Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

Year 1 Annual Report for:

Big River Lead Remediation Structure (BRLRS) Monitoring Project

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November 3, 2016

OEWRI EDR-16-003

PROJECT SCOPE

Lead (Pb) mining activities in the Old Lead Belt, Missouri released large quantities of mining wastes into Big River and Flat River Creek between 1900 and 1972. These wastes consisted primarily of mill tailings with high residual Pb concentrations in sand- and silt-sized particles (<2 mm) released from flotation circuits and fine gravel “chat” wastes (2-16 mm) produced during mining (Pavlowsky et al, 2010). These mining sediments were transported and deposited downstream by river processes to contaminate Big River to toxic levels for Pb and other metals for over 100 mi from Leadwood to its confluence with Meramec River at Eureka (Pavlowsky et al, 2010). Presently, there are still large quantities of contaminated sediment stored in channel bed and bar deposits which provide a potential source of contamination to downstream river segments. Removal of Pb-contaminated sediment from the channel offers an opportunity to decrease the transport rate of sediment-Pb to downstream segments and mitigate long-term contamination risks along Big River. In response to the concerns over the fate of contaminated sediment in Big River, a pilot project to remove contaminated sediment from an impoundment above a low water crossing was implemented in 2009-10 with some success (Owen et al. 2012).

To expand on the earlier pilot project, the **Big River Lead Remediation Structures Project (BRLRS)** was implemented in Spring 2015 to trap contaminated sediment for mitigation purposes. The goal of the BRLRS project was to create managed sedimentation areas where mining-contaminated sediment would be deposited during flood events and later be removed for land disposal. The project site is located along Big River in St. Francis County, Missouri where the channel bends to the north just south of Bonne Terre immediately below the confluence of Flat River Creek (Figure 1). It includes two structures, one designed to collect channel bed-load sediment and the other to trap finer-grained suspended load. The in-channel structure is a Newberry-type rocked riffle used to increase upstream backwater effects, decrease water slope, and trap contaminated bed sediment by settling and deposition (Photo 1). The second structure is an off-line sedimentation basin system which was excavated within the existing floodplain area on the inside of a channel bend. The basin area was situated within areas previously disturbed by soil mining. Sediment-laden water enters a low bank inlet above Flat Creek during high flow conditions, becomes ponded within a vegetated basin system, and deposits or settles contaminated suspended sediment and finer bed sediment (Photos 2-6).

In order to assess and document the effectiveness of BRLRS to resist flood damage and trap contaminated sediment, EPA Region VII contracted OEWRI to survey the post-construction conditions of the site and monitor the performance of the two structures. The proposed goals of the monitoring program were to:

(1) Assess and map the "as-built" condition of the completed structure;
(2) Monitor periodically the condition and stability of the constructed basin and riffle as well as the natural channel and bank system within the project reach given the influence of local geomorphic and human disturbances related to structural stability, flood effects, and sediment conditions;
(3) Monitor and quantify the volume, properties, and geochemistry of contaminated sediment trapped behind the riffle structure;
(4) Monitor and quantify the volume, properties, and geochemistry of contaminated sediment deposited within the off-line floodplain basin structure; and
(5) Evaluate the overall structural integrity and sediment/Pb trapping effectiveness of the BRLRS.

This annual report summarizes the first year of data collection including channel surveys and sediment basin monitoring. Specifically, this report and associated databases contain: (i) Complete geospatial datasets including previous LiDAR data used for present mapping, floodplain, basin, and channel data sets (delivered as separate to the report), (ii) DEM for the site including locations of structures and excavations, (iii) Locations of areas of concern or geomorphic change that may affect long-term stability, (iv) Review of sedimentation trends in basin and channel areas, and (v) Describe the monitoring tasks scheduled to be completed for year two of the project (September 2016 to August 2017).

METHODS

The methods used to assess BRLRS were reviewed by USEPA staff and are detailed below. A Quality Assurance Project Plan (QAPP) was approved by USEPA for this monitoring project for site selection, sampling, and laboratory procedures (Pavlowsky and Owen 2016). In addition, all field and laboratory procedures are described in documentation available on the OEWRI website (https://oewri.missouristate.edu/).

Geospatial Assessment

All topographic surveys were completed using either a Topcon HiPER Lite+ RTK (Real-time Kinematic) global positioning system (GPS) receiver or a Topcon GTS-225 electronic total station when GPS signal is poor under tree canopy. Operation of the GPS and total station will follow the instruction manual and the procedure sheets for the particular model in use (OEWRI 2006a, OEWRI 2009). All survey data is saved in the attached MS Excel Spreadsheet "BRLRS_surveydata (9-13-2016)".

Channel Surveys

Channel surveys included both cross-sections and longitudinal profiles of the study reach. Channel cross-sectional surveys were collected at 22 transect locations 2-5 times throughout the year (Figures 2 and 3). Additionally, due to total station malfunction, cross-sectional surveys were also collected in September 2015 using an auto level at several transect locations. A total of five longitudinal profiles were collected over the monitoring period, including one before construction in November 2014 (Figure 4). All permanent transects for channel surveys were located with monuments (metal posts) located on the left bank. In addition, similar monuments were also positioned on the right channel bank for transects 1 through 15. Each post is labeled by a transect number with a white sign with black lettering. To provide long-term control for survey elevations, three concrete and rebar pin monuments were installed at upstream, middle, and downstream locations within the project site and GPS locations and elevations determined with high resolution RTK surveys. Individual auto-level channel cross-sections for each transect are saved in the MS Excel Spreadsheet "BRLRS_Autolevel_Surveydata (9-13-2016)"

Floodplain Basin Surveys

The floodplain basin was surveyed using a series of east-west transects spaced about 60 ft apart, at key breaks in slope, and around important features of the excavated area in order to map the overall features within the basin. These data were combined with the existing LiDAR dataset to create a map representing the post-construction topography of the site (Figure 5). Mapped features included the upper basin, basin channel, lower basin, inlets, and outlets. All survey data is saved in the attached MS Excel Spreadsheet "BRLRS_surveydata (9-13-2016)" and the combined LiDAR DEM is located in attached BRLRS Geodatabase.

The geospatial database is composed of several sources of spatial data that are readily available in ArcMap, or collected in the field using survey equipment and geo-referenced. Raster files were created in ArcMap 10.2.2 by first converting GPS data from RTK surveys to triangulated irregular networks (TINs). The TINs were converted to a raster using the TIN to Raster tool. Using the Raster Calculator tool, the elevation of two raster files were subtracted from each other to calculate the depth of sediment deposited during particular flooding events. Those depths were then multiplied by a known area to calculate a volume of sediment deposited. This data can be mapped to enhance visualization of deposition quantities and patterns and how they vary over time.

Historical Aerial Photo Analysis

A series of historical aerial photographs were used to identify channel changes within the study reach. Aerial photographs used for this project ranged in age from 1937 to 2007 and are categorized into six sets for historical channel change analysis. The six sets are; 1) 1937, 2) 1954, 3) 1976, 4) 1991, 5) 2007, and 6) 2013 and represents the average year for that set of photos. The 1937, 1954, 1976 and portions of the 1991 photo series sets were acquired through the United States Geological Survey. The 1992 photos from the 1991 photo set were acquired through the Missouri Spatial Data Information Service (MSDIS) and came pre-rectified. The 2007 photographs were used as the base map for this study and were also acquired through MSDIS and came pre-rectified. The remaining photo years required scanning and rectification. Photo years 1937, 1954, 1974, 1976, 1978, 1979, and 1990 were scanned at a resolution ranging from 0.75-2.11 m. The 2013 photos were obtained from Google Earth. Aerial photos were rectified in ArcGIS with a minimum of eight ground control points using a second-order polynomial transformation. Visible channel features were digitized from each photo set using ArcGIS software. Two channel feature files were created, a wetted channel and an active channel, for each set of photo years. The wetted channel was created by digitizing a continuous polygon along the edge of the water for the entire length of the study area for the year the set of photos represents. The active channel was created by digitizing areas of gravel to the existing wetted channel and combining into one continuous polygon layer for each set of years.

Channel Sediment Sampling and Storage

Sediment samples were collected from channel deposits along survey transects at riffles, glides, bars and low floodplains using a perforated shovel to reduce water drainage and fine sediment sapping from the sample. Channel samples were only sampled once during the first year generating 32 channel sediment samples including 6 riffles, 10 bar, 6 glides, and 10 bench deposits. Samples were placed in 1-quart plastic freezer bags, and labeled according to site location.

In-channel sediment storage assessments were based on a series of 12 surveyed transects (6-17) across the channel. The thickness or depth of the alluvial deposits in the channel (i.e., “total storage”) at each transect was calculated by using the elevation of the deepest channel thread (i.e., “thalweg”) as the channel base across the channel and subtracting it from the elevation of the above channel bed and bar surface to get an average depth of sediment within the channel. This was multiplied by the width of the deposit to obtain an area of sediment within the channel. This was then multiplied by the length of the channel represented by that transect equal to half of the distance between the upstream and downstream transect to obtain the volume of material deposited within the channel boundary.

Floodplain Basin Sediment Sampling and Deposition Rates

Sediment deposition was assessed in two ways by using (i) an array of sediment block samplers in the upper basin and (ii) high resolution surveys of the entire off-line basin floor. First, sedimentation rates and patterns within the upper basin were sampled using a network of 25 (16 in x 16 in) patio blocks with top surfaces set even to the elevation of the present ground surface of the basin. The block surface provided a stable reference base upon which to measure overlying sediment deposition remaining after inundation by high flows. Each block was marked with a metal post placed 1 ft north (direction opposite of the channel) to help re-locate the sampling block after deposition and vegetation growth (Photos 7 and 8). Information on sediment deposition was recorded during each sampling event including average sediment depth of five ruler measurements to the nearest millimeter (0.04”) at the four corners and middle of the block and sediment deposit type sand lense, sand massive deposit, mud/fines deposit, and leaf/litter debris layer. The top surface of the sediment block was reset to the new ground elevation after each sampling event. Sedimentation rates were calculated for each block by dividing the average depth of sediment on the block by the time period between sampling events or since the block was cleared and re-leveled. In addition to sediment block sampling, high-density surveys of ground surface elevation using RTK GPS were collected from throughout the entire basin after flooding events to obtain a detailed map of basin topography and to measure the change in sediment storage within the basin.

Sediment samples were collected from each block using a trowel, placed in 1-quart plastic freezer bags, and labeled according to site location. During the first year of monitoring, five sediment sampling events were completed generating a total of 143 individual samples for metals analysis using XRF. Sometimes more than one sample type was collected from a single block during a sampling event where obvious stratigraphic differences were observed within block deposits. Throughout the course of the study, two of the 25 sediment blocks was lost due to burial, flotsam damage, or mowing. A total of 23 blocks were sampled over the entire period, block #4 was sampled only once, block #1 was sampled three times.

Laboratory Methods

Laboratory methods follow the EPA approved Quality Assurance Project Plan (QAPP) for this project (Pavlowsky and Owen 2016). After field collection, sediment samples were brought back to the OEWRI laboratory for processing and geochemical analysis following approved chain-of-custody procedures (OEWRI 2006b). Samples were disaggregated and sieved through a stack of 16 mm, 8 mm, 4 mm, and 2 mm sieves to separate the sediment into individual fractions. The <2 mm fraction was analyzed using an X-MET3000TX+ Handheld X-ray fluorescence (XRF) Analyzer to determine the concentrations of Pb, Zn, Mn, and Ca of the sediment samples (OEWRI 2007). Samples were analyzed and followed the methodology for undertaking semi-quantitative investigations provided by U.S. Environmental Protection Agency (EPA) Method 6200 (U.S. EPA, 1998). Standard checks and duplicates analyses were used every 10 to 20 samples. Quality assurance and quality control (QA/QC) was completed for all XRF data. Additionally, a select group of sediment samples will be sent to an outside laboratory to compare accuracy and precision.

RESULTS

Flood Record During Year 1

Gage height and discharge data from the USGS Big River below Desloge (07017260) gaging station located about 1 km upstream of the site were used to determine: (1) when the channel reached bankfull stage, and (2) the frequency of peak discharges and duration of single flood events that inundated the floodplain. These data, along with the sedimentation record from the sampling blocks and RTK surveys, were used to analyze the quantities, rates, and patterns of sedimentation from individual flooding events. When the stage at the Desloge gage reaches approximately 5.5 ft the depth in the channel at the basin inlet is about 5 ft and water starts to enter the upper basin. When the Desloge gage stage reaches 8.5 ft it is at the point it overtops the road and enters the floodplain basin system (about 8 ft channel depth). Gage records show that between August 1, 2015 to August 5, 2016 there were eight events that were able to enter the basin system by overtopping the road corresponding to a discharge of ≈2,260 ft^3/s (Figure 6). The geomorphic bankfull stage at the site was determined to be about 1 ft higher than the road elevation at channel depths around 9 ft (9.5 ft at Desloge gage). Having 8 events overtopping the road suggests flood frequency over the last year was higher than normal. In a typical year floods stages that are high enough to overtop the road would be expected to occur on average 1-2 times per year.

In-Channel Sedimentation

In general, sediment deposition on the bed and low bar areas occurred along the left and middle thirds of the channel below the Flat River mouth riffle in zone ranging from 40 to 85 ft in width (Table 1). The channel in this segment is bending to the left and so deposition would be expected along the inside of the channel bend in the form of point bar tail and chute “scour and fill” deposits. Further, sand and gravel deposits extend downstream from the Flat River Creek confluence zone in the form of riffle and delta bars. Two sedimentation zones were identified as prospective removal areas for contaminated sediment. Zone A is located along the inside bend of the pool immediately above the riffle structure with sediment depths between 2-2.5 ft deep and contains about 700 yd^3 of sediment. Zone B is located further upstream in the backwater area at the head of the pool with sediment depths ranging from 1.5-4 ft deep and contains about 3,000 yd^3 of available sediment (Figure 8). Not all this sediment may be recent sediment deposited after the construction of the riffle structure. In general, the sediment deposits in the channel are composed of sand (>80% of tailings origin) and fine gravel (about half of tailings origin).

Concentrations of Pb in the <2 mm in-channel sediment deposits collected above the riffle structure had less variability than Zn concentrations, but both metals exceeded the probable effects concentrations (PEC) for metals in freshwater ecosystems for all samples. Of the 32 samples collected, Pb concentrations ranged from 804 ppm to 2,305 ppm and Zn concentrations ranged from 484 ppm to 1,745 ppm (Table 2). The average concentration of Pb for all deposit types was 1,295 ppm, with averages for specific deposits ranging from 1,174 ppm in the mid-bar deposits to 1,380 ppm in the finer bar-tail deposits (Figure 9). “Mud drapes”, which represent the very fine fraction of recent deposition, had the highest Pb concentrations of 1,664 ppm that were surface deposits of fine-grained benches forming along the left channel margin. Bench samples concentrations were slightly lower than the mud drapes, with average Pb concentrations of 1,283 ppm. The average Zn concentrations from all deposit types was 952 ppm, ranging from 684 ppm in mid-bar deposits to 1,182 ppm in the fine bar tail. The mud drape deposits had similar, but slightly lower Zn concentrations compared to the bar-tail at 1,157 ppm. Samples collected from the benches had an average Zn concentration of 997 ppm, which is slightly lower than the mud drapes. These data show in-channel sediment being deposited behind the riffle structure has high concentrations of metals, exceeding the PEC for metals in freshwater ecosystems of 128 ppm Pb and 459 ppm Zn (MacDonald et al. 2000).

Sediment Block Results

Sediment block sampling was used to quantify deposition rates within the upper basin, but also provided information on changes in particle size and geochemistry with corresponding flood events. Over the study period, individual sediment blocks had sediment accumulation of 0.08-1.97 ft with an overall average sediment depth of 0.95 ft (Figure 10, Table 3). The majority (>95%) of sediment being deposited in the upper basin is <2 mm in diameter (Table 4). The exception is blocks #3 and #4 located the inlet of the upper basin that has coarser sediment where the <2 mm fraction makes up 50-60% of the deposit since this area is in the basin “thalweg” or splay formation area near the inlet. When floods enter through the inlet and spread out into the basin, sediment transport capacity drops and the coarser material is deposited first and finer material is carried further into the basin system. In general, concentrations of Pb in the sediment entering the basin tend to be lower near the inlet and increase with distance away from the opening. Of the 112 individual samples collected, Pb concentrations ranged from 479 to 2,315 ppm with an average concentration of 1,140 ppm (Table 5). These concentrations are significantly higher than the aquatic PEC for Pb of 128 ppm established by MacDonald et al. (2000). The concentrations are also above the 400 ppm threshold limit set by the U.S. EPA for residential soil. This threshold limit is also used by EPA Region 7 for soil contamination projects. Average Pb concentrations from individual sediment blocks range from 639-1,435 ppm with an average of 1,116 ppm over the entire study period (Figure 11). Concentrations of Zn ranged from 567 to 4,745 ppm with an average concentration of 1,231 ppm (Table 6). These concentrations are higher than the aquatic PEC for Pb of 459 ppm established by MacDonald et al. (2000).

Upper Basin Sedimentation Areas

Post-construction deposition was also monitored at the upper basin area using repeat surveys. Sediment deposition depth were sampled and mapped for total area of almost 86,821 ft^2 (Table 7). In this area, approximately 1,500 yd^3 of potentially available sediment averaging almost 0.5 ft in depth was deposited. However, when focusing on basin areas where deposition in excess of 0.5 ft occurred, three sedimentation zones were identified for removal (Figure 11). The volume of sediment deposited in these zones range from 60 yd^3 in Zone 3 to 1,041 yd^3 in Zone 1 (Table 7). Average depths in these areas ranges from 0.44 to 0.64 ft, however there are relatively large areas where sedimentation occurred to depths of 1.5 ft or more since May 2015. In most places, the recent deposits are composed of lighter-colored and granular sandy materials that contrast the underlying darker-colored and cohesive soil of the pre-existing ground surface. As of last survey date on 7/8/2016, there is about 1,500 yd^3 of contaminated sediment available for removal in the upper basin area. This storage volume may be larger than expected for average long-term conditions due to two factors. First, inlet enlargement by bank erosion shortly (<6 months) after construction was completed may have added to the volume of sediment in the basin. Second, a relatively frequent series of eight overbank floods filled the basin during the first year of basin operation and therefore the present results may over-represent deposition rates compared to the average number of flood events expected to occur in the future.

Lateral Migration and Bank Erosion

Comparisons of channel locations on aerial photograph series from 1937-2013 show that bank erosion is occurring along the outside/right bank of the river with highest lateral erosion rates generally occurring between transects 11 to 16 (Figure 12). Channel change analysis shows the channel has progressively moved to the east since 1954 and has been building the low floodplain along the west/left bank, including where the southeast culvert opening to the lower basin is located. As the channel has migrated to the east, a large center bar has formed within the channel boundary that is typical of an over widened channel. While the right bank of the river is vegetated providing some erosion protection, the channel location seems to be fairly stable between the 2007 and 2013. Additionally, bank scour has been occurring along the right side of the riffle ramp where flow accelerates over the crest and contacts the hillslope and bank margin. The right bank of the channel near the riffle ramp generally impinges on the base of a bedrock bluff or hillslope. Thus bedrock may be close to the channel margin limiting bank erosion risk to the riffle ramp.

AREAS OF CONCERN

After multiple visits to the BRLRS site, the following six areas of concern were identified (Figure 13):

1) The channel sediment volume available for removal is approximately 3,700 yd3. The volume for removal is less than total sediment storage since some channel areas should be avoided to maintain the channel boundary to protect channel stability and aquatic habitat. Where possible, areas to be avoided include a 5 ft buffer between the excavation boundary to the edges or margins of the following features: (i) bank toe, (ii) vegetated channel bars, (iii) active bars providing structure for riffle or chute channel units, and (iv) deposits on the channel bed where sediment thickness is less than 1 foot.

2) Bank erosion and lateral migration between the confluence of Flat River Creek and the riffle structure that has been occurring since the 1950s. This erosion is probably occurring independently of the constructed riffle. However, bank conditions between transects 11 to 16 should continue to be monitored. If lateral erosion persists, bank stabilization may be required to stop continued sediment release.

3) Erosion is occurring along the right bank near the constructed riffle crest (Photo 10). Erosion should be monitored and stabilization should be considered if it persists.

4) The floodplain basin inlet has widened since construction (Figure 9). Most of this widening occurred in the 6 month period after construction. Currently, inlet enlargement has slowed and inlet dimensions have appeared to stabilize. No action is needed at this time, but should be monitored.

5) The north culvert outlet is blocked by debris floating into the undisturbed treed area to the west of the lower basin. Culvert blockage may be forcing flood waters to overtop the road to the northwest causing a washout (Figure 13). Removal of debris that is blocking the culvert will allow passage of more water during floods and will help prevent the road from washing out.

6) The northwest basin divide is 3.5 ft lower than surrounding high ground and water spilling over the road there is causing erosion. Given that the upper basin inlet has increased in size, more water may be entering the basin from upstream than can be effectively drained by the existing culverts. Adding gravel to the road where it is washing out after flood events would allow better access to the site during wet weather conditions (Figure 12).

YEAR 2 MONITORING PLAN

According to the contract for the project, Year two monitoring activities planned for the period of Aug 1, 2016 to July 31, 2017 include:

1.) Complete one whole-site survey, including all channel and floodplain basin transects and survey areas.

2.) Site visit to monitor sediment deposition at least four times at sedimentation areas, including two trips where recent deposits of basin and channel sediments are collected for analysis.

3.) All sampling and analytical procedures will follow the approved-QAPP for the project.

4.) Deliverables:
    a. Submit four brief, email progress reports to USEPA within two weeks of site visits.
    b. Submit annual report (deadline- 9-1-17)

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TABLES

Table 1. In-channel sediment deposition available for removal.

Deposition Zone	Transect	Avg. Depth (ft)	Width (ft)	Area (ft^2)	Length (ft)	Vol.(ft^3)
A	6	2.0	85	170	42	7,140
A	7	2.5	60	150	68	10,200
A	8	2.5	40	100	26	2,600
					Total Vol. (ft^3)	19,940
				Zone A	**Total Vol. (yd^3)**	**739**
B	11	3.0	45	135	91	12,285
B	12	4.0	40	160	79	12,640
B	13	3.0	50	150	66	9,900
B	14	2.0	70	140	50	7,000
B	15	1.5	70	105	159	16,695
B	16	3.0	40	120	186	22,320
					Total Vol. (ft^3)	80,840
				Zone B	**Total Vol. (yd^3)**	**2,994**

Table 2. Sediment block deposition over the study period.

Sediment	Measured Depth (ft)					Total Depth (ft)
Block ID	8/4/2015	9/17/2015	12/14/2015	1/21/2016	7/8/2016	8/4/2015-7/8/2016
SB1	0.03	0.10	0.06	0.00	0.00	0.19
SB2	0.34	0.01	0.01	0.66	0.09	1.11
SB3	0.13	0.19	0.01	0.00	0.41	0.74
SB4	0.66	1.31	0.00	0.00	0.00	1.97
SB5	0.45	0.20	0.02	0.00	0.62	1.30
SB6	0.45	0.23	0.05	0.33	0.31	1.36
SB7	0.46	0.11	0.03	0.00	0.17	0.77
SB8	0.44	0.04	0.02	0.33	0.00	0.83
SB9	0.32	0.24	0.06	0.00	0.03	0.65
SB10	0.33	0.13	0.24	0.10	0.56	1.36
SB11	0.30	0.05	0.04	0.62	0.28	1.28
SB12	0.01	0.03	0.03	0.26	0.15	0.49
SB13	0.23	0.05	0.02	0.46	0.22	0.97
SB14	0.16	0.04	0.04	0.00	0.48	0.73
SB15	0.01	0.02	0.02	0.20	0.32	0.56
SB16	0.08	0.01	0.01	0.46	0.10	0.66
SB17	0.06	0.00	0.01	0.56	0.07	0.70
SB18	0.07	0.00	0.01	0.07	0.06	0.20
SB19	0.03	0.00	0.00	0.03	0.02	0.08
SB20	0.39	0.00	0.01	0.11	0.04	0.55
SB21	0.10	0.02	0.01	0.33	0.51	0.96
SB22	0.17	0.03	0.01	0.39	0.39	0.99
SB23	0.11	0.02	0.01	0.98	0.83	1.95
SB24	0.37	0.51	0.01	0.39	0.54	1.83
SB25	0.59	0.00	0.04	0.75	0.00	1.39
n	25	25	25	25	25	25
Mean	0.25	0.13	0.03	0.28	0.25	0.95
Stdev.	0.19	0.27	0.05	0.28	0.24	0.52
CV%	76.3	203.2	156.8	99.4	96.0	54.6

Table 3. Grain-size data from sediment block samples

Sediment Block ID	<2 mm (%) 8/4/2015	9/17/2015	12/14/2015	Avg. <2 mm 8/4/2015-12/14/2015
SB1	95.6	100	99.2	98.3
SB2	74.9	91.9	86.7	84.5
SB3	70.1	49.6	57.7	59.1
SB4	60.3	74.6	45.1	59.9
SB5	98.1	92.9	98.2	96.4
SB6	98.4	100	80.0	92.8
SB7	98.8	99.6	93.9	97.4
SB8	99.4	100	100	99.8
SB9	98.6	99.5	99.8	99.3
SB10	96.5	97.0	99.3	97.6
SB11	100	100	96.9	98.9
SB12	100	100	100	100
SB13	99.8	100	100	99.9
SB14	99.6	100	100	99.9
SB15	100	100	100	100
SB16	99.6	100	100	99.9
SB17	99.7	100	100	99.9
SB18	98.9	100	100	99.6
SB19	98.4	NS	NS	98.4
SB20	98.3	100	100	99.4
SB21	99.6	100	100	99.9
SB22	99.0	100	100	99.7
SB23	99.4	100	100	99.8
SB24	99.5	97.3	99.2	98.7
SB25	98.2	NS	99.2	98.7
n	25	23	24	25
Mean	95.2	95.8	94.0	95.1
Stdev.	10.4	11.5	14.1	11.2
CV%	10.9	12.0	15.0	11.8

Table 4. Sediment block deposits Pb concentrations over the study period.

Sediment Block ID	XRF Pb (ppm) 8/4/2015	 9/17/2015	 12/14/2015	 1/21/2016	 7/8/2016	Avg Pb (ppm) 8/4/2015-7/8/2016
SB1	1,134	677	905	1,415	NS	1,033
SB2	1,050	1,167	821	NS	887	981
SB3	1,416	896	819	NS	943	1,018
SB4	678	725	514	NS	NS	639
SB5	1,159	931	914	NS	676	920
SB6	1,030	1,306	1,732	829	2,276	1,435
SB7	1,129	1,054	1,183	NS	1,375	1,185
SB8	1,019	808	1,168	479	NS	869
SB9	1,107	964	630	NS	739	860
SB10	1,089	853	732	1,865	1,246	1,157
SB11	1,064	1,390	1,747	1,023	1,243	1,293
SB12	1,342	1,352	1,629	537	1,343	1,241
SB13	1,087	1,316	2,315	759	1,417	1,379
SB14	1,174	1,331	1,782	870	1,148	1,261
SB15	1,420	1,290	1,652	645	1,403	1,282
SB16	1,194	1,239	1,682	811	1,252	1,236
SB17	1,318	1,247	1,621	1,051	1,087	1,265
SB18	1,484	1,354	1,369	991	1,265	1,293
SB19	928	NS	NS	797	1,100	942
SB20	922	1,254	1,357	999	1,093	1,125
SB21	1,346	1,283	1,499	929	1,394	1,290
SB22	1,232	1,430	1,532	654	1,228	1,215
SB23	1,382	1,387	1,573	883	1,146	1,274
SB24	1,151	774	600	736	715	795
SB25	828	NS	925	970	NS	908
n	25	23	24	19	21	25
Mean	1,147	1,132	1,279	907	1,189	1,116
Stdev.	195	245	471	313	337	205
CV%	17.0	21.7	36.9	34.5	28.3	18.4

Table 5. Sediment block deposits Zn concentrations over the study period.

Sediment	XRF Zn (ppm)					Avg Zn (ppm)
Block ID	8/4/2015	9/17/2015	12/14/2015	1/21/2016	7/8/2016	8/4/2015-7/8/2016
SB1	1,150	707	1,798	NS	NS	1,218
SB2	1,105	1,242	778	927	815	973
SB3	1,220	806	1,079	NS	752	964
SB4	854	1,815	773	NS	NS	1,147
SB5	1,255	1,190	1,303	NS	890	1,160
SB6	1,143	1,439	1,855	1,043	2,466	1,589
SB7	1,123	1,175	1,726	NS	1,449	1,368
SB8	1,072	955	1,249	633	NS	977
SB9	1,082	1,705	930	NS	567	1,071
SB10	1,233	1,255	929	4,745	928	1,818
SB11	1,172	1,319	1,697	1,258	1,241	1,337
SB12	1,233	1,304	1,537	801	1,208	1,217
SB13	1,089	1,133	2,605	645	1,342	1,363
SB14	1,242	1,213	1,730	NS	1,248	1,358
SB15	1,304	1,162	1,624	765	1,393	1,250
SB16	1,109	1,111	1,668	906	1,183	1,195
SB17	1,257	1,091	1,623	1,094	944	1,202
SB18	1,440	1,177	1,200	868	1,155	1,168
SB19	1,153	NS	NS	1,066	935	1,051
SB20	1,316	1,101	1,494	1,145	965	1,204
SB21	1,225	1,110	1,473	1,043	1,448	1,260
SB22	1,228	1,518	1,402	987	1,279	1,283
SB23	1,472	1,182	1,539	1,516	1,115	1,365
SB24	1,176	1,148	747	779	675	905
SB25	1,050	NS	1,071	1,053	NS	1,058
n	25	23	24	18	21	25
Mean	1,188	1,211	1,410	1,182	1,143	1,220
Stdev.	126	245	431	915	395	201
CV%	10.6	20.3	30.6	77.4	34.6	16.5

Table 6. In-channel sediment sample analysis results.

Sample #	Transect #	Landform Type	%>2 mm	%<2 mm	Pb (ppm)	Zn (ppm)
1	Upstream of 22	glide	71.3	28.7	1,144	1,224
2	Upstream of 22	glide	72.3	27.7	1,372	1,250
3	22	mid-bar	61.2	38.8	1,127	1,266
4	22	mid-bar	54.2	45.8	1,207	863
5	21	bar-tail	47.8	52.2	1,142	1,022
6	21	bar-tail	52.8	47.2	2,287	1,465
7	21	low floodplain	5.8	94.2	965	1,107
8	21	low floodplain	0.0	100.0	809	861
9	18	glide	56.0	44.0	1,361	575
10	18	glide	70.4	29.6	1,094	761
11	17	mid-bar	55.3	44.7	2,305	662
12	17	mid-bar	49.6	50.4	804	484
13	18	mud drape	0.0	100.0	1,227	1,019
14	17	mud drape	0.0	100.0	1,300	1,056
15	16	low floodplain	0.0	100.0	1,385	1,293
16	16	low floodplain	0.0	100.0	1,557	1,415
17	16	glide	68.3	31.7	1,337	690
18	16	glide	59.4	40.6	1,141	783
19	16	bar-tail	50.9	49.1	1,054	798
20	16	bar-tail	76.9	23.1	1,266	922
21	6	riffle-sed	51.3	48.7	916	844
22	6	riffle-sed	77.1	22.9	1,120	746
23	7	riffle-sed	65.7	34.3	1,100	611
24	7	riffle-sed	77.4	22.6	1,560	533
25	8	low floodplain	1.6	98.4	1,956	1,306
26	8	low floodplain	0.0	100.0	1,372	1,007
27	1	run	87.3	12.7	1,545	989
28	1	run	71.2	28.8	1,183	708
29	1	bar-tail	54.8	45.2	1,091	708
30	1	bar-tail	17.7	82.3	946	1,033
31	2	low floodplain	0.0	100.0	1,767	1,745
32	2	low floodplain	0.0	100.0	990	703
		n	32	32	32	32
		Mean	42	58	1,295	952
		Stdev.	31	31	367	301
		cv%	73.2	53.8	28.3	31.6

Table 7. Upper basin sediment volume available for removal.

Zone	Area (ft^2)	Avg. Depth (ft)	Volume (ft^3)	Volume (yd^3)
1	43,926	0.64	28,113	1,041
2	8,376	0.44	3,685	136
3	2,933	0.55	1,613	60
Total 1-3	55,235	0.60489	33,411	**1,237**
Basin	86,821	0.46	39,938	**1,479**

FIGURES

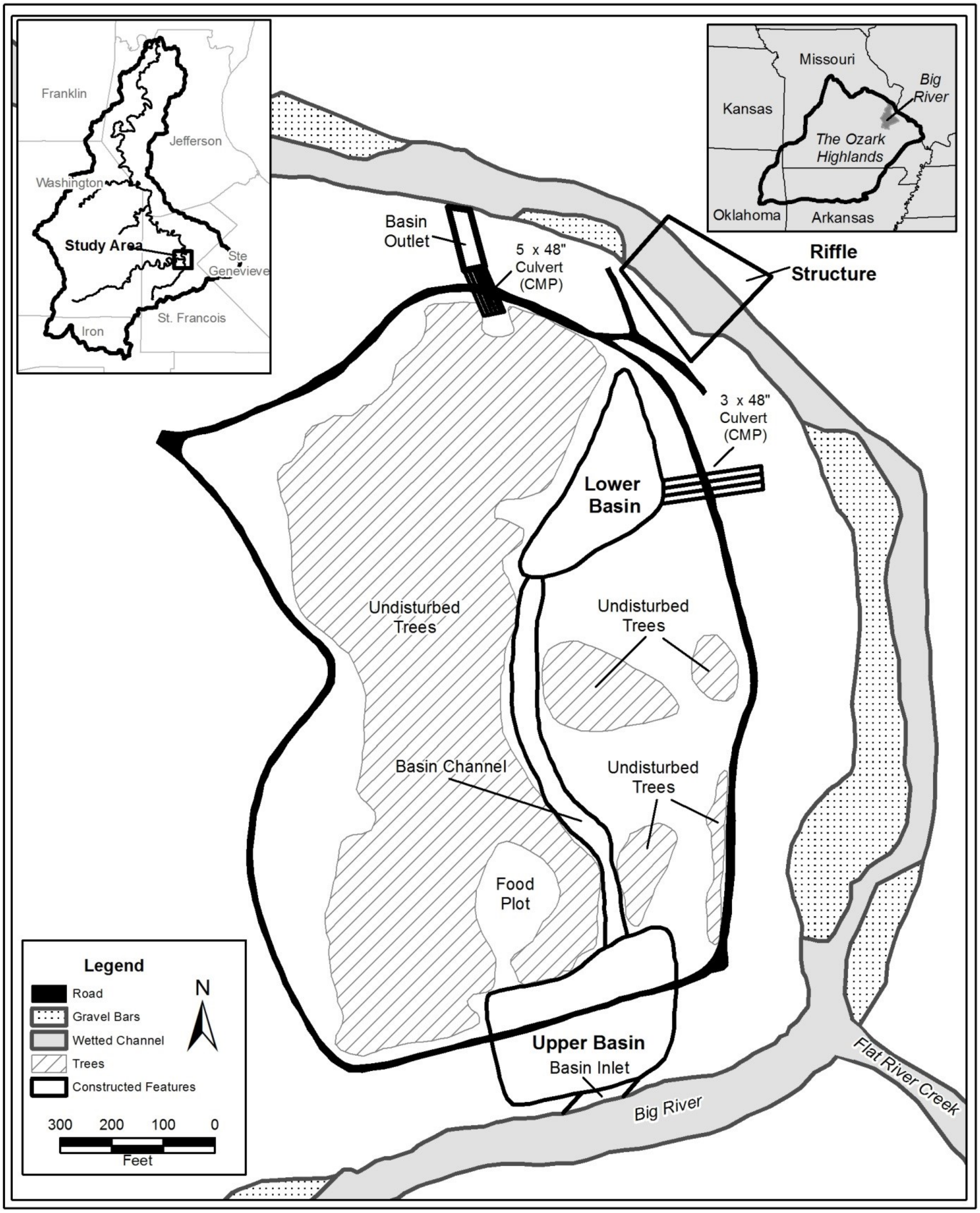

Figure 1. BRLRS Site Map.

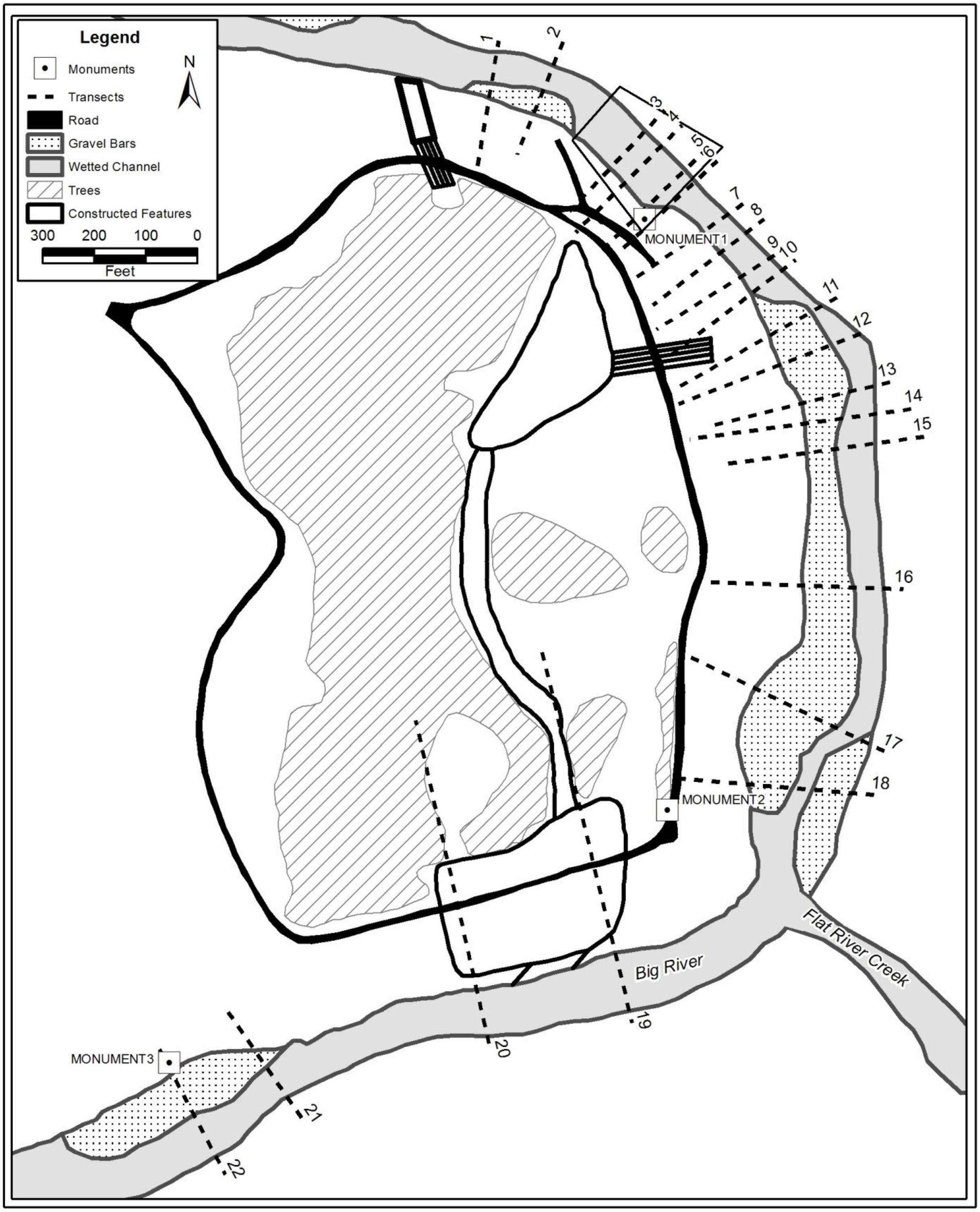

Figure 2. BRLRS Transect Locations.

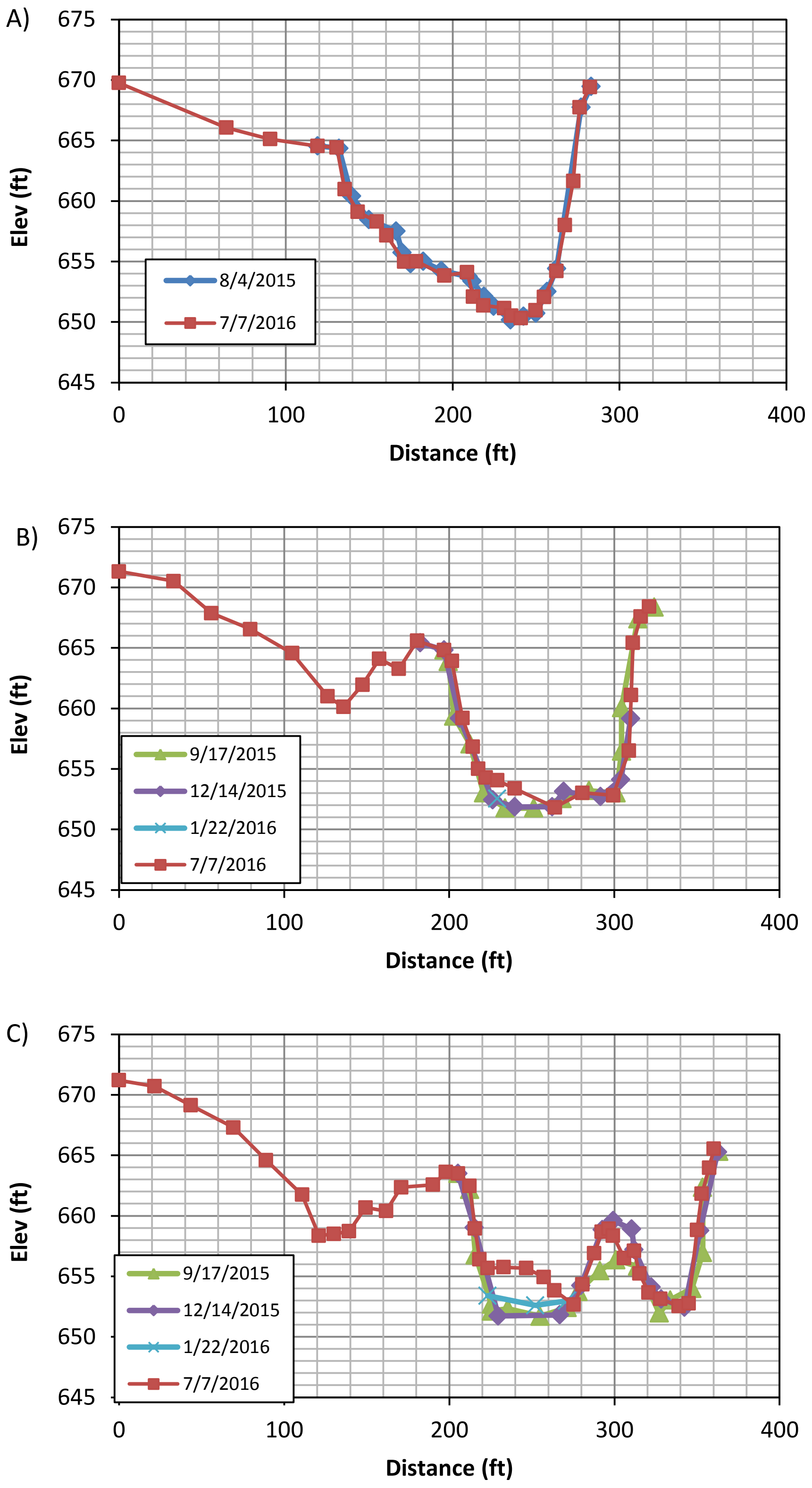

Figure 3. Examples of cross-section surveys at A) Transect 2, B) Transect 10, and C) Transect 11.

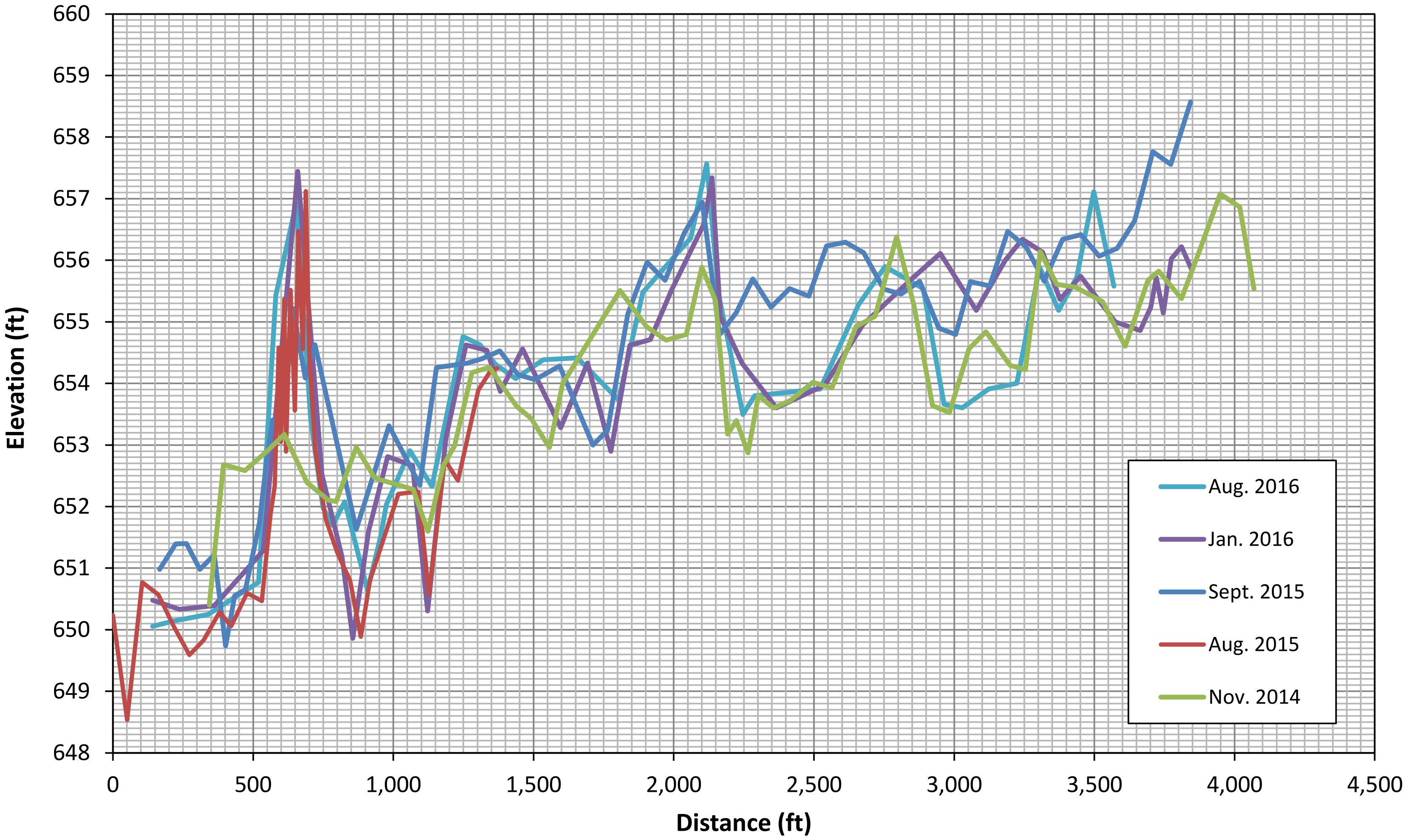

Figure 4. Series of five longitudinal profiles collected for this study.

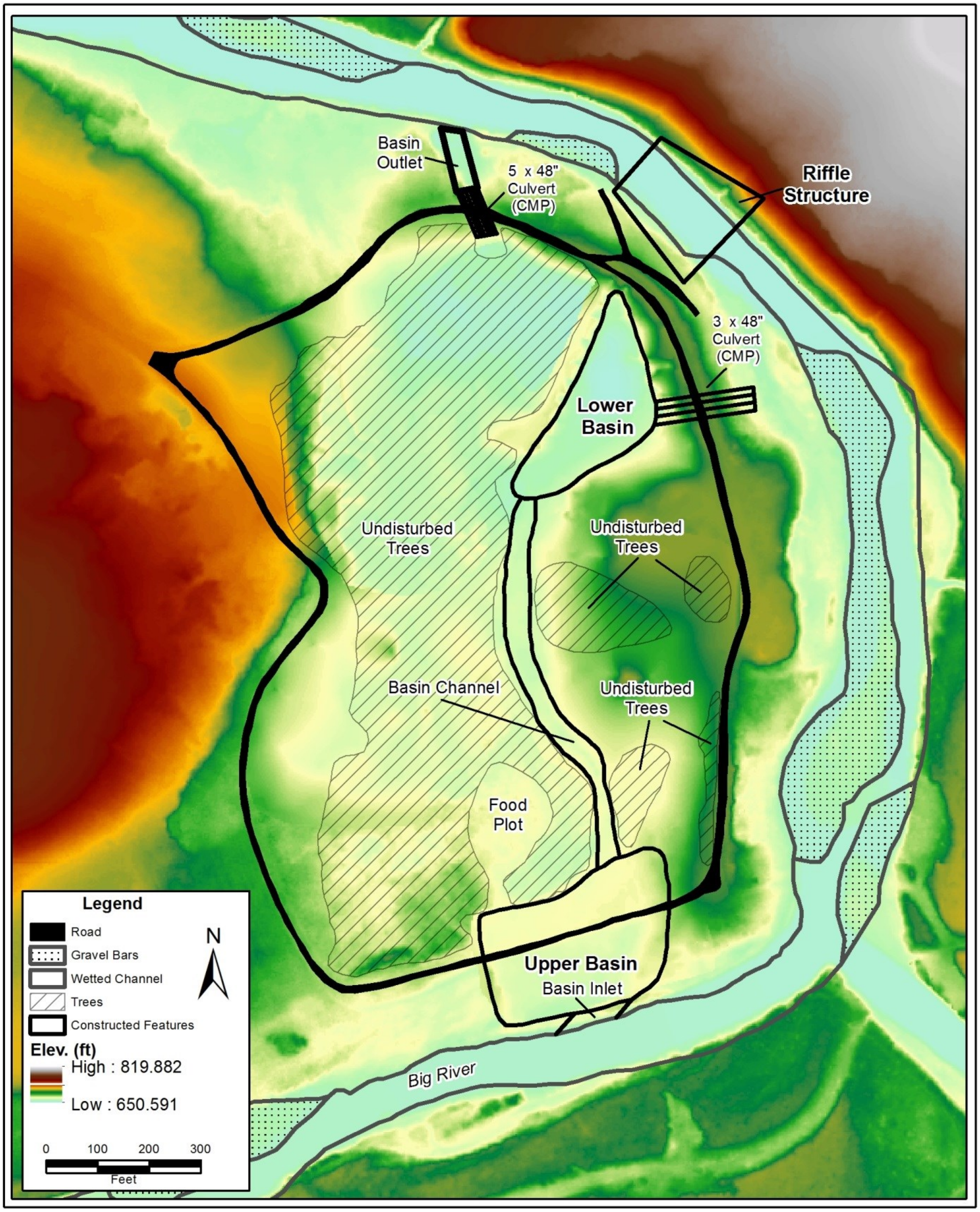

Figure 5. Combined LiDAR DEM with recent survey data included.

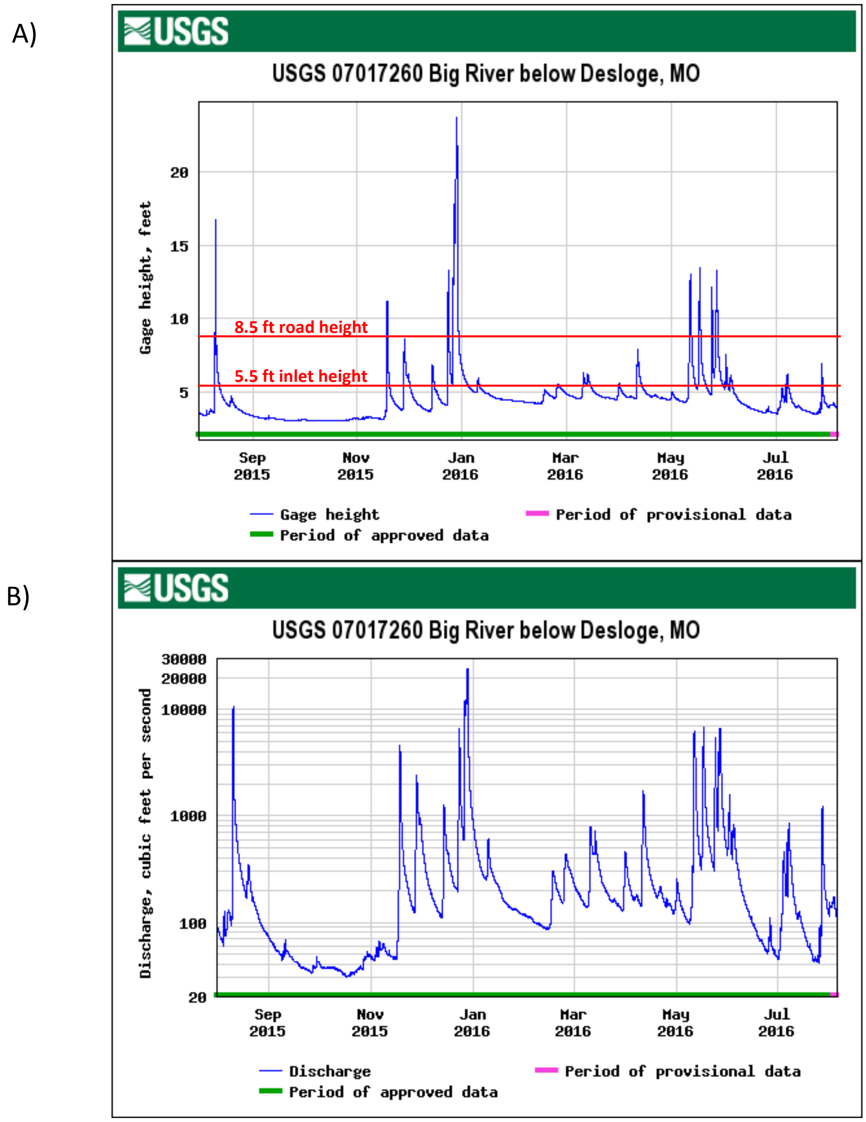

Figure 6. A) Stage height and B) discharge at the Desloge gage from August 1, 2015 to August 5, 2016.

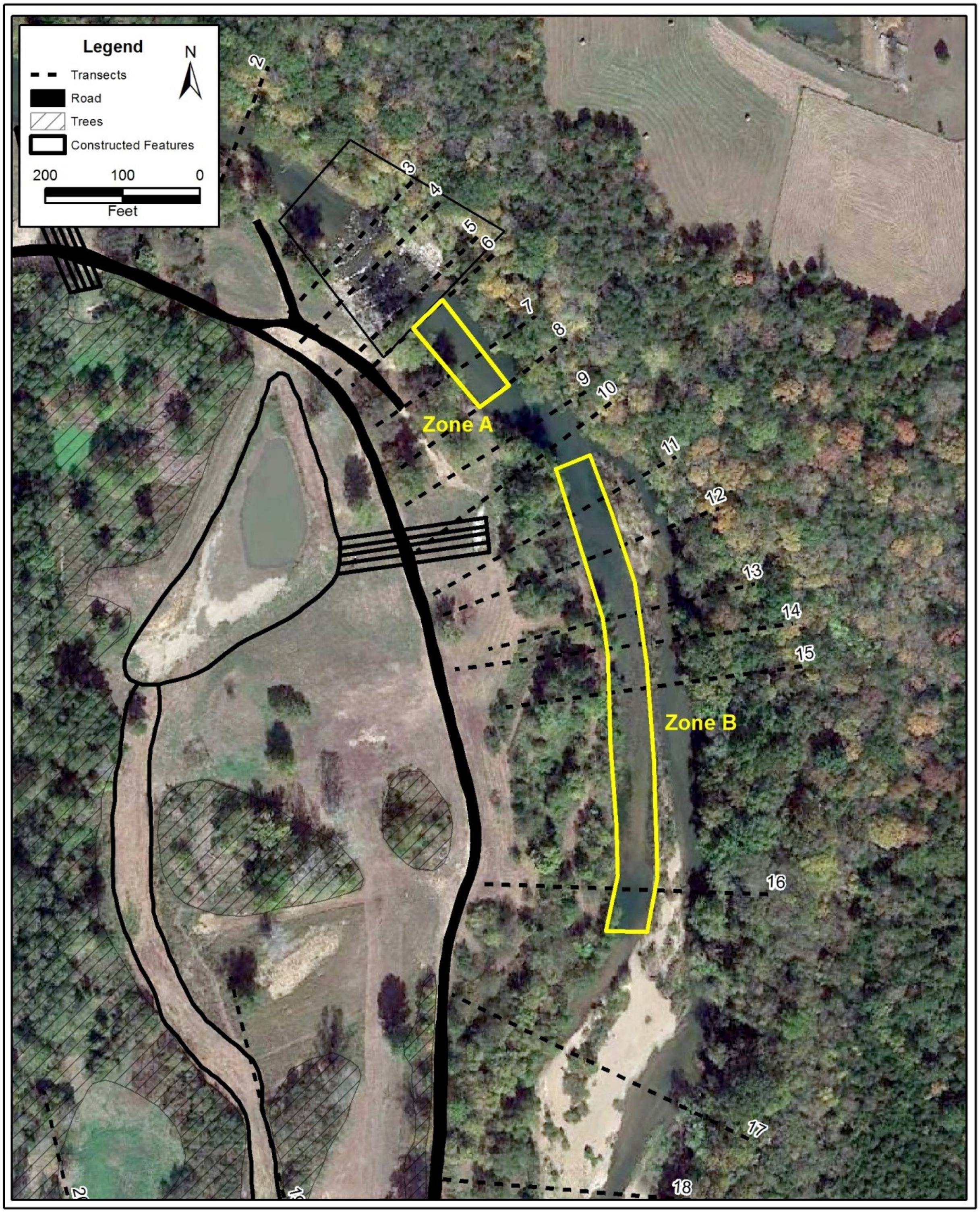

Figure 7. Location of in-channel sedimentation zones.

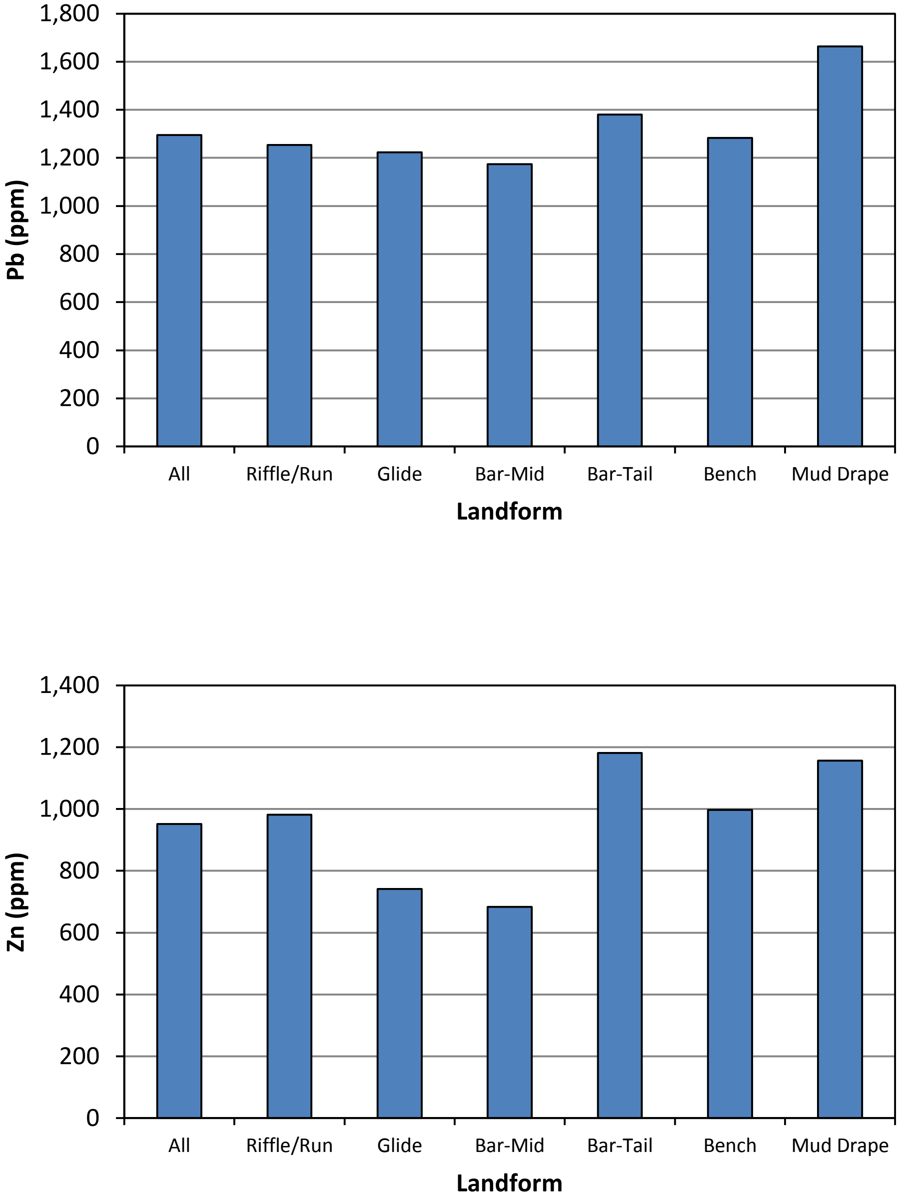

Figure 8. Concentrations of A) Pb and B) Zn from in-channel sediment by deposit type.

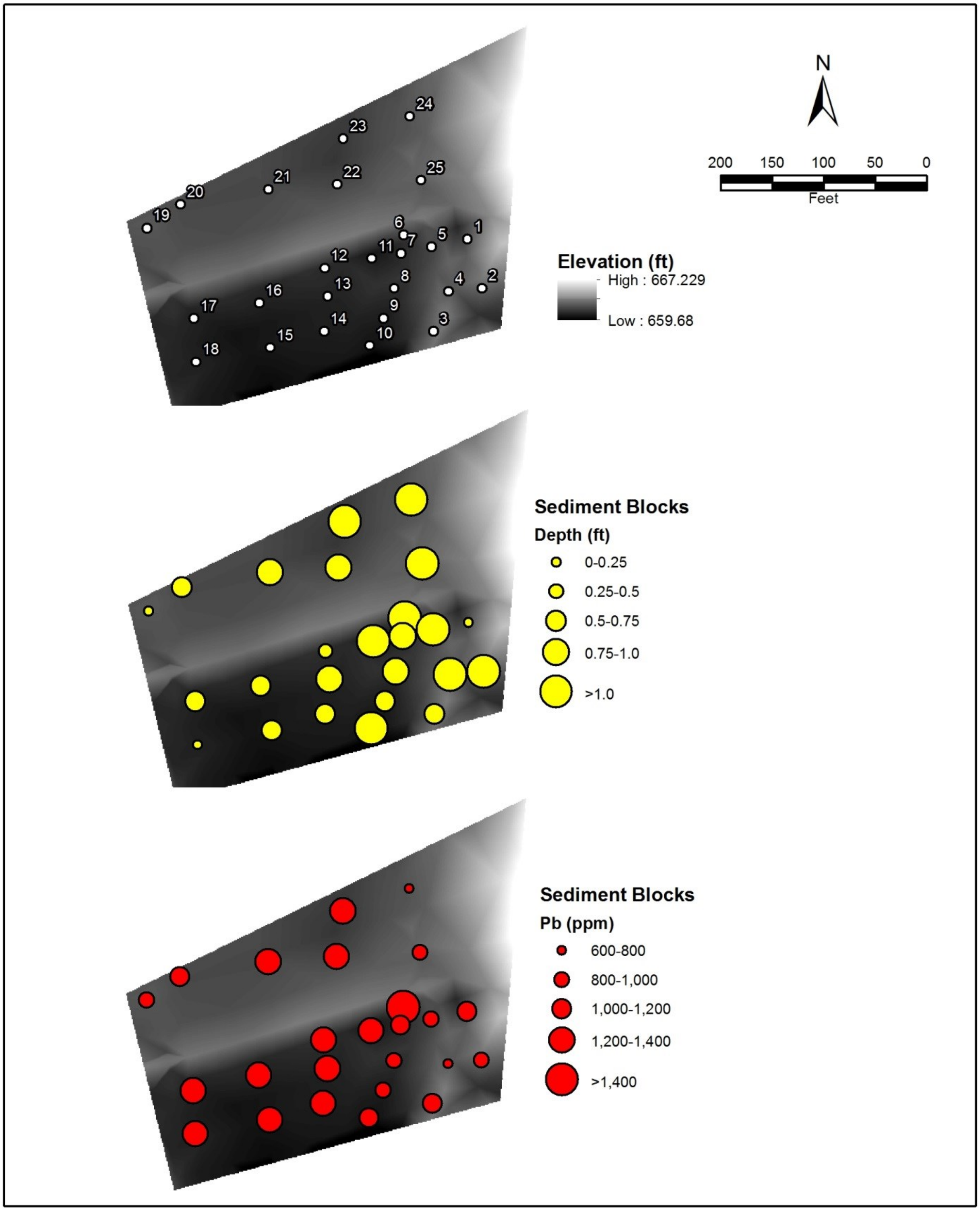

Figure 9. Average depth and Pb concentration of sediment blocks in the upper basin.

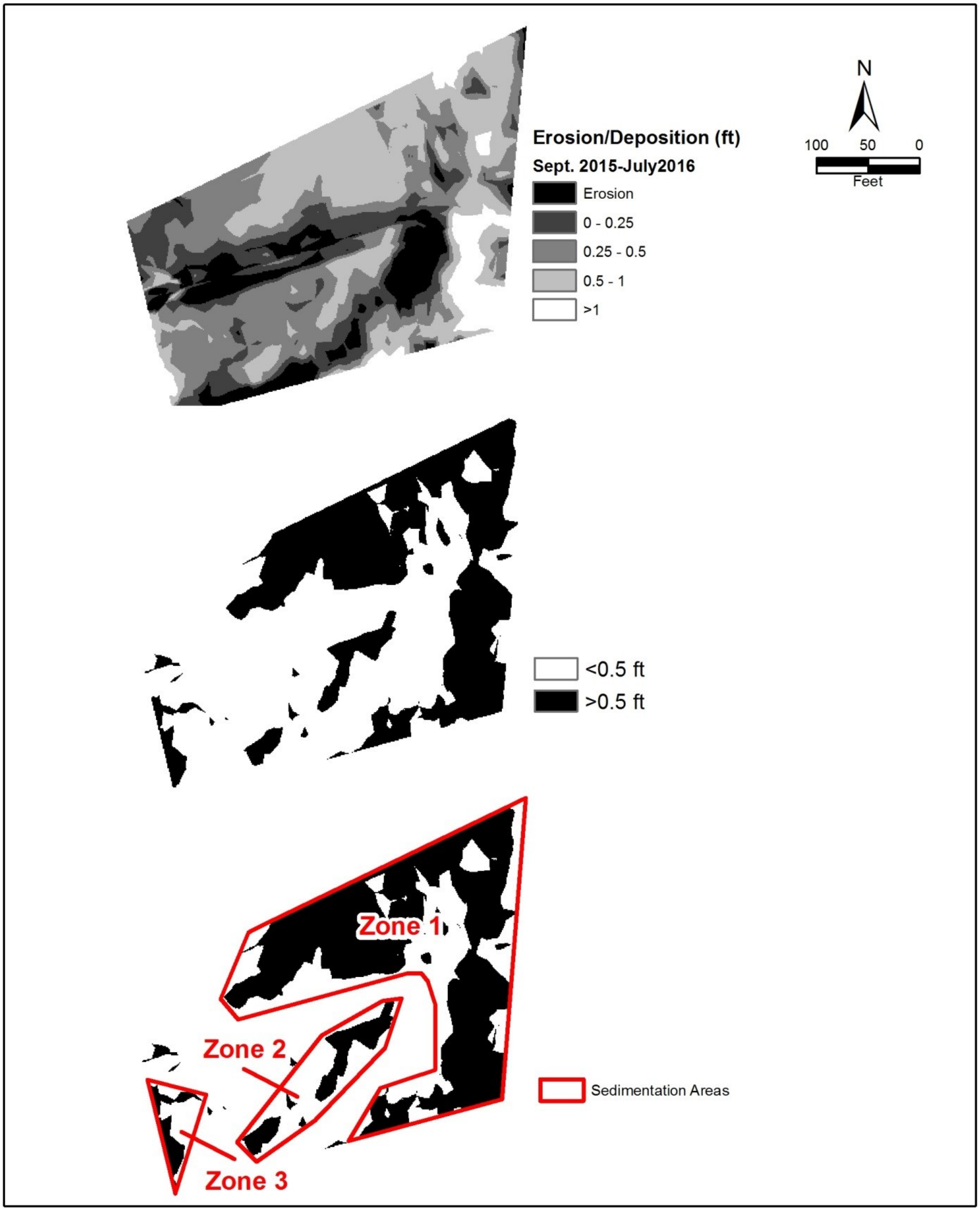

Figure 10. Changes in erosion and deposition in the Upper basin.

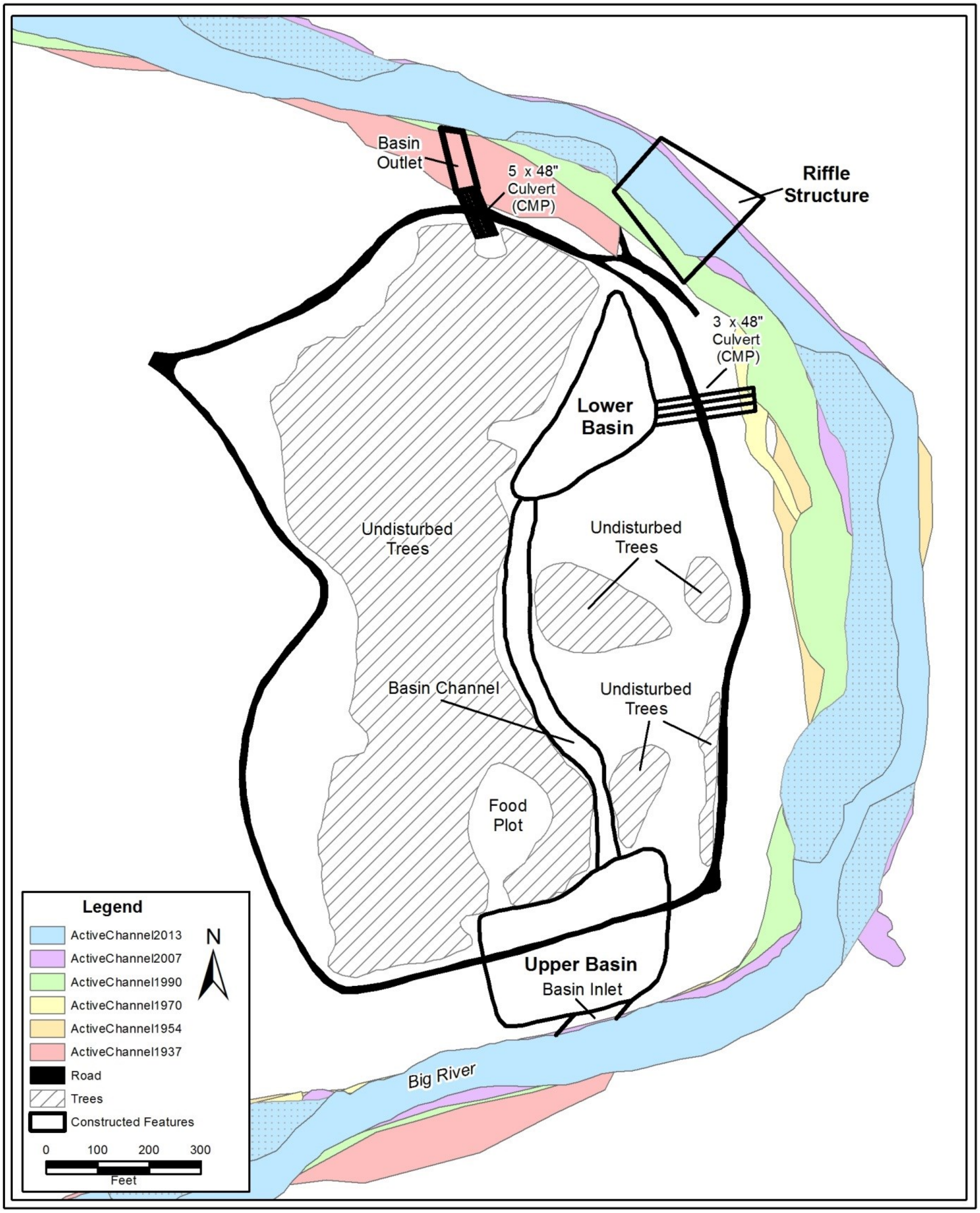

Figure 11. Active channel locations from 1937-2013 at the BRLRS site.

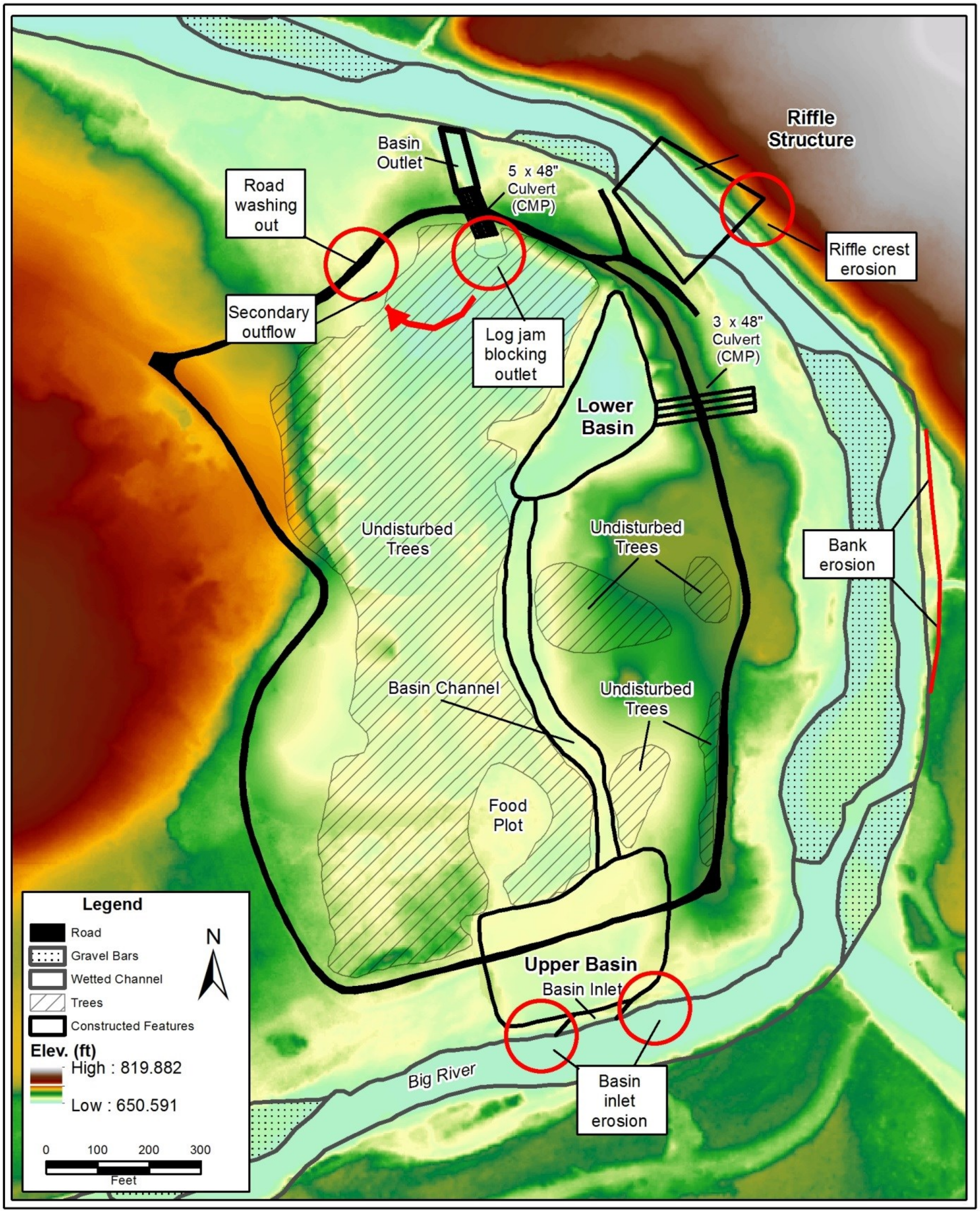

Figure 12. Locations of areas of concern for stability at the BRLRS.

PHOTOS

Photo 1. Constructed riffle at Transect 3 (12/14/15).

Photo 2. Opening to the upper basin (12/14/15).

Photo 3. Upper basin area (12/14/15).

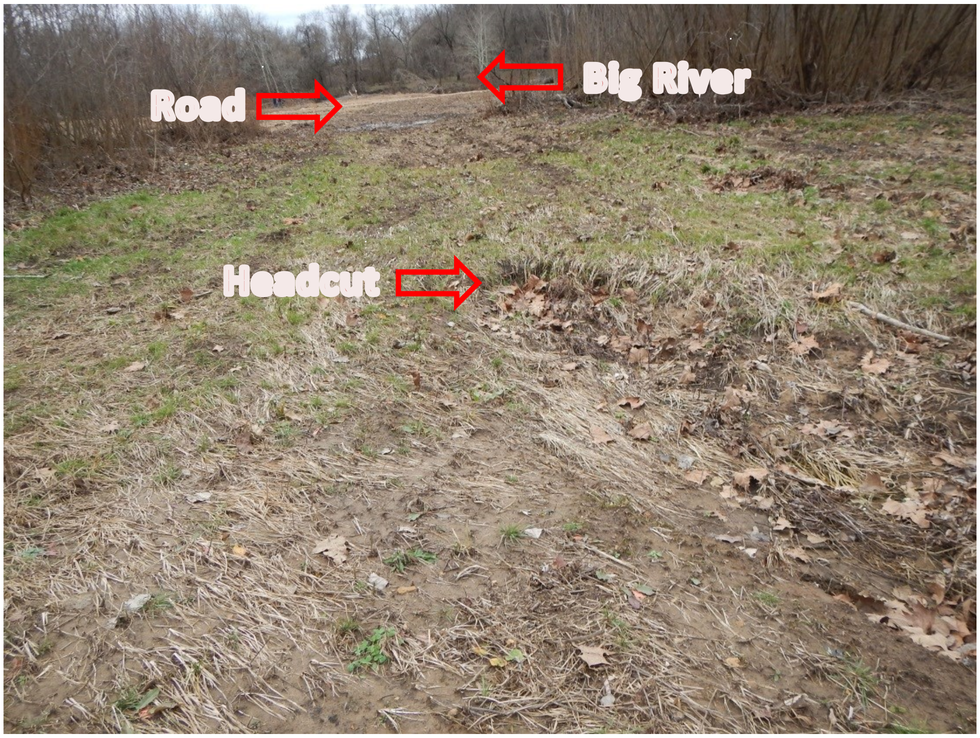

Photo 4. Basin channel opening from the upper basin with headcut (12/14/15).

Photo 5. Basin channel area between the upper and lower basins (12/14/15).

Photo 6. Lower basin wet all year long (12/14/15).


Photo 7. Sediment block #25 and post within the upper basin (9/17/15).

Photo 8. Sediment depth measurements and sample collection from block samplers (1/21/16).

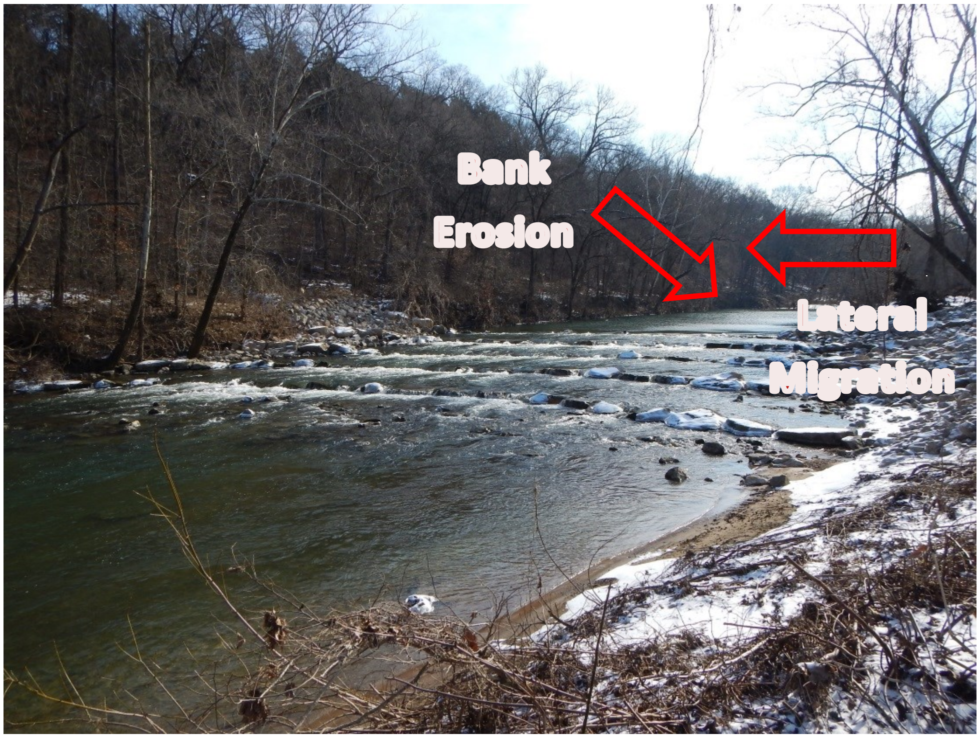

Photo 9. Riffle structure creates high water situation that could weaken bank over time and increase erosion (1/21/16).

Photo 10. Erosion along the right bank near riffle structure crest (1/21/16).

Photo 11. Lowered bank at the upper basin inlet experiencing erosion after several large flood events, upper basin inlet to the right (12/14/15).

Photo 12. Debris jam blocking lower basin secondary outlet (12/14/15).