ENHANCED CONCEPTUAL SITE MODEL FOR THE LOWER BASIN COEUR D'ALENE RIVER

Technical Memorandum Addendum E-1—

Riverbank Characteristics, Erosion Rates, and Lead Contribution

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Riverbank Characteristics, Erosion Rates, and Lead Contribution, Lower Basin of the Coeur d'Alene River (OU3)

PREPARED FOR: U.S. Environmental Protection Agency, Region 10

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1.0 Introduction

This addendum is a supplement to the series of the technical memorandums that make up the Enhanced Conceptual Site Model (ECSM) for the Lower Basin of the Coeur d'Alene River (Lower Basin) (CH2M HILL, 2010a). This and other addendums provide new data, analyses, interpretations, and related information that have become available since publication of the primary ECSM documents in August 2010. This enables the ECSM to remain current and relevant as the remedial investigation and feasibility study proceed. These addendums are grouped under specific ECSM technical memorandum topics to support the individual elements of the ECSM.

The specific purpose of Addendum E-1 is to provide an update to *Technical Memorandum E – Fluvial Geomorphology* (CH2M HILL, 2010b) documenting what is currently known about the banks bounding the main channel in the Lower Basin. Exposed deposits of sediment along riverbanks contain obvious mining and milling-derived material (tailings) and the collapse of undercut banks clearly contributes metals-contaminated sediment that is transported by the river (Exhibit 1). This process, as it relates to recruitment and transport of contaminated sediment, is addressed in this document.

Past efforts to stabilize the riverbanks, conducted by the Kootenai-Shoshone Soil and Water Conservation Service, Silver Valley Natural Resources Trustees, and private property owners, have focused on trying to reduce the rate of bank erosion. A recent pilot project by the U.S. Environmental Protection Agency (EPA) at the Kahnderosa Campground near Cataldo included remediation of a 100-meter section of exposed bank (Maul Foster Alongi, 2014). The primary purpose of the Kahnderosa Campground project was to reduce human exposure by isolating contaminated bank material, with secondary benefits including bank stabilization treatments (vegetative stabilization and riprap) and refining best practices for future remedial actions.

To help guide future efforts regarding bank remediation, EPA and CH2M HILL recognized that a systematic characterization of the composition and erosion rate of the banks was a significant data gap that needed to be addressed in the Lower Basin. Subsequently, additional data were collected, and additional analyses performed on existing data to fill this data gap. This document summarizes the results of these analyses and provides an interpretation of the implications of the findings for management of contaminated sediment in the Lower Basin.

2.0 Purpose and Scope

In the Lower Basin, sediment containing elevated levels of lead and other metals is eroded from the river bed and banks during high flow conditions. Mobilized lead is subsequently deposited in the river bed, in floodplains and off-channel lakes and marshes, or discharged to Coeur d'Alene Lake. The mine tailings present in the riverbanks along the entire 37-mile Lower Basin (from the confluence of the North Fork Coeur d'Alene River and South Fork Coeur d'Alene River to the mouth of the Coeur d'Alene River at Harrison) are visible sources of contaminated sediment to the river (Exhibit 1). The lead in riverbanks is one of multiple sources of lead to the river system, which includes erosion of the river bed, sediment supplied from upstream, erosion of the floodplain surface, and tributaries in the Lower Basin (Bookstrom et al., 2004; CH2M HILL, 2010b). EPA is working with multiple local parties to develop a plan to reduce or eliminate the exposure pathways to humans and wildlife. Understanding the characteristics of the riverbanks and the relative contribution of bank erosion to lead mobilized in the Lower Basin is important for planning effective remedies for the Lower Basin.

The initial ECSM technical memorandum addressing fluvial geomorphology (CH2M HILL, 2010b) listed remaining data gaps and uncertainties relating to landforms and processes. Data gaps included a better understanding of riverbank structure, composition, and erosion rates and processes. The purpose of this addendum is to synthesize past efforts and new field-based studies to characterize the structure, stratigraphy, and composition of the riverbanks, to refine estimates of the rate of erosion of banks, and to develop an approximate estimate of the amount of sediment and lead eroded annually from banks into the Coeur d'Alene River. These estimates will be integrated with other components of the sediment and lead budget, including sediment transport, floodplain deposition, and bed erosion, in *Technical Memorandum Addendum D-3 – Processes of Sediment and Lead Transport, Erosion, and Deposition the Lower Basin Coeur d'Alene River* (CH2M HILL, in review).

In addition to providing a systematic compilation of studies completed by others, this riverbank addendum presents the results of new data collection efforts undertaken since the publication of the ECSM (CH2M HILL, 2010a). This work includes stratigraphic characterization and sampling of exposed riverbanks between the confluence of the North and South Forks and Coeur d'Alene Lake, the collection of 24 sediment cores from the floodplain surface near the banks downstream of River Mile (RM) 148, and detailed measurements of bank erosion rates at five locations using repeat terrestrial LiDAR scanning.

3.0 Background

3.1 Previous Studies

The visible nature of exposed tailings and collapsing riverbanks has instigated several studies and projects to better understand the composition of the banks and to reduce rates of bank erosion. The summary of related work presented in *Technical Memorandum E – Fluvial Geomorphology* (CH2M HILL, 2010b) describes some of this work in detail. An updated summary of bank studies is presented below:

- Rates of riverbank erosion have been estimated by Wetzel (1994), Flagor (2002), and Box, et al. [unpublished data, 1996 to 2002, as cited by Bookstrom et al. (2004)]. The results of these studies are summarized by Bookstrom et al. (2004), and are discussed further in subsequent sections of this technical memorandum.
- Kootenai-Shoshone County Soil and Water Conservation District (KSSWCD, 2009) has monitored a set of bank pins throughout the Lower Basin since June 2008. They also applied the Bank Assessment for Non-point Source Consequences of Sediment (Rosgen, 2006) model, which typically over-predicted bank erosion rates compared with the monitoring results. The KSSWCD bank pin data were reanalyzed along with other data in the compilation presented below.
- Possible remedial alternatives for the Lower Basin were outlined in the Operable Unit 3 Record Decision (EPA, 2002), which included bank stabilization efforts and removal of the "bank wedge" to reduce transport of contaminated mine tailings. A list of eroding bank areas was recommended for stabilization efforts.
- Informal correspondence among S. Box, W. Rust, and J. Rowland between 2003 and 2004 outlined a range of ideas about the composition and structure of the riverbanks, erosion processes and rates, and potential implications for remedial action. These correspondences include notes prepared by S. Box (USGS) for a field trip to the Lower Basin. The discussion by S. Box hypothesized, among other things, that bank erosion was a secondary contributor to lead loading in the Lower Basin. He pointed out that the river has been generally stable since before the onset of active mining in the Upper Basin, though did not provide documentation of this assertion. These correspondences also brought up the question of boat wakes as a contributor to bank erosion, and the suggestion that water velocities along most of the bank lines would be insufficient to erode the banks. Furthermore, S. Box presented some unpublished data on bank retreat rates in the Lower Basin (Exhibit 2). This exchange identified better quantification of the bank erosion contribution of lead, and more detailed information about the composition and structure of the riverbanks, as data gaps. Filling these data gaps was one of the purposes of the additional sampling, and this technical memorandum. The correspondence is included in its entirety as Attachment A.
- Bookstrom et al. (2001; 2004) characterized the stratigraphy and composition of floodplain material by compiling geomorphic mapping with data from cores in a variety of environments. They developed an overall stratigraphic model for the riverbanks, and estimated (based on available data) that the contribution of riverbank erosion amounted to between 8 and 16 percent of the total amount of lead transported past the Harrison gage.

3.2 Bank Erosion Control Efforts

With funding from Federal and state sources as well as contributions by private landowners, efforts have been implemented along the river to stop, or slow, the rate of riverbank erosion. The amount of armored bank was assessed in July 2008 and updated in June 2009 by the KSSWCD, which estimated that a total of 15.3 miles (or 28 percent of the total length, counting both banks) of the river was stabilized or armored as a result of human intervention (KSSWCD, 2009). This estimate does not include riverbanks that have been armored since 2009.

3.3 Conceptual Model of Bank Erosion Processes

Those who live and recreate along the river are familiar with the eroding banks and efforts to stabilize eroding banks with rock, vegetation, and other materials, as shown in Exhibit 1. Bank erosion is a natural process in most river systems; however, local conditions can exacerbate the rate of bank erosion. Exhibit 3 illustrates the current conceptual model of the cyclical process of bank erosion, which is accelerated in the absence of a deep-binding root mass of vegetation or armoring. In addition to seasonal high river flows, hydraulic forces resulting from wind waves and boat wakes can contribute to bank undercutting.

Banks that are undercut collapse in blocks approximately 0.3 to 1 m (1 to 3 feet) thick and as much as a meter high. Collapsed blocks collect at the toe of the slope until they are eroded. Some collapsed blocks are bound together by grass or root mats, reducing the rate of disaggregation. These blocks may remain at the toe of the bank for months to years. Thus, contaminants such as lead are gradually released from the riverbank into the water. Though bank collapse may occur in a matter of seconds, complete erosion (and release of contaminated particles) may take years. This model of bank erosion is similar to the conceptual model presented a decade ago by S. Box (Attachment A).

3.4 Historic River Migration

Erosion of riverbanks is connected with lateral migration of meandering rivers. In general, as banks retreat on one side of the channel, deposition and floodplain formation occurs on the opposite side; if this did not occur, the channel would widen indefinitely. Often bank erosion is concentrated on the outsides of river bends, forced by the formation of bars on the insides of bends. Therefore, the rate of lateral migration of a river, or its planform change, may be interpreted as a general indication of the rate of bank erosion.

The oldest available maps showing the river planform are those from the General Land Office (GLO) (http://www.glorecords.blm.gov/), which represent a compilation of surveys between 1890 and 1910. These show the river before the onset of most of the major impacts from mining. GLO maps were compared with more recent maps of the river to help evaluate the amount of lateral river migration over the past century and qualitatively assess the importance of bank erosion in this river. To do this, the GLO maps were downloaded and georeferenced and the bank lines depicted on these maps were digitized. In addition, bank lines were digitized using aerial photographs from 1937, 1965, 1968, 1975, and 2009; bank lines were defined along the interpreted boundary between mature vegetation and water. The results are shown in Exhibit 4. It should be noted that for clarity, not all banklines are shown in this exhibit - below Cataldo, where little change occurred since the earliest maps, only the banklines for the early GLO maps (compilation of 1890 through 1910) and the most recent (2011) aerial photo bank lines are displayed; banklines for the intermediate dates are not included. The overlay shows substantial changes in the Cataldo Reach (panel D) but virtually no channel changes downstream of Cataldo (panels A through C).

As described qualitatively by S. Box (Attachment A) and by CH2M HILL (2010b), Exhibit 4 shows that the 30-mile reach between Cataldo and Harrison (shown in Exhibit 4 Panels A through C) experienced almost no detectable lateral migration for more than 100 years. In contrast, the 7-mile long reach upstream of Cataldo (Exhibit 4 Panel D) shows active channel change, not only from meander migration but from channel widening and narrowing, the formation and movement of mid-channel vegetated islands, and from avulsions (the channel suddenly occupying a different course).

The behavior of the downstream reach (Exhibit 4 Panels A through C) is different from many river systems in the Pacific Northwest, which typically experience active channel changes from gradual migration or during large floods. The lack of significant channel change in the lower reaches of the Coeur d'Alene River is especially striking because the period of record encompasses more than a century that included at least three major floods (1933, 1974, and 1996). Moreover, this period also includes major impacts on the river that include large discharges of mine waste, the construction and subsequent collapse of sediment-containing dams in the watershed, as well as downstream base level changes from the construction and raising of the Post Falls Dam. As suggested by CH2M HILL (2010b), in *Technical Memorandum E – Fluvial Geomorphology*, the lack of channel migration in the downstream reach is likely a result of multiple factors including the backwater effect from Coeur d'Alene Lake and the presence of controls such as Interstate 90, State Highway 3, bridge crossings, former railroad and road embankments, and dikes. In addition, the lack of lateral migration may partly reflect the nature of the native bed and bank material—as parts of the channel appear to be carved into relatively cohesive deposits—and a relative scarcity of bed load sediment supply that enters from upstream, which reduces the rate of formation and growth of point bars. The raising of Post Falls Dam in 1942 likely further contributed to the lack of lateral migration of the downstream, sand-bed reach.

A more comprehensive examination of the recent history of lateral channel changes based on these data is compiled and interpreted in TM E-4, Riverbed Historic Planform Changes (CH2M HILL, 2013b)

Although the overall rate of channel migration and bank erosion appears relatively minor on the Coeur d'Alene River compared to many river systems, active bank erosion is apparent (e.g., Exhibit 1). The rate of bank erosion and the relative contribution of lead resulting from bank erosion are addressed further in Section 5.0.

4.0 Bank Characterization

Building on the work of Bookstrom et al. (2004), CH2M HILL conducted field investigations between September 2011 and June 2012 to more systematically characterize the composition and structure of riverbanks that are susceptible to bank erosion. The investigation involved reconnaissance-level stratigraphic characterization and mapping (describing the subhorizontal layers of the exposed soil surface in bank faces), followed by an effort to quantitatively measure and sample stratigraphic sections of the exposed banks. The stratigraphic units were identified by discrete stratigraphic boundaries, as described further below. In addition, work in summer 2012 included collecting subsurface sediment cores (vertical) from the riverbed, riverbanks, and floodplain. The riverbed coring work is discussed elsewhere, but the results of the sediment cores collected in the proximal floodplain areas are relevant to the discussion of the bank structure and composition, so are presented here.

4.1 Characterization Methods

4.1.1 Field

Exposed Bank - A CH2M HILL team conducted reconnaissance and measured stratigraphic sections of exposed banks in August, 2011. More systematic stratigraphic measurements and sampling were conducted between November 2011 and January 2012 at 17 bank exposures throughout the Lower Basin (Exhibit 5). Sampling locations were selected to represent typical eroding bank conditions and to provide geographic coverage of the entire Lower Basin (RMs 131 to 168) at representative intervals. At each site, a geologist measured and recorded the stratigraphic sections using the stratigraphic model developed during the reconnaissance (and discussed further below). Field descriptions of each layer of each of the 17 bank exposures are provided in Attachment B, while Attachment D contains annotated photographs of all 17 bank exposures. After delineating stratigraphic boundaries, and clearing the exposure to reduce cross-contamination and ensure a representative sample, a single sample was collected from each stratigraphic unit. Each sample (with one exception) was collected as a composite of the entire stratigraphic unit. At one location (RM 144.1 L), multiple discrete samples were collected within a single stratigraphic unit to begin to evaluate variations or trends within the tailings-rich layer.

Bank Cores – Cores were collected from near-bank floodplain surfaces in June 2012 as part of a larger effort to obtain core transects across the active part of the valley. The effort focused on the river bed, but in three of these transects, cores were also obtained on both banks using a small, hydraulically-powered, direct-push device (Geoprobe) (Exhibit 6). Only these bank cores are discussed in this report. Riverbank cores were collected from points as close to the bank as possible to a distance up to 200 feet from the bank line, and at two to three intermediate locations. Riverbank cores were obtained at RMs 135.5, 144.7 and 147.7 to provide geographic coverage and allow sampling on public property. Cores were 4 feet in length. Core barrels were opened and the stratigraphy documented (Exhibit 6). The cores were scanned using a hand-held X-ray fluorescence (XRF) unit to measure the approximate transitions between stratigraphic units, and composited confirmatory samples were then obtained from within the stratigraphic intervals. The locations of cores were recorded with GPS. Cores were documented with photographs as well as detailed field notes.

4.1.2 Laboratory

The bank characterization samples of the exposed banks were analyzed for grain size distribution by a private laboratory. Metals analyses on the bulk samples were performed by an EPA contract laboratory under the Contract Laboratory Program (CLP), which also sieved the bulk samples and performed separate metals analyses on the fines (<63 micrometers [μm]) and fine sand (63–250 μm) subfractions of each sample. After handling irregularities with the grain size subsamples were discovered, the subsamples were resubmitted for sieving and reanalysis to another EPA CLP laboratory (the bulk samples were not affected by this irregularity, so bulk sample metals were not reanalyzed).

Samples from the riverbank cores were analyzed for grain size by the same laboratory used for exposed bank samples. The samples were analyzed for metals by two separate EPA contract laboratories. Analytical data from the bank cores are presented in Attachment C.

4.2 Revised Stratigraphic Model

Repeated observations of the stratigraphy in exposed riverbank faces indicate that the units observed in riverbanks are consistently definable throughout the Lower Basin (Exhibit 7).

4.2.1 Bank Material Stratigraphic Units

Exposed banks consistently contained three distinct stratigraphic units (or a subset thereof), labeled from top to bottom (youngest to oldest) as A, B, and C. The stratigraphic units are described below as stratigraphic unit descriptions and interpretations, and are illustrated with the photograph in Exhibit 7 and the conceptual diagram in Exhibit 8:

- Unit A—Silty sand or sandy silt, light brown to gray. Poorly bedded, except where thin layer of white volcanic ash (Mt. St. Helens, 1980 eruption) is present. The A1 and A2 units are separated by the ash layer, with A1 above and A2 below. Unit A is interpreted to represent overbank sediment deposition following 1968, when cessation of direct discharges of mine tailings into the river are believed to have reduced the volume and characteristics of suspended sediment in the Lower Basin. The relative similarity in thickness of Units A1 and A2, separated by the ash layer, also suggests similar time frames (1980 to present = 33 years and 1968 to 1980 = 12 years).
- Unit B—Brown-orange silt, sand, and clay, rust colored. Finely bedded to blocky structure. Contains high concentrations of metals that generally decrease from bottom to top. Two subdivisions within unit B were tentatively identified: a lower, possibly finer-grained unit with blocky structure (B2) and upper, sandier unit with wavy bedding structure (B1). The two units, where they are both present, are separated by a gradational contact. It is not clear whether these two observed subdivisions constitute distinct depositional units, or different facies, or if they reflect post-depositional processes leading to their different characteristics. Unit B is interpreted as dominantly mine tailings deposited during the period of most active mine tailings disposal into the South Fork Coeur d'Alene River. The upper boundary is a sharp depositional contact, and is overlain by Unit A. The lower boundary is a sharp depositional contact, and is underlain by Unit C.
- Unit C—Poorly stratified mud, gray. Silt and clay with metals at background concentrations. Unit C is interpreted as consisting of mostly Pleistocene lacustrine mud deposited in glacial Lake Columbia, long before the advent of mining activities in the Upper Basin, with a minor component of more recent, but pre-mining, fluvial deposits of the Coeur d'Alene River. The upper boundary is a sharp depositional contact, and is overlain by Unit B.

Exhibit 8 schematically illustrates the conceptual relationships and characteristics of the stratigraphic units in the exposed banks. In addition to the three stratigraphic layers listed above, the model includes recently deposited sandy beach deposits exposed at lower water (Unit D) and collapsed block material at the base of banks (Unit E), composed of portions of units A, B, and C. In some places, cemented and uncemented river gravel has been observed underlying Unit C, particularly within the Cataldo Reach (Exhibit 5). The collapsed blocks and recent sandy deposits near the toe of the bank represent sediments that are most readily available for mobilization and downstream transport.

Where present, the field investigation sampling included the shoreline deposits (Unit D) and the collapsed blocks (Unit E) present at the base of banks (Exhibit 3).

4.2.2 Relation to Stratigraphic Model of Bookstrom et al. (2004)

The stratigraphic model illustrated in Exhibit 8 is fundamentally consistent with the stratigraphy of Bookstrom et al. (2004), but is also distinct from it, in that the current model is based on a *lithostratigraphic* approach (that is, based on lithology—the physical and chemical characteristics of the units—and on their relative ages), whereas the model proposed by Bookstrom et al. (2004) is based on a *time stratigraphic* characterization (based on absolute age time horizons, independent of lithology). The time-stratigraphic markers identified by Bookstrom et al. (2004) were the base of contamination (assumed to represent the year 1903, as explained on p. 18 of their report); the 1980 Mt St. Helens ash layer (where present); and the surface at the time of sampling (generally mid-1990s).

These two characterization approaches are entirely consistent with one another, but have different purposes. The current model distinguishes between the types of sediments found in the banks in order to guide reasonable and repeatable sampling at bank exposures and to interpret the history of fluvial processes. In contrast, the work by Bookstrom et al. (2004) was primarily geared towards inventorying the amount of sediment and contamination, for which purpose a time-stratigraphic approach is more appropriate. A lithostratigraphic approach is used for this effort because it provides a basis for sampling and more insight into the history of the system processes.

4.3 Characteristics of Exposed Bank Sediments

Based on the stratigraphic model detailed above, bank exposures were measured and sampled at 17 sites in the Lower Basin (Attachment B). Each sample was assigned to a stratigraphic unit, and, to assess downstream patterns, the data were subdivided into four contiguous river reaches as shown in Exhibit 5. In general, at each exposure, a single sample was collected from each stratigraphic unit (though at one location multiple discrete samples were collected to assess variability within the unit; this is discussed below in section 4.3.1). In some exposures, differences between subunits (A1 and A2, B1 and B2) were obvious; however, in other locations, either the Mt. St. Helens ash was absent or there was no obvious transition between B1 and B2, so samples collected were assigned to Unit A or B, as appropriate. The analytical results (grain size distributions and lead and zinc concentrations) for the bank surface stratigraphic samples are summarized in Attachment C.

4.3.1 Results of Bank Sampling

Typical Contaminant Stratigraphy

An example of stratigraphic and analytical results is shown in Exhibit 9. The sample location was at RM 144.1, near Medimont, and illustrates patterns within and among stratigraphic units. Fine-scale sampling of the Unit B segment was conducted to examine variability in lead concentration within the tailings-rich stratigraphic unit, which is generally representative of other locations through the Lower Basin. Photographic and analytical results for each of the 17 bank exposures are presented in Attachment D.

The bulk lead concentration in the upper-most layer - Unit A1 (3,910 milligrams per kilogram [mg/kg]) - was slightly lower than in Unit A2 (5,510 mg/kg), with the two sub-units separated by the Mt. St. Helens Ash Layer from 1980. The ash layer provides a distinct time marker and allows accurate characterization of material deposited since 1980.

The underlying Unit B typically shows two subdivisions, with both exhibiting a rusty color and generally fine-grained structure. Lead concentrations were 4,260 mg/kg in Unit B1, and 9,380 mg/kg in Unit B2.

High-resolution sampling was conducted at the RM 144.1 location to provide data on stratification within the tailings-rich Unit B. Concentrations ranged from around 4,000 mg/kg at the upper boundary to nearly 16,000 mg/kg at the bottom. This indicates that the oldest tailings are more contaminated than those deposited more recently. Furthermore, gradual decrease in lead concentration between Units B2 and B1 suggests that the sediments within Unit B were not emplaced all at once, but were deposited by multiple floods. A variety of factors may be reflected in the pattern, including changing ore milling practices, the amount and characteristics of material stored historically behind plank dams or on the river bed, and the timing and mechanics of flood events.

The lead concentration in Unit C at the location shown in Exhibit 9 was 30 mg/kg, demonstrating the several order-of-magnitude difference in metals content between the pre-mining native material and the overlying contaminated layers. The slump blocks at this location contained 7,470 mg/kg lead, suggesting their source to be Unit B. Beach deposits at the same location contained 2,170 mg/kg lead, indicating that the sediment was similar to that actively transported by the river, and similar to, but slightly less than, Unit A1 (interpreted as recent overbank sediment deposits).

Results of Bank Sampling

Bank sample lead concentration data are summarized in Exhibit 10 and detailed in Attachment C. These data illustrate the differences in the lead and zinc concentrations among the different stratigraphic units, and indicate longitudinal changes in lead concentrations through the Lower Basin. Observations regarding these data are as follows:

- The highest lead concentrations are in the lower portion of Unit B (the early tailings-rich deposits), and directly overlie the lowest concentrations in Unit C (the pre-mining sediments). Unit B2 has a mean lead concentration of 12,700 mg/kg (median value: 10,000 mg/kg), and Unit C has a mean concentration of 67 mg/kg (median value: 31 mg/kg) (Exhibit 9).
- There are notable differences in the Zn/Pb ratios among the different stratigraphic units, with premining sediments (Unit C) having the highest ratio (mean and median = 7.49 and 6.58, respectively) and the earliest mining deposits (Unit B) having the lowest values (0.47 and 0.33). Recent floodplain deposits (Unit A) have intermediate Zn/Pb ratios (2.18 and 0.69). One explanation for this pattern is that the recent floodplain deposits contain a mix of contaminated and uncontaminated sediment and therefore have an intermediate ratio. Box et al. (2005) stated that metal-enriched floodplain sediment can be identified by Zn/Pb ratios less than 1, because of leaching of Zn from soils exposed at the surface. This process may also contribute to the lower ratios in the upper deposits (Unit A) as compared with the buried ones (Unit B).

- The deposits overlying the tailings-rich Unit B, referred to as Unit A and interpreted as overbank floodplain deposits post-dating the end of active mine tailings direct disposal upstream, generally have intermediate concentrations: 3,300 mg/kg for the post-1980 (Unit A2) and 4,700 mg/kg for the deposits thought to date to between 1968 and 1980 (Unit A1). The difference between these suggests that concentrations of lead on sediment in suspension have decreased over time. This observation is in partial agreement with the finding of Bookstrom et al. (2004; p. 31), who found that overall lead concentrations in deposits on the entire floodplain (including banks, levees, lakes, and marshes) decreased by about 13 percent after 1980 as compared with the 1968-1980 interval.
- Lead concentrations within most stratigraphic units tend to decrease in the downstream direction. Concentrations in sediment from Unit B (both B1 and B2) are highest upstream (Cataldo Reach), and concentrations are lowest in the downstream reach (Springston) (Exhibit 10). The earliest tailings-rich deposits (B2) in the Cataldo Reach are more enriched in lead (mean concentration 21,200 mg/kg, median 22,500 mg/kg, range 7,500 to 32,000 mg/kg) than other reaches. There is a similar pattern for samples taken from eroded blocks, which are assumed to have been derived primarily from Unit B.
- Concentrations of lead in shoreline, or beach, deposits (Unit D) are generally lower than any of the bank units (except for the uncontaminated sediments in Unit C.

Sediment particle sizes also show consistent patterns through the Lower Basin (Exhibit 11). The following interpretations summarize grain size data from bank material:

- Most sediment in exposed banks is generally fine-grained, in the silt (4–63 μm) or very fine sand (63–125 μm) ranges. Fine and medium sand-sized sediments (125–500 μm) comprise only a few percent of bank material, and coarse sand and gravel are absent.
- Unit A, consisting of recent overbank floodplain deposits, is composed of silty very fine sand (Exhibit 11).
- Unit B, the tailings-rich stratigraphic unit, contains finer-grained material than Unit A, and can generally be classified as sandy silt. The lower tailings unit (B2) is generally more fine-grained, and the only one of the units that has greater than 50 percent fines on average.
- The grain size distribution of the slump blocks most closely resembles that of Unit B, indicating that this unit was the dominant source of the blocks.
- The grain size distributions of the "shoreline" or beach deposits is dominated by sand, and most closely resemble Unit A, but with a lower portion of silt; this material appears to be sediment transported and exchanged with the channel. Silt-size particles compose less than 25 percent of the shoreline deposits.

Overall patterns in bulk lead concentrations and stratigraphic unit thicknesses throughout the Lower Basin are summarized in Exhibit 12A. These general patterns are interpreted as follows:

- Total bank heights generally decrease in the downstream direction. This, combined with a tendency of higher lead concentrations in the upstream reaches, imply that bank erosion in the upstream (Cataldo and Dudley) reaches probably contributes more lead to the river than the downstream (Springston and Killarney) reaches.

- The thickness of Unit A – interpreted to be post-1968 overbank deposition—does not appear to change systematically in the downstream direction, but varies between about 10 and 40 centimeters (cm). The thickness of Unit B also does not change systematically, but varies considerably between sampling sites, from about 15 cm to 170 cm.
- The thickness of Unit B varies inversely with that of Unit C (Exhibit 12A; compare relative thicknesses of green versus red and orange bars). This pattern suggests that where banks were lower, a greater quantity of the tailings-rich material was able to leave the channel and deposit on the banks.
- Lead concentration in bank material decreases in the downstream direction. Exhibit 12 provides a more detailed display of the general trend illustrated in Exhibit 10; Unit B segments contain highly contaminated (> 20,000 mg/kg lead) layers in most reaches of the Lower Basin, but their abundance is greatest upstream. In the Cataldo Reach, much of the post-mining bank material is composed of such layers, but the frequency and thickness of these deposits generally decreases in downstream reaches.

The inventory of lead in the bank exposures, by reach, is shown in Exhibit 12B. These values were calculated by multiplying the bulk lead concentration in each stratigraphic unit by the unit's corresponding thickness (assuming a bulk density for riverbank material of 1.51 metric tons per cubic meter (m^3), as cited by Bookstrom et al. (2001)), and assuming a width and depth of 1 meter. The inventories shown here provide an estimate of the amount of lead that would be released (over time, as the collapsed blocks erode) by a collapse of 1 cubic meter of corresponding bank material. Observations and interpretations are as follows:

- Unit B accounts for most (82 percent) of the lead inventory in the riverbanks; Unit A accounts for almost all the remaining lead, and virtually no lead is in Unit C. Thus, the amount of lead present in erodible banks generally mirrors the thickness of Unit B present in the banks.
- The inventory of erodible lead generally decreases in the downstream direction, with most of the erodible bank lead within the Cataldo Reach.
- Efforts to reduce the amount of lead entering the Coeur d'Alene River via bank collapse may be most effective if they are concentrated in the upstream (Cataldo to Dudley) reaches.

4.4 Floodplain Shallow Cores

Riverbed sediments were cored and sampled at eight transects throughout the Lower Basin in June 2012 (Exhibit 13). Three of these transects included cores of the near-bank floodplain (between 0 and 200 feet from the bank edge). Bank cores were collected at Springston Marsh/Bare Marsh (RM 135.5), Medimont (RM 144.7) and Strobl Marsh (RM 147.8). The transects are all in relatively straight river reaches with channel widths ranging from 75 to 90 m (250 to 300 feet). These bank cores are described below.

Subsurface transects of the core data are illustrated in Exhibits 14A, 14B and 14C. The coring data summarized in Exhibit 14 show the following:

- The depth of contamination is much deeper beneath the bed than on the floodplain.
- The depth of contamination and lead concentrations appear relatively constant in the banks among the three transects, which were separated by a total of about 12 miles.

The lead concentrations, stratigraphy, and profiles in the floodplain cores are similar to those seen in the exposed banks—that is, thin overlying deposits of sandy material with lead concentrations between about 3,000 and 7,000 mg/kg, overlying slightly thicker deposits containing higher lead content (typically 5,000–15,000 mg/kg).

One of the key observations of bank cores is the thickness of contamination, which represents the floodplain surface in about 1903, when the first contaminated sediments arrived in the Lower Basin (Bookstrom et al., 2004). This, combined with the 1980 Mt. St. Helens ash layer, allows bounding of deposition rates between these dates. Exhibit 15 compares the depths of these two stratigraphic horizons in shallow floodplain shallow cores relative to distance from the edge of the channel. These plots suggest the following:

- Contaminated sediment is present at the surface of the floodplain in all samples, including one 60 m (200 feet) from the bank.
- The depths of contamination in the floodplain shallow cores vary from about 0.1 m to a maximum of 2.1 m. These thicknesses are comparable to the observed thicknesses of contamination in the exposed banks (Exhibit 12A).
- The Mt. St. Helens ash layer was present in 15 of the 25 cores.
- Where present, the Mt. St. Helens ash layer was mostly within a narrow range of depths between 6 and 45 cm, suggesting typical floodplain deposition rates in the range of 0.2 to 1.4 cm per year (cm/year). The deepest ash layers were found in three samples near the edge of the channel at Strobl Right (27 cm), Medimont Left (33 cm), and Strobl Left (46 cm), suggesting that recent deposition rates along the channel margin can be as much as 1 to 1.5 cm/year. However, this deposition rate appears to only occur within 10 m or so from the edge of the channel (Exhibit 15).
- The deposition pattern away from the channel is variable. In the Springston transect, for example, the thickness decreases rapidly away from the channel, whereas in others (e.g., Medimont Right and Strobl Right), thickness appears to increase with distance from the channel (Exhibit 15A).
- The pattern of deposition is likely related to the nature of overbank flood flows in each location. In some locations, a large amount of flow exits the channel during floods and so the velocities near the bank are high enough to keep sediment in suspension; trap efficiency is low adjacent to the channel at those locations and much of the sediment that enters the floodplain is carried further into the floodplain. In other locations, flow may barely overtop the natural levee; so the sedimentation rate may be higher, because nearly all the sediment that leaves the channel deposits close to the bank line.

4.5 Summary of Bank Characterization Interpretations

High lead concentrations (0.5 to 2 percent) exist widely in the banks and floodplain, especially within stratigraphic Unit B (Exhibits 7 through 15). These concentrations, while high, are exceeded by maximum concentrations in the river bed; the maximum levels of lead contamination in the riverbed are several times higher than that measured in the banks.

CH2M HILL interprets Unit B as silt-dominated deposits laid down between 1903 and 1968, the time of greatest mining waste discharges), while the river bed was aggrading. After cessation of direct mine waste discharges in 1968, the river bed began to degrade and the amount, grain size distribution, and lead content of sediment in floods changed dramatically, leading to an abrupt stratigraphic boundary seen in the bank material. Based on these interpretations, the deposits of Unit A have been laid down during seasonal floods since about 1968, and consist of a mixture of reworked tailings derived from the riverbed and much cleaner sediment from the North Fork Coeur d'Alene River. These sandier Unit A deposits have lower concentrations of lead than Unit B but still contain concentrations of about 0.1 to 1 percent lead, which pose risks to both people and the environment. The total thicknesses of contaminated sediment in the floodplain (units A and B), measured in six coring transects, decrease with distance from a maximum of 2 m near the bank line to a constant thickness of about 0.2 to 0.8 m on the distal side of the natural levee, 30 to 60 m (100 to 200 feet) from the bank.. The Mt. St. Helens ash layer is present under much of the floodplain within Unit A at depths of several cm to tens of cm, indicating ongoing overbank deposition of contaminated sediment in the floodplain since 1980.

5.0 Riverbank Supply of Lead

The banks of the Coeur d'Alene River contain exposed layers of contaminated sediment that erode and supply metals to active transport in the river. The riverbanks typically calve off blocks about 1 m in diameter, after the bank face is undercut by flow and wave energy (e.g., from boat wakes). Based on field observations and interpretations supported by laboratory data, these collapsed blocks consist primarily of material from Unit B (tailings-rich sediments), and remain in place at the foot of the bank for periods of months to years, eroding gradually and supplying mobile sediment that can be transported by floods. These blocks may inhibit undercutting of the bank faces. The supply of contaminants to the river from bank erosion can therefore be considered a gradual, chronic process.

Understanding the amount of lead that enters the river by this process is a key element in the prioritization and design of remedial actions in the Lower Basin. For example, if a primary purpose of remedial action is to reduce the amount of lead in transport, entering the lake, or entering floodplains, then it is important to understand the amounts and relative proportions of contaminants coming from different sources and processes. The data required to compute the amount of lead contributed by bank erosion primarily includes estimates of the bank characteristics (heights, lengths, and lead content) and the average, basin-wide rate at which the banks are eroding. The purpose of this section is to use existing data to constrain the amount of lead and contaminated sediment that is contributed to the river each year by bank erosion. The lead and sediment contributions presented below are incorporated into a separate memorandum (CH2M HILL, in preparation) that also includes estimates of all the other components in the sediment budget, including rates of downstream transport, floodplain deposition, and bed erosion.

5.1 Estimate by Bookstrom et al. (2004)

Bookstrom et al. (2004) estimated that "the riverbanks supply about 8 to 16 percent of the suspended sediment transported past the Harrison gage during high-discharge episodes," and "1.5 to 3 percent of the combined annual tonnage of lead-rich sediment that is deposited on the floodplain and in Coeur d'Alene Lake." Based on data available at the time, Bookstrom et al. (2004) estimated that about 6,100 tons of contaminated sediment containing about 38 tons per year of lead entered the Coeur d'Alene River, noting that these values were "median-based" estimates, calculations were using the median rather than mean values of measured bank erosion rates, lead concentrations, etc. The authors cautioned that mean-based estimates would over-estimate actual rates because they are subject to bias from very high measurements; they reported these mean-based values as 11,700 tons/year of sediment and 74 tons/year of lead contributed by bank erosion.

More recent work in the Lower Basin, including that discussed in the previous section, has provided more reliable data for estimating the relative contribution to lead and sediment loads from bank erosion, and is outlined below.

5.2 Parameters for Revised Estimate

The amount of lead contributed by bank erosion is computed as

$$Q_{bk} = L_{bk} \times \rho_b \times (1 - P_{nc}) \times t_{bk} \times C_{pb} \times r_{be} \times 10^{-6}$$

where:

Q_{bk} = mass rate of lead contributed by bank erosion (metric tons per year [metric tons/year]).

L_{bk} = total length of bank line (m) (computed between Cataldo and Harrison).

This is estimated to be 93,200 m, based on digitization of banks in the 2009 aerial photos. This value includes the lengths of both banks.

ρ_b = bulk density of bank material (in metric tons/m^3).

Bookstrom et al. (2001) estimates the median dry density of riverbank sediments to be 1.51 tons/m^3 for the riverbank material, based on data provided by EPA (1998).

P_{nc} = the proportion of bank length that is non-eroding (armored, heavily vegetated, etc.) or otherwise not contributing contaminated sediment (for example, where banks are mostly clean).

This value is not known precisely. However, based on mapping by KSSWCD, at the time of their reporting, 51 segments of riverbank were armored, consisting of about 28 percent of the riverbanks below the Cataldo Dredge Pool (KSSWCD, 2009, p. 17). In addition to armored banks, their mapping assigned an additional 27 percent to "Bank Type 5," essentially consisting of heavily vegetated banks, which is assumed to not contribute substantially to erosion. Also, 3 percent of the riverbank is lined with beach deposits, which do not contribute to bank collapse, and an additional 6 percent by gently sloping sand deposits thickly vegetated with grasses. These proportions of armored banks and heavily vegetated banks are roughly consistent with recent field observations, and provide the best available information on the distribution of bank types. Therefore, the value of P_{nc} is estimated to be on the order of 0.63, or 63 percent; the remaining 37 percent of bank line is assumed to be susceptible to erosion.

t_{bk} = thickness of eroding and contaminated riverbanks (m).

The purpose of this calculation is to estimate the amount of lead entering the river system, not the amount of sediment; thus, it is the average thickness of the contaminated portion of the banks (Units A & B) that is appropriate to the calculation. This value is estimated as 1.3 m —the average thickness of the contaminated portion of the banks at the 14 measured bank exposures that are located between the Cataldo and

Harrison gaging stations (data shown in Exhibit 12; range is 0.4 to 3.6 m). Unit C, which averages 0.5 meters, does not contribute significant amounts of lead and so is not used in this calculation. The average heights of the contaminated and total bank heights for the 17 measured bank exposures, including the three sites upstream of the Cataldo gaging station, are 1.3 m and 2.0 m, respectively.

C_{pb} = the average lead concentration in sediment in the contaminated portion of the banks (mg lead/kg sediment).

The most representative concentration that can be computed using existing data is the thickness-weighted average lead concentration of all the contaminated layers that were measured and sampled in bank exposures within the Springston, Killarney, and Dudley Reaches; this value is 6,500 mg/kg (Exhibit 16). Similar to the above parameter, the average lead concentration represents contaminated bank material—not the average concentration in all bank material.

Exhibit 16 shows estimates of median lead concentration in riverbank stratigraphic units presented by Bookstrom et al. (2004). Median lead concentrations for both pre-1980 and post-1980 riverbank deposits are reported as about 4,600 and 3,300 mg/kg, respectively, and the corresponding mean lead concentrations as 4,600 and 3,500 mg/kg (Bookstrom et al., 2004, Table 10). Bookstrom et al. (2004)'s estimate of the lead concentration in post-1980 deposits is very similar to the mean value from the current study (3,400 mg/kg in Unit A1; Exhibit 16). However, there appears to be a significant difference in the estimates for the pre-1980 deposits, and comparison is not straightforward because bank stratigraphy is subdivided differently in the current study, as discussed in Section 4.2. However, of the pre-1980 contaminated stratigraphic units in the current study (A2, B1, and B2), all are higher than the median-based estimate of 4,600 mg/kg presented in Bookstrom et al. (2004). One explanation of this difference could be that the Bookstrom data only include seven data points, so may not be as representative. Another explanation could be that the current study sampled comparatively more of the tailings-rich sediments. The current study focuses on bank exposures rather than cores throughout the floodplain, and therefore may be more appropriate for estimating the concentration of lead in eroding bank material.

r_{be} = average annual rate of bank erosion of eroding banks (m).

Because this value is multiplied by ($1-P_{nc}$)—the proportion of the banks that are actively eroding—the erosion rate that is relevant is the average rate for those portions of the bank line that are eroding actively, not the entire (armored) bank line. This value is estimated based on multiple data sources as discussed in section 5.3.

10^{-6} = a unit conversion factor for converting to metric ton/year of lead.

5.3 Summary of Bank Erosion Estimates

Numerous studies have been conducted to measure the rates of bank erosion in the Lower Basin. Many of these were summarized by Bookstrom et al. (2004) and in *Technical Memorandum E – Fluvial Geomorphology* (CH2M HILL, 2010b). Additionally, KSSWCD has directly monitored erosion with bank pins in recent years. CH2M HILL also monitored erosion since 2010 at five representative bank erosion sites (each approximately 100 m long) using repeat terrestrial LiDAR scans. Generally, this work has focused on the bank sections with evidence of active erosion, as opposed to developing a representative erosion rate for entire reach bank lines. These efforts to quantify erosion rates are summarized in this following section, and the value selected for r_{be} is explained.

5.3.1 Work Summarized by Bookstrom

Wetzel (1994) created an ordinal-scale map of bank erosion severity, and applied an "empirically calibrated table," estimating a retreat rate of 2 to 6 cm/year for "moderate" and 9 to 15 cm/year for "severe" eroding banks. (Note: CH2M HILL did not evaluate this approach or the calibration table; values are reported directly from the original source.)

Flagor (2002) estimated long-term (~20 year) average rates at 143 locations along the main stem at severely eroding segments of riverbank, including surveyed locations where fence posts, trees, or shrubs could be used to estimate the distance of bank retreat over a known time interval, reporting retreat rates at 7 to 8 cm/year at the severely eroding sites surveyed.

Bookstrom et al. (2004) measured bank retreat at 13 locations between Cataldo and Harrison by monitoring the distance between the bank edge and a stationary stake. Measurements were made over different periods between 1996 and 2002 (notably, a period without major winter floods). The mean retreat rate was 8.9 +/- 15 cm/year, with a median value of 5.1 cm/year. In general, reported retreat rates were higher on outside bends compared to inside bends or in straight reaches. Bookstrom et al. (2004) computed a lead contribution from erosion based on the median bank retreat value of 5.1 cm/year, and estimated that a total of about 6,100 metric tons/year of sediment and 38 metric tons/year of lead are released by lateral erosion of riverbanks.

5.3.2 Kootenai-Shoshone County Studies

KSSWCD (2009) installed erosion pins (horizontally-placed rebar) and monitored them from July 2008 through July 2010—a period that included relatively low flows. Six bank types were identified, representing 21 different sites (Exhibit 17). A total of 47 pieces of rebar (pins) were installed horizontally in the banks, and monitored periodically to measure the length of exposure of each pin. KSSWCD provided the data from the bank pins, which was not published in the 2009 report, to CH2M HILL.

Of the six bank types shown in Exhibit 17, Type 4 appears more like the shoreline deposits in the CH2M HILL characterization of the riverbank zone (Exhibit 8), and Type 6 consists of gently sloping grassy deposits - unlike the vertical eroding banks being considered here. In addition, bank Type 5 consists of heavily vegetated banks, which are assumed to not be eroding and thus part of the non-contributing banks (P_{nc}). Thus, for the purposes of this memorandum, only erosion data from bank Types 1, 2, and 3 were included. Armored banks were also excluded from the analysis.

Over the 3-year monitoring period between 2008 and 2010, which included moderate to low flow years, the rate of bank erosion was reported to range from zero to greater than 0.5 m per year. Most of the pins measured between 0 and 0.2 m/year erosion, and the average rate of bank erosion for all pins was 0.1 m per year (Exhibit 18). The median value was only 0.02 m/year, primarily because the large number of zero values in the data set (17 of 37 did not record erosion). As a result, in that data set, the second-lowest non-zero value is the median value. It is debatable whether the median value of 0.1 m or the median value of 0.02 m is more representative of the typical erosion rate as measured by this data set; likely, the most appropriate value lies within that range.

5.3.3 Terrestrial Laser Scanning Monitoring of Bank Erosion—CH2M HILL, 2009 to 2011

CH2M HILL used a tripod-mounted LiDAR instrument (also referred to as terrestrial laser scanning, TLS) to monitor bank erosion at five sites in the Lower Basin. The five sites, representing four of the bank types identified by KSSWCD and DEQ, were selected with input from Natural Resources Conservation Service, and considered to be banks experiencing higher than average erosion rates. Each bank site was approximately 100 m long, and the approximate heights ranged from 1.5 to 2.5 m. Exhibit 19 shows an example of results from repeat scanning between 2010 and 2011 at one site, Medimont. While the pin measurements completed by KSSWCD and DEQ provided important information at a point-specific scale (where the pin was stuck in the bank), the TLS approach provides a broader swath of information, and likely a more representative estimate of bank erosion.

At each location, the face of the bank was scanned with the instrument from the opposite bank. The scans were conducted at four different times (April 2010, April 2011, December 2011, and March 2013), although it was not possible to survey each of the five sites each visit. The scanning data were analyzed by CH2M HILL with the proprietary software packages Cyclone and MicroStation, to compute volumetric changes (i.e., total volume of erosion, deposition, and net change) at each bank for the survey intervals. The annual average rate of bank erosion was computed by dividing total volume of change at the bank surface by the total surface area of bank and by the time elapsed between surveys. The survey intervals bracketed the relatively small spring snowmelt event in 2010, a large runoff event in January 2011, a relatively large spring snowmelt in 2011, and a series of high flows in April 2012. The computed average erosion rates at the sites varied from 0.01 to 0.11 m/year, with an average erosion rate of 0.04 m/year for the five sites (Exhibit 20).

5.3.4 Summary of Erosion Rate Estimates

The erosion rate estimates from the independent studies, using different methods and time periods, appear to converge on similar erosion rates of erodible banks in the Lower Basin:

- Studies cited by Bookstrom et al. (2004): Wetzel, 0.09–0.15 m/year; Flagor, 0.09 m/year; Bookstrom, 0.05 m/year (median value; average was 0.09 m/year)
- KSSWCD: 0.02 m/year (median) and 0.10 m/year (mean), during a period lacking high flows
- CH2M HILL TLS data: 0.04 m/year, during a period that include high flows

Based on these values, it appears a typical erosion rate of actively eroding banks is in the range of 0.04 to 0.15 m/year, with a value near the lower end of this range, because: (1) the data collection activities are probably biased towards more actively eroding banks and (2) the multiple independent data sets converge on similar values. Thus, a value of 0.08 m/year was chosen as a conservative rate of erosion for the most highly eroding banks.

This reasoning is supported by the lack of channel change shown in Exhibit 4. If the average erosion rate throughout the eroding bank segments was 0.08 m/year, then over the approximately 100 years that have elapsed since the GLO maps were produced, about 8 m of channel widening or migration would have occurred over much (perhaps 1/3 to 1/2) of the river between Cataldo and Harrison. While some minor channel changes are apparent, it does not appear that significant channel change has occurred over large sections of the

Lower Basin. Nonetheless, available data suggest that at least several cm of erosion per year do occur, and 0.08 m/year appears to be a viable, if conservative (high), estimate.

5.4 Lead Contribution from Bank Erosion

The amount of contaminated sediment and lead that enters the Coeur d'Alene River each year via erosion of riverbanks can be estimated using the data cited above. The third column in Exhibit 21 summarizes what are considered to be the best available estimates of representative bank characteristics and erosion rates, and the notes explain the basis for these estimates. In addition, conservative bounding estimates (minimum and maximum) are also provided for each parameter, based on different lines of evidence or professional judgment. It should be noted that the best available estimates of these values are approximations, and generally conservative (tending towards the higher end of reasonable estimates for the lead contribution), because this and previous studies have been biased towards sampling or measuring locations with conspicuous exposed tailings, higher bank exposures, or more clearly eroding bank sections. The minimum and maximum estimates are even more uncertain than the best available estimates; they are simply meant to provide some bounding numbers to try to bracket the possible range of values for the lead contribution.

With these caveats, CH2M HILL estimates that bank erosion contributes about 7,700 metric tons/year of sediment into the Coeur d'Alene River, of which about 4,900 metric tons/year are contaminated sediments. Based on an average lead concentration of about 6,500 mg/kg in bank Units A and B, CH2M HILL estimates that bank erosion contributes approximately 32 metric tons/year of lead into the Lower Coeur d'Alene River.

Using the bounding values for maximum and minimum estimates of each of the six variables, the lead contribution could be as low as 6 metric tons/year, or as high as 122 metric tons/year. However, it is extremely unlikely that the representative value would approach either of these bracketing values, because it would require that the actual value for each of the six variables was at the endpoint of each estimated range, and the probability of this is very low. Considering the various uncertainties in each of the parameters and based on a qualitative judgment, the annual lead contribution from bank erosion, averaged over a period of a decade or two, is probably in the range of 20 to 50 metric tons/year, with 32 metric tons/year providing a best estimate.

6.0 Conclusions

The conclusions of this update on riverbank characteristics, erosion rates, and lead contribution are summarized as follows:

- Bank structure can be generally characterized by three stratigraphic units consisting of (from bottom to top):
    1. Lower Unit (C): gray, fine grained massive sandy silt with background-level concentrations of lead. This unit is interpreted as pre-mining, Pleistocene and Holocene lacustrine sediment and more recent pre-mining fluvial deposits.
    2. Middle Unit (B): red-orange and brown sandy silt with variable bedding structures and high lead concentrations. The unit is subdivided into a lower subunit (B2) with blocky structure and higher lead concentrations, and an upper subunit (B1) with

wavy bedding and lower, but still high, lead concentrations. This unit is interpreted as having been deposited during the period of active river disposal of mine waste between the early 1900s and 1968.

3. Upper Unit (A): gray-brown silty sand with intermediate concentrations of lead, commonly containing the Mt. St. Helens volcanic ash layer near the middle of the unit. The unit is subdivided into a lower subunit (A2) overlying Unit B and underlying the Mt. St. Helens ash, and an upper subunit (A1) between the ash and the surface. The surface subunit (A1) has lower lead concentrations, on average, than the subunit pre-dating the Mt. St. Helens ash (A2). The combined unit A is interpreted as mixed reworked tailings and less-contaminated alluvium deposited overbank during floods since 1968.

- Typical lead concentrations on sediment in the three units reflect their history: Unit C has average lead concentration of about 70 mg/kg, typical of background lead levels; Unit B has average lead concentrations of about 12,700 mg/kg for the lower subunit, and 6,800 mg/kg for the upper subunit; and Unit A has average lead concentrations of 4,700 mg/kg for the lower subunit and 3,400 mg/kg for the upper subunit.
- The pattern of decreasing lead concentration up-section (from B2 to B1 to A2 to A1) suggests that the concentration of lead in suspended sediment decreased over time since the onset of mining.
- Unvegetated bank faces are undermined by fluvial processes and wave action, leading to the slumping or collapse of blocks of bank material 0.3 to 1 m (1 to 3 feet) thick and up to a meter high. The collapsed blocks remain near the bank toe for months to years, eroding gradually.
- Historical data indicate that the channel position downstream of Cataldo has remained remarkably stable over the past 100 years, suggesting that the rate of lateral bank erosion is relatively slow.
- Past studies of bank erosion rates at highly erodible sites converge on a similar range of values for bank retreat, on the order of 4 to 15 cm/year. Sections of riverbank less prone to erosion are probably eroding at rates lower than this.
- Recent monitoring of five 100-m long sections of riverbank using terrestrial laser scanning indicate a similar rate of bank retreat, about 4 cm/year.
- Based on typical values for bank height, bank material lead concentration, and riverbank retreat rate, CH2M HILL estimates that bank erosion contributes an average of about 4,900 metric tons/year of contaminated sediment to the active channel, containing approximately 32 metric tons of lead.

7.0 References

Bookstrom, A.A., Box, S.E., Campbell, J.K., Foster, K.I., and Jackson, B.L. 2001. *Lead-rich Sediments, Coeur d'Alene River valley, Idaho; Area, Volume, Tonnage, and Lead Content*. U.S. Geological Survey Open File Report OF 01-140, 44 p.

Bookstrom, A.A., Box, S.E., Fousek, R.S., Wallis, J.C., Kayser, H.Z., and Jackson, B.L. 2004. *Baseline and Historic Depositional Rates and Lead Concentrations, Floodplain Sediments,* Wetzel, M. 1994. Geology Report: *Coeur d'Alene River Cooperative River Basin Study*. Boise, Idaho, U.S. Soil Conservation Service. 69 p.

Exhibits

Attachments

Exhibit 1. **Photographs of Bank Features and Characteristics along Lower Coeur d'Alene River**
River Bank Addendum to Fluvial Geomorphology of the Lower Basin of the Coeur d'Alene River
Enhanced Conceptual Site Model (OU3)

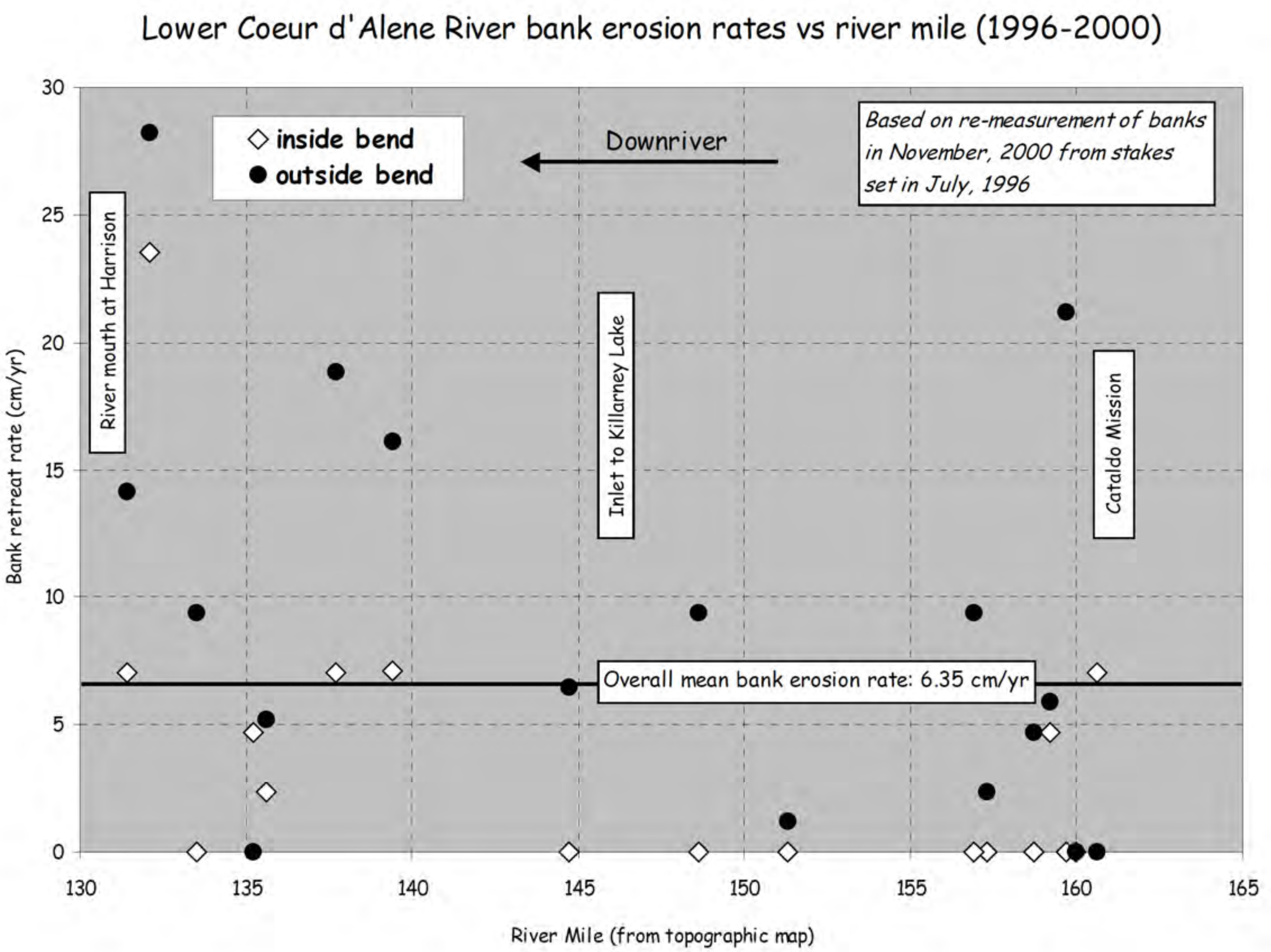


Exhibit 2. **Lower Coeur d'Alene River Bank Erosion Rates vs. River Mile (1996 – 2000)**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

Source: Unpublished notes prepared by S. Box (USGS) for a field trip to the Lower Basin (Box, 2003).

Box, S.E. 2003. Informal notes prepared by S. E. Box (USGS) for a Field Trip to the Lower Basin. Included as Attachment A to this report.

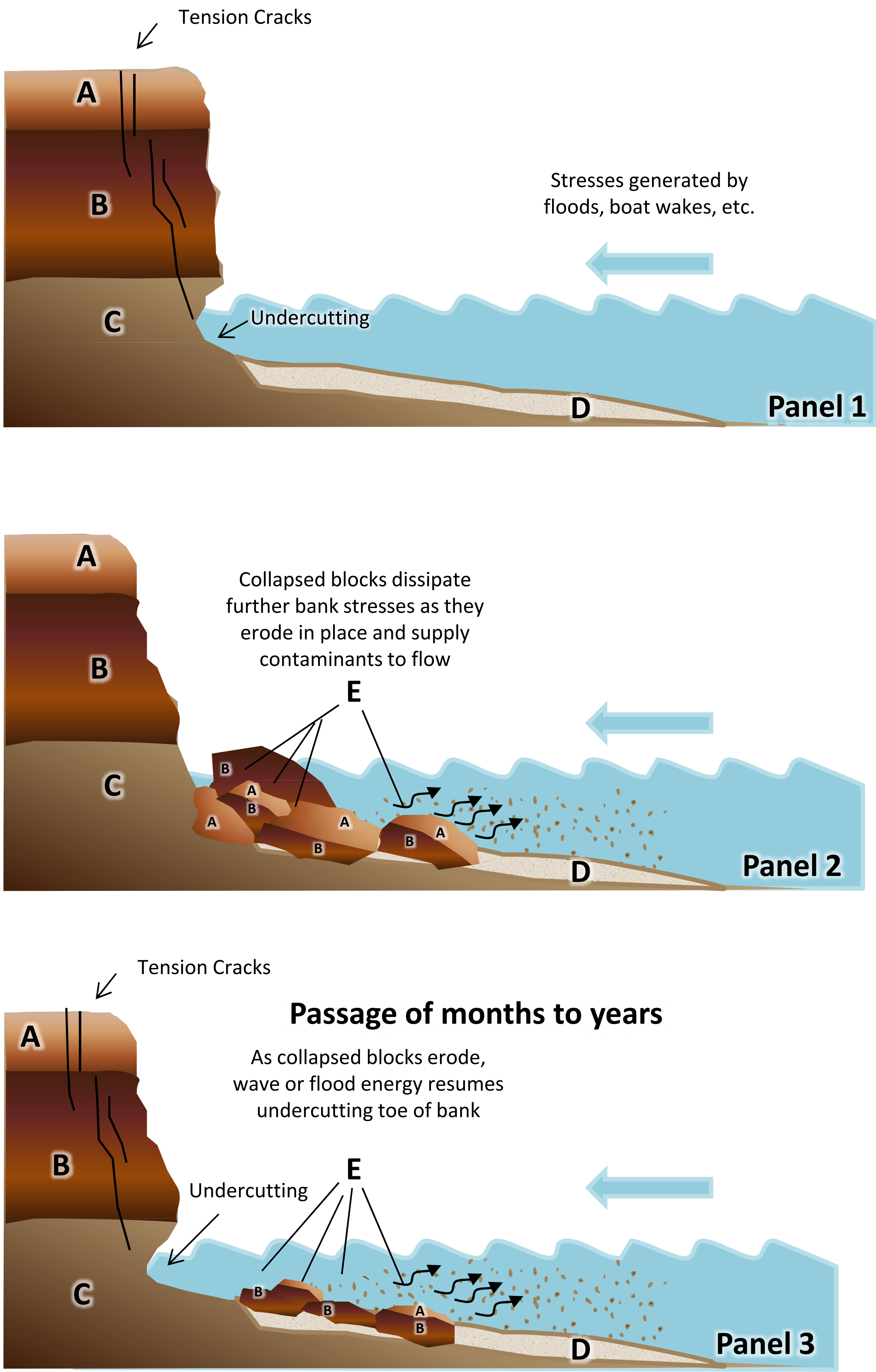
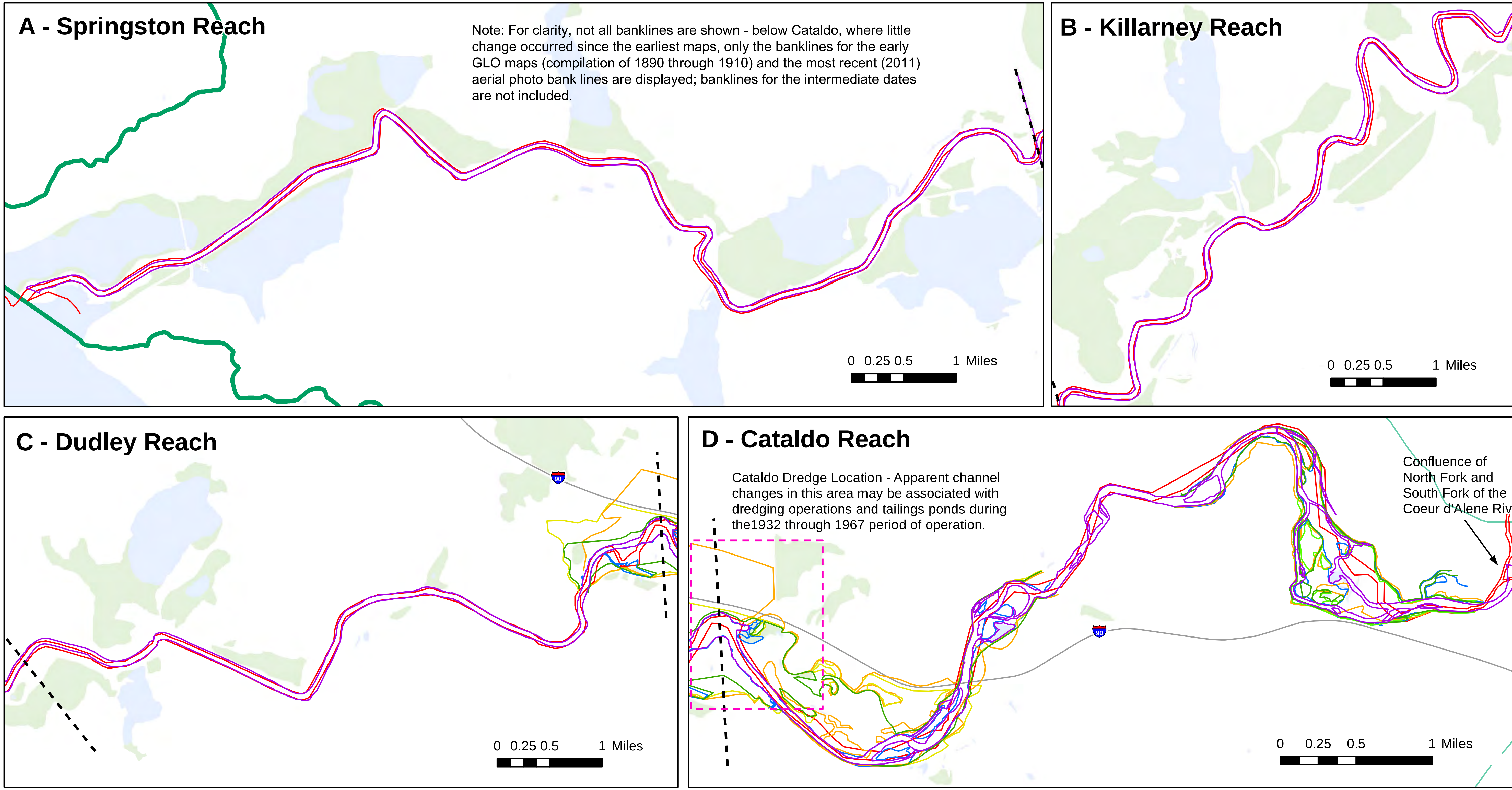
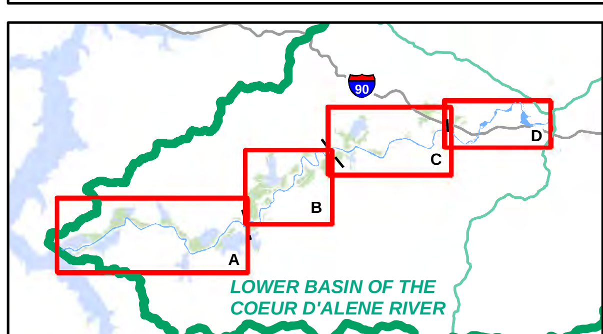


Exhibit 3. **Schematic Diagram of Bank Erosion Cycle in the Coeur d'Alene River**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)





LEGEND

- 2011 Aerial
- 2009 Aerial
- 1975 Aerial
- 1968 Aerial
- 1965 Aerial
- 1937 Aerial
- 1890 - 1910 General Land Office Maps
- Waterbody
- Marsh or Slough
- Reach Divides
- Coeur d'Alene Basin Hydrologic Boundary
- Coeur d'Alene Basin Subbasin Hydrologic Boundary

N

Exhibit 4. **Channel Migration Assessment**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

CH2MHILL

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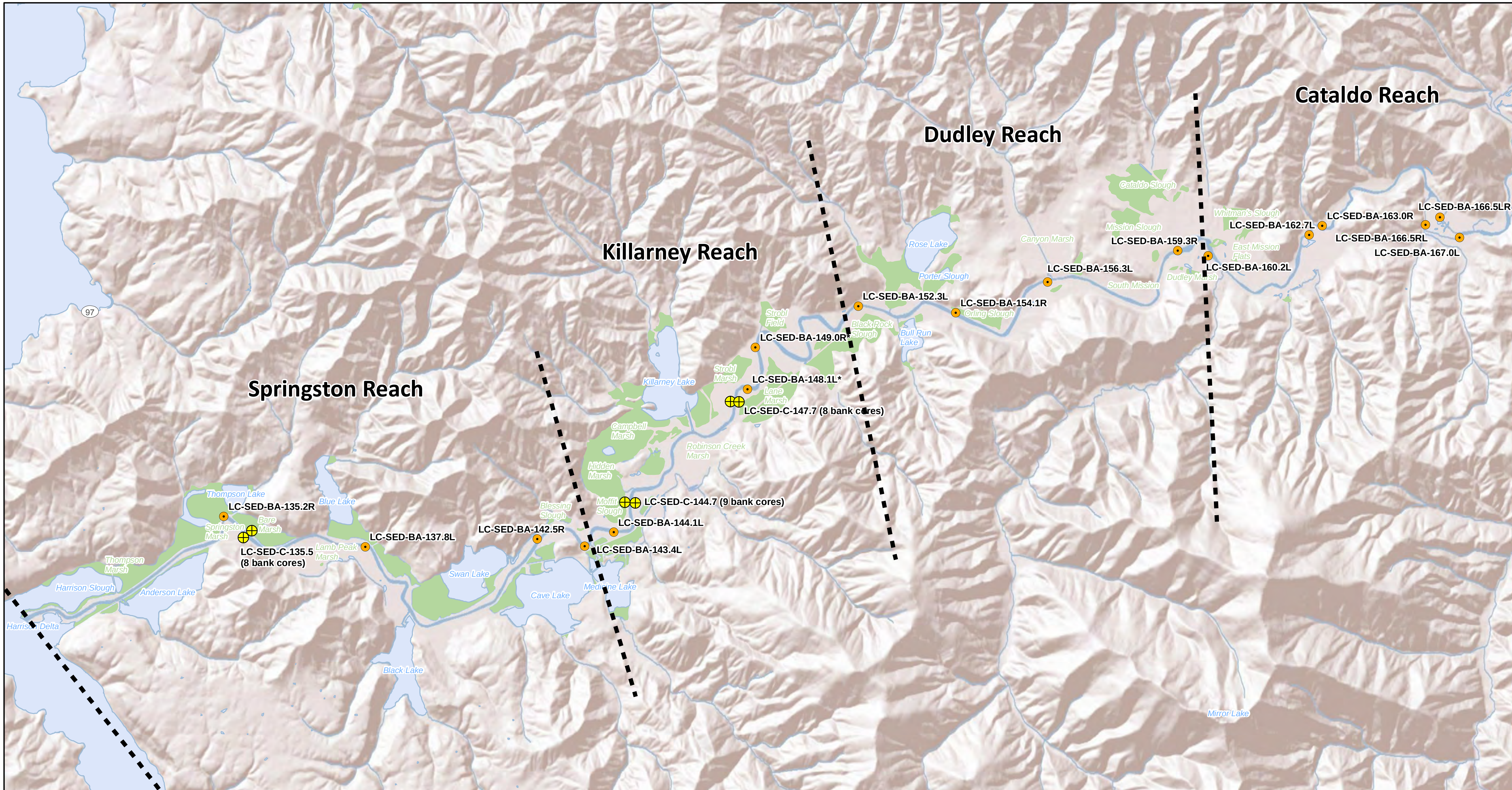

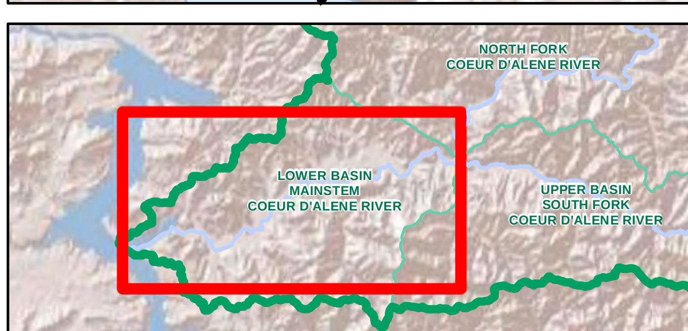

LEGEND

- **Exposed Bank Sampling Location**
- **Bank Core Sampling Location**
- **Waterbody**
- **Marsh or Slough**

Sample Names:
LC = Lower Coeur d'Alene
SED = sediment
BA = Bank Study, Phase 1
###.# = river mile location rounded to the nearest one tenth of a mile
X = either "L" for left side or "R" for right side
* Indicates sample location is approximate and is to be determined in field by the field team.

N

0 1 2 4 Miles

Exhibit 5. **Bank Study Sample Locations Overview Map**
River Bank Addendum to Fluvial Geomorphology of the Lower Basin of the Coeur d'Alene River Enhanced Conceptual Site Model (OU3)

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CH2MHILL

Strobl Transect- RM 147.7 – Right bank

Notes:
Photograph A shows bank coring set up with geoprobe transported by boat to coring locations. The core processing station is shown to the right where field XRF readings and characterization of the cores was performed.
Photograph B shows geoprobe rig used for bank coring.
Photograph C shows a representative core from the right bank of the Strobl transect at river mile (RM) 147.7. The core is aligned with the top (ground surface end) of the core at the left end of the photograph. The callout photographs illustrate the Mt. St. Helens ash layer in the upper part of the core and the horizon between mining-impacted sediments and pre-mining sediments.

Exhibit 6. **Bank Coring Photographs**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

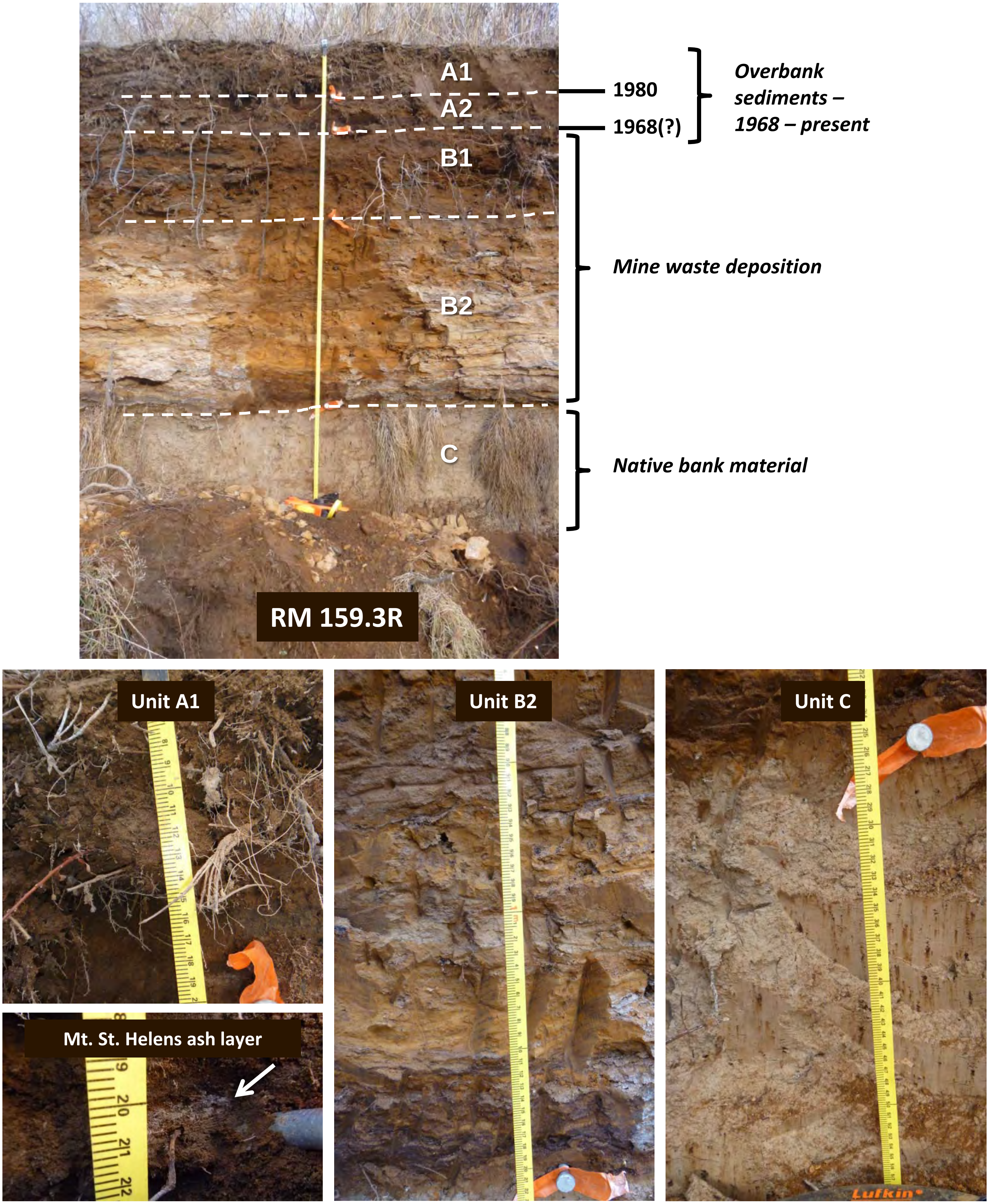


Exhibit 7. **Characteristic Bank Stratigraphy**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

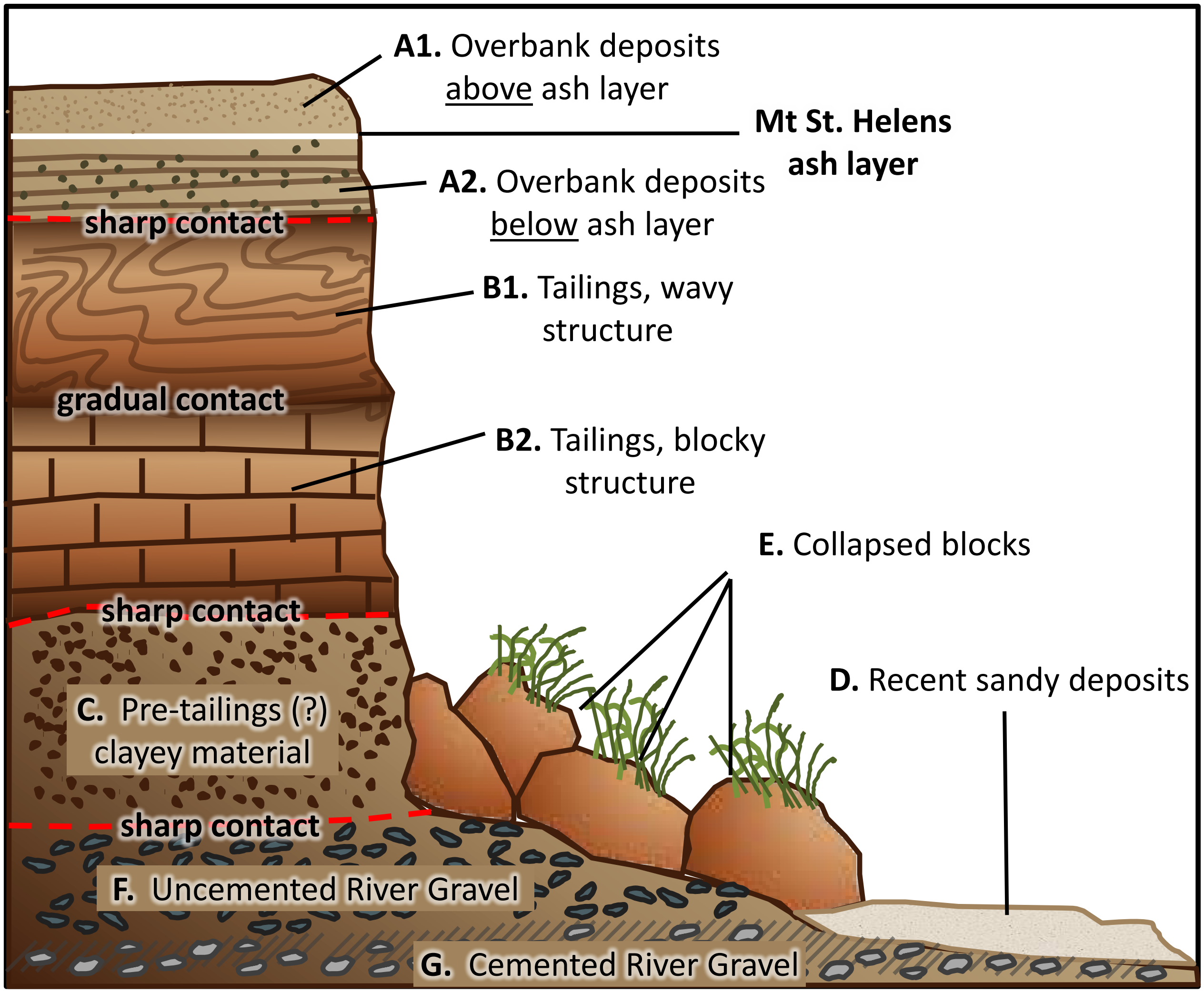
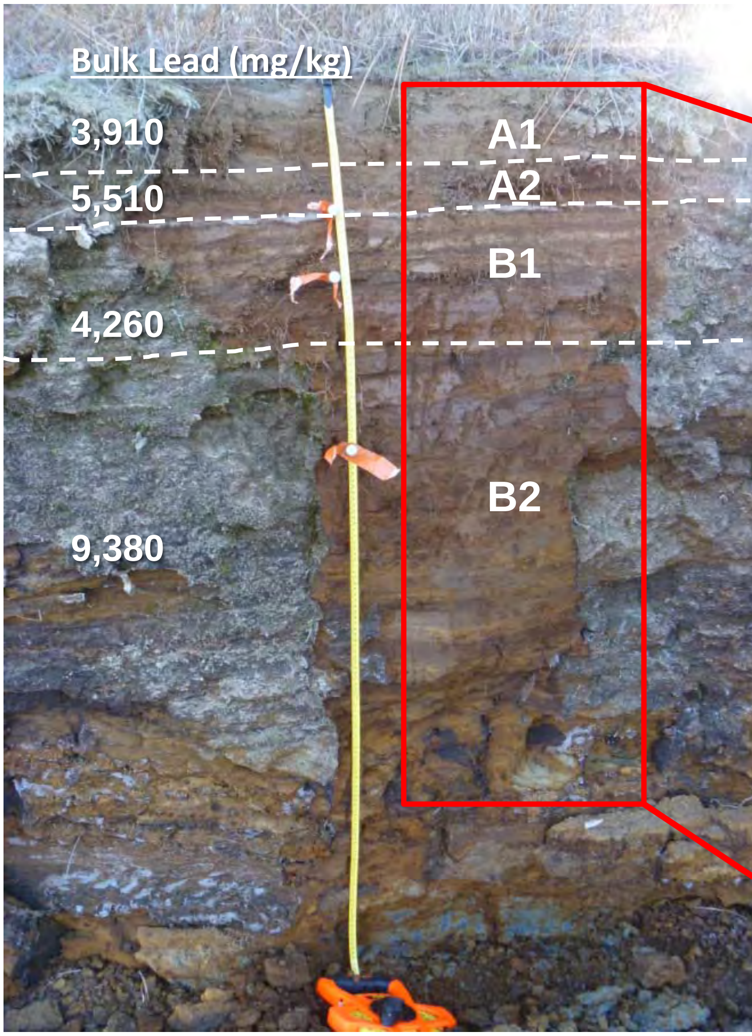
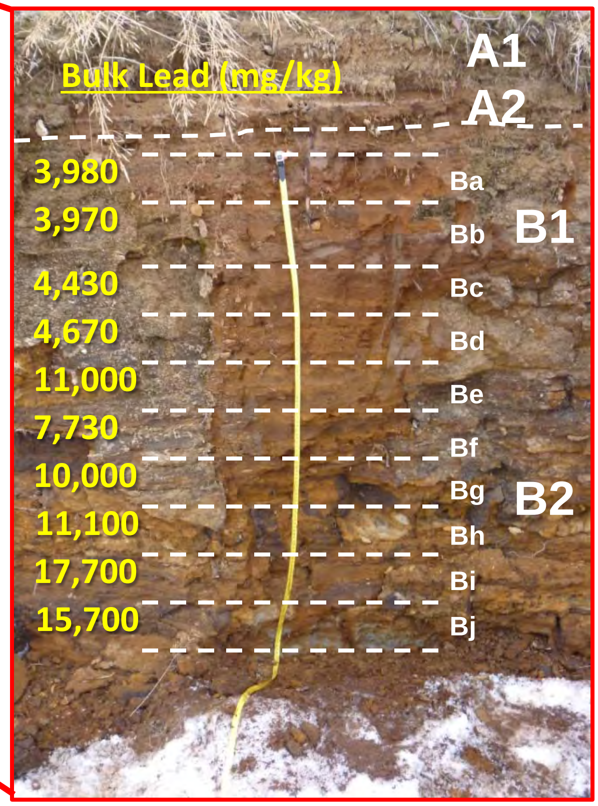


Exhibit 8. **Stratigraphic Model for Banks of the Coeur d'Alene River**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

RM 144.1L (Coarse Scale Sampling)



RM 144.1L (Fine Scale Sampling)



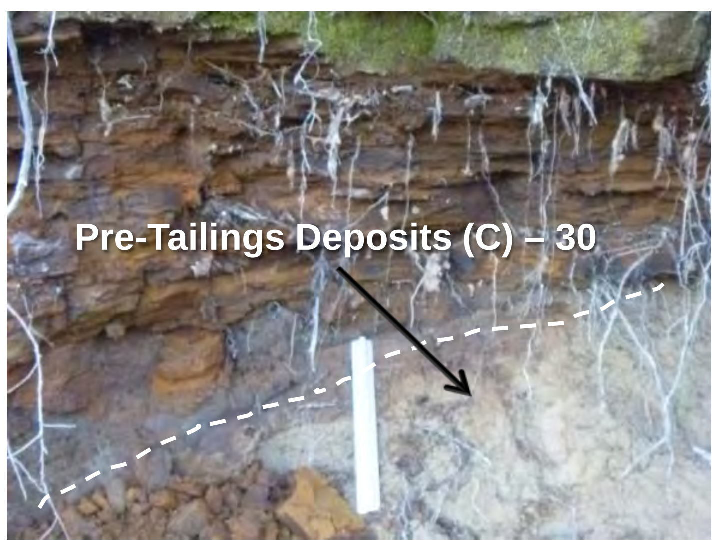
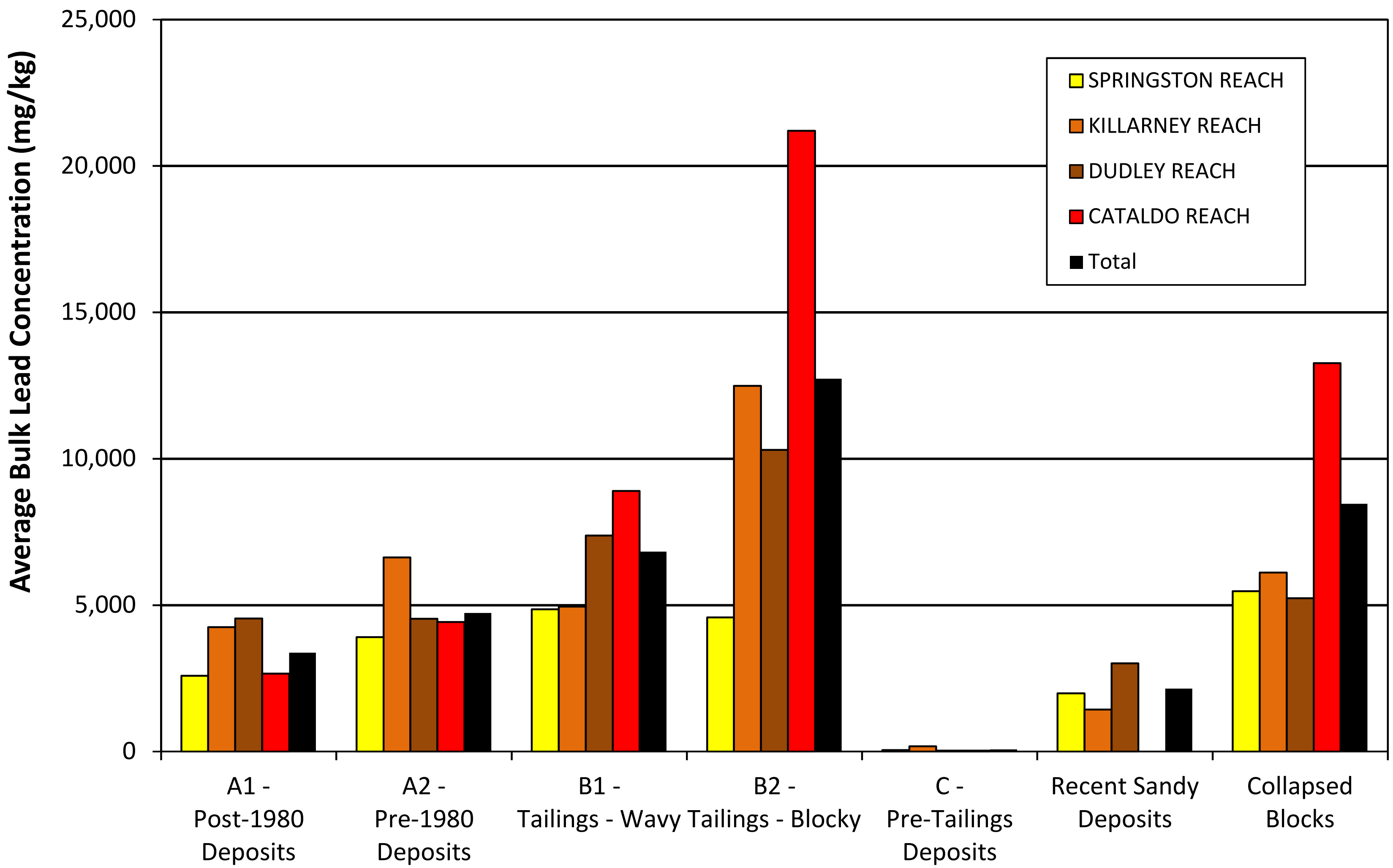
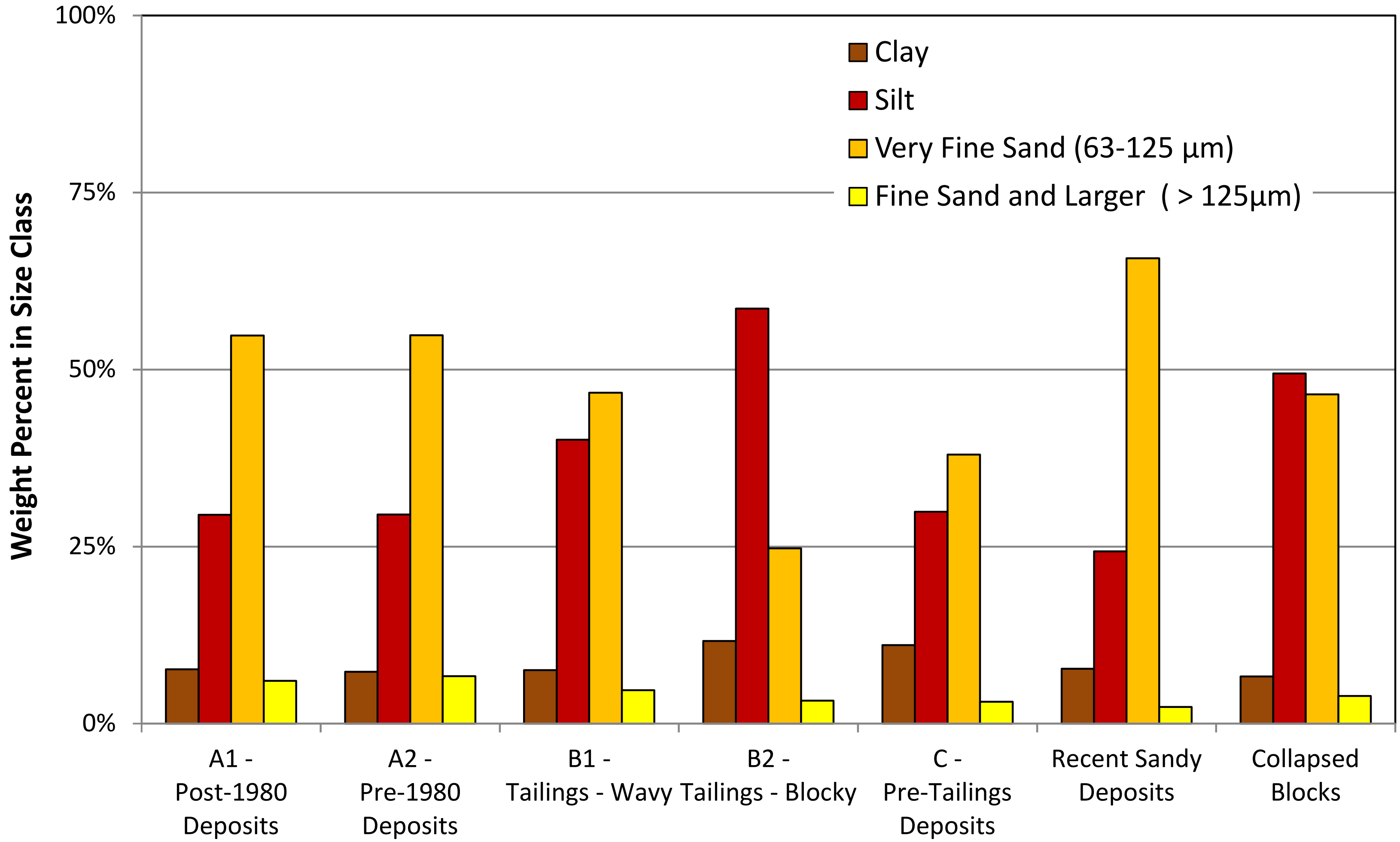


Exhibit 9. **Example Bank Sampling Results of Lead Content by Stratigraphic Layer**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)



Note: Refer to Appendix C for details.

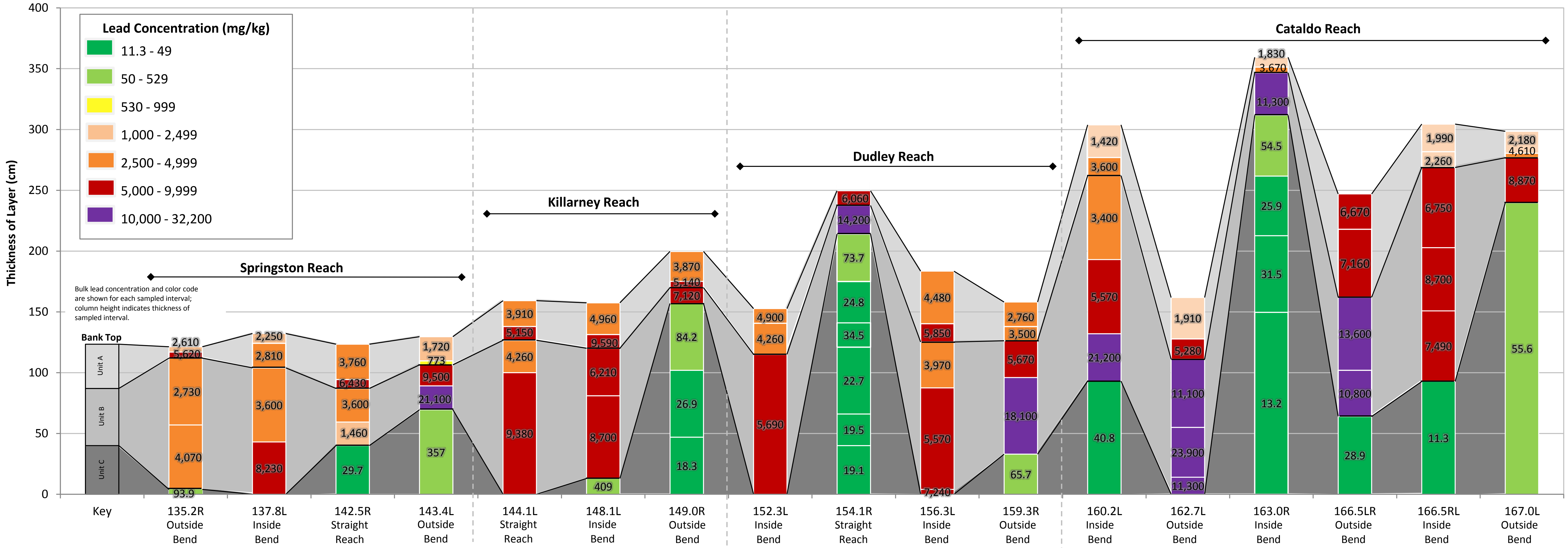
Exhibit 10. **Average Bulk Lead Concentration By Stratigraphic Unit**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)



Note: Refer to Appendix C for details.

Exhibit 11. **Grain Size Distribution by Stratigraphic Unit**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

A. Bulk Lead Concentration (mg/kg) for Bank Face Intervals



B. Total Lead (metric tons) per Stratigraphic Unit (1 m wide and 1 m deep)

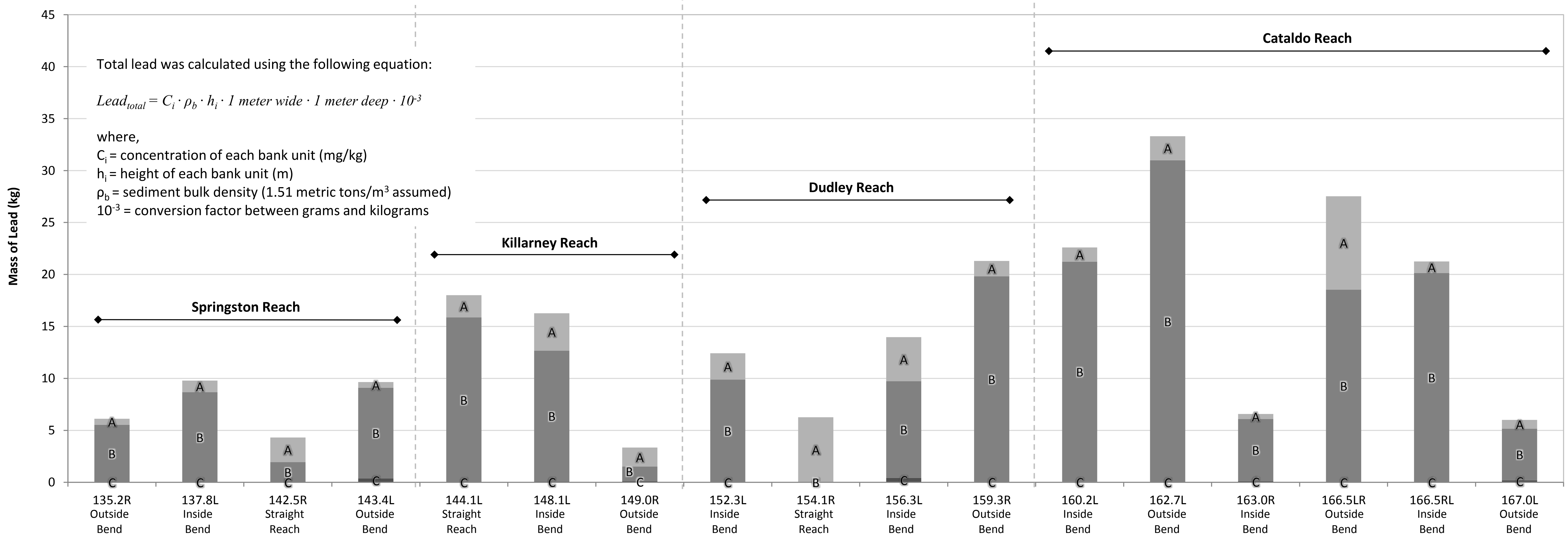
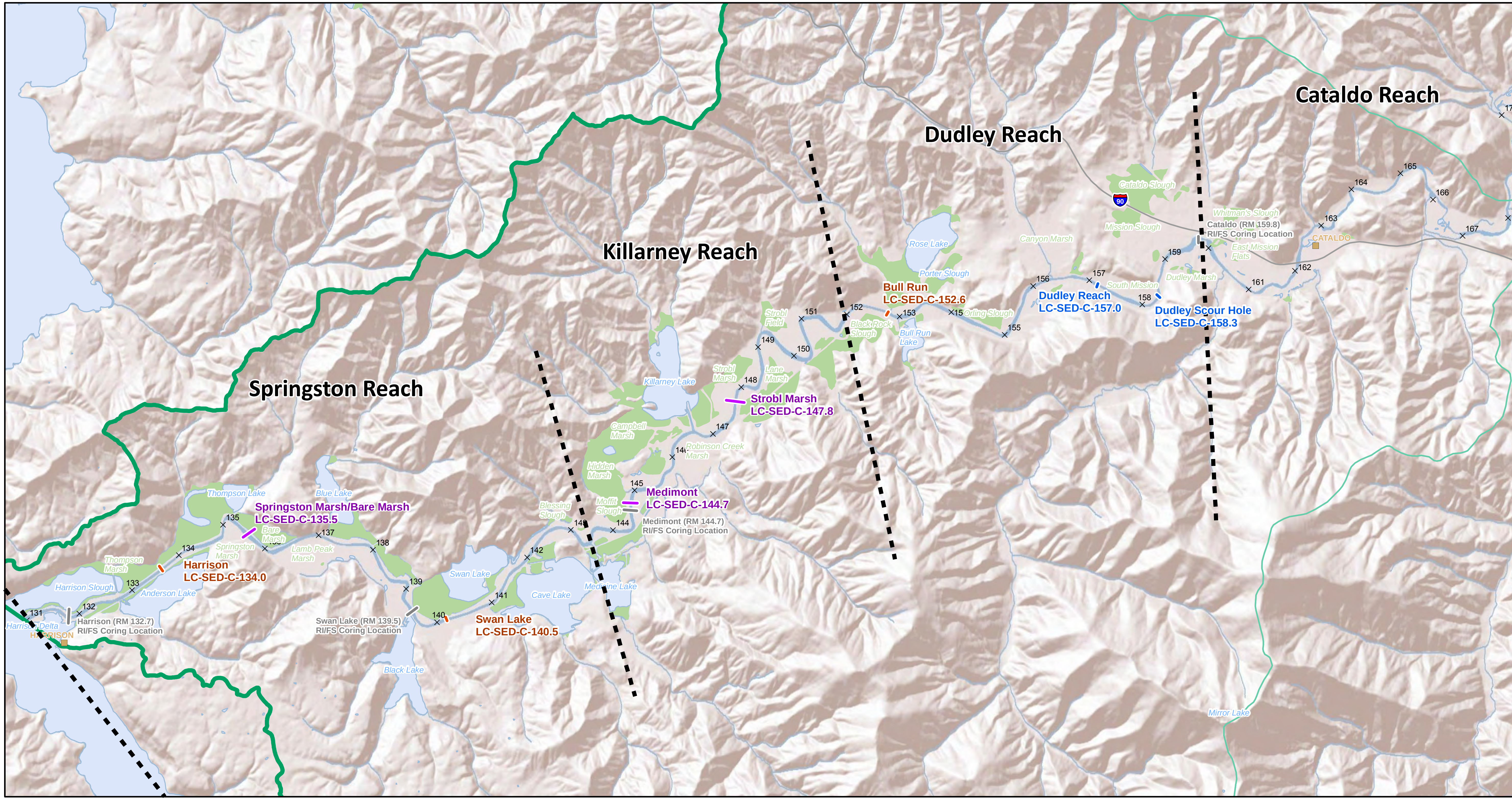
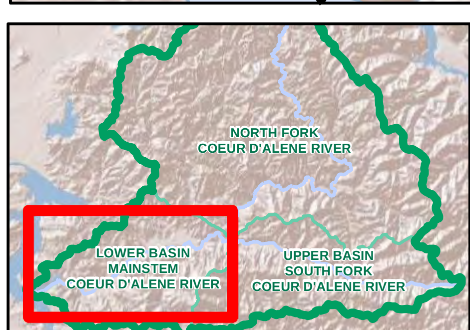


Exhibit 12 (A and B). **Lead Content (A) and Downstream Pattern of Lead Inventory (B) by Stratigraphic Unit**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)





LEGEND

Subsurface Investigation Transect

- Bank-Bed-Bank Transect
- Source Area Focus Transect
- Longitudinal Coverage Transect
- RI/FS Transect Location
- Bed Transect Core Location

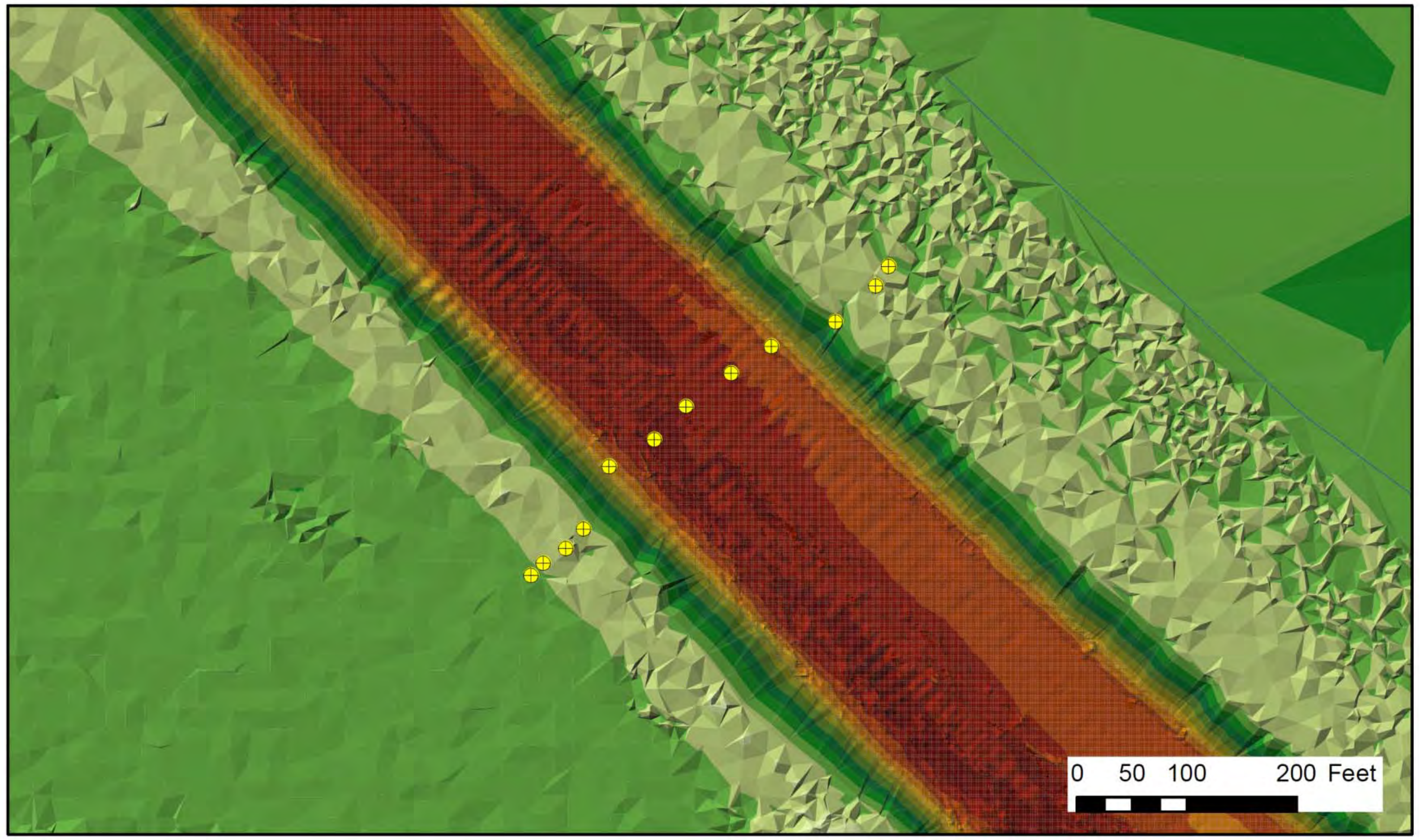
- City
- River Mile Marker
- Interstate Highway
- Waterbody
- Marsh or Slough

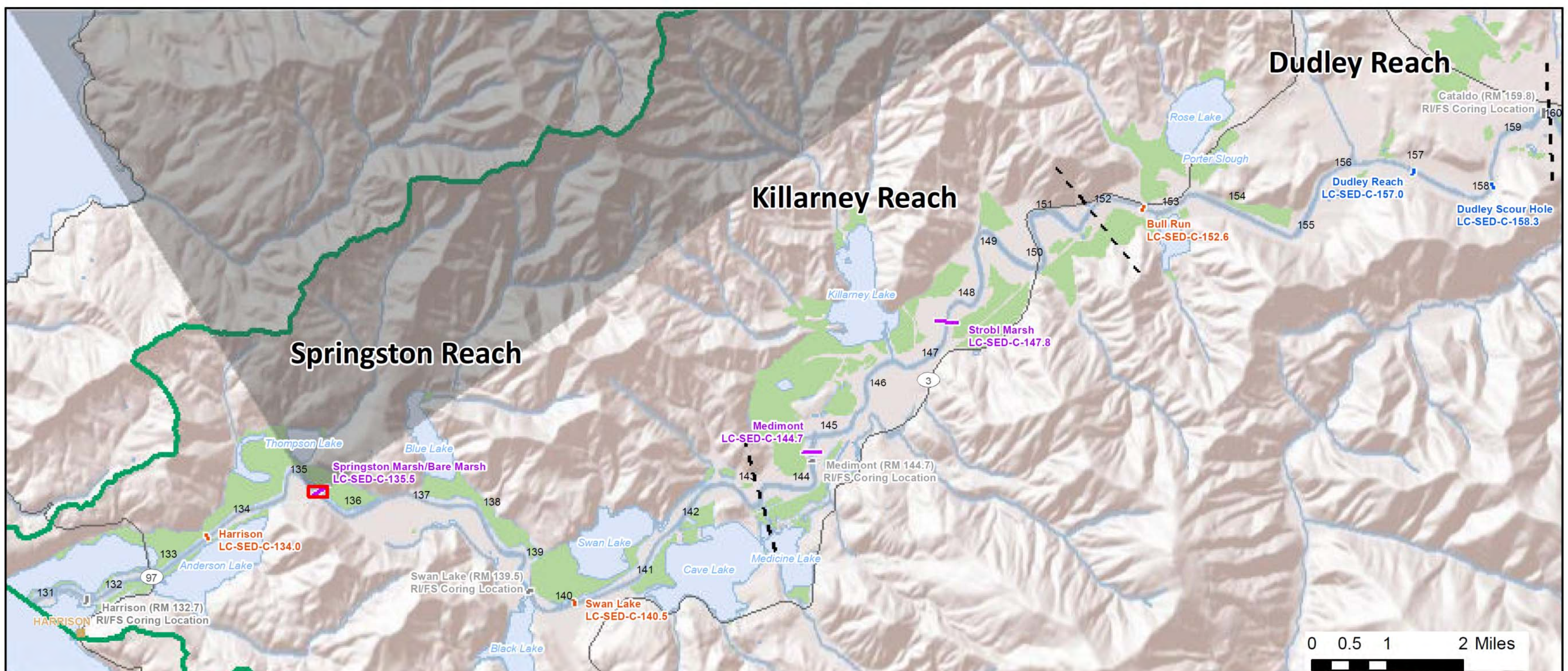
Sample Names:
LC = Lower Coeur d'Alene
SED = sediment
C = Subsurface Core Study
###.# = river mile location rounded to the nearest one tenth of a mile
L, R, DN, UP, and C = left, right, downstream, upstream, and center

0 1 2 4 Miles

N

Exhibit 13. **Lower Coeur d'Alene River Bank and Bed Subsurface Investigation Locations Overview Map**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

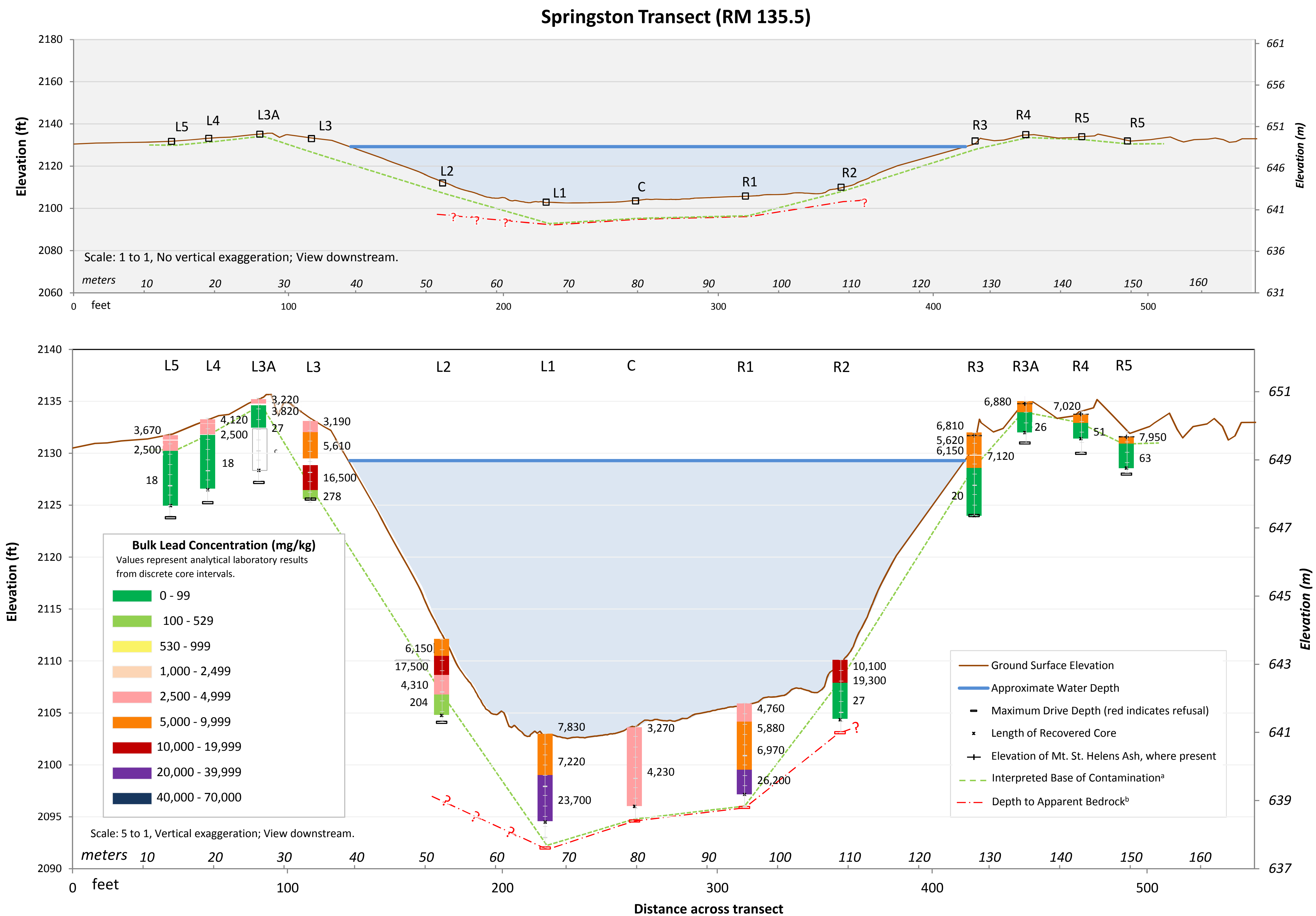




Sample Names:
LC = Lower Coeur d'Alene
SED = sediment
C = Subsurface Core Study
###.# = river mile location rounded to the nearest one tenth of a mile
L, R, DN, UP, and C = left, right, downstream, upstream, and center

N

Exhibit 14A (Sheet 1). **Transect Location and Overview Map, Springston Location**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)



Notes:

[a] Delineation of break between significant contamination from mining waste and non-impacted or minor levels of impact to sediment or soil, based on laboratory data of lead concentrations and/or (where lab data are not available or do not appear to be representative of the entire core segment), field XRF readings and observations of physical stratigraphic breaks. A risk-based threshold of 530 mg/kg lead was used for this delineation. Depths of delineation were not corrected for partial core recoveries.

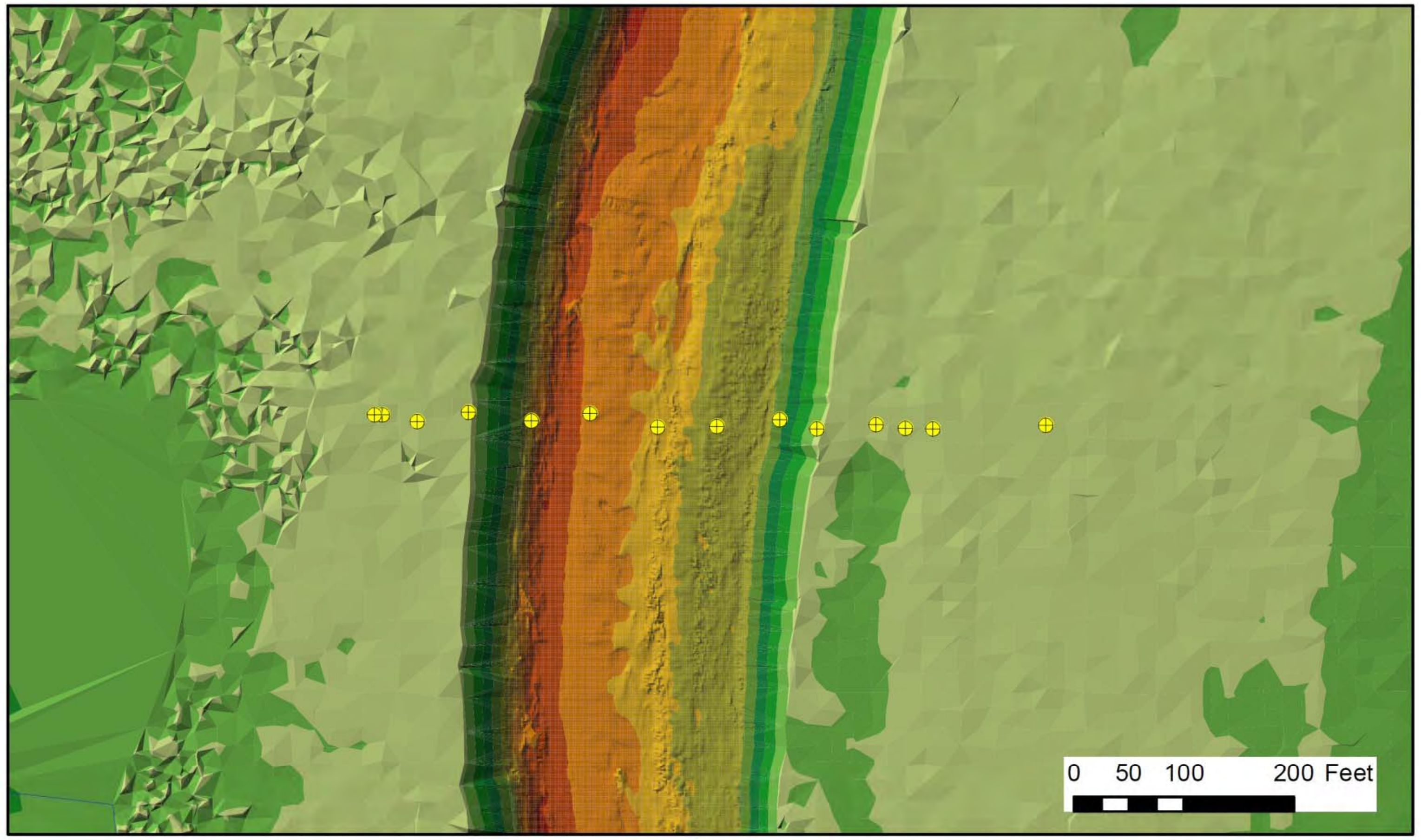
[b] Depth to apparent bedrock was interpreted based on refusal encountered during coring, or where refusal was not encountered, estimated based on interpolation between refusal elevations and best professional judgment.

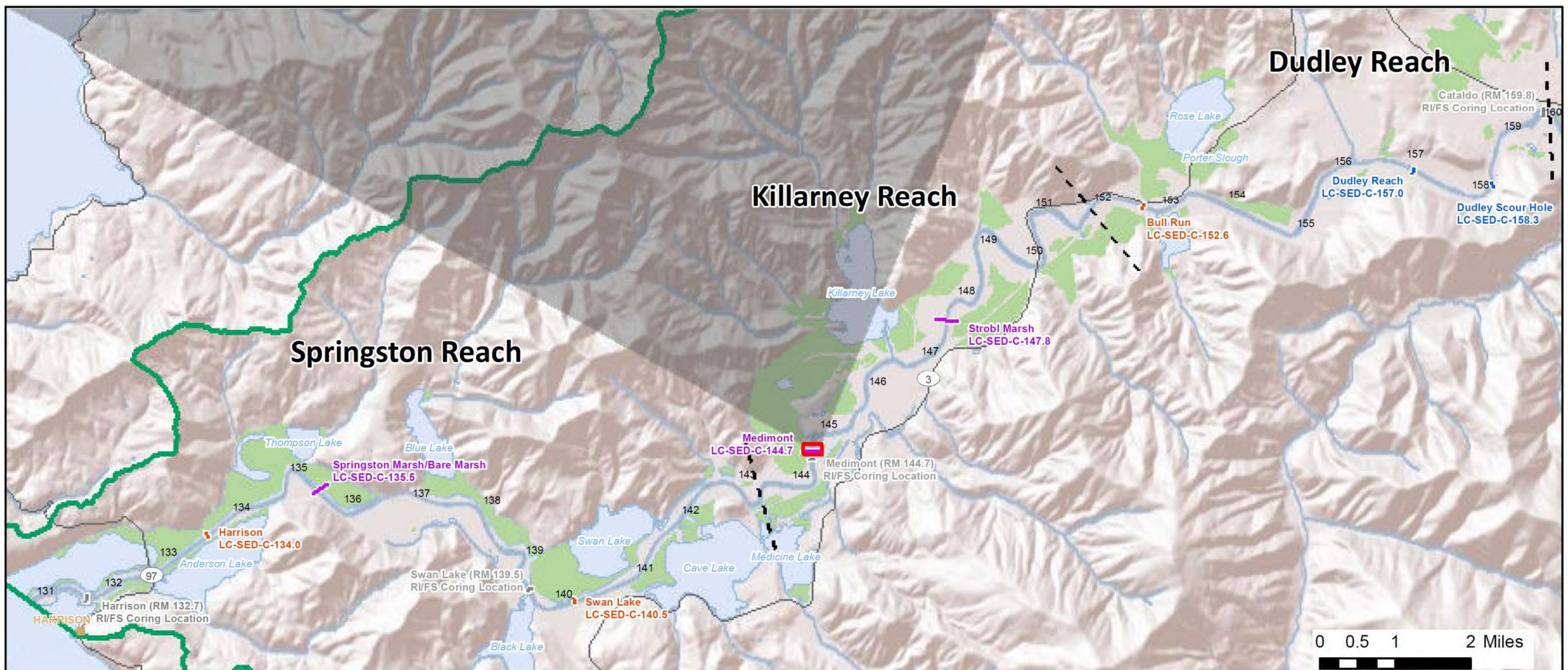
[c] Sample interval was not submitted for laboratory analysis based on field XRF readings indicating the overlying interval was uncontaminated.

Exhibit 14A (Sheet 2). **Transect of Riverbed and Bank Cores Coded by Bulk Lead Content, Springston Location**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Couer d'Alene River (OU3)





Sample Names:
LC = Lower Coeur d'Alene
SED = sediment
C = Subsurface Core Study
###.# = river mile location rounded to the nearest one tenth of a mile
L, R, DN, UP, and C = left, right, downstream, upstream, and center

N

Exhibit 14B (Sheet 1). **Transect Location and Overview Map, Medimont Location**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River(OU3)

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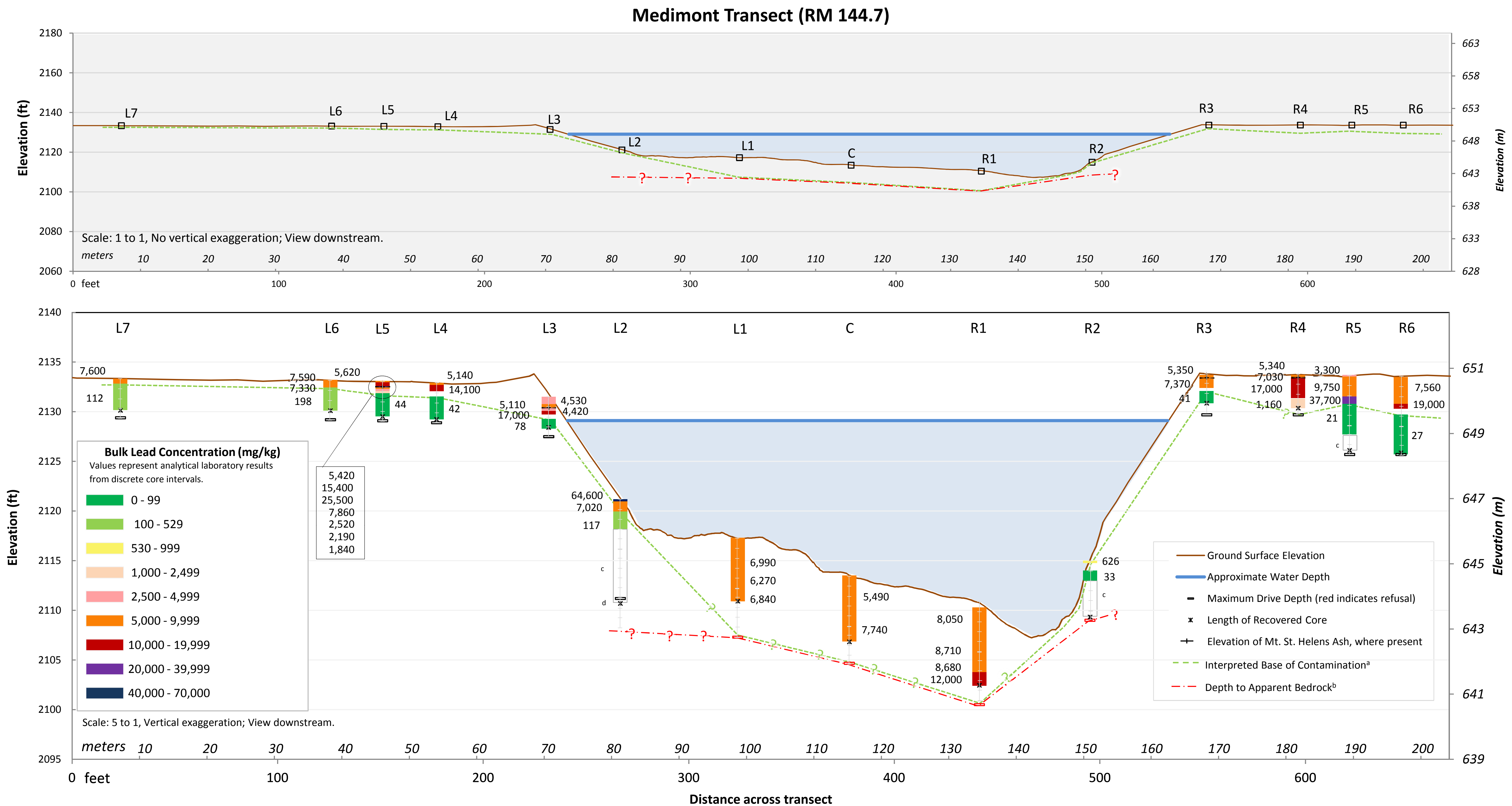
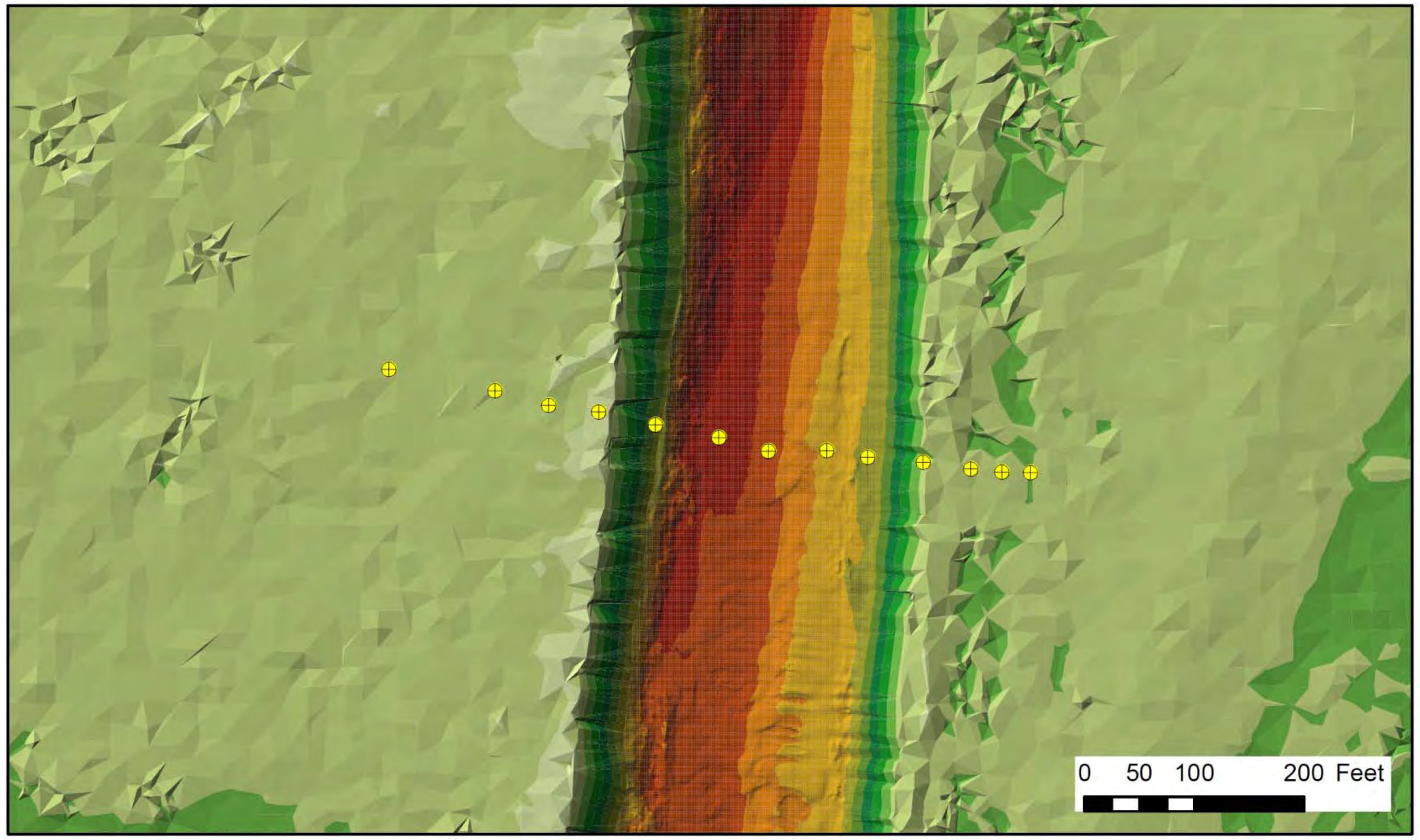


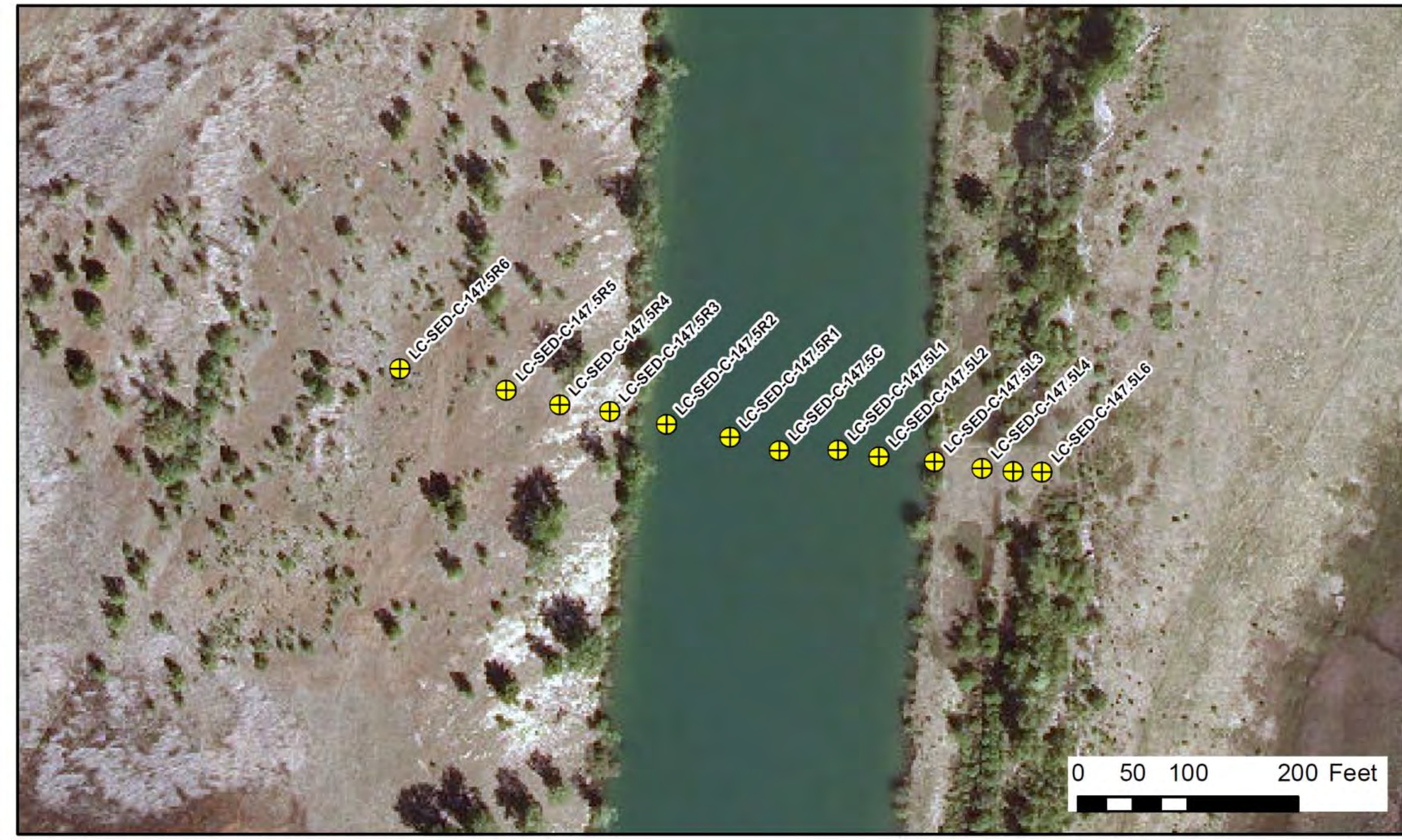
Notes:
[a] Delineation of break between significant contamination from mining waste and non-impacted or minor levels of impact to sediment or soil, based on laboratory data of lead concentrations and/or (where lab data are not available or do not appear to be representative of the entire core segment), field XRF readings and observations of physical stratigraphic breaks. A risk-based threshold of 530 mg/kg lead was used for this delineation. Depths of delineation were not corrected for partial core recoveries.
[b] Depth to apparent bedrock was interpreted based on refusal encountered during coring, or where refusal was not
[c] Sample intervals were not submitted for laboratory analysis based on field XRF readings indicating the overlying interval was uncontaminated.
[d] Core recovery is greater than drive depth due to process of extruding core from sleeve. Later cores were cut out of sleeves to eliminate this source of error.

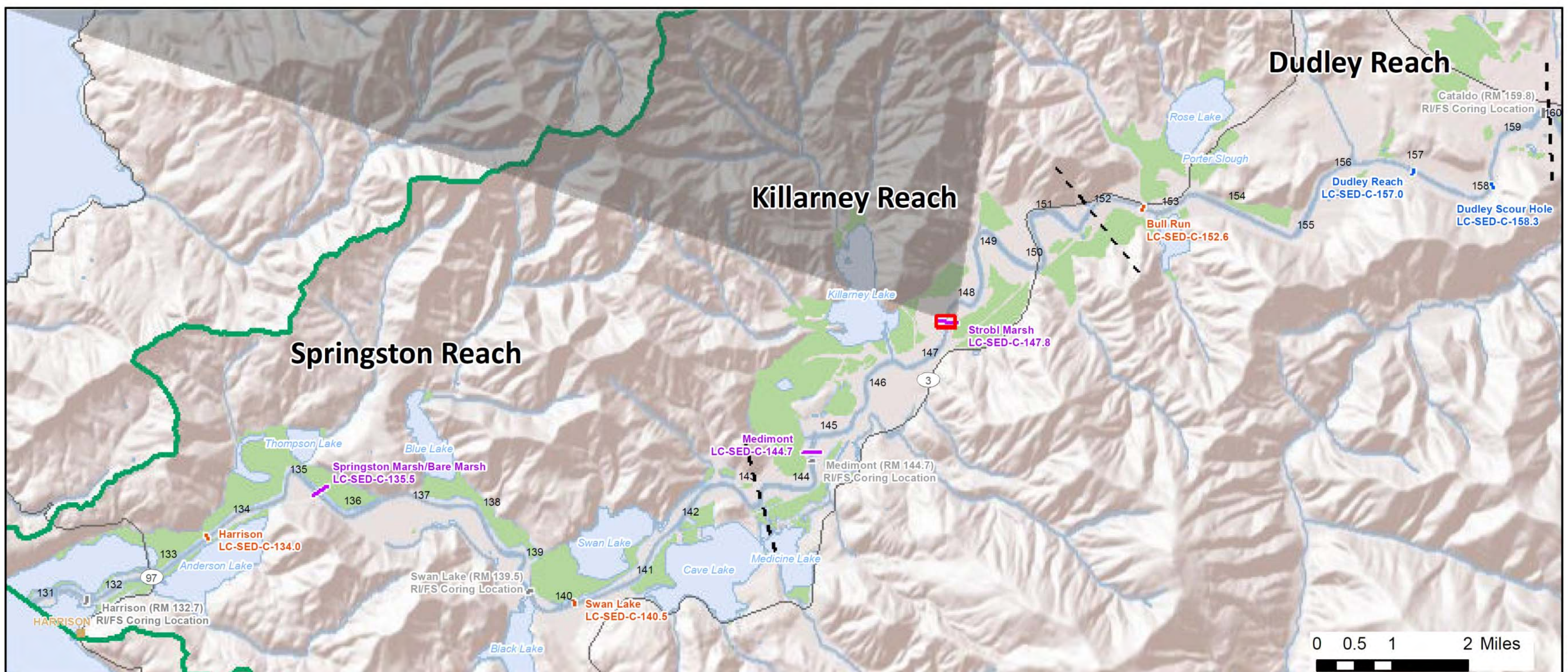
Exhibit 14B (Sheet 2). **Transect of Riverbed and Bank Cores Coded by Bulk Lead Content, Medimont Location**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Couer d'Alene River (OU3)







Sample Names:
LC = Lower Coeur d'Alene
SED = sediment
C = Subsurface Core Study
###.# = river mile location rounded to the nearest one tenth of a mile
L, R, DN, UP, and C = left, right, downstream, upstream, and center

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Exhibit 14C (Sheet 1). **Transect Location and Overview Map, Strobl Location**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

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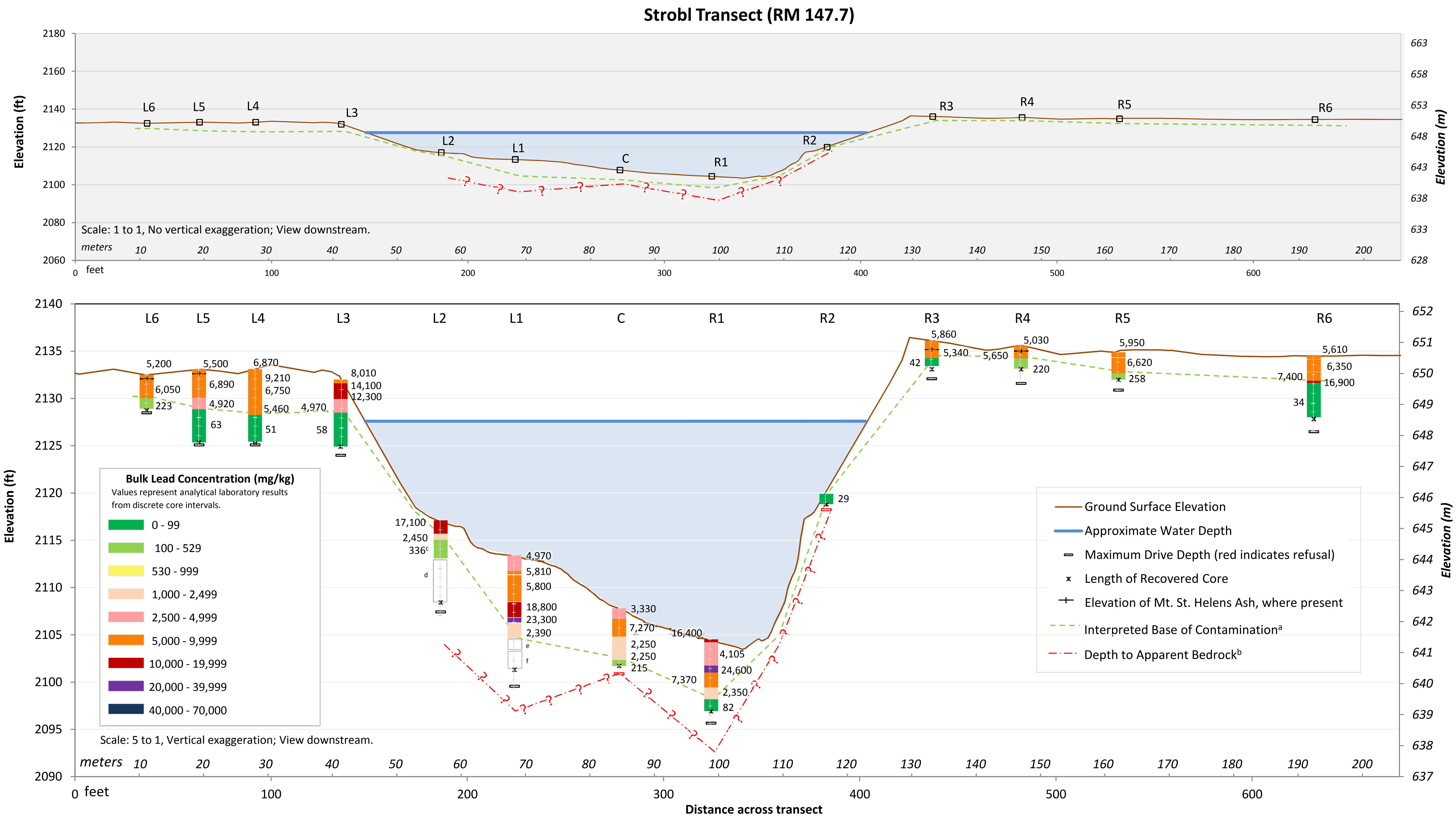


Notes:

[a] Delineation of break between significant contamination from mining waste and non-impacted or minor levels of impact to sediment or soil, based on laboratory data of lead concentrations and/or (where lab data are not available or do not appear to be representative of the entire core segment), field XRF readings and observations of physical stratigraphic breaks. A risk-based threshold of 530 mg/kg lead was used for this delineation. Depths of delineation were not corrected for partial core recoveries.

[b] Depth to apparent bedrock was interpreted based on refusal encountered during coring, or where refusal was not encountered, estimated based on interpolation between refusal elevations and best professional judgment.

[c] The duplicate sample laboratory value for Pb (336 mg/kg) was used for the lowest interval of core L2, rather than the parent value of 796 mg/kg, as this value is more consistent with field XRF readings for this segment (which averaged 16 mg/kg over the sampled interval).

[d] The bottom core interval was not submitted for laboratory analysis based on field XRF readings indicating the overlying interval was uncontaminated. Field XRF readings from this core interval averaged 20 mg/kg Pb.

[e] Core interval was not submitted for laboratory analysis based on field XRF readings indicating the overlying and underlying interval was uncontaminated. (In the core interval above, the laboratory result showed 2,390 mg/kg Pb. The XRF reading at the top of this interval was 1,400 mg/kg Pb, with the remaining 6 XRF reading throughout the length of the core averaging 268 mg/kg Pb.)

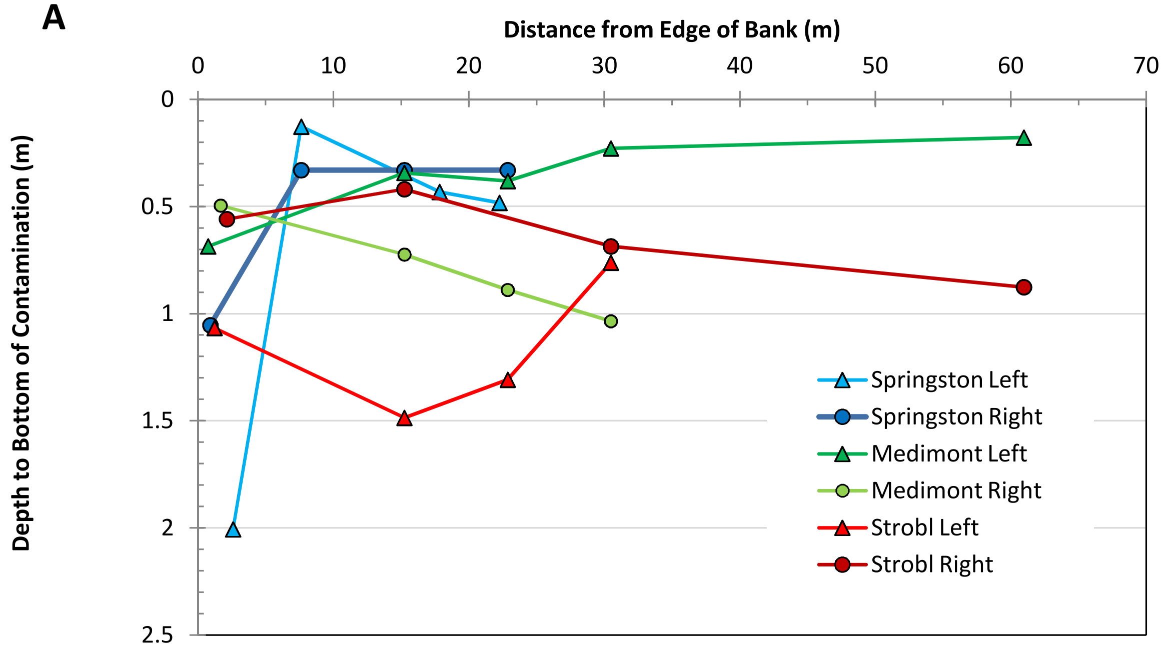
[f] Core interval was not submitted for laboratory analysis. Field XRF readings (4) from this core interval averaged 41 mg/kg Pb.

Exhibit 14C (Sheet 2). **Transect of Riverbed and Bank Cores Coded by Bulk Lead Content, Strobl Location**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Coeur d'Alene River (OU3)

A



B

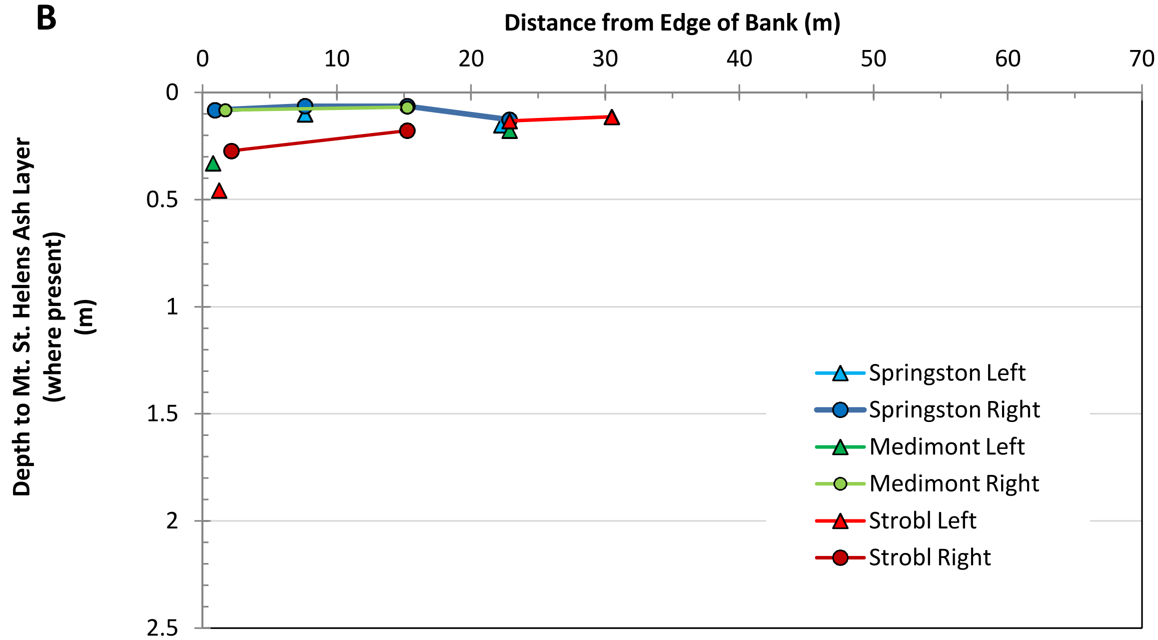


Exhibit 15A and 15B. **Depth to Bottom of Contamination (A) and Mt. St. Helens Ash Layer (B) in Bank Cores**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Coeur d'Alene River (OU3)

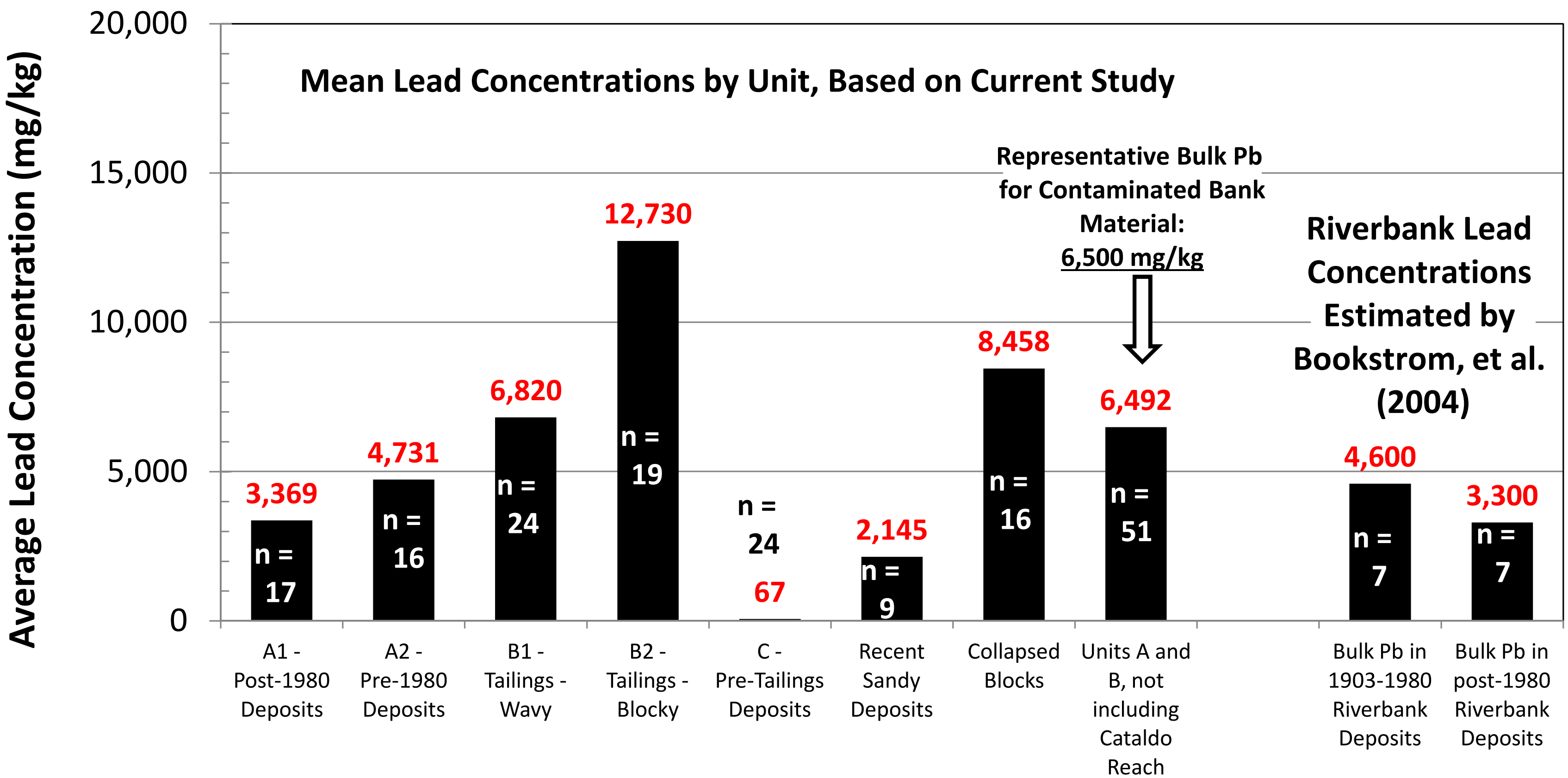


Exhibit 16. **Average Bulk Lead Concentrations by Stratigraphic Unit at 17 Bank Exposures**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

	Category	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Description of Type	**Bank Height**	--	<8 feet	>8 feet	--	--	<5 feet
	Bank Angle	~ 90°	>90°	>90°	--	~ 90°	--
	Root Density	<5%	10 - 15%	10 - 15%	--	>30%	>30%
	Root Depth	≤2 feet	2 - 5 feet	2 - 5 feet	--	≈ Vertical extent of the bank	≈ Vertical extent of the bank
	Bank Soil Description	Mine tailings are prominent. Soils are massive in structure with no visible structure, hard to break apart and occur in large clods. Tailings are easy to distinguish from pre-mining soils (when visible).	Mine tailings are less dominant. Soil structure is not massive.	Mine tailings are less dominant. Soil structure is not massive.	Sandy bars lacking of vegetation and root density	Highly vegetated with shrubs	Thickly vegetated with grasses
Summary	**Total number of miles of bank type**	2.75 miles	11.25 miles	5.59 miles	1.40 miles	14.67 miles	3.49 miles
	Percentage of riverbank	5%	21%	10%	3%	27%	6%

Notes:

Armored banks were classified separately and may be armored with rock or vegetation.

Highlighted bank types were used in erosion calculations.

Photogrpahs of representative bank types are shown below.

Exhibit 17. **Bank Types in Kootenai-Shoshone Soil and Water Conservation District Bank Pin Monitoring**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

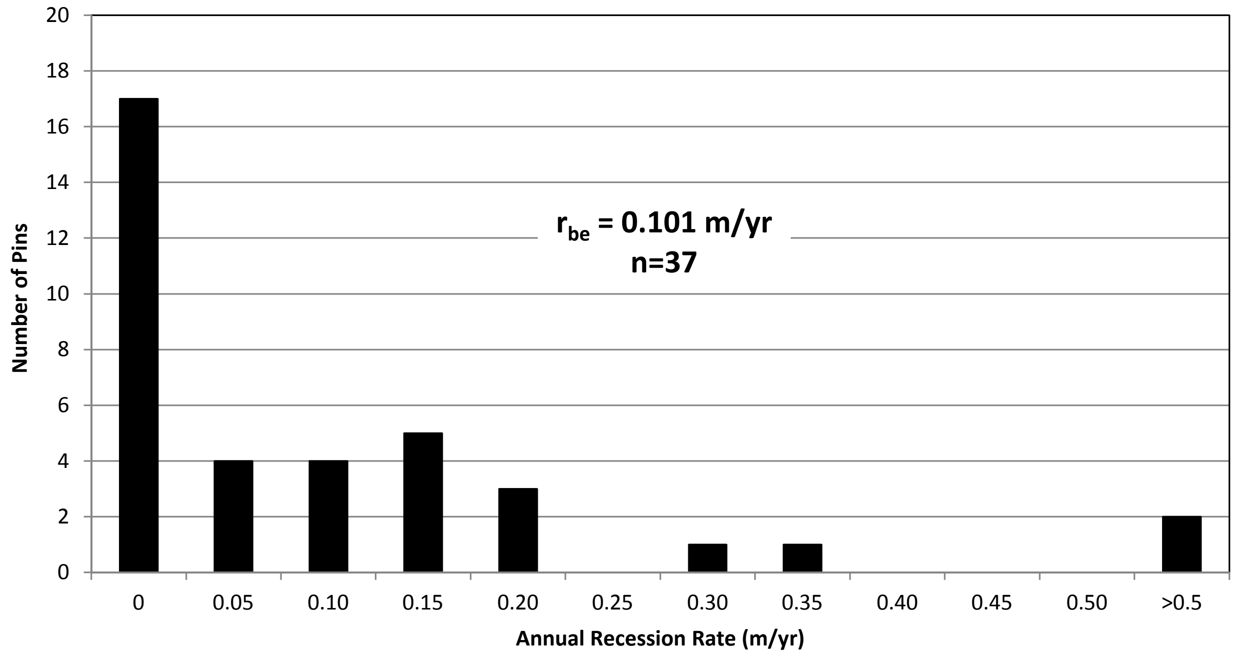


Exhibit 18. **Erosion Rates from Kootenai-Shoshone Soil and Water Conservation District Bank Monitoring from 2008 - 2010, Bank Types 1, 2, and 3**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Coeur d'Alene River (OU3)

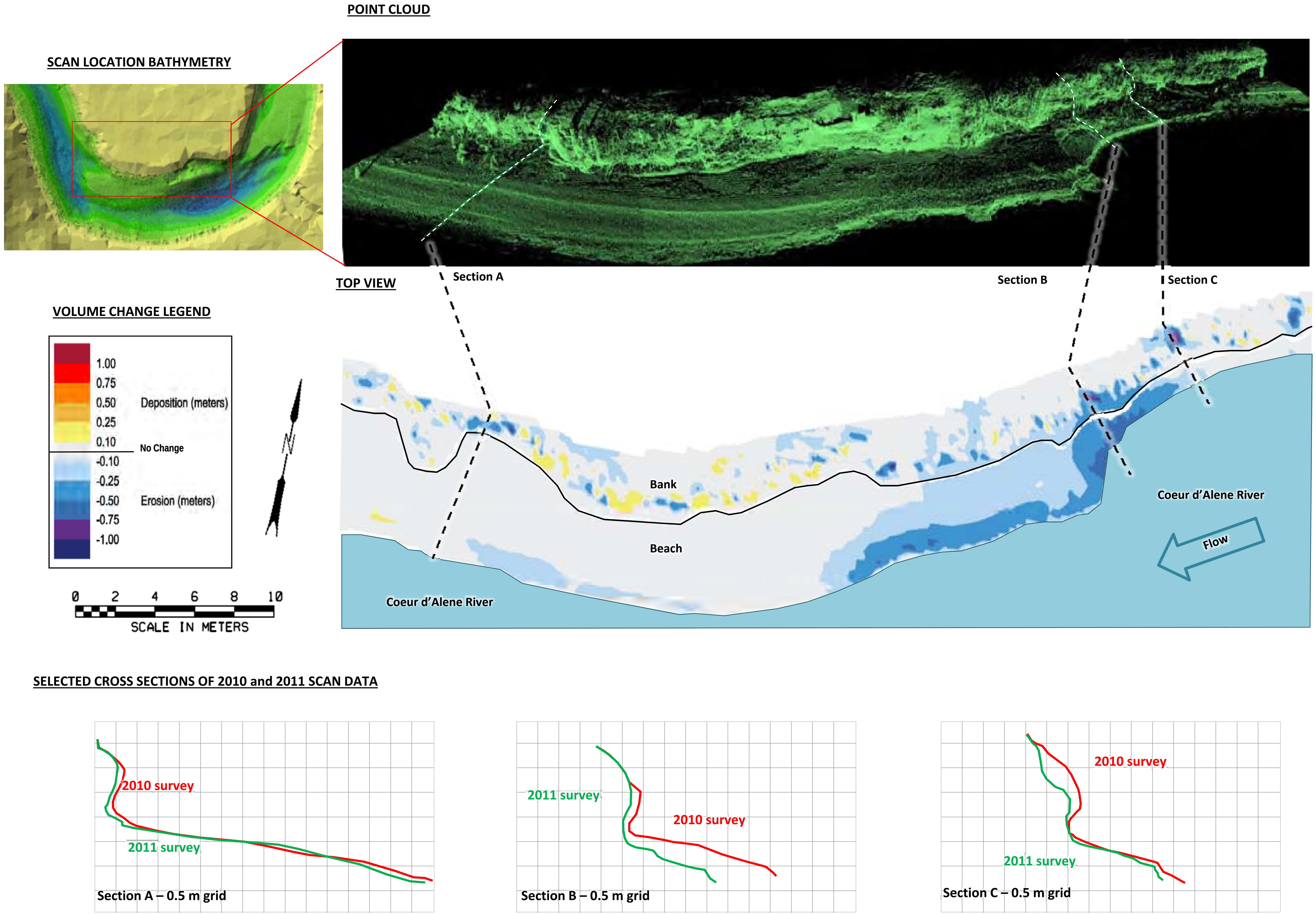


Exhibit 19. **Terrestrial Laser Scanning Example Bank Analysis, Medimont Scanning Location**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

Laser Scanning Locations	Bank Type as Evaluated by KSSWCD/DEQ	Length of Surveyed Bank (m)	Average Height of Surveyed Bank (m)	Period of Laser Scanning	Number of Years of Scanning Results	Average Annual Lateral Rate of Change (m/yr)
Springston Outside bend	1			Apr-11 to Mar-13	2	-0.013
Black Rock Ranch Inside bend	2			Apr-10 to Mar-13	3	-0.007
Medimont Inside bend	1			Apr-10 to Dec-11	1	-0.070
Killarney Straight	3			Apr-10 to Mar-13	3	-0.115
Black Rock Trailhead Inside bend	4			Apr-10 to Mar-13	3	-0.014

Average rate of erosion for all monitored banks **0.044** m/yr

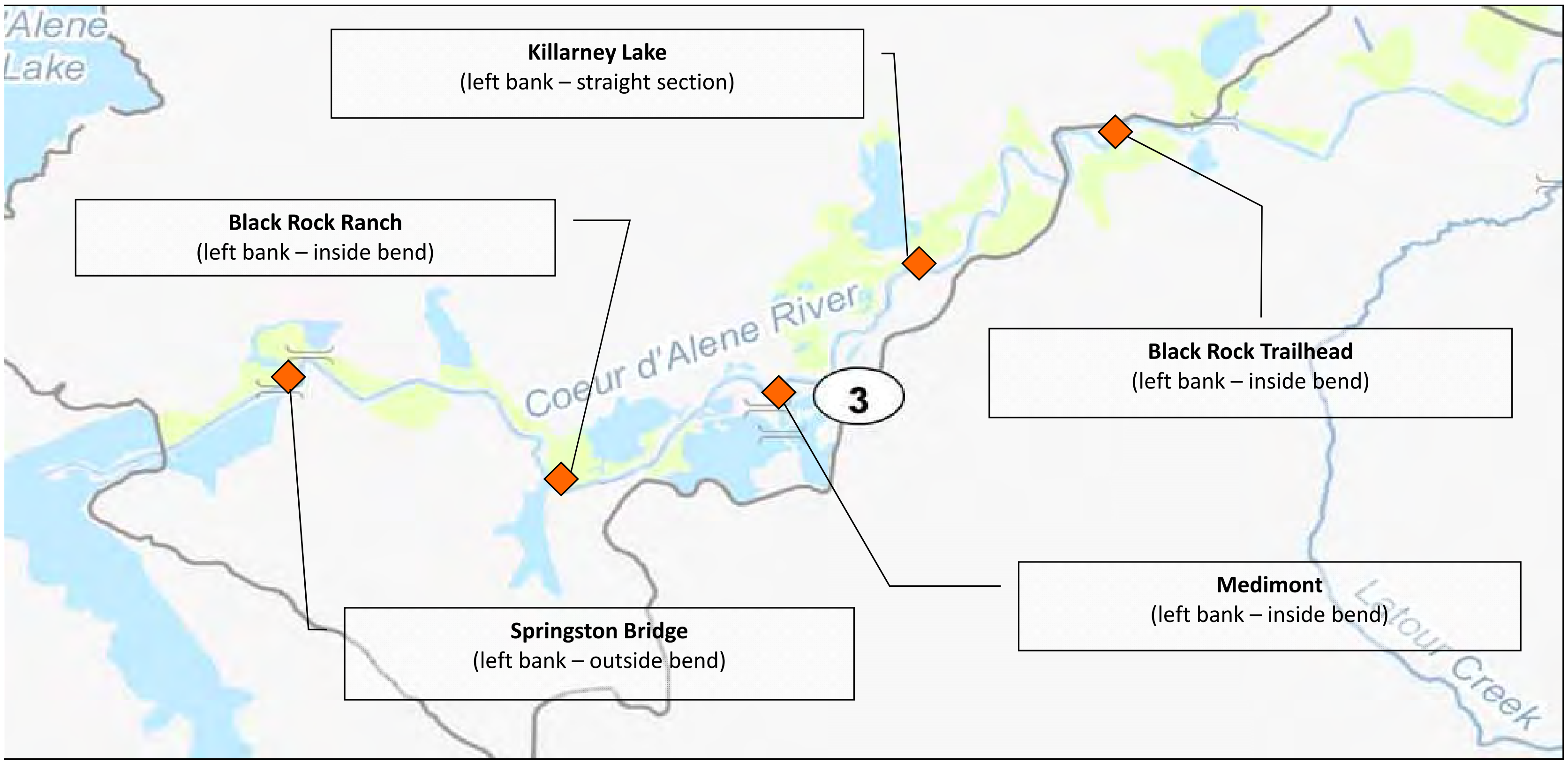


Exhibit 20. **Terrestrial Laser Scanning Locations and Results**
Riverbank Characteristics, Erosion Rates, and Lead Contribution
Lower Basin Coeur d'Alene River (OU3)

Parameter	Minimum Estimate[1]	Maximum Estimate[1]	Best Available Estimate[2]
Length of banks (m)[3]	93,200	93,200	93,200
Proportion of banks that are *not* eroding [4]	0.7	0.4	0.63
Rate of bank erosion (m per yr)[5]	0.04	0.15	0.08
Average thickness of banks (m)[6]	1.5	2	1.85
Thickness of contaminated banks (m)[7]	0.9	1.3	1.18
Bulk density of bank material (tons/m^3)[8]	1.4	1.6	1.51
Average concentration of lead in contaminated banks (mg Pb/kg sediment)[9]	4,000	7,000	6,500
Mass of **sediment** contributed by bank erosion (tons/yr) =	2,349	26,842	7,706
Mass of **contaminated sediment** by bank erosion (tons/yr) =	1,409	17,447	**4,915**
Mass of **lead** by bank erosion (tons/yr) =	6	122	**32**

Notes:

1. Minimum and maximum values made for the purpose of reasonably bracketing the maximum and minimum values of lead contribution. These bracketing values are subjectively determined and not used for any calculations beyond what is shown on this table.

2. Best available estimate given the data presented in this report or in others. Details in the following notes.

3. Based on digitization of the banklines in 2009 air photos. No minimum and maximum values are given because it is assumed that this value is fairly accurate

4. Best available estimate of 0.63 is total bankline minus the estimated proportion of banks that are armored with riprap (28 percent), heavily vegetated (27 percent), or lined with gently sloping beach deposits not prone to bank collapse (6 percent). Percentages are based on bank mapping as presented in KSSWCD (2009) and may not be current. Maximum and minimum values based on subjective judgement based on field observations in Lower Basin.

5. Based on multiple sources of monitoring data - erosion pins, stakes, and repeat terrestrial LiDAR surveys supported by repeat map/air photo analysis. Maximum and minimum values are bounding estimates from different data sources, as explained in section 5.3.

6. Total average height of banks, including both contaminated and noncontaminated sediments. Values are based on stratigraphic measurements summarized in Exhibit 12. Note that average is for the sections measured between the Cataldo and Harrison gages (the area over which the lead contribution is being computed); three sites upstream of Cataldo gage are not included. Maximum and minimum values are subjective based on data shown in Exhibit 12 and general field observations.

7. Average thickness of contaminated sediment in the exposed banks measured in Exhibit 12. Does not include noncontaminated layer (Unit C). Maximum and minimum values are subjective based on data shown in Exhibit 12 and general field observations.

8. Dry bulk density for bank material estimated to be 1.51 tons/m3 by Bookstrom et al. (2001) using from data provided by EPA (1998).

9. Average lead concentration in the contaminated portion of the banks was estimated by simple averaging of all the samples from Units A and B; data in Attachment C. Minimum and maximum bounding values subjective estimates based on data variability.

Exhibit 21. **Sediment and Lead Contributed by Bank Erosion in Lower Basin**

Riverbank Characteristics, Erosion Rates, and Lead Contribution

Lower Basin Coeur d'Alene River (OU3)

ATTACHMENT A

Discussions Regarding Bank Erosion by S. Box, B. Rust, and J. Rowland (2003–2004)

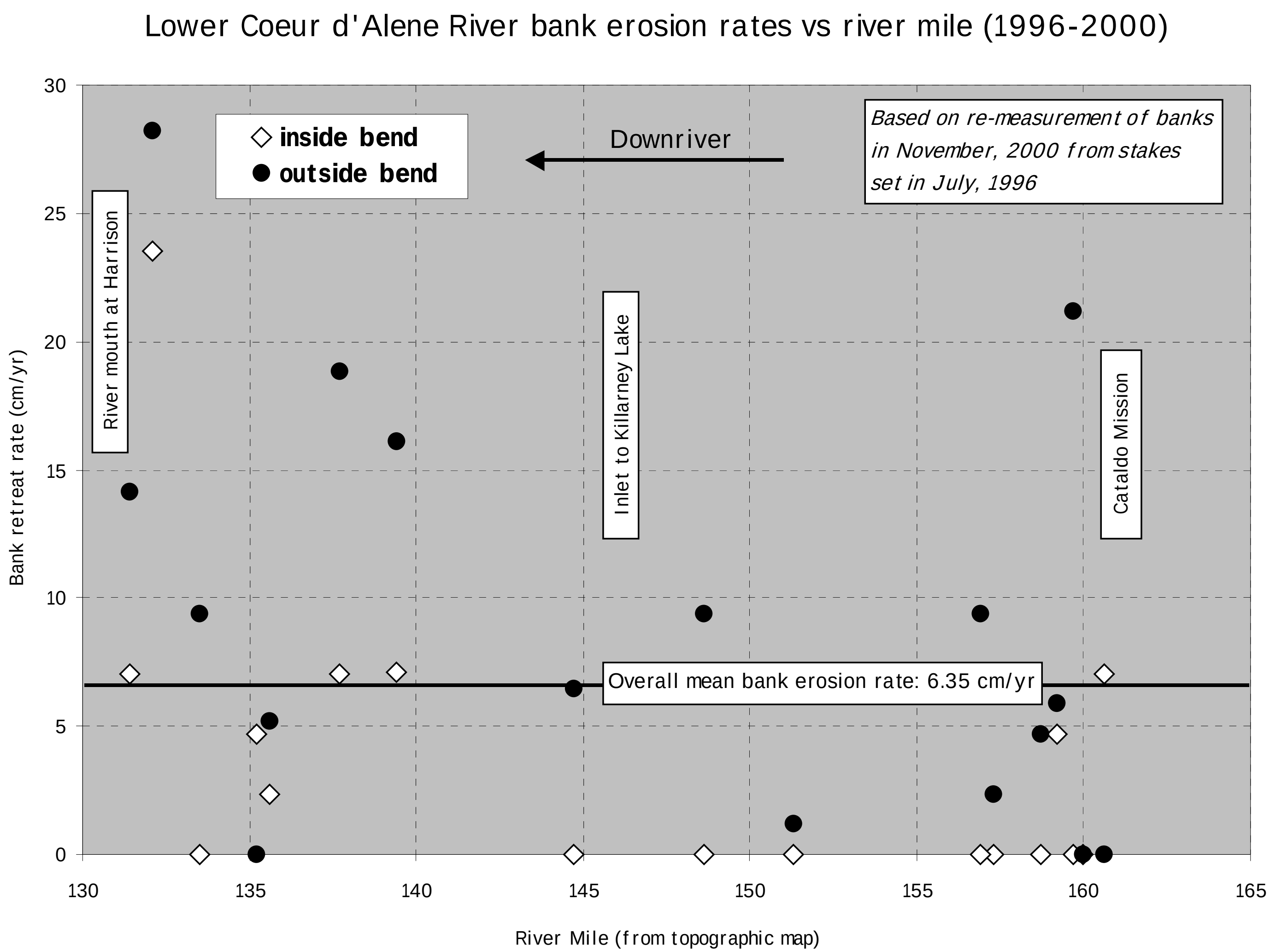
Steve Box, USGS
1/6/03

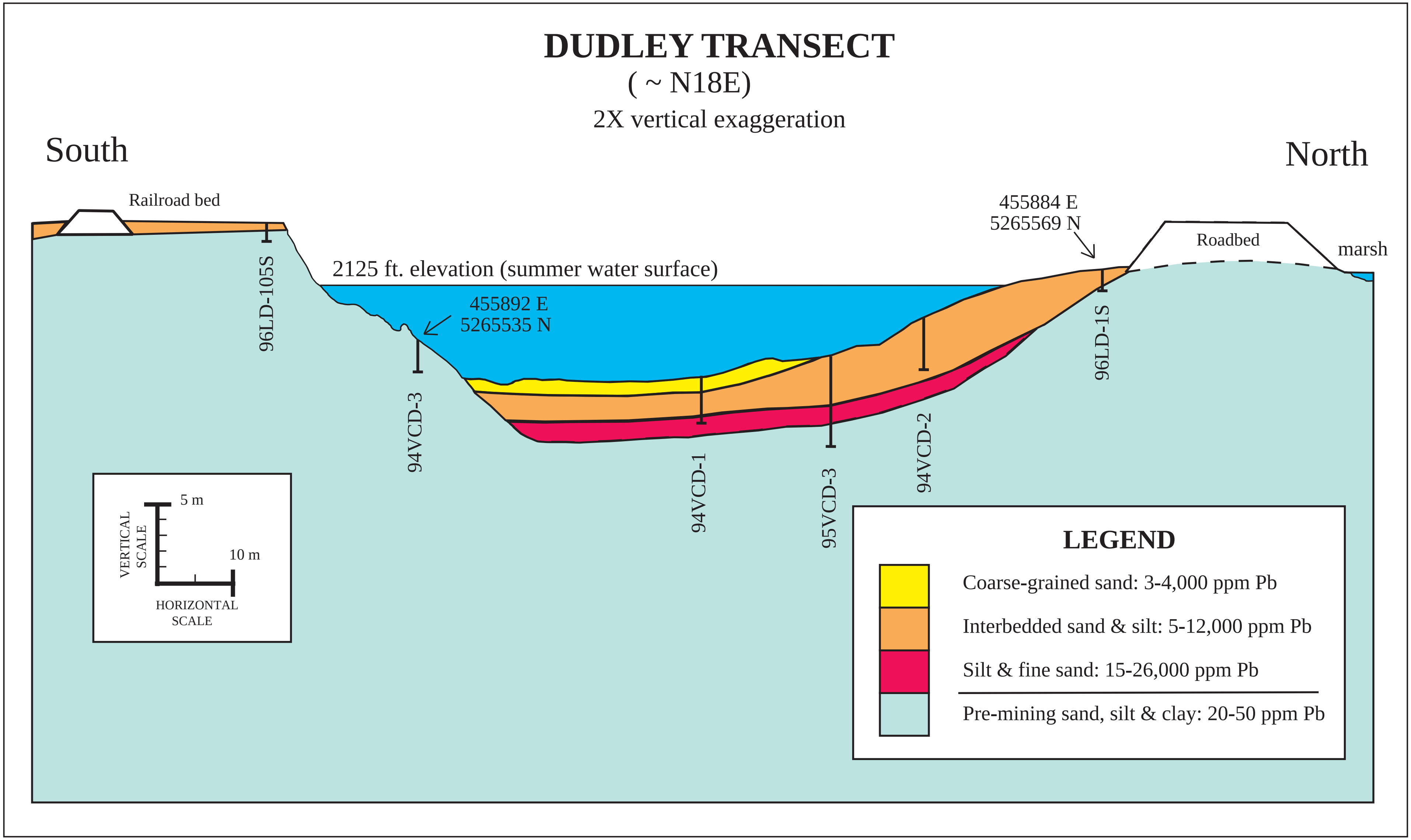
Lower CdA River channel, sediment load and bank erosion concepts

- The river channel in the lower CdA valley downstream of Cataldo Mission is backflooded by the waters of Lake Coeur d'Alene, which is fixed at 2125 feet for the summer months, is drawn down in the fall to about 2120' and fluctuates during winter above and below that depending on winter runoff.
- The natural levee banks of the lower valley channel are composed of fine sand and silt and the natural river bottom is floored by medium sand to silt.
- The river channel in the lower CdA valley has not migrated laterally since 1885.
- Flow velocities in this reach are very low for most of the year (<0.1 foot/second) but can increase to several feet per second during high flow events (6-7 feet/second at Rose Lake and Anderson Lake bridges during February 1996 event).
- A depositional bar 3-4 m thick and 50-60 m wide of historically deposited, metal enriched sandy-silty sediment continuously underlies about two-thirds of the channel width for the 42 km from Cataldo Mission to the delta at Harrison.
- Core samples of this depositional bar show that metal contents increase downward from the top (3-4,000 ppm Pb) to the base (typically >30,000 ppm Pb).
- Prior to 1968 a wedge of metal-enriched sediment had built the levee channelward 3-10 m on one or both flanks of the channel; the wedge is typically <0.5 m thick on the pre-mining levee top and thickens channelward to over 2 m at the summertime river's edge.
- This channel margin wedge has been attacked by erosion along most of the channel flanks downstream of the Cataldo Mission since cessation of tailings dumping in 1968 and has been partly to completely eroded away by bank erosion.
- Erosional riverbanks may be composed entirely of metal-enriched sediment or may expose mostly pre-mining sediment with a thin cap of metal-enriched material, depending how much of the channel margin wedge has been eroded away.
- Deposition of metal-enriched sediment continues to occur on the channel flanks and levee tops during each high flow event. Since 1980 sandy-silty sediment with 3-4,000 ppm Pb has been deposited on riverbanks in the lower valley at a rate of more than a half centimeter per year. This sediment will blanket any remediated banks and levee tops, and the surface soils will remain metal-enriched.

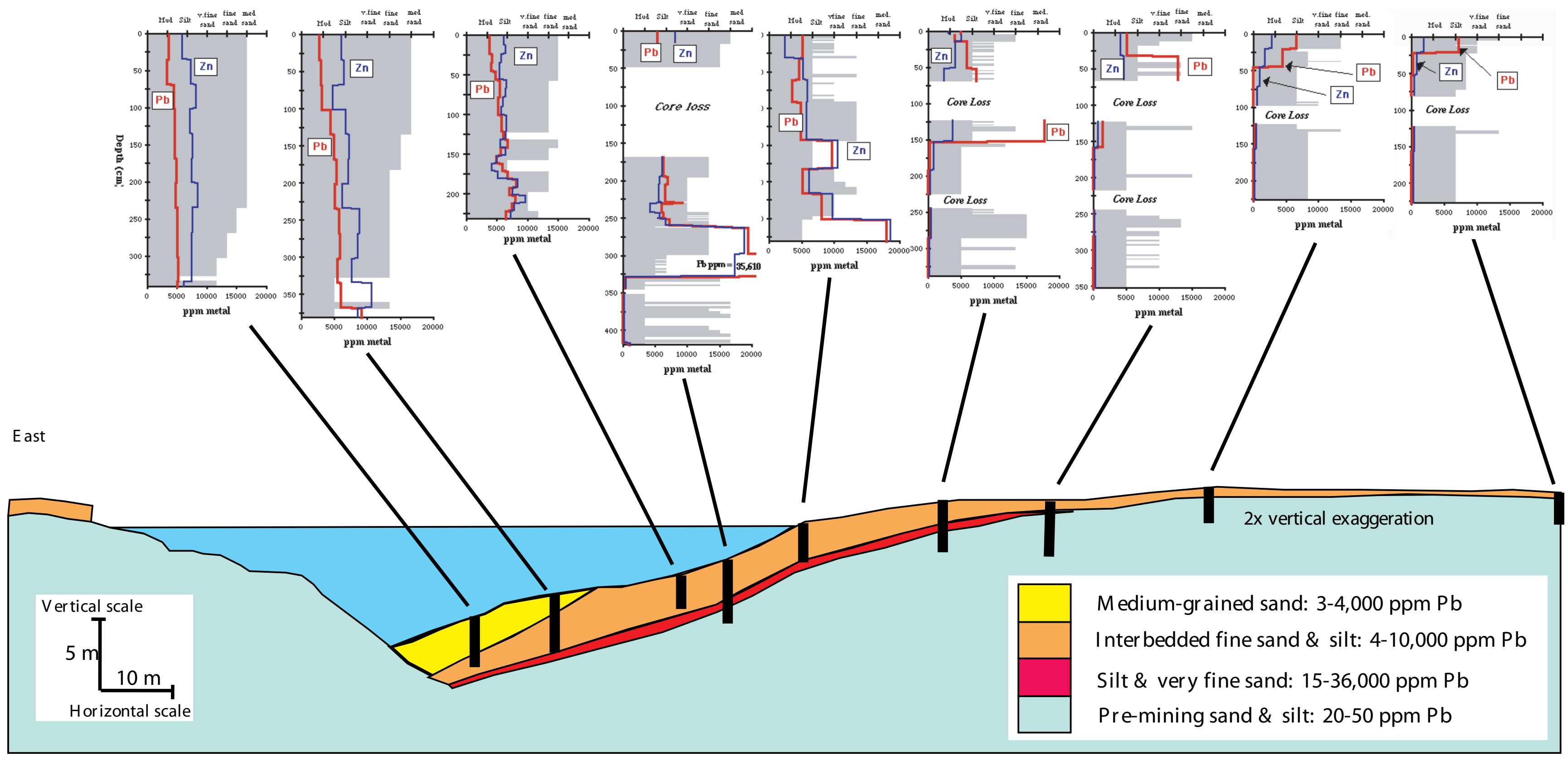
Steve Box, USGS
1/6/03

- Although bank erosion contributes sediment to the deeper channel, its contribution toward the annual sediment load (primarily transported during high flow) is dwarfed by the contribution from the submerged depositional bar that constitutes the bed sediment. Detecting any post-remediation change in either annual sediment load or sediment metal content is unlikely.
- Based on comparison of measurements in July 1996 and in November 2000 at 34 sites, the arithmetic mean bank erosion rate is 6.35 cm/yr; 35% of sites showed no erosion.





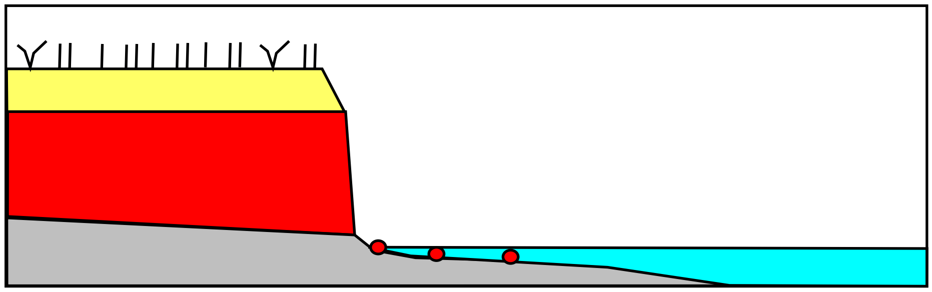
Cross section located on mainstem of Coeur d'Alene River 300m upstream of junction of East Fourth of July marsh road and River road near Dudley. Sample site coordinates are UTM NAD 1927 zone 11. Data from Box, Bookstrom and others, 2001 (http://geopubs.wr.usgs.gov/open-file/of01-139/)



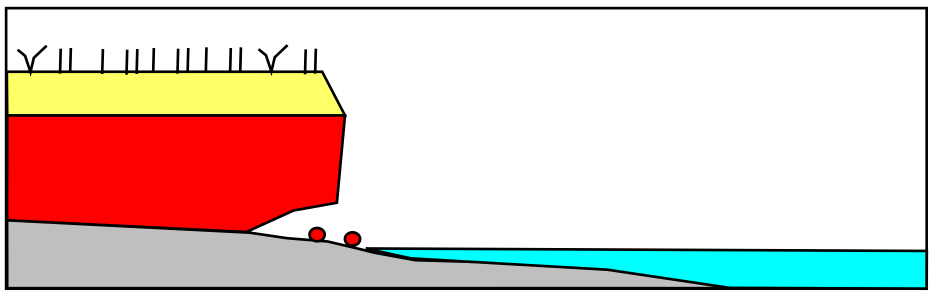
KILLARNEY CORE TRANSECT

Cross-section of core transect across river channel and margins in the lower Coeur d'Alene valley about 1.5 miles downstream of Idaho State Highway 3 bridge. Upper diagrams show lithostratigraphy (shaded) and Pb and Zn contents (red and blue lines) of each core. Data from Box, Bookstrom and others, 2001 (http://geopubs.wr.usgs.gov/open-file/of01-139/).

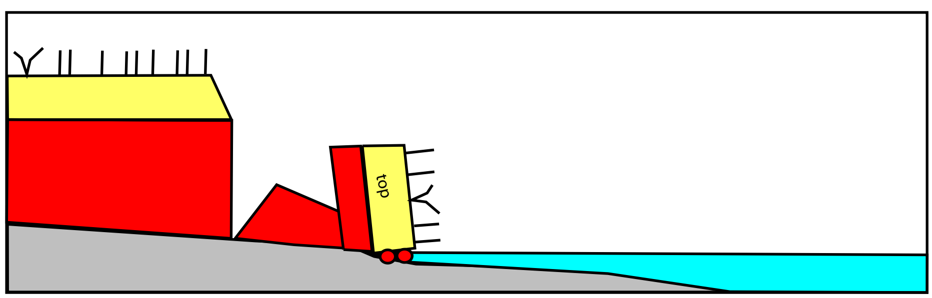
Stages of Bank Erosion, Lower Coeur d'Alene River



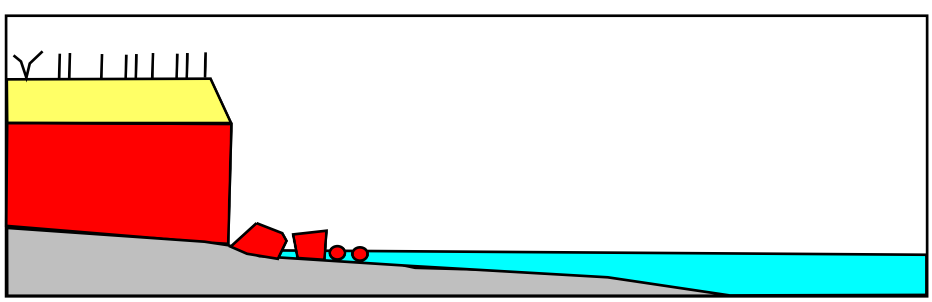
Stage 1: Bank eroded vertical with gravel-sized Fe-cemented fragments on foreshore; bench of pre-mine strata shallowly submerged in front of bank; upper 20% of bank is weakly consolidated fine to medium sand while lower 80% is Fe-cemented silt-fine sand



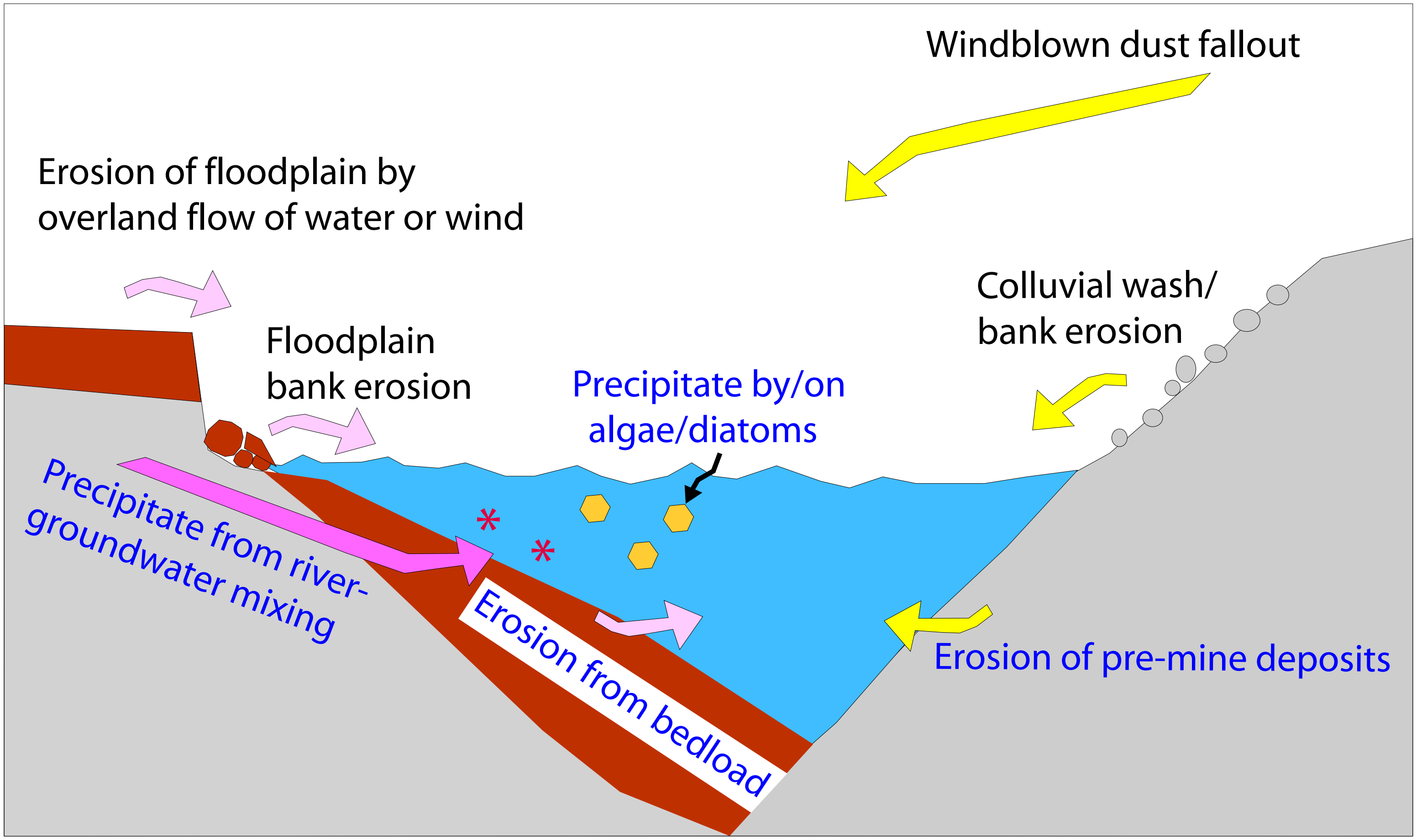
Stage 2: Bank undercutting occurs, typically along contact between clay-rich pre-mine and Fe-cemented tailings-contaminated sediments; focused wave action removes eroded material; undercut lengthens to about 1 meter before block falls



Stage 3: Undercut block falls, rotating forward with some interlayer sliding; collapse typically occurs after growing season during early fall lake drawdown, as shown by rotated grass stalks; upper sandy horizon (held by grass roots) often eroded first.



Stage 4: Erosion focused on fallen blocks, which temporarily protect base of intact bank. blocks gradually disaggregate into coarse sand and gravel sized fe-cemented aggregate fragments. Submerged bench of pre-mine strata finally extends to base of cutbank and cycle returns to stage 1.



Schematic stream channel cross-section showing sources of metal-enriched (pink) and background (yellow) sand and finer sediment

Memorandum to: The Streambank Project Focus Team

From: W. C. Rust

Date: January 28, 2004

Regarding: Lower River Concepts

This Memorandum is a presentation of my present conceptual understanding of the hydrology and geomorphology of the Lower Coeur d'Alene River. I am presenting this in an effort to establish a common base upon which the Streambank PFT can work to resolve philosophical differences. This can only work if persons who do not think my understanding is correct point out those areas where they think I am in error. I am not a hydrologist or geomorphologist but I have a responsibility to Shoshone County to try to understand the situation as well as possible and to advise persons there as to what actions should be taken. If no effort is made to point out errors I may have made then I think we are justified in assuming I am substantially correct.

I will start the discussion by quoting a paper titled "Lower CdA River channel, sediment load and bank erosion concepts" handed out by Steve Box of the USGS during the Lower River field trip in January 2003.

- "The river channel in the lower CdA valley downstream of Cataldo Mission is backflooded by the waters of Lake Coeur d'Alene, which is fixed at 2125 feet for the summer months, is drawn down in the fall to about 2120' and fluctuates during winter above and below that depending on winter runoff.
- The natural levee banks of the lower valley channel are composed of fine sand and silt and the natural river bottom is floored by medium sand to silt.
- The river channel in the lower CdA valley has not migrated laterally since 1885.
- Flow velocities in this reach are very low for most of the year (<0.1 foot/second) but can increase to several feet per second during high flow events (6-7 feet/second at Rose Lake and Anderson Lake bridges during the February 1996 event).
- A depositional bar 3-4 m thick and 50-60 m wide of historically deposited metal enriched sandy-silt sediment continuously underlies about two-thirds of the channel width for the 42-km from Cataldo Mission to the delta at Harrison.
- Core samples of this depositional bar show that metal contents increase downward from the top (3-4,000 ppm Pb) to the base (typically >30,000 ppm Pb).
- Prior to 1968 a wedge of metal enriched sediment had built the levee channelward 3-10 m on one or both flanks of the channel; the wedge is typically <0.5 m thick on the pre-mining levee top and thickens channelward to over 2 m at the summertime waters edge.
- This channel margin wedge has been attacked by erosion along most of the channel flanks downstream of the Cataldo Mission since the cessation of tailings dumping in 1968 and has been partly to completely eroded away by bank erosion.

- Erosional riverbanks may be composed entirely of metal enriched sediment or may expose mostly pre-mining sediment with a thin cap of metal-enriched material, depending on how much of the channel margin wedge has been eroded away.
- Deposition of metal-enriched sediment continues to occur on the channel flanks and levee tops during each high flow event. Since 1980, sandy-silty sediment with 3-4000 ppm Pb has been deposited on riverbanks in the lower valley at a rate of more than a half centimeter per year. This sediment will blanket any remediated banks and levee tops, and the surface soils will remain metal-enriched.
- Although bank erosion contributes sediment to the lower channel, its contribution to the annual sediment load (primarily transported during high flow) is dwarfed by the contribution from the submerged depositional bar that constitutes the bed sediment. Detecting any post-remediation change in either annual sediment load or sediment metal content is unlikely.
- Based on comparison of measurements in July 1996 and in November 2000 at 34 sites, the arithmetic mean bank erosion rate is 6.35 cm/year; 35% of sites showed no erosion."

Following the above statement is a graph showing erosion rates vs river mile that I did not reproduce.

In general, the information I have seen indicates nearly all of these statements are true although some should be clarified.

In the first statement I believe the 2125 should be a 2128.

The fourth statement about flow velocities says velocities can increase to 6-7 feet/second at the Rose Lake and Anderson Lake bridges during high flow events (the February 1996 event). I would like to point out that these locations are pinch points in the channel and this was an extreme event. This is important because velocities elsewhere in the channel and during normal annual high water are probably much lower. All the information I have seen suggests that only in restricted locations do the velocities ever get high enough to erode vegetated or compact clay banks. In most areas, only the highly concentrated energy of boat wake waves undercutting and disaggregating the banks causes lower river erosion. In the Technical Memorandum from Hart-Crowser regarding the Rose Lake Boat Ramp project on page 9 they say that they assumed the cross sectional area and average velocities are equal to those at the USGS Rose Lake guage site. On page 18, they say that the calculated shear stress along the bank above elevation 2128 feet during the February 1996 event was 0.3 psf. They further say that the reported range of allowable shear stress on vegetated side slopes is 0.4 to 3.3 psf. They conclude that storm flows are not likely to destabilize vegetation placed above the high water line. In other words, the velocity during a 10 to 25 year event on the outside of a corner in a constricted part of the river channel is not high enough to erode a vegetated slope. Since we see slopes which were vegetated eroding something else beside storm flows initiates the erosion.

The eighth statement says that the channel margin wedge has been partially to completely eroded away. I think this should be clarified by saying this is particularly true in areas with the most actively eroding banks. There has been a lot of discussion about wedge removal. I think in most of the actively eroding bank areas such as around Medimont bend the wedge is already gone. The five-foot high banks are mostly lacustrian clay with a foot to 18 inches of contaminated sediments on top. So far, there has been no discussion about what we should do with such areas. If these banks are sloped back the clean material from the lower bank could be used to cap the contaminated sediments creating a clean riparian zone.

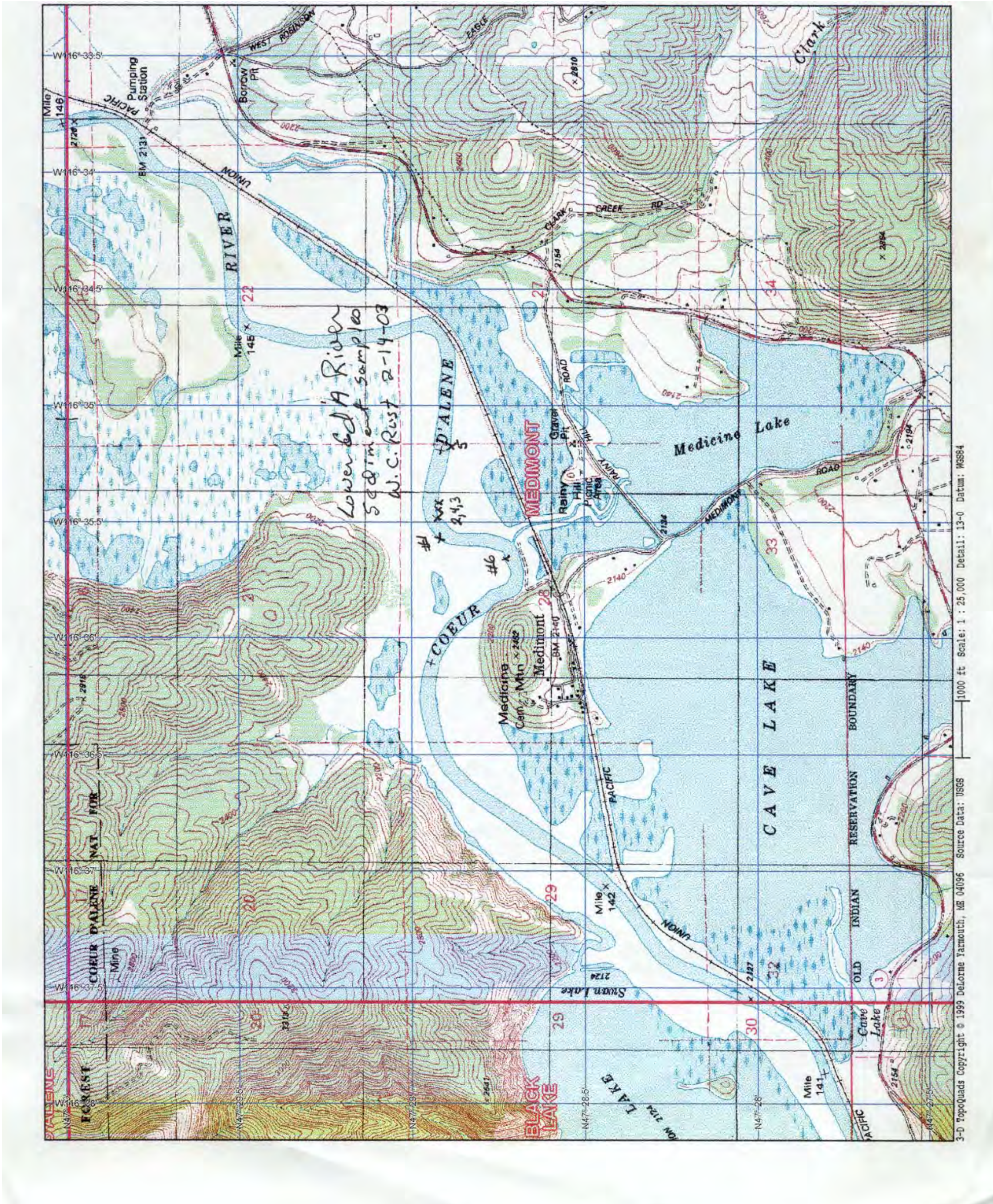
The tenth statement says that since 1980 contaminated sediment has been deposited on the river banks at a rate of more than a half centimeter per year. The presence of Mount Saint Helen's ash layers indicates that this is probably true of the entire lower river floodplain. Although there may be a little reworking, in general, the floodplain is a sink and not a source of contaminated sediment. I think that a careful analysis of the stratigraphy would show steadily decreasing metal contents toward the surface, particularly in the upper reaches toward the Cataldo Mission. This could be important in planning the remediation. The last part of the tenth statement points out the fact that any remediation on the riverbank will be covered with contaminated sediment. If the sediment in the river grades from about 1,200 ppm at Cataldo to about 5,000 at Thompson Lake, it doesn't make any sense to spend a lot to create a clean riparian zone at the lower end of the river. However if the concentration is steadily decreasing at Cataldo and we can do things to increase that rate of decrease then we might be able to anticipate that a clean area near Cataldo would only get a few centimeters of deposition grading from 1,200 ppm down to 700 ppm and lower thus staying reasonably nontoxic.

The eleventh statement says that the annual contribution of sediment by bank erosion is dwarfed by the contribution from the bed sediments. I am not sure I can agree with that statement. I have not seen any explanation of how he arrived at that conclusion and it not consistent with my conceptual view of the processes operating in the lower river area. The slack water part of the river is part of the delta of the Coeur d'Alene River. Historically this whole area has been a depositional area. Core samples containing Mount Mazama ash show historical deposition over the whole area. Recent anthropomorphic changes with additional sediment loads and raising the Lake level should have made it even more so. Statement ten says deposition is still occurring on the banks and in the floodplain. Why is the bed eroding? Why is it not also depositional? It certainly is in the area near Cataldo and in the area below highway 97. Where does it change from depositional to erosional and back to depositional? In order for the bed to be contributing most of the load, it would have to be eroding downward and increasing the channel size. Erosion of the channel margin wedge is also enlarging the channel in this area. What would be driving the general channel enlargement?

Additional problems I have with the concept of the river bottom as the major source are related to the amount and character of the sediment load at Harrison. According to the RI, about 21,000 of the 51,000 tons of sediment load at the 97 bridge during 1999 came from the area between there and Rose Lake. The RI also estimated bank erosion rates of

0.5 and 0.8 feet per bank per year. If we assume the average of 0.65 feet per year applies to 33 miles of eroding bank 4 feet high with a bulk density of 85 pounds per cubic foot we get a contribution of about 20,000 tons. The twelfth statement of the previously quoted handout estimates an erosion rate of 6.35 cm. per year but this rate is for all banks including 35% that do not erode at all. If this rate is applied to both banks of the 99,290 feet of channel from Rose Lake to the 97 bridge with banks averaging 4 feet high one gets a rate of 7,033 tons. A specialist for the Kootenai – Shoshone Soil and Water Conservation District estimated a rate of 3,900 tons per year. If we look at a little more detail, the RI estimated yearly sediment loads at Rose Lake and the 97 bridge based on stream guage data and sediment yield curves. The estimates varied from 5,338 tons in 1992 to 70,617 tons in 1997 for Rose Lake. Figures for the 97 bridge were 9,989 tons for 1994 to 361,476 tons in 1996. I have not seen data that supports the river bottom being the major annual source of sediment.

I also have a question about the character of the sediment load. According to the RI, about 20% of the load at the 97 bridge is sand (plus 63 microns) and 80% is fines (minus 63 microns). I took six samples from eroding riverbanks and exposed sandbars near the Medimont Bend boat launch area. The locations are shown on the attached map. The screen analyses are shown on the attached spreadsheet. At least in this area the banks are much finer than the sandbars exposed during low water which are presumably similar to the river bottom. The banks averaged 82% minus 75 microns while the sandbars averaged 14.6% minus 75 microns. The banks look a lot more like the load at the 97 bridge than the sandbars. If we look at the annual load estimates for the 97 bridge in the RI, the averages are skewed by the year 1996. During that year, the estimated load was 272,565 tons of sand and 88,911 tons of fines. This material looks more like the bottom and I agree that major flood events are likely to mobilize the bottom. This does not mean that during normal years the bottom provides the major part of the sediment load.


Lower CdA River
sediment sampled
W.C. Rust 2-14-03
#1
#6
2,4,3
5
COEUR
D'ALENE
RIVER
MEDIMONT
Medimont
Medicine Mtn
Medicine Lake
CAVE LAKE
Swan Lake
Cave Lake
BLACK LAKE
Rainy Hill
Picnic Area
Gravel Pit
Pumping Station
Borrow Pit
CLARK CREEK RD
OLD INDIAN RESERVATION BOUNDARY
COEUR D'ALENE NAT. FOR.
UNION PACIFIC
3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS
1000 ft Scale: 1 : 25,000 Detail: 13-0 Datum: WGS84

Steve Box
2/10/04

I applaud Bill Rust's efforts to try to forge a common understanding of the sediment transport and deposition processes that operate along the lower Coeur d'Alene River, as the Streambank PFT works toward developing a coherent plan of action. I also appreciate the careful reading he gave to my field trip handout from a year ago. Below I address his comments to my bullet statements. From the outset I would say that, although there are many facts derived from sampling and measurement in the lower river that we are relatively certain of, there are still many uncertainties about many of the important processes.

Statement #1 – Just to clarify the 2125-2128 confusion… The surface water elevations at the CdA River gages at Rose Lake and at Anderson Lake are given by the USGS as their true elevations above sea level, which in summer time is roughly the elevation of CdA Lake and is about 2125'. Unfortunately the CdA Lake gage at Coeur d'Alene has historically been and continues to be reported relative to a USGS benchmark whose original survey gave its elevation as 3' below the real value, so that the lake elevation at Coeur d'Alene is reported as 2128'. Because of the long history of this gage, the 2128' value continues to be used (and is the elevation given in the newspaper every day), even though it is not the correct elevation above sea level. So on the same day the elevation of Cda Lake at Coeur d'Alene is given at 2128', while the lake elevation at Harrison is given at 2125'.

Statement #4 – Bill is correct in pointing out that the river flows of February 9,1996 (8 years ago!) occurred during an extreme event (calculated roughly as a 50 year recurrence interval flow, as I remember, although similar flows occurred in 1974 and 1933) and that these velocities give some idea of what the river is capable but don't happen every year or at every location along the river. Designing remedial actions to withstand these and perhaps even higher flow velocities seems prudent to me, and this sounds like what Hart-Crowser have done in their report (I haven't seen it).

Statement #8 – Bill is correct in noting that many highly eroded and eroding banks along the lower river expose mostly pre-mining, clay-rich, gray levee sediments (not lacustrine because they were deposited during high flows in a levee environment), with 30-50 cm cap of historically deposited, red-brown metal enriched sediment. These banks erode somewhat differently than the weakly cemented red-brown metal enriched banks, and contribute mostly metal-poor sediment to the river. They could be sloped back as Bill suggests, but it should be kept in mind that once they are sloped back enough to become a depositional site, annual or biannual flooding will deposit metal-enriched sediment on that surface and it will no longer be a "clean riparian zone". This recontamination is the major conundrum of bank or riparian remediation along the lower CdA River.

Statement #10 – I agree with most of Bill's assessment here. In general there is some evidence of gradually decreasing metal contents upward in the historically deposited, metal-enriched materials (arriving at the present values below Cataldo of 3,000-5,000 ppm lead). Both bed sediment and sediment deposited during the 1995 and 1996 floods show the lowest sediment metal contents (roughly 1000-2000 ppm lead) along the entire South Fork-main stem CdA River near the Cataldo boat landing. Sediment metal contents increase sharply between there and the Dudley reach, where sediment from recent floods and on the riverbed have more than 5000 ppm lead. Further reducing metal contents of sediment in the Cataldo boat landing area seems like a reasonable and attainable short-term goal and should be coordinated with any bank remediation activities. Dealing with banks in the reach from Dudley downstream to Harrison will be more difficult because of the nagging recontamination problem.

Statement #11 – At issue here is the question of the source of sediment annually transported by the CdA River. "Sediment" is defined as all of the solid material moved by the river along the bed and within the water column in any year. As the lower CdA River rises, water also flows from the river into the lateral lakes and marshes, depositing its suspended load there. The annual quantity of sediment in the RI was estimated from application of instantaneous suspended sediment measurements at the USGS gaging stations to the continuous streamflow measurements; the gain in sediment load from the lower valley was calculated by subtracting the calculated Rose Lake gage load from the Harrison gage load. The suspended sediment lost to the lateral lakes and marshes is not accounted for. These suspended sediment measurements also do not measure sediment moving along the bottom (the samples are collected starting a foot or so above the river bottom), and deposition on the river banks results partly from bed load movement. Bill presents calculations that suggest that the mass of material in annually eroded streambanks in the Rose Lake to Harrison reach is roughly equivalent to the mass of suspended sediment that is gained between Rose Lake and Harrison. From that calculation he suggests that bank erosion, not bed mobilization, is supplying most of the measured suspended sediment. Although I can quibble with some of the numbers used (the bank retreat rate of 0.65 feet/year [20 cm/year] is about 3 times higher than the average rate we measured), I do agree that bank erosion is transferring a significant mass of material into the deeper channel for subsequent transport downstream. As I mentioned above, a lot of suspended sediment is lost to the lateral lakes and marshes so the annual volume of suspended sediment gained in the lower valley must be significantly larger than that measured difference between that at the Rose Lake and Harrison gages.

Geochemical analyses of bed, bank, and (very limited) high-water suspended sediment samples also indicate that bank samples differ from bed and suspended sediments in having low Zn/Pb ratios (less than 0.5) because of leaching of Zn by downward percolating precipitation. Bed and suspended sediment samples have similar Zn/Pb ratios of greater than 1.0, quite distinct from the bank samples. So we aren't simply transferring the eroded bank material downstream each year because then the suspended sediment would look geochemically like bank sediment. Other sources must also be contributed to yield the higher Zn/Pb ratios.

There are a number of possible explanations of this data but we lack the evidence to sort out the possibilities. We know that metal-enriched groundwater moves to the river, especially during fall drawdown of Lake CdA, and that mixing of the slightly acidic and reduced groundwater with the oxidized surface water produces a fine precipitate with a very high Zn/Pb ratio. Also floating algae and diatoms precipitate metals from the river water (also with high Zn/Pb ratio) and these biologic particles settle to the bottom to become part of the sediment. So the mixing of these materials with eroded bank sediment might raise the Zn/Pb ratio of the suspended sediment to observed levels. Careful scanning electron microscope examination of bed, bank and suspended sediments might be able to resolve these components and answer the question.

Steve Box
2/10/04

Let's consider for a minute the concept of the river channel and its sediment. Typically the lower CdA bankful channel (bankful to the top of the levee, generally considered to reflect the average annual or bi-annual high-water elevation) is about 80m wide and 10m deep. Levee heights generally decrease downsteam but average about 2m above summer pool. So during high-flow, bankful episodes, the submerged 2m river banks account for a relatively small part of the river cross section (roughly 5%). The relatively fine-grained size of the bed sediment (medium sand and finer) allows most of the bed sediment surface to be mobilized during high-flow episodes. So in most years the material deposited on the bed surface from bank erosion, groundwater return and biologic fallout, along with some depth into the top of the sandier bed, is mobilized during high flow and carried downstream. Deposition during the waning of the high-flow stage generally returns the bed to roughly its initial configuration, with the new layer a mixture of the mobile pre-existing bed sediments and new material from upstream, from eroding banks, from groundwater mixing and from biologic fallout. Basically the river bed acts as a conveyor belt with a continuous stream of sediment moving along it during high flow.

Variations in each high flow event can lead to net erosion or deposition at any particular site. Analysis of sediment cores from the lower river bed indicate that there has been net deposition of 3-5 m of metal-enriched sediment on the river bottom bars since mining and milling began in 1886. However we don't know if the river bed continues to receive an annual net deposition today or whether there is a net erosion of the river bottom, or whether it has reached a static equilibrium. The May 1980 Mt St Helens ash has not been found in the riverbed sediments and was probably mobilized during the onset of high flow during the December 1980 episode, leaving us without our natural time marker.

Repeated bottom profiling at the Rose Lake bridge gage site (now discontinued) and at the Anderson Lake (Harrison) gage site could be analyzed to try to address that question at those sites. I went through that exercise with data from 1995 to 1997 to look at the response to several high flow events. For each event you see net erosion in some parts of the profile and net deposition in others, and some events lead to net deposition and others to net erosion. The February, 1996 event consistently resulted in net erosion to the Rose Lake, Anderson Lake and also the Cataldo gage profiles. Likewise several boat launch ramps were also eroded and undercut during the 1996 flood, suggesting net erosion to the river channel during that event.

As Bill notes the erosion of the channel margin wedge suggests the river is enlarging its channel and wonders what could be driving that enlargement. I interpret this enlargement as being due to the continued adjustment of the river channel to the cessation of tailings dumping into the river by the concentrating mills in the mining district around 1968. Prior to that time the continuous tailings dumping resulted in an opaque, sediment-saturated river that deposited fine sediment in and along the channel throughout the year which was remobilized during annual high water into the river bar from the deepest part of the river to the levee (the levee-ward part of which is our "channel margin wedge"). With the cessation of tailings sediment input into the channel in 1968, the river began to rework previously deposited material during the annual high-flow episodes, attacking the artificially aggraded banks and bed.

Finally, Bill mentions that the grain size distribution of bank samples he collected near Medimont (80% minus 75 microns) is similar to the grain size distribution of the sediment load at Harrison from the RI but dissimilar to that of river bar sediments he collected (15% minus 75 microns) near Medimont. He suggests that that supports the idea that bank sediments are the major source of the Harrison load. However the grain size distribution of suspended sediment load is controlled by many factors like stream velocity and sorting, as well as by the character of the source material.

Well, I see that my discussion has wandered around a bit, so where does all this lead us? I think that ultimately the important questions in terms of bank remediation are:

1. If we stop the banks from eroding material into the deeper channel, will we reduce the amount of suspended sediment transported by the river?
2. Will bank remediation reduce the metal content of riverine suspended sediment?
3. Will bank remediation reduce the amount or metal content of sediment subsequently deposited on the river bank (generally transported as both suspended and bed load)?

If these reductions in amount and/or metal content of suspended sediment (and bed sediment?) are the true goal of the remediation in the lower CdA valley, I question whether rehabilitating some proportion of the eroding riverbanks will have a measurable effect on either in the nominal 30 year life of CdA Basin remediation. But I think Bill's suggestion of focussing remediation efforts at the upper end of the lake-backflooded river reach (near the Cataldo boat landing) and trying to expand that "cleaner" zone downstream by stabilizing/removing the metal-enriched bed and bank components of the river channel progressing downstream.

February 13, 2004

To: Bill Rust and TLG interested in Lower Basin Planning
From: John Roland
Subject: Lower Basin Forum – Bill's recent Lower River Concepts Memo

In preparation of our meeting on the 17th, Bill R. offered a very useful presentation of lower Basin conceptual issues that are well deserving of discussion. In that context I thought it appropriate to add my assessment of some of the items that Bill discussed and that were further clarified by Steve Box. The following comments are offered on selected portions or statements from Bill's memo:

- *"The natural levee banks of the lower valley channel are composed of fine sand and silt and the natural river bottom is floored by medium sand to silt."*

I concur with the comments related to this subject made by Steve B. and I also think it is important to keep in mind that in the banks there is commonly some degree of cementation, particularly those high in tailings. Geotechnical work prior to construction projects should: 1st- be standard procedure and 2nd- include an evaluation of bank integrity and geotech. properties on a location by location basis relative to specific projects, until such time we have a solid geotech. understanding of the horizons.

- *The river channel in the lower CdA valley has not migrated laterally since 1885.*

This is essentially true, but how to interpret it relative to remedial action is a product of the Basin's history. Geologically, of course, the lower River study area is a floodplain and delta complex. On a macro basin, geological-time-scale level it is depositional complex. On a decades time scale it is a system striving to reestablish equilibrium with reduced input and local-scale erosion and redistribution occurring continuously. Without the aid of dredging the upper channel would have most likely repositioned itself over the last century. Regardless, the ROD goal is to reduce particulate lead from entering Lake CdA. Some of that is from the gradual retreat of banks. The key will be to identify and prioritize the most threatening banks (e.g., richest in metals) and of those segments that are most unstable.

- *Flow velocities in this reach are very low for most of the year (<0.1 foot/second) but can increase to several feet per second during high flow events (6-7 feet/second at Rose Lake and Anderson Lake bridges during the February 1996 event).*

I am requesting that the USGS be tasked to evaluate all their transect velocity records in the lower River over several flow regimes and river positions to confirm for the TLG and engineering designers what our maximum velocity values should be for bank design purposes. I'm not sure if this will be reflected in bank-full conditions or otherwise.

- *A depositional bar 3-4 m thick and 50-60 m wide of historically deposited metal enriched sandy-silt sediment continuously underlies about two-thirds of the channel width for the 42-km from Cataldo Mission to the delta at Harrison.*

This may be semantics, but I wanted to clarify that the river bottom doesn't have a unique or singular bar feature along its bottom, but rather a system of wave forms, involving different types of bars moving and forming along the channel length.

- *Core samples of this depositional bar show that metal contents increase downward from the top (3-4,000 ppm Pb) to the base (typically >30,000 ppm Pb).*

I feel it is valuable if folks visualize this statement as a broad, typical vertical profile characteristic, but not necessarily representative of the active channel conditions. The channel bottom is dynamic and down cutting and deposition is occurring simultaneously along the bottom as flow conditions vary. Older, higher-metal-content horizons may be exposed and contributing to bed or suspended load in certain locations and be buried by less rich newer or active horizons at other positions. As the lower River has now been deprived of its historic tailings sediment burden, the river now may be re-appropriating that net energy shift onto the bed [e.g., net erosion] and banks.

- *Erosional riverbanks may be composed entirely of metal enriched sediment or may expose mostly pre-mining sediment with a thin cap of metal-enriched material, depending on how much of the channel margin wedge has been eroded away.*

Gaining a clearer understanding and inventory of the conditions of banks along the length of the lower River relative to metals-enriched sediment and contaminated wedge magnitude should be an important factor in the prioritization of banks for remediation and possibly the remedial actions taken at any particular location.

- *Deposition of metal-enriched sediment continues to occur on the channel flanks and levee tops during each high flow event. Since 1980, sandy-silty sediment with 3-4000 ppm Pb has been deposited on riverbanks in the lower valley at a rate of more than a half centimeter per year. This sediment will blanket any remediated banks and levee tops, and the surface soils will remain metal-enriched.*

Appreciating that the rate of accumulation is averaged and varies by location is important when considering remedies on a site by site basis. This general trend is an important reality though, and the remedy needs to accept this possibility, as metals in sediments above natural conditions will be in this basin for ever. The factor to accept in many of these cases it that the ROD is striving toward a net decline in metals availability. Thus, for example, if a bank wedge having 40,000 ppm Pb is removed, capped or otherwise "cleaned up" and then is covered by a veneer of 4,000 ppm Pb soil…. is that not a good thing?

- *Detecting any post-remediation change in either annual sediment load or sediment metal content is unlikely.*

The Basin-Wide monitoring plan will attempt to detect large-scale improvements. On a more project-specific level, though, we should be able to design monitoring efforts to permit a definition and measurement of success that can be extrapolated as appropriate to record net improvements.

- *Based on comparison of measurements in July 1996 and in November 2000 at 34 sites, the arithmetic mean bank erosion rate is 6.35 cm/year; 35% of sites showed no erosion."*

This is clearly an area deserving more focused and intense assessment, which was one of the objectives behind the recent Washington TLG representatives CWA study proposals. We are fortunate to have this limited information from USGS, which is a set of opportunistic information gathered during previous channel cross-section work. The averaged value needs to be used with caution. These data were not gathered with the objective of answering the kinds of questions being asked today about the current nature and behavior of retreat along the banks.

On a related note, it also is important to appreciate that the Conservation District bank retreat estimates that Bill referenced are extremely limited in their application to present lower CdA River conditions. As I've noted before, that body of work has been frequently misapplied to our current purposes. It was not intended as an accurate assessment of the current active processes along the lower River system.

"In most areas, only the highly concentrated energy of boat wake waves undercutting and disaggregating the banks causes lower river erosion."

We may never fully come to terms with this issue of boat wakes vs. current and, also, as Steve Box has noted in conversation, erosion influenced by wind. The conditions and nature of this fluvial/reservoir system that man has created and the realities of the geomorphic conditions observed along the lower river show us that both fluvial and wave action affects the banks and levees.

"They [Hart Crowser] *further say that the reported range of allowable shear stress on vegetated side slopes is 0.4 to 3.3 psf. They conclude that storm flows are not likely to destabilize vegetation placed above the high water line. In other words, the velocity during a 10 to 25 year event on the outside of a corner in a constricted part of the river channel is not high enough to erode a vegetated slope. Since we see slopes which were vegetated eroding something else* [inferred to be wave action] *beside storm flows initiates the erosion."*

We must avoid over simplification of such engineering assumptions applied to a specific project. If such assumptions were explicitly and unconditionally true many low energy meandering streams around the world would never have cut banks. What I think is important for our purposes is that we are concerned about un-vegetated, unstable cut banks and are interested in learning more about the nature of the stable, vegetated banks we find also along the lower River.

"Although there may be a little reworking, in general, the floodplain is a sink and not a source of contaminated sediment."

Again, caution is advised. While on a watershed basin scale and in geologic terms the lower River is a depositional area, on a more local level we have erosion and redistribution, not to mention a river system seeking equilibrium from decades of artificial sediment load and a continuation of sediment load entering from the north and south Forks.

"If the sediment in the river grades from about 1,200 ppm at Cataldo to about 5,000 at Thompson Lake, it doesn't make any sense to spend a lot to create a clean riparian zone at the lower end of the river. However if the concentration is steadily decreasing at Cataldo and we can do things to increase that rate of decrease then we might be able to anticipate that a clean area near Cataldo would only get a few centimeters of deposition grading from 1,200 ppm down to 700 ppm and lower thus staying reasonably nontoxic."

Bill is making a couple of interesting points here; one I concur with, the other not. Focusing on the upper end of the lower River is a topic I agree we should explore further. Regarding the Thompson Lake - like example, I would caution that if appropriate protection can be engineered to guard a wetland from severe recontamination then a remedial action at such a location may have higher merit.

Bill's paper also asks several questions about the nature of erosion and deposition along the lower River and also cranks through some loading and erosion numbers as well as grain-size considerations to essentially suggest that the bed is not eroding much, but the banks more so.

I think Steve Box effectively pointed out some of the risks of jumping to quick conclusions on this set of issues. I could respond further, but what really is needed here is more knowledge via focused studies and pilot work. Thus, our planning should identify just what information this project needs to make on-the-ground remedial decisions. Data gathering, modeling, and skilled interpretation seems to be the path toward improving our knowledge on these related topics, in the framework of remedial actions.

"This material looks more like the bottom and I agree that major flood events are likely to mobilize the bottom. This does not mean that during normal years the bottom provides the major part of the sediment load."

It also does not mean that the banks do. We need to resolve how far to carry this contribution question, prior to reaching diminishing returns.

Memorandum to: The Streambank Project Focus Team

From: W. C. Rust

Date: February 22, 2004

Regarding: Continuing Discussion of Lower River Concepts

This memorandum is intended to continue the development of a consistent conceptual model of the lower river. I am responding to John Roland's memo and subjects discussed at the Lower Basin Forum. Regarding John's memo, I generally concur with the statements about bullet items 1,2,3 and 4. Regarding bullet 2, I would like to clarify the changes to the lower river sediment load over time.

Before the 1920s whole tailings from gravity concentration mills were discharged into the river. Most of the coarse fraction was deposited in the upper basin. The fine fraction of these tailings that made it past Cataldo and were deposited in the river contained very high concentrations of lead and zinc. After the development of flotation, ores were ground finer and there was a dramatic increase in recovery. Flotation tailings typically contained less than 1% each of lead and zinc. After starting the dredge in 1932 there was a large decrease in sediment getting past the dredge pond, particularly the sand sizes. In the early years, the dredge was operated to create a large pond to catch sediment from floods. A report on the history of the dredge says the 1933 flood filled the pond to 90% of capacity. It also says they doubled the volume in 1934. During the 1950s and 1960s, the mines were converting to underground sand fill. The sand fraction of the tailings was seperated at the mine and sent back underground. Typically, 50% or more of the tailings had to be recovered for sand fill to refill the openings created when the ore was mined. The load to Cataldo became a lot finer and the load to the lower river even more so. During the 1960s, the mill throughput was about 500,000 tons per year. Tailings disposal to the river would have been about 250,000 tons per year which were about 95% fines. The dredge pumped an average of 288,763 cubic yards per year from 1960 through 1967. If that material had an average bulk density of 80 pounds per cubic foot then this represented about 312,000 tons per year which probably contained nearly all the sand coming from upstream. Then the mines quit dumping tailings in the river and the dredge was shut down. During the 1960s the yearly sediment to Cataldo in tons (ignoring bedload) probably looked like:

	Sand	Fines	Total
From Mines	12,500	237,500	250,000
From North Fork (RI)	15,738	33,382	49,020
From South Fork w/o mines	?	?	?
Total	>28,238	>282,000	>299,020

The sediment out of the Cataldo dredge pond probably was:

	Sand	Fines	Total
Dredge	? 30,000	? 282,000	312,000
Downriver	?	?	?

The net to the lower river was probably small and very fine. After the dredge shut down there would have been a period of time when a lot of fines and sand were being remobilized from the South Fork. That was probably completed by the 1974 flood. I arrived in the valley in 1975 and the river bottom was gravel and cobbles then much as it is now. There was still some erosion from some piles of jig tailings particularly in the Ninemile, Canyon Creek and Smelterville Flats areas. The yearly figures from the RI are:

	Sand	Fines	Total
From North Fork	15,738	33,282	49020
From South Fork	6,767	9,185	15,952
Conf. to Cataldo	?	?	?
Total	>22,505	>42,462	>64,972

Comparable figures at Rose Lake and Harrison are:

At Rose Lake	8,135	18,821	27,207
At Hwy. 97 Bridge	44,628	36,709	81,338

Because I was focused on water quality, I ignored floodplain deposition. According to Mr. Bookstrom he estimated floodplain deposition to be about 192,000 tons per year in the early 1990s. If we look at the river from Cataldo to the 97 bridge we see:

In From Upriver	22,205	42,467	67,972
In From other Tribs.	?	?	?
Total In	>22,205	>42,467	>64,972
Out to Delta	44,628	36,709	81,338
Out to Floodplain	?	?	192,000
Total Out	>44628	>36,709	273,338
Net Out			<205,000

This would have to come from the bed and banks of the river. Even if the banks contributed 20,000 tons, the bed would have to contribute 190,000 tons. As far as I am concerned in bed VS banks the bed has it.

Part of the problem was my assumption that the stratigraphy shown on the cross sections presented by Steve Box were representative of the whole river. That stratigraphy argues against large scale bed reworking. It is between the annual layers of the lake bottom which point to no reworking and the 20 foot thick section at the dredge pond where everything from 1932 to 1968 is gone. Mr. Box's sections show pre-mining clay, gravity tailings, fine flotation tailings and sand post 1968 deposition. There could have been shallow reworking but if there were extensive deep reworking some of the upper three layers would be gone. Perhaps additional cores would show this. In Mr. Box's memo to Kara Seward he says four more transects were planned. Were those completed and is the data available? I also saw mention of cores a half-mile above Dudley and at the Dredge pond. Is other core data available?

In response to John's comment on the fifth bullet, I believe I have explained how that statement and John's statement that this is a typical profile is inconsistent with extensive deep reworking. If the gravity tailings are being exposed and we had enough cores, we should see post 1968 sand on top of gravity tailings. I think the discussion of historical sediment load shows that the load below Cataldo has actually increased substantially since 1968 particularly in the sand sizes. What is really happening is that the river is coming to equilibrium with a radically changed grain size in the sediment load. There is certainly some reworking of the river bottom. We can see this in the point bars. Instead of eroding deep holes in the bottom, most of the load could be coming from the winnowing of the finer sediments out of the bed. Over time, the bed would become coarser until it came to equilibrium with the increased sand load from upstream. This is consistent with my size fraction analysis of bottom material, which showed a relatively small amount of fines. In this case, Mr. Box's sections may be typical.

I agree with John's statement regarding the sixth bullet.

With regard to John's comment on the seventh bullet, I think the question is what factors influence metals availability. If the primary pathway to receptors is from near the surface of the soil then "cleaning up" the banks and floodplain is purely a temporary measure. The lead concentration on the top of the banks and floodplain will be about the same as the last flood. If we have deposition of one centimeter per year and the primary source to receptors is from the top five centimeters then cleaning up an area buys a clean area until the next flood. After that it becomes progressively dirtier and after five floods it is essentially the same as if we had nothing. How much is society willing to pay for a temporary fix. I know superfund guidelines do not encourage this.

Regarding the comment on bullet point 8, if we cannot see the sum of the improvements I do not see how we can see the small part from each project.

Regarding the comment on bullet point 9, I think the overall load balance makes the point moot. I would like to take exception to the statement that the Conservation District's estimates are extremely limited in their application. NRCS is the primary agency in this nation tasked to deal with erosion control. They made their estimates with the objective of decreasing erosion from the banks of the Lower Coeur d'Alene River, which I think is our objective. I think anyone criticizing NRCS estimates of erosion rates and proposals for erosion control should state their qualifications for expertise in that field and why they think their judgment is better than NRCS.

Regarding the comment on the italicized section after bullet point 9, I believe discussion of the Kenai River study will allow us to resolve that issue. They found wind waves were insignificant.

Regarding the comment about the Hart Crowser work, I would ask if low energy meandering streams with heavily vegetated banks really do develop cut banks. I certainly do not know. I think we need to ask someone with extensive experience with these types of streams. The reason this is important is, if we can expect banks stabilized to resist boat wake erosion at the high water mark with fully vegetated slopes above that to resist erosion from major floods, then we can expect that anything buried behind that bank to be as secure as in any repository. This could reduce the cost of bank and floodplain remediation by many millions of dollars.

Regarding John's statement about floodplain reworking, Mr. Bookstrom said that sampling was done in the floodplain at over a hundred locations to assess deposition rates. Mount St. Helen's ash was found in nearly every hole. Anywhere there is substantial reworking of the floodplain the ash layer will be gone. If the ash layer is essentially continuous in all areas where other reworking (Frank Frutchey's plow) did not occur then reworking of the floodplain is not substantial.

Regarding John's statement about Thompson Lake remediation, "appropriate protection to guard the wetland from severe recontamination" is a euphemism for a large river dike. Do we really want to tackle the problems of designing one of those?

Where do we go now? I think we should still pursue streambank stabilization although it may not address the whole problem of particulate lead. Streambank stabilization is in the ROD and it will provide some progress toward satisfying the Clean Water Act ARAR. I think the issue of boat wake erosion VS fluvial erosion can be settled by discussion of the Kenai River Study and a presentation by a qualified engineer with extensive experience like John Fripp, Mr. Bingham of Hart Crowser or someone with similar qualifications. Such a person can tell us what sort of stabilization is needed to withstand wave erosion, what is needed for fluvial erosion and what are the constraints imposed by legal/regulatory requirements for river work. It would be nice to wait for the results of the USGS river modeling but I think we need something in the near future and more detailed information when the modeling work is done.

With regard to the problem of bed erosion, it is my understanding that the USGS river modeling should provide us with some sense of where that is likely to be severe and where it may not be happening. Those results could be used to design a core-sampling program to better characterize the bottom of the river. Core sampling may be very expensive when done by USGS but with Silver Valley wage rates a lot more can be accomplished with less money. It is not a lot different than sampling yards. The combination of the model, detailed bathemetry and additional core sampling should allow us to identify the areas that are most likely to be the largest sources and areas better left alone. We may find, like the bank wedges, in the highly erosional areas the highly contaminated sediments are already gone. Quantative data on grain sizes should also allow us to assess how much contaminated sediment is available from shallow reworking of the bottom sediments.

There needs to be a discussion of whether upland repositories really make sense. It appears to me that burying lead contaminated soil in the floodplain with at least three feet of cover to keep it out of reach of some ones plow is as secure a repository as we are likely to accomplish. It also gives us a source of clean material for a cap. This would greatly simplify lower river remediation. It would also eliminate repository operating and maintenance costs in this area.

Because of recontamination issues, widespread stripping to create clean zones does not make sense to me. If it can be combined with something else like streambanks it should certainly be done but I think any one proposing large expenditures solely to create short term clean zones will have to offer a clear explanation of the objectives, the ARARs we are trying to satisfy and exactly what benefits are expected from the work. Cost will be the largest issue. Perhaps some variation of deep plowing to turn things over and expose cleaner surfaces can be done in a cost-effective manner. I very much doubt that money to strip the material and send it to an upland repository will ever be available and I do not think we should spend much money on preperatory work unless there is some assurance that funds will be available.

March 5, 2004

To: Bill R.
From: John R.
Subject: Selected Responses to your February 22 Lower River Concepts thoughts

In response to the ongoing brainstorming of lower Basin history and system theories I would like to offer a few follow-up responses to your February 22 correspondence, as well as a cautionary statement to those who may be following this process.

The serious chunk of time you've dedicated toward the array of data and information gathered in the lower Basin and lake has been expressed via memoranda to the lower Basin TLG folks. As the TLG advances toward laying down a path forward for lower Basin cleanup, the purpose of these exchanges has been to advance a more common groundwork for establishing data needs and technical discussions, planning, and a desire to find points of common understanding in system processes. This has evolved into a non-binding arena for discussion. That is why the basis for any calculations, the use of proper references, a formal peer review process, etc. have not been a part of this endeavor.

As such, I have a concern that this current series of TLG exchanges, personal perspectives, & views may inadvertently lead outside readers toward misinterpretations, misunderstandings, or misapplications. Thus, while I believe most if not all of the TLG understand these limitations, I offer an important cautionary note, or disclaimer, to readers: *We (the TLG) are in the middle of a technical discussion involving some free and loose application or manipulation of data and broad theorizing at times. These discussions are not in any way a formalized product of the TLG, nor should they be referenced as fact, a replacement for existing peer reviewed bodies of work, the RI/FS, ROD, or widely endorsed works. It would not be recommended for representations, presentations and discussions on most of these discussions to be widely applied or referenced beyond the TLG lower Basin planning participants. The fruits of these discussions will principally be in the form of eventual planning, project and task recommendations to the Commission for work forward. We have a ways to go.*

Specific to your February 22 essay I offer the following footnotes:

- The inherent error and uncertainty surrounding the various loading tables presented is not minor. Over-simplification and -extrapolation is a serious concern. Real considerations of actual comparability and completeness of the various data should be applied very cautiously in the ongoing TLG discussion. If these types of loading values are ultimately deemed important by the TLG to future modeling efforts, for example, then the TLG will need to identify recommended scopes of work tasking a party such as the USGS to re-configure and derive such numbers so that they can be widely applied and defended for planning purposes.

My read of the discussions on loading leads me to infer that the tables alternate between suspended loads and bedloads. Interchanging these two mechanisms in a discussion can be somewhat confusing and can lead to misinterpretations. As we've discussed, these can generally be defined as distinct active processes. To what degree and resolution we need to model these processes at any particular location should be established and driven by our planned remedies.

- In your Feb 22 discussion on the stratigraphy of the channel, the argument is made that "extensive" deep scour or reworking is not occurring. You infer that I believe extensive bed erosion is occurring. Important here is what the word extensive means? I would interpret that to mean widespread evidence that the channel is aggressively down cutting from Cataldo to the mouth. Available cores and other factors indicate this is not likely the case. This is a good thing. Additional coring and modeling may help us locate more erosion-susceptible channel positions or segments. The apparent absence of obvious 'extensive' bed erosion does not, though, change the fact that we continue to measure or observe unacceptable metals-rich suspended load and bed load entering Lake CdA and spilling over to the lateral lakes and floodplain. The ROD remedy incorporates source control measures to begin reducing ongoing releases. A question the TLG will no doubt address is the best manner in which to assure the greatest load reductions. Dredging, bank stabilization, and engineered splays are the primary remedies envisioned by the ROD. The ROD also contemplates the need for additional remedy-oriented data acquisition. Focused, additional coring may indeed aid us in evaluating the frequency and extent of periodic scouring into the most contaminated strata, but the fact remains that the lower River continues to operate as a major source area of mobile metals-rich sediments and that, beyond long-term natural attenuation, these loads are to be reduced through active remediation.

- Part of the Feb 22 discussion included a particle distribution discussion of bed sediments, particularly the finest fraction. The collection of cores for sample analyses also was discussed. A word of caution is appropriate here relative to coring: Rigorous sampling techniques are required to successfully and accurately recover the fine silt and clay fractions of bed sediments especially at the water interface, which is the most readily mobile component of the load. Proper grab or core sampling of sediments is not as simple as yard sampling and requires skilled operators with the right equipment and clear objectives.

- You commented on one statement that I made regarding the measurement of improvements on a project basis vs. the sum of improvements (e.g., detecting large-scale post remedial change). Again, if we measure improvements at a specific site we can extrapolate as to how that reduces loading or will affect the broader environment. Simple examples might include something like: measured shoreline turbidity reduction created by bank stabilization, or the net removal or isolation of contaminated sediment from the environment associated with the river bed or splays. The BEMP will function on a basin-wide level.

- Regarding a comment related to me concerning the application of the Conservation District bank erosion rate report, I am frankly astounded by the apparent wild accusation that I somehow don't see the importance and value of the NRCS or Conservation Districts and their work. My points were apparently missed completely…. generally that being the referenced item is simply not appropriate for our current needs and was not intended to be applied for such. The bank retreat measurement work of USGS provided further context on this topic at the recent first lower basin forum gathering. More importantly, a solid plan for monitoring ongoing bank conditions should be implemented; the sooner the better. Such plans are awaiting TLG approval and adjustment in the context of lower Basin planning.

- Regarding the question of whether low energy, heavily vegetated meandering streams develop cut banks I would offer that the answer is yes, but the magnitude and frequency of exposed banks and their erosion rates is a function of soil characteristics, gradient, hydrographs, climate, etc. In the context of the Feb 22 discussion of whether stabilized banks can effectively serve as repositories I offer the following comments. Such a placement of material would not likely be as "secure as in any repository", assuming we use the word repository to mean a classic engineered waste disposal facility. But on the topic of integrating the on-site re-arrangement of contaminated bank soils into the bank designs, such project-specific placement may be feasible under a variety of scenarios… and not so desirable in some others. This supports the concept of having a tool kit of options to use on a case by case basis and the value of the streambank stabilization demonstration projects.

- Regarding the Thompson Lake conceptual remedial example the Feb 22 memo suggests it is just a euphemism for large river dikes and you effectively question whether such a design would be too large a design, cost or construction challenge to make it a worthy concept. I'm not advocating for or against such a remedy, but it is not appropriate to suggest or infer that it is too complicated or costly to pursue. Potential secondary hydraulic effects are one important aspect, though, that must be evaluated if such a project were of a scale to potentially cause significant channel energy changes. The mapping work and numeric modeling being conceived should notably enhance planning in this regard. If we can implement sound science and engineering I believe it will lead toward appropriate designs and construction that can selectively enhance important wetland sites.

- Regarding the Feb 22 memo recommendation that the TLG consider using floodplain land as disposal sites then capping them with site soils, to eliminate repository needs, I offer the following: So called on-site or opportunistic disposal concepts may indeed materialize as we advance planning on specific remedies, but this will probably be case by case. I believe that on-site, or near-site disposal in the lower Basin could have a place, depending on volumes, location, geology, etc. The lateral lakes targeted for remediation are a related example of where on-site removal and disposal might apply. When looking at this type of disposal several important considerations must be addressed, including factors such as land availability and access, land use, leaching concerns, infiltration, long-term performance, etc. Case histories abound around the country of poorly placed wastes. Closer to home the waste pile moved off the floodplain in lower Canyon Creek is an example of a disposal site that has created a suspected new groundwater point source due to its location, placement, and design.

The advantage of formal repositories is that they can be soundly engineered, operated, and closed. The efforts required to site facilities and gain community acceptance is not trivial. Thus, it is most often best to construct a central facility that supports the broader needs. Further, once a facility is in place it provides certainty and cost predictability for implementation of projects that have disposal as one of their components.

- The Feb 22 memo also provides a commentary of doubt that money to "strip the material and send it to an upland repository will ever be available and I [Bill] do not think we should spend much money on preparatory work unless there is some assurance that funds will be available." In partial response - first, I'm not really sure what was meant by "widespread stripping" relative to the floodplain so I won't address that part. On the second part of the statement I think it is inappropriate and inaccurate to suggest that funds will never be available for upland repositories in the lower Basin. Nor is it appropriate for the TLG membership to guide their planning and advisement on such personal predictions. The ROD envisions and incorporates disposal. Further, the concept of suggesting that preparatory work for such facilities should not be advanced unless there are assurances that funds will be available is misguided. Most government, its infrastructure and implementation proceeds and operates on funds that are not secured into the future. All Superfund sites proceed without absolute guarantees of future funding. This ROD also must proceed on the expectation of funds that will become available from the federal government and the state of Idaho. The ROD is a legal document backed by statute. The EPA has an agreement with the state which establishes a framework for the siting of repositories, both in the upper and lower Basin. The TLG is charged with advising a sound path forward. Finally, concerning repositories, during my 20 + years of working in the environmental business I've yet to see a legitimate waste facility constructed that wasn't utilized. If you build it they will come.

- Finally, the Feb 22 memo introduces the concept of "deep plowing" at certain locations to effectively reduce the level of toxicity in soils, such as flat workable floodplain acreage. This concept has been around for awhile in the environmental cleanup arena and comes up often because of its simplistic, appears low cost, and thus has an appealing nature. In practice its feasibility and actual application is very site-specific. Getting satisfactory and legitimate deep mixing to pull up clean soils for dilution is not as easy as it sounds and has frequently been unsuccessful at high concentration contaminated sites [I am providing, separately, some work done in Washington that I provided a year or two ago]. Thus, in general it may work at marginally contaminated locations where large reductions are not needed. This is not to say that positive examples such as the Frutchey farm do not exist, but the mechanics and application of such examples on a broad scale would need to be closely evaluated to assure feasibility and applicability. On a related note, the concept of plowing as a tool to add fixation amendments and mix them near the top of the soil profile is a concept also worthy of discussion for certain locations and might be combined with a mechanical mixing (dilution) approach.

With that, thanks for reading and I must concede that I will not be able to maintain these exchanges as it is difficult to carve out the time to do so. I sincerely hope, though, that these discussions will be beneficial to achieving real on-the-ground progress in the lower Basin.

ATTACHMENT B

Field Descriptions from Bank Surface Sampling

ATTACHMENT B - Field Descriptions of Exposed Bank sites

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
SPRINGSTON REACH						
RM 135.2 R						
LC-SED-BA-135.2R-A1	A1	0	4.3	sharp	thinly bedded	Brown, fine sand with trace silt, less than 5% silt.
LC-SED-BA-135.2R-A2	A2	5	5	gradual	thinly bedded	Brown, fine sand with trace silt, less than 5% silt.
LC-SED-BA-135.2R-B1	B1	10	55	gradual	wavy	Brown with iron staining, silty fine sand.
LC-SED-BA-135.2R-B2	B2	65	53	sharp	thinly bedded	Bottom portion of layer is mottled and blocky. Brown with iron staining, silty fine sand with occasional silt/clay nodules and thin lenses of fines.
LC-SED-BA-135.2R-C	C	118	4	NA	massive	Gray, fine sand with trace silt. Mottling common. Massive.
LC-SED-BA-135.2R-D	D	122		NA	NA	Tan-gray, fine sand with trace silt.
LC-SED-BA-135.2R-E	E			NA	NA	Same as B1 and B2.
RM 137.8 R						
LC-SED-BA-137.8L-A1	A1	0	8	sharp	massive	Tan, fine sand with trace silt, less than 5% fines.
LC-SED-BA-137.8L-A2	A2	8.8	20.2	gradual	massive	Tan-gray, fine sand with approximately 5% silt.
LC-SED-BA-137.8L-B1	B1	29	61	gradual	thinly bedded	Brown with iron oxidation, very fine sand with approximatley 5% silt.
LC-SED-BA-137.8L-B2	B2	90	43	buried	thinly bedded	Reddish-brown and oxidized silty fine sand with occassional clay lenses and nodules.
LC-SED-BA-137.8L-D	D			NA	NA	Gray, well-sorted fine sand with trace silt.
LC-SED-BA-137.8L-E	E			NA	NA	Combination of B1 & B2.
RM 142.5 R						
LC-SED-BA-142.5A1	A1	0	29	wavy	thinly bedded	Thin bedded, very fine sands with silt, light tan, transistions to orange-reddish brown oxidized sandy silt, very fine-grained sand. Thin alternating bands are visible, heavily rooted.
LC-SED-BA-142.5A2	A2	29.6	7.4	sharp	thinly bedded	Thinly bedded, light orange to light brown. Transitions to dark red-brown, oxidized sandy silt. Upper most layer is silty, with very fine sand, lower layer is sandy with silt (rooted).
LC-SED-BA-142.5B1	B1	37	27.6	gradual	very thinly bedded to wavy	Alternating reddish-brown to orange laminations, consolidated silt with minor fine sands and clay. B1 has weak wavy texture. Transitions to gray (reduced) silty-clayey deposit with minor sand. Transitions back to consolidated oxidized silty deposit with minor clay.
LC-SED-BA-142.5B2	B2	64.6	19.4	gradual	blocky	Alternating black and tan, finer-grained silt and clay deposit. Black layers have an organic (sulfur) smell. Oxidation present in irregular bands. Very slight cohesiveness and plasticity.
LC-SED-BA-142.5C1	C1	84	40	NA	massive	Tan to light brown, very fine grained deposit, higher clay percentage than above. 50/50 silt and caly blend, massive, featureless, roots present, no oxidation.
LC-SED-BA-142.5C2	C2			NA	NA	Fine-grained, well-sorted sand, dark-brown, contains up to 20% silt.
LC-SED-BA-142.5D	D			NA	thinly bedded	Slump block contains B1 and B2 materials. Sample was collected perpendicular to the bedding.
LC-SED-BA-142.5E	E			NA	NA	Fine-grained sand, very little silt content. Sand is well sorted, light tan. Sample collected from 2 locations. Non-recent deposit, thin layer of slough from bank, sand overlies native shelf material.
RM 143.4 L						
LC-SED-BA-143.4L-A1	A1	0	19.8	sharp	thinly bedded	Ash unit difficult to distinguish. Tan, well-sorted fine sand with trace silt.
LC-SED-BA-143.4L-A2	A2	20.4	3.4	sharp	thinly bedded	Brown, poorly sorted sand with ~5% silt. Oxidized zones common.
LC-SED-BA-143.4L-B1	B1	23.8	17.2	gradual	thinly bedded	Brown, fine sandy silt with iron staining.
LC-SED-BA-143.4L-B2	B2	41	19.6	sharp	thinly bedded	Alternating layers of tan and brown. Silty clay with sand lenses.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
LC-SED-BA-143.4L-C	C	60.6		NA	NA	Gray to tan with mottled dark streaks, silty clay with trace sand. Borderline clayey silt.
LC-SED-BA-143.4L-D	D			NA	NA	Exposed bank is poorly sorted sand and gravel with rip-rap. No recent deposit to sample.
LC-SED-BA-143.4L-E	E			NA	NA	Sourced from A1 and A2.

KILLARNEY REACH

RM 144.1 L

LC-SED-BA-144.1L-A1	A1	0	21.2	sharp	thinly bedded	Tan, well-sorted fine sand with less than 5% silt.
LC-SED-BA-144.1L-A2	A2	22	11.4	sharp	thinly bedded	Alternating layers of fine sand and silt with fine sand. Brown and tan respectively.
LC-SED-BA-144.1L-B1	B1	33.4	26.6	gradual	thinly bedded	Brown with iron staining, silt with fine sand.
LC-SED-BA-144.1L-B2	B2	60	100	unknown	thinly bedded with mottling	Brown with iron staining, clayey silt with trace fine sand.
LC-SED-BA-144.1L-C	C			sharp	massive	Tan, silty clay. B1 overlies C. No B2 (blocky) above C. Layer C not visible at sample location.
LC-SED-BA-144.1L-D	D			NA	NA	Fine sand covered with layer B slump blocks.
LC-SED-BA-144.1L-E	E			NA	NA	Abundant from layer B.
LC-SED-BA-144.1L-Ba						Detailed sampling within unit B
LC-SED-BA-144.1L-Bb						
LC-SED-BA-144.1L-Bc						
LC-SED-BA-144.1L-Bd						
LC-SED-BA-144.1L-Be						
LC-SED-BA-144.1L-Bf						
LC-SED-BA-144.1L-Bg						
LC-SED-BA-144.1L-Bh						
LC-SED-BA-144.1L-Bi						
LC-SED-BA-144.1L-Bj						

RM 148.1 L

LC-SED-BA-148.1L-A1	A1	0	26	sharp	massive to thin bedded	Very fine sands with silt, tan to light brown. Heavily rooted, transitions to deep rust-brown to contact of ash layer. Dark layer is fine sand, minor silt.
LC-SED-BA-148.1L-A2	A2	26.6	11.4	gradational	thinly bedded	Alternating bands of light brown to rust-red layers. Reddish-brown layer consists of fine sand with 20% silt. Lower lighter colored bed is silty, minor sand, with clay.
LC-SED-BA-148.1L-B1	B1	38	39	gradational	thinly bedded, visible laminations	Alternating bands of black to orange, red-brown layers. Black layer is sandy with minor silt, lighter banding, contains more silt, becomes more consolidated with depth.
LC-SED-BA-148.1L-B2	B2	77	68	sharp	thinly bedded	Orange rust-red silty sand, alternating bands of oxidation, rooted, contains organic debris, clay content increases with depth.
LC-SED-BA-148.1L-C	C	145	13	NA	massive	Soft, high clay content, cohesive, low plasticity, minor band of oxidized material near B2 contact.
LC-SED-BA-148.1L-D	D			NA	NA	Brown, silty sediment, non-cohesive, non-pastic, saturated. Collected from shelf overlying native material to water's edge.
LC-SED-BA-148.1L-E	E			NA	NA	Collected from various slump blocks consisting of B1 and B2 sediment.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
LC-SED-BA-148.1L-C2	C2		60 - 70	NA	massive	Collected due to difference from collection site. Thicknesses are variable. Consists of clay and silt, saturated, dark-brown to black. This C2 layer was not collected from the sample site. Close proximity layer did not exist at the sample site.
RM 149.0 R						
LC-SED-BA-149.0R-A1	A1	0	24.5	sharp	massive	Fine sand, varies in angularity from sub-angular to sub-rounded, contains up to 10% silt, light brown, heavily rooted, well-sorted.
LC-SED-BA-149.0R-A2	A2	24.8	5.2	sharp/wavy	massive	Multicolored sands, sub-rounded to sub-angular, well-sorted, fine-grained. Contains 10% silt, reddish-brown to light tan color at B contact.
LC-SED-BA-149.0R-B	B	30	13	sharp	wavy	Fine angular to sub-angular sands oxidized, wavy structures (ripple marks). Brick red with ~3 cm thick black lamination in center.
LC-SED-BA-149.0R-Ca	C	43	55	gradual	massive	Silt with trace fine sands. Gray to dark gray. Non-plastic, non-cohesive properties.
LC-SED-BA-149.0R-Cb	C	98	55	gradual	massive	As above, lighter tan-brown color with clay (15%). Slightly cohesive, non-plastic.
LC-SED-BA-149.0R-Cc	C	153	46.94	gradual	massive	Light brown, silt with 20% clay. Cohesive, non-plastic, no coarse inclusions.
LC-SED-BA-149.0R-D	D			NA	NA	Sampled from different location (~ 200' upstream) beneath overhanging tree where D was exposed. Consists of very fine sand with silt, dark tan to brown color, no apparent clay content.
LC-SED-BA-149.0R-E	E			NA	massive to wavy	Consists of A & B layers. Sample taken perpendicular to bedding. 2' x 1 1/2' x 1' block.

DUDLEY REACH

RM 152.3 L						
LC-SED-BA-152.3L-A1	A1	0	12	sharp	massive	Fine-grained, sandy silt light to dark brown, moderately rooted.
LC-SED-BA-152.3L-A2	A2	12.3	25.7	sharp	trough bedding, thinly laminated	Darker red-brown color, fine sand with silt, moderate roots, cross-bedded to lenticular bedding texture (alternating light and dark laminations).
LC-SED-BA-152.3L-B	B	38	115	NA	wavy to thinly bedded	Alternating dark brown to rust-brown bedding. Rust orange where oxidized. Portions are wavy and very thinly laminated. Other sections of B are bedded but not wavy. Does not fit the description of blocky(B2) and is not all B1. Field decision to label as "B". No visible C layer.
LC-SED-BA-152.3L-D	D			NA	massive	Saturated fine sand and silt. Olive-gray to rust-red grains. Well-sorted sand, variable angularity.
LC-SED-BA-152.3L-E	E			NA	wavy to thinly bedded	B layer, thinly bedded to wavy, dark reddish brown to orange to rust-brown. Sample collected perpendicular to bedding.
RM 154.1 R						
LC-SED-BA-154.1R-A1	A1	0	12	sharp	thinly banded	Light brown fine sand with silt, heavily rooted. Becomes rust-red brown near ash layer boundary. Silt with fine sand.
LC-SED-BA-154.1R-A2a	A2	12.4	23.6	sharp	thinly banded	Alternating deep rust-black/brown/tan brown layers. Consists of fine sand and silt, becomes more sandy to next boundary. Contains roots.
LC-SED-BA-154.1R-A2b	A2	36	39	sharp	massive	Mostly dark gray fine sand with silt. Small lens of light brown fine sand with silt. Contains roots silt content decreases with depth.
LC-SED-BA-154.1R-A2c	A2	75	34	gradual	massive	Lighter color than above, silty sand, very fine-grained, contains roots. Light tan-brown to brown.
LC-SED-BA-154.1R-A2d	A2	109	20	gradual	massive	Mostly silt with fine sand, featureless, non-cohesive, gray-brown color, 60% silt, 40% sand.
LC-SED-BA-154.1R-A2e	A2	129	55	gradual	massive	Contains more silt than above, tan-brown color. 80% silt and 20% fine sand.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
LC-SED-BA-154.1R-A2f	A2	184	26	sharp	massive	Light tan, combination of silt, sand, and minor clay. Sand is very fine-grained. Slightly cohesive, non-plastic.
LC-SED-BA-154.1R-C	C	210	40	NA	mottled	Light brown and light gray, mottled silt and clay particles, medium cohesive and low plasticity.
LC-SED-BA-154.1R-D	D			NA	NA	Dark brown, sandy silt. Sand is fine-grained, sample collected from material on shelf, lying above native layer.
LC-SED-BA-154.1R-E	E			NA	NA	Consists of possible B material. Possible B layer in slump blocks--orange clods of fractured, oxidized silt and clay sized particles, heavily rooted. Sample collected from 3 blocks, perpendicular to bedding.
RM 156.3 L						
LC-SED-BA-156.3L-A1	A1	0	43.2	sharp	massive to bedded	Gray-brown, find sand with silt to brown sandy silt, heavily rooted, moist, richer brown to rust-brown closer to A1/A2 boundary.
LC-SED-BA-156.3L-A2	A2	43.7	15.1	sharp	thinly bedded	Two distinct layers; dark black, sandy silt with fine laminations overlain by light brown to rust-brown alternating thin bedded silt with minor fine sand and trace mica.
LC-SED-BA-156.3L-B1	B1	58.8	37.7	gradational	wavy thinly bedded	Thin bedded to thin laminations of alternating rust-brown to dark-brown to tan bands of silt with fine sand, and tan sandy silt, rooted.
LC-SED-BA-156.3L-B2	B2	96.5	83.5	gradational	blocky stratified	Alternating bands of orange, rust-brown, brown silt with minor sand and trace mica, to fine sandy silt. Bioturbation and root wedging evident.
LC-SED-BA-156.3L-C	C	180	4	NA	thinly bedded	Dark gray to light olive-tan massive, trace micas, stiff, very fine sand with silt alternating to dark gray silt with sand.
LC-SED-BA-156.3L-D	D			NA	massive	Well-sorted, fine sands, rust-brown to light tan color, angular to rounded.
LC-SED-BA-156.3L-E	E			NA	thinly bedded	Consists of both B1 and B2. Thinly bedded, blocky. Sample collected perpendicular to strata.
RM 159.3 R						
LC-SED-BA-159.3R-A1	A1	0	20.1	sharp	thin bedded	Two distinct bedding layers; light brown to dark brown, sandy silt, heavily rooted, moist.
LC-SED-BA-159.3R-A2	A2	21	11.8	sharp	thin bedded	Two distinct bedding layers; bottom portion is much thinner; wavy, dark brown to rust brown, silt with minor fine sand and trace mica. Rooted
LC-SED-BA-159.3R-B1	B1	32.8	30.2	gradual	wavy	Alternating rust-colored and dark brown laminations. Silt with minor fine sand and minor roots.
LC-SED-BA-159.3R-B2	B2	63	63	sharp	blocky	Alternating bands of oxidized, dark brown, and light tan deposits. Texture is blocky with wavy sedimentary structures, silty, less moisture and dusty.
LC-SED-BA-159.3R-C	C	126	33	NA	massive	Light olive gray, massive clay with medium elasticity and high cohesiveness, stiff.
LC-SED-BA-159.3R-E	E	159		NA	wavy	Fine sands with silt, rust-brown to dark brown alternating laminations and thin bedding. Sample collected perpendicular to layering and strata.
	Shelf					Shelf consists of slump material (A, B, and soft C) overlying hard stiff clay.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
CATALDO REACH						
RM 160.2 L						
LC-SED-BA-160.2L-A1	A1	0	26.8	sharp	homogenous with minor thin bedding	Fine to medium grained sand with silt, medium brown, lower contact contains thin-bedded light to dark brown layers. Moderately rooted, 60% sand, 40% silt.
LC-SED-BA-160.2L-A2	A2	27	15	gradual	thin laminations	Increased sand content and grain size. Sand is well sorted, medium grained, reddish-orange brown to dark brown. 80% sand, 20% silt.
LC-SED-BA-160.2L-B1a	B1	42	69	sharp	flaser to wavy	Particle size decreases with depth. Bands of dark, oxidized brown and orange thin bedding present. Flaser bedding near lower contact. Sand is fine to medium, variable concentration.
LC-SED-BA-160.2L-B1b	B1	111	61	sharp	flaser to wavy	Alternating thin bedding planes of orange and dark brown sediment. Sand size increases with depth to medium-grained. Flaser bedding prominent. Orange bed is 13 cm thick, 30% fine sand, 70% silt, trace mica.
LC-SED-BA-160.2L-B2	B2	172	39	buried	blocky to banded	Orange and gray banded silt with very fine sand. Oxidation present. Grain size decreases with depth. Non-cohesive, non-plastic, 90% silt, 10% sand.
LC-SED-BA-160.2L-C	C	211	93	NA	massive	Dark gray, silt and clay with no sand, non-plastic, cohesive, 40% clay, 60% silt, rooted.
LC-SED-BA-160.2L-E	E			NA	wavy	3 Large slump blocks. B1 layer predominately.
RM 162.7 L						
LC-SED-BA-162.7L-A1	A1	0	34	wavy	massive to very thinly laminated	Very fine sand with silt. Bedding contains very fine laminations alternating from light brown to black. 30 - 40% silt content, heavily rooted, dark brown.
LC-SED-BA-162.7L-A2	A2	34.2	16.8	gradual	massive	Very fine, multi-colored sand with less silt than A. Sands are sub-rounded, silt content ~ 15%, medium brown color, featureless. Sand is well-sorted.
LC-SED-BA-162.7L-B1	B1	51	56	gradual	thinly bedded, wavy	Contains alternating bands of red-orange, dark-black, to light gray sediment, 90% sand, fine-grained, sub-rounded, angular, minor silt content, ripple marks present, well sorted.
LC-SED-BA-162.7L-B2	B2	107	41	sharp	blocky to thinly bedded	Silt predominantly, no sand present. Alternating bands of reduced/oxidized layers, non-plastic, non-cohesive. Slight mottling present.
LC-SED-BA-162.7L-C	C	148	14	beneath water line	thinly banded	Silt with minor clay, non-plastic, slightly cohesive. Dark gray with minor oxidized bands and lighter olive-tan reduced layers (thin beds) mottled.
LC-SED-BA-162.7L-E	E			NA		Slump blocks
RM 163.0 R						
LC-SED-BA-163.0R-A1	A1	0	8	sharp	massive to thinly bedded	Dark brown, heavily rooted, silt with find sand and trace mica. Dark black/brown lamination near bottom of interval. Organic odor.
LC-SED-BA-163.0R-A2	A2	8.3	4.7	sharp	massive	Dark brown, increased sand content. Sand is fine-grained (90%) with 10% silt and trace mica. Interval is rooted and homogeneous, well-sorted.
LC-SED-BA-163.0R-B	B	13	35	sharp	thinly bedded	Reddish-brown oxidation present, silt content decreases, sand grain size increases from fine to medium, well-sorted, alternating bands of dark red brown to red-brwon. Slight decrease in grain size with depth.
LC-SED-BA-163.0R-Ca	C	48	50	gradual	massive	Top of interval is black organic or charred material. Interval is tan with 85% sand and 15% silt. No clay content. Sand is fine-grained, well-sorted.
LC-SED-BA-163.0R-Cb	C	98	49	gradual	massive	Interval begins with 1 - 2 cm thick black layer of charred wood debris. Silt content increases, sand is not present, no clay, light cream-tan color.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
LC-SED-BA-163.0R-Cc	C	147	63	gradual	massive	Darker tan-brown, no sand, increasing in clay with depth, non-plastic, slightly cohesive. 90% silt, 10% clay.
LC-SED-BA-163.0R-Cd	C	210	149.66	NA	massive	Silty clay with large sandy lenses. Sand lenses are fine to medium grained well sorted, minor (5%) silt content. Silty clay is cohesive, lean, light brown, 40% clay, 30% sand, 30% silt.
LC-SED-BA-163.0R-E	E			NA		Consists of A & B layers.
RM 166.5 LR						
LC-SED-BA-166.5LR-Aa	A	0	29	gradual	massive to slightly graded	Dark brown, poorly sorted mix of coarse gravel, fine sand, silt and trace mica. Layer is heavily rooted and is massive. 80% silt, 10% clay, 10% gravel.
LC-SED-BA-166.5LR-Ab	A	29	56	wavy/gradual	massive alluvium poorly sorted	Brown to medium brown becomes more gravel rich. No texture. 60% silt, 20% sand, 20% gravel. (Alluvium) gravel is rounded, coarse grained.)
LC-SED-BA-166.5LR-Ba	B	85	60	sharp color change	wavy	Reddish brown to orange brown layers. Fine sand with silt with trace mica and wood (random). No coarse sediment. Thickness varies. Fine laminations
LC-SED-BA-166.5LR-Bb	B	145	38	sharp	laminar to blocky	Brighter orange color, oxidized, 85% silt content, 15% sands and trace mica. Sands are very fine, blocky to laminar texture.
LC-SED-BA-166.5LR-C	C	183	64	buried	massive to wavy (lenses)	Olive-tan, sandy bedding. Grain size varies from fine to coarse sands. Trace clay-sized particles and 20% silt.
LC-SED-BA-166.5LR-E	E			NA	loose detritus	Composed of A & B layers.
	G	247		NA		Present beneath C layer. Conglomerate.
RM 166.5 RL						
LC-SED-BA-166.5RL-A1	A1	0	22.6	sharp	massive	Medium brown sand and silt, moderately rooted. Sand is fine grained. 60% sand, 40% silt. Massive, no texture description.
LC-SED-BA-166.5RL-A2	A2	23	13	gradual	massive/thinly bedded	Very fine sand with silt. Heavy moss/roots. Light orange-brown top layer, lower layer is dark brown with heavy roots. Sand content increases in size with depth, graded.
LC-SED-BA-166.5RL-B1a	B1	36	66	gradual	wavy to thinly laminated	Red, brown, black oxidized medium sand-sized particles. Graded - sand size increases with depth up to pea-gravel. Trough bedding present, pocket of coarse, cross-bedded sediment with trace charred wood.
LC-SED-BA-166.5RL-B1b	B1	102	52	gradual	thinly laminated, trough bedding	Alternating bands of orange and dark brown layers. Trough bedding present. Fine sand with minor silt.
LC-SED-BA-166.5RL-B2	B2	154	58	sharp	blocky, thinly laminated	Orange-brown, thinly bedded, fine sand with increasing silt with depth. Two, 3 - 4 cm reduced layers present. Slight mottling.
LC-SED-BA-166.5RL-C	C	212	92.8	NA	massive	Medium to fine sands with silt, no clay present. Layer is olive-tan, featureless.
LC-SED-BA-166.5RL-E	E			NA	thinly bedded	Combined A & B layers
RM 167.0 L						
LC-SED-BA-167.0L-A1	A1	0	18	sharp	massive	Light to dark brown, heavily rooted; small light orange-brown lenses; silt with no sand, non-cohesive
LC-SED-BA-167.0L-A2	A2	18.2	3.8	sharp	massive	Light brown silty sand, rooted, slightly mottled, very dark brown lamination at ash to A2 contact. Sand is very fine grained (80%), 20% silt, trace mica.

	Stratigraphic Unit	Distance between top of interval and top of bank (cm)	Thickness of unit (cm)	Description of Lower Contact	Description of bedding within interval	Field Description
LC-SED-BA-167.0L-B	B	22	37	sharp	thinly laminated to blocky	Alternation between orange-brown and dark brown laminations, oxidized sand and silt; becomes blocky with dark brown layers. Sand is fine grained (40%), 60% silt.
LC-SED-BA-167.0L-C	C	59	239.7	NA	mottled	Mottled olive tan to dark black/brown/orange spotting. Bedding consists of alternating colors of deposits, consists of 30% fine sand, 40% silt, and 30% clay, non-plastic, slightly cohesive
LC-SED-BA-167.0L-E	E			NA	massive to thinly bedded	3' x 2' x 2' block composed of A & B layers.

ATTACHMENT C

Analytical Data from Bank Surface Sampling

ATTACHMENT C - GRAIN SIZE, LEAD, AND METALS DATA FROM SAMPLES

	Grain Size Distribution									Lead Content			Zinc Content			Zn/Pb Ratio
	Clay (<4 µm)	Silt (4-63 µm)	Very Fine Sand (63-125 µm)	Fine Sand (125-250 µm)	Medium Sand (250-500 µm)	Coarse Sand (500-1000 µm)	Very Coarse Sand (1000-2000 µm)	Gravel (> 2000 µm)	Fines (clay and silt)	Fines	Fine Sand	Bulk	Fines	Fine Sand	Bulk	Bulk
RIVER-SCALE STATISTICS																
Unit A - Mean (n = 39)	8%	30%	55%	3%	1%	1%	1%	0%	38%	4,065	3,324	3,778	2,798	2,388	2,486	2.18
Unit A - Median (n = 39)	8%	29%	54%	2%	1%	0%	0%	0%	38%	4,060	3,330	3,670	2,740	2,630	2,090	0.69
Unit B - Mean (n = 40)	9%	48%	38%	2%	1%	1%	0%	0%	57%	8,080	8,050	8,798	3,337	2,618	3,159	0.47
Unit B - Median (n = 40)	9%	46%	37%	2%	1%	0%	0%	0%	56%	6,150	5,720	7,610	2,930	2,410	2,645	0.33
Unit C - Mean (n = 21)	15%	45%	31%	3%	1%	0%	0%	0%	60%	2,047	3,476	1,863	1,778	806	1,440	7.49
Unit C - Median (n = 21)	13%	44%	30%	0%	0%	0%	0%	0%	66%	37	37	44	445	265	301	6.58
SPRINGSTON REACH																
LC-SED-BA-135.2R-A1	2%	7%	90%	0%	0%	0%	0%	0%	9%	4,130	2,310	2,610	5,760	4,450	5,700	2.18
LC-SED-BA-135.2R-A2	5%	25%	68%	1%	0%	0%	0%	0%	30%	4,300	3,090	5,620	4,540	4,000	4,900	0.87
LC-SED-BA-135.2R-B1	5%	33%	60%	1%	0%	0%	0%	0%	38%	3,540	2,610	2,730	3,820	2,560	2,390	0.88
LC-SED-BA-135.2R-B2	5%	46%	46%	1%	1%	0%	0%	0%	51%	4,830	3,290	4,070	2,580	1,240	1,790	0.44
LC-SED-BA-135.2R-C	10%	26%	57%	3%	0%	0%	0%	0%	36%	126	58	94	1,140	677	660	7.03
LC-SED-BA-135.2R-D	2%	7%	84%	6%	0%	0%	0%	0%	10%			1,540			2,690	1.75
LC-SED-BA-135.2R-E	5%	39%	50%	1%	1%	0%	0%	0%	45%	3,720	2,710	3,380	4,120	2,540	2,820	0.83
LC-SED-BA-137.8L-A1	2%	7%	90%	1%	0%	0%	0%	0%	8%	5,440	2,540	2,250	6,990	4,950	4,220	1.88
LC-SED-BA-137.8L-A2	4%	13%	81%	1%	0%	0%	0%	0%	17%	5,470	2,690	2,810	3,990	2,540	2,000	0.71
LC-SED-BA-137.8L-B1	5%	30%	63%	0%	0%	0%	0%	0%	35%	4,450	3,160	3,600	4,900	2,950	3,520	0.98
LC-SED-BA-137.8L-B2	5%	45%	45%	1%	1%	1%	0%	0%	50%	5,820	4,270	8,230	3,060	1,830	2,030	0.25
LC-SED-BA-137.8L-D	2%	7%	90%	0%	0%	0%	0%	0%	9%			1,830			5,860	3.20
LC-SED-BA-137.8L-E	6%	45%	45%	0%	0%	0%	0%	0%	51%	4,730	4,220	8,940	2,640	1,420	1,850	0.21
LC-SED-BA-142.5A1	3%	30%	65%	1%	1%	0%	0%	0%	32%	4,480	3,390	3,760	3,990	2,870	3,450	0.92
LC-SED-BA-142.5A2	9%	39%	45%	4%	4%	1%	0%	0%	47%	4,290	4,600	6,430	3,150	4,180	4,250	0.66
LC-SED-BA-142.5B1	6%	64%	23%	2%	3%	1%	0%	0%	70%	4,250	3,670	3,600	2,430	2,590	2,500	0.69
LC-SED-BA-142.5B2	18%	61%	18%	1%	0%	0%	0%	0%	79%	3,140	1,890	1,460	1,420	536	904	0.62
LC-SED-BA-142.5C1	23%	65%	9%	0%	0%	0%	0%	0%	87%	30	39	30	143	84	116	3.91
LC-SED-BA-142.5C2	3%	65%	31%	0%	0%	0%	0%	0%	68%	16	25	48	102	94	133	2.77
LC-SED-BA-142.5D	1%	24%	74%	1%	0%	0%	0%	0%	25%	2,900	2,330	2,590	3,610	3,590	3,620	1.40
LC-SED-BA-142.5E	1%	54%	40%	3%	1%	0%	0%	0%	55%	2,450	4,060	4,100	2,960	2,440	3,000	0.73
LC-SED-BA-143.4L-A1	4%	23%	54%	3%	4%	4%	6%	0%	28%	3,640	2,580	1,720	4,000	2,640	1,750	1.02
LC-SED-BA-143.4L-A2	6%	34%	24%	5%	8%	7%	12%	2%	40%	3,120	2,800	773	4,040	2,690	880	1.14
LC-SED-BA-143.4L-B1	8%	44%	41%	2%	2%	1%	0%	0%	52%	4,810	5,530	9,500	3,690	2,940	2,870	0.30
LC-SED-BA-143.4L-B2	18%	51%	18%	2%	2%	1%	0%	0%	69%	19,800	21,200	21,100	2,510	2,380	1,850	0.09
LC-SED-BA-143.4L-C	20%	51%	17%	1%	0%	0%	0%	0%	71%	196	120	357	288	88	232	0.65
REACH-SCALE STATISTICS - SPRINGSTON REACH																
Unit A - Mean (n = 8)	4%	22%	65%	2%	2%	1%	2%	0%	26%	4,359	3,000	3,247	4,558	3,540	3,394	1.17
Unit A - Median (n = 8)	4%	24%	67%	1%	1%	0%	0%	0%	29%	4,295	2,745	2,710	4,020	3,435	3,835	0.97
Unit B - Mean (n = 8)	9%	47%	39%	1%	1%	1%	0%	0%	55%	6,330	5,703	6,786	3,051	2,128	2,232	0.53
Unit B - Median (n = 8)	6%	45%	43%	1%	1%	0%	0%	0%	51%	4,630	3,480	3,835	2,820	2,470	2,210	0.53
Unit C - Mean (n = 4)	14%	52%	28%	1%	0%	0%	0%	0%	66%	92	61	132	418	236	285	3.59
Unit C - Median (n = 4)	15%	58%	24%	1%	0%	0%	0%	0%	70%	78	49	71	216	91	183	3.34

	Grain Size Distribution									Lead Content			Zinc Content			Zn/Pb Ratio
	Clay (<4 µm)	Silt (4-63 µm)	Very Fine Sand (63-125 µm)	Fine Sand (125-250 µm)	Medium Sand (250-500 µm)	Coarse Sand (500-1000 µm)	Very Coarse Sand (1000-2000 µm)	Gravel (> 2000 µm)	Fines (clay and silt)	Fines	Fine Sand	Bulk	Fines	Fine Sand	Bulk	Bulk
KILLARNEY REACH																
LC-SED-BA-144.1L-A1	8%	37%	51%	2%	1%	1%	0%	0%	45%	3,760	3,610	3,910	2,740	2,390	2,370	0.61
LC-SED-BA-144.1L-A2	15%	44%	36%	2%	1%	0%	0%	0%	59%	3,520	5,280	5,150	2,890	3,920	2,890	0.56
LC-SED-BA-144.1L-B1	8%	53%	35%	2%	1%	0%	0%	0%	61%			4,260			4,120	0.97
LC-SED-BA-144.1L-B2	10%	60%	25%	2%	2%	1%	0%	0%	70%	8,990	10,300	9,380	2,930	3,120	2,750	0.29
LC-SED-BA-144.1L-C	3%	13%	84%	0%	0%	0%	0%	0%	15%			30			101	3.34
LC-SED-BA-144.1L-D	18%	59%	16%	0%	0%	0%	0%	0%	77%			2,170			4,020	1.85
LC-SED-BA-144.1L-E	8%	64%	24%	2%	1%	0%	0%	0%	73%			7,470			2,300	0.31
LC-SED-BA-144.1L-Ba	15%	46%	36%	2%	1%	0%	0%	0%	62%	4,360	3,460	3,980	3,590	2,870	3,800	0.95
LC-SED-BA-144.1L-Bb	9%	57%	30%	1%	1%	1%	0%	0%	67%	3,680	3,030	3,970	3,060	1,880	3,160	0.80
LC-SED-BA-144.1L-Bc	11%	59%	28%	1%	1%	0%	0%	0%	70%	4,970	4,020	4,430	2,820	1,850	2,250	0.51
LC-SED-BA-144.1L-Bd	11%	60%	26%	1%	1%	0%	0%	0%	71%	4,590	5,260	4,670	1,950	1,520	1,530	0.33
LC-SED-BA-144.1L-Be	13%	61%	24%	1%	1%	0%	0%	0%	74%	8,230	7,770	11,000	2,250	1,500	2,240	0.20
LC-SED-BA-144.1L-Bf	14%	60%	24%	1%	1%	0%	0%	0%	74%	10,300	9,430	7,730	2,220	1,730	1,580	0.20
LC-SED-BA-144.1L-Bg	13%	66%	16%	1%	2%	1%	0%	0%	80%	9,760	9,790	10,000	3,240	2,710	4,050	0.41
LC-SED-BA-144.1L-Bh	15%	69%	12%	1%	2%	1%	0%	0%	84%	9,960	11,800	11,100	4,080	4,400	5,110	0.46
LC-SED-BA-144.1L-Bi	14%	69%	15%	1%	1%	0%	0%	0%	83%	16,500	19,100	17,700	8,740	4,400	5,130	0.29
LC-SED-BA-144.1L-Bj	16%	65%	16%	1%	1%	0%	0%	0%	81%	12,100	16,700	15,700	3,470	3,830	5,610	0.36
LC-SED-BA-148.1L-A1	1%	36%	61%	1%	0%	0%	0%	0%	38%	5,320	3,400	4,960	3,950	2,630	3,880	0.78
LC-SED-BA-148.1L-A2	6%	55%	37%	2%	0%	0%	0%	0%	60%	5,340	3,330	9,590	5,460	4,030	6,590	0.69
LC-SED-BA-148.1L-B1	0%	25%	70%	3%	1%	0%	0%	0%	25%	5,160	3,970	6,210	4,740	4,460	5,910	0.95
LC-SED-BA-148.1L-B2	14%	62%	18%	3%	3%	2%	0%	0%	76%	3,470	5,720	8,700	2,940	3,240	4,230	0.49
LC-SED-BA-148.1L-C	22%	69%	7%	0%	0%	0%	0%	0%	91%	258	515	409	156	139	153	0.37
LC-SED-BA-148.1L-C2	22%	69%	7%	0%	0%	0%	0%	0%	91%	133	107	102	530	265	478	4.69
LC-SED-BA-148.1L-D	10%	75%	15%	0%	0%	0%	0%	0%	85%	354	915	677	558	1,420	793	1.17
LC-SED-BA-148.1L-E	4%	37%	54%	2%	3%	1%	0%	0%	40%			5,980			5,690	0.95
LC-SED-BA-149.0R-A1	5%	12%	76%	3%	1%	0%	0%	0%	17%	6,880	3,370	3,870	5,390	3,060	3,770	0.97
LC-SED-BA-149.0R-A2	2%	12%	81%	3%	1%	0%	0%	0%	14%	6,570	4,090	5,140	4,130	2,990	3,530	0.69
LC-SED-BA-149.0R-B	6%	24%	56%	6%	5%	3%	0%	0%	30%	7,630	5,910	7,120	7,840	7,710	8,280	1.16
LC-SED-BA-149.0R-Ca	10%	28%	55%	2%	0%	0%	0%	0%	38%	106	50	84	940	325	554	6.58
LC-SED-BA-149.0R-Cb	13%	38%	39%	1%	0%	0%	0%	0%	51%	30	17	27	360	159	276	10.26
LC-SED-BA-149.0R-Cc	9%	37%	48%	1%	0%	0%	0%	0%	46%	20	11	18	175	79	149	8.14
LC-SED-BA-149.0R-D	6%	13%	74%	4%	0%	0%	0%	0%	19%	2,530	1,110	1,450	2,960	1,930	1,910	1.32
LC-SED-BA-149.0R-E	1%	17%	73%	5%	1%	0%	0%	0%	18%	7,250	4,300	4,900	5,030	3,060	4,520	0.92
REACH-SCALE STATISTICS - KILLARNEY REACH																
Unit A - Mean (n = 6)	6%	33%	57%	2%	1%	0%	0%	0%	39%	5,232	3,847	5,437	4,093	3,170	3,838	0.72
Unit A - Median (n = 6)	5%	37%	56%	2%	1%	0%	0%	0%	42%	5,330	3,505	5,050	4,040	3,025	3,650	0.69
Unit B - Mean (n = 15)	11%	56%	29%	2%	2%	1%	0%	0%	67%	7,836	8,304	8,397	3,848	3,230	3,983	0.56
Unit B - Median (n = 15)	13%	60%	25%	1%	1%	0%	0%	0%	71%	7,930	6,840	7,730	3,150	2,995	4,050	0.46
Unit C - Mean (n = 6)	13%	42%	40%	1%	0%	0%	0%	0%	55%	109	140	112	432	193	285	5.56
Unit C - Median (n = 6)	11%	37%	43%	0%	0%	0%	0%	0%	48%	106	50	57	360	159	215	5.63

	Grain Size Distribution									Lead Content			Zinc Content			Zn/Pb Ratio
	Clay (<4 µm)	Silt (4-63 µm)	Very Fine Sand (63-125 µm)	Fine Sand (125-250 µm)	Medium Sand (250-500 µm)	Coarse Sand (500-1000 µm)	Very Coarse Sand (1000-2000 µm)	Gravel (> 2000 µm)	Fines (clay and silt)	Fines	Fine Sand	Bulk	Fines	Fine Sand	Bulk	Bulk
DUDLEY REACH																
LC-SED-BA-152.3L-A1	1%	29%	67%	2%	1%	0%	0%	0%	30%	5,600	3,710	4,900	2,790	1,680	2,880	0.59
LC-SED-BA-152.3L-A2	5%	17%	76%	2%	0%	0%	0%	0%	21%	6,060	3,880	4,260	4,370	3,740	5,110	1.20
LC-SED-BA-152.3L-B	5%	40%	52%	1%	0%	0%	0%	0%	45%	4,730	4,140	5,690	2,670	1,970	2,660	0.47
LC-SED-BA-152.3L-D	4%	11%	81%	2%	0%	0%	0%	0%	15%			4,650			2,270	0.49
LC-SED-BA-152.3L-E	6%	43%	48%	1%	0%	0%	0%	0%	49%			2,950			6,640	2.25
LC-SED-BA-154.1R-A1	9%	26%	57%	3%	1%	0%	0%	0%	36%	5,350	3,250	6,060	3,860	2,640	4,060	0.67
LC-SED-BA-154.1R-A2a	5%	23%	69%	2%	0%	0%	0%	0%	28%	14,200	8,500	14,200	4,090	3,430	3,830	0.27
LC-SED-BA-154.1R-A2b[1]	10%	25%	57%	2%	0%	0%	0%	0%	35%	97	39	74	1,240	512	852	11.56
LC-SED-BA-154.1R-A2c[1]	12%	27%	54%	1%	0%	0%	0%	0%	39%	35	15	25	363	164	267	10.77
LC-SED-BA-154.1R-A2d[1]	13%	29%	52%	1%	0%	0%	0%	0%	41%	39	22	35	652	213	437	12.67
LC-SED-BA-154.1R-A2e[1]	11%	30%	51%	1%	0%	0%	0%	0%	41%	26	36	23	384	190	295	13.00
LC-SED-BA-154.1R-A2f[1]	12%	35%	45%	0%	0%	0%	0%	0%	47%	25	12	20	324	126	233	11.95
LC-SED-BA-154.1R-C	15%	40%	38%	0%	0%	0%	0%	0%	55%	24	11	19	252	130	198	10.37
LC-SED-BA-154.1R-D	5%	15%	77%	1%	0%	0%	0%	0%	20%	2,620	1,200	1,620	3,390	2,480	3,170	1.96
LC-SED-BA-154.1R-E	13%	34%	45%	3%	1%	1%	0%	0%	47%	3,450	2,270	3,750	2,260	1,560	2,170	0.58
LC-SED-BA-156.3L-A1	9%	31%	54%	5%	1%	0%	0%	0%	39%	3,860	3,730	4,480	3,210	3,240	3,540	0.79
LC-SED-BA-156.3L-A2	8%	33%	50%	7%	1%	0%	0%	0%	41%	3,560	5,030	5,850	2,730	4,460	3,610	0.62
LC-SED-BA-156.3L-B1	7%	45%	37%	5%	4%	1%	0%	0%	53%	3,460	3,430	3,970	3,830	3,240	4,080	1.03
LC-SED-BA-156.3L-B2	6%	54%	36%	1%	2%	2%	0%	0%	60%	5,400	4,190	5,570	2,080	1,320	1,830	0.33
LC-SED-BA-156.3L-C	9%	75%	12%	0%	0%	0%	0%	1%	84%	7,200	7,470	7,240	5,790	4,780	7,410	1.02
LC-SED-BA-156.3L-D	2%	5%	89%	3%	0%	0%	0%	0%	8%	4,410	1,870	2,780	8,280	4,380	7,040	2.53
LC-SED-BA-156.3L-E	7%	60%	29%	1%	0%	0%	0%	0%	67%	4,970	4,050	5,700	1,940	1,310	1,990	0.35
LC-SED-BA-159.3R-A1	5%	20%	68%	5%	0%	0%	0%	0%	25%	4,060	2,530	2,760	2,470	2,020	2,140	0.78
LC-SED-BA-159.3R-A2	4%	22%	71%	2%	0%	0%	0%	0%	26%	4,570	3,040	3,500	2,680	2,800	2,720	0.78
LC-SED-BA-159.3R-B1	8%	46%	44%	1%	0%	0%	0%	0%	54%	3,680	5,430	5,670	3,150	4,040	4,380	0.77
LC-SED-BA-159.3R-B2	9%	52%	30%	3%	1%	0%	0%	0%	61%	6,150	12,700	18,100	2,490	2,740	4,000	0.22
LC-SED-BA-159.3R-C	22%	65%	3%	1%	1%	0%	0%	0%	88%	25	60	66	275	487	340	5.18
LC-SED-BA-159.3R-E	9%	46%	41%	2%	1%	0%	0%	0%	55%	4,760	8,660	8,550	2,430	2,690	2,820	0.33
REACH-SCALE STATISTICS - DUDLEY REACH																
Unit A - Mean (n = 13)	8%	27%	59%	2%	0%	0%	0%	0%	35%	3,652	2,600	3,553	2,243	1,940	2,306	5.05
Unit A - Median (n = 13)	9%	27%	57%	2%	0%	0%	0%	0%	36%	3,860	3,040	3,500	2,680	2,020	2,720	0.79
Unit B - Mean (n = 5)	7%	47%	40%	2%	2%	1%	0%	0%	54%	4,684	5,978	7,800	2,844	2,662	3,390	0.56
Unit B - Median (n = 5)	7%	46%	37%	1%	1%	0%	0%	0%	54%	4,730	4,190	5,670	2,670	2,740	4,000	0.47
Unit C - Mean (n = 3)	15%	60%	18%	0%	0%	0%	0%	0%	76%	2,416	2,514	2,442	2,106	1,799	2,649	5.52
Unit C - Median (n = 3)	15%	65%	12%	0%	0%	0%	0%	0%	84%	25	60	66	275	487	340	5.18

	Grain Size Distribution									Lead Content			Zinc Content			Zn/Pb Ratio
	Clay (<4 µm)	Silt (4-63 µm)	Very Fine Sand (63-125 µm)	Fine Sand (125-250 µm)	Medium Sand (250-500 µm)	Coarse Sand (500-1000 µm)	Very Coarse Sand (1000-2000 µm)	Gravel (> 2000 µm)	Fines (clay and silt)	Fines	Fine Sand	Bulk	Fines	Fine Sand	Bulk	Bulk
CATALDO REACH																
LC-SED-BA-160.2L-A1	12%	27%	48%	10%	1%	0%	0%	0%	39%	1,540	1,500	1,420	906	804	639	0.45
LC-SED-BA-160.2L-A2	9%	33%	52%	3%	1%	0%	0%	0%	42%	2,990	3,470	3,600	1,390	1,730	1,550	0.43
LC-SED-BA-160.2L-B1a	5%	34%	53%	3%	3%	2%	0%	0%	39%	3,530	2,540	3,400	2,130	1,550	1,980	0.58
LC-SED-BA-160.2L-B1b	2%	30%	61%	8%	2%	0%	0%	0%	32%	7,860	5,520	5,570	1,790	1,020	1,010	0.18
LC-SED-BA-160.2L-B2	7%	51%	40%	0%	0%	0%	0%	0%	58%	21,700	19,600	21,200	7,860	3,280	5,900	0.28
LC-SED-BA-160.2L-C[2]	18%	47%	29%	0%	0%	0%	0%	0%	65%	23	34	41	5,700	3,010	5,890	144.36
LC-SED-BA-160.2L-E	3%	24%	69%	2%	1%	0%	0%	0%	27%	4,010	2,340	2,610	1,940	1,440	1,550	0.59
LC-SED-BA-162.7L-A1	13%	48%	31%	2%	1%	0%	0%	0%	61%	1,900	2,680	1,910	1,210	1,240	1,180	0.62
LC-SED-BA-162.7L-A2	7%	27%	60%	3%	0%	0%	0%	0%	34%	4,310	4,260	5,280	1,410	1,410	1,580	0.30
LC-SED-BA-162.7L-B1	7%	36%	50%	3%	1%	1%	0%	0%	43%	13,200	9,580	11,100	3,200	2,200	3,270	0.29
LC-SED-BA-162.7L-B2	13%	52%	30%	1%	1%	0%	0%	0%	65%	19,400	23,100	23,900	2,900	1,860	2,630	0.11
LC-SED-BA-162.7L-C	13%	69%	11%	0%	0%	0%	0%	0%	82%	32,500	64,300	32,200	16,500	4,460	12,300	0.38
LC-SED-BA-162.7L-E	12%	48%	34%	2%	1%	0%	0%	0%	59%	18,700	24,000	21,900	2,800	2,180	2,440	0.11
LC-SED-BA-163.0R-A1	16%	55%	19%	3%	2%	1%	1%	0%	72%	1,790	2,770	1,830	1,060	1,930	1,190	0.65
LC-SED-BA-163.0R-A2	12%	56%	28%	2%	1%	0%	0%	0%	69%	2,650	4,590	3,670	1,210	1,520	1,280	0.35
LC-SED-BA-163.0R-B	10%	44%	43%	2%	1%	0%	0%	0%	54%	9,220	8,650	11,300	2,440	2,290	2,210	0.20
LC-SED-BA-163.0R-Ca	11%	28%	52%	4%	0%	0%	0%	0%	39%	76	49	55	303	185	194	3.56
LC-SED-BA-163.0R-Cb	19%	61%	11%	0%	0%	0%	0%	0%	80%	41	23	26	542	413	566	21.85
LC-SED-BA-163.0R-Cc	31%	43%	7%	0%	0%	0%	0%	0%	74%	28	37	32	272	411	395	12.54
LC-SED-BA-163.0R-Cd	12%	29%	49%	5%	0%	0%	0%	0%	41%		15	13		139	142	10.76
LC-SED-BA-163.0R-E	10%	40%	45%	2%	1%	0%	0%	0%	50%			6,270			1,630	0.26
LC-SED-BA-166.5LR-Aa	11%	23%	34%	6%	3%	1%	2%	11%	34%	7,910	8,510	6,670	2,220	2,470	1,770	0.27
LC-SED-BA-166.5LR-Ab	10%	21%	51%	6%	4%	2%	1%	2%	31%	8,980	8,350	7,160	2,950	2,770	2,090	0.29
LC-SED-BA-166.5LR-Ba	8%	24%	59%	5%	1%	0%	0%	0%	32%	15,700	13,800	13,600	4,120	3,690	4,240	0.31
LC-SED-BA-166.5LR-Bb	9%	45%	37%	4%	1%	0%	0%	0%	54%	12,200	11,300	10,800	2,670	2,160	2,190	0.20
LC-SED-BA-166.5LR-C	10%	19%	56%	8%	3%	0%	0%	0%	29%	41	18	29	653	280	325	11.25
LC-SED-BA-166.5LR-E	14%	38%	42%	2%	1%	0%	0%	0%	53%	17,100	21,200	24,600	3,540	3,160	4,340	0.18
LC-SED-BA-166.5RL-A1	13%	52%	29%	1%	1%	0%	0%	0%	65%	2,030	2,240	1,990	1,310	1,290	1,200	0.60
LC-SED-BA-166.5RL-A2	5%	12%	64%	17%	2%	0%	0%	0%	17%	4,540	4,120	2,260	2,230	2,810	1,260	0.56
LC-SED-BA-166.5RL-B1a	8%	29%	54%	5%	1%	0%	0%	0%	37%	7,960	7,330	6,750	2,760	2,690	2,140	0.32
LC-SED-BA-166.5RL-B1b	8%	33%	53%	3%	1%	0%	0%	0%	41%	4,950	4,500	8,700	2,210	1,380	1,870	0.21
LC-SED-BA-166.5RL-B2	9%	46%	36%	4%	2%	0%	0%	0%	55%	7,170	6,540	7,490	3,300	2,000	2,310	0.31
LC-SED-BA-166.5RL-C	8%	10%	44%	30%	5%	0%	0%	0%	18%	31	12	11	622	201	187	16.55
LC-SED-BA-166.5RL-E	8%	20%	61%	9%	1%	0%	0%	0%	27%	22,500	15,700	14,600	5,270	4,490	4,710	0.32
LC-SED-BA-167.0L-A1	15%	38%	37%	4%	1%	1%	0%	0%	53%	2,180	2,100	2,180	1,400	1,250	1,470	0.67
LC-SED-BA-167.0L-A2	13%	39%	44%	1%	0%	0%	0%	0%	52%	3,970	4,180	4,610	1,640	1,370	1,600	0.35
LC-SED-BA-167.0L-B	13%	37%	42%	2%	1%	0%	0%	0%	50%	8,480	9,720	8,870	2,280	2,410	2,060	0.23
LC-SED-BA-167.0L-C	23%	45%	17%	1%	0%	0%	0%	0%	68%	33	31	56	823	516	890	16.01
LC-SED-BA-167.0L-E	13%	36%	44%	2%	1%	0%	0%	0%	49%	4,710	8,780	9,620	1,950	2,070	1,890	0.20

	Grain Size Distribution									Lead Content			Zinc Content			Zn/Pb Ratio
	Clay (<4 µm)	Silt (4-63 µm)	Very Fine Sand (63-125 µm)	Fine Sand (125-250 µm)	Medium Sand (250-500 µm)	Coarse Sand (500-1000 µm)	Very Coarse Sand (1000-2000 µm)	Gravel (> 2000 µm)	Fines (clay and silt)	Fines	Fine Sand	Bulk	Fines	Fine Sand	Bulk	Bulk
REACH-SCALE STATISTICS - CATALDO REACH																
Unit A - Mean (n = 12)	11%	36%	41%	5%	1%	1%	0%	1%	47%	3,733	4,064	3,548	1,578	1,716	1,401	0.46
Unit A - Median (n = 12)	12%	35%	40%	3%	1%	0%	0%	0%	47%	2,820	3,795	2,930	1,395	1,465	1,375	0.44
Unit B - Mean (n = 12)	8%	38%	46%	3%	1%	0%	0%	0%	47%	10,948	10,182	11,057	3,138	2,211	2,651	0.27
Unit B - Median (n = 12)	8%	37%	46%	3%	1%	0%	0%	0%	47%	8,850	9,115	9,835	2,715	2,180	2,200	0.26
Unit C - Mean (n = 8)	16%	39%	31%	5%	1%	0%	0%	0%	55%	4,097	7,169	3,607	3,177	1,068	2,321	11.61
Unit C - Median (n = 8)	13%	43%	29%	1%	0%	0%	0%	0%	65%	37	31	32	638	411	395	11.89

Note:

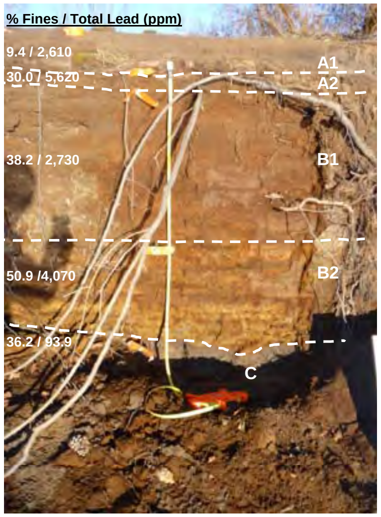
1. These samples, based on laboratory Pb values, appear to have been from Unit C, but were miscategorized as Unit A based on field observations. The river- and reach-averaged lead, zinc, and particle sizes averages and medians are impacted by inclusion of these few samples in Unit A rather than C, but not by a sufficient amount to warrant re-drafting all figures, tables, and text. This error contributes increased scatter into unit-averaged values but otherwise does not affect the conclusions in this report.
2. This sample contains unexpected and suspect values for Zn. Likely error in data transfer; these values were not used in computing average for Zn or Zn/Pb ratios .

ATTACHMENT D

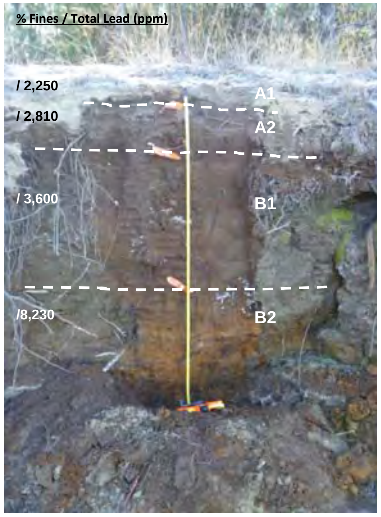
Photographic Documentation of 17 Sampled Banks

ATTACHMENT D – PHOTO DOCUMENTATION OF BANK SAMPLING SITES

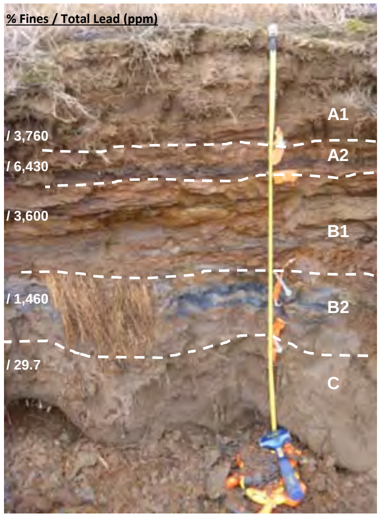
RM 135.2



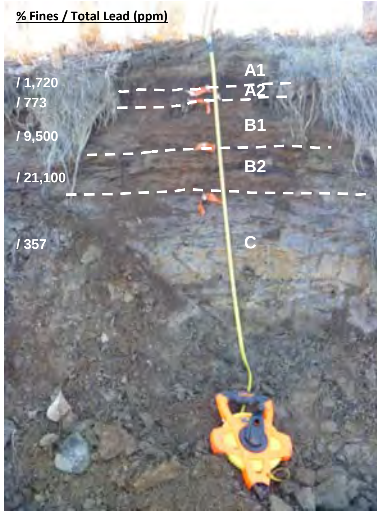
RM 137.8



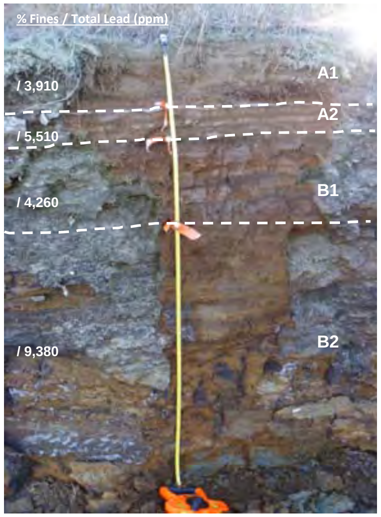
RM 142.5

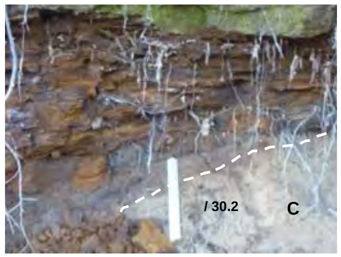


RM 143.4

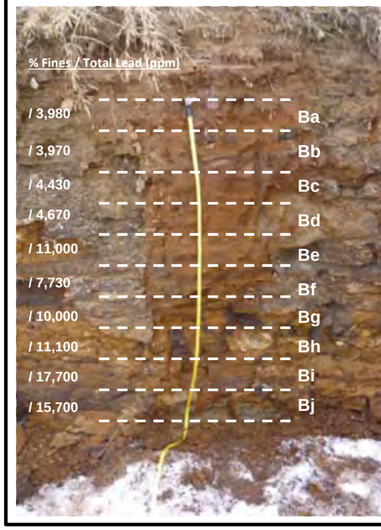


RM 144.1L (Coarse Scale)

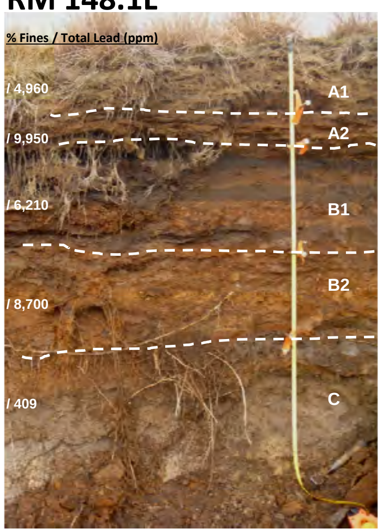




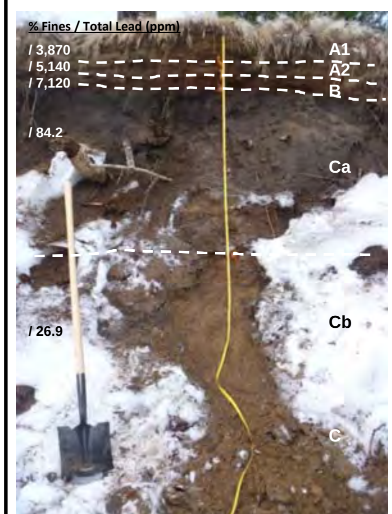
RM 144.1L (Fine Scale)



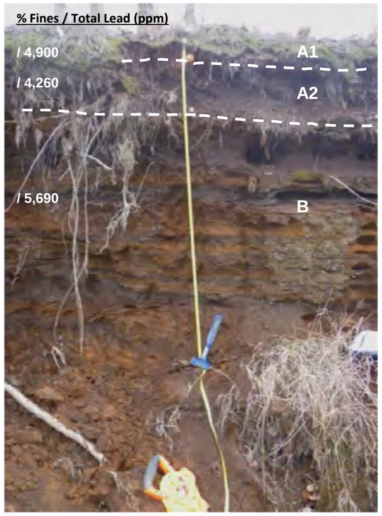
RM 148.1L



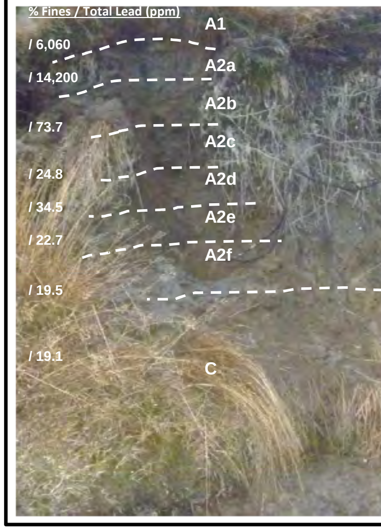
RM 149.0R



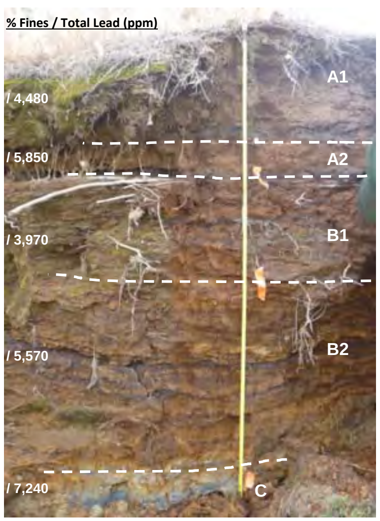
RM 152.3L



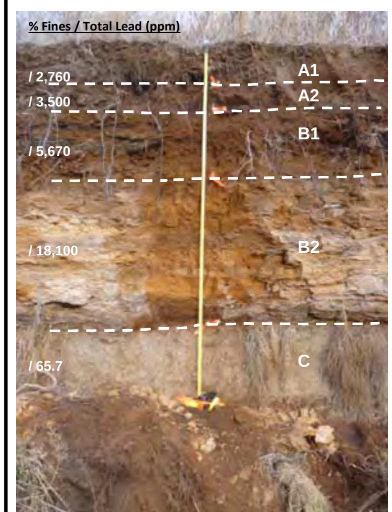
RM 154.1R



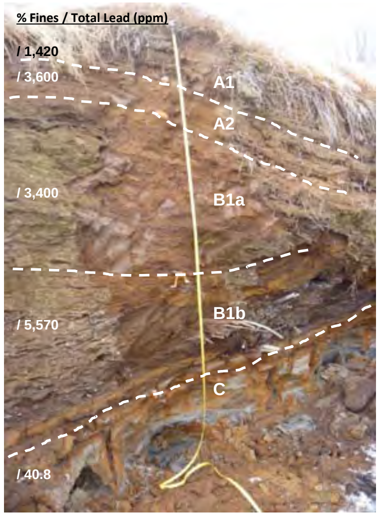
RM 156.3L



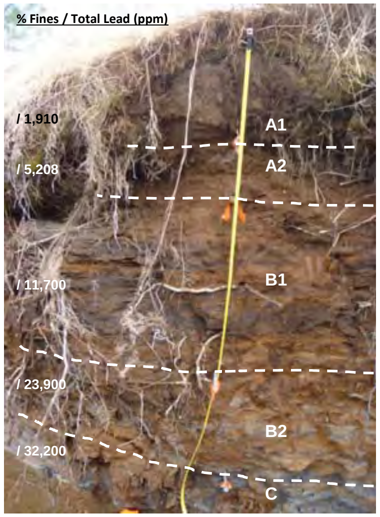
RM 159.3R

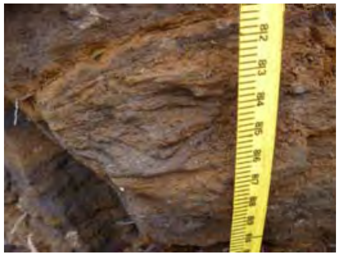


RM 160.2L

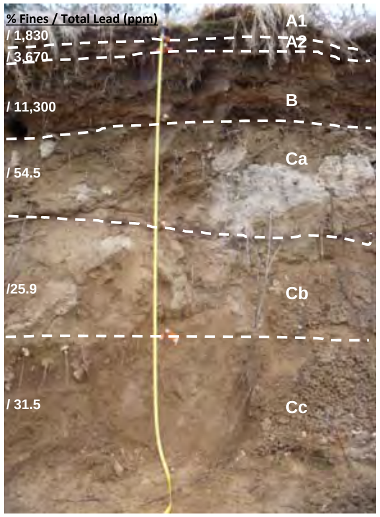


RM 162.7L

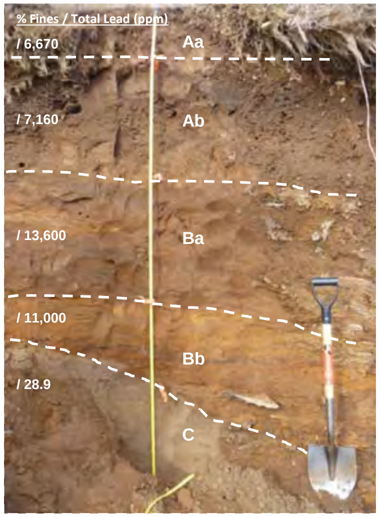




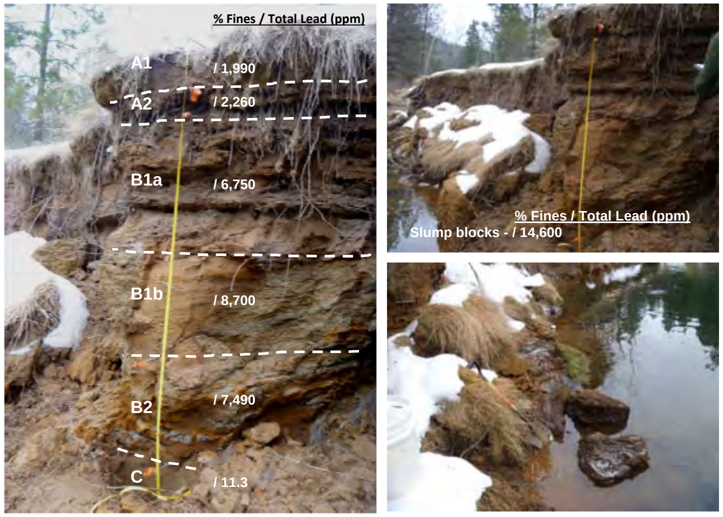
RM 163.0R



RM 166.5L (North Channel)



RM 166.5R (South Channel)



RM 167.0L