equipment was maintained in proper working order, with regular maintenance being performed as required by the manufacturer. Prior to mobilization to the field, personnel inspected the equipment to make sure it is in proper working order. Maintenance notes have been entered into the field logbook as necessary. Instrumentation used include standard metric rulers and survey grade GPS. Digital cameras were used for photo point data collection. RDG instruments are calibrated annually by certified repair technicians. Other survey equipment including survey rods are calibrated monthly by RDG's licensed Professional Land Surveyor, who will also direct all survey work to be performed under this contract.

2.4 Inspection of Field Supplies and Materials

All monitoring supplies and materials were inspected by the sampler to ensure they are in proper condition and working order prior to mobilization to the field. Any problems as well as application of maintenance requirements were documented in the field notes. The following equipment was used.

- Leica Survey Grade GPS (2)
- Inventory forms for physical channel assessment and vegetation transects
- Clip board
- Pencils
- Survey reach maps (laminated)
- Work vest and day packs
- Two-way radios
- Flagging
- Permanent ink pens
- Waterproof footwear (waders)
- 30 and 50 M tape measures and pocket rods
- Polarized glasses
- Solar powered calculators
- Underwater viewing tubes

2.5 Data Management

Survey data is stored in field notes, field forms, and electronically on the survey data collector. Field data has been entered into appropriate spreadsheets and channel survey data were organized as cross-section and profile data. Data entry was completed by RDG staff following QA/QC procedures to screen for data entry errors, etc. RDG project staff will submit all project data to DEQ in a SIM-compatible format in Excel or text delimited file that will provide for minimum data and metadata requirements for import into the EPA eWQX language database. These data are included in the final narrative interpretive report. All data generated during this project is stored at RDG's Whitefish office, and will be made available to the public. The data will be input into EPA's eWQX by RDG.