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

Technical Memorandum Addendum E-5—

Floodplain Sedimentation Rates Developed from One-Dimensional Model Results

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Floodplain Sedimentation Rates Developed from One-Dimensional Model Results, Lower Basin of the Coeur d'Alene River (OU3)

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1.0 Introduction

This addendum is a supplement to the series of 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 other 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 purpose of Addendum E-5 (Floodplain Sedimentation Rates Developed from One-Dimensional Model Results) to *Technical Memorandum E – Fluvial Geomorphology* (CH2M HILL, 2010b), is to provide an improved estimate of the amount and spatial distribution of sediment and lead deposition in the Lower Basin and, especially, the temporal and spatial variability of sediment transport and accumulation in the floodplain. The dynamics of sediment and lead mobility directly affect exposure risks, are critical to planning effective remedial actions, and improve our understanding of the potential for recontamination. Some data that describe floodplain and sedimentation characteristics have been collected in specific areas, including sediment cores, sediment tiles, and surface samples. However, these data do not fully describe the temporal or spatial heterogeneity of floodplain sedimentation.

Data from numerous sediment cores were previously compiled and analyzed by Bookstrom et al. (2004) and were combined with a surficial geologic map of the floodplain (Bookstrom et al., 1999). The Bookstrom et al. (2004) document compiles and evaluates data from numerous studies and compares depositional rates and lead concentrations of sediments deposited across time-stratigraphic intervals and different depositional settings. Average sediment and lead accumulation rates in the floodplain based on these data are compared with more recent measurements of mobile sediment and a refined sediment budget for the Lower Basin in CH2M HILL (2015a). This addendum presents the results of a one-dimensional (1D) sedimentation model that estimates the relative potential for future recontamination and relative sedimentation rates for off-channel and overbank areas. This information, with consideration of the work conducted by Bookstrom et al. (2004), will help guide decisions regarding additional sampling, pilot testing, and related evaluations until the more reliable sediment transport model is completed (scheduled for 2016). It is important to note that model predictions are based on anthropogenic and hydraulic conditions over the past 25 years (the period of evaluation) and should not be used to estimate the volume of sediment that was deposited in earlier periods of historic tailings production and disposal. Discussions of relative uncertainty are specifically addressed in Section 4.

This simple model of sedimentation in the floodplain of the Coeur d'Alene River uses results from a 1D hydraulic model (Hydrological Engineering Centers River Analysis System [HEC-RAS]), with suspended sediment concentration data from gaging stations in the Lower Basin. More detailed analysis of floodplain sedimentation processes will be performed using a two-dimensional (2D) sediment transport model that is being developed at this writing. Although the 2D sediment transport model will be more technically robust, the relatively simple sedimentation analysis performed with the 1D model provides an independent check on results from the 2D model and provides estimates of the relative differences in sedimentation between floodplain units. Additionally, due to the long (multiday) simulation times of the 2D model, running the entire 25-year hydrologic period of record (1988–2012) is not practical; using the 1D model allows for more efficient analysis of longer time scales. The results of the sedimentation model presented in this addendum are being summarized and incorporated into an overall sediment and lead budget of the Lower Basin system (CH2M HILL, 2015a).

This addendum was prepared by the following CH2M HILL staff: Paul Burnet, Tyler Jantzen, Daniel Malmon, and Ryan Mitchell.

2.0 Methodology

The sedimentation model described in this addendum comprises a series of 48 Microsoft Excel spreadsheets, one spreadsheet per model floodplain area element, that calculate sediment deposition at individual time steps over a duration of 25 years. Development of the sedimentation model used data from a calibrated 1D hydraulic model of the Lower Basin of the Coeur d'Alene River (CH2M HILL, 2013a). The 1D hydraulic model was created using the HEC-RAS version 4.1 software developed by the U.S. Army Corps of Engineers (USACE, 2010). In general, sedimentation was calculated as a sediment flux into the floodplain, with a trapping efficiency (TE) applied to that flux describing the proportion of the sediment load captured in the floodplain.

Two distinct model element types are used to represent the floodplain in the 1D model: "off-channel storage" areas (consisting of lakes, marshes, and other large off-channel storage elements) and "overbank flow" areas (representing near-bank floodplain flow areas that are in the model as a subset of the total cross-section flow) (Exhibit 1). The methods used to determine sediment flux and TE in each of these model element types are different and are described in the following sections.

Off-channel storage areas are labeled by the storage area identification number (from the 1D model), and overbank flow areas are labeled by their approximate river mile (RM) and channel location (channel left [L] or channel right [R]). Descriptions of specific floodplain areas use the area name, where available, and the area identification number in [brackets].

It should be noted that TE and sedimentation were not evaluated for Blessing Slough. This is because most medium- and coarse-size sediment entering the Strobl/Killarney/Moffit complex has been deposited before it reaches Blessing Slough (the area in the right floodplain connecting Moffit Slough [1259] and Swan Lake [1265]), and because Blessing Slough has relatively high velocity due to its moderate flow and small cross-sectional area, resulting in limited capacity to settle out remaining fine sediment. While Blessing Slough is an important hydraulic conduit, it was not considered significant to the sediment budget.

2.1 Overview of Methods Common to Both Types of Floodplain Areas

The methods used to calculate floodplain deposition rely on data inputs of flow, sediment concentration, and TE. Some of these data, such as flow, can be estimated by the 1D model on the basis of individual water bodies (also called "units" or "elements" of the HEC-RAS model). Others, such as sediment concentration, are available for general reaches of the river but not the floodplain, and so must be applied more broadly. TE can be estimated in several ways and, for this approach, is computed differently for two types of floodplain areas: off-channel storage areas and overbank flow areas. The sedimentation estimation methods common to both types of areas are described in this subsection. Other methods distinct to each type of area are described in subsequent subsections.

2.1.1 Suspended Sediment Concentration

The general sedimentation modeling approach involves determining sediment flux into a defined portion of the floodplain (a unit or element of the model, or for hydraulic modeling, a "control volume"). This sediment flux is calculated as the suspended sediment concentration (SSC) in the channel times the flow entering the floodplain control volume.

SSC rating curves from three measuring stations (Harrison, Rose Lake, and Cataldo) were used to represent SSC in water entering floodplain areas in different reaches; because SSC generally increases in the downstream direction in the Lower Basin, this approach provides the most representative data for each model element. Development of these SSC rating curves is documented in a related ECSM addendum that describes the sediment and lead budgets of the system (CH2M HILL, 2015a). SSC rating curves were applied to sediment calculations for all floodplain units within the measuring station area of influence. A measuring station area of influence is the area for which that station is closest, similar to a Voronoi or Thiessen polygon. Areas of influence for each measuring station used to match SSC rating curves with each individual floodplain unit are shown in Exhibit 1. SSC rating curves are described by the following power-law regression equation, with values for each parameter listed in Exhibit 2a, and a graph of the curves shown in Exhibit 2b:

$$SSC_i = a*Q^b$$

Where:

SSC_i = suspended sediment concentration at location i
a = SSC rating curve coefficient
b = SSC rating curve exponent
Q = total channel flow at location i

2.1.2 Flow Rates and Sediment Flux into the Floodplain

In general, SSC from the channel is applied to the modeled flow entering the floodplain, with sediment flux into each floodplain element calculated as the product of SSC and modeled flow. This calculation includes an implicit approximation that SSC is vertically well mixed and that SSC in the channel represents SSC entering the floodplain. In reality, SSC is usually higher near the channel bed and lower near the water surface, so water that enters the floodplain would tend to have an SSC lower than that of the main channel. The assumption that main channel SSC represents that of overbank flow would tend to overestimate the amount of sediment that enters the off-channel storage areas.

2.1.3 Trapping Efficiency

TE is the portion of the sediment flux into a floodplain element that is trapped, or remains, within that element. The methods used to calculate TE vary depending on the type of model element (off-channel storage area or overbank flow area). However, the methods for both types of floodplain area depend in part on the settling distance of the characteristic flow path. The characteristic flow paths for this sedimentation model were determined for all areas of the HEC-RAS model based on reviews of aerial imagery and the terrain model (CH2M HILL, 2013a) and professional judgment. In cases where flow enters and exits the floodplain at the same location, such as a marsh with a single tie channel, the flow path is the distance from the entry point to the middle of the marsh and back to the exit point (approximating the average length of the flow path for an average population of particles).

2.1.4 Conversion of Sediment Mass to Volume and Thickness

The mass of sediment trapped in a given floodplain area is converted to sediment volume and then thickness. Conversion from mass to volume uses a bulk density factor of 1.13 metric tons per cubic meter, a value based on samples reported by the U.S. Environmental Protection Agency (EPA, 1998) and Balistrieri et al. (2000) as compiled by Bookstrom et al. (2001).

Converting sediment volume to thickness is conducted for each floodplain element and is computed as the average inundated area of each unit, based on the 25-year hydrologic period of record. Inundated area is computed from an element-specific, elevation-volume-area curve developed from the terrain model, and model results for water surface elevation in that element; the floodplain area for each unit is the 25-year average of the time steps in which the unit was flooded. Total sediment volume trapped is divided by the average inundated area to get the average sediment thickness for each element.

This value is useful for understanding average sedimentation rates for each floodplain unit and provides a reference point for comparison with limited field data (sediment cores and depositional tiles). However, this value does not account for local hydraulics and terrain features that create heterogeneous deposition patterns across a given model floodplain element.

2.1.5 Channel and Floodplain Flow Rates

Flow rates for the Coeur d'Alene River and its floodplain areas were extracted from the 1D model, representing the 25-year period from water year (WY) 1988 through WY 2012. Tributary inflows into the model (other than those of the North Fork and South Fork) have not been developed for periods before 2004 (1D model hydrology is described in the model development report [CH2M HILL, 2013a]). These tributary inflows account for approximately 10 percent of the total flow at Harrison. To ensure that sedimentation model results before WY 2004 are comparable with those after WY 2004, the entire 25-year 1D model run used for the sedimentation model excludes tributary inflows. Similarly, the U.S. Geological Survey (USGS) Harrison gage data used to develop the downstream boundary condition of the 1D model (water surface elevation at Highway 97) are not available before 2004. A multivariate regression approach was used to extend the beginning of the record for this boundary to 1987 (CH2M HILL, 2014). As with the tributary inflow data exclusion, the synthetic boundary condition was used for the full model period (WY 1988 to 2012) so that results before and after 2004 are directly comparable.

Neglecting tributary inflows will result in slightly lower SSC values for flow leaving the river and entering the floodplain because total river flow is underestimated and SSC increases exponentially with total river flow. Conversely, neglecting tributary flows overestimates flows from the river to the floodplain because this underestimates the water level in floodplain storage areas and the resulting hindrance to flows entering from the river. These two countervailing effects, as well as the small portion (10 percent) of total river flow delivered by the tributary inflows, result in a second order (less than 10 percent) net effect on the estimated sediment flux into the floodplain, a source of uncertainty discussed further in Section 4. However, because exclusion of tributary flows affects all water bodies equally, this exclusion is not expected to affect the relative differences between floodplain units.

Off-channel storage areas were modeled at 6-hour time steps (and 12-hour time steps for overbank flow areas) due to technical constraints in the 1D model output files. The sedimentation model uses the 1D model results for input, so the calculation intervals of the sedimentation model are also 6 hours for off-channel areas and 12 hours for overbank flow areas.

2.2 Details of Methods for Off-Channel Storage Areas

Off-channel storage areas are used in the 1D model to represent lateral lakes, wetlands, and marshes. These areas behave—in the model and in reality—similar to reservoirs, with one or more inlet locations, and one or more outlet locations. Flow into and out of off-channel storage areas occurs in the model as weir flow across lateral structures, defined by headwater and tailwater elevations of the adjacent connected features. The connection of storage areas to lateral structures and storage area connections is described in more depth in the model development report (CH2M HILL, 2013a).

In some cases, off-channel storage areas are connected to the river at a single location (such as a tie channel). In other cases, flow enters the storage area at one location and returns to the river at another location, and in other cases, flow exchanges between multiple storage areas in series before returning to the river. Sediment deposition calculations were simplified for some storage areas by grouping two or more storage areas into a single unit for which sedimentation was calculated for the entire unit. Off-channel storage area routing and other notes and assumptions related to the calculation for a specific storage area are documented in Attachment A.

The same general method was used at each export time step for all storage areas, regardless of individual storage area routing, as follows:

1. The sediment flux into a storage area in a time step was determined as the product of the SSC in the main channel and the flow into the storage area over the 6-hour time step.
2. TE in a time step was calculated using empirical relationships based on the unique geometry of each lateral lake and wetland (using the approach explained in Section 2.2.1).
3. The sediment deposited (or trapped) within a lake or wetland was calculated as the product of TE and sediment flux into that storage area.
4. Sediment leaving the off-channel storage area (sediment flux into the storage area minus the sediment trapped in the storage area) was only explicitly tracked when it was the direct flux into another storage area.

2.2.1 Flow Rates and Sediment Flux into Off-Channel Storage Areas

The time series of flow, based on the 1D model output, was used to compute both the SSC and the total flux of sediment into the off-channel storage areas. Because the SSC rating curves are nonlinear, channel flow values averaged over long durations are not appropriate for sediment flux calculations. Thus, sediment flux and TE calculations at off-channel storage areas used 1D model output data at 6-hour intervals. The model parameters used to compute the sediment flux into off-channel storage areas are listed in Exhibit 3. These model parameters were stored in the model output Data Storage System (DSS, a database developed by the U.S. Army Corps of Engineers) file, which allows for 6-hour data to be collected from the entire 25-year record in a single model simulation. For each time step, the SSC in the main channel was computed using the sediment rating curve associated with the appropriate measuring station area of influence (Exhibit 2); and then the total sediment influx was computed by multiplying instantaneous SSC by the volume of the water that entered each off-channel storage reservoir during the time step. The volume of water entering the off-channel storage area is based on instantaneous flow into the storage area at the beginning of the time step.

2.2.2 Trapping Efficiency of Off-Channel Storage Areas

The lateral lakes and marshes in the Lower Basin are assumed to be hydraulically similar to a linear lake or reservoir, and there are multiple approaches for estimating the TE in such settings. TE is a function of a reservoir's physical dimensions (for example, volume, depth, length, and width), the magnitude and variability of the incoming flow and sediment load, the hydraulics of flow through the reservoir (water depth and velocity), and the properties of the sediment.

Empirical methods and data have been shown to provide reasonable estimates of sedimentation rates in lakes and similar water bodies. The most commonly used empirical methods include Churchill (1948), modified Churchill (Roberts, 1982), and Brune (1953). Churchill developed a TE curve for sedimentation basins, small reservoirs, and flood control reservoirs. The Churchill method correlates empirically-measured TEs to a sedimentation index (SI), which is defined as the ratio of retention time to the mean velocity of the water flowing through the basin. The modified Churchill method uses the same empirical data, but correlates to a dimensionless SI index. A TE computed in this way is a function of the geometry of the basin and the inflow, and does not directly consider site-specific sediment properties. The Churchill curves were derived from sites dominated by silt-size materials;

therefore, the curves may over-predict TE if sediments are very fine grained (clay and colloids) and may underpredict TE for sands. Suspended sediment in the Lower Basin is normally dominated by silt, but during large overbank floods, the sand fraction (measured in the main channel) can approach 50 percent (as consistently documented by measurements of suspended sediment made by the USGS and CH2M HILL at multiple stations and flow events in the Lower Basin). Patterns in suspended sediment data and analyses are described in greater detail in *Technical Memorandum Addendum D-3: Sediment and Lead Budgets – Lower Basin of the Coeur d'Alene River (OU3)* (TM Addendum D-3) (CH2M HILL, 2015a).

Four methods of calculating TE were evaluated for potential use in the sedimentation model:

- Churchill (1948)
- Modified Churchill (Roberts, 1982)
- An approximation of the Brune (1953) method (van Rijn, 2013)
- Constant TE values, assuming 30 percent, 60 percent, and 90 percent

The modified Churchill method was selected for the sedimentation model, both because it can be performed at an individual time step (the Brune method is calculated on an annual basis) and thus best represents the temporal variability of the system, and because its input parameters were readily available as 1D hydraulic model output. The modified Churchill approach is as follows:

$$TE = \frac{-20 + 0.95SI^{0.63}}{7500 + SI^{0.63}} \; for \; SI > 6E10^4$$

Where:

SI = Sedimentation index = $\frac{V^2}{Q^2 L}$

V = Volume of storage area (calculated at each time step, based on elevation-volume-area curve developed from terrain model)

Q = Flow into storage area (calculated as total flow from all sources)

L = Flow path length (estimated by measuring the most likely flow path from dominant point of entry to dominant point of exit, based on review of aerial imagery and the digital terrain model)

2.3 Details of Methods for Overbank Flow Areas

Portions of the floodplain referred to as "overbank flow" areas are treated differently in the sedimentation model from lateral lakes and marshes (off-channel storage areas). The overbank flow areas do not have large storage volumes, and flow velocities across them are relatively high. Unlike the lakes and marshes, the overbank flow areas do not fill on the rising limb and then empty when the river stage falls, but instead have more continual flow across them throughout flood stage flows. They, therefore, do not behave like reservoirs and require a different approach for modeling sedimentation.

These areas are also represented differently in the 1D model; they are included as a portion of the cross-section, and as such, the model is able to reliably calculate basic hydraulic parameters such as velocity, hydraulic radius, and average shear stress in these overbank areas.

Cross-sections in the 1D model are spaced relatively closely together—on average 90 meters (m) apart—and so many overbank flow areas are made up of numerous near-parallel cross-sections. To simplify the sedimentation model, a single representative cross-section was selected for each overbank flow area. The selection of the most representative cross-section was made subjectively, balancing flow velocity, depth, and discharge.

2.3.1 Flow Rates and Sediment Flux into Overbank Flow Areas

The time series of flow, based on the 1D model output, was used to compute both the SSC and the total flux of sediment entering the overbank flow areas. Because the SSC rating curves are nonlinear, channel flow values averaged over long durations are not appropriate for sediment flux calculations. Sediment flux and TE calculations in overbank flow areas were based on instantaneous flow rates extracted at 12-hour intervals from the 1D model.

Model parameters used for overbank flow area sedimentation calculations are listed in Exhibit 4. These model parameters are not available in the DSS output file (as the storage area parameters), and so are listed in the HEC-RAS summary output tables. For each time step, the SSC in the main channel was computed using the appropriate sediment rating curve (Exhibit 2); and then the total sediment influx was computed by multiplying instantaneous SSC by the volume of the water that entered each overbank flow area during the time step.

2.3.2 Trapping Efficiency of Overbank Areas

TE in overbank areas was computed as the ratio of the vertical distance a particle will fall over a given flow path to the average depth of water across the overbank flow area:

$$TE(i) = \frac{d_s(i)}{d_w} = \frac{w(i) \times L \times 1000}{d_w \times u_w}$$

Where:

TE = trapping efficiency (proportional) for grain size class *i* (if ratio is less than 1). If ratio is more than 1, then TE(*i*) = 1.

d_s (*i*) = vertical distance (m) that a particle of size *i* will settle during the time it takes a parcel of water to flow across the floodplain. This is approximated as the product of the particle settling velocity and the duration of the flow path. This calculation assumes that settling velocity in still water is applicable to flow over the floodplain, so it neglects the influence of turbulent mixing within the overbank flow. A correction to account for this is discussed below (Section 2.3.3).

d_w = average depth of water flowing across the floodplain (m). Calculated at representative cross-section as the cross-sectional flow area in the overbank divided by the flow width in the overbank. HEC-RAS output variables: [flow area overbank]/[top W act overbank].

L = length of typical floodplain flow path (m).

u_w = average water velocity on floodplain flow path (m/s), determined at representative cross-section. HEC-RAS output variable: [vel overbank].

w_s (i) = vertical settling velocity of particle size class i, explained further below in Section 2.3.3.

i = size classes considered by the calculation, as explained in Section 2.3.3.

2.3.3 Settling Velocity

Vertical settling velocity was calculated using the settling velocity formula of Jimenez and Madsen (2003), which is an update of the settling velocity formula proposed by Dietrich (1982). The Jimenez and Madsen equation is as follows:

$$w_s = W_* \sqrt{(s-1)gd}$$

$$W_* = \left(A + \frac{B}{S_*}\right)^{-1}$$

$$S_* = \frac{d_N}{4\upsilon}\sqrt{(s-1)gd_N}$$

Where:

w_s = settling velocity

W_* = dimensionless settling velocity

s = specific gravity, of sediment, assumed to be 1.65[1]

g = gravitational acceleration, 9.81 (m/s^2)

d = sediment diameter (m, assumed in this context to equal d_s)

d_s = sieving diameter (m)

d_N = nominal diameter (m, the diameter of a sphere of the same volume as the natural particle)

d_S/d_N = 0.9, typical value assumed by Jimenez and Madsen (2003)

A = dimensionless coefficient, 0.954, based on generic shape factor 0.7 and roundness value 3.5, from Table 1 of Jimenez and Madsen (2003)

B = dimensionless coefficient, 5.12, based on generic shape factor 0.7 and roundness value 3.5, from Table 1 of Jimenez and Madsen (2003)

S_* = dimensionless fluid-sediment particle parameter

υ = kinematic viscosity of fluid, 1.00E-6 (kg/(m*s)), water at 20°C

In the Jimenez and Madsen (2003) equations, settling velocity is a function of sediment diameter. To account for the wide range of sediment sizes deposited in the floodplain, a single representative diameter was selected for each of three sediment classes: clay, silt, and sand. The proportion of each of these sediment classes relative to bulk suspended sediment

[1] 1.65 is typical specific gravity for quartz-rich sediments. This value does not account for the influence of heavy metals adsorbed to the particles or in particles themselves. The influence of lead content on specific gravity is currently under investigation, but it is expected to have negligible effect on basin-wide average specific gravity (the value represented here) relative to other uncertainties affecting the sedimentation analysis (discussed in Section 4).

is described below in Section 2.3.5. Representative diameters for each class were selected from an average d50 from eight Laser In Situ Scattering and Transmissometry (LISST) measurements taken at various locations along the river during the April 26 through 28, 2012, flood event. The median diameters of clay range and silt-range particles (2.61 micrometers [µm] and 15.4 µm, respectively) showed consistent readings with the LISST. The median diameter for sand was more variable among the measurements, with the average being 95.2 µm (very fine sand). Based on these particle diameters, using the Jimenez and Madsen (2003) equations, settling velocities for these particles were calculated to be 0.0017 millimeters per second (mm/s), 0.059 mm/s, and 2.1 mm/s.

Uncertainty associated with the selection of representative particle sizes and associated settling velocities is discussed in Section 4. Results from the LISST sampling are discussed in greater depth in TM Addendum D-3 (CH2M HILL, 2015a), and details of the particle size distributions from the eight LISST measurements selected to guide development of representative settling velocities are included in Exhibit 5.

2.3.4 Suspended Sediment Gradation

Sediment deposition in overbank flow areas depends more on particle settling velocity, and thus, specific sediment sizes are needed. Separate settling rate calculations were performed for three particle size classes: sand, silt, and clay. The relative proportions of these size classes were obtained from suspended sediment data from sampling stations at the three USGS gages in the Lower Basin used to develop SSC rating curves (Exhibit 2) and LISST measurements during the April 26 to 28, 2012, flood event. Particle size class proportions were varied according to which sampling station was closest to the overbank flow area (SSC rating curve area of influence in Exhibit 1). The sand and fines (combined clay and silt) proportion of bulk sediment was based on SSC curves from the three suspended sediment sampling locations (Harrison, Rose Lake, and Cataldo). The average of the SSC values for flows at 20,000 cubic feet per second (cfs) and 25,000 cfs was used, since floodplain deposition occurs during overbank flows only. The ratio of silt to clay in suspension was based on the mean ratio for 58 measurements of suspended sediment profiles taken during the April 26 to 28, 2012, flood event using the LISST (CH2M HILL, 2015a). The relative proportions used for the three size classes are shown in Exhibit 6. The median grain size within each of the three size classes, which was needed for the settling velocity calculation, was also based on the LISST data.

3.0 Results and Discussion

The sediment deposition model computed, for each time step and model element, the following outputs:

- Sediment flux entering the floodplain (mass/time)
- Average TE (percent)
- Mass sediment deposition rate (metric tons)
- Average sediment deposition thickness (millimeters [mm])

These results were summed by WY, and the WY estimates are summarized both temporally and spatially in Exhibits 7 through 21. Results represent the best current estimates of floodplain sedimentation. Uncertainties associated with these estimates are described in Section 4.

Over 25 years, the estimated total amount of sediment that entered and was deposited in the floodplain was approximately 1.5 million metric tons and 0.6 million metric tons, or annual averages of 60 thousand metric tons per year entering the floodplain, with deposition of 24 thousand metric tons per year. The overall average TE was about 40 percent, and the overall average deposition rate about 0.7 millimeters per year (mm/year) (across an area of about 30[2] square kilometers, and which varies by WY from 0.0 mm/year to 3.9 mm/year in WY 1996). Over the entire Lower Basin floodplain, sedimentation from WY 1996 and WY 2008 (the largest flood years) accounts for nearly 40 percent of the total sedimentation over the 25 year period from 1988 to 2012. As described in Section 4, these values represent an estimate of sedimentation based on numerous assumptions, approximations, and model results, each with associated uncertainty and limitations. The estimated sedimentation results are most appropriate for comparisons of relative sedimentation values across the Lower Basin and when considering long-term averages such as sedimentation over the 25-year period from 1988 to 2012.

3.1 Spatial Distribution

Exhibits 7 through 12 show the spatial distribution of average annual sediment flux into the floodplain (Exhibit 7), TE (Exhibit 8), sediment mass deposited (Exhibit 9), and sedimentation rate (Exhibit 10). In addition to the average annual value (Panel C in each of these exhibits), the exhibits also show values for the high flow WYs of 1996 and 2008 (Panels A and B). As noted above, these large flood years represent a substantial portion of the overall mass of floodplain sedimentation over the past 25 years. For comparison, Exhibit 10 also shows the average annual sediment deposition rate computed from the depth of the 1980 Mt. St. Helens ash layer in 79[3] cores taken between 1991 and 1998, based on reanalysis of data (CH2M HILL, 2015a) compiled by Bookstrom et al. (2004). Exhibit 10 also shows the thicknesses of sediment deposited on sampling tiles on the floodplain in WYs 2011, 2012, and 2013 (CH2M HILL, 2011a, 2011b, and 2013b). Exhibit 11 tabulates the average sedimentation values shown in the maps in Exhibits 7 through 10 (Panel C). These values were developed using the methods described in Section 2 of this addendum. Exhibit 12 tabulates sedimentation values for high-flow WY 1996 (Exhibit 12a) and WY 2008 (Exhibit 12b). Exhibit 13a tabulates the average annual sedimentation rate at the 79 USGS cores; Exhibit 13b shows the relationship between core sedimentation depth, distance from the channel, and collection date relative to the 1996 flood event; and Exhibit 13c tabulates

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2 As described in Section 2.1.4, this area (29.8 km^2) represents the average inundated area from RM 133 (Highway 97 crossing) to RM 163 (the USGS Cataldo gage) for both the off-channel storage areas and the overbank flow areas. This compares to a value of 53.7 km^2 reported in Bookstrom et al. (2004) representing the entire lower basin (RM 131 to RM 168) and 45.0 reported in Section 6.1 of CH2M HILL (2015a) representing a modification of Bookstrom's area to represent only the Lower Basin from RM 134 (USGS Harrison gage) to RM 163 (USGS Cataldo gage). Both Bookstrom et al. (2004) and CH2M HILL (2015a) are based on the maximum extents of inundated area, as mapped in Bookstrom et al. (1999), while the value used in this report is based on average inundated area. The analysis in this report develops a total mass of sediment deposited on the floodplain, and then converts this mass to depth based on average inundated area. Using the maximum extents of inundated area would have no effect on the mass deposited as calculated in this report; it would however reduce the average deposition depth. In contrast, the Bookstrom et al. (2004) analysis develops a depth of sediment deposited on the floodplain, and then converts this to mass. Comparisons of mass deposited made in the conclusions of this report adjust the Bookstrom et al. (2004) value to account for deposition only across 29.8 km^2.

3 79 cores are a subset of 125 presented and discussed in Bookstrom et al. (2004). These 79 are within the 1D sedimentation analysis area, and exclude those upstream of the USGS Cataldo gage and along portions of the riverbank wedge that are not included in the 1D sedimentation area analysis. Of these 79 cores, 14 (18 percent) were collected after the 1996 flood and include sediment deposition from this event.

the six Basin Environmental Monitoring Plan (BEMP) sampling tiles to compare with calculated sedimentation rates in Exhibit 10.

The highest floodplain flow (and thus the highest sediment flux), in both average and high flow years, enters the following:

- Killarney Lake system (Strobl Marsh [1257], Killarney Lake [1261 & 1260, and Moffitt Slough [1259])
- Swan Lake system (Swan Lake [1265], Blue Marsh [1239], and Blue Lake [1240])
- Overbank flow area 160_R (Exhibit 7)

In average years, nearly all the overbank flow is in the right floodplain (north of the river, Exhibit 7c). However, in WY 1996 portions of the left floodplain also received flow and sedimentation, including Black Rock Slough [1255], Upper Marsh [1248 & 1250], and Anderson Lake [1245] (Exhibit 7a). This additional left floodplain sedimentation represents atypical floodplain activation that only occurs during very large events.

TE is highest in floodplain areas with low flow (and, thus, low velocity); conversely, TE is lowest in areas with high flow. Thus, the areas with the lowest TE are those in the right (north) floodplain that experience large through-flow (Exhibit 8), such as the Killarney Lake system and the Swan Lake system—where the model calculations predict that between 10 and 50 percent of the sediment entering will be deposited there. In contrast, the model predicts that most of the sediment entering areas such as Cave [1242], Thompson [1244], and Medicine Lakes [1262 & 1264] remains there (TE more than 75 percent); in these lakes water is exchanged predominantly through confined access points such as a tie channel during all but the very largest events. These areas fill during the rising stage of floods, then remain full for extended periods during high water, resulting in longer residence times for particles. During the peak of extremely large events, such as the 1996 flood, flows occur over the Trail of the Coeur d'Alenes embankment to cause larger floodplain exchange in systems normally accessed only through confined points, and lower TEs occur, similar to those in the right floodplain.

Floodplain sedimentation (Exhibit 9) is similar to floodplain sediment flux. The largest masses of sediment are deposited in the Killarney Lake system and in Swan Lake [1265]. During high-flow years, a large mass of sediment is also deposited in overbank flow areas 158_R and 160_R. These high sedimentation areas tend to have lower TE values, because high sedimentation is created by high flows and high flux. The same high flows that bring high sediment flux also cause high floodplain velocities and thus lower TE; however, this low TE may be offset by the large sediment flux into these areas, and thus a large mass of sediment may be deposited. Conversely, portions of the floodplain with high TE, such as Lamb Peak Marsh [1268], Cave Lake [1242], Medicine Lake [1262 & 1264], and Lane Marsh [1258 & 1238], may have lower overall sedimentation masses because the flows are limited to essentially one lake volume, and a relatively small amount of sediment enters them. For example, model results show that Rose Lake [9651] only experienced inflow from the river in 1996, and then only 0.02 metric ton of sediment entered the lake—with nearly all the sediment that entered the lake being deposited there (Exhibit 8b).

Exhibit 10c shows the computed sedimentation mass normalized by area (reported as the annual average sedimentation rate, in millimeters per year), compared with field measurements of sediment deposition based on BEMP sediment tiles and the cores compiled by the USGS. These vertical deposition rates assume an average inundation area, determined from 1D hydraulic model results. Overall average sedimentation rates are calculated to be highest in Blue Marsh [1239] and in the overbank flow area 163_L, with average rates above 10 mm/year. These areas have high flow, high flux, high sedimentation, and relatively small depositional areas. Of the larger areas with large overall sedimentation mass, Swan Lake [1265] has the highest deposition rate of 2.2 mm/year.

Overall, the modeled deposition rates are lower than those measured from the cores and deposition tiles (Exhibits 10, 11, and 13). A number of reasons may account for this discrepancy, including the following:

- The modeled deposition rates are average rates over an entire model floodplain element. Areas represented by these elements may range from adjacent to the river to more than 3 kilometers from the river. The average inundated area of elements is greater than 400 hectares, and is represented as a single rate. Sedimentation analysis in these large model floodplain elements does not account for the natural spatial variation in sedimentation caused by local terrain and hydraulics. Exhibit 13b shows a pattern of decreasing deposition rates with increasing distance from the river.
- Conversely, the cores were not collected for the purpose of estimating representative, basin-wide deposition rates, but for site-specific studies. These cores are typically located within 200 meters of the river (41 of 79 are less than 200 meters from the river; the median distance is 150 meters from the river). Thus, the rates estimated from the cores may reflect a sampling bias, with cores being collected primarily in areas where higher than average sedimentation rates is expected (near the river).
- There may also be a preservation bias: the Mt. St. Helens ash layer is only preserved in dry upland floodplain areas such as natural levees, which tend to be close to the channel where sedimentation rates are greater.
- There is also a possible bias related to comparing differing time periods, discussed in Section 3.2.
- Finally, the modeling results could under-predict sedimentation rate—due to either an underestimate of flow and/or sediment flux into the floodplain, or an underestimate of TE. These estimates are discussed in greater length in Section 4.

While the overall trend is that the modeled rates are lower than those measured from USGS cores and depositional tiles, a number of locations where depositional rates derived from coring are in general agreement with the modeled rates (Exhibit 10c and Exhibit 13a). These areas include: 139_L, Medicine Lake [1262 & 1264], Swan Lake [1265], Moffit Slough [1259], Killarney Lake [1261 & 1260], Strobl Marsh [1257], and 160_R. Due to the overall uncertainty types and magnitudes associated with the modeled sedimentation rates (Section 4), it is reasonable that the modeled sediment deposition rates could be approximately 50 percent higher or lower, placing them in closer agreement with the range of variability in the USGS cores (Exhibit 10c, and as discussed in Bookstrom et al. [2004] and CH2M HILL [2015a]).

3.2 Temporal Distribution

Exhibits 14 through 18 show time series of annual floodplain sedimentation parameters. Exhibit 16 tabulates the values shown in the graphs in Exhibits 14 and 15, showing that average annual deposition of 0.7 mm/year varies by WY from 0.0 mm/year to 3.9 mm/year in WY 1996. Exhibit 17 shows cumulative sediment deposited in the floodplain over 25 years to aid comparison of other elements of the sediment budget; because each floodplain area has unique size, shape, and hydraulic characteristics, the temporal patterns of sediment deposition are different for each floodplain area. Exhibit 18 shows the temporal distribution of sedimentation (as in Exhibit 14) for selected individual floodplain areas. These areas were selected because they have high overall sedimentation rates (as overall mass or thickness), or because they are of potential interest for remediation pilot projects.

Floodplain sediment deposition primarily occurs when flow overtops the banks of the main channel, although some minor exchange occurs via tie channels into off-channel storage reservoirs even below bankfull conditions. Bankfull flow is approximately 20,000 cfs in the Lower Basin (measured at the USGS Cataldo gaging station) (CH2M HILL, 2010b). Thus, the largest sediment fluxes to the floodplain occur during high flow years with events that exceed this threshold (Exhibit 14). The greatest floodplain deposition occurs during these high flows (Exhibits 8 through 10), even though TE is lower than average at high flows due to higher water velocity in the floodplain. Panels A and B of Exhibits 7 through 10 show the TE, deposition masses, and deposition rates for two selected high flow years: 1996 and 2008, and Panel C shows the long-term averages. These 2 years combined account for nearly 40 percent of the total sediment deposited over the 25-year modeled period (WYs 1988 to 2012) for the Lower Basin floodplain. The model observation of high deposition during the 1996 event is supported by a similar observation in the USGS core data, in which the highest sedimentation rates more than 10 meters from the river are measured in cores collected after the 1996 event (Exhibit 13b).

Overall, modeling results indicate that more floodplain sedimentation occurred in WY 1996 than in WY 2008 (Exhibit 14). This contrasts with the total fluxes of sediment and lead in the main channel, which were dominated by WY 2008, characterized by an unusually sustained spring runoff (CH2M HILL, 2015a). The "flashier" (rapid rise and fall) flood of 1996 had the highest peak flow (measured at Cataldo) in the 25-year modeled period, but also had low initial lake levels (approximately 2,125 feet), which resulted in significant portions of floodwater being routed into off-channel areas with large available storage (attenuating peak flow lower in the basin). In comparison, the 2008 flood was characterized by sustained high flows and high initial lake level (approximately 2,130.5 feet), in which water filled the floodplain early in the event and reduced further water exchange and attenuation in the floodplain.

Floodplain sedimentation is dominated by years with the largest flood events (Exhibit 14). Over the 25-year modeled period, about 600,000 tons of sediment entered the floodplain, but this total is dominated by several discrete years; many years have comparatively little deposition (Exhibits 14 and 17). Above-average sedimentation occurred in 1996, 1997, 2002, 2008, 2011, and 2012. These 6 years account for 78 percent of the total mass deposited in the 25-year period. The same 6 years account for only 66 percent of the 25-year total sediment flux at Harrison (CH2M HILL, 2015a). TE is typically lowest in the high flow years (Exhibit 14); the modeled average TE in 1996 was 33 percent, compared to the overall average of 40 percent for the 25-year modeled period. In some low flow years, TE is above 85 percent (i.e., in 1992, 2004, and 2010).

Exhibit 15 compares the ratio of floodplain sedimentation to the sediment flux passing the USGS gage at Harrison. During high-flow years, a higher proportion of the sediment transported by the river is deposited in the floodplain due to a greater degree of floodplain "activation" (inundation). According to the model, the sediment deposited in the floodplain in WY 1996 amounted to more than half of the sediment flux passing Harrison that same year. In contrast, during low-flow years, the mass of sediment deposited on the floodplain is less than 10 percent of that passing Harrison. These relationships are examined in more detail in the following section.

Individual floodplain areas (Exhibit 18) tend to have a similar temporal sedimentation pattern as the entire system (Exhibit 14), with some exceptions. The TE of the selected overbank flow areas (151_L, 152_R, and 160_R) is more variable and lower than the TE of the selected off-channel storage areas. Mission Flats (160_R) has lower overall TE than most floodplain areas, and a larger proportion of its total sediment load deposited in 1996, than other floodplain areas. This is consistent with higher sedimentation rates calculated from cores collected in this area in 1998 (Bookstrom, 2004 and Exhibit 13a). Flow into Lane Marsh 2 (1238) is small, and thus TE is high during all years; however, the total amount of sediment deposited in it is negligible (49 tons per year; Exhibit 11). Exhibits 10 and 12 also show the difference between Lane Marsh 1 (North) and Lane Marsh 2 (South). This is consistent with Bookstrom et al. (2004); lead concentrations in surface sediments between the levee crest and the trail embankment in Lane Marsh North were two to three times higher than in the more protected Lane Marsh South.

One of the possible reasons for the 1D sedimentation model predicting lower average basinwide sedimentation than the USGS cores is the time period over which the cores were collected and the events represented by the cores. The cores were collected between 1993 and 1998, while the modeled period was 1988 to 2012. The two largest floods on the Coeur d'Alene River in the last 40 years were in 1996 and 2008 (short-duration and long-duration events, respectively; CH2M HILL 2010a). Most of the cores (72 percent) were collected before 1996 and, therefore, do not consistently include the sedimentation effects of the largest floods, while the model does include the 1996 and 2008 events (and predicts high sedimentation rates for them). Because post-1996 cores tend to have higher sedimentation rates (Exhibit 13b), and because core collection is weighted towards pre-1996, the core-based estimate would be expected to show lower deposition rates than the model which includes larger floods than most of the cores. However, the core estimates still show much higher sedimentation rates than modeled rates, suggesting that the sampling and preservation biases discussed in Section 3.1 outweigh the sampling period bias discussed in Section 3.2.

3.3 Instantaneous Relationships among Flow, Trapping Efficiency, and Sedimentation

Exhibits 19 and 20 show the variability and overall patterns of TE and sedimentation, respectively, as a function of flow. These graphs provide an indication of sediment deposition patterns as function of flow, the probability of which can be predicted based on historical recurrence intervals. Exhibit 19 shows how the overall basin-wide TE decreases rapidly as flow at Cataldo increases. The rate of decrease in TE levels off as flows exceed

20,000 cfs, with the asymptote at a TE of about 30 percent at very high flows. Although there is a clear inverse relationship between TE and flow, there is a wide range of TE values for a given flow—for example, the basin-wide TE at a flow of 10,000 cfs varies from 40 percent to more than 80 percent. A primary factor in this variability is the difference in the corresponding level of Coeur d'Alene Lake, which also has a strong influence on the TE, and which is shown in Exhibit 19. For low flows (less than 10,000 cfs at Cataldo), where lake level can vary greatly, the higher TE tends to occur at higher lake levels (blue and purple dots on Exhibit 19), while lower TE tends to occur a lower lake levels (green and yellow dots). At higher flows (greater than 10,000 cfs at Cataldo), the effect of lake level inverts, with higher lake levels producing lower TE.

Exhibit 20 shows the relationship between instantaneous sedimentation and flow at Cataldo. At low river flow, TE for the entire system floodplain is near 100 percent. However, as sediment flux to the floodplain at low flows is near zero, virtually no sediment deposition occurs in the floodplain. As river flows increase, TE decreases to levels near 30 percent (Exhibit 19), while total sedimentation flux and the mass of sediment deposited increase rapidly. There is an inflection point in Exhibit 20 near 30,000 cfs when flow into the floodplain becomes more widespread, and the amount of floodplain sedimentation increases rapidly above this level.

3.4 Model Flow Paths

An important part of the sedimentation calculation is the volume of flow entering and exiting the floodplain. In Exhibit 21, the movement of water in the channel, and to and from the floodplain via general flow paths, is characterized relative to the total river flow upstream of Strobl Field. While these flow paths represent only water movement, they also provide an indication of sediment transport. In order to compare the generalized flow paths from the 1D model with those from the 2D hydraulic model (for which long-period, such as 25-year, results are not feasible because of long run times), the time period for the paths shown in Exhibit 21 is limited to WY 2011. Further, to allow focus on the flow paths during events that transport higher suspended sediment concentrations and overall sediment loads, the volume exchange shown in Exhibit 21 is limited to times when river flow at Strobl Field is above 10,000 cfs.

Both the 1D and 2D models show relatively high proportions (approximately 30 percent) of the total flow traveling through the right (north) floodplain system at Killarney and Campbell Lakes. This flow enters the floodplain at Strobl Marsh and through the Killarney Tie Channel, and overbank areas. Much of this flow (between 10 and 20 percent of the river volume) returns to the river at Moffit Slough, with the remainder traveling parallel to the river via Blessing Slough, which has bidirectional exchange with the main stem. Right floodplain flow continues through Swan Lake, Blue Marsh, and Blue Lake, after which most flow is maintained in the channel. Smaller proportions of flow are routed through the left (south) floodplain, through Cave and Medicine Lakes.

The 2D hydraulic model is calibrated and validated, and allows comparison of overbank flow paths with the 1D model for time periods practical for 2D hydraulic model runs. (At the time of this writing, the 2D sediment transport model is still being developed and is not yet available for direct calculation of sedimentation rates in the floodplain.) Exhibit 21 compares the 1D and 2D hydraulic models. The results show general agreement between the two models, indicating that uncertainty associated with the 1D sedimentation model and attributable to flow pathways and volumes is relatively constrained. The largest discrepancy between the 1D and 2D results is the amount of flow reentering the river at Moffit Slough. At this location, the 2D model shows just over half of the proportion reentering the river as the 1D model. Part of this is attributable to more flow initially entering the right floodplain in the 1D model, with the remainder likely due to the floodplain flows being attenuated by the 2D floodplain roughness, and being released back to the river more slowly than the 1D model. Some of the attenuated 2D floodplain flow returns to the river after flow at Strobl Field declines below 10,000 cfs, and is, thus, not included in the Exhibit 21 volume calculation and comparison with the 1D model.

4.0 Uncertainty and Limitations

The model indicates complex spatial and temporal relationships between river flow and sediment delivered to the floodplain. This complexity can be ascribed to three primary factors:

- The Lower Basin system comprises 48 separate floodplain areas, all with unique geometries and floodplain characteristics.
- Antecedent Coeur d'Alene Lake levels cause varying relationships between river flow, SSC at time of inflow, floodplain inundation, TE, and sedimentation rates.
- There are numerous complex and nonlinear relationships between flow, suspended sediment concentration, floodplain flow, inundated area, sediment flux, TE, and sediment deposition.

Values based on the results of the 1D sedimentation model are only estimates of the spatial and temporal distribution of floodplain deposition in the Lower Basin. Model results should be used as part of the broader understanding of sediment and lead transport in this complex system.

When considering model results, several factors should be considered relative to model uncertainty. These factors are discussed in detail below. Where feasible, the influence of these factors was quantified by computing the sensitivity of the sedimentation calculations to these input values. This sensitivity analysis was performed on a subset (9 of the 48 floodplain areas), with the 9 areas providing a representative range of geographic locations, flow scenarios, and 1D model elements. A summary of the effect of each of these factors on computed sedimentation is presented in Exhibit 22, which shows a percent increase or decrease in sedimentation relative to the best estimate model input values used for the basin-wide analysis. Some of the factors (described in greater detail below) only consider a subset of the nine floodplain areas used for uncertainty analysis; for instance, some factors only apply to overbank flow areas.

The types of uncertainty considered and quantified in this section (and summarized in Exhibit 22) are unlikely to be additive, and represent only a subset of the basin. However, a reasonable estimate of the overall uncertainty of the sediment deposition model might be +/-50 percent. The application of this range of uncertainty increases the potential agreement between model results, USGS cores, and BEMP sediment tiles (Exhibit 10c and Exhibit 13).In general, the largest uncertainty is associated with the SSC rating curves. However, as discussed in the TM Addendum D-3 (CH2M HILL, 2015a), these uncertainties are still within a reasonable range for typical sediment transport studies. Evaluating all uncertainty factors combined, there is a greater chance that the basin-wide average sedimentation best estimate using the 1D sedimentation model is an overestimate than an underestimate of actual sedimentation.

Specific elements that may contribute to uncertainty in the 1D sedimentation model are discussed below.

4.1 Suspended Sediment Rating Curves

Sediment flux is based on limited discrete SSC rating curves from data collected at Cataldo, Rose Lake, and Harrison and does not account for the variability of SSCs between these sample locations (the current model assumes a step function). The rating curves are based on limited samples and are assigned to floodplain areas based solely on geographic proximity. Specifically, the Rose Lake SSC curve is based on 10 samples and is used to define sediment flux at 26 of the 48 floodplain areas. The Cataldo and Harrison SSC curves are each based on a greater number of samples (50 and 35, respectively); however, such rating curves are typically characterized by a high degree of scatter. In addition, the calculation assumes that the size distribution and concentration of sediment in the entire water column is representative of the water entering the floodplain, even though vertical stratification of suspended sediment in the water column is assumed and has been observed in LISST data, meaning that sediment near the top of the water column may be finer and at a lower concentration than the average.

Suspended sediment concentration is divided into three size classes—clay, silt, and sand—in the overbank flow area calculations; the relative proportion between the sand and fine fractions was derived from the SSC rating curve data. Different TE values were assigned to each size class, so any uncertainty in the SSC curve size fraction split affects the total sediment flux used in this analysis.

A more complete sensitivity analysis of the SSC rating curves is included in TM Addendum D-3 (CH2M HILL, 2015a). In this analysis, three SSC rating curve factors were varied: power-law regression exponents, selection of regression model, and threshold discharge. Summary results are presented in Exhibits 23 through 25, illustrating the variation in sedimentation results due to changes in SSC rating curves. The varied rating curve regression model sensitivity analyses was performed on only the Harrison rating curve.

Changes to the SSC rating curve directly affect only the mass of sediment entering a floodplain area; they do not affect water volume entering the floodplain, floodplain hydraulics, or directly affect TE. However, because the SSC rating curves are nonlinear with respect to channel discharge, and because TE varies depending on discharge (and other hydraulic conditions), changes to SSC rating curves have an indirect effect on average TE.

Of the variations to the SSC rating curves, a change in the power-law regression exponent (-49 to +125 percent change in sedimentation; Exhibit 23) and change in the regression model (-48 to +39 percent change in sedimentation; Exhibit 24) have larger effects, while adjusting the threshold discharge has a relatively minor effect (-17 to +7 percent change in sedimentation; Exhibit 25). However, relative to some sediment flux estimates where uncertainty can range over an order of magnitude, these sensitivities reflect ranges typical of representative data sets.

4.2 Simplifying Assumptions of 1D Model

The 1D model used for this analysis makes many simplifying assumptions that affect predictions of sediment deposition, including weir-flow into storage areas and uniform water surface elevation at river cross-sections. The 1D model does not explicitly track flow connectivity in the overbank areas and may show flow in the floodplain at moderate river flows when none is in fact occurring.

Floodplain flow in off-channel storage areas is measured in the model as net flow across what are sometimes quite long weir-like lateral structures (100s of meters). Net flow at a given instant may in fact be a small magnitude difference between large flows entering and leaving the floodplain over the same lateral structure at a given instant.

The reservoir-like behavior of off-channel storage areas may behave more like overbank flow areas during extremely large events (such as the 1996 flood), with higher velocity channel-like flow in concentrated paths. The 1D model is limited to the assumption that off-channel storage areas always behave like reservoirs, albeit reservoirs with numerous inflow and outflow locations, and that deposition occurs evenly across the entire reservoir. The USGS core data clearly shows that there is a reduction in sediment deposition depth with distance from the channel (Exhibit 13b) and that complex hydraulics result in wide spatial variability, even within a single floodplain area (Exhibit 10c).

Some of the limitations of applying the simplified sedimentation analysis to 1D model results will be reduced or eliminated with completion of the 2D sediment transport model. At the time of this writing, the 2D hydraulic model has been calibrated and validated, and the 2D sediment transport model is being constructed. The sedimentation calculations were performed with output from both the 1D and 2D models to help assess the magnitude of uncertainty associated with using 1D model results. However, it should be noted that the 1D sedimentation model remains based on 1D model input; it is not, nor will it be, equivalent to the 2D sediment transport model that is currently under construction. Because 2D model outputs do not provide all parameters required by the sedimentation model calculation in overbank flow areas, overbank flow areas (e.g., 160_R) are excluded from this comparison.

The effect of using 1D,[4] compared with 2D hydraulic model inputs is shown in Exhibit 26. These calculations were limited to the period for which the 2D hydraulic model results were available, consisting of three events in WY 2011. Considering the eight floodplain areas included in this analysis, the sedimentation model using 2D hydraulics results in a 28 percent decrease in overall sedimentation relative to that using 1D hydraulics. Much of this difference is due to lesser volumes calculated to be entering the floodplain in the 2D model than the 1D model. Of these eight areas, Lane Marsh West (1258) is an anomaly, showing a larger amount of sediment delivered and trapped using 2D model inputs compared with 1D model inputs. In the case of average TE, the 1D and 2D models are quite similar, with the 2D hydraulics yielding an average TE 5 percent higher than the 1D TE. While the 1D and 2D

[4] The 1D model described here is that used for the basin-wide sediment deposition analysis, and is not updated to include changes described in Section 4.3.

models are generally in agreement with respect to TE, there is moderate variability, where some sites (such as Blue Lake) show large TE decreases (16 percent decrease) and other sites (such as Lane –West) show large TE increases (9 percent increase) relative to the 1D model. This spatial variability in TE comparison will affect one of the intended uses of this sediment deposition model: understanding relative differences in sedimentation between floodplain units.

4.3 1D Model Parameterization

In addition to the simplifying assumptions inherent in the 1D model and discussed above, there are numerous ways to parameterize the 1D model. Understanding of the Lower Basin system was refined during the development and calibration of the 2D hydraulic model, which led to several small revisions to the 1D model (CH2M HILL, 2013a). This occurred after the 1D model was calibrated, validated, and finalized, and after the sedimentation analysis was performed. Post-calibration revisions to the 1D model are summarized in an addendum to the 1D model development report (CH2M HILL, 2015b). As with other portions of the uncertainty analysis, selected floodplain area sedimentation analyses were updated with revised 1D model results, and compared to the original 1D model results. This comparison is shown in Exhibit 27, and shows a 5-percent overall decrease in sedimentation with the updated 1D model.

4.4 Choice of Representative Flow Paths

The sediment deposition calculations highly depend on the estimation of representative flow paths and distances, which are subjective judgments. Flow paths were chosen based on an overall understanding of system hydraulics and inspection of aerial imagery; however, the actual flow paths are assumed to be quite variable, depending on microtopographic influences, the site-specific hydraulics of floodplain flow, and the downstream lake level. The floodplain sedimentation model assumes a static flow path, when in reality the flow path of most of the floodplain flow is likely to change with downstream lake level and magnitude of floodplain flow.

The length of the representative flow path is important because the modified Churchill equation used to compute TE in the off-channel storage areas results in a non-linear decrease in TE as the flow path (reservoir length) increases. This is because the equation computes TE as a function of reservoir volume, reservoir length, and flow rate. With volume remaining constant (set by the model), increasing the flow path (reservoir length) effectively narrows the width and reduces reservoir cross-sectional area. With flow rate remaining constant, a reduction in reservoir cross-sectional area produces increased velocity through a given cross-section and, thus, a decrease in calculated TE. It should be noted, however, that the equation used for overbank flow areas results in a linear increase in TE as the flow path is increased.

Results of varying representative flow path lengths for nine selected floodplain areas (both off-channel storage areas and an overbank flow area) are shown in Exhibit 28. Because the representative flow path length directly affects TE (and not the amount of flow or sediment entering an area), Exhibit 28 shows only the variation in sediment trapped and average TE. Adjusting the representative flow path length indirectly affects sediment entering some areas because this volume is based on the sediment mass leaving an adjacent area (for instance, TE in Strobl Marsh [1257] affects sediment entering Killarney Lake [1261 & 1260];

however, the focus of Exhibit 28 remains average TE and sediment deposited as the primary effect. As described above, due to the difference in calculation methods, a shorter representative path increases TE for off-channel storage areas and decreases TE for overbank flow areas (e.g., 160_R). However, for both off-channel storage areas and overbank flow areas, the reasonable range of representative flow paths has a small effect on overall sedimentation (-4 to +5 percent relative to the most likely path) and average system TE (-3 to +2 percent relative to most likely path).

4.5 Model River Flows Biased Low

To expand the analysis time period to 25 years, results from the 1D model before 2004 were required. Model runs before 2004 only use inflows directly from the South Fork and North Fork and do not use tributary inflow elsewhere in the model. In order to be consistent across all 25 years, tributary inflows were excluded from all results (WY 1988 to 2012). This has the effect of lowering the overall river flow (by approximately 10 percent at Harrison), which in turn has the effect of reducing the SSC and total sediment flux into the floodplain. Conversely, neglecting tributary flows underestimates the water level in floodplain storage areas and the resulting hindrance to flows entering from the river, thereby overestimating flows from the river to the floodplain.

The net effect on sedimentation of excluding tributary flows from the 1D model is shown in Exhibit 29 for 9 selected floodplain areas (both off-channel storage areas and an overbank flow area) and tends to decrease total sediment load delivered to the floodplain by approximately 6 percent. There is negligible effect on average TE; thus, the total sedimentation is also decreased by approximately 6 percent. While the magnitude of the decreased floodplain sediment delivery varies by floodplain area, most floodplain areas are affected in the same direction with a decrease in sediment delivery due to the exclusion of tributary inflows in the 1D model.

4.6 Choice of Representative Cross-Sections

The sediment deposition calculations for each overbank flow area highly depend on the selection of the representative cross-section chosen for that location. Among the dozens of cross-sections in a given overbank flow area, total overbank flow rate might vary by up to one and sometimes two orders of magnitude. Sediment concentrations and total flux delivered to an overbank flow area are computed from the overbank flow in the selected cross-section. Additionally, the computed TE for each overbank flow area also depends on multiple variables extracted from each cross-section, such as flow area, top width of the flow, velocity, and flow rate. In addition, TE in the overbank flow areas was corrected for turbulent flow using shear velocity values computed at the representative cross-section. Efforts were made to select the cross-section with a representative flow rate and hydraulics; however, the choice of representative cross-section was based on an overall subjective judgment of which cross-section is most representative at a "typical" overbank flow, and may not represent all flow conditions with equal accuracy.

Results of varying representative cross-sections for a selected overbank flow area (160_R) are shown in Exhibit 30. A moderate effect on sediment delivered, and a small effect (± 1 percent) on average TE, is indicated, with a moderate effect of -26 to +11 percent on total sediment trapped. Given the unique nature of the cross-section geometry in each overbank storage area, the effect of cross-section selection will vary but is expected to be within the approximate range demonstrated by 160_R. This uncertainty only affects overbank flow areas, which represent only 30 percent of the total system floodplain sedimentation (Exhibit 11).

4.7 Representative Sediment Sizes

The grain size distribution of the suspended sediment is also a source of uncertainty. For the overbank flow area calculations, SSC is divided into three grain size classes (clay, silt, and sand); however, the primary data available on grain size for the suspended load are the sand/silt fraction. TE in the overbank flow areas depends on the selection of three representative sediment sizes, and for the sedimentation model, this was guided by LISST data from a single flow event in 2012. These sizes determine the settling velocity and, thus, the TE for each of three sediment size classes. The average median size (d50) for each of the three size classes from eight LISST samples taken at various locations on the river during an April 2012 flood event was used as the representative sediment size. Actual representative sizes may vary depending on event dynamics and river flow rates and may be different than those reflected by the April 2012 data.

Uncertainty analysis related to the impact of the representative sediment size on sedimentation results is presented in Exhibit 31. As with other uncertainty analyses that affect only overbank floodplain areas, this was conducted for a single area: 160_R. LISST or other similar suspended sediment gradation data across a large geographic area are not yet available for events other than the April 2012 event. Thus, the analysis here is limited to examining only the impact of spatial variation in sediment gradation. The best estimate analysis described in Section 2.3.4 uses the average d50 of eight LISST samples; the uncertainty analysis in Exhibit 31 uses the minimum and maximum d50 from these eight LISST samples (see Exhibit 5 for LISST particle size distributions and statistics). Within the single floodplain area, using the minimum d50 reduces average TE from 38 to 36 percent, reducing sedimentation by 5 percent; using the maximum d50 increases average TE from 38 to 41 percent, increasing sedimentation by 6 percent.

4.8 Effect of Turbulence on Settling in Overbank Flow Areas

The overbank flow area TE calculation described in Section 2.3.2 is based on a simple theoretical argument to account for settling velocity, water velocity, overbank path length, and water depth. This simple argument does not consider the effect of turbulent flow reducing TE relative to simple settling during laminar flow. Upward mixing from turbulent flow is not possible to simulate in a 1D (or 2D) hydraulic model and, thus, was ignored, biasing the TE in overbank flow areas high. As an estimate of uncertainty, a TE correction was made using a scaling factor, which adjusted the TE by a factor less than 1 to account for upward mixing due to turbulence.

The magnitude of the scaling factor was set to be a function of the Rouse number, a non-dimensional ratio of settling velocity and shear velocity; this ratio is a measure of the intensity of turbulent mixing of particles in flowing water. The scaling factor ranged from 0.5 for low Rouse numbers (high turbulence relative to settling velocity) to 1.0 for high Rouse numbers (e.g., settling in still water). As a general rule, for a given particle size (and thus settling velocity), a Rouse number above 2.5 suggests that sediment travels as bed load, between 1.2 and 2.5, as a combination of bedload and suspended load, between 0.8 and 1.2, as suspended load, and where the Rouse number is less than 0.8, sediment travels as well mixed wash load (Julien, 1998). Exhibit 32 shows the turbulent flow correction factors used in this uncertainty analysis, as well as the resulting impacts on TE and sedimentation. Although the correction factor is based on a physical argument, the scaling factors shown in Exhibit 32 were determined using professional judgement and are subjective. Using this correction for the example overbank flow area (160_R) reduces average TE from 38 to 19 percent, and thus total sedimentation by 49 percent. This uncertainty only affects overbank flow areas, which represent only 30 percent of the total system floodplain sedimentation (Exhibit 11).

4.9 Results Averaged Spatially Across Model Floodplain Elements

Sedimentation rates developed and shown here are averaged across entire model floodplain elements, and do not account for spatial heterogeneity caused by local hydraulic and terrain effects. Exhibit 10c shows the spatial heterogeneity in core deposition depths; Exhibit 13b shows a clear pattern of decreasing deposition rates with distance from the channel. Care should be taken when comparing these values to discrete or local site samples such as sediment cores and depositional tiles.

5.0 Summary and Conclusions

Floodplain sediment deposition in the Lower Basin was estimated using results from a calibrated 1D hydraulic model (CH2M HILL, 2013a), combined with suspended sediment data from Lower Basin sampling stations. This analysis provides a best estimate approximation of both spatial and temporal relative distribution of sedimentation across floodplain units, or elements, for a duration of 25-years (WYs 1988 to 2012). In general, sedimentation rates were calculated as a sediment flux into the floodplain multiplied by TE, providing the proportion of the sediment flux that settled and remained in the floodplain. Both the sediment influx and the TE vary spatially (among floodplain units, due to their geometry and hydraulic characteristics) and temporally (due to the time series of overbank flow during the 25-year period that was modeled). As described in Section 4, these values represent the current best estimate approximation of sedimentation based on numerous assumptions, approximations, and model results—each with associated uncertainty and limitations. The estimated sedimentation results are most appropriate when applied to comparing relative sedimentation values and depths across the Lower Basin and when considering long-term averages such as the average sedimentation rate over the 25 year period of record. These estimates will be updated as better information is obtained, such as that from 2D sediment transport modeling. Sediment influx and deposition during this 25-year time period was significantly lower than during the decades of mining activity prior to 1968 (Bookstrom et al., 2004).

The model predicts that, on average (over the period of record), about 24,000 metric tons per year of sediment and 68 metric tons per year of lead are deposited in the floodplain. Given the various types of uncertainty summarized in Section 4 and Exhibit 22, it is reasonable that these model estimates could be 50 percent higher or lower (12,000 metric tons per year to 36,000 metric tons per year).

Floodplain sedimentation rates are considerably higher in years with significant overbank flooding than during an average year. Combined, the two highest flow years, 1996 and 2008, account for nearly 40 percent of the total sediment deposited during the 25-year modeled period (WYs 1988 to 2012) over the entire Lower Basin floodplain (an observation that for at least 1996 is corroborated by evidence from USGS cores). The largest mass of sediment is deposited in the reach between Killarney Lake and Swan Lake (Strobl Marsh [1257], Killarney Lake [1261 & 1260, Moffitt Slough [1259]), and Swan Lake [1265)]. During high-flow events, a large mass of sediment is also deposited in overbank flow area 160_R. These areas with high rates of sedimentation tend to have the lower TE values; the high sedimentation is caused by high flows and thus high sediment fluxes into these parts of the floodplain. In contrast, some off-channel areas have little to no flow or sediment influx and thus little to no sediment deposition, including: Lamb Peak 2 [1268], Lamb Peak 1 [1267], Black Lake 1 [1266], Schlepp Field [1243 and 1263] and Rose Lake [9651)].

Overall average sedimentation rates predicted by the model are highest in Blue Marsh [1239] and in the left overbank area located at river mile 163 [163_L], with average modeled rates above 10 mm/year (Exhibit 10; neither of these areas have sufficient core data for comparison or corroboration). These areas have high flow, high amounts of sediment influx, and high sedimentation mass relative to their small depositional areas. Of the larger areas, Swan Lake [1265] has the highest predicted deposition rate of 2.2 mm/year (a rate that closely agrees with core data, and considering the uncertainty associated with SSC rating curve power law exponent [Section 4.1, Exhibit 23] could reasonably be as high as 5.7 mm/year and as low as 1.0 mm/year, which is close to the overall range of median baseline deposition rates presented by Bookstrom et al. [2004] as a function of depositional setting (2.2 mm/year to 6.4 mm/year).

The best estimate modeled sediment and lead deposition rates are a factor of 4 lower than those estimated based on a modified[5] analysis of cores compiled by the USGS (Bookstrom et al., 2004) using median core deposition rates. Possibly explanations for the difference between the two methods are described in Sections 3.1, 3.2, and 4. If both the uncertainty associated with the modeled sediment deposition rates (Section 4 and summarized in Exhibit 22) and the variability of the core deposition rates are considered, estimates of basinwide annual average sediment deposition the two different methods overlap. Using the mean core deposition rate plus or minus one standard deviation in the modified Bookstrom analysis results in a range from 25,000 to 207,000 metric tons per year, overlapping the sediment model analysis reasonable range presented above (12,000 to 36,000 metric tons per year). It should be noted that evaluating all sediment deposition model uncertainty factors combined, there is a higher chance that the basinwide average sedimentation best estimate is an overestimate than an underestimate of actual sedimentation.

While the total annual average basinwide sediment and lead deposition rates produced by the sedimentation model are helpful for understanding the overall magnitude predicted by

5 Floodplain deposition values were modified from Bookstrom et al. (2004) as described in Section 6.1 and Exhibit 44 of CH2M HILL (2015a). They were further modified to be most directly comparable to estimates provided in this report, accounting for the following: a) inclusion of an additional 1.5 km^2 of Anderson Lake and 2.2 km^2 of Thompson Lake; b) overlap of only 0.55 km^2 of riverbank area (instead of 2.2km^2 included in CH2M HILL (2015a); c) removed 17.4 km^2 of Palustrine, Lacustrine Littoral, and Lacustrine Limnetic area so that total depositional area equals 29.8 km^2, matching the area evaluated in this report. The resulting modified Bookstrom et al. (2004) estimate for an area similar to that used here is 101,000 metric tons/year of sediment deposition, equivalent to 2.9 mm/year over the entire analyzed area. If, for each of the depositional setting used in the Bookstrom et al. (2004) analysis, the depositional rate derived from core data is mean+/- 1 standard deviation (instead of the median value used to develop the estimate of 101,000 metric tons/year), the estimate of sediment deposition for the same area used in the sediment deposition model is 25,000 and 207,000 metric tons/year respectively.

the model, the focus of understanding and interpretation of model results should be on the estimate of relative spatial and temporal patterns of deposition—that is, understanding areas and event types that are most (and least) likely to experience sediment and lead deposition.

6.0 References

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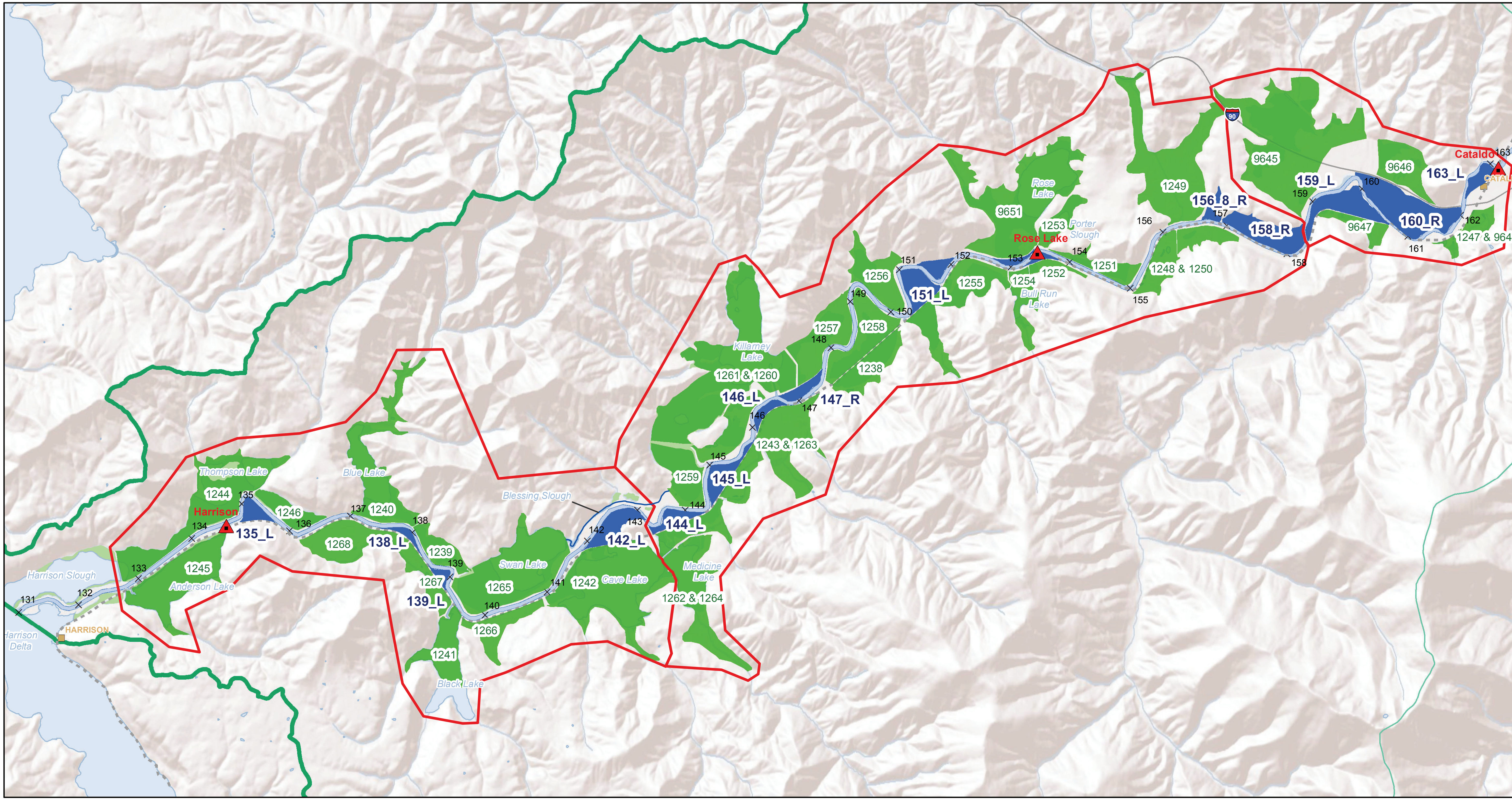
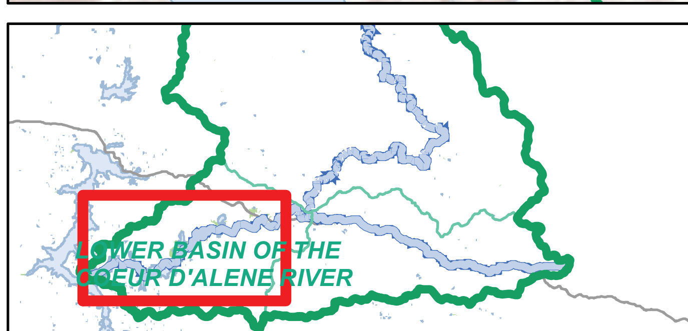
Exhibits

Attachments





LEGEND

- Trail of the Coeur d'Alenes
- River Mile Marker
- City
- Coeur d'Alene Watershed
- Interstate Highway
- Waterbody
- Marsh or Slough
- Overbank Flow Areas (River Mile and Location - Channel Left [L] or Right [R])
- Off-Channel Storage Areas (Storage Area Identification Number)
- SSC Sample Locations
- SSC Rating Curve Area of Influence

N

0 1 2 4 Kilometers

Source: Shaded Relief (ESRI Online Catalog); Coeur d'Alene River Miles (USEPA); NHD (USGS).

Exhibit 1. **1D Model Areas Used for Sedimentation Analysis**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

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Exhibit 2a. **Suspended Sediment Concentration Rating Curve - Regression Parameters**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

	Total Suspended Sediment Concentration			
Station	**a**	**b**	**n**	**r^2**
Cataldo	3.58.E-05	1.44	50	0.78
Rose Lake	6.17.E-06	1.65	10	0.75
Harrison	2.00.E-09	2.58	35	0.78

$SSC_i = a*Q^b$

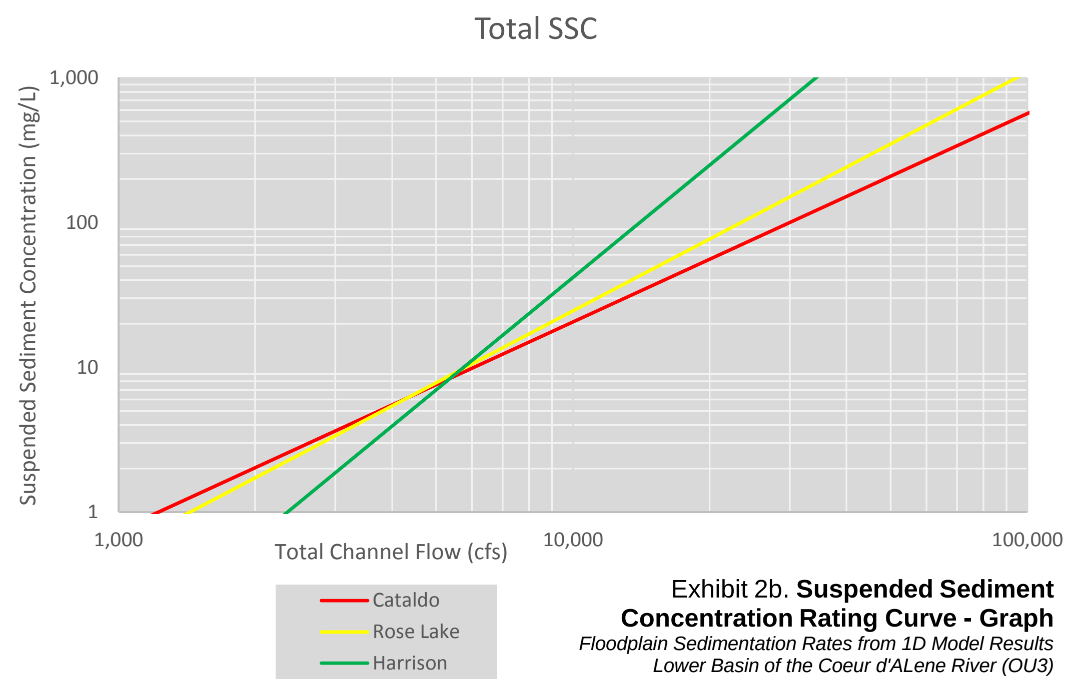


Exhibit 2b. **Suspended Sediment Concentration Rating Curve - Graph**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'ALene River (OU3)

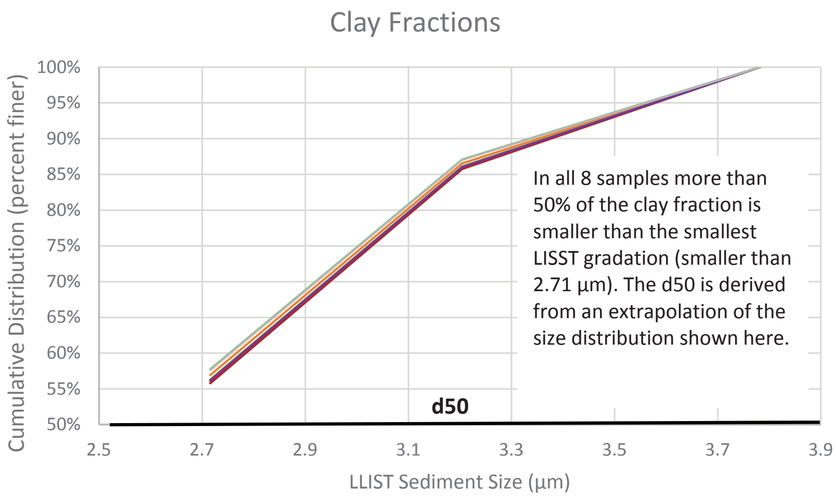
Exhibit 3. **Model Parameters Used in Off-channel Storage Area Sedimentation Calculations**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

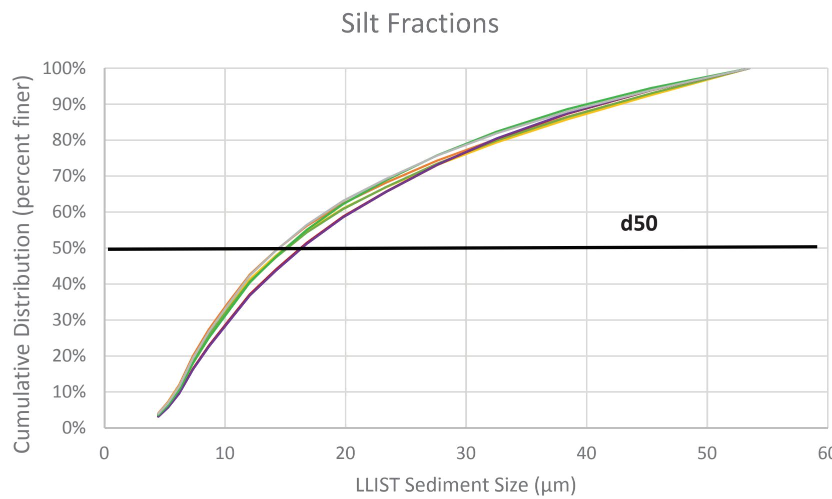
Description	Name	Units	Notes
Flow Entering Storage Area	FLOW-TOTAL	m^3/s	Flow over lateral structure separating storage area from river
Total River Flow	FLOW-HW-US	m^3/s	Flow at cross-section immediately upstream of the lateral structure
Storage Area Water Surface Elevation	STAGE-TW	m, NAVD 88	

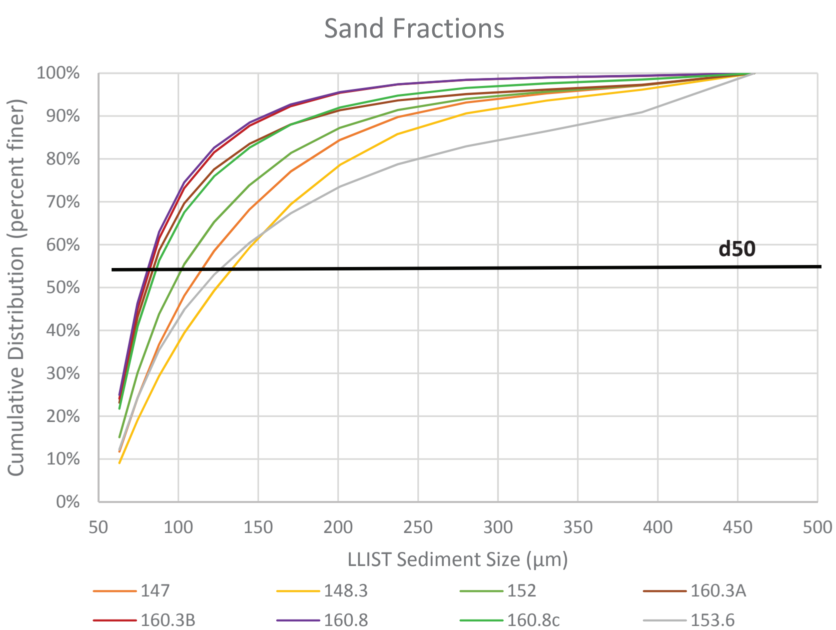
Exhibit 4. **Model Parameters from the Representative Cross-Section Used in Overbank Flow Area Sedimentation Calculations**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

Description	Name	Units	Notes
Total river flow	Q Total	m^3/s	
Flow in the overbank , considered as flow entering the overbank	Q Overbank*	m^3/s	
Average velocity in the overbank	Vel Overbank*	m/s	
Top width of flow in the overbank	Top W Act Overbank*	m	Used with Flow Area to determine average overbank flow depth
Flow area in the overbank	Flow Area Overbank*	m^2	Used with Top Width to determine average overbank flow depth
Water surface elevation over the entire cross-section (channel and overbank)	W.S. Elev	m, NAVD 88	
Average shear stress in the overbank	Shear Overbank*	N/m^2	

* *Overbank* refers to left or right, depending on the location of the overbank flow area.







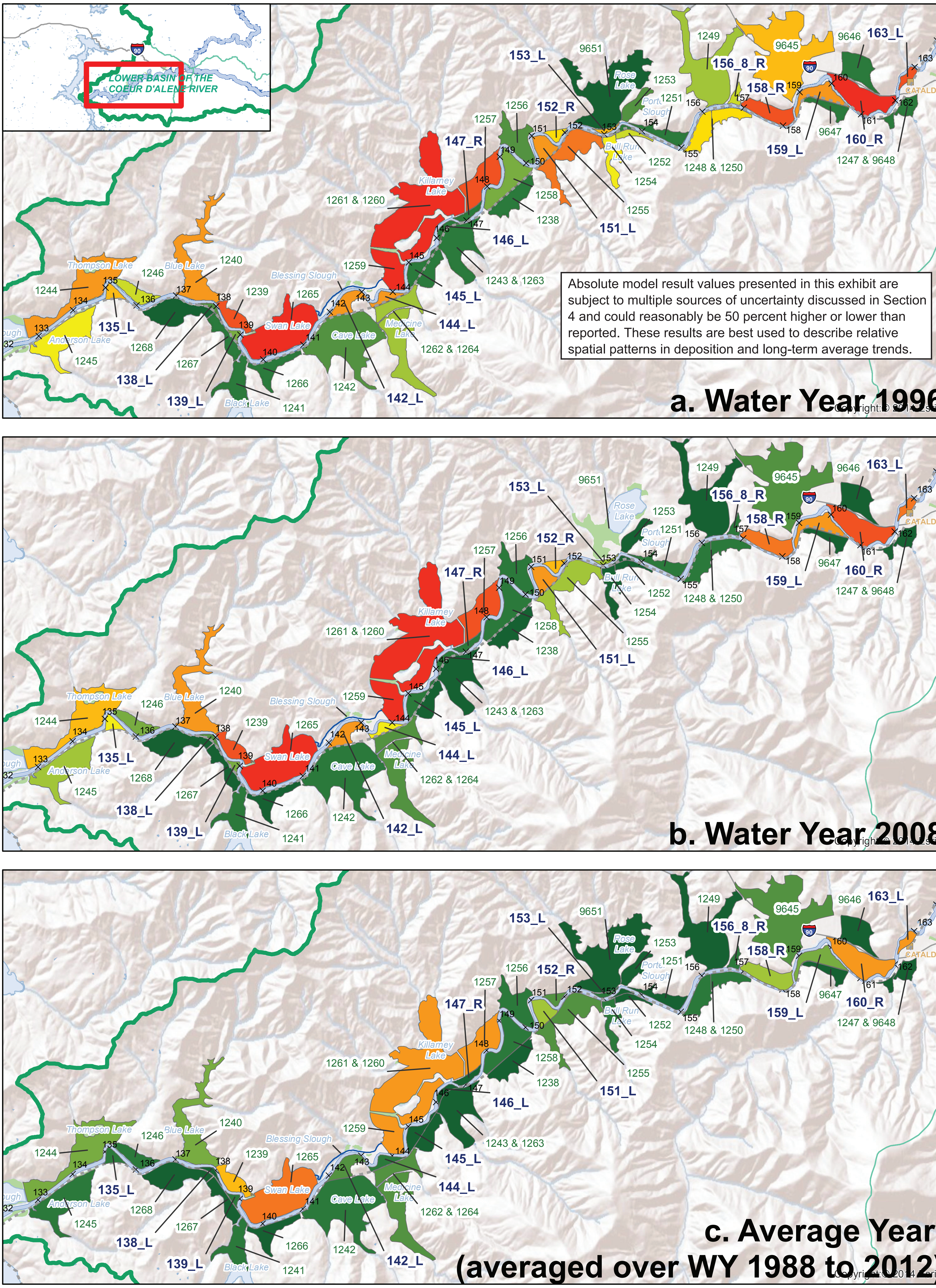
LISST Sample ID	d50 (µm)			Percent of Bulk Suspended Sediment		
	Clay	Silt	Sand	Clay	Silt	Sand
153.6	2.59	14.5	115.5	23%	35%	42%
147	2.60	14.5	107.1	27%	44%	29%
148.3	2.62	15.0	124.0	22%	40%	37%
152	2.61	15.2	96.3	27%	49%	24%
160.3A	2.61	16.4	80.5	27%	59%	14%
160.3B	2.62	16.3	78.6	26%	60%	14%
160.8	2.62	16.4	77.4	27%	60%	13%
160.8C	2.59	15.0	82.4	32%	55%	13%
Mean	2.61	15.4	95.2	26%	50%	23%
Min	2.59	14.5	77.4	22%	35%	13%
Max	2.62	16.4	124.0	32%	60%	42%

	Settling Velocity (mm/s)		
	Clay	Silt	Sand
Mean	0.0017	0.059	2.1
Min	0.0017	0.052	1.4
Max	0.0017	0.067	3.4

Exhibit 5. **Particle Size Distributions from Eight Laser In Situ Scattering and Transmissometry (LISST) Measurements Used to Develop Representative Settling Velocities**

Exhibit 6. **Proportion of Bulk Suspended Sediment by Sediment Gradation Class**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

USGS Gage and Bulk Suspended Sediment Concentration Regression Location	% Sand	% Silt	% Clay
Harrison	49%	32%	19%
Rose Lake	34%	41%	24%
Cataldo	20%	50%	30%



Source: Shaded Relief (ESRI Online Catalog); Coeur d'Alene River Miles (USEPA); NHD (USGS).

LEGEND

- Trail of the Coeur d'Alenes
- River Mile Marker
- City
- Coeur d'Alene Watershed
- Interstate Highway
- Waterbody
- Marsh or Slough

Sediment Flux (metric tons per year)

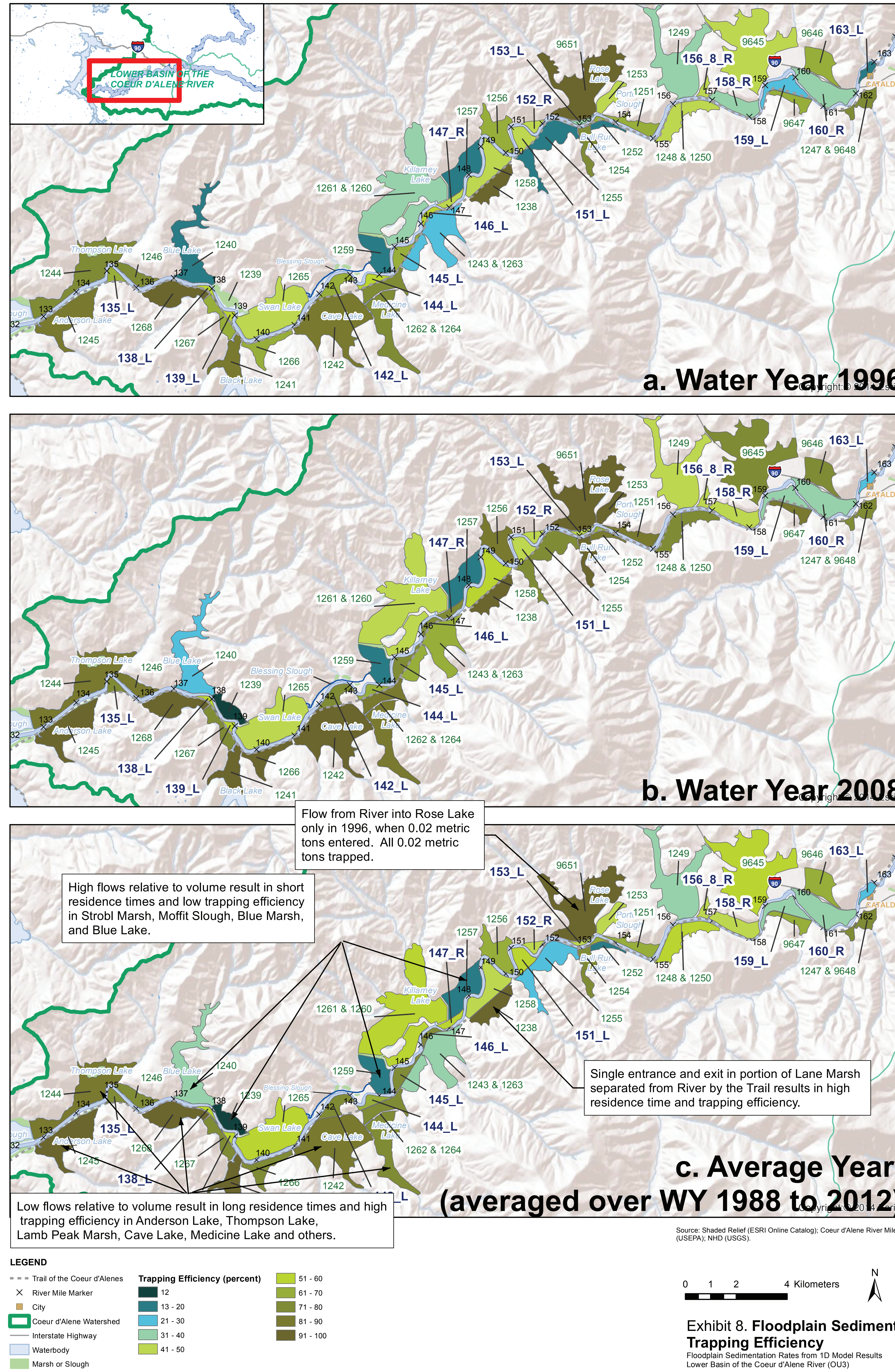
- 0 - 100
- 101 - 500
- 501 - 1000
- 1001 - 1500
- 1501 - 2000
- 2001 - 2500
- 2501 - 3000
- 3001 - 3500
- 3501 - 4000
- 4001 - 10000
- 10001 - 20000
- 20001 - 30000
- 30001+

0 1 2 4 Kilometers

N

Exhibit 7. **Sediment Flux in to the Floodplain**

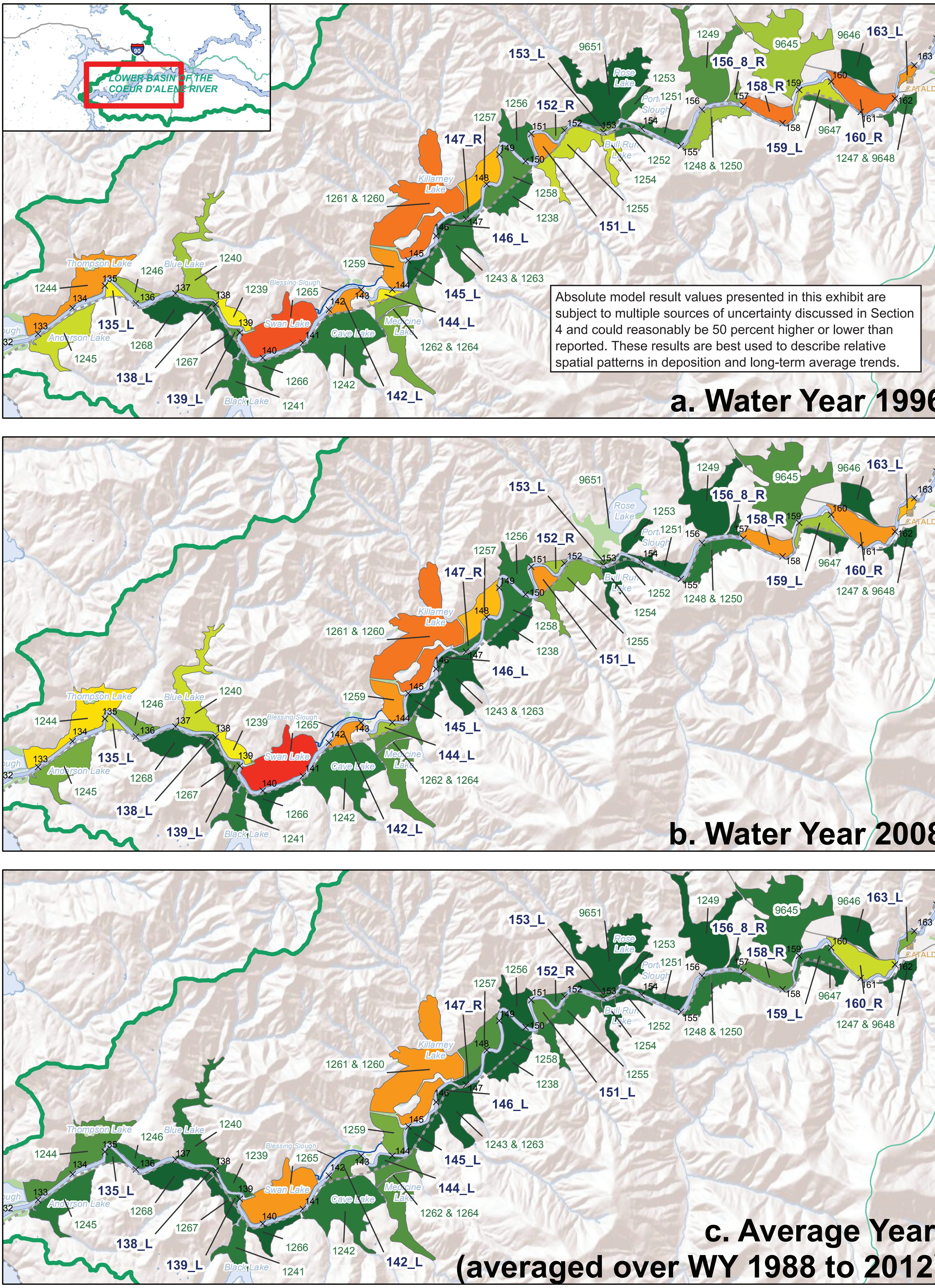
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)



Source: Shaded Relief (ESRI Online Catalog); Coeur d'Alene River Miles (USEPA); NHD (USGS).

Exhibit 8. **Floodplain Sediment Trapping Efficiency**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)



Source: Shaded Relief (ESRI Online Catalog); Coeur d'Alene River Miles (USEPA); NHD (USGS).

LEGEND

- Trail of the Coeur d'Alenes
- River Mile Marker
- City
- Coeur d'Alene Watershed
- Interstate Highway
- Waterbody
- Marsh or Slough

Sediment Trapped (metric tons per year)

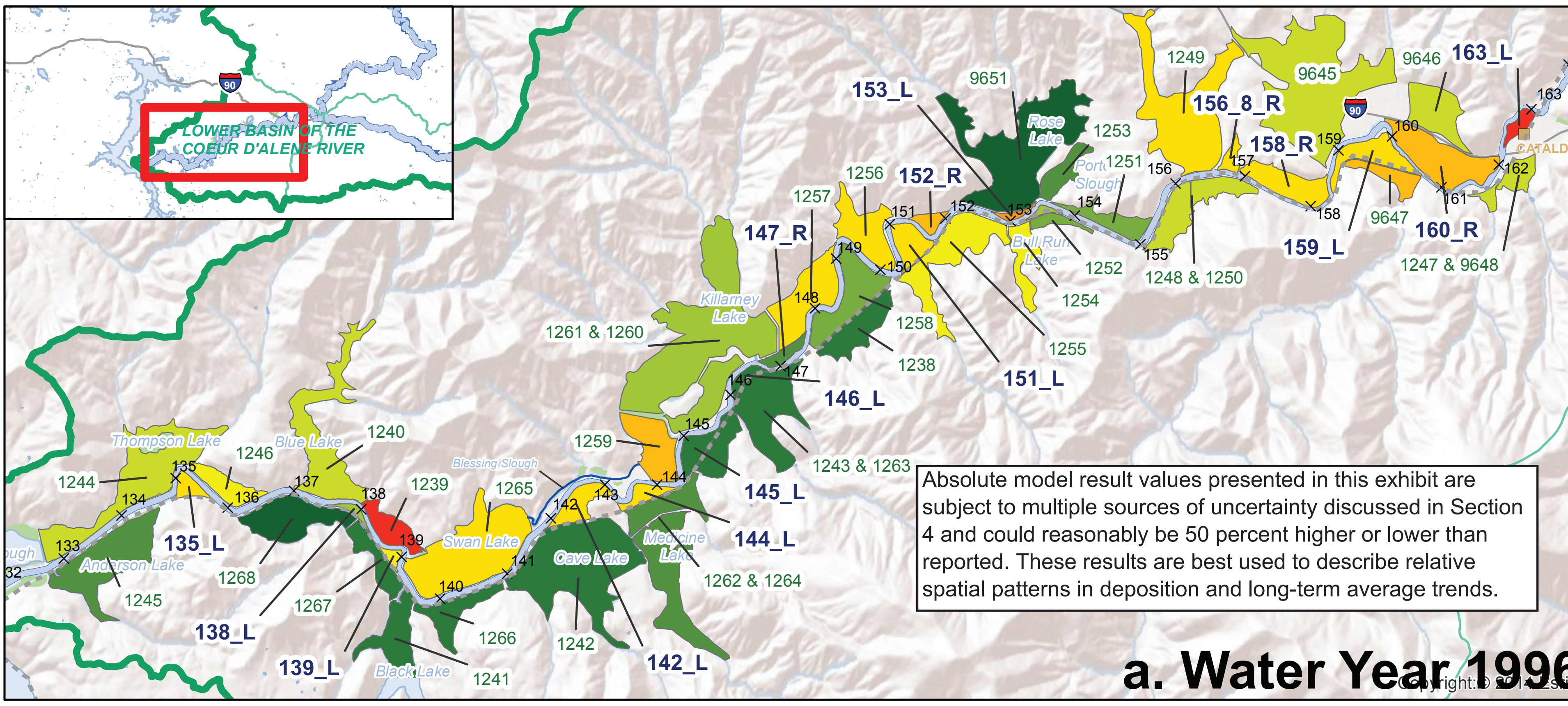
- 0 - 100
- 101 - 500
- 501 - 1000
- 1001 - 1500
- 1501 - 2000
- 2001 - 2500
- 2501 - 3000
- 3001 - 3500
- 3501 - 4000
- 4001 - 10000
- 10001 - 20000
- 20001 - 30000
- 30001 - 70000

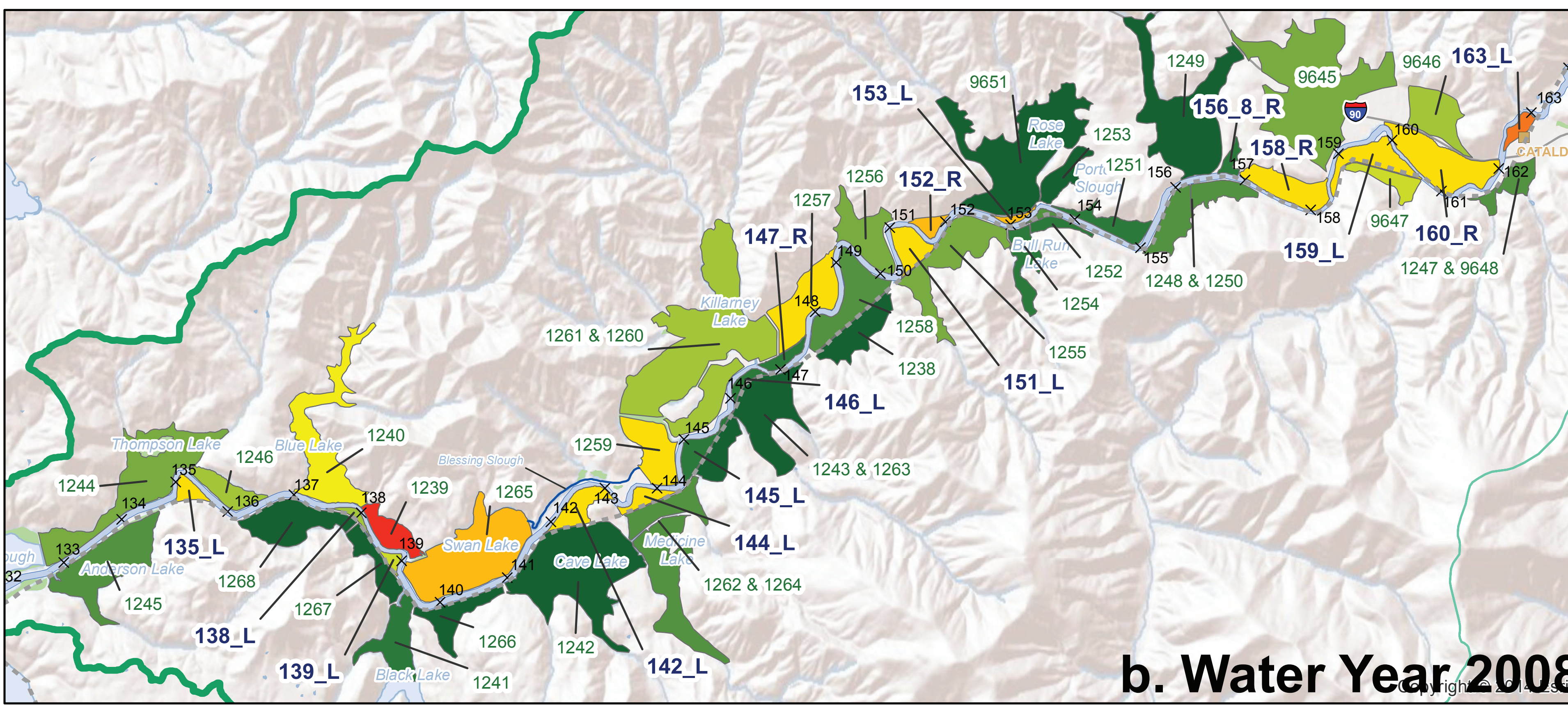
0 1 2 4 Kilometers

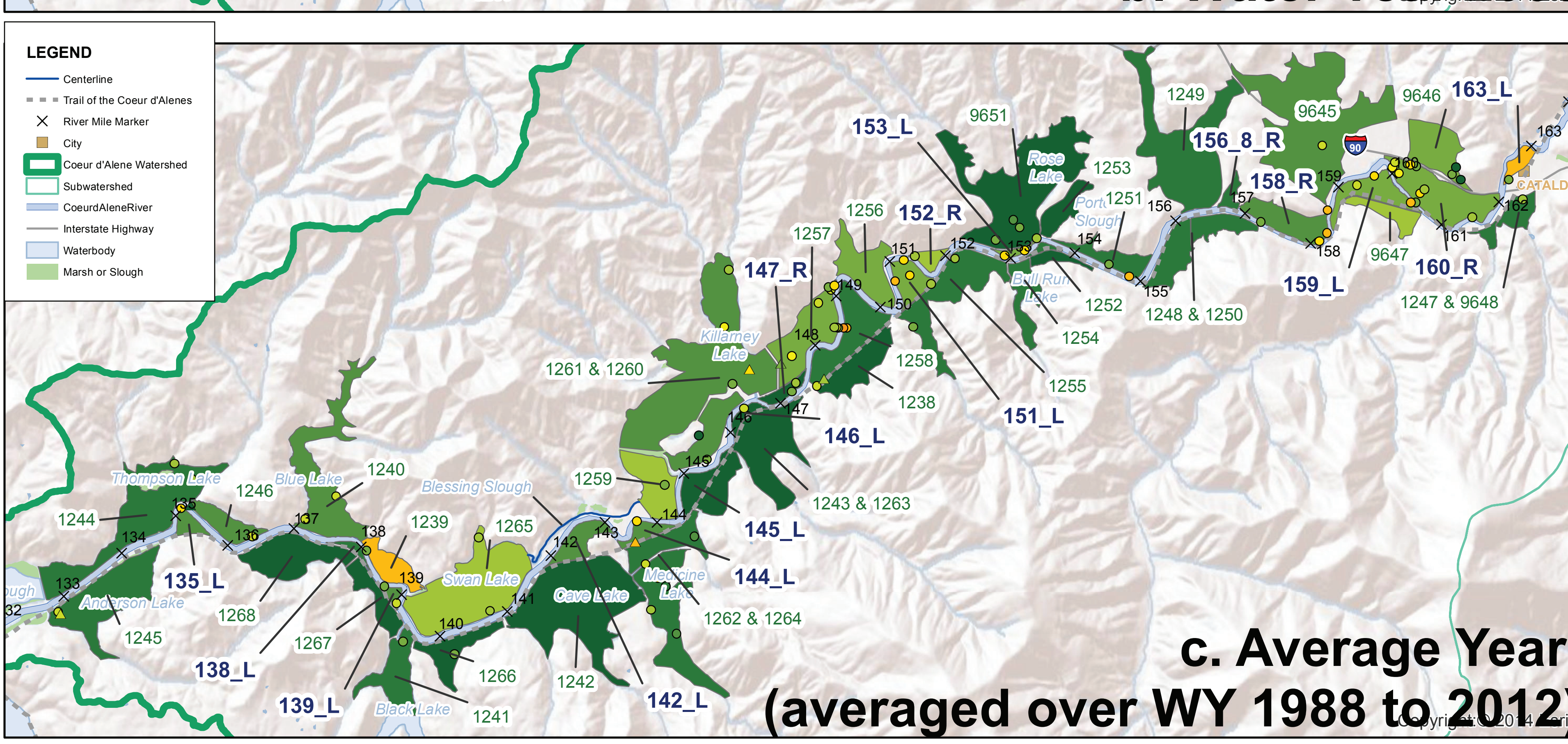
N

Exhibit 9. **Floodplain Sedimentation Mass**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)







Source: Shaded Relief (ESRI Online Catalog); Coeur d'Alene River Miles (USEPA); NHD (USGS).

LEGEND - CONTINUED

Sediment Tiles (mm/year)		USGS Cores (mm/year)		Sedimentation Depth (mm/year)	
0.3	4.1 - 5.0	0.0 - 0.1	4.1 - 5.0	0.0 - 0.1	4.1 - 5.0
0.4 - 0.5	5.1 - 10.0	0.2 - 0.5	5.1 - 10.0	0.2 - 0.5	5.1 - 10.0
0.6 - 1.0	10.1 - 20.0	0.6 - 1.0	10.1 - 20.0	0.6 - 1.0	10.1 - 20.0
1.1 - 2.0	20.1 - 30.0	1.1 - 2.0	20.1 - 30.0	1.1 - 2.0	20.1 - 30.0
2.1 - 3.0	30.1 - 40.0	2.1 - 3.0	30.1 - 40.0	2.1 - 3.0	30.1 - 40.0
3.1 - 4.0	40.1 - 50.0	3.1 - 4.0	40.1 - 50.0	3.1 - 4.0	40.1 - 50.0
	50.1 - 70.0		50.1 - 70.0		50.1 - 70.0

0 1 2 4 Kilometers

N

Exhibit 10. **Floodplain Sedimentation Rate**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d'Alene River (OU3)

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Exhibit 11. **Average Annual Sedimentation**

Off-Channel Storage Area Name	Area ID	River Mile	Average Inundated Area (hectares)	Cumulative Sediment Flux into the Floodplain 1988-2012 (metric tons)	Average Trapping Efficiency (%)	Cumulative Mass Deposited 1988-2012 (metric tons)	Average Annual Deposition Mass (metric tons/year)	Average Annual Lead Deposition Mass (metric tons/year)	Average Annual Deposition Rate (mm/year)	Sediment Mass Percent of Basin Total (%)	Lead Mass Percent of Basin Total (%)
Anderson Lake	1245	132.9	186	12,000	90%	10,000	420	1.6	0.2	1.7%	2.3%
Thompson Lake	1244	135.2	190	31,000	81%	25,000	990	3.7	0.5	4.1%	5.4%
Bare Marsh	1246	135.3	31	6,600	79%	5,200	210	0.8	0.6	0.9%	1.1%
Lamb Peak 2	1268	137	148	140	99%	140	5	0.0	0.0	0.0%	0.0%
Blue	1240	137.1	43	32,000	30%	10,000	390	1.5	0.8	1.6%	2.1%
Blue Marsh	1239	138.1	3	88,000	12%	11,000	420	1.6	11.0	1.7%	2.3%
Lamb Peak 1	1267	138.5	64	220	70%	160	6	0.0	0.0	0.0%	0.0%
Swan	1265	139	237	270,000	56%	150,000	6000	22.2	2.2	24.5%	32.7%
Black Lake 2	1241	139.6	104	4,300	93%	4,000	160	0.6	0.1	0.7%	0.9%
Black Lake 1	1266	140.9	56	250	73%	180	7	0.0	0.0	0.0%	0.0%
Cave	1242	141.1	290	4,400	86%	3,800	150	0.6	0.0	0.6%	0.8%
Medicine	1262 & 1264	143.4	124	22,000	80%	17,000	700	1.8	0.5	2.9%	2.7%
Moffit	1259	145.1	47	210,000	16%	30,000	1400	3.6	2.5	5.6%	5.3%
Schlepp	1243 & 1263	145.8	21	540	32%	170	7	0.0	0.0	0.0%	0.0%
Killarney	1261 & 1260	146.6	416	210,000	53%	110,000	4400	11.5	0.9	17.9%	16.9%
Strobl	1257	147.9	41	110,000	17%	20,000	750	2.0	1.6	3.1%	2.9%
Lane 1	1258	148.7	38	5,200	42%	2,200	87	0.2	0.2	0.4%	0.3%
Lane 2	1238	148.7	72	1,200	100%	1,200	49	0.1	0.1	0.2%	0.2%
Strobl Field	1256	149.4	7	3,000	67%	2,000	80	0.2	1.1	0.3%	0.3%
Black Rock Slough	1255	151.6	50	17,000	46%	4,700	190	0.5	0.3	0.8%	0.7%
Rose Lake	9651	152.8	53	0	67%	0	0	0.0	0.0	0.0%	0.0%
Bull Run 2	1254	153.1	45	2,900	27%	2,300	91	0.2	0.2	0.4%	0.4%
Potter Slough	1253	153.6	41	660	100%	290	12	0.0	0.0	0.0%	0.0%
Bull Run 1	1252	154	22	2,400	43%	340	14	0.0	0.1	0.1%	0.1%
Orling Slough	1251	154.2	16	1,500	44%	1,100	42	0.1	0.2	0.2%	0.2%
Upper Marsh 1 & 2	1248 & 1250	156.2	33	6,300	69%	3,300	130	0.3	0.3	0.5%	0.5%
Canyon Marsh	1249	156.3	10	1,900	40%	710	28	0.1	0.2	0.1%	0.1%
Mission Slough	9645	158.8	42	20,000	37%	10,000	390	0.4	0.8	1.6%	0.6%
Dudley Marsh	9647	159.1	1	1,000	38%	700	28	0.0	2.1	0.1%	0.0%
Whiteman's Slough	9646	160.5	2	970	67%	650	26	0.0	1.1	0.1%	0.0%
Skeel Gulch and South Cataldo	1247 & 9648	161.5	5	990	38%	700	28	0.0	0.5	0.1%	0.0%
Off-Channel Storage Areas Subtotal			**2,438**	**1,100,000**	**41%**	**430,000**	**17,000**	**54**	**0.6**	**70.3%**	**79.3%**
Overbank Flow Area ID											
135-L		135.2	27	10,000	74%	7,400	300	1.1	1.0	1.2%	1.6%
138-L		138	12	2,000	59%	1,200	47	0.2	0.3	0.2%	0.3%
139-L		138.9	13	4,300	58%	2,500	100	0.4	0.7	0.4%	0.6%
142-L		142.6	57	20,000	73%	14,000	570	2.1	0.9	2.4%	3.2%
144-L		143.7	25	11,000	64%	7,000	280	0.7	1.0	1.2%	1.1%
145-L		145	49	450	75%	330	13	0.0	0.0	0.1%	0.1%
146-L		146.4	18	390	71%	280	11	0.0	0.1	0.0%	0.0%
147-R		147.2	26	610	57%	350	14	0.0	0.0	0.1%	0.1%
151-L		151	41	41,000	42%	21,000	830	2.2	1.8	3.4%	3.2%
152-R		151.7	9	16,000	51%	7,500	300	0.8	2.9	1.2%	1.2%
153-R		153.1	6	7,600	78%	3,300	130	0.3	1.9	0.5%	0.5%
153.5-L		153.5	4	260	14%	170	7	0.0	0.2	0.0%	0.0%
156.8-R		156.8	13	2,700	51%	1,200	49	0.1	0.3	0.2%	0.2%
158-R		157.8	96	45,000	45%	18,000	730	1.9	0.7	3.0%	2.8%
159-L		159.1	26	33,000	55%	12,000	500	0.5	1.7	2.1%	0.8%
160-R		160	115	150,000	67%	58,000	2300	2.4	1.8	9.5%	3.6%
163-L		162.7	9	100,000	70%	26,000	1000	1.1	10.3	4.3%	1.6%
Overbank Flow Area Subtotal			**545**	**450,000**	**40%**	**180,000**	**7,200**	**14**	**1.2**	**29.7%**	**20.7%**
System Floodplain Total			**2,983**	**1,600,000**	**40%**	**610,000**	**24,000**	**68**	**0.7**	**100.0%**	**100.0%**

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 12a.**Water Year 1996 Sedimentation**

Off-Channel Storage Area Name	Area ID	WY 1996 Sediment Flux into the Floodplain (metric tons)	WY 1996 Average Trapping Efficiency (%)	WY 1996 Sediment Deposition Mass (metric tons/year)	WY 1996 Deposition Rate (mm/yr)	Proportion of Total (1988-2012) Mass Deposited in WY 1996 (%)
Anderson Lake	1245	2,500	86%	2,200	1.0	21%
Thompson Lake	1244	9,500	74%	7,000	3.3	28%
Bare Marsh	1246	2,400	73%	1,700	4.9	33%
Lamb Peak 2	1268	34	98%	33	0.0	24%
Blue	1240	9,100	19%	1,700	3.5	17%
Blue Marsh	1239	22,000	12%	2,600	68.1	25%
Lamb Peak 1	1267	130	66%	84	0.1	54%
Swan	1265	56,000	48%	27,000	10.2	18%
Black Lake 2	1241	500	90%	440	0.4	11%
Black Lake 1	1266	180	67%	123	0.2	67%
Cave	1242	530	82%	430	0.1	11%
Medicine	1262 & 1264	2,000	73%	1,500	1.0	8%
Moffit	1259	52,000	13%	6,800	12.8	20%
Schlepp	1243 & 1263	460	26%	120	0.5	69%
Killarney	1261 & 1260	37,000	37%	14,000	2.9	13%
Strobl	1257	28,000	14%	4,000	8.6	21%
Lane 1	1258	1,300	43%	530	1.2	24%
Lane 2	1238	300	100%	300	0.4	24%
Strobl Field	1256	720	65%	470	6.3	23%
Black Rock Slough	1255	14,000	17%	2,500	4.4	53%
Rose Lake	9651	0	100%	0	0.0	100%
Bull Run 2	1254	2,800	78%	2,100	4.3	94%
Potter Slough	1253	660	44%	290	0.6	100%
Bull Run 1	1252	2,400	13%	300	1.2	89%
Orling Slough	1251	350	63%	220	1.2	21%
Upper Marsh 1 & 2	1248 & 1250	3,300	47%	1,540	4.1	47%
Canyon Marsh	1249	1,900	37%	700	6.2	99%
Mission Slough	9645	3,800	49%	1,800	3.9	19%
Dudley Marsh	9647	290	65%	190	14.1	27%
Whiteman's Slough	9646	140	69%	100	4.0	15%
Skeel Gulch and South Cataldo	1247 & 9648	270	71%	190	3.4	28%
Off-Channel Storage Areas Subtotal		**250,000**	**32%**	**81,004**	**2.9**	**19%**
Overbank Flow Area ID						
135-L		3,800	69%	2,600	8.7	35%
138-L		510	56%	290	2.1	25%
139-L		1,100	55%	590	4.1	24%
142-L		8,500	65%	5,500	8.5	38%
144-L		4,600	57%	2,600	9.0	37%
145-L		110	66%	74	0.1	22%
146-L		130	58%	76	0.4	28%
147-R		350	46%	160	0.5	45%
151-L		9,700	45%	4,300	9.4	21%
152-R		3,500	41%	1,400	14.0	19%
153-R		3,900	38%	1,500	21.3	45%
153.5-L		129	66%	86	2.1	50%
156.8-R		2,400	45%	1,100	7.4	88%
158-R		26,000	38%	10,000	9.2	55%
159-L		7,700	29%	2,200	7.5	18%
160-R		43,000	31%	13,000	10.3	23%
163-L		29,000	18%	5,200	52.0	20%
Overbank Flow Area Subtotal		**140,000**	**35%**	**51,000**	**8.3**	**28%**
System Floodplain Total		**400,000**	**33%**	**130,000**	**3.9**	**22%**

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 12b.**Water Year 2008 Sedimentation**

Off-Channel Storage Area Name	Area ID	WY 2008 Sediment Flux into the Floodplain (metric tons)	WY 2008 Average Trapping Efficiency (%)	WY 2008 Sediment Deposition Mass (metric tons/year)	WY 2008 Deposition Rate (mm/yr)	Proportion of Total (1988-2012) Mass Deposited in WY 2008 (%)
Anderson Lake	1245	1,600	91%	1,500	0.7	14%
Thompson Lake	1244	3,700	88%	3,300	1.5	13%
Bare Marsh	1246	1,200	87%	1,000	2.9	19%
Lamb Peak 2	1268	31	100%	31	0.0	23%
Blue	1240	8,700	24%	2,100	4.3	21%
Blue Marsh	1239	23,000	12%	2,800	72.7	26%
Lamb Peak 1	1267	58	73%	43	0.1	27%
Swan	1265	62,000	49%	30,000	11.4	20%
Black Lake 2	1241	170	98%	170	0.1	4%
Black Lake 1	1266	10	100%	10	0.0	6%
Cave	1242	140	91%	130	0.0	3%
Medicine	1262 & 1264	890	84%	800	0.5	4%
Moffit	1259	44,000	13%	5,700	10.6	17%
Schlepp	1243 & 1263	28	65%	20	0.1	10%
Killarney	1261 & 1260	32,000	43%	14,000	3.0	13%
Strobl	1257	25,000	14%	3,600	7.6	19%
Lane 1	1258	480	58%	280	0.6	13%
Lane 2	1238	77	100%	77	0.1	6%
Strobl Field	1256	170	84%	140	1.9	7%
Black Rock Slough	1255	1,600	72%	1,200	2.0	25%
Rose Lake	9651	-	0%	-	0.0	0%
Bull Run 2	1254	80	98%	81	0.2	4%
Potter Slough	1253	-	100%	-	0.0	0%
Bull Run 1	1252	37	83%	31	0.1	9%
Orling Slough	1251	100	85%	88	0.5	8%
Upper Marsh 1 & 2	1248 & 1250	310	78%	240	0.7	8%
Canyon Marsh	1249	12	45%	5	0.0	1%
Mission Slough	9645	880	76%	670	1.4	7%
Dudley Marsh	9647	59	84%	49	3.7	7%
Whiteman's Slough	9646	76	76%	58	2.4	9%
Skeel Gulch and South Cataldo	1247 & 9648	64	80%	51	0.9	7%
Off-Channel Storage Areas Subtotal		**210,000**	**33%**	**68,300**	**2.5**	**16%**
Overbank Flow Area ID						
135-L		2,900	78%	2,200	7.4	30%
138-L		600	58%	350	2.6	30%
139-L		1,000	55%	560	3.9	22%
142-L		5,400	77%	4,200	6.5	29%
144-L		2,700	65%	1,700	6.1	25%
145-L		110	77%	87	0.2	26%
146-L		100	77%	80	0.4	29%
147-R		150	72%	110	0.4	30%
151-L		8,700	47%	4,100	8.9	20%
152-R		3,600	42%	1,500	14.8	20%
153-R		1,800	43%	760	11.0	23%
153.5-L		55	60%	33	0.8	19%
156.8-R		100	43%	57	0.4	5%
158-R		14,000	42%	5,900	5.5	33%
159-L		5,300	34%	1,800	6.1	14%
160-R		24,000	36%	8,600	6.6	15%
163-L		14,000	25%	3,500	35.2	14%
Overbank Flow Area Subtotal		**80,000**	**42%**	**36,000**	**5.8**	**20%**
System Floodplain Total		**290,000**	**36%**	**100,000**	**3.1**	**17%**

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 13a. **Average Annual Sedimentation at USGS Cores**

River Mile	Sedimentation Analysis Area ID	Core ID	Year Collected	Depositional Setting	Distance to River (m)	Depth to St. Helens Layer (cm)	Average Annual Deposition Rate (mm/year)	Average Annual Deposition Rate from 1D Sedimentation Model (mm/year)	1D Annual Sedimentation as Percent of USGS Core (percent)
132.8	1245	H934.2	1993	Lacustrine - Littoral	170	5.1	3.9	0.2	5%
135.1	135_L	94xb19	1994	Riverbank	0	10	7.1	1.0	14%
135.2	1244	T91A	1991	Lacustrine - Limnetic	603	3	2.7	0.5	17%
135.2	1244	BL9323	1993	Palustrine	911	3.2	2.5	0.5	18%
136.4	1246	93SBB22	1993	Palustrine	81	4	3.1	0.6	19%
137.1	1240	BL9339	1993	Upland	264	5.1	3.9	0.8	21%
137.6	1240	BL9347	1993	Lacustrine - Littoral	912	5.1	3.9	0.8	21%
138.1	1239	BL9346	1993	Upland	32	1.9	1.5	11.0	735%
138.7	139_L	BL9345	1993	Riverbank	19	1.9	1.5	0.7	47%
139.1	139_L	BL9354	1993	Riverbank	0	5.1	3.9	0.7	18%
139.6	1241	BL9355	1993	Lacustrine - Littoral	307	1.6	1.2	0.1	11%
140.2	1266	BL9360	1993	Palustrine	454	1.9	1.5	0.0	1%
140.8	1265	BL9370	1993	Upland	119	3.8	2.9	2.2	**77%**
141.5	1265	BL9369	1993	Lacustrine - Littoral	1377	3.8	2.9	2.2	**77%**
143.7	144_L	93ABM4	1993	Upland	15	12	9.2	1.0	11%
143.9	1262 & 1264	M9395	1993	Upland	669	4.5	3.4	0.5	15%
144	1262 & 1264	M91A	1991	Lacustrine - Littoral	897	4	3.6	0.5	14%
144	1262 & 1264	M9394	1993	Lacustrine - Littoral	1647	3.8	2.9	0.5	17%
144	1262 & 1264	M93109	1993	Palustrine	2330	1.3	1	0.5	50%
144.1	1262 & 1264	M92CS	1992	Lacustrine - Limnetic	1235	5.2	4.3	0.5	12%
144.2	1262 & 1264	M93108	1993	Lacustrine - Littoral	1410	0.6	0.5	0.5	**100%**
144.3	1262 & 1264	M93107	1993	Palustrine	434	1.3	1	0.5	50%
144.8	1259	M93106	1993	Palustrine	260	2.5	1.9	2.5	**134%**
145.4	1261 & 1260	T98M-43	1998	Upland	150	2	1.1	0.9	**84%**
145.9	1261 & 1260	M93104	1993	Palustrine	574	0	0	0.9	
146.4	146_L	L93118	1993	Upland	10	5.1	3.9	0.1	1%
146.5	1261 & 1260	L93119	1993	Upland	488	2.5	1.9	0.9	49%
147.2	147_R	L93128	1993	Upland	19	2.5	1.9	0.0	3%
147.4	147_R	93SBL32	1993	Upland	114	3	2.3	0.0	2%
147.5	1238	L93135	1993	Palustrine	103	5.1	3.9	0.1	2%
147.8	1257	93SBL31	1993	Upland	333	6	4.6	1.6	35%
147.9	1261 & 1260	91SBKF2	1991	Lacustrine - Limnetic	1693	5	4.5	0.9	21%
148.6	1258	96K178E	1996	Upland	240	18	11.3	0.2	2%
148.6	1258	96K114E	1996	Upland	209	33	20.6	0.2	1%
148.6	1257	94GID3	1994	Upland	43	3	2.1	1.6	**77%**

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 13a (continued). **Average Annual Sedimentation at USGS Cores**

River Mile	Sedimentation Analysis Area ID	Core ID	Year Collected	Depositional Setting	Distance to River (m)	Depth to St. Helens Layer (cm)	Average Annual Deposition Rate (mm/year)	Average Annual Deposition Rate from 1D Sedimentation Model (mm/year)	1D Annual Sedimentation as Percent of USGS Core (percent)
148.6	1257	94GID5	1994	Palustrine	67	5	3.6	1.6	45%
148.6	1257	94GID6	1994	Palustrine	103	3	2.1	1.6	**77%**
148.9	1257	93SBL30	1993	Upland	366	4	3.1	1.6	**52%**
149.1	1257	93SBL27B	1993	Upland	57	4	3.1	1.6	**52%**
149.1	1257	L93137	1993	Palustrine	122	2.5	1.9	1.6	**85%**
149.2	1257	93SBL27	1993	Riverbank	0	7	5.4	1.6	30%
149.2	1261 & 1260	L93121	1993	Palustrine	2373	3.8	2.9	0.9	32%
150.3	1255	L93154	1993	Lacustrine - Littoral	457	1.6	1.2	0.3	28%
150.7	151_L	94xl13	1994	Riverbank	1	15	10.7	1.8	17%
151.2	151_L	T98L-36	1998	Upland	330	16.5	9.2	1.8	20%
151.2	151_L	94xl04	1994	Riverbank	4	10	7.1	1.8	25%
151.4	152_R	L93156	1993	Upland	35	2.9	2.2	2.9	**132%**
151.7	151_L	L93162	1993	Upland	126	3.8	2.9	1.8	**62%**
152.1	1255	T98R-30	1998	Upland	200	4	2.2	0.3	15%
152.7	9651	T98R-28	1998	Upland	230	2.5	1.4	0.0	0%
152.9	153_R	94xra21	1994	Riverbank	1	10	7.1	1.9	27%
153.3	153_R	94xra15	1994	Riverbank	3	12	8.6	1.9	22%
153.4	9651	RL93178	1993	Upland	437	1.6	1.2	0.0	0%
153.4	9651	RL93177	1993	Upland	667	1	0.8	0.0	0%
153.5	153_R	94xr98	1994	Riverbank	0	4	2.9	1.9	**65%**
154.5	1251	RL93193	1993	Upland	56	2.5	1.9	0.2	12%
154.9	1251	93SBR13	1993	Riverbank	9	15	11.5	0.2	2%
156.6	1249	RL93206	1993	Palustrine	1450	1.6	1.2	0.2	21%
157.3	158_R	RL93213	1993	Riverbank	0	1.6	1.2	0.7	**56%**
158.2	158_R	94xr30	1994	Riverbank	1	13	9.3	0.7	7%
158.4	158_R	94xr25	1994	Riverbank	1	22	15.7	0.7	4%
158.7	158_R	94xr17	1994	Riverbank	1	17	12.1	0.7	6%
159.3	159_L	T98R-31	1998	Upland	120	5.5	3.1	1.7	**55%**
159.6	159_L	C93236	1993	Riverbank	6	11.4	8.8	1.7	19%
159.9	160_R	C93235	1993	Upland	37	5.1	3.9	1.8	45%
160	160_R	93CSC03	1993	Riverbank	1	6	4.6	1.8	39%
160.1	160_R	T98C-17	1998	Upland	45	8	4.4	1.8	40%
160.1	160_R	T98C-21	1998	Palustrine	440	14	7.8	1.8	23%
160.2	160_R	C93244	1993	Upland	414	2.2	1.7	1.8	**104%**
160.5	160_R	T98C-16	1998	Upland	240	9.9	5.5	1.8	32%

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 13a (continued). **Average Annual Sedimentation at USGS Cores**

River Mile	Sedimentation Analysis Area ID	Core ID	Year Collected	Depositional Setting	Distance to River (m)	Depth to St. Helens Layer (cm)	Average Annual Deposition Rate (mm/year)	Average Annual Deposition Rate from 1D Sedimentation Model (mm/year)	1D Annual Sedimentation as Percent of USGS Core (percent)
160.6	159_L	93SBC15	1993	Upland	4	15	11.5	1.7	15%
160.9	9646	T98C-18	1998	Upland	1025	3	1.7	1.1	**64%**
160.9	9646	C93249	1993	Upland	1033	0	0	1.1	
161.5	160_R	93SBC10	1993	Riverbank	8	3	2.3	1.8	**77%**
161.5	9646	C93250	1993	Upland	825	0	0	1.1	
162.2	1247 & 9648	T98C-25	1998	Upland	450	5	2.8	0.5	17%
162.4	163_L	T98C-8	1998	Upland	125	3	1.7	10.3	605%

Notes:
- see Technical Memorandum Addendum D-3: Sediment and Lead Budgets (CH2M HILL, 2015a) for additional discussion of the USGS core data.
- highlighted cells (with **bold**) text are within +/- 50% of USGS core deposition rate.

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

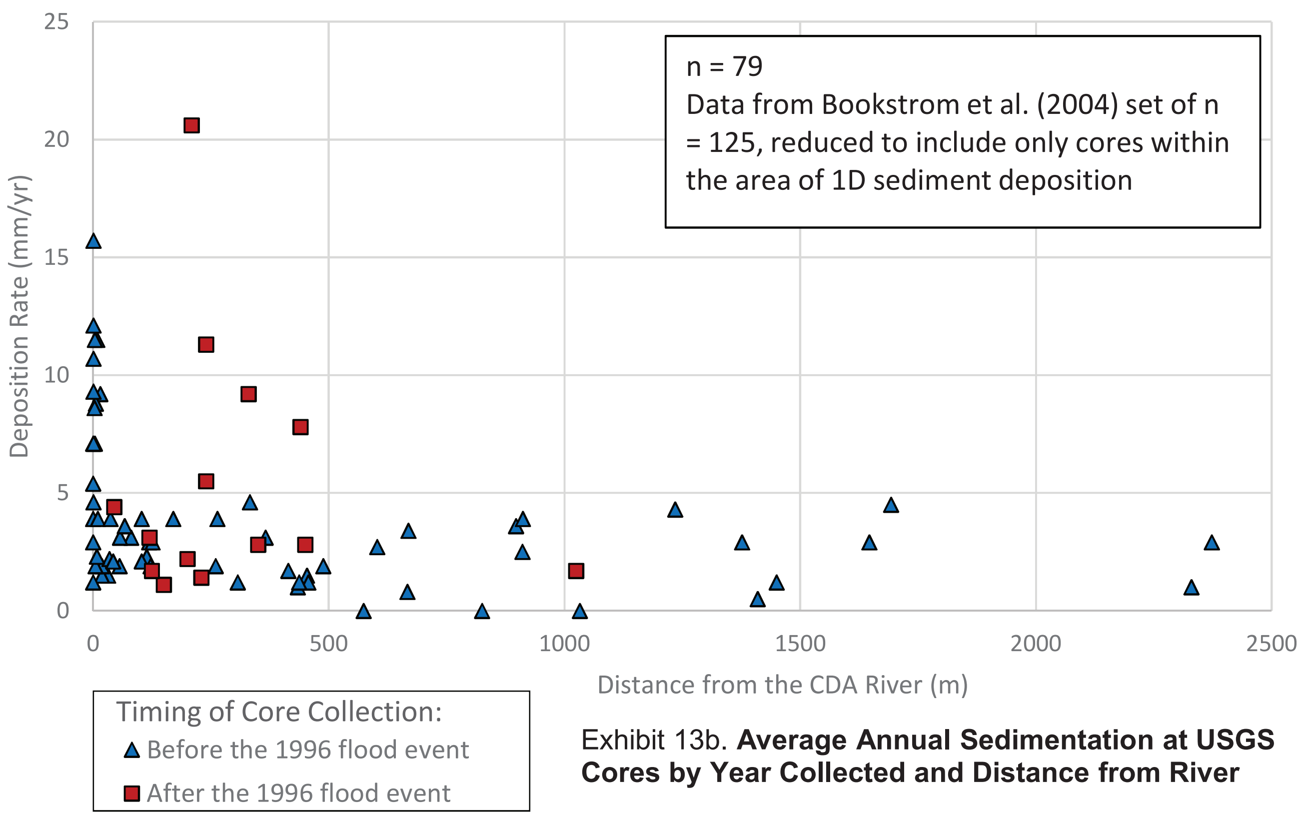


Exhibit 13b. **Average Annual Sedimentation at USGS Cores by Year Collected and Distance from River**

Exhibit 13C. **Average Annual Sedimentation at BEMP Sediment Tiles**

River Mile	Sedimentation Analysis Area ID	Tile Location ID	Average Annual Deposition Rate (mm/year)	Average Annual Deposition Rate from 1D Sedimentation Model (mm/year)	1D Annual Sedimentation as Percent of Tile Deposition Rate (percent)
132.8	1245	LC-BSED-D-108	4	0.2	5%
143.5	144_L	LC-BSED-D-106	13	1.0	8%
135.3	1246	LC-BSED-D-107	0.3	0.6	197%
147.6	1258	LC-BSED-D-103	3	0.2	7%
146.7	1261 & 1260	LC-BSED-D-105	9	0.9	10%
147.3	1257	LC-BSED-D-104	2	1.6	**81%**

Notes:
- see the BEMP Sediment Sampling Data Summary reports (CH2M HILL, 2011a, 2011b, and 2013b) for additional discussion of the sediment tile data.
- highlighted cells (**with bold**) text are within +/- 50% of USGS core deposition rate.

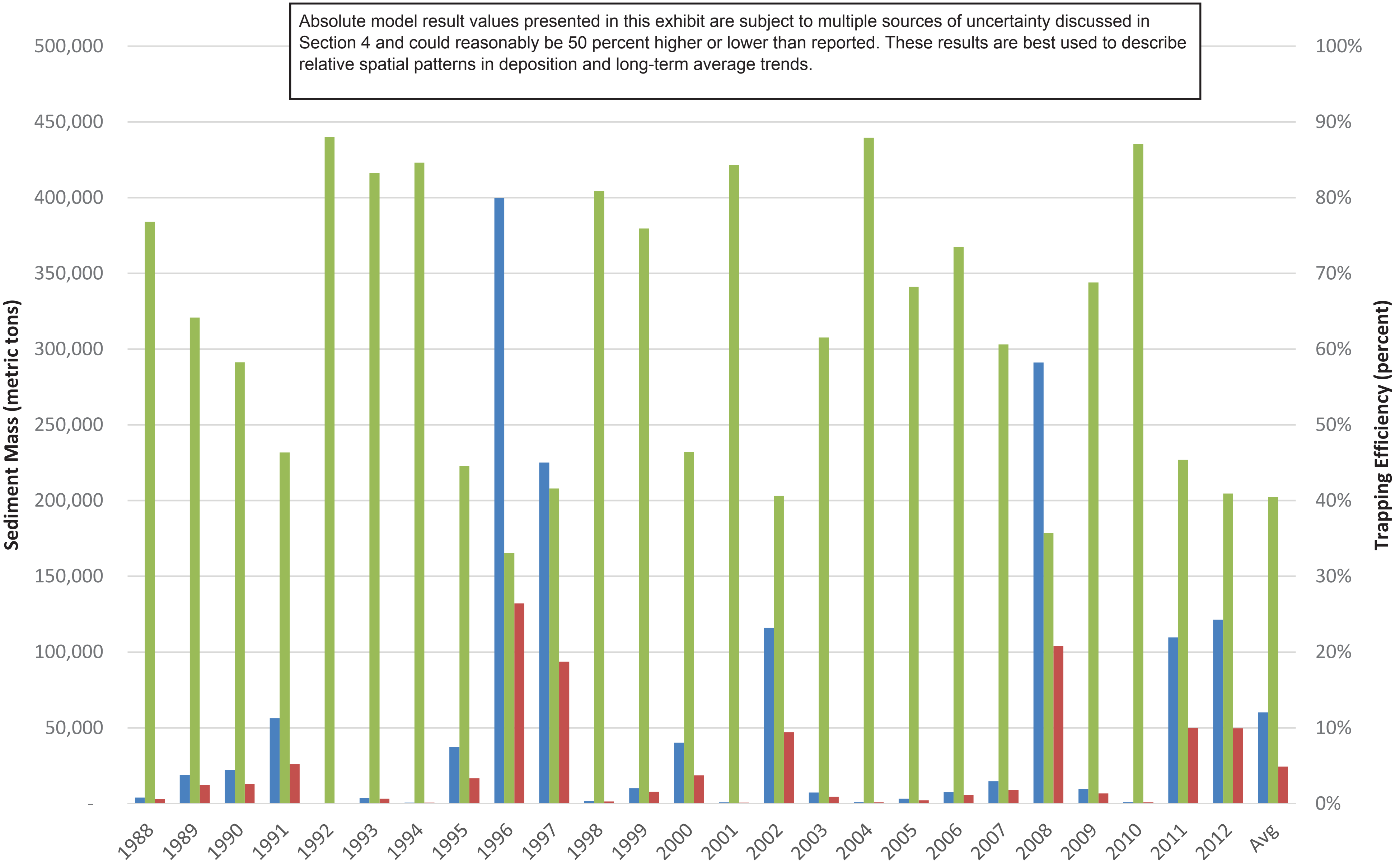


Exhibit 14. **Floodplain Sedimentation by Water Year for the Entire Lower Basin**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d' Alene River (OU3)

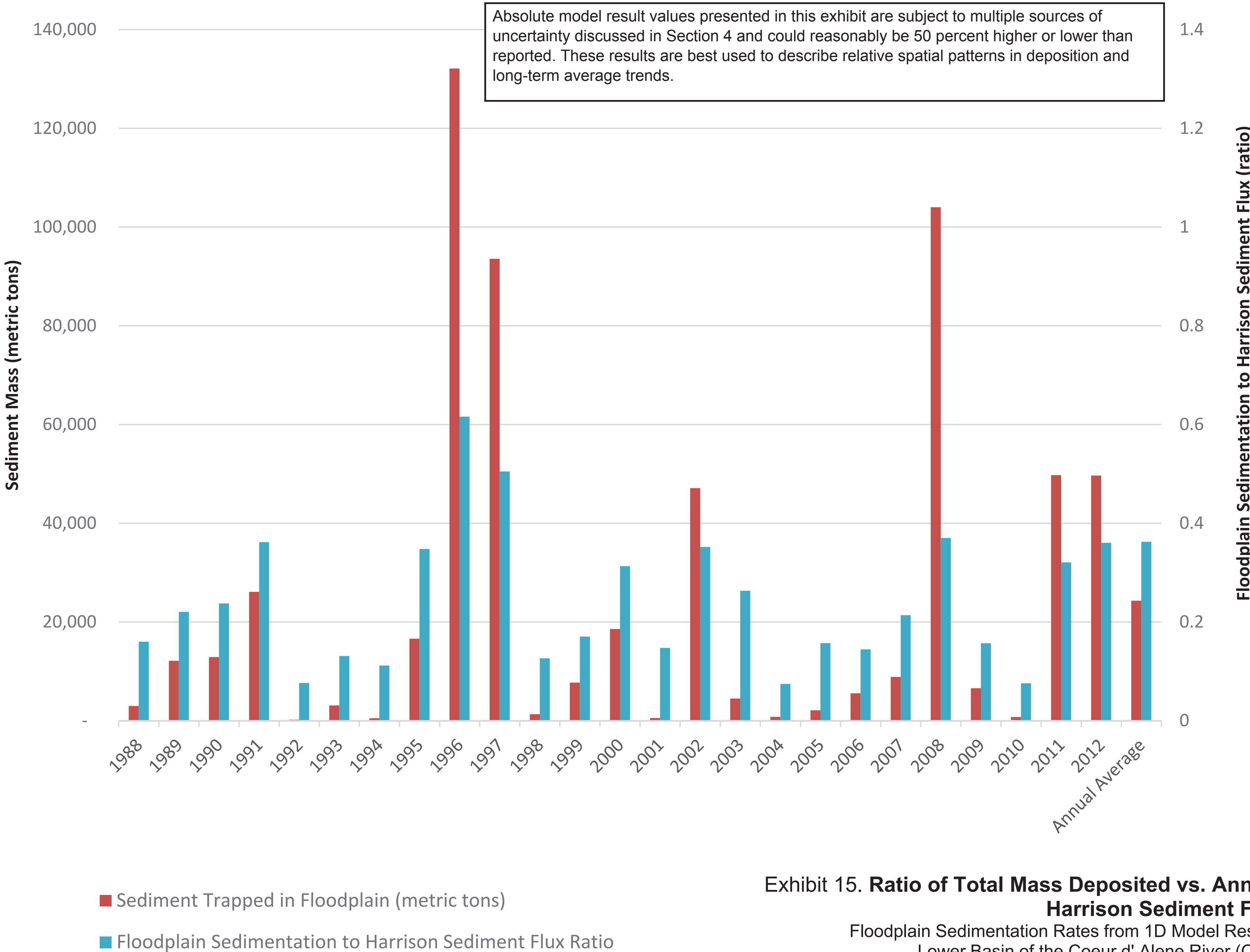


Exhibit 15. **Ratio of Total Mass Deposited vs. Annual Harrison Sediment Flux**

Floodplain Sedimentation Rates from 1D Model Results

Lower Basin of the Coeur d' Alene River (OU3)

Exhibit 16. **Sedimentation by Water Year**

Water Year	Sediment Flux into the Floodplain 1988-2012 (metric tons)	Trapping Efficiency of the Entire Lower Basin (%)	Cumulative Mass Deposited 1988-2012 (metric tons)	Average Annual Deposition Rate (mm/year)	Ratio of Total Mass Deposited to Annual Harrison Sediment Flux
1988	3,900	77%	3,000	0.1	16%
1989	19,000	64%	12,000	0.4	22%
1990	22,000	58%	13,000	0.4	24%
1991	56,000	46%	26,000	0.8	36%
1992	230	88%	200	0.0	8%
1993	3,700	83%	3,100	0.1	13%
1994	590	85%	500	0.0	11%
1995	37,000	45%	17,000	0.5	35%
1996	400,000	33%	130,000	3.9	62%
1997	230,000	42%	90,000	2.7	50%
1998	1,600	81%	1,300	0.0	13%
1999	10,000	76%	8,000	0.2	17%
2000	40,000	46%	19,000	0.6	31%
2001	650	84%	550	0.0	15%
2002	120,000	41%	50,000	1.5	35%
2003	7,300	62%	4,500	0.1	26%
2004	890	88%	780	0.0	7%
2005	3,100	68%	2,100	0.1	16%
2006	7,500	73%	5,500	0.2	14%
2007	15,000	61%	9,000	0.3	21%
2008	290,000	36%	100,000	3.0	37%
2009	9,500	69%	6,600	0.2	16%
2010	850	87%	740	0.0	8%
2011	110,000	45%	50,000	1.5	32%
2012	120,000	41%	50,000	1.5	36%
Total	**1,500,000**	**41%**	**610,000**	**0.7**	**36%**

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

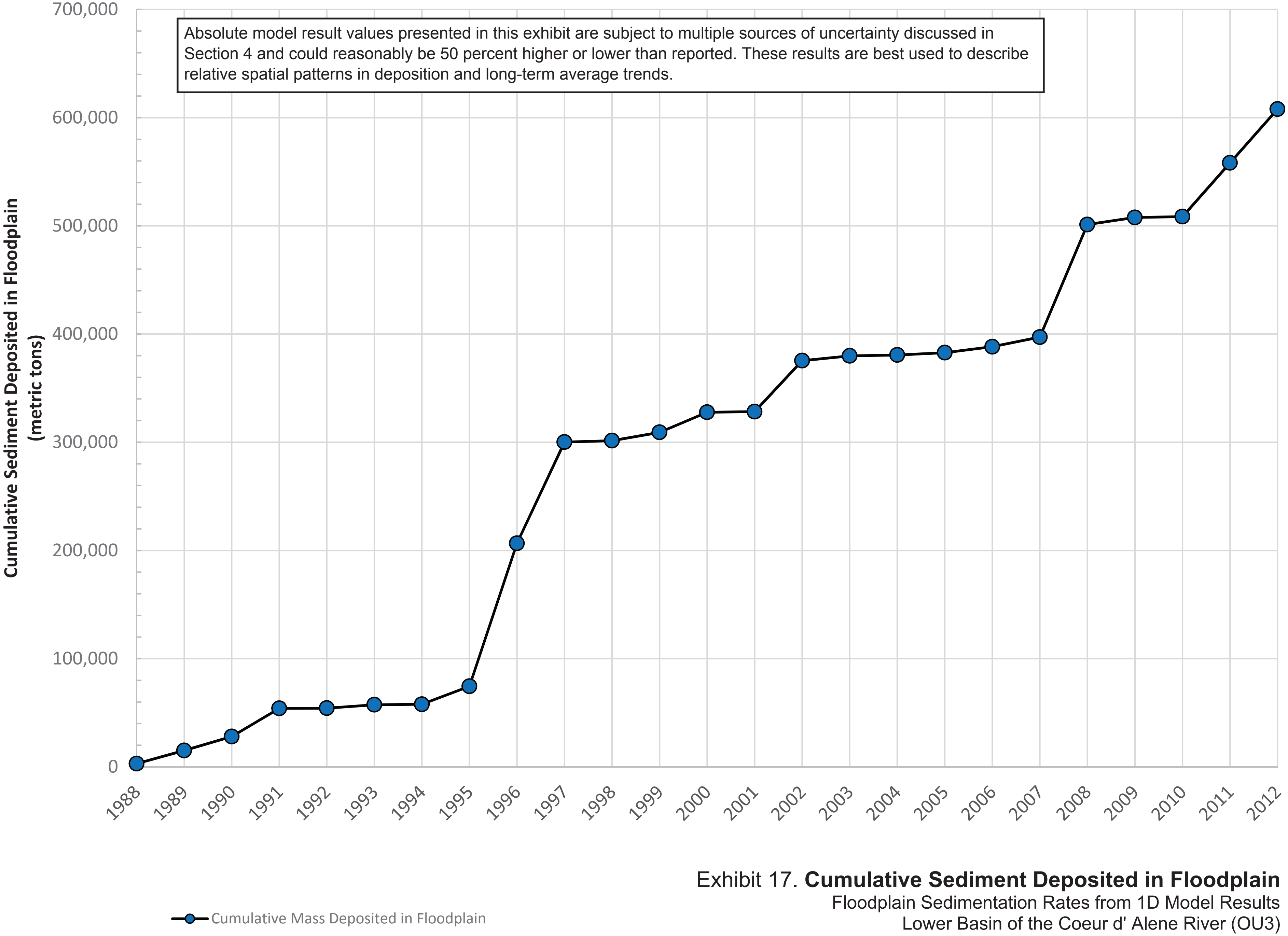
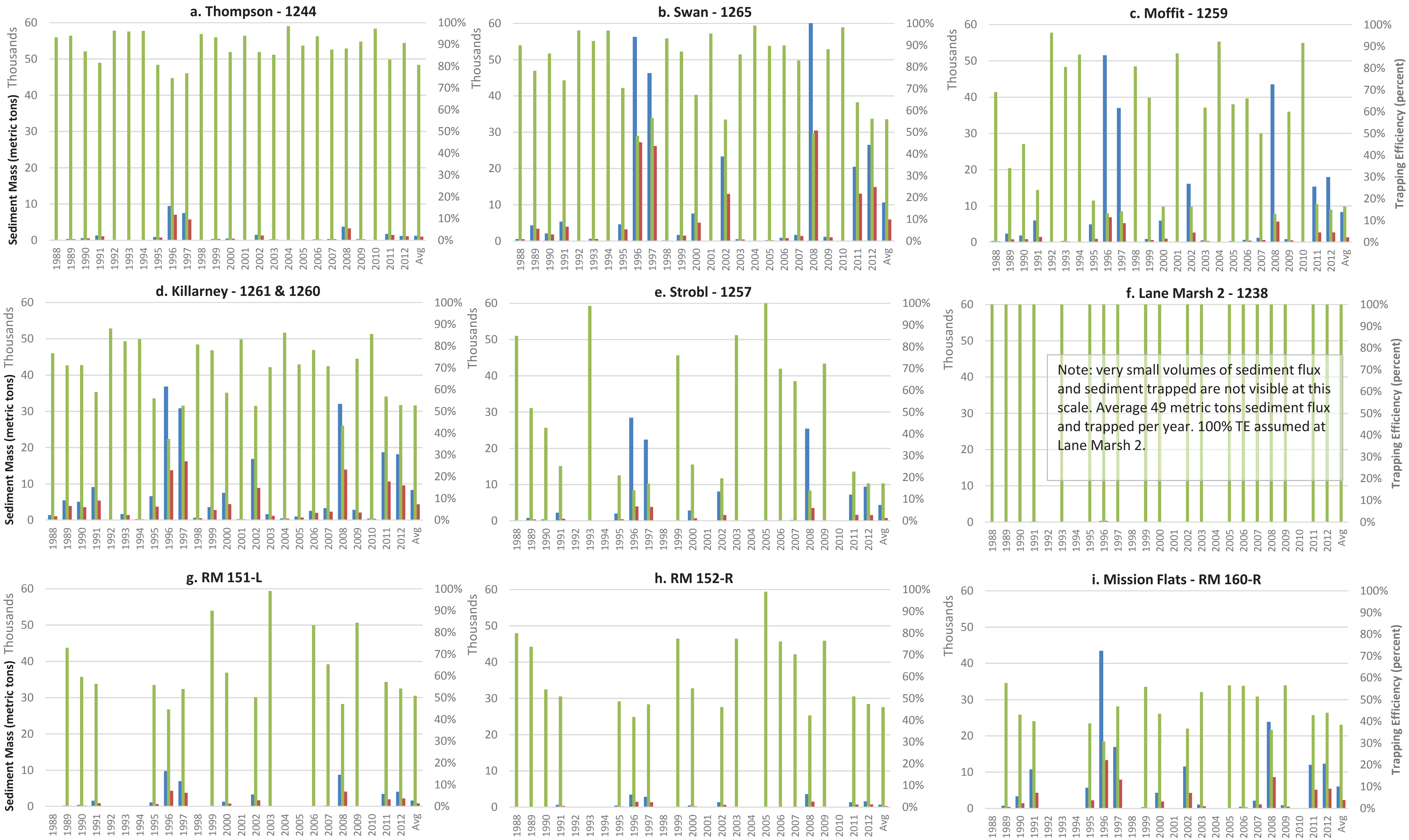


Exhibit 17. **Cumulative Sediment Deposited in Floodplain**
Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d' Alene River (OU3)



- Sediment Flux into Floodplain (metric tons)
- Sediment Trapped in Floodplain (metric tons)
- Average Trapping Efficiency (percent)

Absolute model result values presented in this exhibit are subject to multiple sources of uncertainty discussed in Section 4 and could reasonably be 50 percent higher or lower than reported. These results are best used to describe relative spatial patterns in deposition and long-term average trends.

Exhibit 18a-i. **Floodplain Sedimentation by Water Year for Select Floodplain Areas**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d' Alene River (OU3)

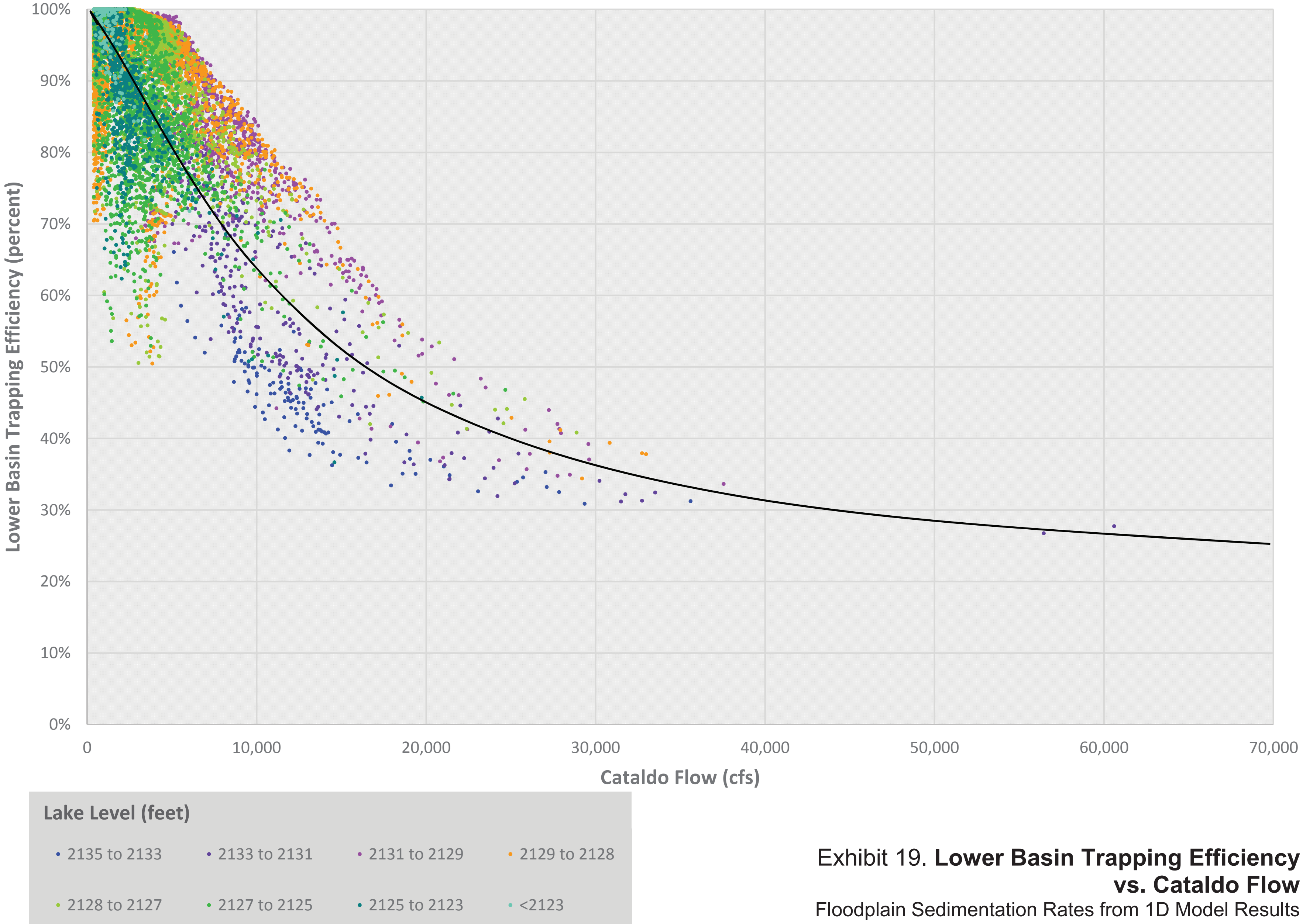


Exhibit 19. **Lower Basin Trapping Efficiency vs. Cataldo Flow**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d' Alene River (OU3)

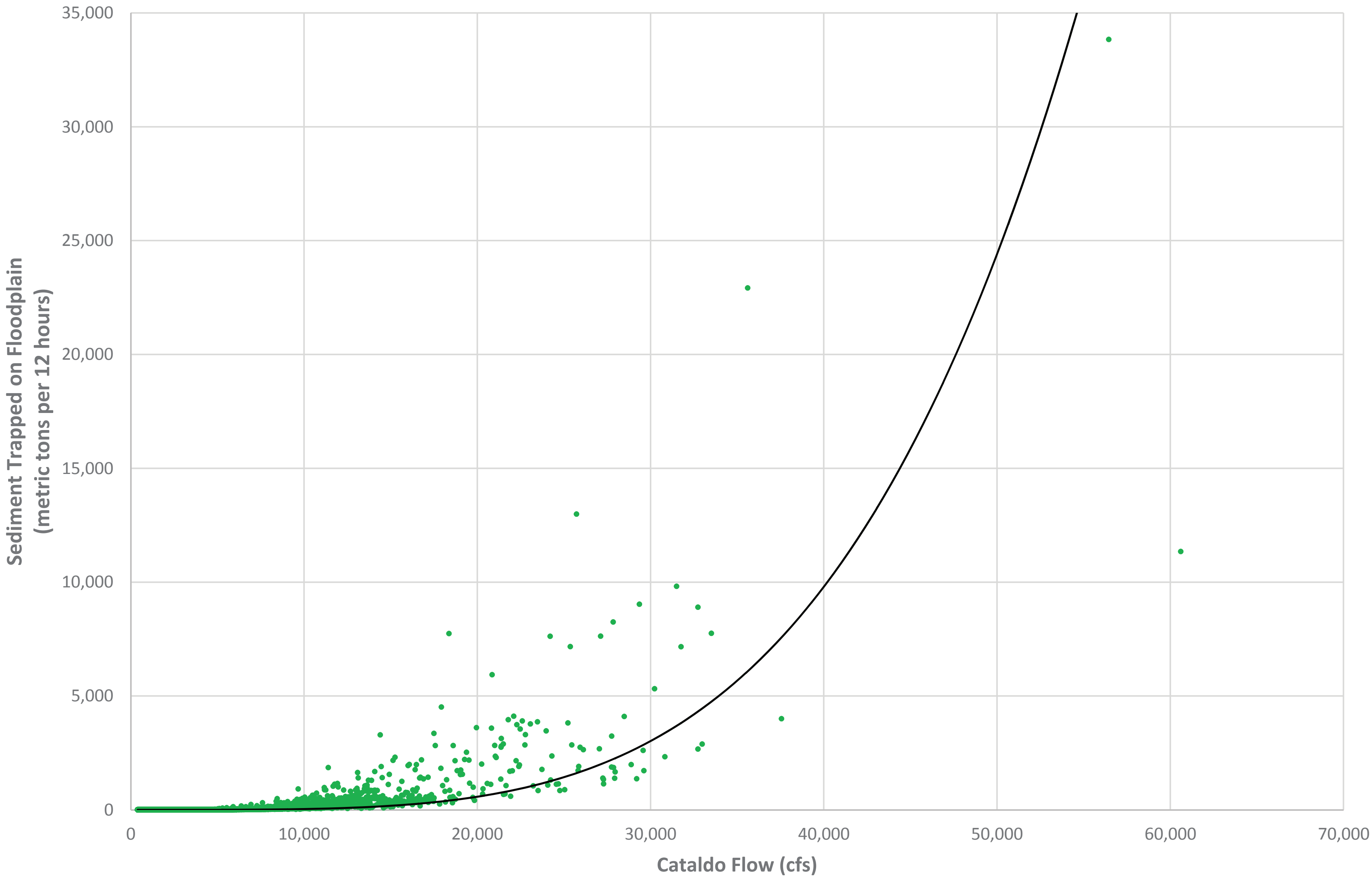
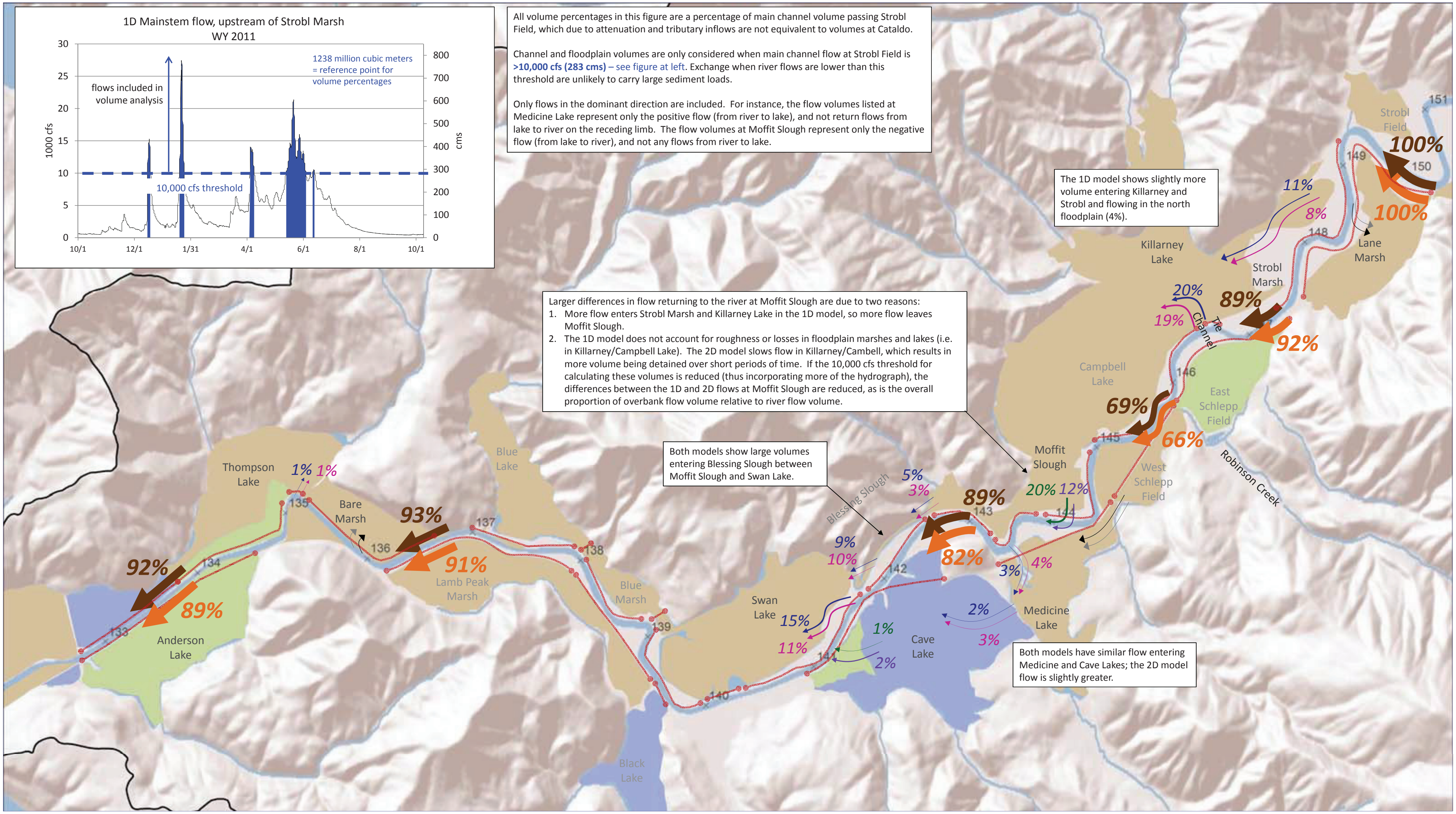


Exhibit 20. **Sediment Trapped in Lower Basin Floodplain vs. Cataldo Flow**

Floodplain Sedimentation Rates from 1D Model Results
Lower Basin of the Coeur d' Alene River (OU3)



LEGEND

- 140 River Mile
- Water Flux Line
- 1D Main Channel Flow, Arrow Size Scaled to Magnitude
- 2D Main Channel Flow, Arrow Size Scaled to Magnitude
- Blue Lakes/Marshes (based on 2008 flood imagery)
- Semi-Turbid Lakes/Marshes (based on 2008 flood imagery)
- Turbid Lakes/Marshes (based on 2008 flood imagery)

1D Floodplain Volume Exchange

Arrow size scaled to WY 2011 volume exchange. Arrow location is generalized.

- Volume exchange from river to floodplain
- Volume exchange from floodplain to river
- Volume exchange less <1% of main channel volume at Strobl Field
- *12%* Volume exchanged in WY 2011, as percent of total main channel volume at Strobl Field

2D Floodplain Volume Exchange

Arrow size scaled to WY 2011 volume exchange. Arrow location is generalized.

- Volume exchange from river to floodplain
- Volume exchange from floodplain to river
- Volume exchange less <1% of main channel volume at Strobl Field
- *12%* Volume exchanged in WY 2011, as percent of total main channel volume at Strobl Field

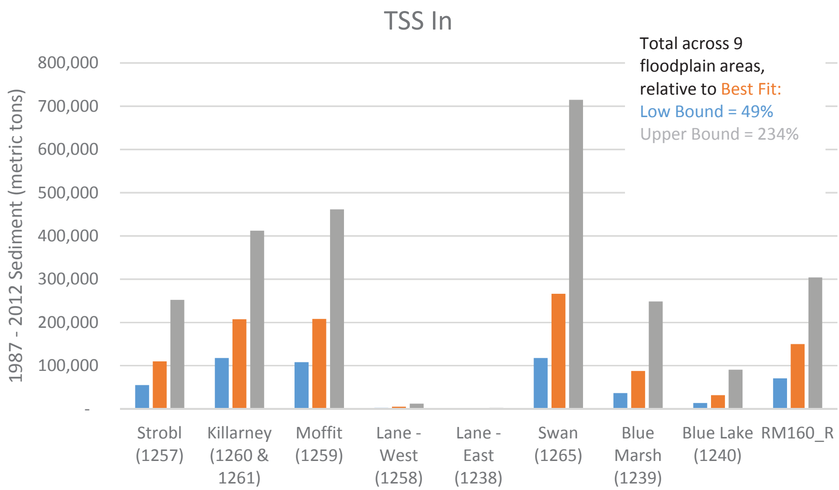
Exhibit 21. **1D and 2D Model Flow Paths**

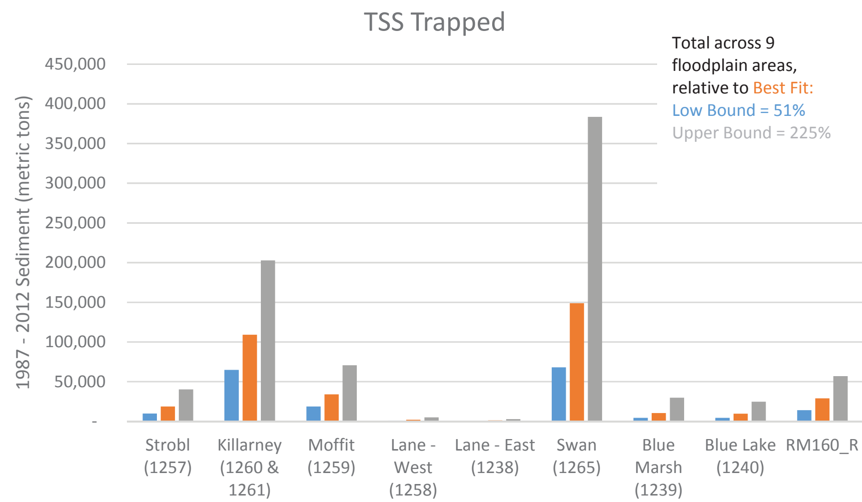
Exhibit 22. **Uncertainty Analysis Summary**

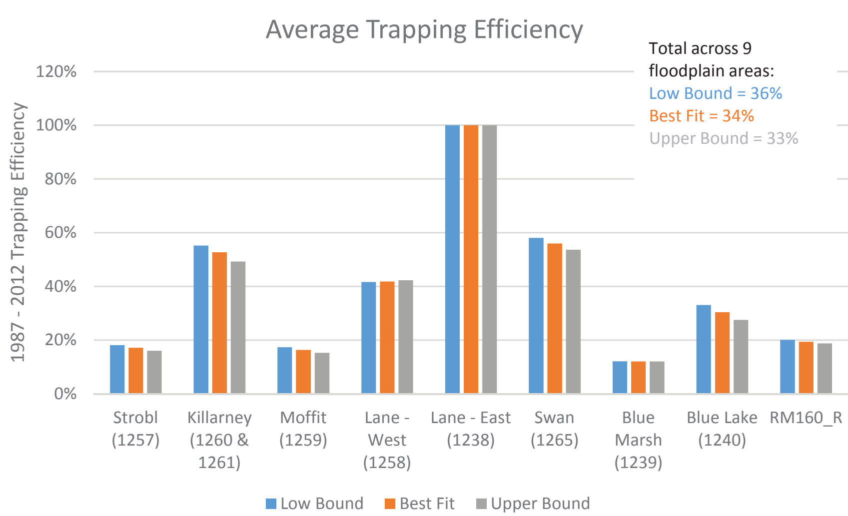
Uncertainty Factors	Detailed Exhibit (number)	Report Section (number)	% Change in Average Annual Sedimentation, relative to Best Estimate	
			Low	High
SSC Rating Curve - Varied Power-Law Regression	23	4.1	-49%	125%
SSC Rating Curve - Varied Regression Models	24	4.1	-48%	39%
SSC Rating Curve - Varied Threshold Discharge	25	4.1	-17%	7%
1D vs. 2D	26	4.2	-28%	none
Updated 1D Model	27	4.3	-4%	none
Varied Representative Flow Lengths	28	4.4	-4%	5%
Exclusion of Tributary Inflows	29	4.5	none	6%
Representative Cross Section	30	4.6	-26%	11%
Varied Representative Sediment Sizes	31	4.7	-5%	6%
Turbulent Flow Correction Factor	32	4.8	-49%	none
SSC uniform in vertical water column		4.1	-?? model likely overestimates; not quantified	none

Notes:

- See the Detailed Exhibit for changes for specific floodplain areas considered as part of the uncertainty analysis.
- See the applicable report section for additional information and background behind each uncertainty type.
- The change in average annual sedimentation was calculated for between 1 and 9 of the 48 floodplain areas. Each area has unique hydraulics and sedimentation characteristics, and may not be representative of average or typical basin sedimentation.
- The uncertainties presented here are not necessarily independent and/or additive.
- **These values should be used to guide understanding of overall and relative uncertainty magnitude.**

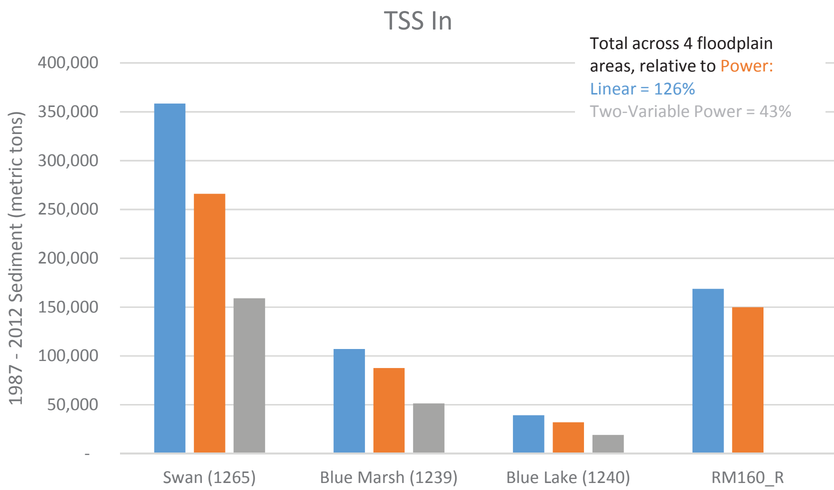


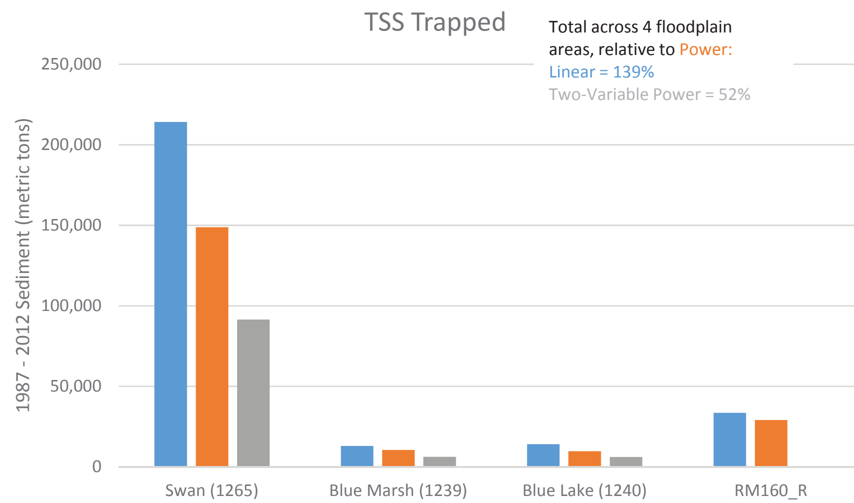


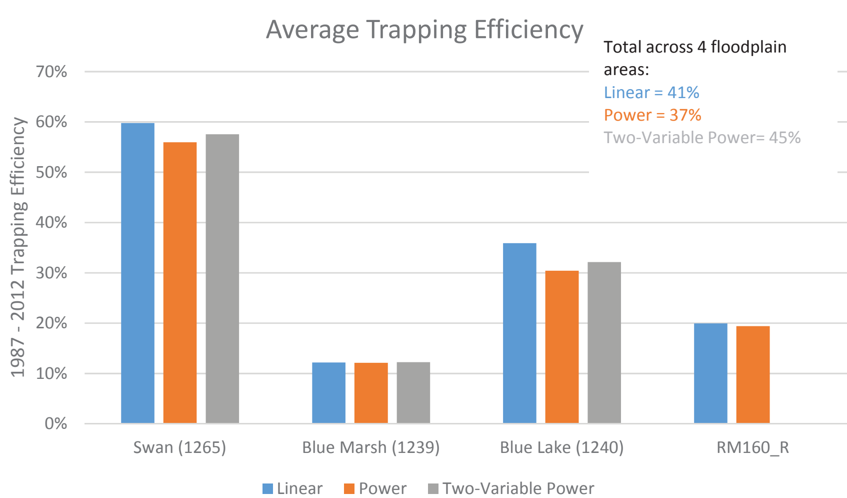


See the Sediment and Lead Budgets TM (CH2M HILL, 2015a) for a full description of the SSC rating curve sensitivity analysis.

Exhibit 23. **Sedimentation Results Using SSC Rating Curves with Varied Power-Law Regression Coefficients**



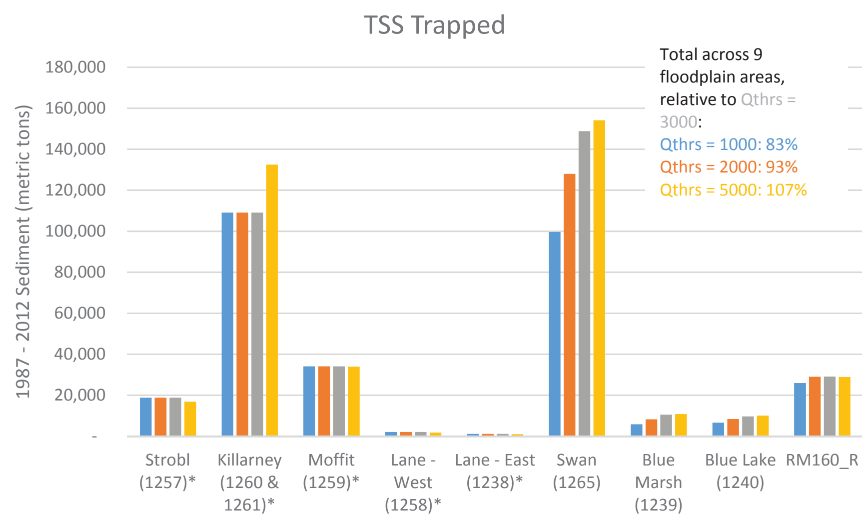


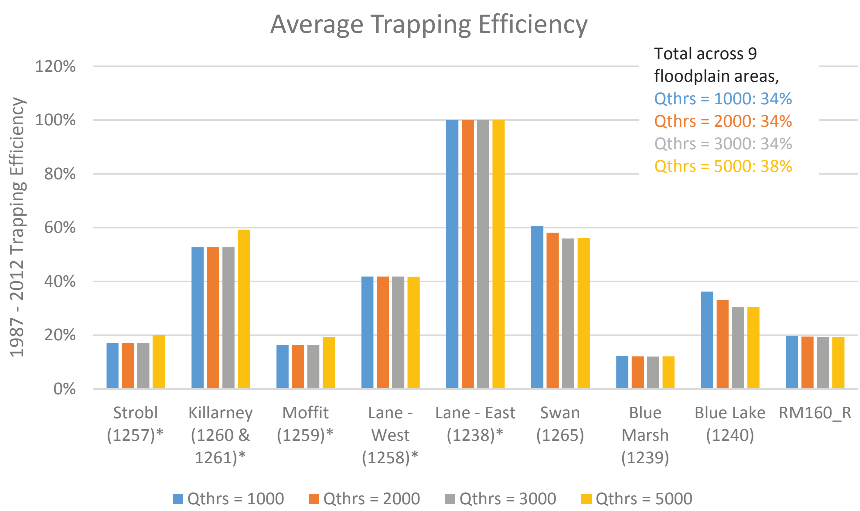


Regression model sensitivity analysis was not performed for the Rose Lake SSC rating curve, and thus the following floodplain areas are excluded from this analysis: Strobl (1257), Killarney (1260 & 1261), Moffit (1259), Lane West (1258) and Lane East (1238). In addition, the Two-Variable Power regression was only performed on the Harrison gage, thus RM160_R is excluded from the Two-Variable Power analysis.

See the Sediment and Lead Budgets TM (CH2M HILL, 2015a) for a full description of the SSC rating curve sensitivity analysis.

Exhibit 24. **Sedimentation Results Using SSC Rating Curves with Varied Regression Models**



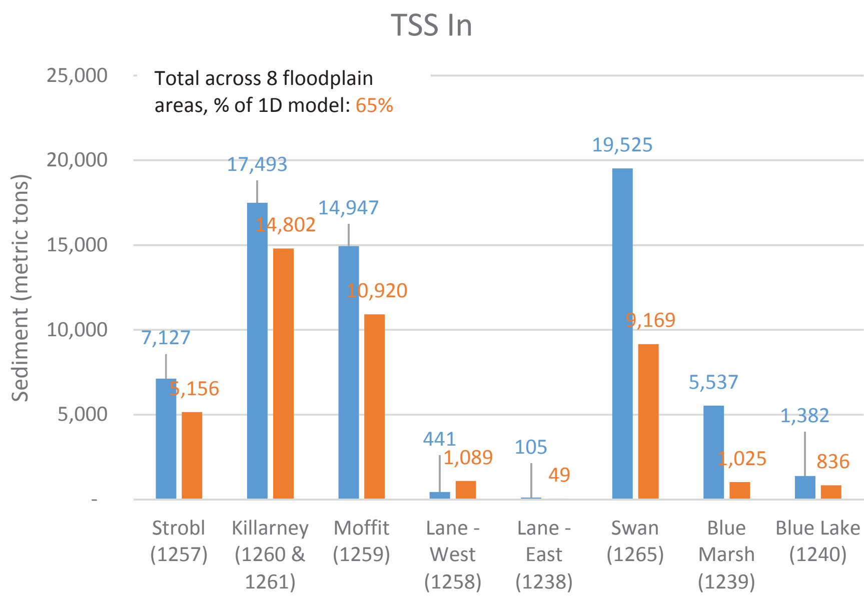


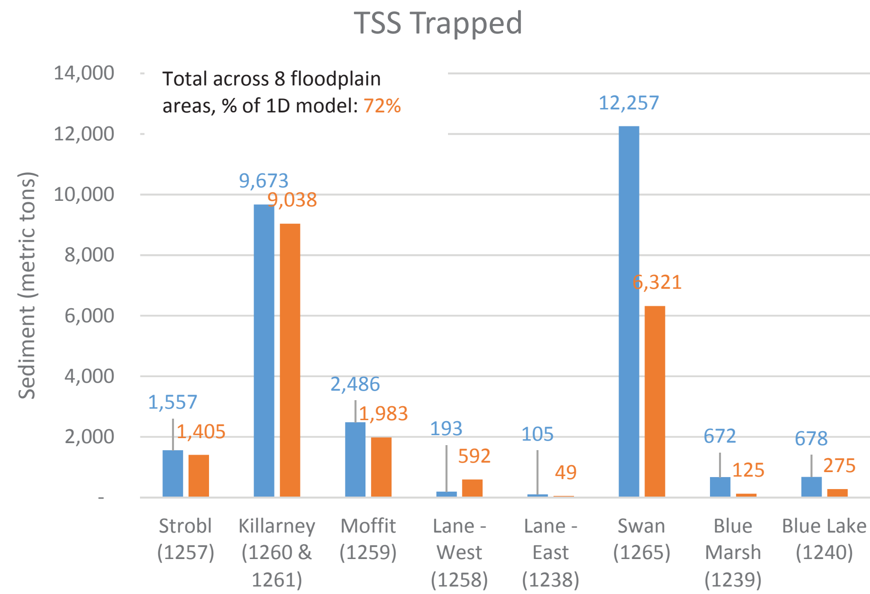
* Rose Lake SSC rating curve is identical for Qthrs = 1000, 2000 and 3000, affecting Strobl (1257), Killarney (1260 & 1261), Moffit (1259), Lane West (1258) and Lane East (1238).

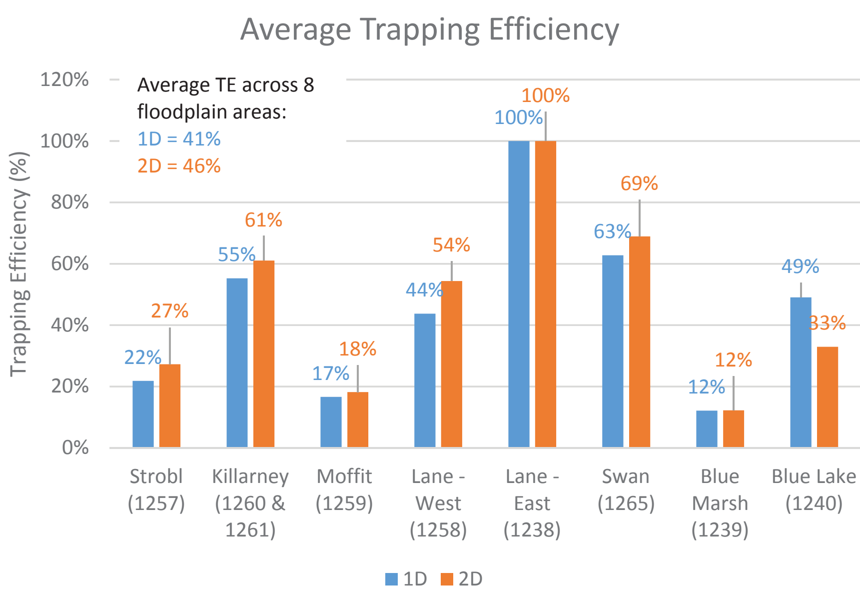
Qthrs = Threshold Discharge

See the Sediment and Lead Budgets TM (CH2M HILL, 2015a) for a full description of the SSC rating curve sensitivity analysis.

Exhibit 25. **Sedimentation Results Using SSC Rating Curves with Varied Threshold Discharge**

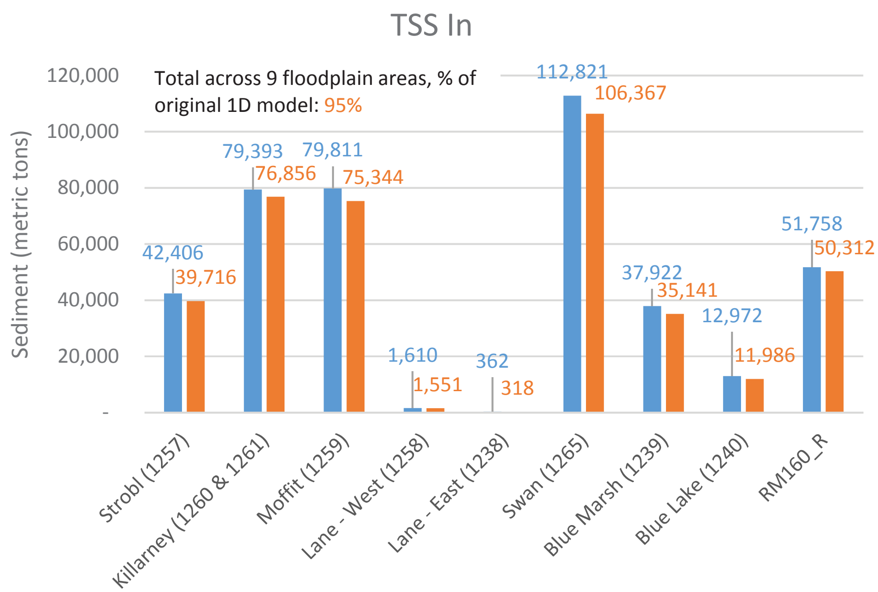


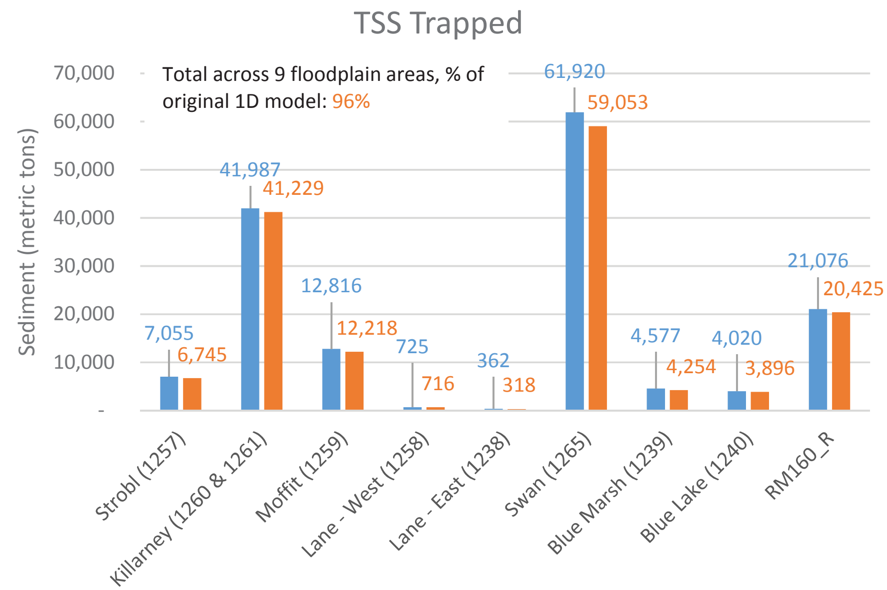


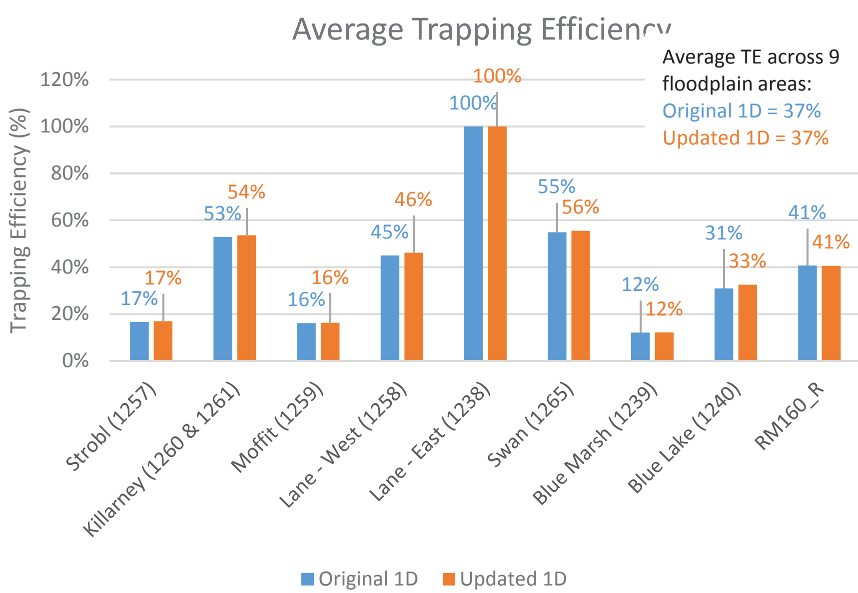


Note: this analysis is limited to the time period for which 2D model data was available. This includes: December 10 to December 22, 2010; January 10 to January 22, 2011; and March 10 to May 31, 2011.

Exhibit 26. **Sedimentation Results Using Varied Hydraulic Model Input (1D and 2D)**

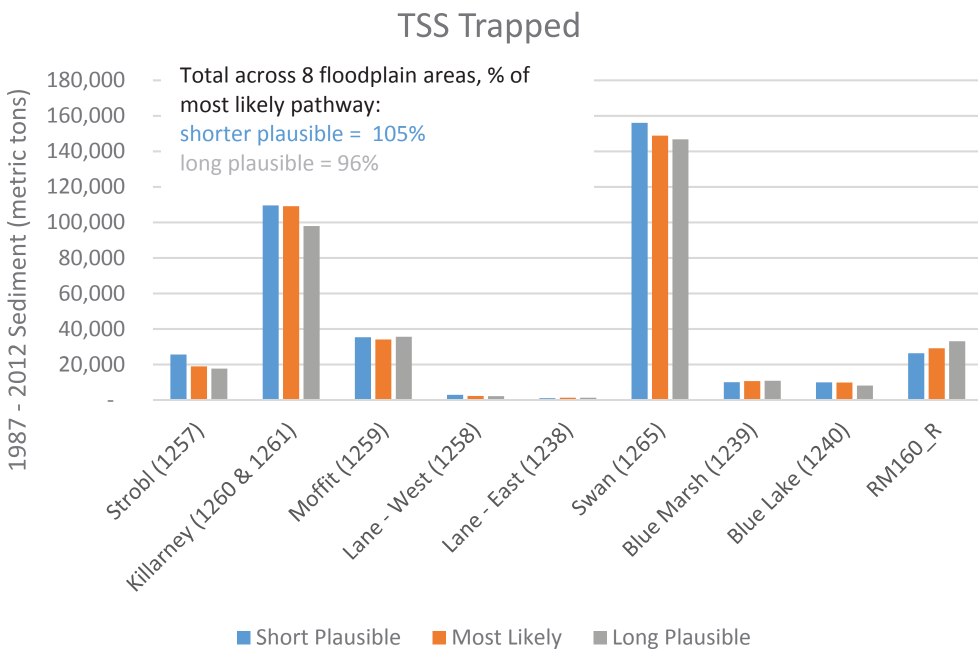






Note: this analysis is limited to the time period from March 2004 to September 2012.

Exhibit 27. **Sedimentation Results Using Updated 1D Model Input**



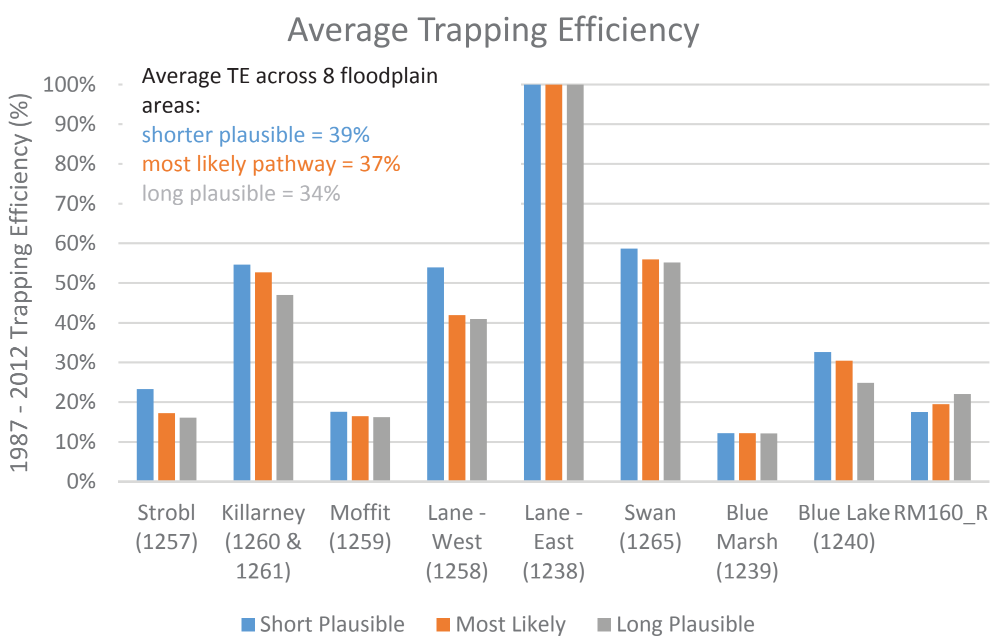
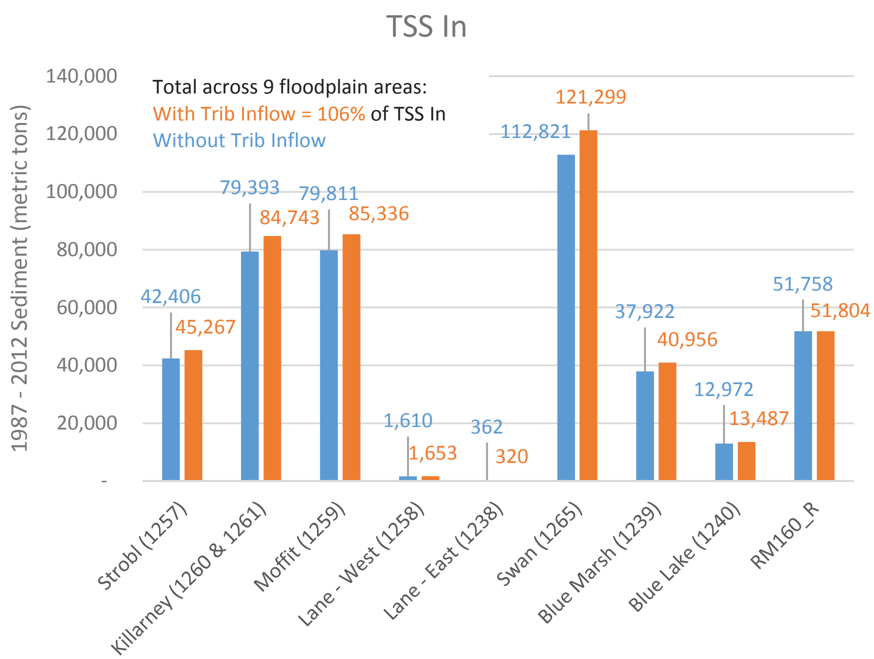
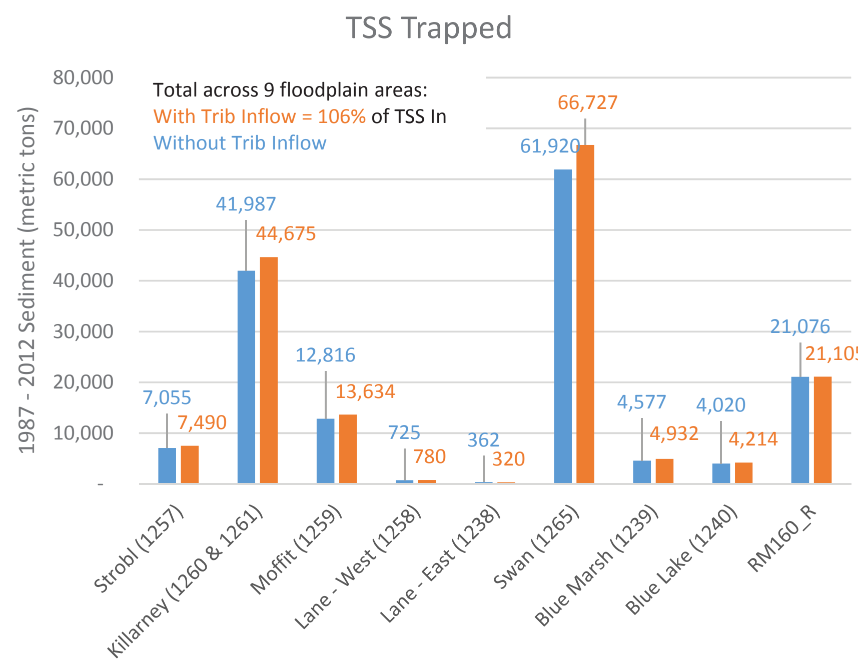


Exhibit 28. **Sedimentation Results Using Varied Representative Flow Path Lengths**





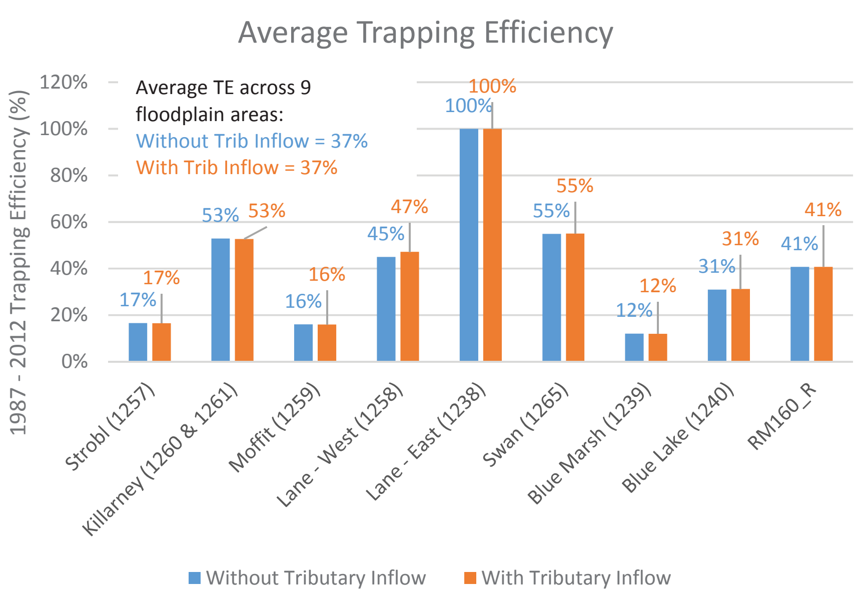
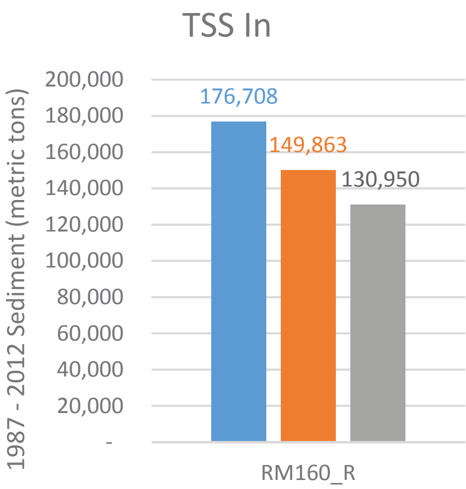
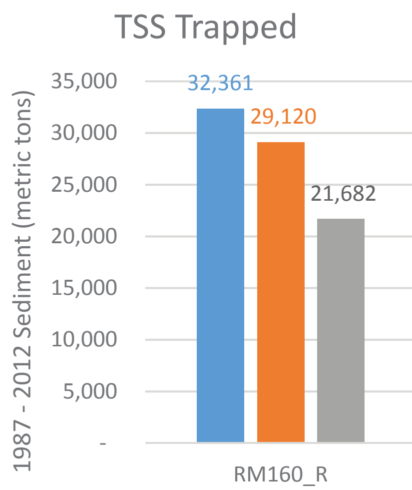


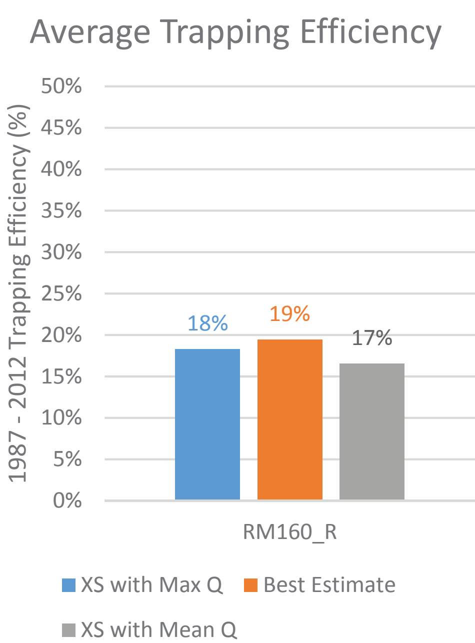
Exhibit 29. **Sedimentation Results With and Without Tributary Inflows Included in the 1D Model**



Relative to Best Estimate:
XS with Max Q = 118%
XS with Mean Q = 87%

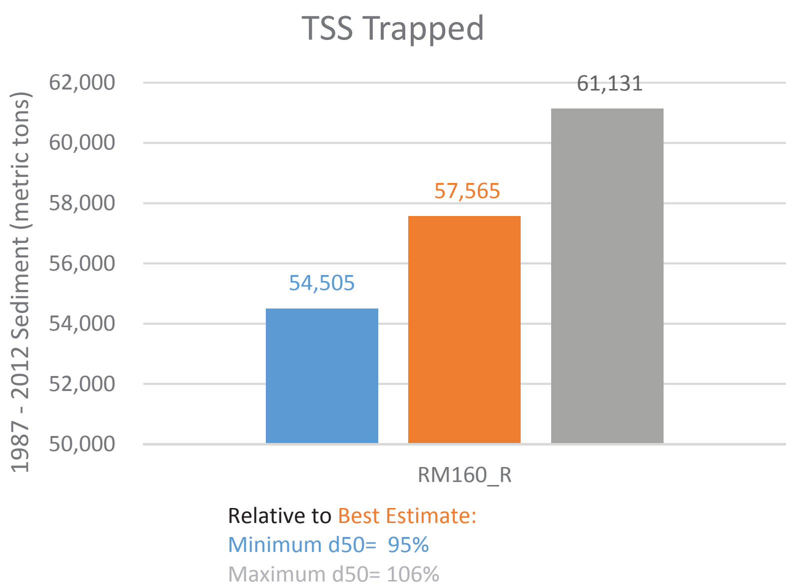


Relative to Best Estimate:
XS with Max Q = 111%
XS with Mean Q = 74%



There are 25 cross sesctions (XS) in the given overbank flow area [160_R]. The "Best Estimate" was chosen based on visual inspection. In addition, the cross section with the flow closest to the average flow of all 25 cross sections (Mean Q), and the cross section with the greatest flow (Max Q) were selected for comparison.

Exhibit 30. **Sedimentation Results Using Varied Representative Cross Sections in Overbank Flow Areas**



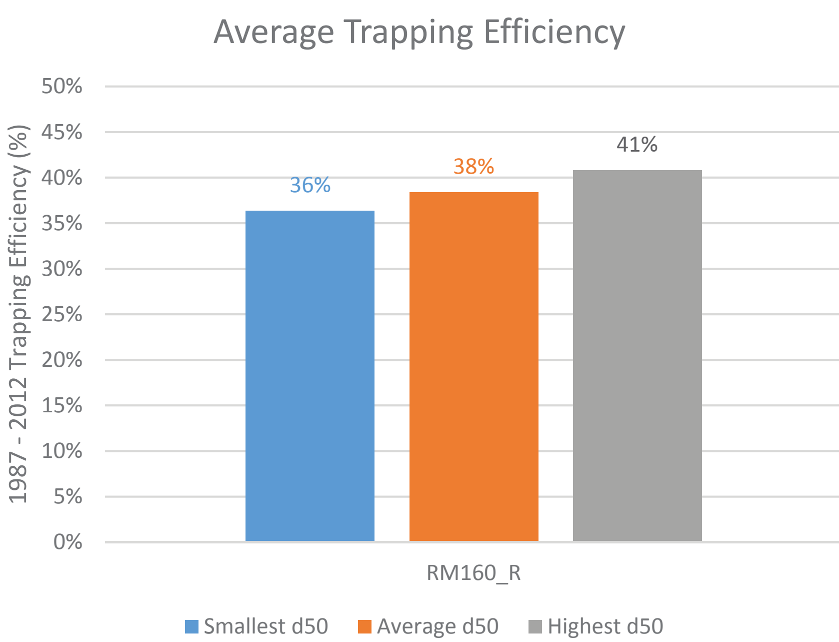


Exhibit 31. **Sedimentation Results using Varied Representative Sediment Sizes**

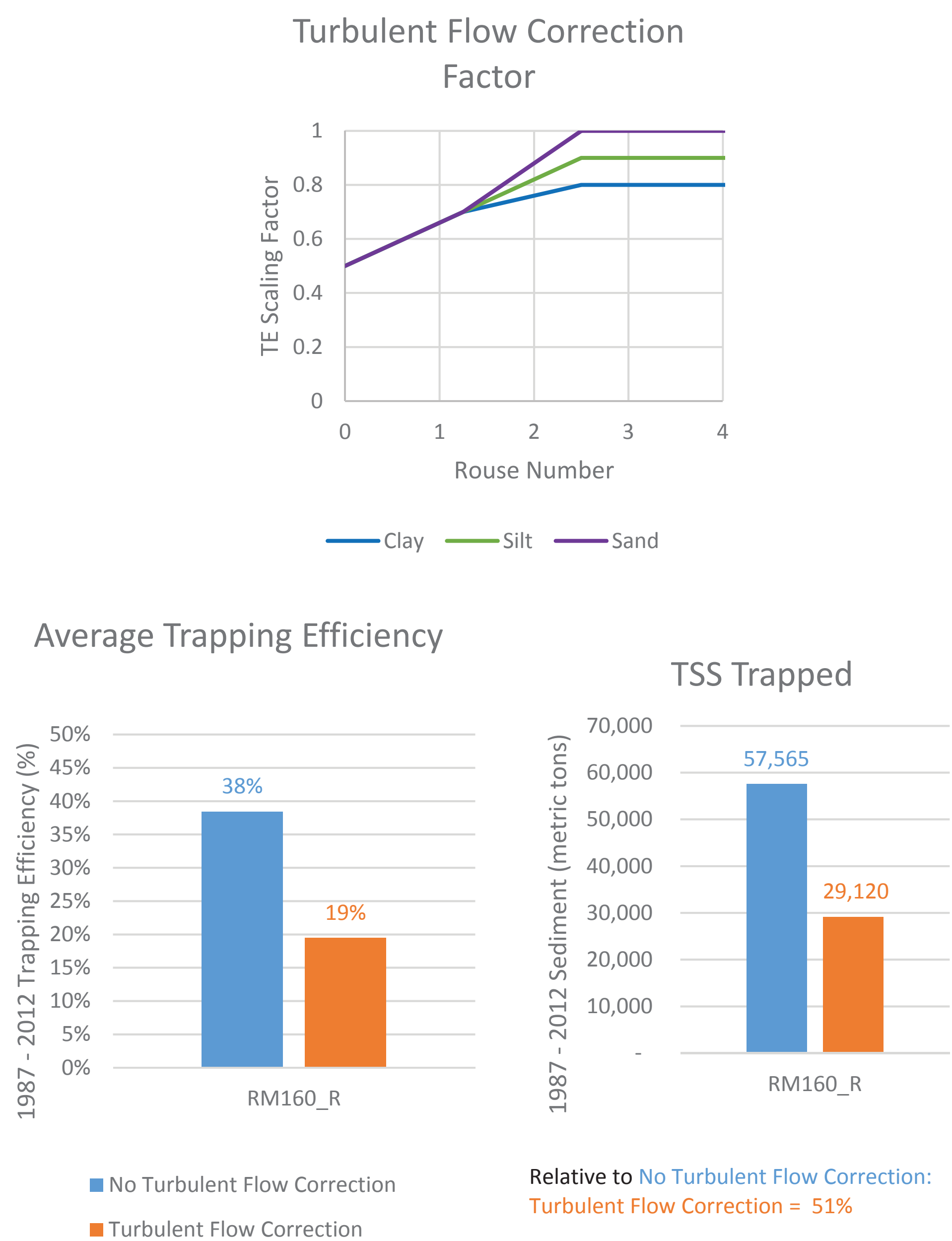


Exhibit 32. **Sedimentation Results using a Turbulent Flow Correction Factor**

ATTACHMENT A

Individual Off-channel Storage Area Routing Notes and Assumptions

ATTACHMENT A

Individual Off-channel Storage Area Routing Notes and Assumptions

Common methodologies for determining sediment flux, trapping efficiency, and sedimentation mass were used for off-channel storage areas and for overbank flow areas. These methods are described in the main text of this addendum. Some of the unique hydrology and hydraulics of individual floodplain elements were considered in sedimentation calculations to more accurately track flow and sediment flux. The following assumptions and notes describe some of these:

1. **General notes** (apply to all off-channel storage areas, unless otherwise noted)
   - Only positive flow is considered when adding multiple flows together for TE and sediment flux calculations.
   - Sediment over a Storage Area Connection (SAC) is calculated as SS_out (mass, not concentration times flow). This is transported even if there is no flow over the SAC. When Q is 0, Churchill TE is 100. For example: when no flow over (SAC 1281+1280), all of Killarney_SS_out still deposits into Moffit. Because Q into Moffit is 0, TE in Moffit is 100 percent, and all of Killarney_SS_out settles in Moffit.
   - Sediment out is assumed to have a single path. In the case of Killarney, all sediment out is assumed to go to Moffit; none is returned to river, even though flow leaves Killarney Tie Channel and Hidden Marsh.
   - Flows back to the river are not considered or quantified. Sediment returned to the river is not tracked.
2. **Model Storage Area Grouping**: the following storage areas were grouped into a single unit for area, volume and flow analysis. This areas were selected for grouping because of bi-directional flow between the areas, and in order to simplify the analysis.
   - Medicine Lake 3 [1262] and Medicine Lake 4 [1264]
   - East Schlepp Field [1263] and West Schlepp Field [1243]
   - Killarney Lake [1261] and Hidden Marsh/Campbell Lake [1260]
   - Upper Marsh 1 [1248] and Upper Marsh 2 [1250]. Flow enters Upper Marsh 2 first, then crosses over into Upper Marsh 1 over SAC 1287. During very high flows, flow enters Upper Marsh 1 and flows into Upper Marsh 2. Because the flow over 1287 is bidirectional, Upper Marsh 1&2 is treated as a single feature, with “common” flow path length.
   - Skeel Gulch [1247] and South Cataldo [9648]

3. **Sedimentation Analysis Routing**: the following storage areas were linked together for sediment routing. This means that the sediment leaving one storage area contributed to sediment entering another storage area. For the purpose of sedimentation analysis, all other storage areas received sediment only from the River.
    - Swan Lake [1265] contributes sediment to Blue Marsh [1239], which contributes sediment to Blue Lake [1240]
    - Medicine Lake [1262 & 1264] contributes sediment to Cave Lake [1242]
    - Strobl Marsh [1257] contributes sediment to Killarney Lake and Hidden Marsh/Campbell Lake [1261 & 1260], which contributes sediment to Moffit Slough [1259]
    - Lane Marsh 1 [1258] contributes sediment to Lane Marsh 2 [1238]
    - Bull Run Lake 1 [1252] contributes sediment to Bull Run Lake 2 [1254], which contributes sediment to Black Rock Slough [1255]
4. **Lane Marsh (Lane Marsh 1 [1258] and Lane Marsh 2 [1238])**
    - 100 percent trapping in Lane 2 [1258]
    - $(1\text{-}TE_{Lane1})SSC_{EnteringLane1}Q_{Lane1toLane2}$ = flux into Lane 2
    - If $Q_{Lane1toLane2} > Q_{RiverToLane1}$, use $Q_{RiverToLane1}$ to determine SS flux into Lane 2 so that sediment isn't "created"; conserve sediment mass coming from river
    - When $Q_{Lane1toLane2} < Q_{RiverToLane1}$, assume that sediment leaving Lane 1 but not entering Lane 2 is returning to river. This flow is not available from the model.
5. **Strobl Marsh [1257], Killarney Lake & Campbell Lake [1261 & 1260], Moffit Slough [1259]**
    - Single TE for Killarney even through multiple routes of flow (from Strobl, Killarney Tie Channel, and Hidden overbank). TE evaluated with one Q and one L
    - No flow from river in to Moffit
6. **Medicine Lake [1262 & 1264] and Cave Lake [1242]**
    - Assume that flow goes from River, to Medicine Lake 3&4 [1262&1264], to Cave [1242], to River. No other flow paths or sediment sources are accounted for. Assume that all sediment not trapped in Medicine 3+4 goes to Cave; some returns to River via Cave. This assumption is supported by model and Level Logger data. Total Medicine+Cave TE is: 97 percent.
    - Assume that Schlepp Field [1243 & 1264] does not contribute flow or sediment to Medicine Lake

7. **Swan Lake [1265], Blue Marsh [1239], and Blue Lake [1240]**
    - Ignores Q and SS from Blessing Slough
    - One single flow length for Swan 1, despite multiple entry points and paths.
    - Sediment into Swan 2 is sediment leaving Swan 1 multiplied by proportion of flow leaving LS 11987.67 to flow leaving SAC 1274, plus additional sediments directly from River.
    - Sediment into Blue is sediment leaving Swan 2 multiplied by proportion of flow leaving LS 10188.80 to flow leaving SAC 1270, plus additional sediments directly from River.
8. **Bull Run 1 [1252], Bull Run 2 [1254], and Black Rock Slough [1255]**
    - Include flow into Black Rock Slough from LS 30864 in addition to that from Bull Run 2 over SAC 1285.
    - Assume all sediment not trapped in Bull Run 1 goes to Bull Run 2, and all not trapped in Bull Run 2 goes to Black Rock Slough. Flow mostly follows these paths. During each flood event, flows first goes from River into Bull Run 2 via Black Rock, and then switch to flowing from Bull Run 1 to Black Rock via Bull Run 2. Overall volume tends to go from Bull Run 1 to Black Rock via Bull Run 2.