Final Technical Memorandum
Human Health Risk Assessment of Shoreline Surface Waters and Sediments, and Groundwater in Shallow Piezometers Site 07, Calf Pasture Point

Former Naval Construction Battalion Center Davisville
North Kingstown, Rhode Island

Naval Facilities Engineering Command Mid-Atlantic
Contract Number N62472-03-D-0057
Contract Task Order 019

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FINAL TECHNICAL MEMORANDUM

HUMAN HEALTH RISK ASSESSMENT OF SHORELINE SURFACE WATERS AND SEDIMENTS, AND GROUNDWATER IN SHALLOW PIEZOMETERS SITE 07, CALF PASTURE POINT

FORMER NAVAL CONSTRUCTION BATTALION CENTER DAVISVILLE NORTH KINGSTOWN, RHODE ISLAND

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION – NAVY (CLEAN) CONTRACT

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HUMAN HEALTH RISK ASSESSMENT OF SHORELINE SURFACE WATERS AND SEDIMENTS, AND GROUNDWATER IN SHALLOW PIEZOMETERS SITE 07, CALF PASTURE POINT FORMER NAVAL CONSTRUCTION BATTALION CENTER DAVISVILLE NORTH KINGSTOWN, RHODE ISLAND

EXECUTIVE SUMMARY

This human health risk assessment (HHRA) was conducted to evaluate risks associated with potential human exposure to volatile organic compounds (for example trichloroethene) detected in surface water and shallow groundwater samples, and volatile organic compounds (VOCs) and metals detected in sediment samples collected along the Site 07 shoreline. The impetus for the assessment was the detection of VOCs in groundwater samples collected from shoreline piezometers at Site 07. The environmental samples were collected as part of the long-term monitoring program for Site 07 as required by the Record of Decision established for this site (September 1999). For purposes of completeness, the assessment also re-evaluated risks using the analytical data for shellfish previously collected during the Phase III Remedial Investigation for Site 07. The HHRA was prepared per methodology presented in the *Final Technical Memorandum, Human Health Risk Assessment Methodology for the Evaluation of Shoreline Surface Waters and Sediments, and Groundwater in Shallow Piezometers, Site 07 (Calf Pasture Point), Former Naval Construction Battalion Center (NCBC) Davisville, RI* (December 2006). The methodology was reviewed and approved by EPA Region I and the Rhode Island Department of Environmental Management (RIDEM).

The following chemicals of potential concern were selected for the HHRA utilizing a conservative toxicity screening protocol:

- ***Shallow groundwater (from piezometers along the shoreline):*** 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1-dichloroethene, 1,2-dicholoroethane, benzene, chloroform, cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride.
- ***Surface water (along the shoreline):*** 1,1,2,2-tetrachloroethane, cis-1,2-dichloroethene, trichloroethene, and vinyl chloride.
- ***Sediments (along the shoreline):*** Trichloroethene, vinyl chloride, aluminum, arsenic, beryllium, and iron.
- ***Shellfish data (as presented in the Phase III Remedial Investigation for Site 07):*** Polycyclic aromatic hydrocarbons (benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene), Aldrin, 4,4'-DDE, Aroclor-1242, Aroclor-1254, and Aroclor-1260, arsenic, cadmium, chromium, copper, iron, manganese, mercury, nickel, and silver.

The human receptors considered in the HHRA were individuals potentially exposed to the chemicals of potential concern in the Site 07 shoreline surface waters, sediments, or shallow groundwater while swimming, wading, or gathering shellfish. The exposure pathways evaluated were:

- Dermal contact (skin surface exposure) with or the incidental ingestion of surface waters and sediments while swimming, wading, or gathering shellfish.
- Dermal contact with shallow groundwater while digging into the shoreline sediments to gather shellfish.
- Consumption of shellfish collected along the Site 07 shoreline.

Chemical intakes (or doses) resulting from exposure to chemicals of concern were estimated according to the exposure assumptions (e.g., water or sediment ingestion rates) and equations presented in aforementioned Technical Memorandum dated December 2006. The exposure assumptions and equations presented in this Technical Memorandum are conservative (i.e., the exposure assumptions were selected to error on the side of safety).

Standard EPA methodology, as presented in the EPA's Risk Assessment Guidance for Superfund (Part A) (December 1989), was used to estimate cancer and non-cancer risk. Cancer risk estimates were presented in terms of the probability of developing cancer. Non-cancer risk estimates were presented in terms of a hazard quotient which is simply the ratio of an exposure dose or concentration to an acceptable dose or concentration.

All of the cancer risk estimates developed for potential human exposure to chemicals of potential concern in the shallow groundwater, surface waters, and sediments while swimming, wading, or shell-fishing were within the EPA's generally acceptable cancer risk range and did not exceed the State of Rhode Island cancer risk benchmark of 10^{-5}. All of the hazard quotients and hazard indices for these same potential exposures were less than 1.

The cancer risk and non-cancer risk estimates developed for consumption of shellfish do exceed both EPA and State of Rhode Island risk management benchmarks. The primary chemicals of potential concern contributing to the cancer and non-cancer risk estimates are arsenic, mercury, and the polychlorinated biphenyls. However, a review of source area data for Site 07 and background data for sediments and shellfish indicates that these chemicals are not present in the shellfish as a consequence of disposal activities at Site 07. The shellfish samples were collected in the mid-1990's and the determination that mercury concentrations in shellfish are not related to Site 07 disposal activities is clearly documented in the September 1999 ROD for Calf Pasture Point.

1.0 INTRODUCTION

This technical memorandum presents the results of a human health risk assessment (HHRA) of volatile organic chemicals (VOCs) detected in the surface water and shallow groundwater (piezometers), and VOCs and metals detected in sediment samples collected along the shoreline at Site 07 Calf Pasture Point, Former Naval Construction Battalion Center (NCBC) Davisville, Kingstown, Rhode Island. The assessment was prepared to evaluate human health risks potentially associated with exposures to these environmental media while swimming, wading, and shell fishing along the Site 07 shoreline. A "No Wading" sign currently exists along the Site 07 shoreline.

This HHRA was prepared under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. 62472-03-D-0057, Contract Task Order No. 19.

1.1 Site History

Calf Pasture Point is a peninsula located in the northeast portion of the former NCBC Davisville. Site 07 is located in the southern portion of Calf Pasture Point, bordered by Allen Harbor to the south and west and Narragansett Bay to the east (Figure 1-1). Site 07 is the former location of three earthen-covered munitions bunkers which were located in the middle of Calf Pasture Point to the north, east, and south of a bedrock outcrop. This outcrop is a prominent hill with a maximum elevation of approximately 55 feet above mean sea level (MSL), located north of well MW07-07S (Figure 1-2). The bunkers were demolished by the Navy in February 1997 and September 2000.

Some time between 1968 and 1974, in the area south of the former munitions bunkers, a trench was reportedly filled with cans that contained Decontaminating Agent Non-Corrosive (DANC) solution. This trench is believed to be the source of a chlorinated volatile organic compound (CVOC) groundwater plume that is present beneath Site 07. The approximate location of the disposal area has been inferred through various phases of investigation at Site 07.

The Navy completed a Remedial Investigation/Feasibility Study (RI/FS) for Site 07 in September 1998. In September 1999, a Record of Decision (ROD) was signed to document the selection of the following remedy for Site 07:

- A deed restriction prohibiting the use of groundwater in order to prevent human contact with, or use of, impacted groundwater (e.g. for drinking or showering purposes). The deed restriction also imposes restrictions on the future use of the property (recreational only) and requires that any

building, structure, or other improvement be designed and constructed to include adequate ventilation.

- Long-term monitoring (LTM) of groundwater, as well as sampling of sediment in the shoreline area as warranted based upon trends in the groundwater data. LTM at Site 07 also includes risk monitoring to demonstrate the protection of human health and the environment, which is the objective of this Technical Memorandum.

- Five-year reviews as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

In November 2000, the Navy completed a Conceptual Long-Term Monitoring Plan (CLTMP) for Site 07, establishing the basis for the long-term monitoring program that is currently being implemented at the Site. In July 2001, the Navy completed a Quality Assurance Project Plan (QAPP) for the long-term monitoring program (LTMP). LTM at Site 07 commenced in August 2001 on a nine-month monitoring schedule. To date, seven monitoring events have been completed (the seventh event occurred in November 2006, but this HHRA was completed before validated data was available from this event).

In October 2004, based upon the detection of CVOCs in shoreline piezometers adjacent to the Allen Harbor entrance channel, and as directed by the LTM QAPP rules, the Navy performed supplemental groundwater and surface water sampling from P07-06 through P07-10 and P07-24. This supplemental sampling was performed bi-monthly until January 2006 to monitor the concentrations of CVOCs present in shallow groundwater and surface water along the Site 07 shoreline. The supplemental data, along with data collected during the first six 9-month sampling events, was used to support this shoreline HHRA.

1.2 Shoreline Human Health Risk Assessment

The shoreline HHRA utilizes shallow groundwater (piezometer), surface water, and sediment sampling results to calculate human health risks associated with wading and shellfishing along the Site 07 shoreline adjacent to the Allen Harbor entrance channel. The samples used to support the assessment were collected as part of the LTMP for Site 07 (and supplemental investigations) as described in the *Quality Assurance Project Plan for Long-Term Monitoring of Site 07 (Calf Pasture Point), NCBC, North Kingstown, Rhode Island* (EA, July 2001).

The shallow groundwater samples were collected from shoreline piezometers located along the northern bank of the entrance channel separating Narragansett Bay from Allen Harbor (i.e., the southern boundary of Site 07) and along the Allen Harbor shoreline which adjoins the western edge of Site 07. The screened

interval for the piezometers is approximately two to three feet below ground surface (bgs). The surface water samples (shallow shoreline samples) were collected from eight locations co-located with piezometer stations positioned along the northern bank of the entrance channel separating Narragansett Bay from Allen Harbor. The sediment samples were collected from six locations also located in this area. All samples were collected at low- to mid-tide. For purposes of completeness, the HHRA also re-assessed the analytical data for shellfish previously evaluated in the Phase III RI for Site 07.

The HHRA was prepared per methodology presented in the *Final Technical Memorandum, Human Health Risk Assessment Methodology for the Evaluation of Shoreline Surface Waters and Sediments, and Groundwater in Shallow Piezometers, Site 07 (Calf Pasture Point), Former Naval Construction Battalion Center (NCBC) Davisville, RI* (TtNUS, December 2006).

2.0 CHEMICAL OF POTENTIAL CONCERN SELECTION AND DETERMINATION OF THE EXPOSURE POINT CONCENTRATION

2.1 Determination of Chemicals of Potential Concern

Chemicals of Potential Concern (COPCs) are those chemicals evaluated qualitatively or quantitatively in a HHRA to determine potential human health risks as a result of exposure to an environmental medium. COPCs for this Site 07 Shoreline Risk Assessment (SRA) were selected primarily based on a toxicity screen (i.e., a comparison of site contaminant concentrations to conservative toxicity screening values). In addition, as discussed below, factors such as frequency of detection were considered in some cases.

2.1.1 Derivation of Screening Criteria

The toxicity screening levels used to identify ***COPCs*** for the Site 07 SRA were based on preliminary remediation goals (PRGs) for residential soil and tap-water developed by USEPA Region 9 (USEPA Region 9, October 2004, updated December 28, 2004), criteria established by the Rhode Island Department of Environmental Management, Office of Waste Management (RIDEM, February 2004), and USEPA Region 3 risk-based concentrations (RBCs) for fish tissue (USEPA, Region 3, October 20, 2006). COPCs were selected based on the lowest screening level derived from these criteria.

The screening concentrations based on the PRGs and RBCs correspond to a systemic hazard quotient (HQ) of 0.1 for non-carcinogens or an incremental lifetime cancer risk of 1 $x10^{-6}$ for carcinogens. Note that the USEPA Region 9 PRGs and the USEPA Region 3 RBCs for non-carcinogens are based on an HQ of 1.0, whereas the screening concentrations are based on an HQ of 0.1. The screening concentrations are based on an HQ of 0.1 to account for the potential cumulative effects of several

chemicals affecting the same target organ or producing the same adverse non-carcinogenic effect. Chemicals detected at maximum concentrations in surface water or groundwater that exceed screening concentrations based on the Region 9 PRGs for tap water or the RIDEM criteria for groundwater were selected as COPCs for groundwater or surface water. Chemicals detected at maximum concentrations in sediment that exceed screening concentrations based on the Region 9 PRGs for residential soil or the RIDEM direct contact for residential soils were selected as COPCs for sediment. Chemicals detected at maximum concentrations in shellfish tissue samples that exceed screening concentrations based on the Region 3 RBCs for consumption of fish were selected as COPCs for shell-fish consumption.

Individual chemicals were eliminated as COPCs if they are detected at a frequency less than 5 percent in any given medium but only if there were no other indications that the chemical would pose an unacceptable risk to receptors (e.g., there was no evidence of a contaminant "hot spot").

2.1.2 Selection of COPCs

Groundwater

Analytical data for shallow groundwater samples collected between August 2001 and January 2006 from piezometers locations PZ1 through PZ33 were evaluated in the COPC selection. Eighteen VOCs were detected in the shallow groundwater samples collected at the Site 07. A comparison of the maximum detected groundwater concentrations to screening levels based on the USEPA Region 9 PRGs for ingestion of tap water and RIDEM GA groundwater objectives is presented in Table 2-1. The following chemicals were detected in the shallow groundwater samples at maximum concentrations exceeding the COPC screening levels and were retained as COPCs for shallow groundwater at Site 07:

1,1,2,2-TCA	1,1,2-TCA	1,1-DCE	1,2-DCA	Benzene
Chloroform	*cis*-1,2-DCE	*trans*-1,2-DCE	TCE	Vinyl Chloride

- TCA = tetrachloroethane, DCA = dichloroethane, TCE = trichloroethene, DCE = dichloroethene

Concentrations of tetrachloroethene also exceeded the USEPA Region 9 PRG but were less than the RIDEM GA groundwater objectives. The maximum detected concentration of tetrachloroethene (1.19 µg/L) is also less than the USEPA MCL (5 µg/L). Tetrachloroethene was detected in only 6 of 238 samples. Tetrachloroethene was not retained as a COPC because it was detected infrequently in groundwater (less than 2.5 percent of the samples) and at low concentrations (i.e., less than the EPA MCL and RIDEM GA groundwater objectives). Concentrations of total 1,2-DCE also exceeded the screening criteria. The analytical result reported for total 1,2-DCE for each sample is the sum of the

results reported for the "cis" and "trans" isomers of 1,2-DCE. Consequently 1,2-DCE was evaluated in this HHRA as cis-1,2-DCE and trans-1,2-DCE.

Surface Water

Analytical data for surface water samples collected between December 1995 and January 2006 from locations SW04 through SW10 and location SW24 were evaluated in the COPC selection. Six VOCs were detected in the surface water samples collected at the Site 07. A comparison of the maximum detected surface water concentrations to screening levels based on the USEPA Region 9 PRGs for ingestion of tap water and RIDEM GA groundwater objectives is presented in Table 2-2. The following chemicals were detected in the surface water samples at maximum concentrations exceeding the COPC screening levels and were retained as COPCs for surface water at Site 07:

- 1,1,2,2-tetrachloroethane, cis-1,2-dichloroethene, trichloroethene, and vinyl chloride

Concentrations of 1,1,2-trichloroethane also exceeded the USEPA Region 9 PRG but were less than the RIDEM GA groundwater objectives. The maximum detected concentration of 1,1,2-trichloroethane (3 µg/L) is also less than the USEPA MCL (5 µg/L). 1,1,2-Trichloroethane was detected in only 2 of 89 samples. 1,1,2-Trichloroethane was not retained as a COPC because it was detected infrequently in groundwater (less than 2.2 percent of the samples) and at low concentrations (i.e., less than the EPA MCL and RIDEM GA groundwater objectives).

Sediment

Analytical data for sediment samples collected between September 2002 and September 2005 from locations SD05 through SD10, SD15, SD16, SD20, SD21, and SD22 were used in the COPC selection. 10 VOCs and 12 inorganics were detected in sediment samples collected at Site 07. A comparison of the maximum detected sediment concentrations to screening levels based on the USEPA Region 9 PRGs and RIDEM direct contact criteria for residential exposures is presented in Table 2-3. The following chemicals were detected in sediments at maximum concentrations exceeding the COPC screening levels and were retained as COPCs for sediment at Site 07.

- VOCs [trichloroethene and vinyl chloride]
- Inorganics [aluminum, arsenic, beryllium, and iron]

Concentrations of trichloroethene, arsenic, and iron exceeded the USEPA Region IX PRGs but were less than the RIDEM direct contact criteria. Concentrations of beryllium exceeded the RIDEM direct contact criteria but were less than the USEPA Region 9 PRGs.

Shellfish

Analytical data for shellfish samples evaluated in the human health risk assessment prepared for the Phase III Remedial Investigation Report (dated September 1998) were used in the COPC selection. Twenty-one SVOCs, 12 pesticides/PCBs, and 12 inorganics were detected in shellfish samples collected from Allen Harbor in the general vicinity of Site 07. A comparison of the maximum detected concentrations in shellfish to USEPA Region 3 RBCs for fish tissue is presented in Table 2-4. The following chemicals were detected in shellfish at maximum concentrations exceeding the COPC screening levels and were retained as COPCs for shellfish at Site 07.

- SVOCs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene]
- Pesticides/PCBs [Aldrin, 4,4'-DDE, Aroclor-1242, Aroclor-1254, and Aroclor-1260]
- Inorganics [arsenic, cadmium, chromium, copper, iron, manganese, mercury, nickel, and silver]

2.2 Calculation of the Exposure Point Concentration

The ***exposure point concentration (EPC),*** which is calculated for COPCs only, is an estimate of the chemical concentration within an exposure unit (EU). The EPC is an estimate of the concentration to which a receptor may be exposed and is used to estimate exposure intakes. An EU is the area over which receptor activity is expected to occur. The two most important considerations in defining an EU are: 1) the anticipated receptor activity, and 2) the spatial distribution of contaminant concentrations. The EPCs calculated for receptors potentially exposed to the environmental media along the Site 07 shoreline considered the presence of a "hot spot" area along the southern boundary of Site 07 (locations 07-02 through 07-10 and 07-20 through 07-24, (see Figure 2-1). The EPC calculations also considered the fact that COPC levels have changed at some locations over the time-span that the Site 07 long-term monitoring program has been conducted. For example, VOC concentrations in the more recent sediment data (2004, 2005) exceed VOC concentrations detected in samples collected in 2002 and 2003. Consequently, the Site 07 SRA evaluated the following different data groupings/EUs for shallow groundwater, surface waters, and sediments:

Shallow Groundwater (Piezometers) (Table 2-5):

- **Case 1:** All available VOC data for 2005 and 2006 for locations 07-02 through 07-10, and locations 07-20 through 07-24 (i.e., the southern boundary area).

- **Case 2**: All available VOC data for the last quarter of sampling (November 2005 through January 2006) for locations 07-02 through 07-10, and locations 07-20 through 07-24 (i.e., the most recent data for the southern boundary area).
- **Case 3**: All available VOC data for 2005 and 2006 for ***all*** locations.
- **Case 4**: All available VOC data for 2005 and 2006 for all locations ***except*** those noted in Case 1 and Case 2 (i.e., ***not including*** the southern boundary area).

Surface Waters (Table 2-6):

- **Case 1:** All available VOC data for 2005 and 2006 for locations 07-04 through 07-10, and location 07-24 (i.e., all 2005/2006 data collected under the long-term monitoring plan).
- **Case 2:** All available VOC data for the last quarter of sampling (November 2005 through January 2006) for locations 07-04 through 07-10, and location 07-24 (i.e., the most recent data collected under the long-term monitoring plan).

Sediments (Table 2-7):

- **Case 1:** All available 2004 and 2005 VOC data plus any available metals data collected under the long term monitoring program.

The following guidelines were used to calculate the EPCs:

- If the data set for an EU contained fewer than 10 samples, the EPC was defined as the maximum detected concentration.

- If the data set for an EU contained 10 or more samples, the 95 percent upper confidence limit (UCL) on the arithmetic mean, which was based on the distribution of the data set, was selected as the EPC. EPCs were calculated following *USEPA's Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA, December 2002).

- One-half the sample quantitation limit was used as a surrogate concentration for non-detect results. Duplicates were averaged for purposes of calculating the EPC for COPCs in the environmental media along the shoreline at Site 07.

The RAGS Part D Table 3s in Attachment 1 present the EPCs and additional statistical information, including the rationale for the selection of each EPC value. The EPCs were calculated using a version of EPA's PROUCL modified to operate in batch mode (i.e., calculate the desired statistics for multiple parameters in a single run).

The shell fish data evaluated in this HHRA are presented in Table 2-8.

3.0 METHODOLOGIES FOR CALCULATING CHEMICAL INTAKE

The human health risk assessment (HHRA) of the COPCs detected in the shallow groundwater, shallow surface water, shoreline sediments, and shellfish assumed that receptors may be exposed as a result of ***trespass or recreational activities*** along the Site 07 shoreline area. Specifically it is assumed that:

- Recreational receptors may be exposed to surface waters (dermal contact, incidental ingestion) and sediments (dermal contact, incidental ingestion) while swimming/wading along the shoreline or to surface waters (dermal contact, incidental ingestion), exposed sediments (dermal contact, incidental ingestion), or shallow groundwater (dermal contact) while harvesting shellfish. The recreational receptor harvesting shellfish may also be exposed as a result of the consumption of shellfish taken from the Site 07 shoreline area.

- The receptor is a resident living in proximity to NCBC Davisville and is exposed over a 30-year duration, including exposure that may occur during childhood and adolescent years. Therefore, the following three receptors were considered in the HHRA:

    - Adult
    - Adolescent child (approximately age 8 through 16)
    - Young child (approximately age 2 through 7)

It should be noted that there are no formal recreational facilities (e.g., public swimming areas) located along this shoreline area and there are currently no plans to develop a public swimming area in the future. Therefore, it is unlikely that a young child (approximately age 2 through 7) would be *routinely* exposed to the environmental media along this shoreline. However, conservatively, exposures to young children were evaluated in the HHRA.

3.1 Methodology for Calculating Intake for the Dermal Route of Exposure

The recommended HHRA methodology for the dermal route of exposure considers the most current U.S. Environmental Protection agency (USEPA) guidance on the subject: *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim (EPA/540/R/99/005) (USEPA, July 2004 (Attachment 2)* as well as

guidance presented in the *USEPA Exposure Factors Handbook, Volume I, General Factors (EPA/600/P-95/002Fa) (USEPA, August 1997).*

The methodology assumes that a recreational receptor may be dermally exposed to COPCs detected in the shallow shoreline surface waters and shoreline sediments while trespassing or recreating at Site 07. The HHRA also considered dermal exposure to the shallow groundwater that may occur while a receptor (adolescent or adult) is harvesting shellfish along the Site 07 shoreline.

The following equation was used to calculate the dermal absorbed dose hypothetically resulting from dermal exposure to COPCs in the shoreline surface water and the shallow groundwater:

$DAD = (DA_{event} * EV * ED * EF * SA) / (BW * AT)$

The terms of the equation are defined in the following table:

Parameter	Adult	Receptors Adolescent	Young Child
Dermal absorbed dose (DAD) (mg/kg/day)	Calculated	Calculated	Calculated
Absorbed dose per event (DA_{event}) – (mg/cm^2)	Calculated[1]	Calculated[1]	Calculated[1]
Events/day (EV)	1	1	1
Exposure duration (ED) (years)	15	9	6
Exposure frequency (EF) (days/year)	80	80	80
Skin surface area exposed (SA) – (cm^2) - Swimming in surface water - Exposure to surface water while shell fishing - Exposure to shallow groundwater while shell fishing	 18,000 5,940 1,800	 13,000 4,300 1,300	 7,300 Not applicable Not applicable
Body weight (BW) (kg)	70	45	15
Averaging time (AT) for Carcinogens – (days) (AT = 70 yr * 365 days/yr)	25,550	25,550	25,550
Averaging time (AT) for Non-carcinogens – (days) (AT = ED * 365 days/yr)	5,475	3,285	2,190

1 - The DA_{event} term is calculated based on the chemical concentration, chemical specific permeability constant, and other intermediate terms as demonstrated in Attachment 2.

An exposure frequency of 80 days per year was used in the HHRA. This value was selected based on discussions and negotiations with USEPA Region I and RIDEM and is based on the assumption that a recreational receptor may visit the shoreline an average of 2 to 3 days per week over the course of the warmer-weather months (April through October). The combined exposure duration of 30 years is the duration typically recommended by USEPA for evaluation of the residential land use scenario (USEPA,

December 1989) and assumes that the receptor lives in close proximity to NCBC Davisville and routinely visits the shoreline. The skin surface area exposed for the recreational user assumes that the total skin surface area is directly contacting the surface water while the receptor is swimming along the shoreline and that approximately 33 percent of the total skin surface area is exposed while harvesting shellfish. As indicated above, the HHRA also evaluated dermal exposure to the shallow groundwater while harvesting shellfish; it was assumed that 10 percent of the total skin surface area (i.e., the hands and a portion of the arms) were exposed to the shallow groundwater while harvesting shellfish. (The total skin surface areas [50^{th} percentile values] and body weights of the receptors are based on information presented in RAGS E and the 1997 version of the Exposure Factors Handbook [EFH]) (USEPA; August 1997) (see Attachment 3).

The DA_{event} term (i.e., the absorbed chemical dose per event) is calculated based on the chemical concentration in the surface water, the chemical specific dermal permeability coefficient, the exposure time (a 2-hour exposure time was assumed), and several other intermediate terms and calculations as demonstrated in Attachment 2).

The following equation was used to calculate the dermal absorbed dose hypothetically resulting from dermal exposure to COPCs in exposed sediments:

DAD = (Conc * CF * EV * ED * EF * SA * AF* ABS) / (BW * AT)

The DAD, EV, ED, EF, BW, and AT terms were defined previously for dermal exposure to surface water. It was assumed that the recreational receptor harvesting shellfish would be more intensively contacting exposed sediments than the recreational receptor simply swimming/wading along the shoreline (i.e., the SA assumed for the recreational receptor harvesting shellfish was set at approximately 33 percent of the total skin surface area while the SA assumed for the recreational receptor simply swimming/wading along the shoreline was set at approximately 25 percent of the total skin surface area). ABS (unitless) is the chemical specific absorption factor as specified in RAGS Part E (see Attachment 4). SA and other terms listed in the equation but not previously defined are presented in the following table:

Parameter	Adult	Receptors Adolescent	Young Child
Chemical concentration in sediments (Conc.) (mg/kg)	Measured	Measured	Measured
Conversion Factor (CF) (kg/mg)	10^{-6}	10^{-6}	10^{-6}
Skin surface area exposed (SA) – (cm^2)	4,500 (swimming or wading) 6,073 (clamming)	3,250 (swimming or wading) 4,300 clamming)	1,825 (swimming or wading) Not applicable
Sediment adherence factor (AF) – (mg/cm^2)	0.335 (swimming, wading, or clamming)	5 (swimming or wading) 0.335 (clamming)	5 (swimming or wading)

The sediment adherence values are based on data presented in Shoaf et al (2005). The average dermal sediment loading for the 50th percentile male and female child (age 7 to 12) playing in tide flat sediment was calculated to be 5 mg/cm^2. This sediment loading value was based on the 50th percentile child male and female total exposed surface area of 3,065 cm^2 for hands, forearms, lower legs, face and feet calculated from Tables 8-1, 8-2, and 8-3 of the Child-Specific Exposure Factors Handbook (USEPA, September 2002) and the dermal loading to these body parts of children playing in the tide flat reported by Shoaf et al (2005). The average and maximum dermal sediment loading for the 50th percentile adult male and female clam digger was calculated to be 0.335 and 7 mg dry weight per cm^2, respectively. This was based on the 50th percentile adult male and female total exposed surface area of 6,073 cm^2 for hands, forearms, lower legs, face, and feet calculated from Tables 6-2 and 6-3 of the Exposure Factors Handbook (USEPA, July 1997) and the dermal loading to these parts of adult clam diggers reported by Shoaf et al, (2005).

3.2 Methodology for Calculating Intake for the Ingestion Route of Exposure

The HHRA methodology for the ingestion route of exposure considers USEPA guidance, Risk Assessment for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part A) Interim Final (EPA/540/1-89/002) (USEPA, December 1989) as well as many of the exposure assumptions already presented for the evaluation for the dermal route of exposure. Also, note that the ingestion pathway considered in this HHRA is the ***incidental ingestion*** pathway only because the shoreline surface water can not be used as a domestic drinking water supply due to salinity.

The following equation was used to calculate the exposure dose hypothetically resulting from ingestion of COPCs in shoreline surface waters:

Dose = (Conc. * IR* ET * ED * EF) / (BW * AT)

The ED, EF, BW, and AT terms were defined above. Other terms presented in the equation are defined in the following table:

Parameter	Adult	Receptors Adolescent	Young Child
Chemical concentration in shoreline surface water (Conc.) (ug/L)	Measured	Measured	Measured
Shoreline surface water ingestion Rate (IR) – (L/hr)	0.05 (swimming) 0.01 (harvesting shellfish)	0.05 (swimming) 0.01 (harvesting shellfish)	0.05 (swimming) Not applicable
Exposure time per day (ET) – (hrs/day)	2	2	2

The surface water ingestion rate of 0.01 L/hr for the adolescent and adult receptors (harvesting shellfish) differs from that recommended in USEPA, RAGS Part A as the ingestion rate appropriate for a recreational swimming scenario (0.05 L/hr; USEPA, December 1989). This surface water ingestion rate is based on professional judgment and a recommendation published in USEPA Region IV guidelines for a wading-type scenario (USEPA Region IV, May 2000).

The following equation was used to calculate the exposure dose hypothetically resulting from ingestion of COPCs in exposed shoreline sediments:

Dose = (Conc. * IR* CF * FI * ED * EF) / (BW * AT)

The ED, EF, CF, BW, and AT terms were defined above. Other terms presented in the equation are defined in the following table:

Parameter	Adult	Receptors Adolescent	Young Child
Chemical concentration in shoreline sediment (Conc.) (ug/L)	Measured	Measured	Measured
Fraction ingested from source (FI) – unitless	1	1	1
Sediment ingestion Rate (IR) – (mg/day)	50	100	200

The sediment ingestion rate for the adult receptor is the daily ingestion rate recommended by the USEPA for soil ingestion assuming a residential land use scenario. The sediment ingestion rate for the adolescent receptor is based on professional judgment.

3.3 Methodology for Calculating Intake for the Consumption of Shellfish

The HHRA methodology for calculation of chemical intake resulting from the consumption of shellfish considers USEPA guidance, Risk Assessment for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part A) Interim Final (EPA/540/1-89/002) (USEPA, December 1989) and the USEPA 1997 Exposure Factors Handbook as well as seafood consumption rates available as a result of the Narragansett Bay Project (NBP-92-105, Brown et al., Clark University, 1992).

The following equation was used to calculate the exposure dose hypothetically resulting from ingestion of COPCs in shellfish:

Dose = (Conc. * IR* FI * CF * ED * EF) / (BW * AT)

All terms were defined in the following table:

Parameter	Adult	Receptors Adolescent	Young Child
Chemical concentration in shellfish (Conc.)[1] (mg/kg)	Concentration based on data presented in the Phase III RI report for Site 07.		
Shellfish Ingestion [2] Rate (IR) – (mg/day)	26,000	26,000	5,500
Fraction ingested from source (FI) – unitless	0.5	0.5	0.5
Conversion Factor (CF)(kg/mg)	10^{-6}	10^{-6}	10^{-6}
Exposure duration (ED)(years)	15	9	6
Exposure frequency (EF) (days/year)	350	350	350
Body weight (BW) (kg)	70	45	15
Averaging time (AT) for Carcinogens – (days) (AT = 70 yr * 365 days/yr)	25,550	25,550	25,550
Averaging time (AT) for Non-carcinogens – (days)(AT = ED * 365 days/yr)	5,475	3,285	2,190

1) The EPC for human exposure to chemical concentration in the shellfish was based on the environmental data presented in the Phase III Remedial investigation report prepared for Site 07 (dated September 1998).

2) Adult/Adolescent: 227,000 mg seafood per serving * 40 servings per year *1 year/350 days = 26,000 mg/day based on data presented in the 1997 USEPA Exposure Factors Handbook. Small child: 48,000 mg seafood per serving * 40 servings per year *1 year/350 days = 5,500 mg/day Source: Narraganset Bay Project, NBP-92-105, Brown et al., Clark University, 1992. Servings per year: Professional judgment based on recreational level reported in USEPA's "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories" EPA 823-B-00-007, August 2000.

4.0 TOXICITY CRITERIA

The carcinogenic potency of a compound is often expressed in terms of a cancer slope factor (CSF). The potential of a compound to produce noncarcinogenic effects is often expressed in terms of a reference dose (RfD). Oral and inhalation reference doses (RfDs) and cancer slope factors (CSFs) used in this

HHRA to estimate the potential for adverse carcinogenic and non-carcinogenic effects were obtained from the following primary USEPA sources (USEPA, December 2003):

- Integrated Risk Information System (IRIS) (Online).

- USEPA Provisional Peer Reviewed Toxicity Values (PPRTVs) – The Office of Research and Development/National Center for Environmental Assessment (NCEA) Superfund Health Risk Technical Support Center develops PPRTVs on a chemical specific basis when requested by USEPA's Superfund program.

- Other Toxicity Values – These sources include but are not limited to California Environmental Protection Agency (Cal EPA) toxicity values, the Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs), and the Annual Health Effects Assessment Summary Tables (HEAST) (USEPA, July 1997).

Although RfDs and CSFs can be found in several toxicological sources, USEPA's IRIS on-line database is the preferred source of toxicity values. This database is continuously updated and values presented have been verified by USEPA. The USEPA Region 3 Risk-Based Concentration (RBC) Table was also used as a source of toxicity criteria when these criteria were not available from the aforementioned references. Oral and dermal RfDs and CSFs for the constituents identified as COPCs for Site 07 are presented in Tables 5.1 and 6.1 in Attachment 1.

5.0 RISK CHARACTERIZATION

Potential risks (noncarcinogenic and carcinogenic) for human receptors resulting from the potential exposures outlined in the exposure assessment are quantitatively determined during the risk characterization component of the HHRA. Sections 5.1 and 5.2 outline the methods used to quantitatively estimate the type and magnitude of potential risks for human receptors. The detailed results of the risk characterization are provided in the RAGS Part D tables presented in Attachment 1. A summary of the risk characterization for Site 07 is provided in Section 5.3.

5.1 Quantitative Risk Estimation

Quantitative estimates of risk for the Site 07 COPCs were calculated according to risk assessment methods outlined in USEPA guidance (USEPA, December 1989). Lifetime cancer risks are expressed in the form of dimensionless probabilities, referred to as incremental lifetime cancer risks (ILCRs), based on

CSFs. Noncarcinogenic risk estimates are presented in the form of hazard quotients (HQs) that are determined through a comparison of intakes with published RfDs.

ILCR estimates were generated for each COPC using estimated exposure intakes and published CSFs, as follows:

$$ILCR = (Estimated\ Exposure\ Intake)(CSF)$$

If the above equation results in an ILCR greater than 0.01, the following equation was used:

$$ILCR = 1-[exp(-Estimated\ Exposure\ Intake)(CSF)]$$

An ILCR of 1×10^{-6} indicates that the exposed receptor has an one-in-one-million chance of developing cancer under the defined exposure scenario. Alternatively, such a risk may be interpreted as representing one additional case of cancer in an exposed population of one million persons.

As mentioned previously, noncarcinogenic risks were assessed using the concept of HQs and Hazard Indices (HIs). The HQ for a COPC is the ratio of the estimated intake to the RfD, as follows:

$$HQ = (Estimated\ Exposure\ Intake) / (RfD)$$

An HI was generated by summing the individual HQs for all COPCs. The HI is not a mathematical prediction of the severity of toxic effects and therefore is not a true "risk"; it is simply a numerical indicator of the possibility of the occurrence of noncarcinogenic (threshold) effects.

5.2 Interpretation of Risk Assessment Results

To interpret the quantitative risk estimates and to aid risk managers in determining the need for remediation, quantitative risk estimates were compared to typical USEPA risk benchmarks. The USEPA has defined a "target cancer risk" range of 1×10^{-6} to 1×10^{-4} (i.e., a one-in-ten thousand to one in-one-million chance of developing cancer). Individual or cumulative ILCRs greater than 1×10^{-4} are typically not considered as protective of human health, and ILCRs less than 1×10^{-6} are typically regarded as protective. HQs and HIs are typically evaluated using a value of 1.0. Generally, adverse noncarcinogenic health effects are not anticipated if an HQ or HI, developed on a target organ-/effect-specific basis, does not exceed 1.0 (unity). If an HI exceeds unity, a segregation of target organ effects associated with exposure to COPCs is performed. Only those chemicals that affect the same target organ(s) or exhibit similar critical effect(s) were regarded as truly additive. Consequently, it may be possible for a cumulative HI to exceed 1.0, but no adverse health effects are anticipated if the COPCs do not affect the same target organ or exhibit the same critical effect.

As a general guideline, remediation (e.g., institutional controls) is recommended when the cancer risk estimates or total HIs (developed on a target organ/target effects basis) for critical receptors of concern exceed 1 x 10^{-4} or 1, respectively. However, as indicated in RAGS Part D, the upper limit of the acceptable cancer risk range is not a discrete limit at exactly 1 x 10^{-4}. Risks slightly greater than 1 x 10^{-4} may be considered to be acceptable (i.e., protective) if justified based on site-specific conditions, including any uncertainties about the nature and extent of contamination and associated risks. Risk management decisions are made on a case by case basis when the cancer risk estimates are within the 1 x 10^{-4} to 1 x 10^{-6} cancer risk range. No remediation is recommended when the cancer risk estimates are less than 1 x 10^{-6}. The following factors will also be considered in the evaluation of the risk assessment results:

- The magnitude of the media-specific risk estimates.

- Significant uncertainties in the baseline HHRA that would tend to overestimate baseline risk assessment results such as uncertainties in the HHRA intake estimates (and their impact on the risk estimates) and uncertainties associated with the toxicity criteria. These are evaluated qualitatively in the uncertainty analysis section.

- Significant uncertainties in the EPC estimates that would tend to overestimate baseline risk assessment results.

5.3 Results of the Risk Characterization

This section contains a summary of the results of the risk characterization for Site 07. Quantitative risk estimates for potential human receptors were developed for those chemicals identified as COPCs. Uncertainties associated with the risk estimates are discussed in Section 6. The methodology used to calculate the risks presented in this section was discussed in Sections 2, 3, 4, 5.1 and 5.2. For Site 07, potential cancer risks and HIs were calculated for child, adolescent, adult, and lifelong recreational users. Potential cancer risks and HIs are summarized in Table 5-1. Sample calculations are included in Attachment 5 and the results of the risk assessment in RAGS Part D format are included in Attachment 1.

5.3.1 Groundwater

As discussed in Section 2.2, four cases were evaluated for receptor exposure to COPCs in the shallow groundwater (sampled via piezometer). Adolescent and adult recreational users were assumed to be exposed to the shallow groundwater while digging for shellfish. The HIs for all four cases were less than