HUMAN HEALTH RISK ASSESSMENT

POST-REMEDIATION SEDIMENT EVALUATION
LIBERTY PARK LAKE
SALT LAKE CITY, UTAH

FINAL
MAY 10, 2011

PREPARED FOR:

Chevron Pipe Line Company
Project Management Group
4800 Fournace Place, Room W324A
Bellaire, TX 77401-2324

PREPARED BY:

McDaniel Lambert, Inc.
1608 Pacific Avenue, Suite 201
Venice, CA 90291
310-392-6462

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May 10, 2011
Date

TABLE OF CONTENTS

FIGURES

TABLES

ATTACHMENTS

GLOSSARY of ACRONYMS & ABBREVIATIONS

Acronym	Explanation
ADAF	Age-Dependent Adjustment Factor
BaP	Benzo(a)pyrene
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BF	Bioavailability Factor
The City	Salt Lake City
CDI	Chronic Daily Intake
CEM	Conceptual Exposure Model
CPL	Chevron Pipe Line Company
COPC	Chemical of Potential Concern
CSF	Cancer Slope Factor
DEQ	Department of Environmental Quality
DRO	Diesel Range Organics
EPC	Exposure Point Concentration
ft	Feet
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk
MOA	Mode of Action
mg/kg	Milligrams Per Kilogram
mg/kg-d	Milligrams Per Kilogram per Day
NRC	National Research Council
OEHHA	California Office of Environmental Health Hazard Assessment
PAH	Polycyclic Aromatic Hydrocarbon
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RfD	Reference Dose
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
TPH	Total Petroleum Hydrocarbon
TPH-DRO	Total Petroleum Hydrocarbon as Diesel
TPH-GRO	Total Petroleum Hydrocarbon as Gasoline
TPH-MO	Total Petroleum Hydrocarbon as Motor Oil
UCL	Upper Confidence Limit

EXECUTIVE SUMMARY

Sediment samples collected from Liberty Park Lake, Salt Lake City, Utah following the June 2010 Red Butte Creek spill contained very low levels of petroleum hydrocarbons, indicating that clean-up efforts had removed the crude oil. However, some polycyclic aromatic hydrocarbons (PAHs) were also detected and the sources could not be determined. Although swimming and wading in the Lake are prohibited, the regulatory agencies overseeing the cleanup effort requested that a human health risk assessment (HHRA) be conducted to evaluate the potential health effects associated with the PAHs detected in Lake sediment. The HHRA found that the cancer risks associated with unrestricted (i.e., residential) and recreational use of the Lake are below or within the USEPA risk management range, defined as an incremental cancer probability of one in one million to one in ten thousand. The noncancer hazards for unrestricted or recreational exposure to Lake sediment are below the USEPA level of concern of 1.0.

This HHRA was completed at the request of Salt Lake City (the City) environmental staff and the Utah Department of Environmental Quality (DEQ) to evaluate the magnitude of health risks presented by PAHs detected in confirmation sediment samples collected at Liberty Park Lake (the Lake), with the objective of demonstrating that the Lake is safe for recreational activities. In addition, the regulatory agencies requested that unrestricted, that is to say residential, use of the Lake be evaluated. Realistically, park visitors are likely to have little contact with Lake sediment for a number of reasons, including use restrictions and physical barriers. Recreational activities on the Lake are limited to launching and retrieving paddle boats. Posted signage prohibits wading and swimming, although incidental contact might occur if a park visitor fell out of a paddle boat or ignored the wading and swimming prohibition. However, any incidental contact with PAHs remaining in Lake sediment is further restricted by the Lake's concrete curb wall, cobbled banks and the presence of angular rock. The concrete aprons around the Red Butte Creek and Emigration Creek inlets make sediments underlying these structures particularly inaccessible.

This HHRA evaluated the potential cancer risks and noncancer hazards from PAHs detected in sediment confirmation samples collected from the bottom and walls of Liberty Park Lake, and from beneath the concrete aprons of the Red Butte Creek and Emigration Creek inlets. Because PAHs are commonly found in urban environments at low levels, in addition to being present in crude oil at low levels, the sources of the levels detected in some samples at the Lake cannot be determined with certainty. Two potential exposure scenarios were evaluated: 1) a very conservative scenario which assumes the lake is on a residential property and is accessed almost daily for 30 years (known as the "unrestricted use scenario"), and 2) a more realistic "recreational user" scenario which better reflects the Lakes actual use and assumes contact with the Lake bottom sediments once a week during the summer weeks for 30 years. Exposure pathways considered in this HHRA included incidental ingestion of and dermal contact with Lake sediment. The exposures and associated risks in this assessment were developed using the reasonable maximum exposure approach promulgated by the United States Environmental Protection Agency (USEPA 1989). This approach estimates the maximum exposure reasonably expected to occur in a population in order to provide a health protective estimate of exposure within the range of possible exposures. Exposure assumptions were made in accordance with

regulatory guidance (USEPA 1989) and best professional judgment. Potential health risks were estimated by combining site-specific information with the analytical data for sediment confirmation samples collected from the Lake in November and December 2010, and January and April 2011.

Table ES-1 summarizes the estimated health risks associated with unrestricted and recreational use of the Lake in terms of the incremental lifetime cancer risk (ILCR) and the noncarcinogenic hazard index (HI), based on PAHs detected in post-restoration sediment confirmation samples. The potential cancer risks from unrestricted exposure (i.e., residential) to the bottom and beneath the walls of Liberty Park Lake, as well as from underneath the concrete aprons of the two inlets, are estimated to be within the USEPA risk management range specified by the National Contingency Plan of $1x10^{-6}$ (one in a million) to $1x10^{-4}$ (one in ten thousand; USEPA 1990). The noncancer hazards for unrestricted use in all Lake "exposure areas" are well below the USEPA level of concern of 1.0.

The potential cancer risk from recreational exposure to PAHs detected in sediment samples collected from the walls and bottom of Liberty Park Lake is below the low end of the USEPA risk management range ($1x10^{-6}$). The potential cancer risks associated with PAHs detected in sediments underneath the concrete aprons of the Red Butte and Emigration Creek inlets are within the USEPA risk management range, although exposure to sediment in these areas is currently precluded by the concrete aprons that cover the sediments. The noncancer hazards for recreational use of all Lake "exposure areas" are well below the USEPA level of concern of 1.0.

Table ES-1. Summary of Potential Cancer Risks and Noncancer Hazards

	Resident (Unrestricted Use)		Recreator	
Exposure Area	**ILCR**	**HI**	**ILCR**	**HI**
Liberty Park Lake Wall and Bottom Sediments				
Adult	$1x10^{-5}$	0.00003	$7x10^{-7}$	0.000002
Child	NA	0.0002	NA	0.00002
Liberty Park Lake Red Butte Creek Inlet Sediments				
Adult	$2x10^{-5}$	0.00006	$1x10^{-6}$	0.000004
Child	NA	0.0005	NA	0.00004
Liberty Park Lake Emigration Creek Inlet Sediments				
Adult	$2x10^{-5}$	0.00006	$1x10^{-6}$	0.000004
Child	NA	0.0005	NA	0.00004

Notes:
ILCR = Incremental lifetime cancer risk; HI = Noncancer hazard index
$1x10^{-5}$ = 0.00001 = 1 excess cancers per one hundred thousand people exposed.
NA = Not applicable; for direct contact exposure pathways, cancer risk is evaluated over a lifetime, assuming 6 years of exposure as a child and 24 years as an adult (USEPA 2002).

Major assumptions and conclusions of this HHRA include the following:

- Health risk estimates are based exclusively on PAHs detected in sediment confirmation samples collected from Liberty Park Lake following cleanup and restoration activities initiated following the June 2010 crude oil release.
- The Lake is part of a larger recreational area where signs are posted prohibiting wading or swimming, and physical deterrents such as the Lake's concrete curb wall, cobbled

banks and the presence of angular rock, limit human exposure. Sediments collected from underneath the concrete aprons of the Red Butte Creek and Emigration Creek inlets are particularly inaccessible. Given the impediments to accessing Lake sediments, it is not likely that park visitors would have regular contact with this material. Therefore the risks estimated in this HHRA likely represent worst-case estimates.

- For unrestricted (residential) use, the estimated cancer risks are within the USEPA risk management range of $1x10^{-6}$ to $1x10^{-4}$.
- For recreational use, contact with Lake bottom/wall sediments result in cancer risk estimate below the low end of the USEPA risk management range. Cancer risks associated with the unlikely exposure to PAHs in sediment beneath the inlet concrete aprons are within the risk management range.
- For all receptors, the estimated noncancer hazards are well below the USEPA level of concern of 1.0.
- It is not possible to determine if the residual low concentrations of TPH and PAHs are from urban runoff, crude oil, or a combination of the two sources.
- Liberty Park Lake sediments do not present a health risk to park users.

1.0 INTRODUCTION

On June 12, 2010, crude oil released from a pipeline in Red Butte Canyon was found in Red Butte Creek in Salt Lake City County, Utah. Approximately 800 barrels of crude oil were released, with some reaching the Red Butte Creek, Liberty Park Lake, and Jordan River. Under the oversight of the Unified Command, Chevron Pipe Line Company (CPL) initiated cleanup, recovery and restoration activities. Immediate measures were taken to minimize the impact of the crude oil on Liberty Park Lake, including maintaining boom operations and deploying emergency response equipment. Remediation activities were carried out at Liberty Park Lake in accordance with the approved Removal Action Plan (ENTACT 2010) developed by Chevron, Salt Lake City (the City), Salt Lake Valley Health, and the Utah Department of Environmental Quality (DEQ). The remediation effort included excavation of impacted sediment from the Lake bottom and walls, removal of the existing curb wall and any impacted sediment beneath the wall, and the collection of sediment confirmation samples to evaluate the completeness of the cleanup (ENTACT 2010 and CPL 2010).

Following the CPL work plan (CPL 2010), sediment confirmation samples were collected from the Lake bottom and wall, and from beneath the concrete aprons of the inlet and outlet. Samples were analyzed for total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene, and xylenes (BTEX), and the polycyclic aromatic hydrocarbons (PAHs) naphthalene and benzo(a)pyrene (BaP). Although Chevron and the agencies had agreed it would be appropriate to measure BaP in three sediment samples with the highest TPH concentrations, an error in the analyses request resulted in BaP being evaluated in all sediment samples, regardless of whether or not TPH was detected. To further evaluate the detections of BaP in some sediment samples, CPL conducted additional PAH analyses, which included the quantification of the US Environmental Protection Agency's (USEPA) 16 priority pollutant PAHs.

Liberty Park Lake, following Spring 2011 rainfall

Detections of TPH in confirmation samples were very low (ranging from non-detect to 205 mg/kg-dry weight; see Table 1-1), all well below the project cleanup goal of 1,000 mg TPH/kg-sediment, and are not indicative of the presence of residual crude oil in Lake sediments. However, concentrations of two PAHs, BaP and dibenzo(a,h)anthracene exceeded the USEPA's conservative Regional Screening Levels (RSLs) for residential soil (USEPA 2010a). The City and the Utah DEQ requested a human health risk assessment of the PAHs detected in confirmation sediment samples collected at Liberty Park Lake be performed to demonstrate that Liberty Park Lake is safe for recreational activities. As per a conference call on April 19, 2011, the City requested an evaluation of future unrestricted use (e.g. residential).

1.1 OBJECTIVE AND SCOPE

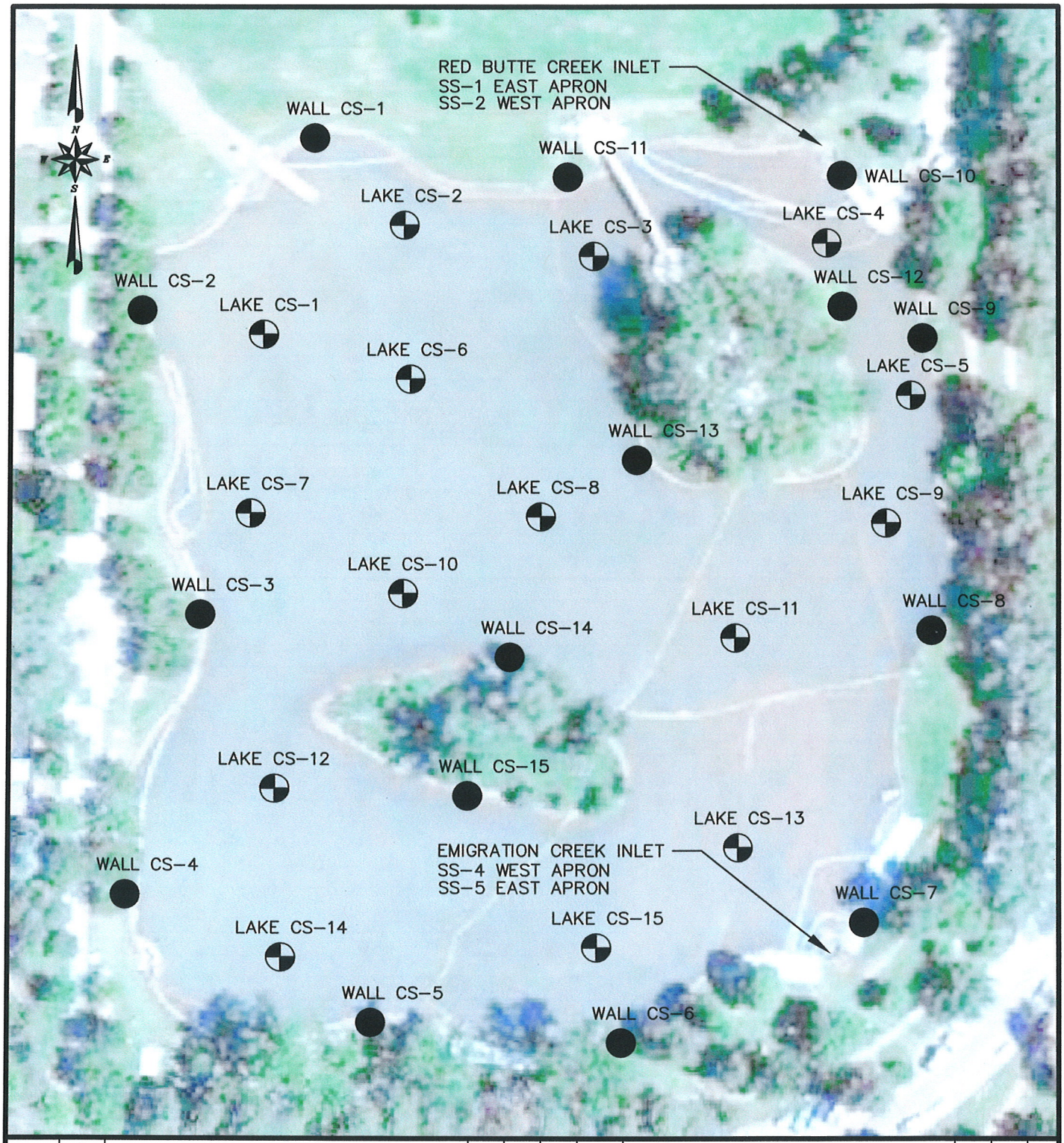
The overall objective of this HHRA is to quantify the magnitude of potential human health risks from contamination detected in Liberty Park Lake sediment following cleanup, recovery and restoration efforts undertaken following the June 2010 Red Butte Canyon oil spill. Although use of Liberty Lake Park is exclusively recreational, the regulatory agencies overseeing the cleanup and restoration efforts requested an evaluation of unrestricted – or residential – use of the Lake. The HHRA also evaluates a more realistic recreational exposure scenario. Although wading and swimming in the Lake are prohibited, incidental contact could occur if a park visitor fell out of a paddle boat or ignored the signage prohibiting wading and swimming. Therefore the HHRA evaluates potential risk from exposure to PAHs in Lake sediment for:

- Resident (adult and child), and
- Recreator (adult and child).

1.2 SEDIMENT CONFIRMATION SAMPLING

Post-excavation sediment confirmation samples were collected from the walls and bottom of Liberty Lake in November and December 2010 and January 2011, and from beneath the Red Butte Creek Inlet and Emigration Creek Inlet concrete aprons in April 2011. As shown in Figure 1-1, 30 sediment confirmation samples were collected from six inches below surface of the Lake bottom (Lake CS-1 to 15) and the Lake walls (Wall CS-1 to 15).[1] In addition, two sediment confirmation samples were collected from ***beneath*** each of the two inlet concrete aprons. All of these samples were analyzed for diesel-range total petroleum hydrocarbons (TPH-DRO, C10-C28), BTEX, and napththalene; all but four of the Lake wall/bottom sediment samples also were analzyed for BaP. All but nine Lake bottom/wall sediment samples (corresponding to eight locations) were analyzed for gasoline-range total petroleum hydrocarbons (TPH-GRO, C6-C10). In addition, 12 of the Lake bottom/wall and all four of the inlet sediment confirmation samples were analyzed for the 16 priority pollutant PAHs via USEPA Method 8270D in selected ion

[1]Field duplicate samples, identified as Lake BD-1, Lake BD-3, and Wall BD-1, were collected from Lake CS-7, Lake CS-9, and Wall CS-7, respectively.



REV

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Chevron Red Butte Release Pipe Line

DR TAJ CH. GW
DR APP.
ENGR.
DPR'G. DEPT.
APPROVED
ENG'R. DEPT.

MP 174.5 RED BUTTE RELEASE LIBERTY PARK LAKE RESTORATION CONFIRMATION SAMPLE LOCATIONS UNDER INLET APRONS AND FORMER CURB WALL AND LAKE BOTTOM

SCALE 1" = 100' DATE 4-2011

C. C.
S. D.

FIGURE 1-1

monitoring (SIM) mode. The laboratory data packages corresponding to these analyses are included as Attachment 1.

In the Lake bottom and wall sediment samples, TPH-GRO was detected in only four of the samples analyzed, at concentrations ranging from 0.0807 mg/kg-dry weight (Wall CS-9) to 0.437 mg/kg-dry weight (Wall CS-12). Limited and low detections of volatile hydrocarbons include benzene (Wall BD-1/CS-7), toluene (Lake CS-14 and -15, Wall BD-1/CS-7), xylenes (Wall BD-1/CS-7), and naphthalene (Wall CS-12). Diesel range TPH was detected at 28 locations, at very low concentrations ranging from 0.08 to 205 mg/kg-dry weight (Table 1-1). Benzo(a)pyrene was detected at 14 of the 26 locations analyzed, with detected concentrations ranging from 0.0115 to 0.453 mg/kg-dry weight (Table 1-1). Thirteen of these detected concentrations exceed the residential RSL for BaP (0.015 mg/kg), and the six detected dibenzo(ah)anthracene concentrations exceed the corresponding residential RSL (also 0.015 mg/kg; see Table 1-2).

In the Lake inlet sediment samples, TPH-GRO was not detected. Diesel range TPH was detected in all four samples, at concentrations ranging from 83.2 to 198 mg/kg-dry weight (Table 1-1). Benzo(a)pyrene also was detected in all four samples at concentrations exceeding the residential RSL (0.064 to 0.185 mg/kg-dry weight; Table 1-1). Dibenzo(ah)anthracene was detected in three of the four inlet samples, all at levels exceeding residential RSL (0.0232 to 0.0336 mg/kg-dry weight; Table 1-2). There is no apparent correlation between TPH and BaP levels in sediment, and BaP was not detected in the sample with the highest TPH concentration. Given the low levels of TPH detected in Lake sediment confirmation samples, and the lack of correlation between TPH and BaP, it is unclear whether the PAHs detected in these samples are residual material from the spill, or related to some other source such as anthropogenic background (see Section 7.2.1 for further discussion of potential PAH sources).

1.3 HUMAN HEALTH RISK ASSESSMENT PROCESS

As shown in Figure 1-2 below, the risk assessment process consists of six distinct steps.

Figure 1-2. Human Health Risk Assessment Process

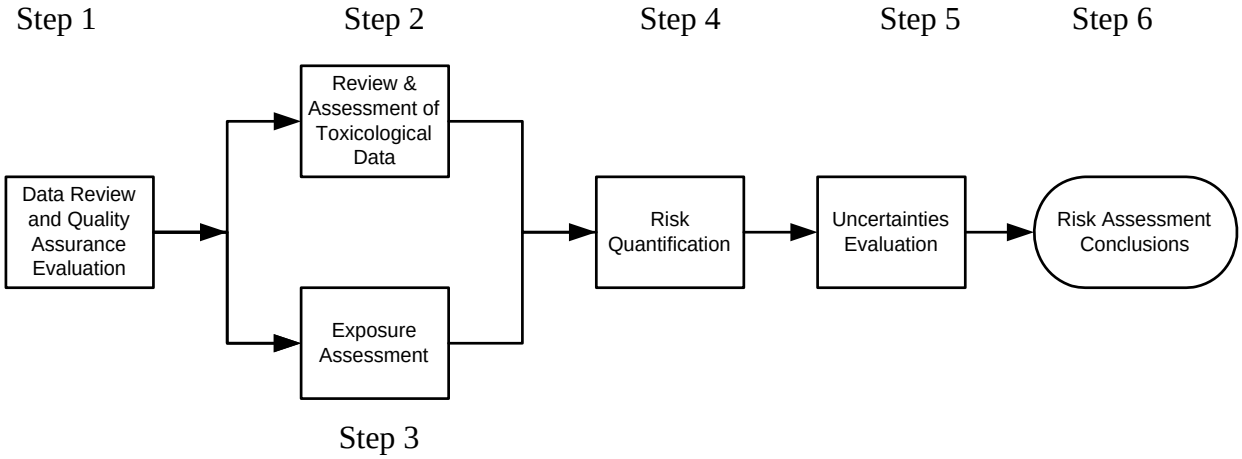

Table 1-1. Confirmation Sediment TPH-DRO and BaP Results Summary

Sample ID	DRO	BaP
Lake CS-1	< 23.5	< 0.0048
Lake CS-2	44	**0.163**
Lake CS-3	63.5	< 0.0053
Lake CS-4	62.8	**0.0263**
Lake CS-5	38.1	**0.0205**
Lake CS-6	78.7	**0.0683**
Lake CS-7	42.7	< 0.0057
Lake BD-1 (CS-7 dup)	43.9	< 0.0058
Lake CS-8	123	NA
Lake CS-9	196.1	**0.0518**
Lake BD-3 (CS-9 dup)	56.9	**0.0347**
Lake CS-10	46.5	< 0.0044
Lake CS-11	45.4	**0.036**
Lake CS-12	30.5	**0.453**
Lake CS-13	114	< 0.0044
Lake CS-14	61.5	< 0.0117
Lake CS-15	102	< 0.005
Wall CS-1	44.2	**0.054**
Wall CS-2	34.2	0.0115
Wall CS-3	28.4	**0.063**
Wall CS-4	31.3	< 0.0057
Wall CS-5	33.9	< 0.0056
Wall CS-6	187	< 0.0054
Wall CS-7	< 28.2	< 0.0047
Wall BD-1 (CS-7 dup)	117.0	< 0.0047
Wall CS-8	205	NA
Wall CS-9	0.081	**0.0157**
Wall CS-10	61.9	**0.0468**
Wall CS-11	36.6	**0.109**
Wall CS-12	145.4	**0.0317**
Wall CS-13	56.9	NA
Wall CS-14	< 24.9	NA
Wall CS-15	29.2	< 0.0040
SS-1	189	**0.160**
SS-2	198	**0.115**
SS-4	148	**0.185**
SS-5	83	**0.0639**

Concentrations are in mg/kg-dry weight.
NA = Not analyzed.
Bold text indicates residential RSL exceedance (0.015 mg/kg-day weight).

Table 1-2. Liberty Park Lake Sediment Confirmation Samples PAH Results

	Confirmation Sediment Sample ID							Residential RSL[1]
	Lake CS-2	Lake CS-4	Lake CS-5	Lake CS-9	Lake BD-3 (CS-9 Dup)	Lake CS-11	Lake CS-12	
PAHs (ug/kg)								
Naphthalene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	3,600
1-Methylnaphthalene	<4.60	<12.7	<11.4	36.7	<14.5	<13.8	<5.37	22,000
2-Methylnaphthalene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	310,000
Indene	<4.60	<12.7	<11.4	32.4	<14.5	<13.8	<5.37	NV
Acenaphthylene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	NV
Acenaphthene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	3,400,000
Fluorene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	2,300,000
Anthracene	<4.60	<12.7	<11.4	<16.2	<14.5	<13.8	<5.37	17,000,000
Phenanthrene	<4.60	18.6	<11.4	50.7	16.4	15.7	<5.37	NV
Fluoranthene	24.8	23.7	12.9	44.3	31.8	36.9	<5.37	2,300,000
Pyrene	30.4	23.7	<11.4	46.4	32.8	38.7	<5.37	1,700,000
Benz(a)anthracene	21.2	24.6	15.9	44.3	25.1	31.4	<5.37	150
Chrysene	19.3	28.0	<11.4	<16.2	37.6	16.6	<5.37	15,000
Benzo(b)fluoranthene	52.5	19.5	14.4	37.8	33.7	22.1	21.5	150
Benzo(k)fluoranthene	85.6	14.4	11.4	<16.2	21.2	17.5	<5.37	1,500
Benzo(a)pyrene	**163**	**26.3**	**20.5**	**51.8**	**34.7**	**36**	**453**	15
Indeno(1,2,3-cd)pyrene	59.8	24.6	21.3	47.5	49.2	24	24.7	150
Dibenzo(a,h)anthracene	**53.4**	<12.7	<11.4	**18.3**	**15.4**	<13.8	<5.37	15
Benzo(ghi)perylene	46.0	<12.7	<11.4	45.3	20.2	36.9	<10.7	NV
TOTAL PAHs (detected; mg/kg)	0.56	0.20	0.10	0.46	0.32	0.28	0.50	NV

Notes

[1]Residential RSL = Residential Regional Screening Level; bold text indicates residential RSL exceedance

NA = Not applicable

NV = No value

Table 1-2. Liberty Park Lake Sediment Confirmation Samples PAH Results

	Confirmation Sediment Sample ID										Residential RSL[1]
	Wall CS-1	Wall CS-3	Wall CS-9	Wall CS-10	Wall CS-11	Wall CS-12	SS-1	SS-2	SS-4	SS-5	
PAHs (ug/kg)											
Naphthalene	<5.16	<5.50	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	3,600
1-Methylnaphthalene	<5.16	<5.50	<13.8	<13.0	<5.27	22.9	<10.7	<10.6	<15.3	<11.4	22,000
2-Methylnaphthalene	<5.16	<5.50	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	310,000
Indene	<5.16	14.3	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	NV
Acenaphthylene	<5.16	<5.50	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	NV
Acenaphthene	<5.16	<5.50	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	3,400,000
Fluorene	<5.16	<5.50	<13.8	<13.0	<5.27	<13.2	<10.7	<10.6	<15.3	<11.4	2,300,000
Anthracene	<5.16	12.1	<13.8	35.5	<5.27	<13.2	24.3	21.1	<15.3	<11.4	17,000,000
Phenanthrene	<5.16	20.9	<13.8	26.0	28.4	29.9	55.8	28.9	<15.3	<11.4	NV
Fluoranthene	<5.16	39.6	<13.8	35.5	40.0	31.7	142	73.2	96.8	31.2	2,300,000
Pyrene	<5.16	52.8	<13.8	38.1	49.5	32.6	152	83.1	130	34.2	1,700,000
Benz(a)anthracene	<5.16	15.4	13.8	26.0	36.8	30.8	102	62.7	93.8	39.6	150
Chrysene	<5.16	25.3	<13.8	17.3	32.6	31.7	95.9	55.6	77.5	28.9	15,000
Benzo(b)fluoranthene	32.0	75.9	13.8	32.0	64.2	25.5	139	97.9	152	51.7	150
Benzo(k)fluoranthene	<5.16	121	<13.8	24.3	105	15.0	58.7	34.5	55	<11.4	1,500
Benzo(a)pyrene	**53.7**	**62.7**	**15.7**	**46.8**	**109**	**31.7**	**160**	**115**	**185**	**63.9**	15
Indeno(1,2,3-cd)pyrene	44.4	60.5	19.3	35.5	84.2	29.9	95.2	78.8	107	34.2	150
Dibenzo(a,h)anthracene	**35.1**	**39.6**	<13.8	**26.0**	**74.7**	<13.2	**29.3**	**23.2**	**33.6**	<11.4	15
Benzo(ghi)perylene	20.6	23.1	<13.8	62.4	55.8	13.2	61.5	34.5	41.8	<11.4	NV
TOTAL PAHs (detected; mg/kg)	0.19	0.56	0.063	0.405	0.68	0.29	1.116	0.709	0.97	0.28	NV

Notes

[1]Residential RSL = Residential Reg

NA = Not applicable

NV = No value

In Step 1, the data associated with the Lake are reviewed and the analytical results compiled. The data are screened according to data usability criteria established for risk assessment. Constituents with data meeting these quality criteria are carried forward in the risk assessment as the chemicals of potential concern (COPCs).

In Step 2, COPC-specific toxicity values are compiled for use in the quantitative risk analysis. The following toxicity values are used: (1) values published in USEPA's Integrated Risk Information System (IRIS) (USEPA 2010a), (2) USEPA's Provisional Peer Reviewed Toxicity Values (USEPA 2011); (3) other toxicity values identified in USEPA's RSLs (USEPA 2010), or (4) surrogate values.

In Step 3, exposure scenarios are developed to (1) describe the potential exposures at the Lake for future land-use and (2) provide a basis for quantifying those exposures. Each exposure scenario addresses the residual COPCs, the potential route or mechanism of exposure, and potentially exposed human populations (known as "receptors"). When site-specific data for scenario development are unavailable, conservative values found in USEPA guidance are used.

In *Step 4*, the toxicity and exposure assessments are summarized and integrated into quantitative expressions of risk. This includes COPC-specific, multi-pathway risks for each of the Lake's potential receptors. The risk values presented in a risk assessment are conditional estimates derived from a considerable number of conservative, health-protective assumptions about exposure and toxicity. Thus, to place the risk estimates in proper perspective, it is important to specify the assumptions and uncertainties inherent in the risk assessment. This process is conducted in *Step 5*. This step may also involve the reevaluation of data or the identification of additional data requirements to decrease uncertainty.

Step 6 involves the development and presentation of conclusions that can be inferred from the findings of the risk assessment. This step provides risk managers with insight into the interpretation of the risk assessment results.

1.4 GUIDANCE DOCUMENTS

The following guidance documents and/or information sources were used in the preparation of this risk assessment:

- *Risk Assessment Guidance for Superfund (RAGS), Volume I—Human Health Evaluation Manual*, Part A, Interim Final (USEPA 1989)
- *Risk Assessment Guidance for Superfund (RAGS), Volume I—Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*, Interim (USEPA 2004)
- *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (USEPA 2002)

- Integrated Risk Information System (IRIS) database (USEPA 2011)
- USEPA Regional Screening Levels (RSLs) Table (USEPA 2010a)

1.5 REPORT ORGANIZATION

This HHRA is divided into eight sections. *Section 1* provided the background information with respect to PAHs detected in Liberty Park Lake sediment confirmation samples, outlined the objectives, and presented the risk assessment process.

Section 2 addresses the conceptual exposure model. *Section 3* identifies the COPCs for the site, which in this HHRA are limited to PAHs. The data sources used in the risk assessment are discussed within the context of a hierarchy developed on the basis of the data quality criteria and objectives. *Section 4* presents the calculations for exposure point concentrations (i.e., concentrations of chemicals in sediment). *Section 5* summarizes the toxicity information for both carcinogenic and noncarcinogenic health effects for each chemical. *Section 6* presents the risk characterization methodology and the resulting health risk estimates. *Section 7* discusses uncertainties associated with the estimated risk values. The potential magnitude and direction of bias that may be introduced by each identified uncertainty factor to the estimated risk values are evaluated. *Section 8* summarizes the findings and the conclusions of this report, while *Section 9* identifies the references used in this report.

2.0 CONCEPTUAL EXPOSURE MODEL

An evaluation of the potential human health risks posed by a site requires the identification of populations that may be exposed to site-related chemicals and to determine the routes by which these exposures may occur. The conceptual exposure model (CEM) provides the basis for a comprehensive evaluation of the potential risks to human health by identifying the mechanisms through which receptors may be exposed to residual COPCs at a site. The CEM traces the COPCs identified at a site in a logical migration from their sources through various release mechanisms and exposure routes to potentially affected receptors.

As outlined in Section 1.1, this HHRA is being completed at the request of the regulatory agencies to evaluate the magnitude of health risks presented by PAHs detected in confirmation sediment samples collected at Liberty Park Lake, with the objective of demonstrating that Liberty Park Lake is safe for recreational activities. In addition, the regulatory agencies also requested that unrestricted, that is to say residential, use of the Lake be evaluated.

Realistically, park visitors are likely to have little contact with Lake sediment for a number of reasons, including use restrictions and physical barriers. Recreational activities on the Lake are limited to launching and retrieving paddle boats. Posted signage prohibits wading and swimming, although incidental contact might occur if a park visitor fell out of a paddle boat or ignored the wading and swimming prohibition. However, any incidental contact with PAHs remaining in Lake sediments is further restricted by the presence of the Lake's concrete wall, cobbled banks, and the presence of angular rock. The concrete aprons around the Red Butte Creek and Emigration Creek inlets make these sediments particularly inaccessible.

Left: Liberty Park Lake, following reconstruction of concrete wall and replacement of cobble along banks
Right: Concrete apron surrounding inlet

As shown in Figure 1-1 and the pictures above, exposure to sediments beneath the concrete inlet aprons is even less likely than exposure to Lake bottom/wall sediments. Therefore, three discrete "exposure areas" are considered in this risk assessment: 1) Lake wall and bottom sediments, 2) Red Butte Creek inlet sediments, and 3) Emigration Creek inlet sediments. The potential receptors and associated exposure pathways evaluated in each of these exposures areas are:

1. Adult and child residential user who may be exposed to PAHs from:
    - Incidental ingestion of sediment, and
    - Direct contact with sediment
2. Adult and child recreational user who may be exposed to PAHs from:
    - Incidental ingestion of sediment, and
    - Direct contact with sediment

3.0 CHEMICALS OF POTENTIAL CONCERN

As described in Section 1.2, although only low levels of TPH and PAHs were detected in sediment confirmation samples collected from the Lake, concentrations of the two PAHs (BaP and dibenzo(a,h)anthracene) exceeded health-protective residential RSLs in some samples. As a result, the regulatory agencies requested an evaluation of the potential health risks associated with these compounds. Therefore, PAHs are the only chemicals of potential concern. The data included in this risk assessment were not subjected to a formal data usability analysis. The sediment confirmation sample dataset was compiled based on the laboratory data packages included as Attachment 1. These data packages were reviewed for four of the key data usability criteria (USEPA 1992):

1. Reports: In this case the available laboratory data packages were evaluated for completeness. The data should be reported in a format that provides adequate data and data documentation.
2. Analytical Methods and Detection Limits: Documents that the appropriate analytical methods are able to identify COPCs and that reporting limits that meet risk assessment requirements.
3. Data Review: An examination of laboratory and method performance for the samples and analytes.
4. Data Quality Indicators: Data quality indicators provide quantitative measures of the completeness, comparability, representativeness, precision, and accuracy of the environmental analytical data. These indicators are assessed through the review of sampling and analytical data and accompanying documentation.

Review of available laboratory data reports and electronic files found that the data adequately meet the required criteria. Overall, reporting limits were below their respective health screening levels, indicating that they are appropriate for risk assessment purposes.

4.0 EXPOSURE ASSESSMENT

The exposure assessment process quantifies the magnitude, frequency, and duration of exposure for those populations and pathways selected for quantitative evaluation in the conceptual exposure model (Section 2). To quantify exposures, where appropriate and sufficient data are available, statistically representative concentrations of PAHs were estimated for each of the three Lake sediment exposure areas. For the two inlet exposure areas, maximum concentrations were used as the PAH exposure point concentrations (EPCs). These EPCs are assumed to be equal to the representative concentration in sediment for direct exposures such as dermal contact and incidental ingestion. In the exposure quantification step, receptor-specific exposure parameters are applied to the sediment EPCs, resulting in intake factors for direct exposure to sediment.

4.1 DEVELOPMENT OF EXPOSURE POINT CONCENTRATIONS

Only two sediment samples were collected from each of the Lake inlets, therefore EPCs in these two exposure areas are based on maximum PAH concentrations, as summarized in Table 4-1. The large number of Lake bottom and wall samples analyzed for PAHs, allow the calculation of statistically representative concentrations of PAHs in this exposure area. Of the 30 Lake bottom and wall locations sampled, 26 sediment samples were analyzed for BaP; 12 of these samples also were evaluated for USEPA's 16 priority pollutant PAHs. As the data allowed, exposure was evaluated using the 95% upper confidence limit (UCL) of the arithmetic mean concentration, based on the 95% UCL method recommended by ProUCL (version 4.00.05, USEPA 2010b). The reporting limit was substituted for non-detect observations and in the case of duplicate samples (Lake BD-1, Lake BD-3, Wall BD-1) the larger of the original and duplicate was used to calculate the 95% UCL. When detected observations were insufficient to calculate a 95% UCL, EPCs are based on maximum COPC concentrations. Additionally, when a PAH was not detected in any sample, half of the minimum reporting limit is used as the EPC to be health protective. The ProUCL (USEPA 2010) "output" is included as Attachment 2, and the "Liberty Park Lake Wall and Bottom Sediments" exposure area EPCs are presented in Table 4-1.

4.2 EXPOSURE QUANTIFICATION

This section provides standard equations for estimating human intake associated with the selected exposure pathways. The equations, exposure parameters, and parameter values were taken from USEPA's *Risk Assessment Guidance for Superfund (RAGS)* (USEPA 1989 and USEPA 2004); and USEPA's *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (USEPA 2002). The receptor-specific exposure parameters are presented in Section 4.2.1. The intake equations and the resulting intake factors (for ingestion and dermal exposure), which were used to evaluate both cancer risk and noncancer hazard, are presented in

Table 4-1. Sediment PAH Summary Statistics and Exposure Point Concentrations

Chemical	Matrix	Frequency	NonDetects	Detects	UCL Calculation Method Used in HHRA	95% UCL	EPC
		Detects / Total	Min – Max	Min – Max			
Liberty Park Lake Wall and Bottom Sediments							
Acenaphthene	sediment	0 / 12	0.0046 - 0.015	-	NA	NA	0.0023
Acenaphthylene	sediment	0 / 12	0.0046 - 0.015	-	NA	NA	0.0023
Anthracene	sediment	2 / 12	0.0046 - 0.015	0.012 - 0.036	NA	NA	0.036
Benz(a)anthracene	sediment	10 / 12	0.0052 - 0.0054	0.015 - 0.044	Kaplan Meier	0.029	0.029
Benzo(b)fluoranthene	sediment	12 / 12	-	0.014 - 0.076	Student-t	0.045	0.045
Benzo(k)fluoranthene	sediment	9 / 12	0.0052 - 0.014	0.011 - 0.12	Kaplan Meier	0.060	0.060
Benzo(g,h,i)perylene	sediment	8 / 12	0.011 - 0.014	0.013 - 0.062	Kaplan Meier	0.039	0.039
Benzo(a)pyrene	sediment	14 / 26	0.0040 - 0.012	0.012 - 0.45	Kaplan Meier	0.088	0.088
Chrysene	sediment	8 / 12	0.0052 - 0.014	0.017 - 0.038	Kaplan Meier	0.027	0.027
Dibenz(a,h)anthracene	sediment	6 / 12	0.0054 - 0.014	0.018 - 0.075	Kaplan Meier	0.040	0.040
Fluoranthene	sediment	9 / 12	0.0052 - 0.014	0.013 - 0.044	Kaplan Meier	0.034	0.034
Fluorene	sediment	0 / 12	0.0046 - 0.015	-	NA	NA	0.002
Indeno(1,2,3-cd)pyrene	sediment	12 / 12	-	0.019 - 0.084	Student-t	0.050	0.050
1-Methylnaphthalene	sediment	2 / 12	0.0046 - 0.014	0.023 - 0.037	NA	NA	0.037
2-Methylnaphthalene	sediment	0 / 12	0.0046 - 0.015	-	NA	NA	0.0023
Naphthalene	sediment	0 / 12	0.0046 - 0.015	-	NA	NA	0.0023
Pyrene	sediment	8 / 12	0.0052 - 0.014	0.024 - 0.053	Kaplan Meier	0.040	0.040
Liberty Park Lake Red Butte Creek Inlet Sediments							
Acenaphthene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
Acenaphthylene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
Anthracene	sediment	2 / 2	-	0.021 - 0.024	NA	NA	0.024
Benz(a)anthracene	sediment	2 / 2	-	0.063 - 0.102	NA	NA	0.10
Benzo(b)fluoranthene	sediment	2 / 2	-	0.098 - 0.139	NA	NA	0.14
Benzo(k)fluoranthene	sediment	2 / 2	-	0.035 - 0.06	NA	NA	0.059
Benzo(g,h,i)perylene	sediment	2 / 2	-	0.035 - 0.062	NA	NA	0.062
Benzo(a)pyrene	sediment	2 / 2	-	0.12 - 0.16	NA	NA	0.16
Chrysene	sediment	2 / 2	-	0.056 - 0.096	NA	NA	0.096
Dibenz(a,h)anthracene	sediment	2 / 2	-	0.023 - 0.029	NA	NA	0.029
Fluoranthene	sediment	2 / 2	-	0.073 - 0.142	NA	NA	0.14
Fluorene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
Indeno(1,2,3-cd)pyrene	sediment	2 / 2	-	0.079 - 0.095	NA	NA	0.095
1-Methylnaphthalene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
2-Methylnaphthalene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
Naphthalene	sediment	0 / 2	0.011 - 0.011	-	NA	NA	0.0053
Pyrene	sediment	2 / 2	-	0.098 - 0.139	NA	NA	0.14
Liberty Park Lake Emigration Creek Inlet Sediments							
Acenaphthene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Acenaphthylene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Anthracene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Benz(a)anthracene	sediment	2 / 2	-	0.040 - 0.094	NA	NA	0.094
Benzo(b)fluoranthene	sediment	2 / 2	-	0.052 - 0.15	NA	NA	0.15
Benzo(k)fluoranthene	sediment	1 / 2	0.011 - 0.011	0.055 - 0.055	NA	NA	0.055
Benzo(g,h,i)perylene	sediment	1 / 2	0.011 - 0.011	0.042 - 0.042	NA	NA	0.042
Benzo(a)pyrene	sediment	2 / 2	-	0.064 - 0.19	NA	NA	0.19
Chrysene	sediment	2 / 2	-	0.029 - 0.078	NA	NA	0.078
Dibenz(a,h)anthracene	sediment	1 / 2	0.011 - 0.011	0.034 - 0.034	NA	NA	0.034
Fluoranthene	sediment	2 / 2	-	0.031 - 0.097	NA	NA	0.097
Fluorene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Indeno(1,2,3-cd)pyrene	sediment	2 / 2	-	0.034 - 0.11	NA	NA	0.11
1-Methylnaphthalene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
2-Methylnaphthalene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Naphthalene	sediment	0 / 2	0.011 - 0.015	-	NA	NA	0.0057
Pyrene	sediment	2 / 2	-	0.034 - 0.13	NA	NA	0.13

Notes:
Concentrations are in mg/kg-dry weight.
95% UCL = 95% Upper Confidence Limit
EPC = Exposure Point Concentration

Section 4.2.2. For cancer risk these intake factors were age-adjusted, assuming that the lifetime exposure of thirty years results from six years of exposure as a child and 24 years of exposure as an adult.

4.2.1 Receptor-Specific Exposure Parameters

Unrestricted use is evaluated based on default residential exposure parameters; these are the same as the exposure assumption used in the development of the residential soil RSLs (USEPA 2010a). For recreational use, receptor-specific exposure parameters were identified based on best-professional judgment. Exposure parameters are summarized in Table 4-2, and described below.

Table 4-2. Exposure Parameters

Abbreviation	Name	Value and Units	Source
$IngR_c$	Sediment Ingestion Rate – child	200 mg/day	USEPA 2002
$IngR_a$	Sediment Ingestion Rate – adult	100 mg/day	USEPA 2002
FI	Fraction Soil Contaminated	1 (unitless)	Health-protective assumption
BF	Ingestion Bioavailability Factor	1 (default)	Health-protective assumption
SA_c	Exposed Surface Area – child	2,800 cm^2	USEPA 2004
SA_a	Exposed Surface Area – adult	5,700 cm^2	USEPA 2004
AF_c	Adherence Factor – child	0.2 mg/cm^2	USEPA 2004
AF_a	Adherence Factor – adult	0.07 mg/cm^2	USEPA 2004
ABS	Dermal Absorption Coefficient - PAHs	0.13	USEPA 2004
BW_c	Body Weight – child	15 kg	USEPA 2002
BW_a	Body Weight – adult	70 kg	USEPA 2002
EF_{res}	Exposure Frequency – resident	350 days/year	USEPA 2002
EF_{rec}	Exposure Frequency – recerator	26 days/year	Site-specific
ED_c	Exposure Duration – child	6 years	USEPA 2002
ED_a	Exposure Duration – adult	24 years	USEPA 2002
CF	Sediment Conversion Factor	10^6 mg/kg	
$AT_{carcinogens}$	Averaging Time – Carcinogens	25,500 days	USEPA 2002
$AT_{noncarcinogens}$	Averaging Time – Non-Carcinogens (adult)	8,760 days	USEPA 2002
$AT_{noncarcinogens}$	Averaging Time – Non-Carcinogens (child)	2,190 days	USEPA 2002

Adult and child residents are assumed to have direct contact (ingestion and dermal) with sediments in the Lake for 350 days per year for a period of 30 years (6 years as a child and 24 years as an adult; USEPA 2002). Soil ingestion rates (e.g., 100 and 200 mg-day, respectively for adults and children), dermal exposure parameters (e.g., exposed skin surface areas of 5,700 cm^2

and 2,800 cm^2, respectively for adults and children), body weights (70 and 15 kg, respectively for adults and children) and averaging times are consistent with USEPA guidance documents (USEPA 2002 and 2004).

Recreational use exposure parameters are the same as for residential receptors except for the exposure frequency. Adult and child recreational users are assumed to have direct contact (ingestion and dermal) with PAHs in sediment for once per week for six months of the year (due to Lake closure to boating activities during winter months), for a total of 26 days per year for 30 years.

4.2.2 Sediment Intake Factors

4.2.2.1 *Incidental Ingestion*

Equation 6-14 from the RAGS (USEPA 1989) was used to quantify intake from the ingestion pathway:

$$CDI_{si} = (C_s \times IngR \times CF \times FI \times EF \times ED \times BF)$$

For unrestricted exposure via incidental ingestion, the chemical-specific chronic daily intakes are calculated by multiplying the EPCs by the intake factors of 1.28×10^{-5} for noncarcinogens (child), 1.57×10^{-6} for carcinogens and 6.71×10^{-6} for mutagens.[2] For recreational exposure via incidental ingestion, the chemical-specific chronic daily intakes are calculated by multiplying the EPCs by the intake factors of 9.50×10^{-7} for noncarcinogens (child), 1.16×10^{-7} for carcinogens and 4.98×10^{-7} for mutagens. Table 4-3 presents detailed calculations for each of these intake factors.

4.2.2.2 *Dermal Contact*

Equation 6-15 from the RAGS (USEPA 1989) was used to quantify intake from the dermal contact pathway:

$$CDI_{sd} = (C_s \times SA \times CF \times AF \times EF \times ED \times ABS)/(BW \times AT)$$

For unrestricted exposure via dermal contact, the chemical-specific chronic daily intakes are calculated by multiplying the EPCs by the intake factors of 4.65×10^{-6} for noncarcinogens (child), 6.43×10^{-7} for carcinogens and 2.57×10^{-6} for mutagens. For recreational exposure via dermal contact, the chemical-specific chronic daily intakes are calculated by multiplying the EPCs by the intake factors of 3.46×10^{-7} for noncarcinogens (child), 4.77×10^{-8} for carcinogens and 1.91×10^{-7} for mutagens. Table 4-4 presents detailed calculations for each of these intake factors.

[2]Age-dependent adjustment factors (ADAFs) have been included to account for susceptibility from early-life exposure to mutagenic carcinogens, as described in Section 5.1.1.

Table 4-3. Intake Factors for Exposure via Ingestion of Sediment

Oral Sediment Intake Factor (IForal):

Noncarcinogens:

$$IF_{oral} = \frac{IngR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Carcinogens:

$$IF_{oral/adj} = \frac{IngR_c \times BF \times CF \times FI \times EF \times ED_c}{BW_c \times AT} + \frac{IngR_a \times BF \times CF \times FI \times EF \times ED_a}{BW_a \times AT}$$

Mutagens:

$$IF_{oral/mu} = \frac{BF \times CF \times FI \times EF \times IFSM_{adj}}{AT}$$

where:

$$IFSM_{adj} = \frac{ED_{0-2} \times IngR_c \times 10}{BW_c} \quad \frac{ED_{2-6} \times IngR_c \times 3}{BW_c} - \frac{ED_{6-16} \times IngR_a \times 3}{BW_a} + \frac{ED_{16-30} \times IngR_a \times 1}{BW_a}$$

IF_{oral} = Oral Intake Factor, kg sediment/kg body weight-day
IngR = Ingestion Rate, mg/day
BF = Bioavailability Factor, unitless
CF = Conversion Factor, kg to mg
FI = Fraction Ingested from Contaminated Source, unitless
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
BW = Body Weight, kg
AT = Averaging Time, days

	Population											
	Resident		Resident - Mutagens				Recreational User		Recreational User - Mutagens			
Exposure Variable	Adult	Child (0-6 years)	Mutagenic 0 to 2 yrs	Mutagenic 2 to 6 yrs	Mutagenic 6 to 16 yrs	Mutagenic 16 to 30 yrs	Adult	Child (0-6 years)	0 to 2 yrs	2 to 6 yrs	6 to 16 yrs	16 to 30 yrs
IngR	100	200	200	200	100	100	100	200	200	200	100	100
CF	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06
FI	1	1	1	1	1	1	1	1	1	1	1	1
EF	350	350	350	350	350	350	26	26	26	26	26	26
ED	24	6	2	4	10	14	24	6	2	4	10	14
BW	70	15	15	15	70	70	70	15	15	15	70	70
$AT_{carcinogens}$	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550
$AT_{nonarcinogens}$	8760	2190	2190	2190	8760	8760	8760	2190	2190	2190	8760	8760

PATHWAY-SPECIFIC INTAKE FACTORS:
Chemical-Specific Intake Factors via Sediment Ingestion (IF_{oral}), kg sediment/kg body weight-day

Carcinogens	1.57E-06	NA	3.65E-06	2.19E-06	5.87E-07	2.74E-07	1.16E-07	NA	2.71E-07	1.63E-07	4.36E-08	2.04E-08
Noncarcinogens	1.37E-06	1.28E-05	NA	NA	NA	NA	1.02E-07	9.50E-07	NA	NA	NA	NA

NA = Not Applicable

Table 4-4. Intake Factors for Dermal Exposure to Sediment

Dermal Sediment Intake Factor (IFdermal):

Noncarcinogens:

$$IF_{dermal} = \frac{SA \times AF \times ABS \times x \times CF \times EF \times ED}{BW \times AT}$$

Carcinogens:

$$IF_{dermal/adj} = \frac{SA_c \times AF \times ABS \times CF \times EF \times ED_c}{BW_c \times AT} + \frac{SA_a \times AF \times ABS \times CF \times EF \times ED_a}{BW_a \times AT}$$

Mutagens:

$$IF_{dermal/mu} = \frac{ABS \times CF \times EF \times IFMS_{adj}}{AT}$$

where:

$$IFSM_{adj} = \frac{ED_{0-2} \times AF_c \times SA_c \times 10}{} + \frac{ED_{2-6} \times AF_c \times SA_c \times 3}{BW_c} + \frac{ED_{6-16} \times AF_a \times SA_a \times 3}{BW_a} + \frac{ED_{16-30} \times AF_a \times SA_a \times 1}{BW_a}$$

IF_{dermal} = Dermal Intake Factor, kg sediment/kg body weight-day
SA = Surface Area, cm^2/day
AF = Skin Adherence Factor, mg/cm^2
ABS = Absorption Factor, unitless
CF = Conversion Factor, kg to mg
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
BW = Body Weight, kg
AT = Averaging Time, days

	Population											
	Resident		Resident - Mutagenic Action				Recreational User		Recreational - Mutagenic Action			
Exposure Variable	Adult	Child (0-6 years)	Mutagen 0 to 2 yrs	Mutagen 2 to 6 yrs	Mutagen 6 to 16 yrs	Mutagen 16 to 30 yrs	Adult	Child (0-6 years)	Mutagen 0 to 2 yrs	Mutagen 2 to 6 yrs	Mutagen 6 to 16 yrs	Mutagen 16 to 30 yrs
SA	5700	2800	2800	2800	5700	5700	5700	2800	2800	2800	5700	5700
AF	0.07	0.2	0.2	0.2	0.07	0.07	0.07	0.2	0.2	0.2	0.07	0.07
ABS	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
CF	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06
EF	350	350	350	350	350	350	26	26	26	26	26	26
ED	24	6	2	4	10	14	24	6	2	4	10	14
BW	70	15	15	15	70	70	70	15	15	15	70	70
$AT_{carcinogens}$	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550	25550
$AT_{nonarcinogens}$	8760	2190	2190	2190	8760	8760	8760	2190	2190	2190	8760	8760

PATHWAY-SPECIFIC INTAKE FACTORS:
Chemical-Specific Intake Factors via Dermal Sediment Contact (IF_{dermal}), kg sediment/kg body weight-day

Carcinogens	6.43E-07	NA	1.33E-06	7.98E-07	3.05E-07	1.42E-07	4.77E-08	NA	9.88E-08	5.93E-08	2.26E-08	1.06E-08
Noncarcinogens	7.11E-07	4.65E-06	NA	NA	NA	NA	5.28E-08	3.46E-07	NA	NA	NA	NA

NA = Not Applicable

5.0 DOSE-RESPONSE ASSESSMENT

This section provides information regarding the potential for health risks from exposure to chemicals detected at the site. Specifically, this section provides a quantitative estimate of the relationship between exposure and severity or probability of human biological effects for the COPCs identified in Section 3. Section 5.1 identifies carcinogenic toxicity values for potentially carcinogenic PAHs evaluated in the risk assessment. Section 5.2 describes how dose-response, or toxicity values, are established and used for noncarcinogenic PAHs.

In accordance with USEPA's Superfund guidance hierarchy of sources to identify dose-response values (USEPA 2003), and consistent with the development of the RSLs (USEPA 2010a), relevant carcinogenic and noncarcinogenic dose-response values for this HHRA were obtained from the following sources (in descending order of preference):

1. Tier 1 – USEPA's Integrated Risk Information System (USEPA 2011);
2. Tier 2 – USEPA's Provisional Peer Reviewed Toxicity Values (USEPA 2011);
3. Tier 3 – Other Toxicity Values: This includes additional USEPA and non-USEPA sources of toxicity information. Priority is given to those sources of information that are the most current, transparent and peer-reviewed. Since the 2003 guidance does not rank the Tier 3 sources, the USEPA created a hierarchy among these sources in development of the RSLs (USEPA 2010) as follows:
    a. The Agency for Toxic Substances and Disease Registry (ATSDR),
    b. The Cal/EPA OEHHA's Chronic Reference Exposure Levels (RELs),
    c. PPRTV Appendix Screening Toxicity Values, and
    d. Health Effects Assessment Summary Tables (HEAST) Toxicity Values.

5.1 CARCINOGENIC CONSTITUENTS

The incremental lifetime cancer risk (ILCR) attributed to a carcinogen is calculated as a product of the daily intake (mg/kg-d) and the cancer slope factor (CSF). USEPA's model of carcinogenesis assumes the relationship between exposure to a carcinogen and cancer risk is linear over the entire dose range, except at very high doses (USEPA 1989). This linearity assumes there is no threshold-of-exposure dose below which harmful effects will not occur. Because of this, carcinogenic effects are considered to be cumulative across age groups when considering lifetime exposures. The CSFs for the PAHs evaluated in this report are presented in Table 5-1. Although no dermal CSFs are available from the sources identified above, the USEPA has devised a method for making route-to-route (oral-to-dermal) extrapolations for systemic effects (USEPA 2004), as described in Section 5.3 below.

Table 5-1. Chemical of Potential Concern Toxicity Criteria

CHEMICAL	Cancer Slope Factors (CSF)					Noncancer Reference Doses (RfD)			
	Oral CSF $(mg/kg\text{-}day)^{-1}$	Source	Dermal CSF $(mg/kg\text{-}day)^{-1}$	GIABS	Muta-genic?	Oral RfD (mg/kg-day)	Source	Dermal RfD (mg/kg-day)	GIABS
PAHs									
Acenaphthene	NC	IRIS	NC	1.0		6.00E-02	IRIS	*6.00E-02*	1.0
Acenaphthylene	NC	IRIS	NC	1.0		*6.00E-02*	*Ace (IRIS)*	*6.00E-02*	1.0
Anthracene	NC	IRIS	NC	1.0		3.00E-01	IRIS	3.00E-01	1.0
Benz(a)anthracene	7.30E-01	BaP*TEF (USEPA RSL)	7.30E-01	1.0	M	*3.00E-01*	*Anth (IRIS)*	*3.00E-01*	1.0
Benzo(b)fluoranthene	7.30E-01	BaP*TEF (USEPA RSL)	7.30E-01	1.0	M	*4.00E-02*	*Fluoranth (IRIS)*	*4.00E-02*	1.0
Benzo(k)fluoranthene	7.30E-02	BaP*TEF (USEPA RSL)	7.30E-02	1.0	M	*4.00E-02*	*Fluoranth (IRIS)*	*4.00E-02*	1.0
Benzo(g,h,i)perylene	NC	IRIS	NC	1.0		*3.00E-02*	*Pyrene (IRIS)*	3.00E-02	1.0
Benzo(a)pyrene	7.30E+00	IRIS	7.30E+00	1.0	M	*3.00E-02*	*Pyrene (IRIS)*	*3.00E-02*	1.0
Chrysene	7.30E-03	BaP*TEF (USEPA RSL)	7.30E-03	1.0	M	*3.00E-02*	*Pyrene (IRIS)*	*3.00E-02*	1.0
Dibenz(a,h)anthracene	7.30E+00	BaP*TEF (USEPA RSL)	7.30E+00	1.0	M	*3.00E-01*	*Anth (IRIS)*	3.00E-01	1.0
Fluoranthene	NC	IRIS	NC	1.0		4.00E-02	IRIS	4.00E-02	1.0
Fluorene	NC	IRIS	NC	1.0		4.00E-02	IRIS	4.00E-02	1.0
Indeno(1,2,3-cd)pyrene	7.30E-01	BaP*TEF (USEPA RSL)	7.30E-01	1.0	M	*3.00E-02*	*Pyrene (IRIS)*	3.00E-02	1.0
1-Methylnaphthalene	2.90E-02	USEPA RSL (PPRTV)	2.90E-02	1.0		7.00E-02	*USEPA RSL (ATSDR)*	7.00E-02	1.0
2-Methylnaphthalene	NC	IRIS	NC	1.0		4.00E-03	IRIS	4.00E-03	1.0
Naphthalene	NC	Cal/EPA	NC	1.0		2.00E-02	IRIS	2.00E-02	1.0
Pyrene	NC	IRIS	NC	1.0		3.00E-02	IRIS	3.00E-02	1.0

M = mutagenic mode of action
NC = No Criteria

Sources:
Cal/EPA = California Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database (Cal/EPA 2010a)
Ch REL = Chronic REL in OEHHA's table of Reference Exposure Levels
IRIS = USEPA's Integrated Risk Information System (http://www.epa.gov/iris/) (USEPA 2010a)
OEHHA = Human-Exposure-Based Screening Numbers Developed to Aid Estimation of Cleanup Costs for Contaminated Soil (Cal/EPA 2005b)
USEPA RSLs = USEPA Regions 3, 6, and 9 Regional Screening Levels (http://www.epa.gov/region09/superfund/prg/rsl-table.html)
PPRTV = Provisional Peer Reviewed Toxicity Value as cited by USEPA
r = route extrapolation

5.1.1 Carcinogens with Mutagenic Mode of Action

There are numerous carcinogenic modes of action (MOAs), including but not limited to inhibition of cell death, immune suppression, and mutagenicity, that may cause chemical exposures to differentially affect a particular population segment or lifestage. The USEPA has evaluated cancer risks associated with childhood (early-life) exposures, and has developed specific guidance on potency adjustments for carcinogens acting through a mutagenic MOA (USEPA 2005a and b). The guidance recommends an approach for modifying toxicity estimates from chronic studies to address the potential for differential risk of early-life exposures. Specifically, BaP is one of the chemicals that USEPA has identified as having a mutagenic MOA for carcinogenicity and for which the use of default age-dependent adjustment factors (ADAFs) is recommended in quantitative risk assessment (USEPA 2005a and b, 2010a). Since this HHRA includes evaluation of child receptors, ADAFs are used for evaluating the potential risk associated with BaP and other mutagenic PAHs during early-life exposure. Consistent with the ADAFs proposed in the USEPA guidance (2005b), cancer risk includes:

- A 10-fold adjustment for exposures before 2 years of age (i.e., spanning a 2-year time interval from the first day of birth up until a child's second birthday);
- A 3-fold adjustment for exposures between 2 and <16 years of age (i.e., spanning a 14-year time interval from a child's second birthday up until their sixteenth birthday), and
- No adjustment for exposures after turning 16 years of age.

PAHs identified by the USEPA as having a mutagenic mode of action are identified in Table 5-1.

5.2 NONCARCINOGENIC CONSTITUENTS

For the noncarcinogenic effects of specific constituents, USEPA assumes a dose exists below which no adverse health effects will be seen (USEPA 1989). Below this "threshold" it is believed that exposure to a chemical can be tolerated without adverse effects. Adverse effects manifest only when physiologic protective mechanisms are overcome by exposure to doses above the threshold. For all exposure routes, a chemical-specific reference value dose (RfD), is derived. The RfD, expressed in units of milligrams per kilogram-day (mg/kg-d), represents the daily oral intake of a constituent (averaged over a year) per kilogram of body weight that is below the effect threshold for the constituent. The USEPA assumes noncarcinogenic exposure doses are not cumulative from age group to age group over a lifetime of exposure (USEPA 1989). Dermal RfDs are derived from oral RfDs, as described in Section 5.3. When reference values are not available for some PAHs, values for surrogate compounds are selected, based on structure-activity relationships (surrogate compounds are identified as sources in Table 5-1).

5.3 ROUTE-TO-ROUTE EXTRAPOLATION

Ideally, route-specific toxicity factors account for dosimetry information on the dose-response relationship for systemic effects from the absorbed dose. In the absence of dermal toxicity

factors, USEPA has devised a method for making route-to-route (oral-to-dermal) extrapolations for systemic effects (USEPA 2004). Using absorption efficiency information from oral administration studies, toxicity factors are adjusted to represent the absorbed dose rather than the administered dose. When gastrointestional absorption of a chemical in the critical study is poor (e.g, 10%), the absorbed dose is much smaller than the administered dose. To account for this, the RfDs and CSFs are multiplied or divided, respectively, by the recommended GI absorption values (ABS_{GI}). For PAHs, the USEPA recommends that it be assumed that 100% of the administered oral dose is absorbed, meaning that the dermal and oral toxicities are assumed to be equal.

6.0 RISK CHARACTERIZATION

Risk characterization, the final step in the risk quantification process, combines data from the conceptual exposure model (Section 2), the COPC selection process (Section 3), the exposure assessment (Section 4), and the dose-response assessment (Section 5) to estimate the potential carcinogenic and noncarcinogenic effects of COPCs over the applicable duration of exposure. The USEPA (1989) states that for carcinogens "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen." The risk from potential carcinogenic effects resulting from exposure to site-related COPCs is presented as the ILCR. The ILCR is an upper-bound estimate of the incremental cancer probability (i.e., the incremental probability above that of an individual getting cancer for reasons other than the chemical exposure) for individuals who may be exposed to site-related, potentially carcinogenic, COPCs under the exposure scenarios previously described. The hazard associated with potential noncarcinogenic health effects is presented as the Hazard Index (HI), which is the ratio of the site-related dose of a chemical to the maximum acceptable dose.

6.1 QUANTITATIVE RISK CHARACTERIZATION METHODOLOGY

As discussed above, health risk assessments use two different values to evaluate potential health impacts: the ILCR and the HI. The ILCR is compared to a range of acceptable probabilities to determine whether the potential risk poses an unacceptable cancer health risk. The USEPA currently uses an ILCR of 1 in 1,000,000 ($1x10^{-6}$) to 1 in 10,000 ($1x10^{-4}$) as the range of acceptable risk (USEPA 1990, 1991). The risk that is acceptable is very much dependent on site-specific characteristics that include: the number of people potentially exposed, the likelihood of exposure, the chemicals driving the risk, the uncertainties driving risk the future use(s) of the site, public concerns, and the decisions of local risk managers. The HI is compared to a threshold level of 1.0 (USEPA 1989). Some PAHs pose both a noncarcinogenic hazard and a carcinogenic risk to receptors; risks from these PAHs were characterized for both types of health effects.

6.1.1 Carcinogenic Effects

At low doses, the risk of developing cancer (ILCR) for the ingestion and dermal exposure pathways is calculated as follows (USEPA 1989):

$$Risk = (CDI_i)*(CSF_i)$$

where

CDI_i = chronic lifetime average daily intake for $COPC_i$ (mg/kg-day)

CSF_i = cancer slope factor for $COPC_i$ $(mg/kg\text{-}day)^{-1}$

Chronic daily intake (CDI) values and ECs were estimated per Section 4, and CSFs were presented in Section 5. The following equation was used to sum cancer risks from the PAHs:

$$Risk_t = Risk\ (COPC_1) + Risk\ (COPC_2) + \ldots\ Risk\ (COPC_n)$$

where

$Risk_t$ = total risk of cancer incidence for a given pathway

$Risk\ (COPC_n)$ = individual carcinogenic COPC risk

Similarly, to account for exposure via multiple pathways (ingestion and dermal contact), the total ILCR was calculated by summing the pathway-specific risks (USEPA 1986). The basis for the carcinogenic slope factor used in cancer risk calculations is either lifetime exposure, or a significant portion of a lifetime.

6.1.2 Noncarcinogenic Effects

The potential for health effects resulting from exposure to a noncarcinogenic COPC is evaluated by comparing a receptor's estimated upper-bound exposure or intake level to the RfD of that COPC (USEPA 1989). The ratio of intake to the RfD is termed the Hazard Quotient (HQ). If the HQ is greater than 1.0, there may be concern for potential noncarcinogenic health effects. The level of concern increases as the HQ increases above unity, although the two are not linearly related (USEPA 1989). The HQ for the ingestion and dermal exposure pathways is calculated as follows:

$$HQ_i = CDI_i/RfD_i$$

where

HQ_i = hazard quotient for $COPC_i$ (unitless)

CDI_i = chronic average daily intake of $COPC_i$ (mg/kg-d)

RfD_i = reference dose of $COPC_i$ (mg/kg-d)

When receptors are exposed to more than one COPC through multiple pathways, it is useful to develop a total HI. The HI is the sum of HQs across COPCs and pathways (USEPA 1986). The HI also is compared to a threshold level of 1.0. HIs were calculated by assuming dose additivity for all COPCs, regardless of the type of toxic effect (e.g., the hazard from chemicals causing effects on the kidney is added to the hazard from chemicals causing effects on the liver; USEPA 1986, 1989). This assumption is conservative. The noncancer hazard from all the PAHs was calculated as the sum of the HQs by:

$$HI_t = HQ(COPC_1) + HQ(COPC_2) + \ldots\ HQ(COPC_n)$$

where

HI_t = total hazard index for a given pathway

$HQ(COPC_n)$ = individual noncarcinogenic COPC hazard

Exposure pathway HIs are also summed to produce a total HI specific to a receptor.

6.2 HEALTH RISK CHARACTERIZATION FOR THE SITE

Table 6-1 summarizes the potential health risks to future Lake users in terms of the ILCR and the noncarcinogenic HI, based on current environmental conditions. Risk estimates are based on exposures to sediment in three discrete exposure areas in Liberty Park Lake. These exposures and the associated risks detailed in this HHRA were developed using the reasonable maximum exposure (RME) approach, as promulgated by USEPA. The RME approach, which estimates the maximum exposure reasonably expected to occur in a population, is intended to provide a conservative estimate of exposure within the range of possible exposures. Because the RME approach was used to quantify potential health risks in this assessment, if the RME values are below acceptable limits, then all other, lesser exposures related to the Lake sediment are below these limits (USEPA 1989). Each entry in the table below is supported by detailed calculations of health risks by for each receptor for each PAH and pathway (included as Attachment 3).

Table 6-1. Summary of Potential Cancer Risks and Noncancer Hazards

	Resident (Unrestricted Use)		Recreator	
Exposure Area	**ILCR**	**HI**	**ILCR**	**HI**
Liberty Park Lake Wall and Bottom Sediments				
Adult	9.5E-06	0.000028	7.1E-07	0.0000021
Child	NA	0.00023	NA	0.000017
Liberty Park Lake Red Butte Creek Inlet Sediments				
Adult	1.5E-05	0.000061	1.1E-06	0.0000045
Child	NA	0.00051	NA	0.000038
Liberty Park Lake Emigration Creek Inlet Sediments				
Adult	1.7E-05	0.000059	1.3E-06	0.0000044
Child	NA	0.00049	NA	0.000037

Notes:
ILCR = Incremental lifetime cancer risk; HI = noncancer hazard index
For direct contact exposure pathways, cancer risk is evaluated over a lifetime, assuming 6 years of exposure as a child and 24 years as an adult (USEPA 2002).
$9.5x10^{-6}$ = 0.0000095 = 95 excess cancers per ten million people exposed.

Unrestricted (i.e., residential) use of Liberty Park Lake results in and estimated incremental lifetime cancer risk from PAHs in bottom/wall sediment of $1x10^{-5}$. The cancer risks for exposure to sediments underneath the Butte Creek or Emigration Creek inlets are both estimated to be $2x10^{-5}$. All estimated noncancer hazards are very low, ranging from 0.00003 for adult exposure to Lake bottom/wall sediments to 0.0005 for child exposures to sediments underneath either the Butte Creek or Emigration Creek inlets. These risk results assume that a future resident comes in contact with Lake sediment 350 days per year.

For recreational users of Liberty Park Lake, the estimated incremental lifetime cancer risk to PAHs in bottom/wall sediment is $7x10^{-7}$. The cancer risks for exposure to sediments underneath the Butte Creek or Emigration Creek inlets are both estimated to be $1x10^{-6}$. All estimated noncancer hazards are very low, ranging from 0.000002 for adult exposure to Lake bottom/wall

sediments to 0.00004 for child exposures to sediments underneath either the Butte Creek or Emigration Creek inlets. These risk results assume that a park visitor comes in contact with Lake sediment (e.g. falls into the Lake during boating activities) 26 times per year for 30 years.

7.0 UNCERTAINTIES

The goal of a health risk assessment is to provide scientific and objective risk estimates that enable effective risk management. However, when using health risk assessment results for decision-making, one should consider the methods employed in deriving the predicted risk values. Reviewers may be misled if they rely only on a simplified numerical representation of risk without considering the uncertainties, limitations, and assumptions inherent in the health risk assessment process. In order to provide the reader with perspective on the quality of the predicted risk values, this section considers the uncertainty and associated conservatism inherent in this HHRA, as recommended by USEPA guidance.

7.1 SOURCES OF UNCERTAINTY

Health risk assessments generally incorporate two types of uncertainty, measurement and informational. Measurement uncertainty includes the use of discrete samples to define overall site conditions and the variability of COPC concentrations. For example, this risk assessment assumes that chemicals are present in specific exposure areas at concentrations equal to the maximum detected concentration. Gaps in information necessary to complete risk calculations result in a different kind of uncertainty. In some instances, the impact of informational uncertainty is significant. For example, information on whether and how a chemical causes health effects may be lacking. The high-to-low dose and interspecies extrapolations for dose-response relationships (which are the basis of the toxicity factors) can also be used to limit uncertainty.

Risk assessment is an iterative process involving sequential evaluation of all site data. Once any type of uncertainty is introduced into the early stages of the process, it propagates as calculations proceed. In its guidance for human health risk assessments, the USEPA states that "*it is more important to identify the key site-related variables and assumptions that contribute most to the uncertainty than to precisely quantify the degree of uncertainty in the health risk assessment*" (USEPA 1989).

7.2 UNCERTAINTIES IN SITE CHARACTERIZATION

Site characterization and COPC selection are potential sources of uncertainty in any health risk assessment. Specific uncertainties related to these activities for Liberty Park Lake are presented below. Frequently, a major source of uncertainty in risk assessment is the quality and quantity of the site characterization data upon which the risk assessment is based. However, sediments from Liberty Park Lake have been well-characterized, as shown in Figure 1-1. While the current composition and distribution of PAHs in the Lake sediment has been documented, the source of this material has not been definitively identified, as discussed in Section 7.2.1. Also, risks are

based on concentrations currently detected in the sediment; as discussed in Section 7.2.1, environmental conditions may change over time.

7.2.1 Sources of PAHs Detected in Lake Sediments

McDaniel Lambert evaluated the potential source(s) of the PAHs detected in Liberty Park Lake sediment (McDaniel Lambert 2011). The minimal levels of petroleum hydrocarbon detected, the absence of low molecular weight PAHs typically associated with crude oil, as well as the poor correlation between concentrations of BaP and diesel-range petroleum hydrocarbons all suggest that crude oil may not be the source of the PAHs detected in the Lake sediment. As summarized in Section 1.2, diesel-range TPH was detected in all but two locations samples, with detections ranging from 0.08 to 205 mg/kg-dry weight; these levels are not indicative of the presence of residual crude oil. Benzo(a)pyrene was detected in 18 of the 30 Lake locations evaluated (60%), at concentrations ranging from 0.0115 to 0.453 mg/kg-dry weight. If the spilled crude oil was the source of the BaP detected in the sediment, one would expect a linear correlation between DRO and BaP. As shown in Figure 7-1, there is no relationship between the DRO and BaP levels: there is a high level of variability in BaP concentrations over a very small range of TPH, and no BaP was detected in the sample with the highest petroleum hydrocarbon level. An alternative source of the PAHs is urban background – PAHs from commonly occur in the environment as a result of anthropogenic activities such as combustion of organic matter and fossil fuels (e.g., automobile use and power generation) (Neff 2005; Boehm 2010). Stormwater runoff can be a source of these compounds to surface waters and to sediments within nearby water bodies (Neff 2005; Boehm 2010). The levels of petroleum hydrocarbons and PAHs detected in the Lake sediment, as well as the predominance of high molecular weight PAHs, are consistent with an urban background source. A recently collected sediment samples from an urban drainage not impacted by the spill, Mill Creek, had a low level of TPH (167 mg/kg DRO) and PAH concentrations similar to those seen in Liberty Lake (Figure 7-2), particularly for the higher molecular weight PAHs.[3] Therefore, it is not possible to determine if the residual low concentrations of TPH and PAHs detected in Lake sediment are from urban runoff, crude oil, or a combination of the two sources.

7.2.2 Species of Site Constituents

Another uncertainty with regard to site constituents is the potential for natural attenuation and weathering of the chemicals in the environment. Natural attenuation is defined as the reduction in concentration and mass due to naturally occurring processes in the environment. Natural attenuation includes physical processes such as dispersion, diffusion, dilution by recharge, and volatilization. There are also chemical processes, such as sorption and chemical or abiotic

[3]The Lake sediment PAH concentrations shown in Figure 7-2 are the average of detected levels in the 16 locations where all PAHs were analyzed (see Table 1-2), with the error bars showing the 95% UCL of the mean (defined in Section 4.1).

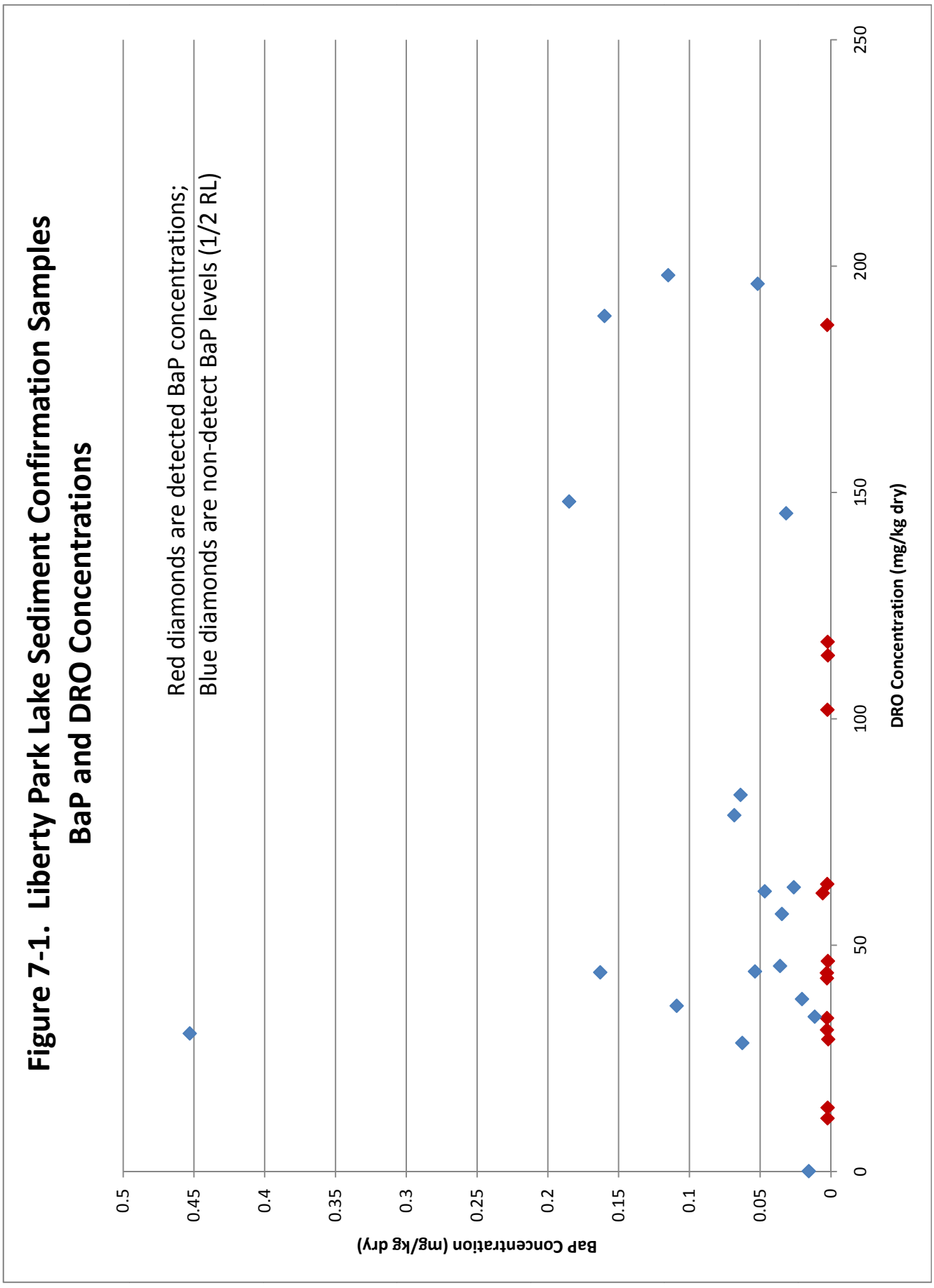
Figure 7-1. Liberty Park Lake Sediment Confirmation Samples
BaP and DRO Concentrations
Red diamonds are detected BaP concentrations;
Blue diamonds are non-detect BaP levels (1/2 RL)
BaP Concentration (mg/kg dry)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
DRO Concentration (mg/kg dry)

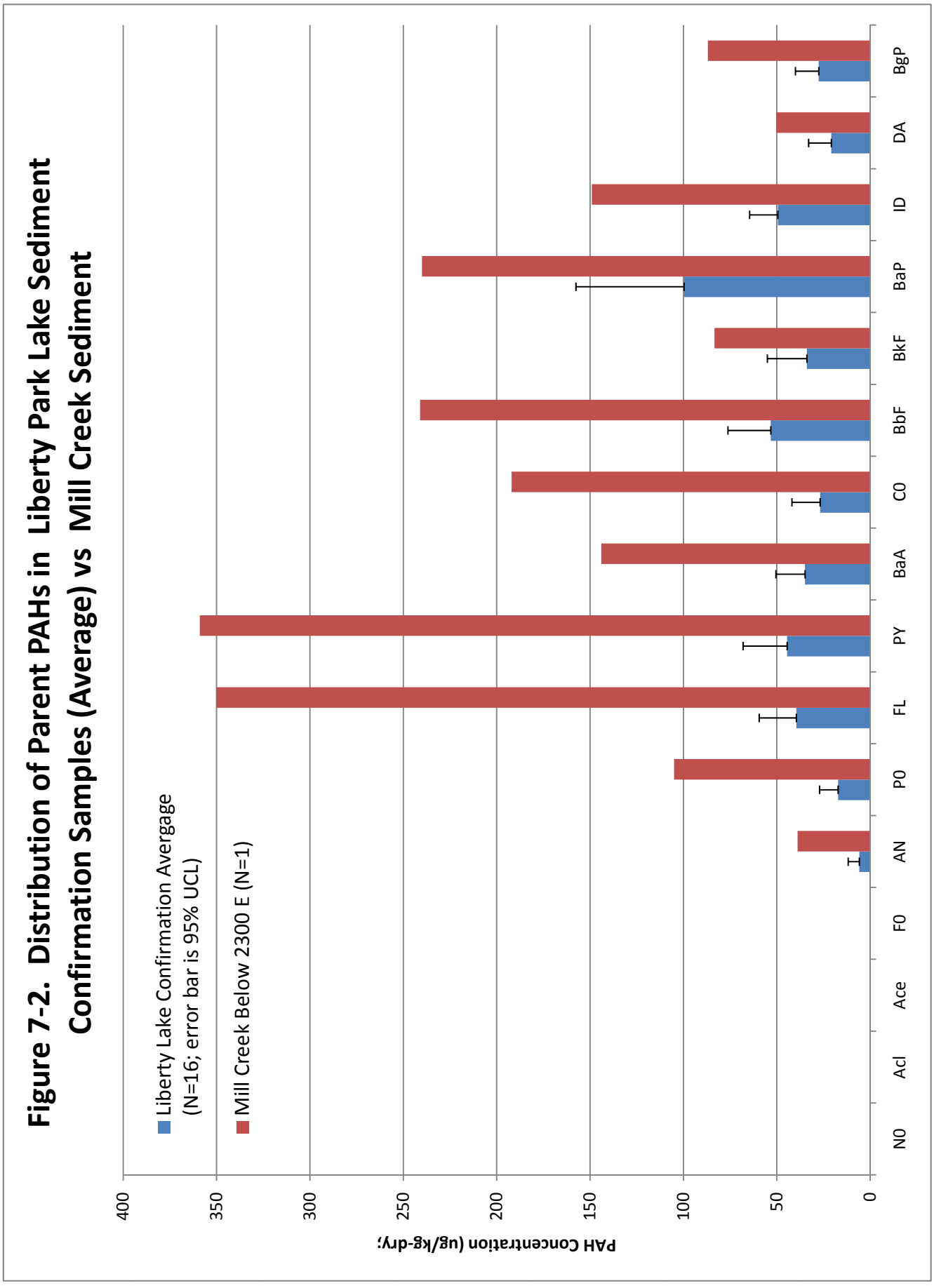
Figure 7-2. Distribution of Parent PAHs in Liberty Park Lake Sediment Confirmation Samples (Average) vs Mill Creek Sediment
Liberty Lake Confirmation Avergage (N=16; error bar is 95% UCL)
Mill Creek Below 2300 E (N=1)
PAH Concentration (ug/kg-dry)
0
50
100
150
200
250
300
350
400
NO
Acl
Ace
FO
AN
PO
FL
PY
BaA
CO
BbF
BkF
BaP
ID
DA
BgP

reactions and biological processes. Over time, these processes may alter concentrations and the chemical structure of existing chemicals. If changes in chemical composition and/or concentration occur at the Lake, this may result in changes in the risks and hazards reported in this assessment.

7.3 UNCERTAINTIES IN EXPOSURE ASSESSMENT

The uncertainty associated with the receptor exposure estimates depends on the quality of the selected input parameters. This section addresses the uncertainty related to the quantification of exposure concentrations and COPC intakes with regard to these input parameters.

7.3.1 Exposure Pathways

This HHRA assumes that park visitors regularly ingest and have dermal contact with the Lake sediment. Realistically, recreators are likely to have little contact with Lake sediment for a number of reasons, including use restrictions and physical barriers. Recreational activities on the Lake are limited to launching and retrieving paddle boats. Wading and swimming in the Lake are prohibited, although incidental contact might occur if a park visitor fell out of a paddle boat or ignored the wading and swimming prohibition. Incidental contact with PAHs detected in Lake sediment is further restricted by the Lake's concrete curb wall, cobbled banks and the presence of angular rock. The concrete aprons around the Red Butte Creek and Emigration Creek inlets make sediments underlying these structures particularly inaccessible. Because most park visitors are not expected to actually contact the Lake sediment, the risks estimated in this report are likely overestimates.

7.3.2 Exposure Parameters

Many assumptions must be made in order to estimate human exposure to chemicals. To conduct the exposure assessment, it was necessary to develop assumptions about general characteristics and potential human exposures in various areas of a site. For each exposure pathway, assumptions were made about several exposure parameters, including the following: the activity patterns for an individual that may result in exposure; the frequency for occurrence of each activity; the routes of exposure by which an individual could be exposed; and the amount of impacted media an individual may contact during the activity.

The unrestricted use scenario assumes daily contact with sediments for 350 days per year for 30 years, which is unrealistic considering the current land use as a public park. Given the prohibition of wading and swimming in the Lake, the recreational scenario of contact 26 times per year for 30 years also seems unlikely. In addition, other conservative assumptions were made with regards to sediment ingestion rates and skin surface area exposed to sediment. One important assumption influencing the results is the rate of dermal absorption of chemicals from sediment. Very few directly applicable data exist to support estimates of the rate at which chemicals present in soil or sediment may be absorbed through the skin during and following

dermal contact. Estimates of chemical intake for dermal contact exposure pathway are based on health protective assumptions about the frequency and amount of dermal contact with sediment. In addition, estimates of the fraction of a chemical that is subsequently transported across the skin (i.e., absorbed) are also included in the chemical intake estimates.

Another assumption that tends to overestimate exposure is that PAHs in sediment are 100% bioavailable upon oral ingestion. There is strong support in the literature oral availabilities of less than 100% for PAHs (Magee et al. 1996; NRC 2003). Based on a number of studies in rats and mice, Magee et al. (1996) determined a point estimate of 29% (or 0.29) oral bioavailability of PAHs in soil. The 29% value also is consistent with values previously used in PAH risk assessments with the USEPA as the lead agency (NRC 2003). The health-protective assumption of 100% bioavailability of PAHs in sediment likely results in an overestimate of the exposure via ingestion of these chemicals.

Overall, the exposure parameters used in the calculation of risk are generally consistent with USEPA guidance for deriving estimates for the reasonable maximum exposure (RME). Many of the exposure variables recommended by the USEPA for the RME case represent the upper 90^{th} or 95^{th} percentile values. Because chemical intake may be substantially overestimated using this conservative approach, cancer risks and noncancer hazards are likely to be overestimated.

7.3.3 Exposure Point Concentrations

A source of conservatism typically built into risk assessments is the use of the 95% UCL, rather than the average concentration, in estimating COPC exposure concentrations for evaluating health effects to receptors. In this HHRA, exposure in the "Lake Park Lake Wall and Bottom Sediments" area was evaluated using the 95% UCL. The 95% UCL is a statistic that quantifies the uncertainty associated with the sample mean concentration. By using this method to estimate EPCs, there is 95% confidence that receptors are exposed to a mean concentration that is equal to or below the UCL. Although the 95% UCL is likely to overestimate the mean concentration, there is a 5% probability that the 95% UCL could underestimate average exposure and associated risks. For the two inlet exposure areas, EPCs were based on maximum PAH concentrations. The use of maximum values is health protective and likely results in an overestimate of associated health risks.

7.4 UNCERTAINTIES IN DOSE-RESPONSE ASSESSMENT

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) evaluations of the constituents. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a constituent that induces adverse effects in laboratory animals will induce adverse effects in humans. Dose-response assessment is the process of characterizing the relationship between the administered

dose of an agent and the incidence and severity of adverse health effects in an exposed population.

In this assessment, PAH cancer slope factors and reference doses were based on guidelines recommended by the regulatory agencies and professional organizations cited. To ensure that potential health impacts to the exposed receptors will not be underestimated, regulatory agencies use uncertainty (or safety) factors in calculating dose-response values. The built-in uncertainty (and associated conservatism) with the derivation of the dose-response values carries through to the predicted risk values. This risk assessment also used the hazard index, which assumes that the toxic effects of all noncarcinogenic constituents are additive. The uncertainties associated with extrapolation and hazard indices are discussed in greater detail below.

7.4.1 Extrapolation

Uncertainties related to toxicity assessment are inherent in the modeling of dose-response relationships for exposure to constituents and in calculating numerical estimators to predict health effects with a margin of safety. In the absence of (or in addition to) reliable epidemiological data, experimental laboratory data are used for dose-response assessments. Extrapolation from animals to humans is also inherent to the process of toxicity testing, as is route-to-route extrapolation. The inference that adverse effects found in animal bioassays conducted in the laboratory are indicative of likely human toxicity is fundamental to toxicological research and risk assessment. Examples of uncertainties that may be used in modeling of dose-response relationships, upon which CSF or RfD values are based, include extrapolation of findings:

- from laboratory animal experiments to humans (uncertainties arising from surface-area-based dose conversion and interspecies extrapolation);
- from high exposure levels to low exposure levels;
- from acute exposures to chronic exposures or from occupational conditions to non-occupational or environmental conditions; and
- from oral toxicity values to dermal toxicity values, using gastrointestinal absorption factors, when available.

The level of uncertainty of constituents varies because information concerning some constituents and their associated health effects is comparatively scarce while, for others, more information is available from health effects studies.

7.4.2 Chemicals without Toxicity Factors

Noncancer toxicity factors are not available for the majority of the PAHs. Based on structure activity relationships, other PAHs were identified as surrogates, as noted in Table 5-1. The use of this surrogate is conservative based on structure activity relationships and may result in an overestimation of risk.

7.5 CONCLUSIONS REGARDING UNCERTAINTY

Although it is difficult to quantify the uncertainties associated with all the assumptions made in this risk assessment, the use of conservative assumptions likely contributed to a substantial overestimation of exposure and risk. Language suggested by the USEPA (1989b) to explain the effect of using conservative assumptions in cancer risk assessments is as follows:

> *These values are upper-bound estimates of excess cancer risk potentially arising from lifetime exposure to the chemical in question. A number of assumptions have been made in the derivation of these values, many of which are likely to overestimate exposure and toxicity. The actual incidence of cancer is likely to be lower than these estimates and may be zero.*

Overall, the cumulative conservativeness regarding exposure (e.g., that a park visitor will have frequent contact with Lake sediment containing, at a minimum, 95%UCL concentrations of PAHs) utilized in this HHRA are likely to result in an overestimate of the potential risks associated with PAHs detected in the Lake sediment.

8.0 DISCUSSION AND CONCLUSIONS

This HHRA evaluated the potential cancer risks and noncancer hazards from PAHs detected in sediment confirmation samples collected from the bottom and walls of Liberty Park Lake, and from beneath the concrete aprons of the Red Butte Creek and Emigration Creek inlets. Populations evaluated included residential users, and a more realistic recreational user. Exposure pathways considered in this HHRA included incidental ingestion of and dermal contact with Lake sediment. The exposures and associated risks in this assessment were developed using the reasonable maximum exposure approach promulgated by the United States Environmental Protection Agency (USEPA 1989). This approach estimates the maximum exposure reasonably expected to occur in a population in order to provide a health protective estimate of exposure within the range of possible exposures. Exposure assumptions were made in accordance with regulatory guidance (USEPA 1989) and best professional judgment. Potential health risks were estimated by combining site-specific information with the analytical data for sediment confirmation samples collected from the Lake in November and December 2010, and January and April 2011.

Table ES-1 summarizes the estimated health risks associated with unrestricted and recreational use of the Lake in terms of the incremental lifetime cancer risk (ILCR) and the noncarcinogenic hazard index (HI), based on PAHs detected in post-restoration sediment confirmation samples. The potential cancer risks from unrestricted exposure (i.e., residential) to the bottom and beneath the walls of Liberty Park Lake, as well as from underneath the concrete aprons of the two inlets, are estimated to be within the USEPA risk management range specified by the National Contingency Plan of $1x10^{-6}$ to $1x10^{-4}$ (USEPA 1990). The noncancer hazards for unrestricted use in all Lake exposure areas are well below the USEPA level of concern of 1.0.

The potential cancer risk from recreational exposure to PAHs detected in sediment samples collected from the walls and bottom of Liberty Park Lake is below the low end of the USEPA risk management range ($1x10^{-6}$). The potential cancer risks associated with PAHs detected in sediments underneath the concrete aprons of the Red Butte and Emigration Creek inlets are within the USEPA risk management range, although exposure to sediment in these areas is highly unlikely. The noncancer hazards for recreational use of all Lake exposure areas are well below the USEPA level of concern of 1.0.

Table 8-1. Summary of Potential Cancer Risks and Noncancer Hazards

Exposure Area	Resident (Unrestricted Use)		Recreator	
	ILCR	HI	ILCR	HI
Liberty Park Lake Wall and Bottom Sediments				
Adult	$1x10^{-5}$	0.00003	$7x10^{-7}$	0.000002
Child	NA	0.0002	NA	0.00002
Liberty Park Lake Red Butte Creek Inlet Sediments				
Adult	$2x10^{-5}$	0.00006	$1x10^{-6}$	0.000004
Child	NA	0.0005	NA	0.00004
Liberty Park Lake Emigration Creek Inlet Sediments				
Adult	$2x10^{-5}$	0.00006	$1x10^{-6}$	0.000004
Child	NA	0.0005	NA	0.00004

Notes:
ILCR = Incremental lifetime cancer risk; HI = Noncancer hazard index
$1x10^{-5}$ = 0.00001 = 1 excess cancers per one hundred thousand people exposed.
NA = Not applicable; for direct contact exposure pathways, cancer risk is evaluated over a lifetime, assuming 6 years of exposure as a child and 24 years as an adult (USEPA 2002).

Major assumptions and conclusions of this HHRA include the following:

- Health risk estimates are based exclusively on PAHs detected in sediment confirmation samples collected from Liberty Park Lake following cleanup and restoration activities initiated following the June 2010 crude oil release.
- The Lake is part of a larger recreational area where signs are posted prohibiting wading or swimming, and physical deterrents such as the Lake's concrete curb wall, cobbled banks and the presence of angular rock, limit human exposure. Sediments collected from underneath the concrete aprons of the Red Butte Creek and Emigration Creek inlets are particularly inaccessible. Given the impediments to accessing Lake sediments, it is not likely that park visitors would have regular contact with this material. Therefore the risks estimated in this HHRA likely represent worst-case estimates.
- For unrestricted (residential) use, the estimated cancer risks are within the USEPA risk management range of $1x10^{-6}$ to $1x10^{-4}$.
- For recreational use, contact with Lake bottom/wall sediments result in cancer risk estimate below the low end of the USEPA risk management range. Cancer risks associated with the unlikely exposure to PAHs in sediment beneath the inlet concrete aprons are within the risk management range.
- For all receptors, the estimated noncancer hazards are well below the USEPA level of concern of 1.0.
- It is not possible to determine if the residual low concentrations of TPH and PAHs are from urban runoff, crude oil or a combination of the two sources
- Liberty Park Lake sediments do not present a health risk to park users.

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ATTACHMENTS

ATTACHMENT 1

Laboratory Data Packages for Liberty Park Lake Sediment Confirmation Samples
(Provided on CD)

ATTACHMENT 2

ProUCL Output

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	ProUCLin.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Benzo_a_full

General Statistics

Number of Valid Data	26	Number of Detected Data	14
Number of Distinct Detected Data	14	Number of Non-Detect Data	12
		Percent Non-Detects	46.15%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0115	Minimum Detected	-4.465
Maximum Detected	0.453	Maximum Detected	-0.792
Mean of Detected	0.0821	Mean of Detected	-3.01
SD of Detected	0.114	SD of Detected	0.962
Minimum Non-Detect	0.004	Minimum Non-Detect	-5.521
Maximum Non-Detect	0.0117	Maximum Non-Detect	-4.448

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	13
Number treated as Detected	13
Single DL Non-Detect Percentage	50.00%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.587	Shapiro Wilk Test Statistic	0.963
5% Shapiro Wilk Critical Value	0.874	5% Shapiro Wilk Critical Value	0.874
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.0455	Mean	-4.356
SD	0.0917	SD	1.647
95% DL/2 (t) UCL	0.0762	95% H-Stat (DL/2) UCL	0.155
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-4.172
		SD in Log Scale	1.467
		Mean in Original Scale	0.0461
		SD in Original Scale	0.0914
		95% t UCL	0.0767
		95% Percentile Bootstrap UCL	0.0781
		95% BCA Bootstrap UCL	0.104

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only
k star (bias corrected)	0.924	Data appear Gamma Distributed at 5% Significance Level

Theta Star	0.0889
nu star	25.88

A-D Test Statistic	0.725
5% A-D Critical Value	0.758
K-S Test Statistic	0.758
5% K-S Critical Value	0.235

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	1E-12
Maximum	0.453
Mean	0.0683
Median	0.0491
SD	0.0865
k star	0.307
Theta star	0.223
Nu star	15.95
AppChi2	7.927
95% Gamma Approximate UCL	0.137
95% Adjusted Gamma UCL	0.144

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.0495
SD	0.0881
SE of Mean	0.0179
95% KM (t) UCL	0.0801
95% KM (z) UCL	0.079
95% KM (jackknife) UCL	0.0781
95% KM (bootstrap t) UCL	0.136
95% KM (BCA) UCL	0.0875
95% KM (Percentile Bootstrap) UCL	0.084
95% KM (Chebyshev) UCL	0.128
97.5% KM (Chebyshev) UCL	0.161
99% KM (Chebyshev) UCL	0.228

Potential UCLs to Use

95% KM (BCA) UCL	0.0875

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzaanthracene

General Statistics

Number of Valid Data	12	Number of Detected Data	10
Number of Distinct Detected Data	10	Number of Non-Detect Data	2
		Percent Non-Detects	16.67%

Raw Statistics

Minimum Detected	0.0138
Maximum Detected	0.0443
Mean of Detected	0.026
SD of Detected	0.00996
Minimum Non-Detect	0.00516
Maximum Non-Detect	0.00537

Log-transformed Statistics

Minimum Detected	-4.283
Maximum Detected	-3.117
Mean of Detected	-3.717
SD of Detected	0.392
Minimum Non-Detect	-5.267
Maximum Non-Detect	-5.227

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	2
Number treated as Detected	10
Single DL Non-Detect Percentage	16.67%

UCL Statistics

Normal Distribution Test with Detected Values Only

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.949
5% Shapiro Wilk Critical Value	0.842

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.0221
SD	0.0128
95% DL/2 (t) UCL	0.0288
Maximum Likelihood Estimate(MLE) Method	
Mean	0.0215
SD	0.0135
95% MLE (t) UCL	0.0285
95% MLE (Tiku) UCL	0.0288

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	5.346
Theta Star	0.00487
nu star	106.9
A-D Test Statistic	0.238
5% A-D Critical Value	0.727
K-S Test Statistic	0.727
5% K-S Critical Value	0.267

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0112
Maximum	0.0443
Mean	0.0236
Median	0.0229
SD	0.0107
k star	4.045
Theta star	0.00582
Nu star	97.07
AppChi2	75.35
95% Gamma Approximate UCL	0.0303
95% Adjusted Gamma UCL	0.0316

Note: DL/2 is not a recommended method.

Shapiro Wilk Test Statistic	0.953
5% Shapiro Wilk Critical Value	0.842

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-4.087
SD	0.935
95% H-Stat (DL/2) UCL	0.0573
Log ROS Method	
Mean in Log Scale	-3.873
SD in Log Scale	0.509
Mean in Original Scale	0.0233
SD in Original Scale	0.0111
95% t UCL	0.029
95% Percentile Bootstrap UCL	0.0284
95% BCA Bootstrap UCL	0.0284

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.024
SD	0.00975
SE of Mean	0.00297
95% KM (t) UCL	0.0293
95% KM (z) UCL	0.0289
95% KM (jackknife) UCL	0.0292
95% KM (bootstrap t) UCL	0.03
95% KM (BCA) UCL	0.0295
95% KM (Percentile Bootstrap) UCL	0.029
95% KM (Chebyshev) UCL	0.0369
97.5% KM (Chebyshev) UCL	0.0425
99% KM (Chebyshev) UCL	0.0535

Potential UCLs to Use

95% KM (t) UCL	0.0293
95% KM (Percentile Bootstrap) UCL	0.029

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Chrysene

General Statistics

Number of Valid Data	12	Number of Detected Data	8
Number of Distinct Detected Data	8	Number of Non-Detect Data	4
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0166	Minimum Detected	-4.098
Maximum Detected	0.0376	Maximum Detected	-3.281
Mean of Detected	0.0261	Mean of Detected	-3.689
SD of Detected	0.00778	SD of Detected	0.311
Minimum Non-Detect	0.00516	Minimum Non-Detect	-5.267
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	4
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	8
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	33.33%

Warning: There are only 8 Detected Values in this data

Note: It should be noted that even though bootstrap may be performed on this data set

the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.93	Shapiro Wilk Test Statistic	0.917
5% Shapiro Wilk Critical Value	0.818	5% Shapiro Wilk Critical Value	0.818
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.0189	Mean	-4.295
SD	0.0124	SD	0.965
95% DL/2 (t) UCL	0.0253	95% H-Stat (DL/2) UCL	0.0499
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	0.0195	Mean in Log Scale	-3.946
SD	0.0115	SD in Log Scale	0.454
95% MLE (t) UCL	0.0255	Mean in Original Scale	0.0212
95% MLE (Tiku) UCL	0.026	SD in Original Scale	0.00946
		95% t UCL	0.0261
		95% Percentile Bootstrap UCL	0.0257
		95% BCA Bootstrap UCL	0.0259

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only
k star (bias corrected)	7.778	Data appear Normal at 5% Significance Level
Theta Star	0.00335	

nu star	124.5

A-D Test Statistic	0.35
5% A-D Critical Value	0.715
K-S Test Statistic	0.715
5% K-S Critical Value	0.294

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0166
Maximum	0.0376
Mean	0.0238
Median	0.0194
SD	0.00701
k star	10.42
Theta star	0.00229
Nu star	250.1
AppChi2	214.5
95% Gamma Approximate UCL	0.0278
95% Adjusted Gamma UCL	0.0285

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.0229
SD	0.00743
SE of Mean	0.00229
95% KM (t) UCL	0.027
95% KM (z) UCL	0.0267
95% KM (jackknife) UCL	0.0268
95% KM (bootstrap t) UCL	0.0274
95% KM (BCA) UCL	0.028
95% KM (Percentile Bootstrap) UCL	0.0273
95% KM (Chebyshev) UCL	0.0329
97.5% KM (Chebyshev) UCL	0.0372
99% KM (Chebyshev) UCL	0.0457

Potential UCLs to Use

95% KM (t) UCL	0.027
95% KM (Percentile Bootstrap) UCL	0.0273

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzobfluoranthene

General Statistics

Number of Valid Observations	12
Number of Distinct Observations	11

Raw Statistics

Minimum	0.0138
Maximum	0.0759
Mean	0.0343
Median	0.0288
SD	0.02
Coefficient of Variation	0.584
Skewness	1.101

Log-transformed Statistics

Minimum of Log Data	-4.283
Maximum of Log Data	-2.578
Mean of log Data	-3.518
SD of log Data	0.554

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.873
Shapiro Wilk Critical Value	0.859

Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.954
Shapiro Wilk Critical Value	0.859

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	0.0446

Assuming Lognormal Distribution

95% H-UCL	0.05

95% UCLs (Adjusted for Skewness)	
95% Adjusted-CLT UCL (Chen-1995)	0.0457
95% Modified-t UCL (Johnson-1978)	0.0449

95% Chebyshev (MVUE) UCL	0.0585
97.5% Chebyshev (MVUE) UCL	0.0691
99% Chebyshev (MVUE) UCL	0.0898

Gamma Distribution Test	
k star (bias corrected)	2.776
Theta Star	0.0123
MLE of Mean	0.0343
MLE of Standard Deviation	0.0206
nu star	66.63
Approximate Chi Square Value (.05)	48.84
Adjusted Level of Significance	0.029
Adjusted Chi Square Value	46.53
Anderson-Darling Test Statistic	0.345
Anderson-Darling 5% Critical Value	0.737
Kolmogorov-Smirnov Test Statistic	0.147
Kolmogorov-Smirnov 5% Critical Value	0.247

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution	
95% Approximate Gamma UCL	0.0467
95% Adjusted Gamma UCL	0.0491

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics	
95% CLT UCL	0.0438
95% Jackknife UCL	0.0446
95% Standard Bootstrap UCL	0.0433
95% Bootstrap-t UCL	0.0481
95% Hall's Bootstrap UCL	0.0472
95% Percentile Bootstrap UCL	0.0438
95% BCA Bootstrap UCL	0.0451
95% Chebyshev(Mean, Sd) UCL	0.0594
97.5% Chebyshev(Mean, Sd) UCL	0.0703
99% Chebyshev(Mean, Sd) UCL	0.0917

Potential UCL to Use	
Use 95% Student's-t UCL	0.0446

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Benzokfluoranthene

General Statistics

Number of Valid Data	12	Number of Detected Data	9
Number of Distinct Detected Data	9	Number of Non-Detect Data	3
		Percent Non-Detects	25.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0114	Minimum Detected	-4.474
Maximum Detected	0.121	Maximum Detected	-2.112
Mean of Detected	0.0462	Mean of Detected	-3.484
SD of Detected	0.0443	SD of Detected	0.937
Minimum Non-Detect	0.00516	Minimum Non-Detect	-5.267
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	4
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	8
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	33.33%

Warning: There are only 9 Detected Values in this data

Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.749
5% Shapiro Wilk Critical Value	0.829

Data not Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.0356
SD	0.0424
95% DL/2 (t) UCL	0.0576
Maximum Likelihood Estimate(MLE) Method	
Mean	0.0258
SD	0.052
95% MLE (t) UCL	0.0527
95% MLE (Tiku) UCL	0.0546

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.986
Theta Star	0.0468
nu star	17.75
A-D Test Statistic	0.938
5% A-D Critical Value	0.737
K-S Test Statistic	0.737
5% K-S Critical Value	0.285

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	1E-12
Maximum	0.121
Mean	0.0354
Median	0.0163
SD	0.0426
k star	0.187
Theta star	0.189
Nu star	4.499
AppChi2	0.928

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.828
5% Shapiro Wilk Critical Value	0.829

Data not Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-4.018
SD	1.275
95% H-Stat (DL/2) UCL	0.152
Log ROS Method	
Mean in Log Scale	-4.001
SD in Log Scale	1.233
Mean in Original Scale	0.0356
SD in Original Scale	0.0424
95% t UCL	0.0576
95% Percentile Bootstrap UCL	0.056
95% BCA Bootstrap UCL	0.0597

Data Distribution Test with Detected Values Only

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.0375
SD	0.0392
SE of Mean	0.012
95% KM (t) UCL	0.059
95% KM (z) UCL	0.0572
95% KM (jackknife) UCL	0.0583
95% KM (bootstrap t) UCL	0.0695
95% KM (BCA) UCL	0.0603
95% KM (Percentile Bootstrap) UCL	0.0575
95% KM (Chebyshev) UCL	0.0898
97.5% KM (Chebyshev) UCL	0.112
99% KM (Chebyshev) UCL	0.157

Potential UCLs to Use

95% KM (BCA) UCL	0.0603

95% Gamma Approximate UCL	0.171
95% Adjusted Gamma UCL	0.224

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Indeno123cdpyrene

General Statistics

Number of Valid Observations	12	Number of Distinct Observations	12

Raw Statistics

Minimum	0.0193
Maximum	0.0842
Mean	0.0398
Median	0.0327
SD	0.0202
Coefficient of Variation	0.508
Skewness	1.038

Log-transformed Statistics

Minimum of Log Data	-3.948
Maximum of Log Data	-2.475
Mean of log Data	-3.334
SD of log Data	0.48

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.879
Shapiro Wilk Critical Value	0.859

Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.93
Shapiro Wilk Critical Value	0.859

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	0.0503

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	0.0513
95% Modified-t UCL (Johnson-1978)	0.0506

Assuming Lognormal Distribution

95% H-UCL	0.0544
95% Chebyshev (MVUE) UCL	0.0641
97.5% Chebyshev (MVUE) UCL	0.0747
99% Chebyshev (MVUE) UCL	0.0955

Gamma Distribution Test

k star (bias corrected)	3.607
Theta Star	0.011
MLE of Mean	0.0398
MLE of Standard Deviation	0.0209
nu star	86.56
Approximate Chi Square Value (.05)	66.11
Adjusted Level of Significance	0.029
Adjusted Chi Square Value	63.39
Anderson-Darling Test Statistic	0.457
Anderson-Darling 5% Critical Value	0.733
Kolmogorov-Smirnov Test Statistic	0.205
Kolmogorov-Smirnov 5% Critical Value	0.246

Data appear Gamma Distributed at 5% Significance Level

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL	0.0494
95% Jackknife UCL	0.0503
95% Standard Bootstrap UCL	0.0491
95% Bootstrap-t UCL	0.0526
95% Hall's Bootstrap UCL	0.0513
95% Percentile Bootstrap UCL	0.0491
95% BCA Bootstrap UCL	0.0514
95% Chebyshev(Mean, Sd) UCL	0.0652

97.5% Chebyshev(Mean, Sd) UCL	0.0762
99% Chebyshev(Mean, Sd) UCL	0.0979

Assuming Gamma Distribution

95% Approximate Gamma UCL	0.0521
95% Adjusted Gamma UCL	0.0543

Potential UCL to Use — Use 95% Student's-t UCL 0.0503

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Dibenzoahanthracene

General Statistics

Number of Valid Data	12	Number of Detected Data	6
Number of Distinct Detected Data	6	Number of Non-Detect Data	6
		Percent Non-Detects	50.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0183	Minimum Detected	-4.001
Maximum Detected	0.0747	Maximum Detected	-2.594
Mean of Detected	0.0412	Mean of Detected	-3.292
SD of Detected	0.0203	SD of Detected	0.501
Minimum Non-Detect	0.00537	Minimum Non-Detect	-5.227
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	6
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	50.00%

Warning: There are only 6 Detected Values in this data

Note: It should be noted that even though bootstrap may be performed on this data set the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.952	Shapiro Wilk Test Statistic	0.994
5% Shapiro Wilk Critical Value	0.788	5% Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.0235	Mean	-4.239
SD	0.023	SD	1.074
95% DL/2 (t) UCL	0.0354	95% H-Stat (DL/2) UCL	0.069

Maximum Likelihood Estimate(MLE) Method	
Mean	0.0146
SD	0.0328
95% MLE (t) UCL	0.0315
95% MLE (Tiku) UCL	0.0355

Log ROS Method	
Mean in Log Scale	-4.034
SD in Log Scale	0.854
Mean in Original Scale	0.0249
SD in Original Scale	0.0219
95% t UCL	0.0362
95% Percentile Bootstrap UCL	0.0354
95% BCA Bootstrap UCL	0.0375

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	2.631
Theta Star	0.0157
nu star	31.57
A-D Test Statistic	0.158
5% A-D Critical Value	0.698
K-S Test Statistic	0.698
5% K-S Critical Value	0.333

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0183
Maximum	0.0747
Mean	0.0412
Median	0.0414
SD	0.0142
k star	6.989
Theta star	0.00589
Nu star	167.7
AppChi2	138.8
95% Gamma Approximate UCL	0.0498
95% Adjusted Gamma UCL	0.0513

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.0297
SD	0.0174
SE of Mean	0.00551
95% KM (t) UCL	0.0396
95% KM (z) UCL	0.0388
95% KM (jackknife) UCL	0.0386
95% KM (bootstrap t) UCL	0.0422
95% KM (BCA) UCL	0.0483
95% KM (Percentile Bootstrap) UCL	0.0436
95% KM (Chebyshev) UCL	0.0537
97.5% KM (Chebyshev) UCL	0.0641
99% KM (Chebyshev) UCL	0.0845

Potential UCLs to Use

95% KM (t) UCL	0.0396
95% KM (Percentile Bootstrap) UCL	0.0436

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Fluoranthene

General Statistics

Number of Valid Data	12	Number of Detected Data	9
Number of Distinct Detected Data	9	Number of Non-Detect Data	3
		Percent Non-Detects	25.00%

Raw Statistics

Minimum Detected	0.0129
Maximum Detected	0.0443

Log-transformed Statistics

Minimum Detected	-4.351
Maximum Detected	-3.117

Mean of Detected	0.0322	Mean of Detected	-3.494
SD of Detected	0.00997	SD of Detected	0.385
Minimum Non-Detect	0.00516	Minimum Non-Detect	-5.267
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	4
Number treated as Detected	8
Single DL Non-Detect Percentage	33.33%

Warning: There are only 9 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.93
5% Shapiro Wilk Critical Value	0.829

Data appear Normal at 5% Significance Level

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.847
5% Shapiro Wilk Critical Value	0.829

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method

Mean	0.0251
SD	0.0153
95% DL/2 (t) UCL	0.0331

Maximum Likelihood Estimate(MLE) Method

Mean	0.0346
SD	0.00687
95% MLE (t) UCL	0.0381
95% MLE (Tiku) UCL	0.0389

Assuming Lognormal Distribution

DL/2 Substitution Method

Mean	-4.025
SD	1.043
95% H-Stat (DL/2) UCL	0.0789

Log ROS Method

Mean in Log Scale	-3.696
SD in Log Scale	0.493
Mean in Original Scale	0.0275
SD in Original Scale	0.012
95% t UCL	0.0337
95% Percentile Bootstrap UCL	0.0328
95% BCA Bootstrap UCL	0.033

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	6.077
Theta Star	0.00529
nu star	109.4
A-D Test Statistic	0.506
5% A-D Critical Value	0.722
K-S Test Statistic	0.722
5% K-S Critical Value	0.279

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.0273
SD	0.0117
SE of Mean	0.00357
95% KM (t) UCL	0.0337
95% KM (z) UCL	0.0332
95% KM (jackknife) UCL	0.0339

Minimum	0.0129	95% KM (bootstrap t) UCL	0.0328
Maximum	0.0443	95% KM (BCA) UCL	0.0364
Mean	0.0295	95% KM (Percentile Bootstrap) UCL	0.0349
Median	0.0283	95% KM (Chebyshev) UCL	0.0429
SD	0.00983	97.5% KM (Chebyshev) UCL	0.0496
k star	6.68	99% KM (Chebyshev) UCL	0.0628
Theta star	0.00441		
Nu star	160.3	**Potential UCLs to Use**	
AppChi2	132	95% KM (t) UCL	0.0337
95% Gamma Approximate UCL	0.0358	95% KM (Percentile Bootstrap) UCL	0.0349
95% Adjusted Gamma UCL	0.0369		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Pyrene

General Statistics

Number of Valid Data	12	Number of Detected Data	8
Number of Distinct Detected Data	8	Number of Non-Detect Data	4
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0237	Minimum Detected	-3.742
Maximum Detected	0.0528	Maximum Detected	-2.941
Mean of Detected	0.0393	Mean of Detected	-3.265
SD of Detected	0.00978	SD of Detected	0.264
Minimum Non-Detect	0.00516	Minimum Non-Detect	-5.267
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	4
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	8
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	33.33%

Warning: There are only 8 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.962	Shapiro Wilk Test Statistic	0.946
5% Shapiro Wilk Critical Value	0.818	5% Shapiro Wilk Critical Value	0.818
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.0277
SD	0.0189
95% DL/2 (t) UCL	0.0375
Maximum Likelihood Estimate(MLE) Method	
Mean	0.0268
SD	0.0201
95% MLE (t) UCL	0.0372
95% MLE (Tiku) UCL	0.0383

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-4.012
SD	1.154
95% H-Stat (DL/2) UCL	0.107
Log ROS Method	
Mean in Log Scale	-3.479
SD in Log Scale	0.38
Mean in Original Scale	0.0329
SD in Original Scale	0.0123
95% t UCL	0.0393
95% Percentile Bootstrap UCL	0.0382
95% BCA Bootstrap UCL	0.0388

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	10.92
Theta Star	0.0036
nu star	174.8
A-D Test Statistic	0.248
5% A-D Critical Value	0.716
K-S Test Statistic	0.716
5% K-S Critical Value	0.294

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0237
Maximum	0.0528
Mean	0.0367
Median	0.0327
SD	0.00872
k star	15.24
Theta star	0.00241
Nu star	365.7
AppChi2	322.4
95% Gamma Approximate UCL	0.0416
95% Adjusted Gamma UCL	0.0424

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.0341
SD	0.0105
SE of Mean	0.00324
95% KM (t) UCL	0.0399
95% KM (z) UCL	0.0394
95% KM (jackknife) UCL	0.04
95% KM (bootstrap t) UCL	0.0395
95% KM (BCA) UCL	0.0426
95% KM (Percentile Bootstrap) UCL	0.0412
95% KM (Chebyshev) UCL	0.0482
97.5% KM (Chebyshev) UCL	0.0543
99% KM (Chebyshev) UCL	0.0663

Potential UCLs to Use

95% KM (t) UCL	0.0399
95% KM (Percentile Bootstrap) UCL	0.0412

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(ghi)perylene

General Statistics

Number of Valid Data	12	Number of Detected Data	8

Number of Distinct Detected Data	8	Number of Non-Detect Data	4
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0132	Minimum Detected	-4.328
Maximum Detected	0.0624	Maximum Detected	-2.774
Mean of Detected	0.0379	Mean of Detected	-3.389
SD of Detected	0.0176	SD of Detected	0.546
Minimum Non-Detect	0.0107	Minimum Non-Detect	-4.538
Maximum Non-Detect	0.0138	Maximum Non-Detect	-4.283

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	5
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	7
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	41.67%

Warning: There are only 8 Detected Values in this data

Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.949	Shapiro Wilk Test Statistic	0.92
5% Shapiro Wilk Critical Value	0.818	5% Shapiro Wilk Critical Value	0.818
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.0273	Mean	-3.962
SD	0.0211	SD	0.954
95% DL/2 (t) UCL	0.0382	95% H-Stat (DL/2) UCL	0.0677
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	0.022	Mean in Log Scale	-3.815
SD	0.0274	SD in Log Scale	0.767
95% MLE (t) UCL	0.0361	Mean in Original Scale	0.0284
95% MLE (Tiku) UCL	0.0382	SD in Original Scale	0.0199
		95% t UCL	0.0387
		95% Percentile Bootstrap UCL	0.0373
		95% BCA Bootstrap UCL	0.0387

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only
k star (bias corrected)	2.867	Data appear Normal at 5% Significance Level
Theta Star	0.0132	
nu star	45.88	
A-D Test Statistic	0.327	**Nonparametric Statistics**
5% A-D Critical Value	0.719	Kaplan-Meier (KM) Method

K-S Test Statistic	0.719
5% K-S Critical Value	0.295

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0132
Maximum	0.0624
Mean	0.0333
Median	0.0257
SD	0.0157
k star	3.887
Theta star	0.00856
Nu star	93.29
AppChi2	72.01
95% Gamma Approximate UCL	0.0431
95% Adjusted Gamma UCL	0.0449

Note: DL/2 is not a recommended method.

Mean	0.0297
SD	0.0178
SE of Mean	0.00549
95% KM (t) UCL	0.0395
95% KM (z) UCL	0.0387
95% KM (jackknife) UCL	0.0389
95% KM (bootstrap t) UCL	0.0401
95% KM (BCA) UCL	0.0429
95% KM (Percentile Bootstrap) UCL	0.0412
95% KM (Chebyshev) UCL	0.0536
97.5% KM (Chebyshev) UCL	0.064
99% KM (Chebyshev) UCL	0.0843

Potential UCLs to Use

95% KM (t) UCL	0.0395
95% KM (Percentile Bootstrap) UCL	0.0412

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

ATTACHMENT 3

Individual PAH Potential Cancer Risks and Noncancer Hazards

Attachment 3. Noncancer Hazard - Sediment Confirmation Samples
Liberty Park Lake,
Salt Lake City, UT

	Resident				Recreational User			
	Adult			Child	Adult			Child
CHEMICAL	Ing	Dermal	Direct Total	(0-6 years)	Ing	Dermal	Direct Total	(0-6 years)
Liberty Park Lake Wall and Bottom Sediments								
Acenaphthene	NC	NC	NC	NA	NC	NC	NC	NA
Acenaphthylene	NC	NC	NC	NA	NC	NC	NC	NA
Anthracene	NC	NC	NC	NA	NC	NC	NC	NA
Benz(a)anthracene	1.435E-07	5.508E-08	1.99E-07	NA	1.066E-08	4.091E-09	1.47E-08	NA
Benzo(b)fluoranthene	2.186E-07	8.390E-08	3.02E-07	NA	1.624E-08	6.233E-09	2.25E-08	NA
Benzo(k)fluoranthene	2.925E-08	1.123E-08	4.05E-08	NA	2.173E-09	8.342E-10	3.01E-09	NA
Benzo(g,h,i)perylene	NC	NC	NC	NA	NC	NC	NC	NA
Benzo(a)pyrene	4.308E-06	1.654E-06	5.96E-06	NA	3.200E-07	1.228E-07	4.43E-07	NA
Chrysene	1.322E-09	5.074E-10	1.83E-09	NA	9.818E-11	3.769E-11	1.36E-10	NA
Dibenz(a,h)anthracene	1.940E-06	7.447E-07	2.68E-06	NA	1.441E-07	5.532E-08	1.99E-07	NA
Fluoranthene	NC	NC	NC	NA	NC	NC	NC	NA
Fluorene	NC	NC	NC	NA	NC	NC	NC	NA
Indeno(1,2,3-cd)pyrene	2.448E-07	9.396E-08	3.39E-07	NA	1.818E-08	6.980E-09	2.52E-08	NA
1-Methylnaphthalene	1.666E-09	2.740E-09	4.41E-09	NA	1.238E-10	5.080E-11	1.75E-10	NA
2-Methylnaphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Naphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Pyrene	NC	NC	NC	NA	NC	NC	NC	NA
TOTAL:	6.89E-06	2.65E-06	**9.53E-06**	**NA**	5.12E-07	1.96E-07	**7.08E-07**	**NA**
Liberty Park Lake Red Butte Creek Inlet Sediments								
Acenaphthene	NC	NC	NC	NA	NC	NC	NC	NA
Acenaphthylene	NC	NC	NC	NA	NC	NC	NC	NA
Anthracene	NC	NC	NC	NA	NC	NC	NC	NA
Benz(a)anthracene	4.993E-07	1.917E-07	6.91E-07	NA	3.709E-08	1.424E-08	5.13E-08	NA
Benzo(b)fluoranthene	6.804E-07	2.612E-07	9.42E-07	NA	5.055E-08	1.940E-08	6.99E-08	NA
Benzo(k)fluoranthene	2.874E-08	1.103E-08	3.98E-08	NA	2.135E-09	8.194E-10	2.95E-09	NA
Benzo(g,h,i)perylene	NC	NC	NC	NA	NC	NC	NC	NA
Benzo(a)pyrene	7.832E-06	3.007E-06	1.08E-05	NA	5.818E-07	2.233E-07	8.05E-07	NA
Chrysene	4.695E-09	1.802E-09	6.50E-09	NA	3.487E-10	1.339E-10	4.83E-10	NA
Dibenz(a,h)anthracene	1.434E-06	5.506E-07	1.98E-06	NA	1.065E-07	4.090E-08	1.47E-07	NA
Fluoranthene	NC	NC	NC	NA	NC	NC	NC	NA
Fluorene	NC	NC	NC	NA	NC	NC	NC	NA
Indeno(1,2,3-cd)pyrene	4.660E-07	1.789E-07	6.45E-07	NA	3.462E-08	1.329E-08	4.79E-08	NA
1-Methylnaphthalene	2.406E-10	9.876E-11	3.39E-10	NA	1.788E-11	7.336E-12	2.52E-11	NA
2-Methylnaphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Naphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Pyrene	NC	NC	NC	NA	NC	NC	NC	NA
TOTAL:	1.09E-05	4.20E-06	**1.51E-05**	**NA**	8.13E-07	3.12E-07	**1.13E-06**	**NA**
Liberty Park Lake Emigration Creek Inlet Sediments								
Acenaphthene	NC	NC	NC	NA	NC	NC	NC	NA
Acenaphthylene	NC	NC	NC	NA	NC	NC	NC	NA
Anthracene	NC	NC	NC	NA	NC	NC	NC	NA
Benz(a)anthracene	4.592E-07	1.763E-07	6.35E-07	NA	3.411E-08	1.309E-08	4.72E-08	NA
Benzo(b)fluoranthene	7.441E-07	2.856E-07	1.03E-06	NA	5.527E-08	2.122E-08	7.65E-08	NA
Benzo(k)fluoranthene	2.692E-08	1.034E-08	3.73E-08	NA	2.000E-09	7.677E-10	2.77E-09	NA
Benzo(g,h,i)perylene	NC	NC	NC	NA	NC	NC	NC	NA
Benzo(a)pyrene	9.056E-06	3.476E-06	1.25E-05	NA	6.727E-07	2.582E-07	9.31E-07	NA
Chrysene	3.794E-09	1.456E-09	5.25E-09	NA	2.818E-10	1.082E-10	3.90E-10	NA
Dibenz(a,h)anthracene	1.645E-06	6.314E-07	2.28E-06	NA	1.222E-07	4.690E-08	1.69E-07	NA
Fluoranthene	NC	NC	NC	NA	NC	NC	NC	NA
Fluorene	NC	NC	NC	NA	NC	NC	NC	NA
Indeno(1,2,3-cd)pyrene	5.238E-07	2.011E-07	7.25E-07	NA	3.891E-08	1.494E-08	5.38E-08	NA
1-Methylnaphthalene	2.588E-10	1.062E-10	3.65E-10	NA	1.922E-11	7.890E-12	2.71E-11	NA
2-Methylnaphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Naphthalene	NC	NC	NC	NA	NC	NC	NC	NA
Pyrene	NC	NC	NC	NA	NC	NC	NC	NA
TOTAL:	1.25E-05	4.78E-06	**1.72E-05**	**NA**	9.26E-07	3.55E-07	**1.28E-06**	**NA**

Notes:
NA = Not Applicable
NC = No Criteria

Attachment 3. Noncancer Hazard - Sediment Confirmation Samples
Liberty Park Lake,
Salt Lake City, UT

	Resident						Recreational User					
	Adult			Child (0-6 years)			Adult			Child (0-6 years)		
CHEMICAL	Ing	Dermal	Direct Total	Ing	Dermal	Direct Total	Ing	Dermal	Direct Total	Ing	Dermal	Direct Total
Liberty Park Lake Wall and Bottom Sediments												
Acenaphthene	5.251E-08	2.724E-08	7.97E-08	4.901E-07	1.784E-07	6.69E-07	3.901E-09	2.023E-09	5.92E-09	3.641E-08	1.325E-08	4.97E-08
Acenaphthylene	5.251E-08	2.724E-08	7.97E-08	4.901E-07	1.784E-07	6.69E-07	3.901E-09	2.023E-09	5.92E-09	3.641E-08	1.325E-08	4.97E-08
Anthracene	1.621E-07	8.408E-08	2.46E-07	1.513E-06	5.507E-07	2.06E-06	1.204E-08	6.246E-09	1.83E-08	1.124E-07	4.091E-08	1.53E-07
Benz(a)anthracene	1.338E-07	6.942E-08	2.03E-07	1.249E-06	4.547E-07	1.70E-06	9.942E-09	5.157E-09	1.51E-08	9.279E-08	3.378E-08	1.27E-07
Benzo(b)fluoranthene	1.529E-06	7.931E-07	2.32E-06	1.427E-05	5.195E-06	1.95E-05	1.136E-07	5.892E-08	1.73E-07	1.060E-06	3.859E-07	1.45E-06
Benzo(k)fluoranthene	2.047E-06	1.062E-06	3.11E-06	1.910E-05	6.953E-06	2.61E-05	1.520E-07	7.886E-08	2.31E-07	1.419E-06	5.165E-07	1.94E-06
Benzo(g,h,i)perylene	1.799E-06	9.332E-07	2.73E-06	1.679E-05	6.112E-06	2.29E-05	1.336E-07	6.932E-08	2.03E-07	1.247E-06	4.540E-07	1.70E-06
Benzo(a)pyrene	4.018E-06	2.084E-06	6.10E-06	3.750E-05	1.365E-05	5.12E-05	2.985E-07	1.548E-07	4.53E-07	2.786E-06	1.014E-06	3.80E-06
Chrysene	1.233E-06	6.395E-07	1.87E-06	1.151E-05	4.188E-06	1.57E-05	9.159E-08	4.751E-08	1.39E-07	8.548E-07	3.111E-07	1.17E-06
Dibenz(a,h)anthracene	1.810E-07	9.386E-08	2.75E-07	1.689E-06	6.148E-07	2.30E-06	1.344E-08	6.973E-09	2.04E-08	1.255E-07	4.567E-08	1.71E-07
Fluoranthene	1.156E-06	5.995E-07	1.76E-06	1.079E-05	3.927E-06	1.47E-05	8.586E-08	4.454E-08	1.30E-07	8.014E-07	2.917E-07	1.09E-06
Fluorene	7.877E-08	4.086E-08	1.20E-07	7.352E-07	2.676E-07	1.00E-06	5.851E-09	3.035E-09	8.89E-09	5.461E-08	1.988E-08	7.45E-08
Indeno(1,2,3-cd)pyrene	2.283E-06	1.184E-06	3.47E-06	2.131E-05	7.756E-06	2.91E-05	1.696E-07	8.797E-08	2.58E-07	1.583E-06	5.762E-07	2.16E-06
1-Methylnaphthalene	7.182E-07	3.725E-07	1.09E-06	6.703E-06	2.440E-06	9.14E-06	5.335E-08	2.767E-08	8.10E-08	4.980E-07	1.813E-07	6.79E-07
2-Methylnaphthalene	7.877E-07	4.086E-07	1.20E-06	7.352E-06	2.676E-06	1.00E-05	5.851E-08	3.035E-08	8.89E-08	5.461E-07	1.988E-07	7.45E-07
Naphthalene	1.575E-07	8.171E-08	2.39E-07	1.470E-06	5.352E-07	2.01E-06	1.170E-08	6.070E-09	1.78E-08	1.092E-07	3.976E-08	1.49E-07
Pyrene	1.823E-06	9.457E-07	2.77E-06	1.702E-05	6.194E-06	2.32E-05	1.354E-07	7.025E-08	2.06E-07	1.264E-06	4.601E-07	1.72E-06
TOTAL:	1.82E-05	9.45E-06	**2.77E-05**	1.70E-04	6.19E-05	**2.32E-04**	1.35E-06	7.02E-07	**2.05E-06**	1.26E-05	4.60E-06	**1.72E-05**
Liberty Park Lake Red Butte Creek Inlet Sediments												
Acenaphthene	1.210E-07	6.277E-08	1.84E-07	1.129E-06	4.111E-07	1.54E-06	8.989E-09	4.663E-09	1.37E-08	8.390E-08	3.054E-08	1.14E-07
Acenaphthylene	1.210E-07	6.277E-08	1.84E-07	1.129E-06	4.111E-07	1.54E-06	8.989E-09	4.663E-09	1.37E-08	8.390E-08	3.054E-08	1.14E-07
Anthracene	1.110E-07	5.755E-08	1.69E-07	1.036E-06	3.770E-07	1.41E-06	8.243E-09	4.275E-09	1.25E-08	7.693E-08	2.800E-08	1.05E-07
Benz(a)anthracene	4.658E-07	2.416E-07	7.07E-07	4.347E-06	1.582E-06	5.93E-06	3.460E-08	1.795E-08	5.25E-08	3.229E-07	1.175E-07	4.40E-07
Benzo(b)fluoranthene	4.760E-06	2.469E-06	7.23E-06	4.443E-05	1.617E-05	6.06E-05	3.536E-07	1.834E-07	5.37E-07	3.300E-06	1.201E-06	4.50E-06
Benzo(k)fluoranthene	2.010E-06	1.043E-06	3.05E-06	1.876E-05	6.830E-06	2.56E-05	1.493E-07	7.746E-08	2.27E-07	1.394E-06	5.073E-07	1.90E-06
Benzo(g,h,i)perylene	2.808E-06	1.457E-06	4.26E-06	2.621E-05	9.540E-06	3.58E-05	2.086E-07	1.082E-07	3.17E-07	1.947E-06	7.087E-07	2.66E-06
Benzo(a)pyrene	7.306E-06	3.790E-06	1.11E-05	6.819E-05	2.482E-05	9.30E-05	5.427E-07	2.815E-07	8.24E-07	5.065E-06	1.844E-06	6.91E-06
Chrysene	4.379E-06	2.271E-06	6.65E-06	4.087E-05	1.488E-05	5.57E-05	3.253E-07	1.687E-07	4.94E-07	3.036E-06	1.105E-06	4.14E-06
Dibenz(a,h)anthracene	1.338E-07	6.940E-08	2.03E-07	1.249E-06	4.545E-07	1.70E-06	9.939E-09	5.155E-09	1.51E-08	9.276E-08	3.377E-08	1.27E-07
Fluoranthene	4.863E-06	2.522E-06	7.39E-06	4.539E-05	1.652E-05	6.19E-05	3.613E-07	1.874E-07	5.49E-07	3.372E-06	1.227E-06	4.60E-06
Fluorene	1.815E-07	9.415E-08	2.76E-07	1.694E-06	6.166E-07	2.31E-06	1.348E-08	6.994E-09	2.05E-08	1.258E-07	4.581E-08	1.72E-07
Indeno(1,2,3-cd)pyrene	4.347E-06	2.255E-06	6.60E-06	4.057E-05	1.477E-05	5.53E-05	3.229E-07	1.675E-07	4.90E-07	3.014E-06	1.097E-06	4.11E-06
1-Methylnaphthalene	1.037E-07	5.380E-08	1.58E-07	9.680E-07	3.524E-07	1.32E-06	7.705E-09	3.996E-09	1.17E-08	7.191E-08	2.618E-08	9.81E-08
2-Methylnaphthalene	1.815E-06	9.415E-07	2.76E-06	1.694E-05	6.166E-06	2.31E-05	1.348E-07	6.994E-08	2.05E-07	1.258E-06	4.581E-07	1.72E-06
Naphthalene	3.630E-07	1.883E-07	5.51E-07	3.388E-06	1.233E-06	4.62E-06	2.697E-08	1.399E-08	4.10E-08	2.517E-07	9.161E-08	3.43E-07
Pyrene	6.347E-06	3.292E-06	9.64E-06	5.924E-05	2.156E-05	8.08E-05	4.715E-07	2.446E-07	7.16E-07	4.401E-06	1.602E-06	6.00E-06
TOTAL:	4.02E-05	2.09E-05	**6.11E-05**	3.76E-04	1.37E-04	**5.12E-04**	2.99E-06	1.55E-06	**4.54E-06**	2.79E-05	1.02E-05	**3.81E-05**
Liberty Park Lake Emigration Creek Inlet Sediments												
Acenaphthene	1.301E-07	6.750E-08	1.98E-07	1.215E-06	4.421E-07	1.66E-06	9.667E-09	5.014E-09	1.47E-08	9.023E-08	3.284E-08	1.23E-07
Acenaphthylene	1.301E-07	6.750E-08	1.98E-07	1.215E-06	4.421E-07	1.66E-06	9.667E-09	5.014E-09	1.47E-08	9.023E-08	3.284E-08	1.23E-07
Anthracene	2.603E-08	1.350E-08	3.95E-08	2.429E-07	8.842E-08	3.31E-07	1.933E-09	1.003E-09	2.94E-09	1.805E-08	6.569E-09	2.46E-08
Benz(a)anthracene	4.283E-07	2.222E-07	6.50E-07	3.998E-06	1.455E-06	5.45E-06	3.182E-08	1.650E-08	4.83E-08	2.970E-07	1.081E-07	4.05E-07
Benzo(b)fluoranthene	5.205E-06	2.700E-06	7.91E-06	4.858E-05	1.768E-05	6.63E-05	3.867E-07	2.006E-07	5.87E-07	3.609E-06	1.314E-06	4.92E-06
Benzo(k)fluoranthene	1.884E-06	9.770E-07	2.86E-06	1.758E-05	6.399E-06	2.40E-05	1.399E-07	7.258E-08	2.12E-07	1.306E-06	4.754E-07	1.78E-06
Benzo(g,h,i)perylene	1.909E-06	9.900E-07	2.90E-06	1.781E-05	6.484E-06	2.43E-05	1.418E-07	7.355E-08	2.15E-07	1.323E-06	4.817E-07	1.81E-06
Benzo(a)pyrene	8.447E-06	4.382E-06	1.28E-05	7.884E-05	2.870E-05	1.08E-04	6.275E-07	3.255E-07	9.53E-07	5.857E-06	2.132E-06	7.99E-06
Chrysene	3.539E-06	1.836E-06	5.37E-06	3.303E-05	1.202E-05	4.51E-05	2.629E-07	1.364E-07	3.99E-07	2.454E-06	8.931E-07	3.35E-06
Dibenz(a,h)anthracene	1.534E-07	7.958E-08	2.33E-07	1.432E-06	5.212E-07	1.95E-06	1.140E-08	5.912E-09	1.73E-08	1.064E-07	3.872E-08	1.45E-07
Fluoranthene	3.315E-06	1.720E-06	5.03E-06	3.094E-05	1.126E-05	4.22E-05	2.463E-07	1.277E-07	3.74E-07	2.298E-06	8.366E-07	3.14E-06
Fluorene	1.952E-07	1.013E-07	2.96E-07	1.822E-06	6.632E-07	2.49E-06	1.450E-08	7.522E-09	2.20E-08	1.353E-07	4.926E-08	1.85E-07
Indeno(1,2,3-cd)pyrene	4.886E-06	2.534E-06	7.42E-06	4.560E-05	1.660E-05	6.22E-05	3.629E-07	1.883E-07	5.51E-07	3.388E-06	1.233E-06	4.62E-06
1-Methylnaphthalene	1.115E-07	5.786E-08	1.69E-07	1.041E-06	3.790E-07	1.42E-06	8.286E-09	4.298E-09	1.26E-08	7.734E-08	2.815E-08	1.05E-07
2-Methylnaphthalene	1.952E-06	1.013E-06	2.96E-06	1.822E-05	6.632E-06	2.49E-05	1.450E-07	7.522E-08	2.20E-07	1.353E-06	4.926E-07	1.85E-06
Naphthalene	3.904E-07	2.025E-07	5.93E-07	3.644E-06	1.326E-06	4.97E-06	2.900E-08	1.504E-08	4.40E-08	2.707E-07	9.853E-08	3.69E-07
Pyrene	5.936E-06	3.079E-06	9.02E-06	5.540E-05	2.017E-05	7.56E-05	4.410E-07	2.287E-07	6.70E-07	4.116E-06	1.498E-06	5.61E-06
TOTAL:	3.86E-05	2.00E-05	**5.87E-05**	3.61E-04	1.31E-04	**4.92E-04**	2.87E-06	1.49E-06	**4.36E-06**	2.68E-05	9.75E-06	**3.65E-05**