

## APPENDIX C

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### MEMORANDA FROM SYRACUSE RESEARCH CORPORATION AND E-MAIL FROM EPA

- PHASE II BEACH SURFACE SEDIMENT  
DATA QUALITY OBJECTIVES AND  
SAMPLING DESIGN (TONEL 2008A,  
PERS. COMM.)
- PHASE II BEACH SUBSURFACE  
SEDIMENT SAMPLING DESIGN  
RECOMMENDATION (TONEL 2008B,  
PERS. COMM.)
- FOLLOW-UP RE: SEDIMENT IVBA  
(STIFELMAN 2008, PERS. COMM.)



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
REGION 10  
1200 Sixth Avenue  
Seattle, WA 98101

May 21, 2008

**Reply to**  
**Attn Of:** ECL-111

Marko E. Adzic  
Manager, Environmental Engineering  
Teck Cominco American, Inc.  
501 North Riverpoint Boulevard, Suite 300  
Spokane, Washington 99202

Re: Upper Columbia River (UCR) Remedial Investigation and Feasibility Study

Dear Mr. Adzic:

The purpose of this letter is three-fold: (1) to provide Teck Cominco the data quality objectives (DQOs) and sampling design components for beach surface sediment sampling at the Upper Columbia River Site in support of the baseline human health risk assessment, (2) to highlight the portion of the enclosed May 20, 2008 memorandum that describes the need for beach subsurface sediment sampling (page 5), and (3) to inform Teck Cominco that the EPA will be requiring the submittal of a draft beach surface and subsurface sediment sampling and analysis plan.

The EPA, through its contractor, Syracuse Research Corporation, has prepared the enclosed May 20, 2008 memorandum on beach surface sediment sampling in support of sampling and analysis plan development. As stated in the May 20 memorandum, DQOs for subsurface sediments (>6 inches) will be provided to Teck Cominco under separate memorandum. Because of the anticipated need for EPA and Teck Cominco to further discuss beach sediment sampling-related matters, e.g., beach subsurface sediment sampling, EPA is not, at this time, establishing a due date for the submittal of a draft beach surface and subsurface sediment sampling and analysis plan.

Marc Stifelman and I will be in touch with you and/or your designated contact person(s) regarding further discussions on beach sediment sampling. If you have any questions, please feel free to contact me at (206) 553-0323.

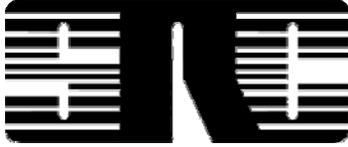
Sincerely,

A handwritten signature in cursive script that reads "Monica Tanel".

Monica Tanel  
Technical Team

Enclosure

cc: Participating Parties



Syracuse Research Corporation  
999 18<sup>th</sup> Street, Suite 1975  
Denver, CO 80202  
(303) 292-4760 phone  
(303) 292-4755 fax

***MEMORANDUM***

To: Monica Tonel, Marc Stifelman (EPA, Region 10)  
From: Lynn Woodbury, Bill Brattin (SRC)  
Task: FD052.CF999.842  
Date: May 20, 2008  
Re: Phase II Beach Surface Sediment Data Quality Objectives and Sampling Design

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As discussed in the draft Human Health Risk Assessment (HHRA) Workplan for the Upper Columbia River (UCR) Site (EPA 2008), surface sediment data from the UCR Site are available from several studies. However, the available data are not sufficient to fully characterize the nature and extent of contamination for all chemicals of interest (COIs), so additional sediment data are needed.

The purpose of this memorandum is to summarize the Data Quality Objectives (DQOs) for beach surface sediment sampling at the UCR Site in support of the baseline HHRA. This memorandum also includes the sampling design components of the beach sediment Sampling and Analysis Plan (SAP).

## 1.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) define the type, quality, quantity, purpose, and intended uses of data to be collected (EPA, 2006a). In brief, the DQO process typically follows a seven-step procedure, as follows:

1. State the problem
2. Identify the goal of the study
3. Identify information inputs
4. Define the boundaries (in space and time) of the study
5. Develop the analytic approach
6. Specify performance or acceptance criteria
7. Develop the detailed plan for obtaining data

Following these seven steps helps ensure that the project plan is carefully thought out and that the data collected will provide sufficient information to support the key decisions which must be made.

### 1.1 Step 1 – State the Problem

The UCR Site is located in the north central portion of the State of Washington and includes approximately 150 river miles of the Columbia River, extending from the United States-Canada border to the Grand Coulee Dam. A remedial investigation and feasibility study (RI/FS) is currently underway to investigate the nature and extent of contamination that has resulted from historical and continuing discharges of toxic substances into the Columbia River, including, but not limited to, releases from smelting processes and facility operations by Teck Cominco Metals Limited (TCM) at the Trail facility located in Trail, British Columbia.

#### 1.1.1 Site Conceptual Model

##### Sources of Contamination

**TCM Smelter.** The TCM facility is located on the UCR approximately 10 miles upstream from the U.S.-Canada border. Major current operations at the facility include primary smelting of zinc and lead ores and secondary smelting for production a variety of metal products, arsenic products, ammonium sulfate fertilizers, sulfuric acid, and ferrous granules (i.e., granulated slag) (EPA, 2003). Emissions from the TCM smelter, historic and current, that have potential relevance to the UCR Site include but are not limited to:

- discharges of liquid effluents to the UCR (currently treated on-site)
- discharges of granulated slag to the UCR prior to mid-1995 (currently stored on-site)
- accidental spills, “upsets”, and drainage to the UCR from seepage and surface runoff
- historical waste dumping into the UCR and tributaries
- discharges of gases and particulate aerosols to air

**Le Roi/Northport Smelter.** The Le Roi/Northport smelter is a former smelter located approximately 7 river miles downstream of the U.S.-Canada border in Northport, WA. The facility smelted cooper, gold, lead and silver ores intermittently from 1896 to 1922 (EPA, 2003). A soil removal action was conducted on the property and the town of Northport by EPA in 2004.

**Other Mines and Mills.** Numerous mines and mills in Stevens county, Pend Oreille county, and Ferry county have operated along the UCR and/or its tributaries.

**Other Industrial Processes.** A variety of other industrial operations are or were present in the vicinity of the UCR and its tributaries. Due to its proximity and associated compounds, a potentially significant operation is the Zellstoff Celgar Ltd. (Zellstoff) bleached kraft pulp mill in Castlegar, B.C., approximately 30 river miles upstream of the U.S.-Canada border (EPA, 2003). The facility has operated since 1960 and, prior to a 1994 plant modernization, discharged chlorinated organic compounds and fiber into the UCR (EPA, 2003) and sulfur emissions into the air.

**Municipal and Non-Point Sources.** A variety of municipal and non-point sources are potentially relevant to the UCR Site, including municipal wastewater and sewage treatment plants that discharge into the UCR and its tributaries, the Stevens County Sanitary Landfill, potential non-permitted discharges and spills to the UCR and its tributaries, agricultural runoff of nutrients and pesticides to surface water, and other non-point sources.

### Fate and Transport Mechanisms

Sediments at beaches and along the shoreline at the UCR Site are influenced by a complex series of fate and transport mechanisms. The Phase I Sediment Sampling Approach and Rationale (A&R) (CH2M HILL 2004) and the Data Evaluation (CH2M HILL 2006) reports provide a detailed description of the fate and transport of metals in sediment at the UCR Site. In brief, there are four primary transport mechanisms for the mobilization of COIs within the UCR, including:

- *Solution transport.* Dissolved COIs may be transported in solution until chemical conditions result in precipitation, sorption to particulates, or biological uptake.
- *Suspended transport.* Suspended particles of granulated slag or particle-bound COIs may be transported in the water column until flow velocities decrease to allow settlement and deposition.
- *Surface transport.* Small “mats” of granulated slag and fibrous materials containing granulated slag or other COIs can be transported along the water surface until they sink or become suspended in the water column.
- *Bed transport.* COIs in bed sediments may be transported through traction or saltation along the bottom of the river or reservoir.

In addition, there are several physical and chemical processes and anthropogenic activities that affect the fate and transport of COIs in UCR sediments. These processes include:

- Dam operations and UCR management
- Source reductions
- Granulated slag distribution, accumulation, and re-mobilization
- Sediment accretion and burial
- Biological uptake and conversion
- TOC-mediated bioavailability and mobility

The Phase I Sediment Sampling Data Evaluation (CH2M HILL 2006) report provides a detailed description of how these processes influence COI concentrations in sediment at the UCR Site.

## Human Populations of Potential Concern

The UCR Site is extensively used for recreation, subsistence hunting, fishing, and gathering, and for cultural pursuits important to local Native American tribes. In addition, several tribal, federal, state agencies, and local municipalities maintain facilities within the site (i.e., parks and campgrounds, marinas, ferry boats operations, and archeological sites), which provides additional opportunities for occupational contact with the site. Therefore, potential scenarios for exposure to COIs at site beaches and shorelines may include:

- Subsistence hunting, fishing, and gathering activities
- Residential activities
- Recreational activities (e.g., camping, swimming, boating)
- Occupational activities

### *1.1.2 Problem Statement*

Sediments along the bed and banks of the UCR are contaminated with COIs released into the environment by sources including, but not limited to, slag and other discharge effluent and emissions from the TCM facility in Trail, BC. Preliminary risk calculations using available data on the concentrations of metals and other contaminants in sediment (EPA 2008) indicate that metals are the contaminants most likely to be of concern to human health. Preliminary estimates of cancer risks from incidental ingestion of dioxins/furans in sediment under the most intensive exposure scenario were quite low (9E-08 to 5E-06) and were usually 20-500 times lower than cancer risks from arsenic (EPA 2008). Therefore, for the purposes of future surface sediment sampling efforts, EPA has decided to focus on metals and radionuclides<sup>1</sup> (e.g., U-238 and Ra-226), and rely on current data to assess risks from all other COIs.

While the existing sediment data set does provide information on spatial and temporal variability for a majority of the metals of interest, additional data are needed to provide:

- Measured metal and radionuclide sediment concentrations for some beaches that are of importance for human use
- Site-specific information on relative bioavailability (RBA) for metals in sediment
- Data on the variation of concentration of metals as a function of grain size

## **1.2 Step 2 – Identify the Goal of the Study**

The goal of the study is to collect additional sediment data that will allow reliable characterization of risks to humans who are exposed to the sediments. These findings will be used by risk managers to help determine whether or not EPA must take action at one or more locations to ensure that risks to humans from beach sediments along the UCR do not exceed an acceptable level.

## **1.3 Step 3 – Identify Information Inputs**

Two basic types of site-specific data are needed to determine the level of risk to humans exposed to sediments at specifically designated beach areas and other high-use bank shore areas along the UCR:

1. Reliable and representative measurements of the levels of chemicals that are present in beach sediments that may be encountered during human exposure scenarios.

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<sup>1</sup> U-238 and Ra-226 were added to the list of COIs in response to comments from the Participating Parties on the Draft HHRA Workplan (EPA 2008).

2. Reliable and representative data on the routes and levels of human exposure to the sediments.

Because metals are one important class of contaminants known to be of potential concern in sediments, two additional data needs include: 1) estimates of the relative bioavailability (RBA) of metals in the sediment, and 2) data on the natural (“background”) level of metals in sediments. Efforts to collect data on the RBA for lead and arsenic are included in this memorandum. DQOs to support collection of background sediment will be developed a later date under a separate memorandum in cooperation with the Participating Parties and other technical staff supporting the RI/FS.

## **1.4 Step 4 – Define the Boundaries of the Study**

### *1.4.1 Spatial Bounds*

There are three independent variables that are important to characterize the spatial pattern of contaminant levels in beach sediments:

1. **River mile.** Available data indicate that, with few exceptions (e.g., beryllium, nickel, vanadium), concentrations of most common metals tend to be highest in the upstream reaches of the UCR, and decrease as a function of distance downstream. In addition, there may be several other point and non-point sources along the length of the UCR that could contribute to contaminant levels.
2. **Elevation above water.** Because water levels are not constant over time, contaminant levels in beaches may also vary as a function of distance from the waters edge (i.e., elevation).
3. **Depth below the surface.** Similarly, because of varying rates of release and the effect of water flow, concentrations of contaminants in beach sediments may vary as a function of depth below the surface.

Thus, full characterization of contaminant levels in beach sediments requires reliable and representative data as a function of river mile, elevation, and depth. For the purposes of this planning effort, focus is placed on characterization of sediments in the interval between minimum and maximum water elevations, because these sediments are exposed (i.e., are above water) for at least some part of the year and are the most likely source of human contact with sediments. In addition, attention is focused on surface sediments (i.e., 0-6 inches), since these are the sediments that are likely to be contacted by most human receptors at the site.

DQOs for subsurface sediments (> 6 inches), which are of potential concern for humans who are exposed during construction, maintenance, or other excavation scenarios, will be developed at a later date under a separate memorandum in cooperation with the Participating Parties and other technical staff supporting the RI/FS. The subsurface sediment DQOs will address exposures for three exposure scenarios:

- 1) Recreational exposures associated with beach play digging
- 2) Occupational exposures associated with construction, maintenance, or utility work
- 3) Occupational exposures associated with archeological excavations (note: may not be practical to sample directly because of the potential to disturb artifacts or remains)

It is anticipated that subsurface sample core would be collocated with surface samples to quantify observed COI concentration trends as a function of depth. Because of the reduced potential for exposure and the greater difficulty collecting the samples relative to surface sediment samples, it is expected that the number of subsurface samples collected will be less than the number of surface samples. Evaluations of collocated surface and subsurface samples could be used to estimate or bound potential subsurface sediment exposures.

## Defining Exposure Areas

An exposure area (EA) is defined as location where a specified receptor is likely to be exposed at random over the course of the exposure duration (usually assumed to be many years). Due to the wide variety of receptor populations considered at this site, EAs could be quite variable in size, ranging from individual beaches to larger reaches. At this time, site-specific information on area usage is not available. It is anticipated that the future recreational use survey and the dietary survey for the Confederated Tribes of the Colville Reservation will provide information on typical use scenarios and patterns for the UCR Site. The EAs utilized in the baseline HHRA will be delineated based on these site-specific surveys.

For the purposes of this planning effort, the sampling design will be optimized to allow for the evaluation of potential risks across a range of EAs, ranging from individual beaches to larger reaches. It is believed that the natural unit of human exposure is no smaller than a beach.

### *1.4.3 Temporal Bounds*

#### Temporal Variability

Concentration values in sediments may tend to vary over time, especially when they are under water and subject to the various fate and transport processes that apply to submerged sediments. However, once a sediment becomes exposed, it is considered likely that concentrations will remain relatively constant until the sediment becomes re-submerged.

With regard to longer-term time trends and between-year temporal variability, one possible factor that might tend to cause a concentration change is the cessation of granulated slag discharges from the TCM facility in mid-1995. In addition, liquid effluent discharge rates from the TCM facility have also tended to decrease over time (Cox et al. 2005; Canada's National Pollutant Release Inventory [NPRI<sup>2</sup>]). Because of these factors, concentrations of metals in beach sediment may tend to decrease over time, although the rate and magnitude of any such trend are not known. Although releases from historically deposited slag along the river may tend to continue for many years, current reservoir and river management operations and the associated reduction in annual peak flow discharges (compared to historical conditions) have reduced the potential for large-scale mobilization or redistribution of historically deposited slag, so it is not considered likely that concentrations will tend to increase in the future.

Based on the assumption that concentrations of metals in sediment are either remaining about constant or tending to decrease over time, risk evaluations based on current sediment concentration values are unlikely to underestimate risks under future conditions. Therefore, even though long-term changes in concentration might be occurring, collection of long-term time trend concentration data is not considered to be a critical data gap for the purposes of the baseline HHRA.

#### Sample Collection Timing

Because the medium of interest for evaluating human exposures is exposed sediment, the time frame of interest for the collection of beach sediments is primarily dictated by when the sediments are exposed. Below Onion Creek (in the portion of the UCR most influenced by the reservoir), because the surface area of side bank sediments that are exposed reaches a maximum during the spring reservoir draw-down, sampling during the spring draw-down allows the greatest access for characterizing spatial patterns of

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<sup>2</sup> [http://www.ec.gc.ca/pdb/querysite/facility\\_history\\_e.cfm?opt\\_npri\\_id=0000003802&opt\\_report\\_year=2006](http://www.ec.gc.ca/pdb/querysite/facility_history_e.cfm?opt_npri_id=0000003802&opt_report_year=2006)

contaminants in exposed sediments. Above Onion Creek, side bank sediments are likely to be maximally exposed after spring run-offs in late summer/early fall when river discharge is at its typical seasonal low.

Therefore, sediment sample collection should be performed during the spring reservoir draw-down (i.e., late April-early May) for locations below Onion Creek and in late summer/early fall for locations above Onion Creek.

## 1.5 Step 5 – Define the Decisions to Be Made

EPA has not yet determined the final decision rules that will be used to judge whether risks to humans from beach sediments are above a level of concern. However, for the purposes of this planning effort, it is assumed that the decision will be based on the estimated level of cancer and non-cancer risks to an RME individual from the population with the greatest potential for contact with sediments (i.e., traditional subsistence scenario). The level of risk that would be considered unacceptable is a matter of risk judgment. For the purposes of planning sediment DQOs, it is assumed that the level of concern is 1/10 the typical CERCLA risk threshold, where the threshold cancer risk is 1E-04 and the threshold non-cancer hazard quotient is 1.0. Thus, Risk-Based Concentrations (RBCs<sup>3</sup>) for incidental ingestion of sediment were calculated based on a hazard quotient of 0.1 and a cancer risk of 1E-05. Table 1 presents the RBC values, along with available information on typical background (reference) concentrations in sediment and soil. As seen, for some metals, the RBC is within the range of available reference concentrations, which underscores the importance of collecting site-specific sediment data on background concentrations.

## 1.6 Step 6 – Specify Acceptable Limits on Decision Errors

### 1.6.1 Specifying Statistical Hypotheses

When making decisions in which concentrations are compared to a level of potential concern, statistical hypotheses should be established based on the presumption of contamination. In other words, the baseline condition (or null hypothesis,  $H_0$ ) should assume that sediments are contaminated, and the baseline condition should be retained until data indicate that it is highly unlikely to be true (EPA 2006a). For the purposes of this planning effort, the statistical hypotheses are defined as:

- $H_0$  – the true mean concentration of chemical  $i$  in surface sediment is greater than or equal to the sediment RBC
- $H_A$  – the true mean concentration of chemical  $i$  in surface sediment is less than the sediment RBC

### 1.6.2 Specifying Tolerable Limits on Decision Errors

In making decisions about the level of health risk associated with exposures to beach sediments, two types of decision errors are possible:

- A **false negative** decision error would occur if a risk manager decides that exposure to sediments is not of significant health concern, when in fact it is of concern.
- A **false positive** decision error would occur if a risk manager decides that exposure to sediments is above a level of concern, when in fact it is not.

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<sup>3</sup> This memorandum is not intended to summarize Applicable or Relevant and Appropriate Requirements (ARARs) or support decision-making on remedial alternatives. It is anticipated that the beach sediment site sampling and analysis plans (SAPs) would incorporate human and ecological RBCs, as well as all ARARs, when specifying the analytical requirements.

EPA is most concerned about guarding against the occurrence of false negative decision errors, since an error of this type may leave humans exposed to unacceptable levels of contaminants in beach sediments. For this reason, it is anticipated that risk estimates used in risk management decision-making will be based on the 95% upper confidence limit (UCL) of the long-term average concentration. Use of the 95UCL to estimate exposure and risk provides a high confidence that the risk estimates are more likely to be high than low, and there is no more than a 5% probability that the true mean is above the RBC.

EPA is also concerned with the probability of making false positive decision errors. Although this type of decision error does not result in unacceptable human exposure, it may result in unnecessary expenditure of resources. For the purposes of this effort, the goal is to seek to ensure that, if the true mean is  $\leq \frac{1}{2}$  the RBC, then risk (calculated based on the 95UCL) will not be deemed unacceptable more than 20% of the time. This goal can be achieved by adjusting the number of samples collected, since increased sample number tends to narrow the uncertainty distribution around the mean.

## 1.7 Step 7 – Develop the Detailed Plan for Obtaining Data

### 1.7.1 Estimating the Number of Samples Needed per Exposure Area

#### General Approach

The relationship between the number of samples ( $n$ ) needed per EA in order to achieve the DQOs objectives for both false negative and false positive decision-making depends on: a) the nature of the underlying distribution and its inherent variability, and b) the proximity of the mean to a decision threshold. For convenience, the ratio of the true mean to the decision threshold may be indicated by  $\gamma$ . The highest quantity of data is needed when  $\gamma$  is close to 1 (e.g., 0.5 to 0.9). If the true mean is much lower than the RBC (e.g.,  $\gamma < 0.1$ ), a large dataset is not necessary to make the appropriate risk management decision.

In most cases, environmental data sets are right skewed, and are often reasonably well approximated by lognormal distributions. Based on this, Monte Carlo simulation was used to investigate the probability of a false positive decision as a function of  $\gamma$ , sample size ( $n$ ), and the value of the log-transformed standard deviation ( $\sigma$ ). Samples were drawn from a lognormal distributions with parameters  $\mu$  and  $\sigma$  (the log-transformed mean and standard deviation). The arithmetic mean for this distribution is given by:

$$\text{mean} = \text{EXP}(\mu + 0.5 \cdot \sigma^2)$$

The initial assessment focused on the case when  $\gamma = 0.5$ , since this is the value selected to define the DQO to limit false positive decision-making. The 95UCL was calculated based on Land's H-UCL (Land 1971, 1975), as follows:

$$UCL = \text{EXP}(\mu + 0.5 \cdot \sigma^2 + \sigma \cdot H_{1-\alpha} / \sqrt{n-1})$$

where:

- $\mu$  = mu, log-transformed mean
- $\sigma$  = sigma, log-transformed
- $\alpha$  = desired confidence level (for 95UCL,  $\alpha = 0.05$ )
- $H$  = H statistic ( $1 - \alpha$ )
- $n$  = number of samples

If the calculated 95UCL was larger than the RBC, this results in a false positive decision error.

Figure 1 shows the probability of a false positive decision error as a function of  $n$  for several different values of  $\sigma$  (ranging from 0.1 to 1.5) when the true mean is  $\frac{1}{2}$  the RBC. As shown, when  $\sigma = 1.0$ , the number of samples needed per EA to limit the probability of a false positive decision error to less than 20% is about 30 samples. As the value of  $\sigma$  increases, the number of samples needed to ensure a false positive rate of less than 20% also increases.

As noted above, the choice of defining the true mean as  $\frac{1}{2}$  the RBC as the goal for limiting false positive decision errors is a risk management judgment. This decision is based on the understanding that if the ratio of the true mean to the RBC ( $\gamma$ ) were lower, the number of samples needed to ensure a false positive rate of less than 20% would decrease. Conversely, if  $\gamma$  were higher, the number of samples needed to ensure a false positive rate of less than 20% would increase. This is illustrated in Figure 2. This figure shows the probability of a false positive decision error as a function of  $n$  for several values of  $\gamma$  (ranging from 0.2 to 1.0). In these simulations, the value of  $\sigma$  was held constant at 1.0. As seen, as  $\gamma$  increases from 0.6 toward 1.0, the number of samples needed ensure a false positive rate of less than 20% rapidly becomes too high to feasibly be implemented.

### Estimating the Value of $\sigma$

The value of  $\sigma$  (the between sample log-standard deviation) is dependent upon how the data are divided into EAs. Because the number of samples needed is highly dependent upon  $\sigma$ , delineation of EAs is an important component of the sampling design.

As noted above, the delineation of EAs is based mainly on the likely activity patterns of the exposed human receptor populations. Exposures are assumed to be random over an EA, and risk from a chemical is related to the arithmetic mean concentration of that chemical averaged over the entire EA. Over the course of multiple years, many individuals will access the UCR Site at a number of different locations rather than always going to the exact same location. Therefore, the upper boundary of the size of an EA will be a reach. The UCR Site was segregated into six reaches based on consideration of distinct geomorphic features, general hydraulic characteristics, and expected differences regarding the principal mechanisms for transport or deposition of particle-bound chemicals of interest.

- **Reach 1** extends from the U.S-Canada border (USGS RM 745) southward past the city of Northport to USGS RM 730, near Onion Creek.
- **Reach 2** extends from near Onion Creek (USGS RM 730) to the approximate upstream head of Marcus Flats (USGS RM 711).
- **Reach 3** extends from the approximate upstream head of Marcus Flats (USGS RM 711) to just downstream of Kettle Falls (USGS RM 699).
- **Reach 4** extends from just downstream of Kettle Falls (USGS RM 699) to just upstream of the confluence with the Spokane River (USGS RM 640) and represent the middle reservoir. This reach is further divided into two sub-reaches. **Reach 4a** extends from USGS RM 699, at the confluence of the Colville River, to USGS RM 676, just upstream of Inchelium. **Reach 4b** extends from USGS RM 676 to USGS RM 640 near the confluence with the Spokane River.
- **Reach 5** extends from USGS RM 640 to USGS RM 617.
- **Reach 6** extends from USGS RM 617 to the Grand Coulee Dam (near USGS RM 597).

However, because some individuals may visit the UCR Site within a use area that is smaller than the reaches specified above, the lower size boundary of an EA will be represented as a single beach. EPA believes the natural unit of exposure is no smaller than a beach.

As noted previously, at this time, site-specific information on area usage is not available. It is anticipated that the future recreational use survey and the dietary survey for the Confederated Tribes of the Colville Reservation will provide information on typical use scenarios and patterns for the UCR Site. The EAs utilized in the baseline HHRA will be delineated using information from these site-specific surveys.

#### Estimates of $\gamma$ and $\sigma$ for Varying Exposure Areas

As noted above, for a specified EA, the number of samples needed to ensure an acceptable false positive rate depends upon the proximity of the true mean to the RBC ( $\gamma$ ) and the underlying variability ( $\sigma$ ) in the concentration distribution.

Several data sets are available which provide information on measured metal concentrations in surface sediment at the UCR Site that can guide the sampling design planning. This evaluation is based only on transect bank sediment samples from the 2005 EPA Phase I Sediment Study because they are representative of grab samples<sup>4</sup> across the UCR Site. Sediment data were grouped by reach and by 10-mile segment. Ideally, data in this evaluation would have been grouped by reach and by beach, to represent the full range of EA sizes. However, the available transect sediment data set is too limited to provide meaningful statistics grouped by beach. Therefore, a 10-mile segment approach was used to provide estimates for a smaller EA size.

Table 2 presents a summary of observed  $\gamma$  values by reach and by 10-mile segment. As seen, most reaches and 10-mile segments have one or more metals with observed  $\gamma$  values between 0.3 to 0.6. Therefore, it is important to optimize the sampling design to allow reliable evaluation of the risk from the “close call” metals.

Table 3 presents a summary of the observed values of  $\sigma$  for metals by reach and by 10-mile segment. As seen, observed values of  $\sigma$  range from about 0.1 to 1.3 by reach and 0.03 to 1.7 by 10-mile segment.

It is important to note that measured estimates of  $\sigma$  are only uncertain estimates of the true underlying value of  $\sigma$ , with the degree of uncertainty depending on the true value of  $\sigma$  and the number of samples collected. Figure 3 provides an example of the variability in observed values of  $\sigma$  as a function of the size of the data set. In this example, the true  $\sigma$  is equal to 1.0. When the size of the data set is 50 samples, observed values of  $\sigma$  may range from about 0.8 to 1.2. As the number of samples decreases, the width of the variability range increases. Therefore, because most of the values of  $\sigma$  shown in Table 3 are based on data sets of 30 samples or less, they should not be interpreted as highly precise.

Table 4 presents a summary of the observed values of  $\sigma$  for the “close call” metals identified in Table 2. In most instances, the observed value of  $\sigma$  is about 0.8, but can range up to about 1.2-1.3 for some metals (depending on whether samples are grouped by reach or by 10-mile segment). This means that the number of samples per reach needed to limit false positive decision errors will vary from about 20 to 50 samples, depending upon  $\sigma$  (using the relationships illustrated in Figure 1).

#### Example for Zinc

Figure 4 presents concentrations of zinc in transect bank sediment grab samples by river mile, stratified into each reach. As seen, concentrations tend to be highest in Reach 1 with levels generally decreasing downstream. As indicated in the table below the figure, the observed values of  $\sigma$  for zinc tend to be higher in the upper reaches (1.1 to 1.2) than in the lower reaches (0.5 to 0.8). Based on these reach-

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<sup>4</sup> Samples collected using compositing strategies will tend to reduce the variability in the underlying distribution of the data set and were excluded.

specific values of  $\sigma$ , and using the relationships illustrated in Figure 1, it is estimated that 10 to 45 samples would be needed for each reach in the upper reaches and 10 to 20 samples would be needed for each reach in the lower reaches to ensure a false positive rate of less than 20% for zinc.

Figure 5 presents concentrations of zinc in sediment by river mile stratified into 10-mile segments. As indicated in the table below the figure, values of  $\sigma$  ranged from about 0.3 to 1.4 across 10-mile segments, with the highest values above river mile 690. For 10-mile segments where the value of  $\sigma$  is above 1.0, more than 30 samples would be needed for each segment to ensure a false positive rate of less than 20%.

### *1.7.2 Selection of Sampling Locations*

Although the existing sediment data set includes numerous samples from beaches and bank areas across the UCR Site, the available sediment samples do not provide data for some areas of importance for human use. Table 5 presents the 33 beaches that have been identified for sampling as part of the Phase II effort based on the findings of the 2005 Phase I beach sampling effort by EPA, community input, as well as input from the Participating Parties. Figure 6 presents a map of the 33 selected beaches. These sampling locations were selected because they represent areas that are important based on human use.

### *1.7.3 Assessment of the Importance of Elevation*

As described above, one of the important processes that influences fate and transport of contaminants in sediment is water level fluctuations as a result of Grand Coulee Dam operations. Ongoing reservoir management protocols have maintained a fairly controlled set of conditions in the UCR. On average, water elevation from June through December is at about 1,285 ft above mean sea level (amsl). From January through May, water elevation decreases steadily, with a low pool elevation of about 1,245 ft amsl in April/May<sup>5</sup>.

While it is expected that most recreational visitors would be exposed to sediments in the summer months during a high pool conditions, other populations of interest (e.g., subsistence, occupational) may have year-round exposures to sediments. Because slag and other contaminants are deposited in beaches via water transport, and because the level of the water may vary over time, it is possible that the level of contamination in beaches may vary as a function of elevation above the low water level. If so, individuals who are exposed primarily along the waters edge (e.g., individuals that fish or gather basket-making materials) may be preferentially exposed to sediments from the lower elevation, while individuals that camp or hunt may be exposed to sediments from the middle or upper elevations. If spatial gradients are apparent as a function of elevation, not accounting for these differences in the delineation of decision areas may either over- or under-estimate actual risks.

Beach sediment data<sup>6</sup> collected from three elevations during low pool conditions in 2005 were evaluated in order to determine if spatial gradients were apparent as a function of elevation. At each of 15 beaches, a 3-point composite sample was collected representing the lower (1,255 ft amsl), middle (1,270 ft amsl), and upper (1,285 ft amsl) elevation. Figure 7 presents a comparison of sediment concentrations at the lower elevation to concentrations at the middle and upper elevation for arsenic, cadmium, copper, iron, lead, and zinc<sup>7</sup>. In these graphs, values are plotted above zero when concentrations are higher at lower elevation relative to middle or upper elevation, and values are plotted below zero when concentrations are higher at middle or upper elevations relative to lower elevation. As shown, a tendency for a spatial

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<sup>5</sup> Data from Columbia River Data Access in Real Time (DART) - <http://www.cbr.washington.edu/dart/dart.html>

<sup>6</sup> This evaluation is based on beach composite samples from the 2005 EPA Phase I study.

<sup>7</sup> These metals were selected because they are likely to be constituents of granulated slag and have a detection frequency of at least 80%.

pattern is apparent in the upper reaches (i.e., upstream of about river mile 700, Reaches 1-3), with concentrations at the lower elevation tending to be higher than the middle or upper elevation. In the lower reaches, differences in concentration as a function of elevation are not apparent.

However, just because spatial gradients may be present in the upper reaches, this does not necessarily mean that these differences are important for the purposes of making risk management decisions. If the risk management decision for the EA when accounting for differences in elevation is the same as when differences in elevation are ignored, then characterizing changes in concentration as a function of elevation is of less importance.

In order to evaluate the importance of stratifying exposure as a function of elevation, risk estimates for each beach were calculated using the RBCs shown in Table 1 based on the beach-wide mean concentration (Approach A) and based on the lower elevation concentration (Approach B). In order to determine if risk management decisions would differ depending upon the elevation approach, results were summarized using the following matrix:

|   |                              | <b>Approach A: Based on Beach-Wide Mean Conc.</b> |                              |
|---|------------------------------|---|------------------------------|
|   |                              | Risks below level of concern                      | Risks above level of concern |
| <b>Approach B: Based on Lower Elevation Conc.</b> | Risks below level of concern | agree   | false positive               |
|   | Risks above level of concern | false negative                                    | agree                        |

As illustrated, a false negative decision error would occur if a risk manager decides that exposure to sediments at a specified beach is not of significant health concern based on the beach-wide approach, when in fact it is of concern based on the lower elevation approach. EPA is most concerned about guarding against the occurrence of false negative decision errors, since an error of this type may leave humans exposed to unacceptable levels of contaminants in beach sediments.

Table 6 summarizes the results of this evaluation for arsenic, cadmium, copper, iron, lead, and zinc. As seen, for most metals, the false negative error rate is 0%, which indicates that use of a beach-wide approach is unlikely to leave humans exposed to unacceptable levels of contaminants in beach sediments. However, for cadmium, use of the beach-wide approach would not have been adequately protective at 2 beaches.

These results suggest that spatial gradients as a function of elevation are unlikely to be important for the purposes of making risk management decisions for most metals at most locations. A similar evaluation performed using the elevation-stratified targeted sediment data from Majewski et al. (2003) supports the conclusion that for most metals, stratification by elevation is not likely to alter risk conclusions. In addition, because risk management decisions will be based on total risks across all metals, potential differences in metal-specific risks as a function of elevation are not likely to significantly influence risk management decisions at a beach. Therefore, the sample design should not stratify EAs based on elevation.

#### 1.7.4 Choosing a Sampling Design

##### Use of Compositing

When selecting a sampling design, the goal is to make efficient use of available time, money, and human resources, without sacrificing the representativeness and quality of the collected data. One way to minimize analytical costs is to utilize a compositing sampling protocol. Compositing reduces the number of analyses performed, while still allowing an accurate estimate of the population mean. In addition, because the variation between composite samples tends to be lower than the variation between grab samples, uncertainty around the mean of a set of composites is smaller than for a set of grab samples.

For this analysis, let:

$$\begin{aligned}n &= \text{total number of grab samples collected} \\m &= \text{numbers of composite samples prepared from the } n \text{ grab samples} \\k &= \text{number of grab samples per composite sample} = n/m\end{aligned}$$

Based on the central limit theorem, as the number of grab samples per composite ( $k$ ) increases, the distribution of the sampling variability between composites will approach a normal distribution. The 95UCL of the mean for data drawn from a normal distribution is given by:

$$95UCL = \text{mean} + \text{stdev} \cdot t_{m-1} / \sqrt{m}$$

However, for values of  $m$  less than several hundred, the approach to normality is incomplete, and the distribution of composite values is only approximately normal.

The results of a Monte Carlo simulation based on an assumed underlying lognormal distribution with a  $\sigma$  value of 1.25 (representative of a high-end  $\sigma$  value based on measured sediment data; see Table 2) and an assumed total of 60 grab samples are shown in Figure 8. In this figure, Panel A presents results where the UCL is calculated using the lognormal (Land) equation and Panel B presents results where the UCL is calculated using the normal t-equation. As shown in Panel A, if any compositing strategy is employed, computation of 95UCL values using the lognormal UCL equation results in an increase in the frequency of 95UCL values that are smaller than the true mean, such that the tolerable limit for a false negative decision error (5%) is substantially exceeded. Based on this, it is clear that it is not appropriate to use the lognormal UCL equation for samples that are composites, even when the grab samples are drawn from an underlying lognormal distribution.

Using the normal t-equation to calculate the UCL (Figure 8 Panel B) reduces the false negative error rate considerably, but values are still above the goal of 5%. This can be compensated for by computing the 99% UCL rather than the 95% UCL. The results of a Monte Carlo simulation based on an assumed underlying lognormal distribution with a value of  $\sigma$  of 1.25 and an assumed total of 60 grab samples are shown in Figure 9. In this figure, Panel A presents results based on a 95UCL and Panel B presents results based on a 99UCL, both calculated using the normal t-equation.

Table 7 (Panel A) presents statistics for false positive and false negative error rates for alternate compositing strategies based on a total of 60 grab samples. As seen, based on the 99UCL, a strategy of 10 composites of 6 each yields a false negative error rate of 7% (slightly higher than the target of 5%), and a false positive error rate of 16% (slightly better than the target of 20%). A strategy of 5 composites of 12 each improves the false negative error rate to achieve the goal of 5%, although the false positive error rate increases to slightly above the goal of 20%.

As illustrated in Table 4, values of  $\sigma$  for many of the “close call” metals are usually about 0.8. In this case ( $\sigma = 0.8$ ), fewer composites and/or fewer grab samples per composite may be adequate. Table 7 (Panel B) presents statistics for false positive and false negative error rates for alternate compositing strategies based on a total of 30 grab samples. As seen, assuming  $\sigma = 0.8$ , a strategy of 6 composites of 5 each will be more than adequate if the mean is about  $\frac{1}{2}$  the RBC ( $\gamma = 0.5$ ), and 3 composites of 10 each will be more than adequate if the mean is about  $\frac{1}{4}$  the RBC ( $\gamma = 0.25$ ).

Based on this evaluation, the sampling design should use a compositing approach of 5 composites of 12 grab samples at each of the 33 beaches selected for sampling. This compositing strategy will achieve the DQOs for COIs with high variability ( $\sigma = 1.25$ ), and will be more than adequate for COIs with lower variability ( $\sigma = 0.8$ ) and/or where the ratio of the true mean to the RBC ( $\gamma$ ) is less than 0.5.

### Sample Collection Design

In the HHRA, exposures are assumed to be random over an EA, and risk from a chemical is related to the arithmetic mean concentration of that chemical averaged over the entire EA. Thus, capturing spatial variability within a designated EA is not necessary. EPA believes the natural unit of exposure is no smaller than a beach, so a sampling methodology that incorporates collection of samples across a beach addresses the data needs for the baseline HHRA. To ensure that samples are representative of the beach being investigated, the grab sampling points should be spatially distributed across the entire beach. This ensures that if “hot spots” of contamination are present at a beach, they would be represented in approximate proportion to their areal extent.

Grab sampling points at each beach should be identified using a systematic grid overlay approach<sup>8</sup>. The grid size will be beach-specific and determined based on an estimate of the beach size divided by the target number of grab sample points. For example, if a specified beach is 37,500 ft<sup>2</sup>, the optimum grid size to accommodate 5 composites of 12 grab samples each (60 target grab sample points) would be a grid of 25 ft x 25 ft (37,500 ft<sup>2</sup> / 60 = 625 ft<sup>2</sup>; 25 ft x 25 ft = 625 ft<sup>2</sup>). Grab sample points would be placed at the center of each grid and composited in accordance with a systematic overlapping approach (i.e., every 5th grab sample collected would be composited together based on a systematic grid traverse approach). Figure 10 illustrates this compositing strategy. For the purposes of this illustration, the starting point was placed in the upper left corner; in the field, the starting grid would be selected randomly. This sample collection design ensures beach-wide spatial coverage and allows for estimation of the arithmetic mean within acceptable limits on uncertainty.

## **2.0 ADDITIONAL EVALUATIONS**

### *2.1 Size-Fractioning Evaluation*

As described in the HHRA Workplan, the main pathway by which humans are likely to be exposed to contaminants in sediment is by incidental ingestion of sediment particles adhering to the hands. Although data are limited, for soil exposures, it is generally expected that smaller “fine” particles are more likely to adhere to the hands than coarse particles (Choate et al., 2006; Kissel, Richter & Fenske, 1996). For sediment exposures, due to the wet nature of sediments, the adherence of coarse particles may occur more frequently relative to soils, but the degree to which this may occur is unknown (Choate et al., 2006; Kissel, Richter & Fenske, 1996). Studies at other sites have shown that concentrations of metals between

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<sup>8</sup> Software tools such as Visual Sampling Plan (VSP) can be utilized to implement this sampling approach. <http://vsp.pnl.gov>

different size fractions (e.g., fine, coarse) can vary from concentrations reported in the bulk sample (EPA 2001; EPA 2007a).

At the UCR Site, information on variation of concentration as a function of grain size is limited. During the 2005 EPA Phase I Sediment Study, sediment samples from three beaches – Northport Boat Launch (RM735), Kettle Fall Swim Beach (RM700), and Columbia Campground (RM635) – were separated into particles less than 75  $\mu\text{m}$  (“fine”) and particles greater than 75  $\mu\text{m}$  (“coarse”). Table 8 summarizes the metal concentrations for each size fraction. Figure 11 presents a comparison of the metal concentration in the fine fraction to the coarse fraction. In this figure, a ratio greater than 1.0 indicates that concentrations in the fine fraction were higher than the coarse fraction. Based on a review of this figure, these data show:

- At beaches in the lower reaches (Kettle Falls Swim Beach and Columbia Campground), concentrations in the fine fraction tend to be about 2 times higher than the coarse fraction for all metals.
- At the Northport Boat Launch, concentrations in the coarse fraction were higher than the fine fraction for several metals, including aluminum, antimony, calcium, chromium, cobalt, copper, iron, manganese, potassium, selenium, sodium, and zinc. This is consistent with the hypothesis that these metals are associated with the coarse-grained granulated slag materials that have been deposited in the upper reaches.
- For mercury, concentrations in the fine fraction were consistently higher than the coarse fraction at all beaches.

Based on these limited data, it appears that sediment concentrations of metals do vary as a function of particle size and that the relationship between the particle size and concentration will likely vary spatially. Therefore, beach sediment samples collected during the Phase II Sediment Study should incorporate size-fractioning to allow for a more robust evaluation of the relationship between sediment particle size and metal concentrations throughout the UCR Site. One composite sample per beach should be randomly selected and split for size-fractioning analysis.

The selection of the appropriate size-fractioning cut-offs is based on professional judgment. In other EPA regions, when evaluating human health risks from soil ingestion, a 250  $\mu\text{m}$  (60 mesh) sieve is used to separate coarse particles from fine particles. Because adhering soil is mostly composed of particles less than 125  $\mu\text{m}$  (Choate et al., 2006), finer sediments will be sieved using a 125  $\mu\text{m}$  (115 mesh) sieve. At the UCR Site, it will also be useful to separate the fine fraction even further using a 63  $\mu\text{m}$  (250 mesh) sieve. According to Majewski et al. (2003), sediment particles less than 63  $\mu\text{m}$  are expected to be representative of airborne dusts generated during ambient and high-wind conditions. In addition, STI (2006) states that sediment particles less than 63  $\mu\text{m}$  are representative of the size fraction most likely to be incidentally ingested by Tribal members. Therefore, the selected beach sediment samples should be sieved into four fractions:

- 2 mm - 250  $\mu\text{m}$
- 250  $\mu\text{m}$  - 125  $\mu\text{m}$
- 125  $\mu\text{m}$  - 63  $\mu\text{m}$
- < 63  $\mu\text{m}$

While some beach areas may have a limited quantity of particles within the < 63  $\mu\text{m}$  fraction, the sediment investigation conducted by Majewski et al. (2003) has illustrated that it is possible to obtain sufficient sample size within this size fraction at locations throughout the UCR Site. Sample preparation methods should be based on established techniques similar to those employed in Majewski et al. (i.e.,

Fishman and Friedman (1989), Horowitz et al. (1989; 2001)) to reduce the potential for data quality issues related to sample preparation.

## 2.2 Relative Bioavailability (RBA) Evaluation

In the HHRA Workplan, when evaluating ingestion exposures of metals from sediment, the RBA was set equal to default values (i.e., 0.8 for arsenic, 0.6 for lead, 1.0 for all other metals) (EPA 1994; EPA 2000). However, it is considered likely that the absorption of metals from sediment may not be as high as from food or water, so this approach will often tend to overestimate risks from incidental ingestion of sediment. Therefore, it would be desirable to have reliable site-specific RBA data for metals in sediment in order to support adjusting the toxicity factors for the baseline HHRA.

The best method of determining RBA is through *in vivo* bioavailability studies. However, because *in vivo* studies can be slow and costly, scientists have been working to develop alternative *in vitro* procedures that may provide faster and less costly alternatives for estimating RBA. In the case of lead, estimates of RBA can be determined from the fraction of lead which solubilizes in an *in vitro* system is referred to as *in vitro* bioaccessibility (IVBA) (EPA, 2007b).

Similar studies have been performed for arsenic. However, at present, the correlation between *in vivo* relative bioavailability (RBA) and IVBA for arsenic is relatively weak ( $R^2 = 0.17$ ) (EPA 2005). Because of this, EPA has determined that it is not possible to make accurate quantitative estimates of RBA from currently available IVBA data. However, IVBA data will provide useful qualitative information regarding the likely degree of accuracy of the default assumption that the RBA of arsenic is 0.8. For example, if the IVBA data yield results mainly  $< 0.4$ , it would be concluded that a value of 0.8 is likely too conservative and that risk estimates based on this value are likely somewhat too high. This information would be presented in the uncertainties section of the baseline HHRA.

Beach sediment samples collected during the Phase II Sediment Study should be analyzed for lead and arsenic using IVBA analysis methods to allow for site-specific refinements in the RBA used when evaluating potential risks from incidental ingestion of sediment. Because IVBA may depend upon grain size, IVBA analyses should be performed on each of the three size-fractionated sample aliquots described above.

## 3.0 DATA QUALITY ASSESSMENT

EPA's seven-step DQO process (EPA 2006a) was developed to provide a *prospective* process for ensuring sampling programs meet data quality needs. EPA has also developed a Data Quality Assessment (DQA) process (EPA 2006b) which provides the methodology for performing a *retrospective* evaluation of environmental data to determine if they meet the program objectives and are of the right type, quality, and quantity to support their intended use. Although the DQA is typically performed after data collection, the formulation of statistical hypotheses and statements of acceptance criteria are important components of the both the DQO process and the DQA.

Prior to performing the baseline HHRA, the available sediment data will be evaluated to ensure they are adequate to support risk management decisions for human health. Figure 12 provides the retrospective decisional flow chart (DFC) that will be used to evaluate environmental data adequacy for each exposure medium. As seen, the DFC is medium, EA, and COI-specific, and considers spatial and temporal representativeness, detection limit adequacy, and uncertainty in determining data quality for the baseline HHRA. If it is determined that the data are not adequate to support risk calculations, risk managers will determine if additional data will be collected to support human health risk management decisions. If additional sediment sampling is needed, DQOs would be developed to guide future data collection efforts.

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**TABLE 1**  
**RISK-BASED CONCENTRATIONS (RBCs) FOR INCIDENTAL INGESTION OF**  
**METALS AND RADIONUCLIDES IN SURFACE SEDIMENT**

| Analyte Name | Non-Cancer                            |             |                      | Cancer                                   |            |                      | Lowest Sediment RBC (mg/kg) | Notes | Sediment Reference Concentration Range (mg/kg) [1] |
|--------------|---------------------------------------|-------------|----------------------|--|------------|----------------------|-----------------------------|-------|--|
|              | Target HQ: 0.1                        |             |                      | Target Risk: 1E-05                       |            |                      |                             |       |  |
|              | HIF <sub>sed</sub> (kg/kg-d): 1.7E-05 |             |                      | HIF <sub>TWAsed</sub> (kg/kg-d): 4.9E-06 |            |                      |                             |       |  |
|              | oRfD (mg/kg-d)                        | oRfD Source | Sediment RBC (mg/kg) | oSF (mg/kg-d) <sup>-1</sup>              | oSF Source | Sediment RBC (mg/kg) |                             |       |  |
| Aluminum     | 1.0E+00                               | P           | 5,733                | --                                       |            | --                   | 5,733                       |       |  |
| Antimony     | 4.0E-04                               | I           | 2.3                  | --                                       |            | --                   | 2.3                         |       | 0.1 - 1.4  |
| Arsenic      | 2.4E-04                               | I           | 1.38                 | 1.9E+00                                  | I          | 1.09                 | 1.09                        | (a)   | 1 - 10   |
| Barium       | 2.0E-01                               | I           | 1,147                | --                                       |            | --                   | 1,147                       |       |  |
| Beryllium    | 2.0E-03                               | I           | 11                   | --                                       |            | --                   | 11                          |       |  |
| Cadmium      | 1.0E-03                               | I           | 5.7                  | --                                       |            | --                   | 5.7                         | (b)   |  |
| Calcium      | --                                    |             | --                   | --                                       |            | --                   | --                          |       |  |
| Chromium     | 1.5E+00                               | I           | 8,600                | --                                       |            | --                   | 8,600                       | (c)   |  |
| Cobalt       | 2.0E-02                               | P           | 115                  | --                                       |            | --                   | 115                         |       |  |
| Copper       | 4.0E-02                               | H           | 229                  | --                                       |            | --                   | 229                         |       | 10 - 25  |
| Iron         | 7.0E-01                               | P           | 4,013                | --                                       |            | --                   | 4,013                       |       | 5,100 - 34,000                                     |
| Lead         |                                       |             |                      |  |            |                      | 400                         | (d)   | 8 - 47   |
| Lithium      | 2.0E-02                               | E           | 115                  | --                                       |            | --                   | 115                         |       |  |
| Magnesium    | --                                    |             | --                   | --                                       |            | --                   | --                          |       |  |
| Manganese    | 4.7E-02                               | I           | 268                  | --                                       |            | --                   | 268                         | (e)   | 129 - 1,000  |
| Mercury      | 3.0E-04                               | I           | 1.7                  | --                                       |            | --                   | 1.7                         | (f)   |  |
| Molybdenum   | 5.0E-03                               | I           | 29                   | --                                       |            | --                   | 29                          |       |  |
| Nickel       | 2.0E-02                               | I           | 115                  | --                                       |            | --                   | 115                         |       |  |
| Potassium    | --                                    |             | --                   | --                                       |            | --                   | --                          |       |  |
| Selenium     | 5.0E-03                               | I           | 29                   | --                                       |            | --                   | 29                          |       |  |
| Silver       | 5.0E-03                               | I           | 29                   | --                                       |            | --                   | 29                          |       |  |
| Sodium       | --                                    |             | --                   | --                                       |            | --                   | --                          |       |  |
| Strontium    | 6.0E-01                               | I           | 3,440                | --                                       |            | --                   | 3,440                       |       |  |
| Thallium     | 7.0E-05                               | O           | 0.40                 | --                                       |            | --                   | 0.40                        |       |  |
| Tin          | 6.0E-01                               | H           | 3,440                | --                                       |            | --                   | 3,440                       |       |  |
| Titanium     | --                                    |             | --                   | --                                       |            | --                   | --                          |       |  |
| Uranium      | 3.0E-03                               | I           | 17                   | --                                       |            | --                   | 17                          | (g)   | 0.5  |
| Vanadium     | 1.0E-03                               | E           | 5.7                  | --                                       |            | --                   | 5.7                         |       |  |
| Zinc         | 3.0E-01                               | I           | 1,720                | --                                       |            | --                   | 1,720                       |       |  |

RBC = risk-based concentration                      HIF = Human Intake Factor                      -- = no toxicity data

Toxicity Data Sources: I = IRIS   H = HEAST   A = HEAST Alternate   M = ATSDR MRL (chronic)  
 E = EPA-NCEA provisional value   O = other   P = EPA provisional peer-reviewed value

- (a) Oral toxicity values adjusted based on RBA of 0.80.
- (b) Based on toxicity values for food.
- (c) Based on toxicity values for Chromium III.
- (d) Based on residential exposure scenario.
- (e) Based on toxicity values for non-food. oRfD adjusted by a modifying factor of 3, in accord with IRIS recommendations.
- (f) Assumes chemical form of mercury is mercuric chloride.
- (g) Based on toxicity values from IRIS.

[1] As presented in Table 2-2 of the Beach Screening Level Risk Assessment. Values based on sediment reference samples collected by EPA in 2005, the USGS in 1995 and 1990, and Ecology's Natural Background Soil Metals Concentrations in Washington State.

See Appendix A for details on the derivation of the Human Intake Factor (HIF<sub>sed</sub>).

**RISK-BASED CONCENTRATIONS FOR RADIONUCLIDES:**

**Equations:**

$$RBC = \frac{\text{Target Risk [1E-05]}}{[\text{oSF}_{\text{soil}} * \text{IR}_{\text{TWA}_{\text{sed}}} * \text{EF} * \text{ED}] + [\text{SF}_{\text{ext}} * \text{ACF} * \text{EF}/365 * \text{ED} * \text{ET}]}$$

$$\text{IR}_{\text{TWA}_{\text{sed}}} = (\text{IR}_{\text{child}} * \text{ED}_{\text{child}} + \text{IR}_{\text{adult}} * \text{ED}_{\text{adult}}) / \text{ED}_{\text{total}}$$

$$= (300 \text{ mg/d} * 4 \text{ yrs} + 300 \text{ mg/d} * 64 \text{ yrs}) / 68 \text{ yrs}$$

$$= 300 \text{ mg/d} >> 0.3 \text{ g/d}$$

ACF = area correction factor (default = 0.9) [1]

**Risk-Based Concentrations:**

| Element (Atomic No.) | Isotope  | Slope Factor [2]          |                                      | Sediment RBC (pCi/g) |
|----------------------|----------|---------------------------|--------------------------------------|----------------------|
|                      |          | Soil Ingestion (risk/pCi) | External Exposure (risk/y per pCi/g) |                      |
| Radium (88)          | Ra-226+D | 7.30E-10                  | 8.49E-06                             | 4.3E-03              |
| Uranium (92)         | U-238+D  | 2.10E-10                  | 1.14E-07                             | 3.1E-01              |

[1] <http://epa-prgs.ornl.gov/radionuclides/acf.shtml>

[2] <http://www.epa.gov/radiation/health/>

See Appendix A for details on the exposure parameters.

**TABLE 2  
VALUES OF GAMMA (MEAN:RBC)**

**Panel A: By Reach**

| Metal     | 1     | 2     | 3     | 4a    | 4b    | 5     | 6     |
|-----------|-------|-------|-------|-------|-------|-------|-------|
| Aluminum  | 1.62  | 1.33  | 1.67  | 1.23  | 1.52  | 1.38  | 1.37  |
| Antimony  | 10.48 | 4.51  | 1.16  | 0.96  | 0.36  | 1.68  | 1.26  |
| Arsenic   | 11.13 | 5.15  | 4.76  | 2.34  | 4.40  | 5.52  | 3.86  |
| Barium    | 0.59  | 0.33  | 0.21  | 0.08  | 0.07  | 0.07  | 0.05  |
| Beryllium | 0.07  | 0.06  | 0.07  | 0.05  | 0.07  | 0.06  | 0.06  |
| Cadmium   | 0.35  | 0.44  | 0.33  | 0.07  | 0.07  | 0.08  | 0.04  |
| Chromium  | 0.006 | 0.003 | 0.003 | 0.002 | 0.002 | 0.001 | 0.001 |
| Cobalt    | 0.20  | 0.10  | 0.07  | 0.06  | 0.07  | 0.05  | 0.05  |
| Copper    | 3.36  | 1.04  | 0.17  | 0.09  | 0.06  | 0.05  | 0.04  |
| Iron      | 18.82 | 7.90  | 4.91  | 3.53  | 4.53  | 3.86  | 3.78  |
| Lead      | 0.80  | 0.37  | 0.22  | 0.05  | 0.04  | 0.03  | 0.02  |
| Manganese | 5.25  | 2.15  | 1.30  | 1.04  | 1.16  | 1.05  | 1.00  |
| Mercury   | 0.11  | 0.16  | 0.13  | 0.04  | 0.02  | 0.02  | 0.01  |
| Nickel    | 0.10  | 0.13  | 0.17  | 0.13  | 0.15  | 0.09  | 0.08  |
| Selenium  | 0.24  | 0.24  | 0.16  | 0.09  | 0.07  | 0.09  | 0.09  |
| Silver    | 0.04  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  |
| Thallium  | 3.59  | 4.00  | 4.21  | 3.60  | 3.31  | 3.19  | 3.13  |
| Uranium   | 1.16  | 0.86  | 0.75  | 0.61  | 0.61  | 0.60  | 0.59  |
| Vanadium  | 5.00  | 4.42  | 5.28  | 4.12  | 4.45  | 3.06  | 3.15  |
| Zinc      | 3.64  | 1.09  | 0.21  | 0.05  | 0.05  | 0.04  | 0.04  |

**Panel B: By 10-Mile Segment**

| Metal     | 740   | 730   | 720   | 710   | 700   | 690   | 680   | 670   | 660   | 650   | 640   | 630   | 620   | 610   | 600   |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Aluminum  | 1.26  | 1.80  | 1.26  | 1.65  | 1.62  | 1.12  | 1.14  | 1.42  | 1.38  | 1.55  | 1.57  | 1.38  | 1.38  | 1.46  | 1.32  |
| Antimony  | 9.02  | 11.25 | 5.04  | 1.50  | 1.16  | 0.89  | 1.23  | 0.72  | 0.17  | 1.37  | 0.41  | --    | 1.68  | 1.26  | --    |
| Arsenic   | 5.49  | 13.96 | 5.13  | 5.05  | 4.78  | 2.23  | 2.49  | 2.34  | 5.29  | 5.50  | 4.09  | 5.84  | 4.91  | 5.86  | 2.94  |
| Barium    | 0.46  | 0.66  | 0.32  | 0.28  | 0.22  | 0.12  | 0.06  | 0.07  | 0.05  | 0.08  | 0.07  | 0.06  | 0.08  | 0.07  | 0.05  |
| Beryllium | 0.06  | 0.07  | 0.06  | 0.07  | 0.07  | 0.05  | 0.05  | 0.06  | 0.05  | 0.07  | 0.07  | 0.05  | 0.06  | 0.06  | 0.06  |
| Cadmium   | 0.30  | 0.37  | 0.37  | 0.60  | 0.31  | 0.18  | 0.03  | 0.06  | 0.04  | 0.05  | 0.09  | 0.03  | 0.15  | 0.05  | 0.03  |
| Chromium  | 0.004 | 0.006 | 0.003 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| Cobalt    | 0.15  | 0.22  | 0.10  | 0.07  | 0.07  | 0.05  | 0.05  | 0.06  | 0.07  | 0.08  | 0.07  | 0.05  | 0.05  | 0.05  | 0.04  |
| Copper    | 2.39  | 3.84  | 1.28  | 0.26  | 0.17  | 0.15  | 0.06  | 0.07  | 0.07  | 0.07  | 0.06  | 0.04  | 0.06  | 0.05  | 0.03  |
| Iron      | 12.65 | 21.91 | 8.84  | 4.88  | 5.02  | 3.24  | 3.47  | 3.92  | 4.61  | 4.77  | 4.50  | 4.12  | 3.58  | 4.03  | 3.65  |
| Lead      | 0.41  | 1.00  | 0.34  | 0.41  | 0.21  | 0.14  | 0.02  | 0.03  | 0.03  | 0.03  | 0.05  | 0.02  | 0.04  | 0.02  | 0.02  |
| Manganese | 3.56  | 6.10  | 2.49  | 1.08  | 1.37  | 0.88  | 0.97  | 1.09  | 1.02  | 1.39  | 1.23  | 1.09  | 0.98  | 1.12  | 0.94  |
| Mercury   | 0.08  | 0.12  | 0.11  | 0.26  | 0.13  | 0.10  | 0.03  | 0.02  | 0.01  | 0.02  | 0.04  | 0.01  | 0.02  | 0.01  | 0.01  |
| Nickel    | 0.09  | 0.11  | 0.11  | 0.16  | 0.18  | 0.11  | 0.14  | 0.16  | 0.22  | 0.18  | 0.11  | 0.09  | 0.08  | 0.09  | 0.07  |
| Selenium  | 0.19  | 0.31  | 0.24  | 0.24  | 0.16  | 0.08  | 0.07  | 0.13  | 0.05  | 0.06  | 0.07  | 0.10  | 0.08  | 0.10  | 0.08  |
| Silver    | 0.02  | 0.05  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  | 0.02  |
| Thallium  | 3.75  | 3.51  | 3.89  | 4.19  | 4.28  | 3.76  | 3.58  | 3.49  | 3.18  | 3.32  | 3.30  | 3.11  | 3.34  | 3.24  | 3.03  |
| Uranium   | 1.02  | 1.23  | 0.84  | 0.85  | 0.75  | 0.62  | 0.67  | 0.59  | 0.60  | 0.58  | 0.62  | 0.58  | 0.62  | 0.61  | 0.57  |
| Vanadium  | 3.99  | 5.51  | 4.16  | 5.04  | 5.41  | 3.75  | 3.95  | 4.68  | 4.33  | 4.65  | 4.29  | 3.05  | 3.14  | 3.12  | 3.12  |
| Zinc      | 2.19  | 4.36  | 1.32  | 0.33  | 0.22  | 0.11  | 0.03  | 0.04  | 0.03  | 0.03  | 0.06  | 0.03  | 0.05  | 0.04  | 0.03  |

 Ratio between 0.3 - 0.6

-- = no data available

No RBC available for calcium, magnesium, potassium, or sodium.

**TABLE 3  
VALUES OF SIGMA**

**Panel A: By Reach**

| Metal     | 1    | 2    | 3    | 4a   | 4b   | 5    | 6    |
|-----------|------|------|------|------|------|------|------|
| Aluminum  | 0.44 | 0.35 | 0.49 | 0.42 | 0.32 | 0.23 | 0.33 |
| Antimony  | 0.85 | 1.25 | 0.72 | 1.23 | 0.94 | --   | --   |
| Arsenic   | 0.84 | 0.73 | 0.91 | 0.65 | 0.88 | 0.67 | 1.03 |
| Barium    | 0.69 | 0.74 | 0.91 | 0.67 | 0.41 | 0.39 | 0.40 |
| Beryllium | 0.35 | 0.37 | 0.58 | 0.51 | 0.38 | 0.27 | 0.38 |
| Cadmium   | 0.81 | 0.96 | 1.18 | 0.88 | 0.99 | 1.16 | 0.95 |
| Calcium   | 0.55 | 0.61 | 1.05 | 0.79 | 0.74 | 0.93 | 0.79 |
| Chromium  | 0.67 | 0.46 | 0.63 | 0.49 | 0.51 | 0.28 | 0.65 |
| Cobalt    | 0.80 | 0.54 | 0.50 | 0.49 | 0.38 | 0.25 | 0.35 |
| Copper    | 1.14 | 1.21 | 0.79 | 0.74 | 0.52 | 0.47 | 0.52 |
| Iron      | 0.79 | 0.61 | 0.49 | 0.44 | 0.27 | 0.19 | 0.25 |
| Lead      | 0.78 | 0.87 | 1.19 | 0.95 | 0.71 | 0.57 | 0.38 |
| Magnesium | 0.43 | 0.43 | 0.72 | 0.47 | 0.39 | 0.27 | 0.37 |
| Manganese | 0.88 | 0.68 | 0.57 | 0.50 | 0.50 | 0.28 | 0.45 |
| Mercury   | 0.94 | 1.22 | 1.33 | 1.11 | 1.11 | 1.15 | 1.07 |
| Nickel    | 0.16 | 0.35 | 0.61 | 0.52 | 0.59 | 0.25 | 0.73 |
| Potassium | 0.50 | 0.37 | 0.51 | 0.55 | 0.40 | 0.25 | 0.33 |
| Selenium  | 0.78 | 0.82 | 0.57 | 0.37 | 0.52 | 0.36 | 0.60 |
| Silver    | 0.73 | 0.19 | 0.26 | 0.18 | 0.10 | 0.12 | 0.14 |
| Sodium    | 0.96 | 0.81 | 0.79 | 0.49 | 0.62 | 0.44 | 0.52 |
| Thallium  | 0.12 | 0.25 | 0.31 | 0.18 | 0.16 | 0.10 | 0.16 |
| Uranium   | 0.78 | 0.45 | 0.39 | 0.36 | 0.23 | 0.10 | 0.16 |
| Vanadium  | 0.28 | 0.28 | 0.48 | 0.41 | 0.28 | 0.31 | 0.32 |
| Zinc      | 1.07 | 1.23 | 1.08 | 0.76 | 0.60 | 0.56 | 0.45 |

**Panel B: By 10-Mile Segment**

| Metal     | 740  | 730  | 720  | 710  | 700  | 690  | 680  | 670  | 660  | 650  | 640  | 630  | 620  | 610  | 600  |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Aluminum  | 0.32 | 0.47 | 0.37 | 0.23 | 0.52 | 0.56 | 0.31 | 0.35 | 0.20 | 0.39 | 0.38 | 0.21 | 0.28 | 0.23 | 0.36 |
| Antimony  | 0.57 | 0.98 | 1.34 | 0.44 | 0.72 | 1.24 | 1.23 | 1.26 | 0.36 | --   | 1.30 | --   | --   | --   | --   |
| Arsenic   | 0.27 | 0.96 | 0.81 | 0.35 | 0.97 | 0.91 | 0.59 | 0.46 | 0.59 | 0.69 | 1.10 | 0.49 | 0.90 | 0.69 | 1.05 |
| Barium    | 0.50 | 0.77 | 0.76 | 0.72 | 0.98 | 1.08 | 0.39 | 0.47 | 0.34 | 0.54 | 0.42 | 0.28 | 0.53 | 0.40 | 0.35 |
| Beryllium | 0.29 | 0.37 | 0.37 | 0.26 | 0.63 | 0.62 | 0.44 | 0.42 | 0.26 | 0.43 | 0.43 | 0.25 | 0.34 | 0.29 | 0.40 |
| Cadmium   | 0.69 | 0.88 | 0.94 | 0.90 | 1.20 | 1.53 | 0.50 | 0.76 | 0.50 | 0.22 | 1.29 | 0.71 | 1.62 | 0.81 | 0.98 |
| Calcium   | 0.35 | 0.62 | 0.62 | 1.06 | 0.87 | 0.95 | 0.81 | 0.64 | 0.75 | 0.71 | 0.73 | 0.96 | 0.99 | 0.78 | 0.79 |
| Chromium  | 0.49 | 0.74 | 0.52 | 0.26 | 0.67 | 0.69 | 0.38 | 0.37 | 0.39 | 0.51 | 0.47 | 0.31 | 0.31 | 0.24 | 0.73 |
| Cobalt    | 0.61 | 0.88 | 0.60 | 0.24 | 0.54 | 0.66 | 0.44 | 0.36 | 0.30 | 0.41 | 0.45 | 0.33 | 0.21 | 0.32 | 0.34 |
| Copper    | 0.73 | 1.31 | 1.27 | 0.80 | 0.82 | 1.32 | 0.42 | 0.37 | 0.35 | 0.49 | 0.62 | 0.55 | 0.46 | 0.48 | 0.45 |
| Iron      | 0.55 | 0.87 | 0.68 | 0.23 | 0.53 | 0.63 | 0.35 | 0.30 | 0.25 | 0.32 | 0.30 | 0.24 | 0.16 | 0.23 | 0.25 |
| Lead      | 0.21 | 0.93 | 0.84 | 0.87 | 1.23 | 1.71 | 0.43 | 0.68 | 0.51 | 0.49 | 0.84 | 0.34 | 0.80 | 0.29 | 0.35 |
| Magnesium | 0.40 | 0.45 | 0.41 | 0.58 | 0.73 | 0.68 | 0.37 | 0.36 | 0.35 | 0.40 | 0.42 | 0.28 | 0.34 | 0.27 | 0.38 |
| Manganese | 0.63 | 0.97 | 0.75 | 0.15 | 0.61 | 0.60 | 0.43 | 0.47 | 0.37 | 0.49 | 0.58 | 0.26 | 0.35 | 0.46 | 0.41 |
| Mercury   | 0.54 | 1.11 | 1.10 | 1.22 | 1.39 | 1.74 | 0.65 | 0.88 | 0.88 | 0.85 | 1.47 | 1.10 | 1.29 | 0.84 | 1.15 |
| Nickel    | 0.07 | 0.16 | 0.33 | 0.25 | 0.65 | 0.69 | 0.39 | 0.39 | 0.41 | 0.50 | 0.60 | 0.37 | 0.16 | 0.27 | 0.82 |
| Potassium | 0.33 | 0.53 | 0.40 | 0.24 | 0.55 | 0.50 | 0.54 | 0.52 | 0.39 | 0.49 | 0.41 | 0.21 | 0.32 | 0.26 | 0.33 |
| Selenium  | 0.73 | 0.84 | 0.86 | --   | 0.57 | 0.34 | 0.29 | 0.37 | 0.20 | 0.13 | 0.63 | 0.41 | 0.35 | 0.43 | 0.65 |
| Silver    | 0.10 | 0.88 | 0.18 | 0.20 | 0.27 | 0.28 | 0.10 | 0.14 | 0.10 | 0.06 | 0.07 | 0.03 | 0.13 | 0.14 | 0.10 |
| Sodium    | 0.68 | 1.08 | 0.92 | 0.27 | 0.84 | 0.53 | 0.46 | 0.39 | 0.28 | 0.57 | 0.74 | 0.14 | 0.51 | 0.41 | 0.56 |
| Thallium  | 0.13 | 0.12 | 0.26 | 0.18 | 0.34 | 0.28 | 0.09 | 0.13 | 0.10 | 0.11 | 0.21 | 0.08 | 0.12 | 0.13 | 0.17 |
| Uranium   | 0.49 | 0.90 | 0.49 | 0.27 | 0.43 | 0.08 | 0.09 | 0.47 | 0.39 | 0.17 | 0.21 | 0.09 | 0.12 | 0.13 | 0.17 |
| Vanadium  | 0.13 | 0.29 | 0.28 | 0.19 | 0.52 | 0.56 | 0.35 | 0.29 | 0.17 | 0.39 | 0.32 | 0.32 | 0.38 | 0.27 | 0.34 |
| Zinc      | 0.67 | 1.22 | 1.28 | 0.85 | 1.16 | 1.43 | 0.29 | 0.53 | 0.37 | 0.37 | 0.73 | 0.31 | 0.79 | 0.41 | 0.47 |

$\sigma < 0.5$   
  $0.5 < \sigma \leq 1$   
  $\sigma > 1$

-- = no data available

**TABLE 4  
SIGMA VALUES FOR "CLOSE CALL" METALS**

**Panel A: By Reach**

| Metal     | 1    | 2    | 3    | 4a | 4b   | 5    | 6    |
|-----------|------|------|------|----|------|------|------|
| Aluminum  |      |      |      |    |      |      |      |
| Antimony  |      |      |      |    | 0.94 |      |      |
| Arsenic   |      |      |      |    |      |      |      |
| Barium    | 0.69 | 0.74 |      |    |      |      |      |
| Beryllium |      |      |      |    |      |      |      |
| Cadmium   | 0.81 | 0.96 | 1.18 |    |      |      |      |
| Chromium  |      |      |      |    |      |      |      |
| Cobalt    |      |      |      |    |      |      |      |
| Copper    |      |      |      |    |      |      |      |
| Iron      |      |      |      |    |      |      |      |
| Lead      |      | 0.87 |      |    |      |      |      |
| Manganese |      |      |      |    |      |      |      |
| Mercury   |      |      |      |    |      |      |      |
| Nickel    |      |      |      |    |      |      |      |
| Selenium  |      |      |      |    |      |      |      |
| Silver    |      |      |      |    |      |      |      |
| Thallium  |      |      |      |    |      |      |      |
| Uranium   |      |      |      |    |      | 0.10 | 0.16 |
| Vanadium  |      |      |      |    |      |      |      |
| Zinc      |      |      |      |    |      |      |      |

**Panel B: By 10-Mile Segment**

| Metal     | 740  | 730  | 720  | 710  | 700  | 690 | 680 | 670  | 660  | 650  | 640  | 630  | 620 | 610 | 600  |
|-----------|------|------|------|------|------|-----|-----|------|------|------|------|------|-----|-----|------|
| Aluminum  |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Antimony  |      |      |      |      |      |     |     |      |      |      | 1.30 |      |     |     |      |
| Arsenic   |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Barium    | 0.50 |      | 0.76 |      |      |     |     |      |      |      |      |      |     |     |      |
| Beryllium |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Cadmium   | 0.69 | 0.88 | 0.94 |      | 1.20 |     |     |      |      |      |      |      |     |     |      |
| Chromium  |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Cobalt    |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Copper    |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Iron      |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Lead      | 0.21 |      | 0.84 | 0.87 |      |     |     |      |      |      |      |      |     |     |      |
| Manganese |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Mercury   |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Nickel    |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Selenium  |      | 0.84 |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Silver    |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Thallium  |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Uranium   |      |      |      |      |      |     |     | 0.47 | 0.39 | 0.17 |      | 0.09 |     |     | 0.17 |
| Vanadium  |      |      |      |      |      |     |     |      |      |      |      |      |     |     |      |
| Zinc      |      |      |      | 0.85 |      |     |     |      |      |      |      |      |     |     |      |

|  |                       |
|--|-----------------------|
|  | $\sigma < 0.5$        |
|  | $0.5 < \sigma \leq 1$ |
|  | $\sigma > 1$          |

**TABLE 5  
LIST OF BEACHES SELECTED FOR SAMPLING**

| Reach | Index | Approx. River Mile | Location  | Descending bank |
|-------|-------|--------------------|---|-----------------|
| 1     | 1     | 742                | Black Sand Beach                                  | Left (L)        |
|       | 2     | 735                | Northport Beach                                   | L               |
|       | 3     | 729                | Dalles Orchard                                    | L               |
|       | 4     | 729-730            | Onion Creek                                       | L               |
| 2     | 5     | 722                | China Bend  | L               |
|       | 6     | 722                | Depositional area just downstream from China Bend | Right (R)       |
|       | 7     | 716                | Bossburg Flat                                     | L               |
|       | 8     | 714                | Snag Cove   | R               |
|       | 9     | 711.5              | Evans Campground/Beach                            | L               |
| 3     | 10    | 710                | Summer Island                                     | R               |
|       | 11    | 708                | Kamloops Island                                   | R               |
|       | 12    | 705                | Welty Bay   | L               |
|       | 13    | 700                | Kettle Falls Marina                               | L               |
|       | 14    | 700                | Lyons Island                                      | L               |
|       | 15    | 699                | Colville Flats                                    | L               |
|       | 16    | 699                | Colville River                                    | L               |
| 4     | 17    | 693                | Bradbury Beach                                    | L               |
|       | 18    | 686                | Barnaby Island Campground                         | R               |
|       | 19    | 677                | AA Campground 2                                   | R               |
|       | 20    | 664                | Nez Perce Creek                                   | R               |
|       | 21    | 661                | Hunters   | L               |
|       | 22    | 655                | Naborlee  | L               |
|       | 23    | 653                | Wilmont Creek                                     | R               |
|       | 24    | 650                | Mitchell Point                                    | R               |
|       | 25    | 657                | Enterprise  | L               |
|       | 26    | 645.25             | McGuire's   | L               |
| 5     | 27    | 636                | Seven Bays  | L               |
|       | 28    | 634                | Mouth of Hawk Creek                               | L               |
|       | 29    | 624                | Whitestone Campground                             | R               |
|       | 30    | 620                | Jones Bay   | L               |
| 6     | 31    | 611                | Swawilla Basin                                    | L               |
|       | 32    | 598                | Eden Harbor                                       | R               |
|       | 33    | 597                | Crescent Bay                                      | L               |

**TABLE 6  
INFLUENCE OF ELEVATION APPROACH ON RISK MANAGEMENT DECISIONS**

| Reach                      | Beach                    | River Mile | ESTIMATED RISK (CONCENTRATION/RBC) |            |                 |            |                 |            |                 |            |                 |            |                 |            |
|----------------------------|--------------------------|------------|------------------------------------|------------|-----------------|------------|-----------------|------------|-----------------|------------|-----------------|------------|-----------------|------------|
|                            |                          |            | Arsenic                            |            | Cadmium         |            | Copper          |            | Iron            |            | Lead            |            | Zinc            |            |
|                            |                          |            | Lower Elevation                    | Beach-wide | Lower Elevation | Beach-wide | Lower Elevation | Beach-wide | Lower Elevation | Beach-wide | Lower Elevation | Beach-wide | Lower Elevation | Beach-wide |
| 1                          | Black Sand Beach         | 742        | 11.83                              | 16.80      | 0.17            | 0.21       | 7.06            | 9.03       | 49.09           | 49.42      | 0.69            | 0.64       | 8.66            | 9.11       |
| 2                          | Northport Boat Launch    | 735*       | 12.73                              | 10.37      | 0.52            | 0.44       | 6.02            | 4.94       | 28.25           | 24.66      | 0.77            | 0.63       | 5.59            | 4.67       |
| 3                          | Dalles Orchard           | 729        | 13.30                              | 13.30      | 0.37            | 0.38       | 5.67            | 5.06       | 26.91           | 24.93      | 0.51            | 0.51       | 5.06            | 4.59       |
|                            | North Gorge Campground   | 718        | 7.86                               | 6.20       | 0.73            | 0.55       | 0.94            | 0.54       | 7.35            | 5.73       | 0.54            | 0.42       | 0.99            | 0.60       |
|                            | Marcus Island Campground | 708        | 4.78                               | 4.65       | 1.27            | 0.84       | 0.22            | 0.18       | 4.39            | 4.46       | 0.74            | 0.46       | 0.53            | 0.33       |
|                            | Kettle Falls Swim Beach  | 700*       | 1.37                               | 1.15       | 0.04            | 0.03       | 0.08            | 0.05       | 4.34            | 3.04       | 0.02            | 0.02       | 0.03            | 0.02       |
| 4a                         | Haag Cove                | 697        | 1.69                               | 1.15       | 1.36            | 0.73       | 0.15            | 0.08       | 4.51            | 2.91       | 0.56            | 0.31       | 0.41            | 0.22       |
|                            | French Rocks Boat Launch | 690        | 1.91                               | 1.81       | 0.08            | 0.08       | 0.06            | 0.06       | 2.99            | 2.74       | 0.05            | 0.05       | 0.06            | 0.05       |
| 4b                         | Cloverleaf Branch        | 675        | 5.14                               | 3.16       | 0.42            | 0.36       | 0.13            | 0.09       | 5.63            | 4.24       | 0.26            | 0.14       | 0.17            | 0.12       |
|                            | AA Campground            | 673        | 2.64                               | 3.18       | 0.17            | 0.11       | 0.06            | 0.07       | 3.99            | 4.31       | 0.08            | 0.05       | 0.09            | 0.06       |
|                            | Rogers Bar Campground    | 658        | 0.71                               | 1.24       | 0.01            | 0.02       | 0.02            | 0.03       | 1.23            | 2.03       | 0.01            | 0.01       | 0.01            | 0.02       |
| 5                          | Columbia Campground      | 642*       | 3.45                               | 3.41       | 0.28            | 0.14       | 0.08            | 0.06       | 4.16            | 3.91       | 0.15            | 0.07       | 0.14            | 0.10       |
|                            | Lincoln Mill Boat Ramp   | 633        | 4.33                               | 4.53       | 0.08            | 0.03       | 0.03            | 0.04       | 2.54            | 3.07       | 0.01            | 0.01       | 0.02            | 0.02       |
| 6                          | Keller Ferry No. 2       | 615        | 3.45                               | 3.33       | 0.09            | 0.09       | 0.04            | 0.04       | 3.89            | 3.67       | 0.01            | 0.01       | 0.02            | 0.02       |
|                            | Spring Canyon Campground | 600        | 7.57                               | 6.44       | 0.09            | 0.09       | 0.03            | 0.03       | 3.84            | 3.70       | 0.02            | 0.02       | 0.03            | 0.03       |
| <b>False Negative (%):</b> |                          |            | <b>0%</b>                          |            | <b>13%</b>      |            | <b>0%</b>       |            | <b>0%</b>       |            | <b>0%</b>       |            | <b>0%</b>       |            |
| <b>False Positive (%):</b> |                          |            | <b>7%</b>                          |            | <b>0%</b>       |            |
| <b>Agree (%):</b>          |                          |            | <b>93%</b>                         |            | <b>87%</b>      |            | <b>100%</b>     |            | <b>100%</b>     |            | <b>100%</b>     |            | <b>100%</b>     |            |

Concentration > RBC

**Table 7**  
**False Negative and False Positive Rates for Alternate Compositing Strategies**

**Panel A: Assuming a Total of 60 Grab Samples**  
 $\sigma = 1.25$

| Strategy<br>(m x k) | 95% UCL (Normal) |                | 99% UCL (Normal) |                |
|---------------------|------------------|----------------|------------------|----------------|
|                     | False Negative   | False Positive | False Negative   | False Positive |
| 60 x 1              | 16.8%            | 6.9%           | 9.3%             | 12.3%          |
| 20 x 3              | 16.4%            | 7.4%           | 8.6%             | 13.7%          |
| 10 x 6              | 15.5%            | 8.2%           | 7.3%             | 16.1%          |
| 5 x 12              | 14.0%            | 10.3%          | 5.2%             | 25.7%          |
| 3 x 20              | 11.5%            | 17.1%          | 3.0%             | 53.9%          |

False Negative = UCL < true mean

False Positive = UCL > RBC (where RBC = 2 \* true mean)

**Panel B: Assuming a Total of 30 Grab Samples**  
 $\sigma = 0.8$

| Strategy<br>(m x k) | 99% UCL (Normal) |                     |                     |
|---------------------|------------------|---------------------|---------------------|
|                     | False Negative   | False Positive (2x) | False Positive (4x) |
| 30 x 1              | 5.3%             | 4.1%                | 0.0%                |
| 10 x 3              | 4.4%             | 6.0%                | 0.0%                |
| 6 x 5               | 3.5%             | 9.8%                | 0.0%                |
| 3 x 10              | 1.8%             | 43.8%               | 1.8%                |

False Negative = UCL < true mean

False Positive (2x) = UCL > RBC (where RBC = 2 \* true mean)

False Positive (4x) = UCL > RBC (where RBC = 4 \* true mean)

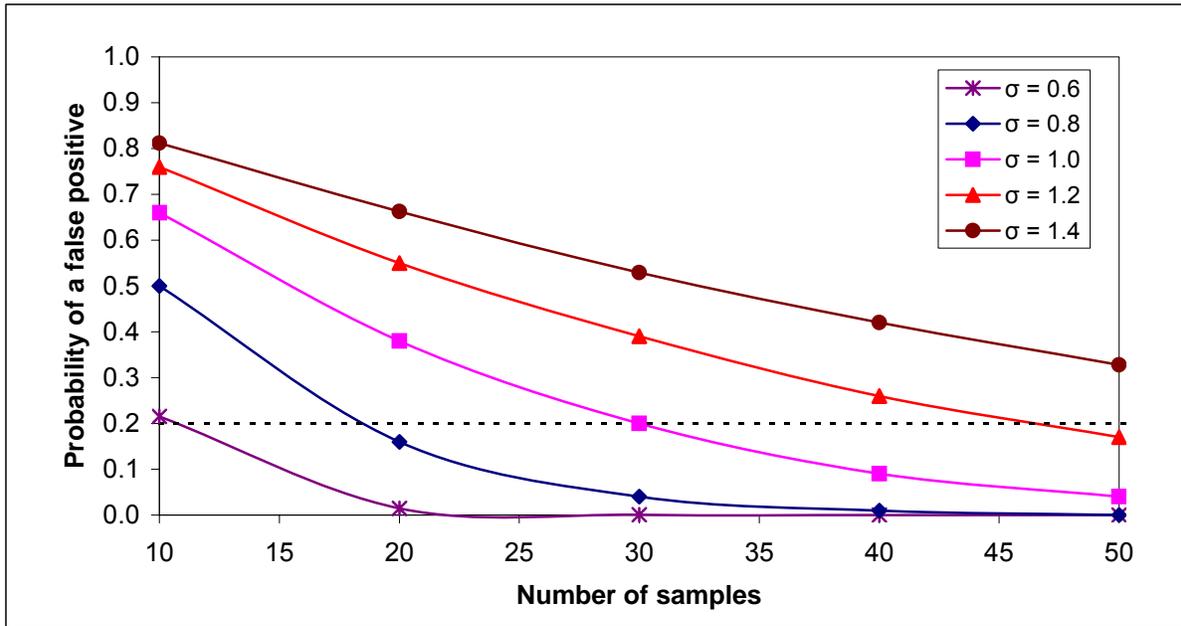
**Table 8**  
**EPA 2005 Phase I Size Fractioned Sediment Sample Results for Metals**

| Analyte Type | Analyte   | Units | Northport Boat Launch (RM735BSF) |      |                  |      | Kettle Falls Swim Beach (RM700BSF) |      |                  |      | Columbia Campground (RM642BSF) |      |                  |   |
|--------------|-----------|-------|----------------------------------|------|------------------|------|------------------------------------|------|------------------|------|--------------------------------|------|------------------|---|
|              |           |       | Fraction > 75 µm                 |      | Fraction < 75 µm |      | Fraction > 75 µm                   |      | Fraction < 75 µm |      | Fraction > 75 µm               |      | Fraction < 75 µm |   |
| Metals       | Aluminum  | mg/kg | 12300                            |      | 8400             |      | 6430                               |      | 14000            |      | 8350                           |      | 16400            |   |
|              | Antimony  | mg/kg | 47.4                             |      | 3.9              | J    | --                                 |      | --               |      | --                             |      | --               |   |
|              | Arsenic   | mg/kg | 10.1                             |      | 10.4             |      | 1.2                                |      | 2                |      | 2.6                            |      | 3.9              |   |
|              | Barium    | mg/kg | 1230                             |      | 1030             |      | 59.2                               |      | 182              |      | 92.3                           |      | 175              |   |
|              | Beryllium | mg/kg | 0.71                             | E    | 0.59             | E    | 0.33                               | E    | 0.76             | E    | 0.42                           | E    | 0.85             | E |
|              | Cadmium   | mg/kg | 4.8                              |      | 5.5              |      | 0.34                               | J    | 0.82             |      | 0.81                           |      | 1.6              |   |
|              | Calcium   | mg/kg | 55000                            |      | 27700            |      | 3740                               |      | 14000            |      | 2080                           |      | 3900             |   |
|              | Chromium  | mg/kg | 80.3                             |      | 29.4             |      | 14.1                               |      | 33               |      | 13.2                           |      | 21               |   |
|              | Cobalt    | mg/kg | 34.3                             |      | 12.7             |      | 5.3                                |      | 11.4             |      | 6.2                            |      | 10.2             |   |
|              | Copper    | mg/kg | 1530                             | E    | 278              | E    | 11.9                               | E    | 26.7             | E    | 9.8                            | E    | 24.1             | E |
|              | Iron      | mg/kg | 126000                           | D    | 35100            |      | 12800                              |      | 24600            |      | 14100                          |      | 21000            |   |
|              | Lead      | mg/kg | 267                              |      | 325              |      | 7.5                                |      | 21.8             |      | 26.1                           |      | 47.4             |   |
|              | Magnesium | mg/kg | 13100                            |      | 14200            |      | 4250                               |      | 9380             |      | 3670                           |      | 4750             |   |
|              | Manganese | mg/kg | 2380                             |      | 690              |      | 211                                |      | 568              |      | 187                            |      | 389              |   |
|              | Mercury   | mg/kg | 0.072                            | J    | 0.32             |      | 0.008                              | J    | 0.031            | J    | 0.043                          | J    | 0.078            | J |
|              | Nickel    | mg/kg | 14.7                             |      | 21.1             |      | 13                                 |      | 27               |      | 11.3                           |      | 18.8             |   |
|              | Potassium | mg/kg | 2970                             |      | 1630             |      | 955                                |      | 2850             |      | 1730                           |      | 2800             |   |
|              | Selenium  | mg/kg | 8                                |      | 3.9              |      | 1.3                                | J    | 2.5              | J    | 0.94                           | J    | 1.5              | J |
|              | Silver    | mg/kg | --                               |      | --               |      | --                                 |      | --               |      | --                             |      | --               |   |
|              | Sodium    | mg/kg | 1210                             |      | 214              | J    | 147                                | J    | 355              | J    | 77.2                           | J    | 226              | J |
| Thallium     | mg/kg     | 2.3   | U                                | 2.4  | U                | 2    | U                                  | 2.5  | U                | 1.9  | U                              | 2.6  | U                |   |
| Uranium      | mg/kg     | 18.8  | U                                | 19.2 | U                | 16.3 | U                                  | 19.8 | U                | 15.5 | U                              | 20.4 | U                |   |
| Vanadium     | mg/kg     | 38.5  |                                  | 39.4 |                  | 27.5 |                                    | 47.3 |                  | 19.7 |                                | 32.4 |                  |   |
| Zinc         | mg/kg     | 10100 | D                                | 1860 |                  | 44.6 |                                    | 106  |                  | 154  |                                | 222  |                  |   |

-- = no data available; results were rejected by the data validator

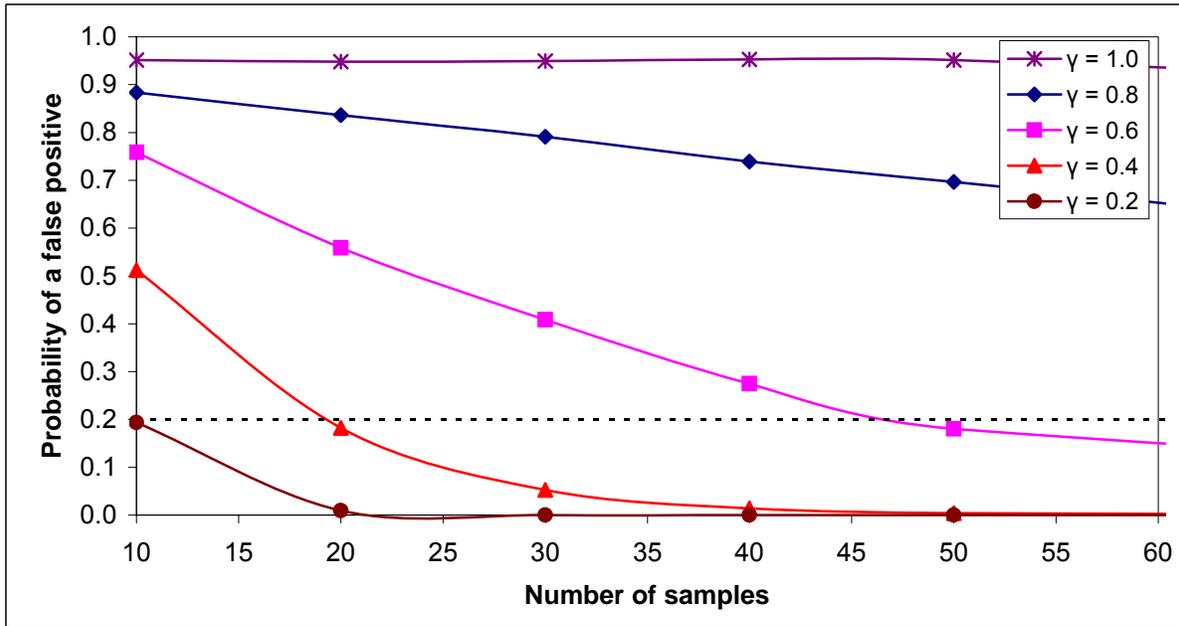
| Analyte Type  | Analyte    | Units | RM735BSF | RM700BSF | RM642BSF |
|---------------|------------|-------|----------|----------|----------|
| Size Fraction | Colloids   | %     | 0.1      | 0.2      | 0.3      |
|               | Silt       | %     | 11.4     | 11.0     | 28.9     |
|               | Clay       | %     | 0.1      | 0.6      | 2.2      |
|               | Gravel     | %     | 0.3      | 15       | 3        |
|               | Med. Sand  | %     | 30.5     | 34.1     | 21       |
|               | Fine Sand  | %     | 56.9     | 34.3     | 37.2     |
|               | Co. Sand   | %     | 0.7      | 4.8      | 7.4      |
|               | Sand Total | %     | 88.1     | 73.2     | 65.6     |
|               | <200 Total | %     | 11.6     | 11.8     | 31.4     |

**FIGURE 1**  
**FALSE POSITIVE ERROR RATE FOR SEVERAL DIFFERENT VALUES OF SIGMA**



False Positive = 95UCL > RBC, where the true mean is 1/2 the RBC

**FIGURE 2**  
**FALSE POSITIVE ERROR RATE FOR SEVERAL DIFFERENT VALUES OF GAMMA**

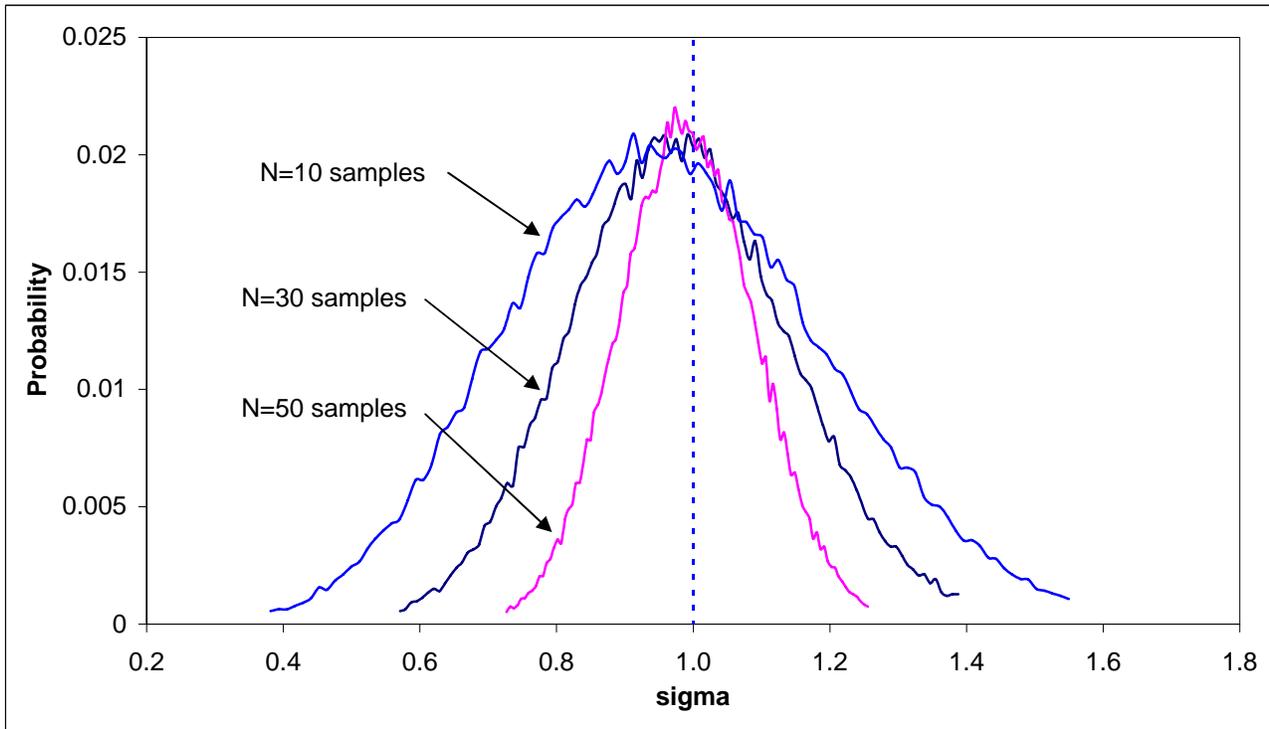


sigma = 1.0

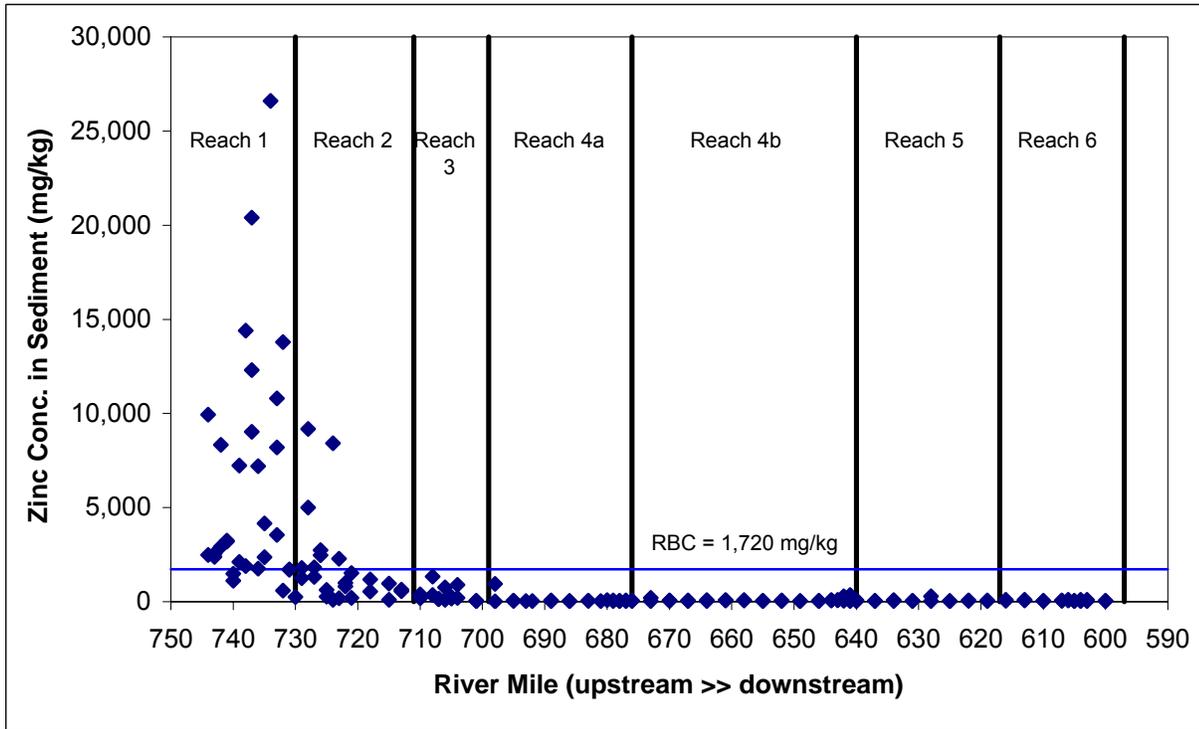
$\gamma = \text{true mean} / \text{RBC}$

False Positive = 95UCL > RBC, where the true mean is  $\gamma * \text{RBC}$

**FIGURE 3**  
**EXAMPLE OF VARIABILITY IN SIGMA**



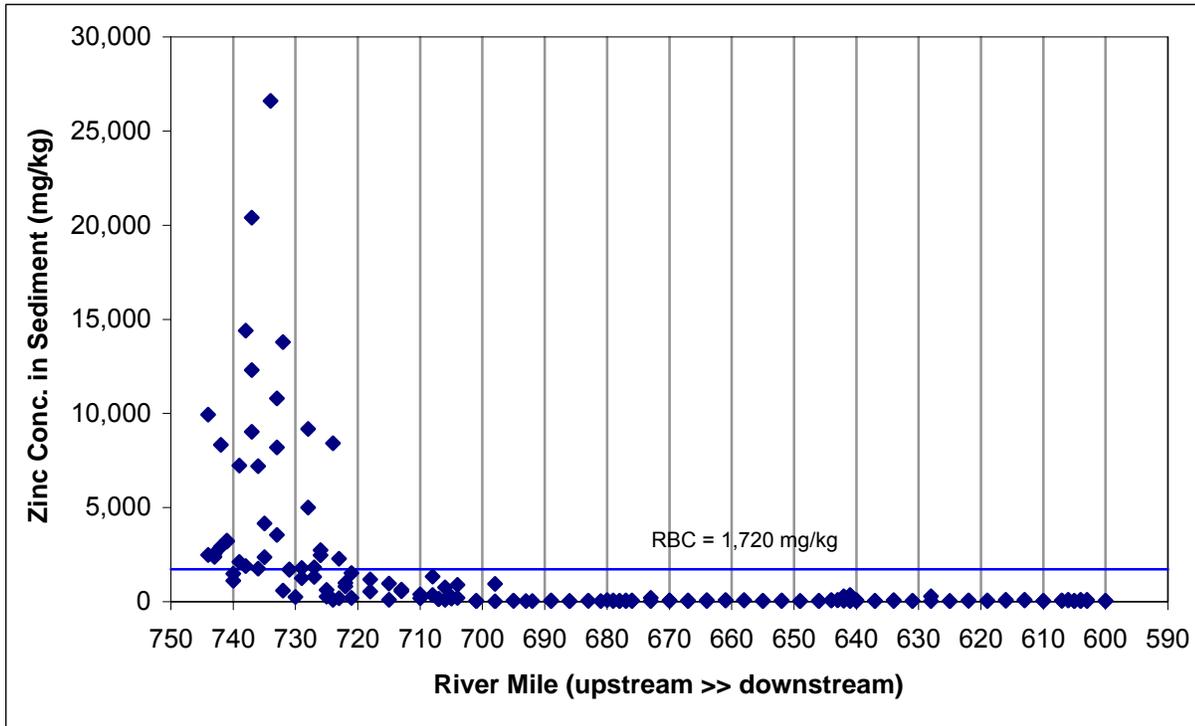
**FIGURE 4**  
**VARIABILITY OF ZINC CONCENTRATIONS IN SURFACE SEDIMENT BY REACH**



| HHRA Reach | n  | Mean (mg/kg) | Stdev (mg/kg) | $\mu$ | $\sigma$ | 95UCL (mg/kg) [1] |
|------------|----|--------------|---------------|-------|----------|-------------------|
| Reach 1    | 30 | 6,257        | 6,270         | 8.26  | 1.07     | 8,585             |
| Reach 2    | 24 | 1,874        | 2,399         | 6.88  | 1.23     | 2,849             |
| Reach 3    | 14 | 359          | 381           | 5.38  | 1.08     | 604               |
| Reach 4a   | 22 | 87           | 194           | 3.90  | 0.76     | 268               |
| Reach 4b   | 30 | 80           | 75            | 4.15  | 0.60     | 139               |
| Reach 5    | 14 | 64           | 67            | 3.95  | 0.56     | 142               |
| Reach 6    | 18 | 61           | 28            | 4.01  | 0.45     | 74                |

[1] Based on ProUCL v4.0

**FIGURE 5**  
**VARIABILITY OF ZINC CONCENTRATIONS IN SURFACE SEDIMENT BY 10-MILE SEGMENT**



| 10-Mile Segment | n  | Mean (mg/kg) | Stdev (mg/kg) | $\mu$ | $\sigma$ | 95UCL (mg/kg) [1] |
|-----------------|----|--------------|---------------|-------|----------|-------------------|
| 740             | 10 | 3,764        | 2,936         | 8.01  | 0.67     | 6,622             |
| 730             | 20 | 7,503        | 7,142         | 8.38  | 1.22     | 11,523            |
| 720             | 18 | 2,277        | 2,657         | 7.08  | 1.28     | 3,751             |
| 710             | 8  | 571          | 368           | 6.10  | 0.85     | 818               |
| 700             | 12 | 371          | 410           | 5.35  | 1.16     | 688               |
| 690             | 6  | 190          | 375           | 4.08  | 1.43     | 1,712             |
| 680             | 8  | 48           | 15            | 3.84  | 0.29     | 58                |
| 670             | 12 | 64           | 48            | 4.00  | 0.53     | 90                |
| 660             | 6  | 60           | 20            | 4.04  | 0.37     | 77                |
| 650             | 6  | 54           | 21            | 3.92  | 0.37     | 70                |
| 640             | 14 | 96           | 99            | 4.25  | 0.73     | 212               |
| 630             | 6  | 46           | 16            | 3.78  | 0.31     | 59                |
| 620             | 6  | 86           | 101           | 4.11  | 0.79     | 266               |
| 610             | 8  | 63           | 27            | 4.06  | 0.41     | 81                |
| 600             | 12 | 59           | 28            | 3.97  | 0.47     | 73                |

[1] Based on ProUCL v4.0

FIGURE 6

SELECTED BEACH SAMPLING LOCATIONS

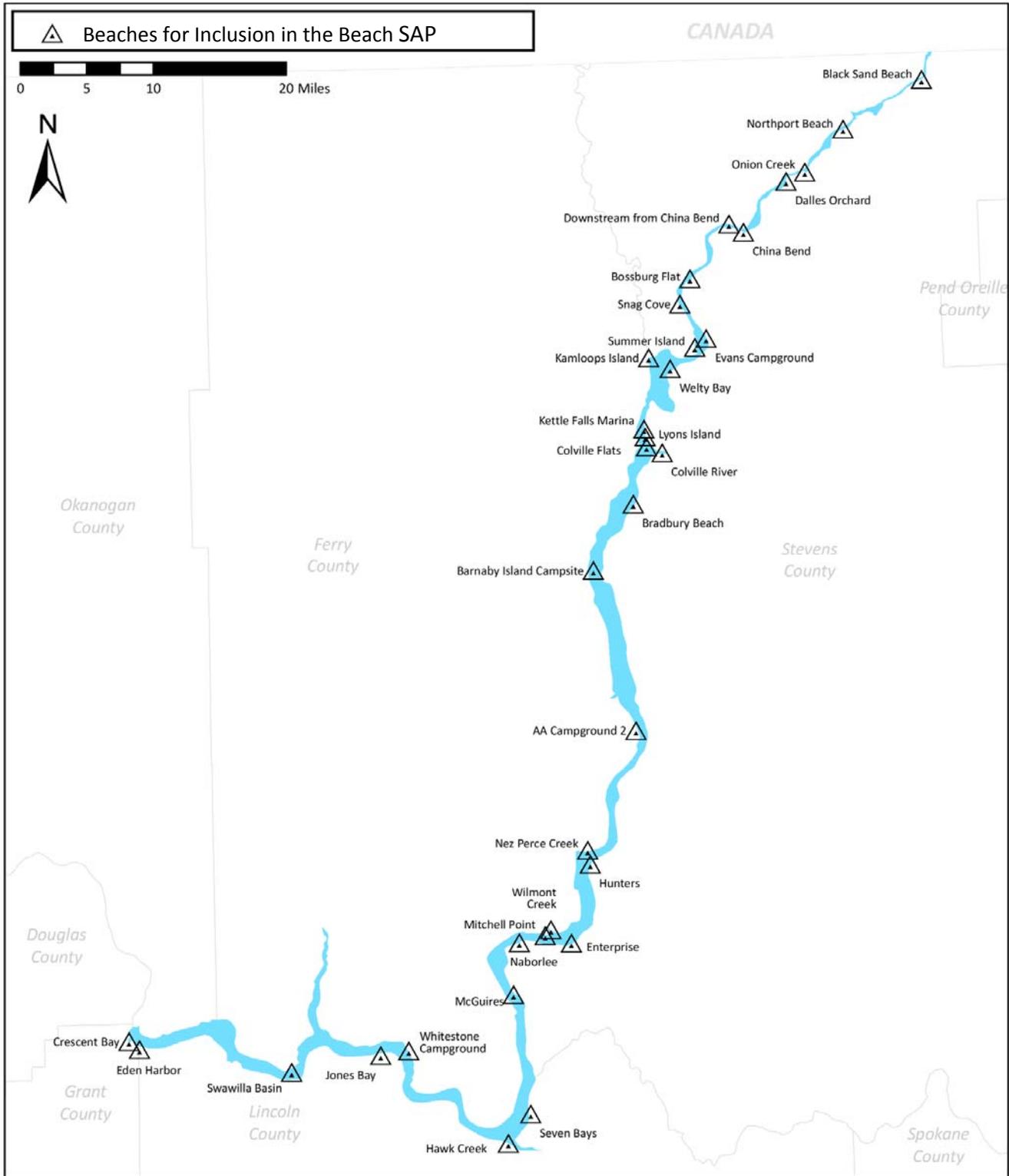
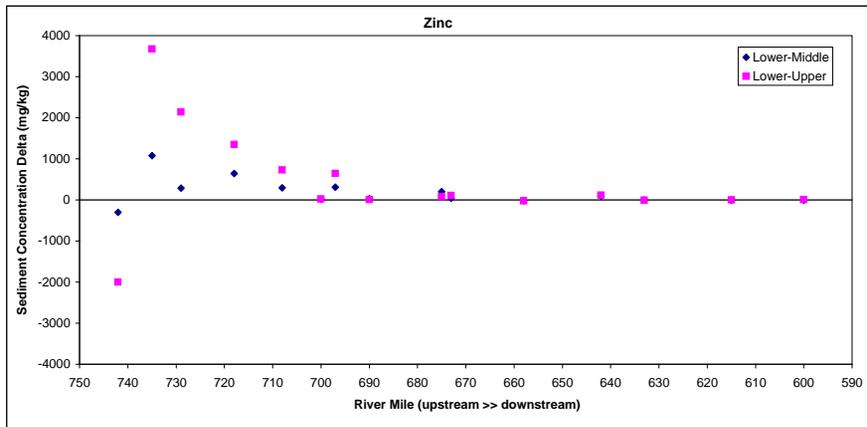
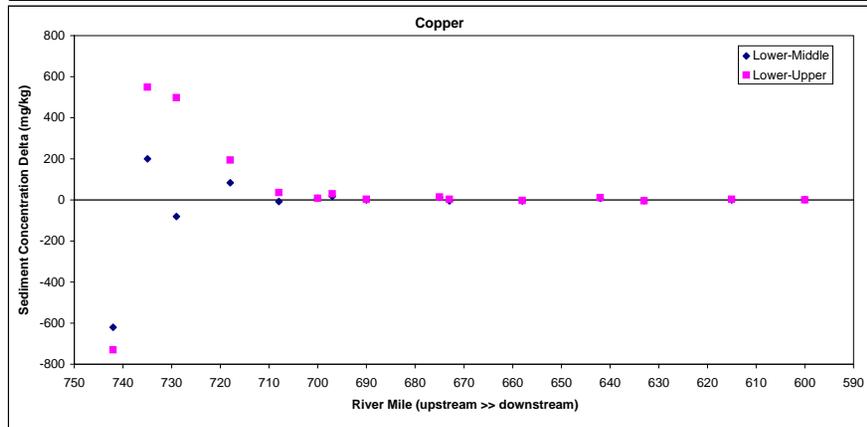
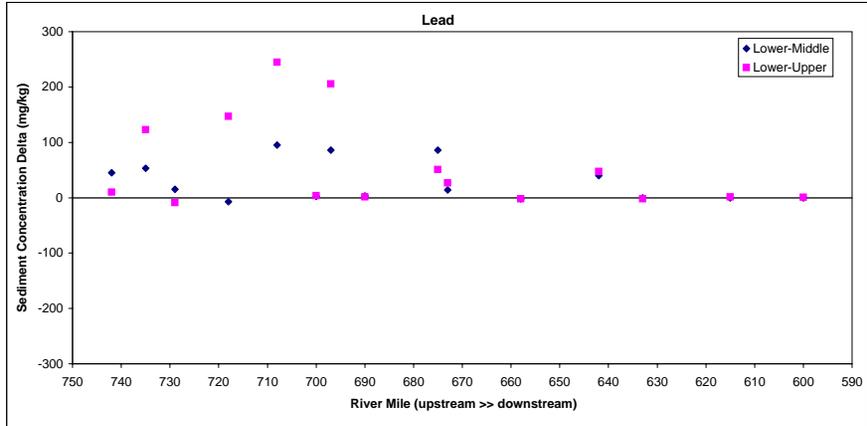
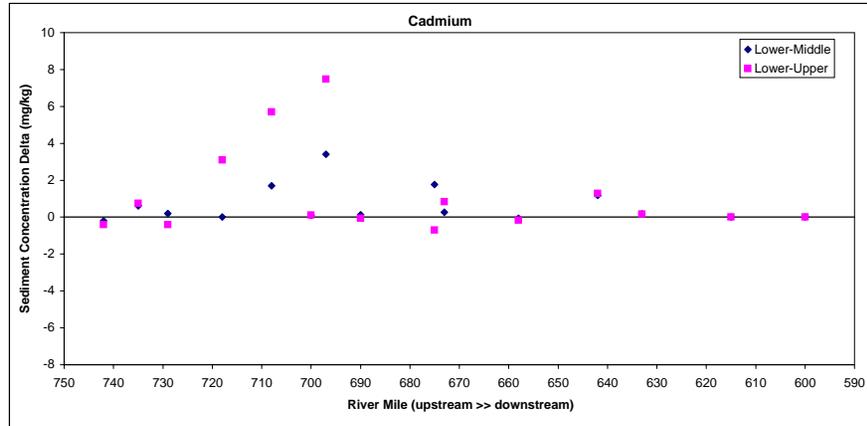
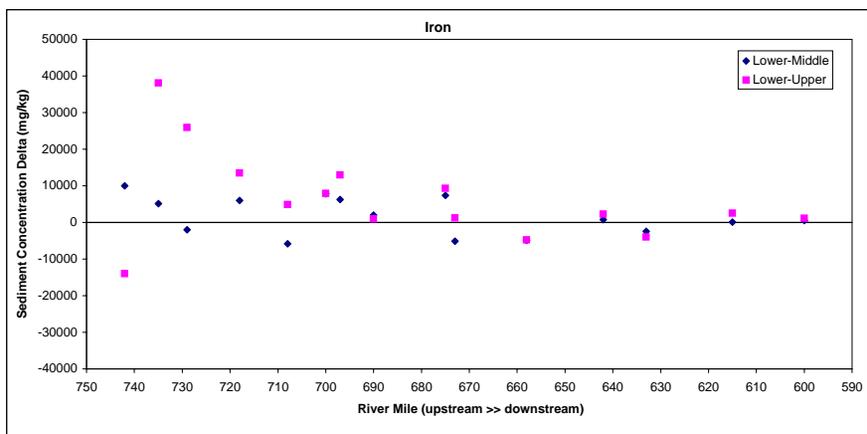
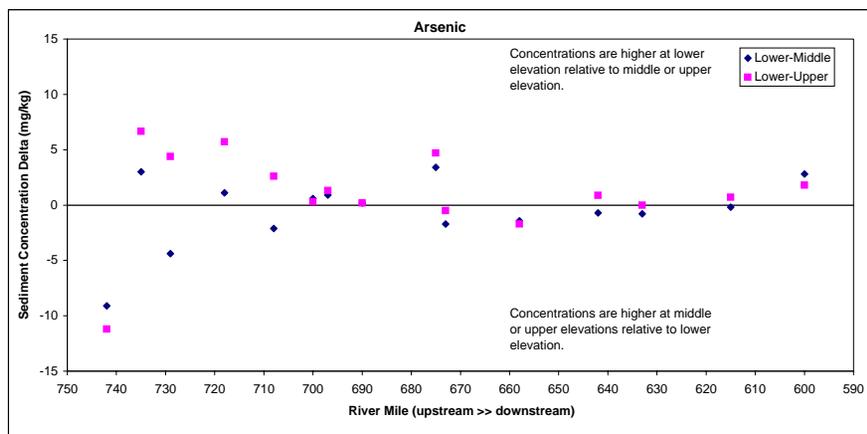
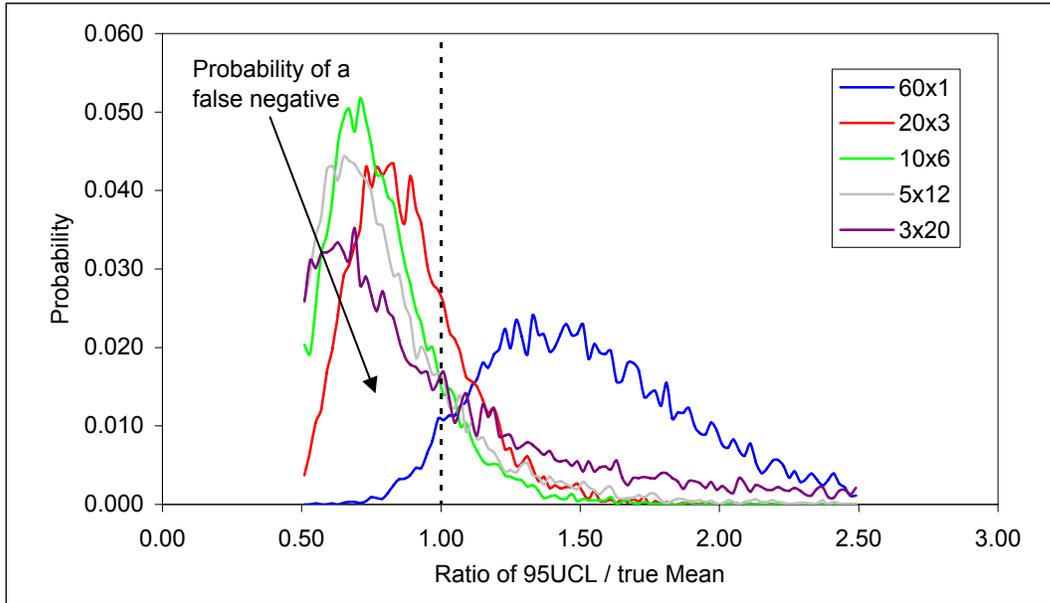


FIGURE 7  
COMPARISON OF BEACH SEDIMENT CONCENTRATIONS FROM THREE ELEVATIONS

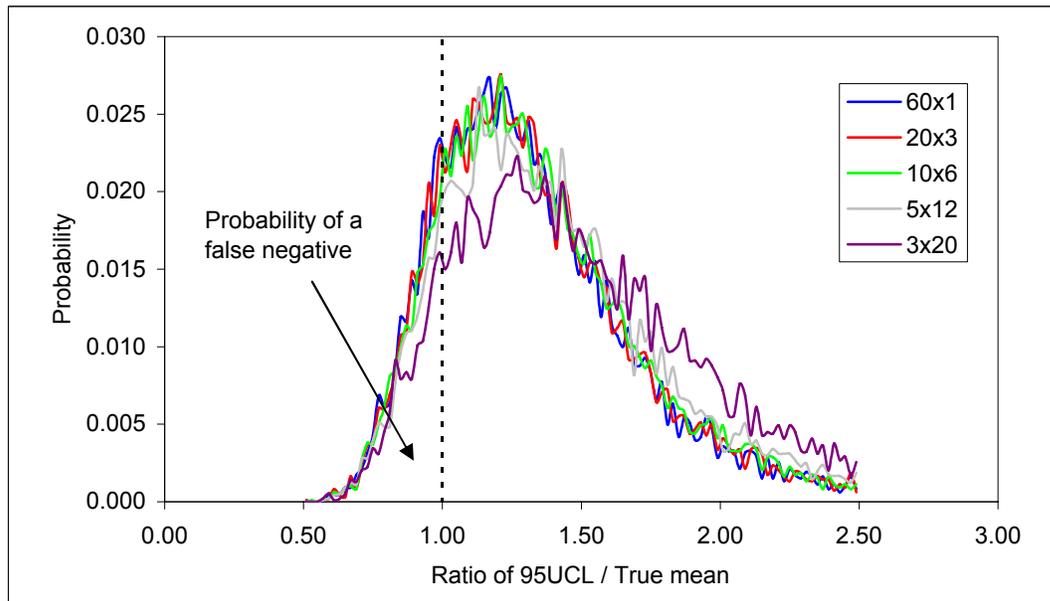


**Figure 8**  
**Comparison of UCL Calculation Strategies for Alternate Compositing Strategies**  
 Lognormal vs. Normal ( $\sigma = 1.25$ )

**Panel A: 95% UCL Calculated Using Lognormal (Land) Equation**

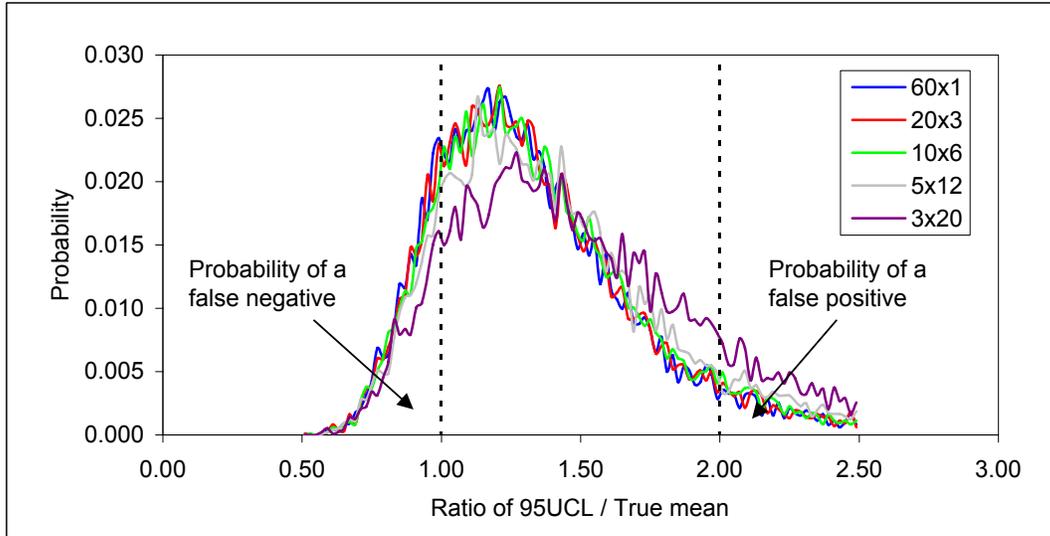


**Panel B: 95% UCL Calculated Using Normal (t) Equation**

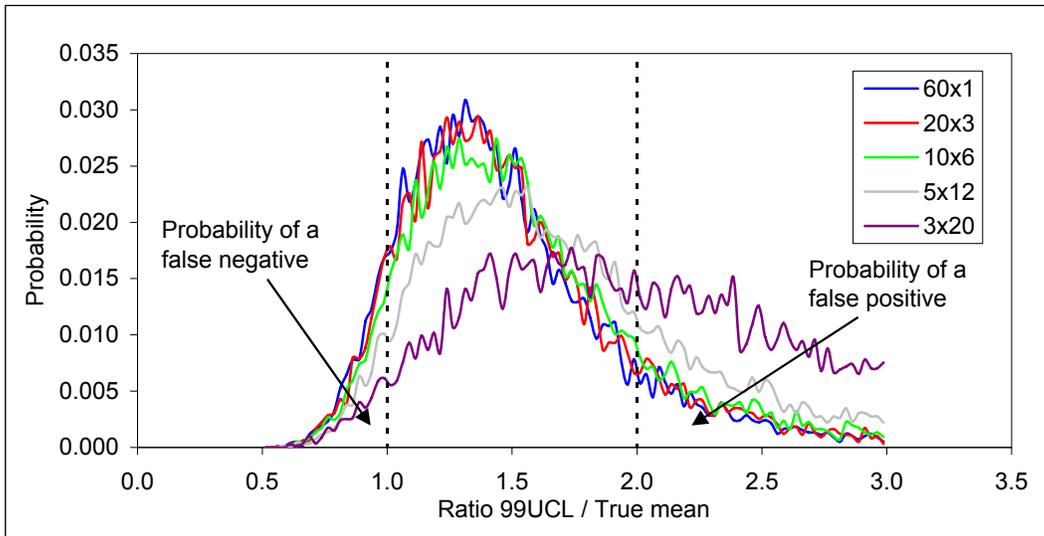


**Figure 9**  
**Comparison of UCL Calculation Strategies for Alternate Compositing Strategies**  
95% UCL vs. 99% UCL ( $\sigma = 1.25$ )

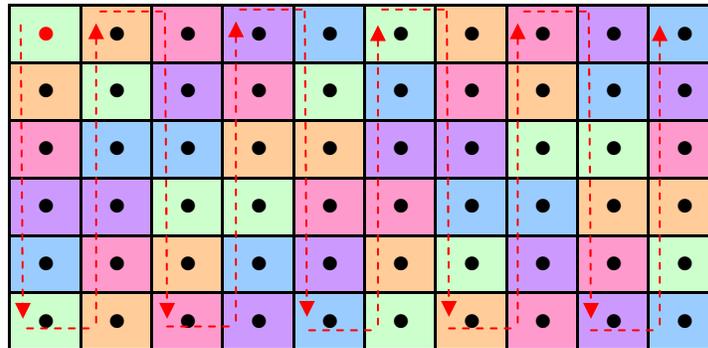
**Panel A: 95% UCL Calculated Using Normal (t) Equation**



**Panel B: 99% UCL Calculated Using Normal (t) Equation**



**Figure 10**  
**Example of Grid Overlay Systematic Overlapping Composite Sampling Design**

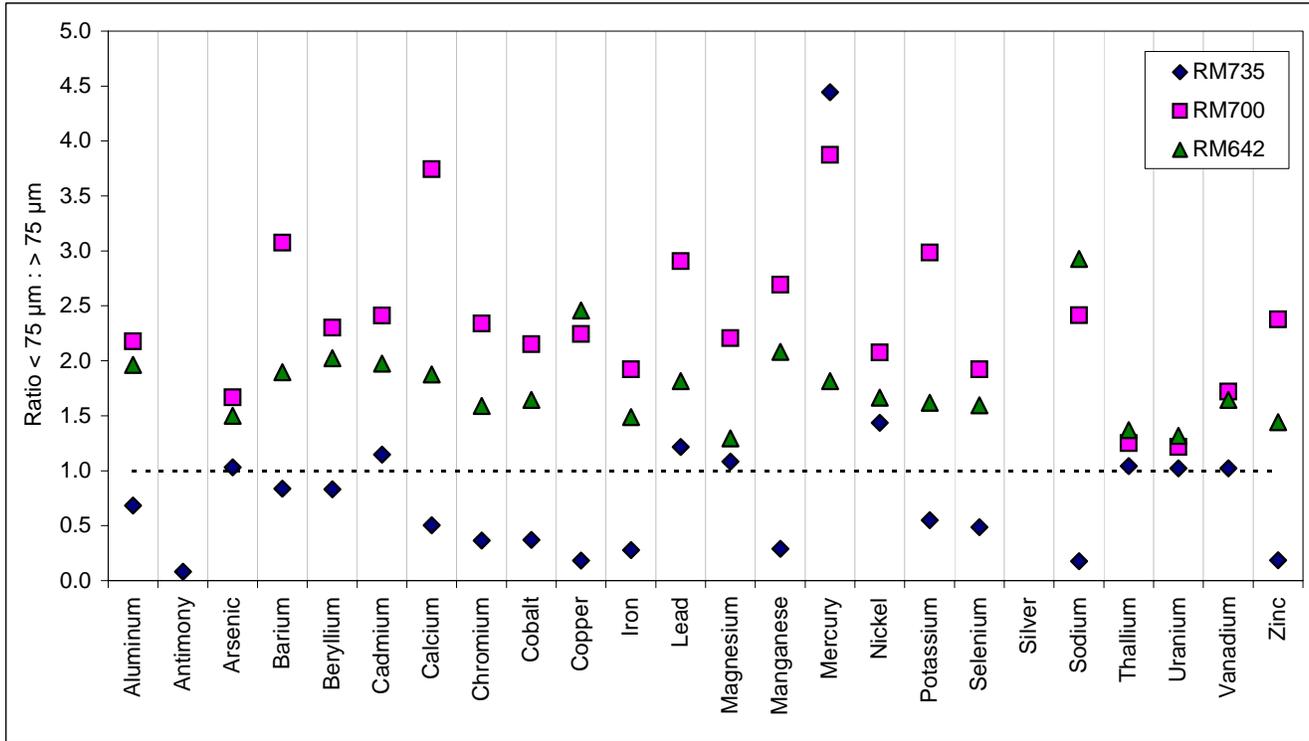


- grab sample
- starting location
- > grid traverse direction

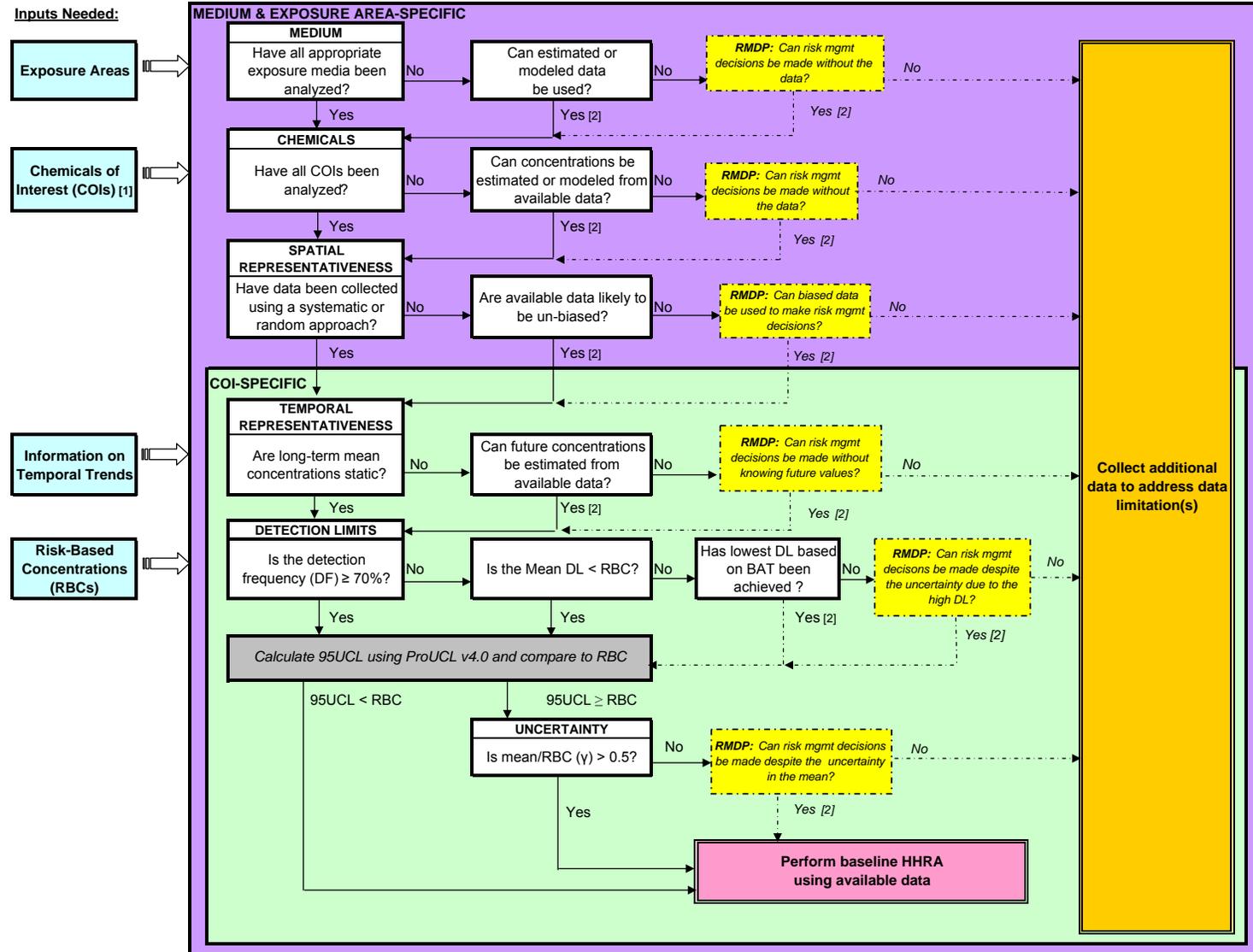
5 composites of 12 grab samples each:

|  |  |
|--|--|
|  | composite 1 (1st, 6th, 11th, 16th, ...)  |
|  | composite 2 (2nd, 7th, 12th, 17th, ...)  |
|  | composite 3 (3rd, 8th, 13th, 18th, ...)  |
|  | composite 4 (4th, 9th, 14th, 19th, ...)  |
|  | composite 5 (5th, 10th, 15th, 20th, ...) |

**FIGURE 11**  
**COMPARISON OF CONCENTRATIONS IN SIZE-FRACTIONED SAMPLES**



**FIGURE 12  
RESTROSPECTIVE DECISIONAL FLOW CHART TO EVALUATE  
ENVIRONMENTAL DATA ADEQUACY IN SUPPORT OF HUMAN HEALTH RISK ASSESSMENT<sup>1</sup>**



DF = detection frequency (N detects / N total samples)  
DL = detection limit  
95UCL = 95% upper confidence limit on the mean

RBC = risk-based concentration  
BAT = best available techniques  
RMDP = risk management decision point

[1] For a medium, the COI list may be limited to those COIs reasonably expected to occur based on fate and transport processes (i.e., dioxin/furans are more likely to be present in tissues and sediment relative to water). For the purposes of risk assessment support, the COI list may also be limited to those COIs with available toxicity data.

[2] Uncertainty section of baseline HHRA should include a discussion of data limitations and the direction and magnitude of any potential data biases.

**APPENDIX A**

**Human Intake Factor for Incidental Ingestion of Surface Sediment (HIF<sub>sed</sub>)**

*Maximally exposed receptor = Traditional subsistence scenario*

| Exposure Parameter                | Units          | RME Value and Source |                                    |                 |                                    |
|-----------------------------------|----------------|----------------------|------------------------------------|-----------------|------------------------------------|
|                                   |                | Adult                |                                    | Child           |                                    |
| Body weight                       | kg             | 70                   | USEPA 2005                         | 17.2            | USEPA 2005                         |
| Exposure Frequency                | days/yr        | 365                  | Prof. judgment, Harper et al. 2002 | 365             | Prof. judgment, Harper et al. 2002 |
| Exposure Duration                 | years          | 64                   | Harper et al. 2002                 | 4               | Harper et al. 2002                 |
| Exposure Time                     | hrs/d          | 4                    | Prof. judgment                     | 4               | Prof. judgment                     |
| Averaging Time (non-cancer)       | days           | 23,360               | USEPA 1989                         | 1,460           | USEPA 1989                         |
| Averaging Time (cancer)           | days           | 25,550               | USEPA 1989                         | 25,550          | USEPA 1989                         |
| Ingestion rate of sediment        | mg/day         | 300                  | Harper et al. 2002 [1]             | 300             | Harper et al. 2002 [2]             |
| <i>Conversion factor</i>          | <i>kg/mg</i>   | <i>1E-06</i>         |                                    | <i>1E-06</i>    |                                    |
| <b>HIF (non-cancer)</b>           | <b>kg/kg-d</b> | <b>4.29E-06</b>      |                                    | <b>1.74E-05</b> |                                    |
| <b>HIF (cancer)</b>               | <b>kg/kg-d</b> | <b>3.92E-06</b>      |                                    | <b>9.97E-07</b> |                                    |
| <b>HIF<sub>TWA</sub> (cancer)</b> | <b>kg/kg-d</b> | <b>4.92E-06</b>      |                                    |                 |                                    |

Harper et al. 2002. Spokane Tribe RME Exposure Parameters.

USEPA 1989. Risk Assessment Guidance for Superfund (RAGS), Part A.

USEPA 2005. Midnite Mine HHRA.

[1] Table 1. Soil intake rate is reported as 400 mg/d (100 mg/d from indoor sources + 300 mg/d for outdoor scenarios). For the purposes of the HHRA Workplan, it was assumed that UCR site exposures were restricted to outdoor scenarios only (300 mg/d). Reported soil intake rates were assumed to apply to sediment exposures.

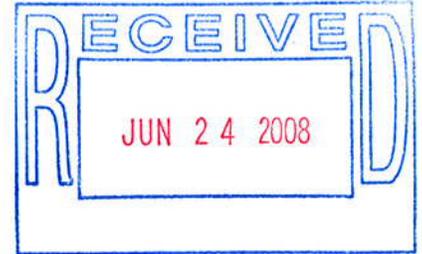
[2] Intake rates for child assumed to be equal to adult. This is supported by Section 3.7 in Harper et al. (2002) which identifies soil intake rates for child and adult as being equal.



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June 20, 2008



**CERTIFIED MAIL – RETURN RECEIPT REQUESTED**

Reply To: ECL-111

Marko E. Adzic  
Teck Cominco American Incorporated  
501 North Riverpoint Boulevard, Suite 300  
Spokane, Washington 99202

Dear Mr. Adzic:

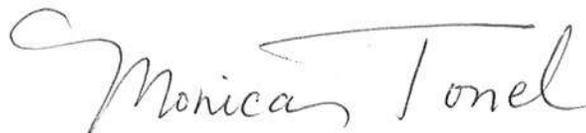
EPA is hereby disapproving Teck Cominco's February 2007 Draft Field Sampling Plan for the 2007 Sediment Investigation of Beaches and Depositional Areas<sup>1</sup> (draft QAPP/Field Sampling Plan). Teck Cominco's draft QAPP/Field Sampling Plan is deficient because it does not address the refined data quality objectives (DQOs) appropriate for a Phase II investigation. EPA's prior October 12, 2007 letter to Teck Cominco communicated EPA's intent to disapprove the draft QAPP/Field Sampling Plan. Although the RI/FS Work Plan is not final, EPA has progressed sufficiently on its Human Health Risk Assessment Work Plan to allow further development of the QAPP/Field Sampling Plan for beaches.

Since Teck Cominco's submission of the Draft QAPP/Field Sampling Plan, EPA has provided extensive assistance to Teck Cominco in the development of components of the QAPP/Field Sampling Plan. EPA's assistance has included: 1) providing a list of beaches that reflect the Participating Parties' input, 2) providing letters (dated March 21, 2008 and May 21, 2008) that transmitted the DQOs and sampling design components for surface sediment sampling at the UCR Site; 3) participating in a workshop with Teck Cominco during which EPA presented the framework for the beach sampling design, and 4) participating in telephone discussions to engage and receive input regarding technical approaches. Enclosed are the design components for beach subsurface sediment sampling at the Upper Columbia River Site in support of the baseline human health risk assessment and the development of the QAPP/Field Sampling Plan. The foregoing collectively constitute EPA's comments on Teck Cominco's draft QAPP/Field Sampling Plan.

<sup>1</sup> Integral Consulting Inc., and Parametrix, in consultation with HydroQual, Inc., and Archaeological Investigations Northwest, Inc., February 23, 2007, Draft Quality Assurance Project Plan for the 2007 Sediment Investigation of Beaches and Depositional Areas, Appendix A Draft Field Sampling Plan, prepared for Teck Cominco American Incorporated

Although the Settlement Agreement and EPA's October 12, 2007 letter to Teck Cominco indicate that Teck Cominco has thirty (30) days to incorporate all information and comments by EPA and to resubmit a Field Sampling Plan, EPA is hereby allowing Teck Cominco a longer period of time to resubmit a QAPP/Field Sampling Plan in order to provide ample time for the development of an acceptable deliverable. Teck Cominco must submit a revised QAPP/Field Sampling Plan to EPA within sixty (60) days of receipt of this notice of disapproval.

Sincerely,

A handwritten signature in cursive script that reads "Monica Tonel". The signature is written in black ink and is positioned above the printed name and title.

Monica Tonel  
UCR Site Technical Team

Enclosure

cc: David Godlewski, TCAI  
Janet Deisley, Teck Cominco Limited  
Sheila Eckman, EPA  
Dan Audet, U.S. DOI  
John Roland, WA Department of Ecology  
Patti Bailey, Colville Confederated Tribes  
Randy Connolly, Spokane Tribe



Syracuse Research Corporation  
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(303) 292-4755 fax

## MEMORANDUM

To: Monica Tonel, Marc Stifelman (EPA, Region 10)  
From: Lynn Woodbury (SRC)  
Task: FD052.CF999.842  
Date: June 18, 2008  
Re: Phase II Beach Subsurface Sediment Sampling Design Recommendations

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As discussed in the draft *Human Health Risk Assessment (HHRA) Workplan for the Upper Columbia River (UCR) Site* (EPA 2008), data on the concentrations of chemicals of interest (COIs) from subsurface sediment samples from beaches and shorelines along UCR Site are extremely limited. There are only two samples (one from the flats near Haag Cove and one from Marcus Flats near Pingston Creek) which provide information on subsurface sediments (18-24 inches) from UCR beaches. These samples were collected in the spring of 2001 as part of the *UCR Expanded Site Investigation* (EPA 2003) and were analyzed for metals, pesticides, PCBs (as Aroclor), grain size, and total organic carbon (TOC). Table 1 summarizes the results from these samples. Pesticides and PCBs (as Aroclor) were not detected in either subsurface sample. Collocated surficial (0-6 inches) sediment data is only available for the sample from Haag Cove. A comparison of the concentrations in the surficial sample to the subsurface sample at this location shows that the surficial sediment tended to have higher metals concentrations than the subsurface sediment.

The available data are not sufficient to characterize the nature and extent of potential subsurface contamination for the purposes of evaluating human exposures, so additional subsurface sediment data are needed. The sampling design recommendations for the Phase II beach subsurface sediment sampling at the UCR Site in support of the baseline HHRA are as follows:

- Collect one core (0-30 inches) using a hand auger from 5 locations<sup>1</sup> at each of the 34 beaches that will be sampled as part of the Phase II beach surface sediment sampling. The collection from 5 locations per beach will allow for exposure calculations on a beach-specific basis.
- Core samples should be stratified into 3 depth strata – 0-6 inches, 6-18 inches, and 18-30 inches – and each depth strata analyzed separately.
  - The maximum depth of 30 inches is based on professional judgment, and assumes that human receptor populations of interest (*e.g.*, recreational, occupational, subsistence) are most likely to be exposed to sediments no deeper than 30 inches under typical exposure scenarios (*e.g.*, without heavy excavation equipment).
  - The three depth strata cut-offs are also based on professional judgment to represent potential differences in exposure scenarios. For example, recreational scenarios (*e.g.*, child playing in beach sand) may occur at maximum depth of 18 inches, while occupational scenarios (*e.g.*, digging associated with archaeological or maintenance activities) may encounter a depth of 30 inches.
- Sampling locations at each beach should be selected randomly from within the human use areas designated by the beach surface sediment sampling investigation.

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<sup>1</sup> Subsurface sampling locations should not be the same locations selected for the surface sediment grab samples.

- Figure 1 illustrates the analysis and compositing recommendations as discussed below:
  - Each depth strata at each location (5 locations x 3 depth strata) will be analyzed for target analyte list (TAL) metals/metalloids<sup>2</sup>.
  - To address sample mass requirements, a single composite sample of each depth strata will be analyzed for grain size (e.g., ASTM D422), TOC, and the full list of COIs, including elemental uranium, radionuclides (e.g., U-238 and Ra-226), pesticides, PAHs, SVOCs, and PCBs (as Aroclor).
  - PCB congeners, dioxin/furan congeners, and PBDEs will only be analyzed in depth strata composites where TOC is greater than 1%. As seen in Figure 2, in the EPA 2005 Phase I Sediment Study, sediment samples with TOC levels less than 1% usually did not have surficial sediment dioxin/furan concentrations that were above a risk-based concentration<sup>3</sup> (RBC) for incidental ingestion of sediment.

References:

EPA (U.S. Environmental Protection Agency). 2003. Upper Columbia River Expanded Site Inspection Report; Northeast Washington. TDD:01-02-0028. Contract: 68-S0-01-01. U.S. Environmental Protection Agency, Region 10, Seattle, WA. 84 pp.

\_\_\_\_\_. 2008. Work Plan for the Human Health Risk Assessment for the Upper Columbia River Site Remedial Investigation and Feasibility Study. Draft – February 2008.

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<sup>2</sup> CERCLA TAL list: Aluminum · Antimony · Arsenic · Barium · Beryllium · Cadmium · Calcium · Chromium · Cobalt · Copper · Iron · Lead · Magnesium · Manganese · Mercury · Nickel · Potassium · Selenium · Silver · Sodium · Thallium · Vanadium · Zinc

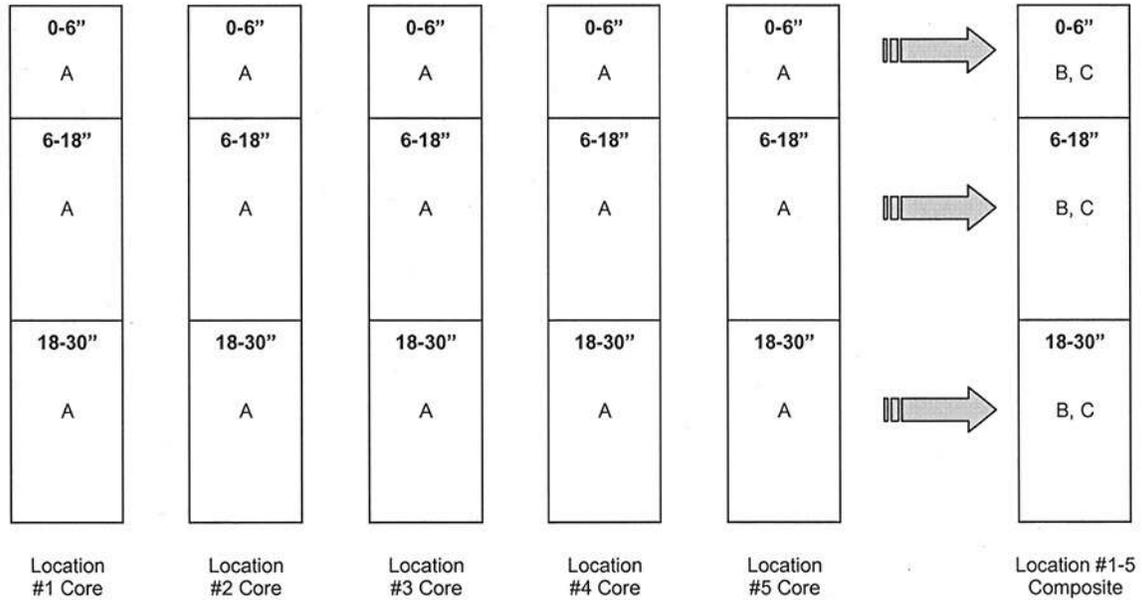
<sup>3</sup> RBC derived based on traditional subsistence exposure scenario and target cancer risk of 1E-06.

**Table 1**  
**UCR Expanded Site Investigation (EPA 2003) Subsurface Sediment Locations**

| Station:                  |                    |        | CS017                            |              | CS024                             |              |
|---------------------------|--------------------|--------|----------------------------------|--------------|-----------------------------------|--------------|
| Station Location:         |                    |        | UCR, on flats fronting Haag Cove |              | Marcus Flats, near Pingston Creek |              |
| River Mile:               |                    |        | RM 697                           |              | RM 705                            |              |
| Sample Date(s):           |                    |        | 5/18/2001                        |              | 6/8/2001                          |              |
| Sample ID:                |                    |        | CR-018-SD                        | CR-066-SD    | not collected                     | CR-062-SD    |
| Collection Depth:         |                    |        | 0-6 inches                       | 18-24 inches | 0-6 inches                        | 18-24 inches |
| Analyte Group             | Analyte            | Units  |                                  |              |                                   |              |
| Metals                    | Aluminum           | mg/kg  | 9540                             | 9540         |                                   | 6810         |
|                           | Antimony           | mg/kg  | 2.4 BJL                          | 0.72 UJK     |                                   | 1.6 UJK      |
|                           | Arsenic            | mg/kg  | 13.1                             | 2.8          |                                   | 5.8          |
|                           | Barium             | mg/kg  | 1030                             | 175          |                                   | 147          |
|                           | Beryllium          | mg/kg  | 0.53 BJK                         | 0.53 BJK     |                                   | 0.29 B       |
|                           | Cadmium            | mg/kg  | 8.6                              | 0.43 B       |                                   | 0.1 U        |
|                           | Calcium            | mg/kg  | 34900                            | 5560         |                                   | 162000       |
|                           | Chromium           | mg/kg  | 25.2                             | 9.4          |                                   | 12.9         |
|                           | Cobalt             | mg/kg  | 6.5 BJK                          | 4 B          |                                   | 4.7 B        |
|                           | Copper             | mg/kg  | 67.7 JL                          | 15.6 JL      |                                   | 18.1 JL      |
|                           | Iron               | mg/kg  | 25900                            | 11500        |                                   | 11700        |
|                           | Lead               | mg/kg  | 439                              | 26.8         |                                   | 6.7 JL       |
|                           | Magnesium          | mg/kg  | 21400                            | 2970         |                                   | 5090         |
|                           | Manganese          | mg/kg  | 420                              | 315          |                                   | 327          |
|                           | Mercury            | mg/kg  | 0.93                             | 0.06 U       |                                   | 0.08 U       |
|                           | Nickel             | mg/kg  | 22.7                             | 9.2 B        |                                   | 14.3         |
|                           | Potassium          | mg/kg  | 1590 JL                          | 1060 B       |                                   | 1330 B       |
|                           | Selenium           | mg/kg  | 0.86 U                           | 0.82 U       |                                   | 1.2 U        |
|                           | Silver             | mg/kg  | 1.8 BJK                          | 0.32 B       |                                   | 0.32 U       |
|                           | Sodium             | mg/kg  | 276 BJK                          | 276 BJK      |                                   | 337 U        |
| Thallium                  | mg/kg              | 0.98 U | 0.94 U                           |              | 1.3 U                             |              |
| Vanadium                  | mg/kg              | 33.9   | 19.2                             |              | 16.6 B                            |              |
| Zinc                      | mg/kg              | 1180   | 84.2                             |              | 42.3                              |              |
| PCB                       | As Aroclor         | mg/kg  | 0.085 U (a)                      | 0.083 U (a)  |                                   | 0.1 U (a)    |
| Pesticides                | 4,4'-DDD           | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | 4,4'-DDE           | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | 4,4'-DDT           | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Aldrin             | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | alpha-BHC          | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | alpha-Chlordane    | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | beta-BHC           | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | delta-BHC          | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | Dieldrin           | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Endosulfan I       | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | Endosulfan II      | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Endosulfan sulfate | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Endrin             | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Endrin aldehyde    | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | Endrin ketone      | mg/kg  | 0.0042 U                         | 0.0041 U     |                                   | 0.005 U      |
|                           | gamma-BHC          | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | gamma-Chlordane    | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | Heptachlor         | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | Heptachlor epoxide | mg/kg  | 0.0022 U                         | 0.0021 U     |                                   | 0.0026 U     |
|                           | Methoxychlor       | mg/kg  | 0.022 U                          | 0.021 U      |                                   | 0.026 U      |
| Toxaphene                 | mg/kg              | 0.22 U | 0.21 U                           |              | 0.26 U                            |              |
| Sediment Characterization | Clay               | %      | 30                               | 30           |                                   | 10 <         |
|                           | Gravel             | %      | 0                                | 0            |                                   | 1            |
|                           | Percent Sand       | %      | 20                               | 20           |                                   | 45           |
|                           | Silt               | %      | 50                               | 40           |                                   | 45           |
|                           | TOC                | %      | 1.66                             | 1.04         |                                   | 1.58         |

(a) maximum detection limit for reported Aroclor mixtures

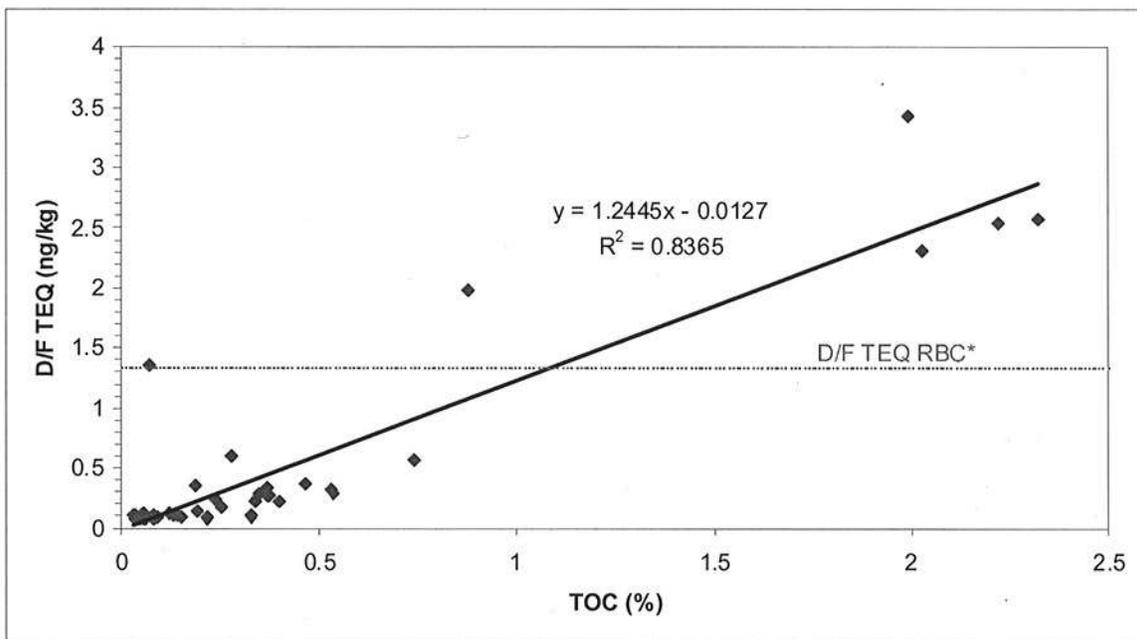
**Figure 1**  
**Illustration of Analysis and Compositing Recommendations**



Analysis List:

- A – TAL metals/metalloids
- B – Grain size (e.g., ASTM D422), TOC, elemental uranium, radionuclides (e.g., U-238 and Ra-226), pesticides, PAHs, SVOCs, PCBs (as Aroclor)
- C – If TOC > 1%, dioxin/furan congeners, PCB congeners, PBDEs

Figure 2  
Correlation between TOC and D/F TEQ in Phase I Sediment Samples



\*D/F TEQ RBC based on Subs. Trad. and 1E-06 cancer risk = 1.3 ng/kg

## Dina Johnson

---

**From:** Stifelman.Marc@epamail.epa.gov  
**Sent:** Thursday, June 12, 2008 9:37 AM  
**To:** Rosalind Schoof; Dina Johnson  
**Cc:** Tonel.Monica@epamail.epa.gov; brattin@syrres.com; follansbee@syrres.com; white@syrres.com; diamond@syrres.com; thayer@syrres.com; woodbury@syrres.com  
**Subject:** Follow-up re: Sediment IVBA  
**Attachments:** Bioaccessibility 06-02-08 SRC.pdf



Bioaccessibility  
06-02-08 SRC....

Roz,

This came up during one our beach sediment discussions.

I wanted to clarify EPA IVBA policy & how it will likely apply to our beach sed IVBA for the Upper Columbia.

Pls see attached file from Gary & feel free to contact us if you have any questions.

(See attached file: Bioaccessibility 06-02-08 SRC.pdf)

Regards,

-Marc

\*\*\*\*\*

"A little is enough."

- Pete Townshend

Marc Stifelman, Toxicologist  
U.S. Environmental Protection Agency, Region 10 Office of Environmental Assessment, Risk  
Evaluation Unit 1200 Sixth Avenue, Suite 900 Mail Stop: OEA-095 Seattle, Washington  
98101-3140 Tele 206/553-6979 Facs 206/553-0119 stifelman.marc@epa.gov

TO: Marc Stifelman, Monica Tonel, EPA Region 10  
FROM: Gary Diamond, Mark Follansbee, Lynn Woodbury; SRC  
DATE: 05/30/08  
RE: UCR beach sediment bioaccessibility assessments

The 03/21/08 draft of the DQO memo captures the current position of OSRTI, that the *in vitro* bioaccessibility assay (IVBA, the so-called “Drexler method”) described in EPA 2007 is considered to be a validated method for assessing *in vivo* relative bioavailability (RBA) of lead in soils and soil-like materials, providing that the soils have been adequately characterized with respect to lead mineralogy and that these soil characteristics are represented by the data sets used to establish the predictive regression model relating RBA to IVBA. Other limitations and considerations for applying the IVBA assay in site risk assessments are discussed in the cover letter to EPA 2007.

The DQO memo also captures the current position of OSRTI that it does not consider the IVBA method described in EPA 2005, or any other *in vitro* bioaccessibility assay for arsenic, to be valid for predicting RBA, for regulatory purposes. Nevertheless, as indicated in the DQO memo, application of the IVBA assay at the UCR site would be valuable, and should be encouraged for the following reasons:

- Data on the magnitude (i.e., categorical) of IVBA and spatial variability in IVBA would inform us about the need for and design of studies to assess RBA using *in vivo* assays (e.g., swine or other animal models). We may want to consider this possibility in the sampling plan; to ensure that we could composite sufficient sample for a validation test of UCR sediments (i.e., compare IVBA against RBA) were it needed.
- Research is also currently underway to optimize the IVBA assay for arsenic for predicting RBA. We may want to consider the possibility that these methods become available over the next 12-24 months, in which case, the option could open could become available to reassess IVBA with the optimized assay, were sufficient sample archived.
- Research is currently underway to evaluate *in vivo* bioassays. Ideally, these studies would be conducted with soils from a variety of sites across the U.S. assay for arsenic for predicting RBA. We may want to consider collecting soil samples to share with OSRTI for use in the evaluation of the assays.

Regarding application of the IVBA to other metals; here again, OSRTI does not consider the method to be valid for estimating RBA for metals other than lead. Furthermore, in our opinion, IVBA assessments of metals other than lead and arsenic could not be reliably used to estimate RBA for these metals either quantitatively or categorically. Nevertheless, application of the IVBA assay at the UCR site to other metals would yield information about the magnitude and spatial variability of acid solubility of these metals and about correlations in acid solubility among metals. This information may be valuable for assessing nature and extent of contamination.

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EPA. 2005. Estimation of Relative Bioavailability of Arsenic in Soil and Soil-Like Materials by In Vivo and In Vitro Methods. EPA Review Draft – October 2005.

EPA. 2007. Estimation of Relative Bioavailability of Lead in Soil and Soil-Like Materials Using In Vivo and In Vitro Methods. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency. OSWER 9285.7-77. May 2007.

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Bioaccessibility  
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Marc Stifelman, Toxicologist  
U.S. Environmental Protection Agency, Region 10 Office of Environmental Assessment, Risk  
Evaluation Unit 1200 Sixth Avenue, Suite 900 Mail Stop: OEA-095 Seattle, Washington  
98101-3140 Tele 206/553-6979 Facs 206/553-0119 stifelman.marc@epa.gov

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