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NSB NEW LONDON
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DEPARTMENT OF THE NAVY
NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
10 INDUSTRIAL HIGHWAY
MAIL STOP, #82
LESTER, PA 19113-2090

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Ser 2562\1823\ME
IN REPLY REFER TO

AUG 03 1995

Ms. Kymberlee Keckler
Remedial Project Manager
U.S. Environmental Protection Agency
J.F.K. Federal Building (HAN-CAN1)
Boston, MA 02203-2211

Mr. Mark Lewis
Connecticut Department of Environmental Protection
Bureau of Water Management
79 Elm Street
Hartford, CT 06106

RE: PROPOSED RISK ASSESSMENT EXPOSURE SCENARIOS AND INPUT PARAMETERS DRAFT FINAL PHASE II RI, NAVAL SUBMARINE BASE NEW LONDON, GROTON, CT

Dear Ms. Keckler and Mr. Lewis:

Please find enclosed a copy of the revised text and tables from Section 3.0 of the Draft Phase II RI report which summarizes the Proposed Risk Assessment Exposure Scenarios and Input Parameters to be evaluated in the Draft Final Phase II RI. This information is being submitted to the EPA and CTDEP for review and comment as per the action item from the June 29, 1995 scoping meeting.

For ease of reading, additions to the text have been "redlined" and deletions have been "striked". The most significant revision to the risk assessment information was the exclusion of a future residential exposure scenario at each site. This scenario is hypothetical in nature because the Navy intends for NSB-NLON to remain Navy property in the future. However, the scenario has been included, in addition to the existing industrial exposure scenario, at the request of the EPA and CTDEP.

In order to meet our mutual goal of submitting the Draft Final Phase II RI in the Fall of 1995, it is hopeful that the EPA and CTDEP can review this document and submit comments in a timely manner. If you have any questions regarding the text please do not hesitate to contact me at (610) 595-0567 ext. 162.

Sincerely,

Mark Evans

MARK EVANS
Remedial Project Manager
By direction of the
Commanding Officer

Copy to: Ms. Patti Tyler, EPA
Mr. Dale Weiss, TRC
Mr. Andy Stackpole, NSB-NLON
Mr. Matthew Cochran, HNUS - Pittsburgh
Mr. Corey Rich, HNUS - Pittsburgh

3.3.3.3 Potential Routes of Exposure

A receptor can come into contact with contaminants in a variety of ways, which are generally the result of interactions between a receptor's behavior or lifestyle and an exposure medium. This assessment defines an exposure route as a stylized description of the behavior that brings a receptor into contact with a contaminated medium.

Air. This pathway is based on the scenario that a receptor is immersed in air that contains suspended particulates and volatile organic vapors originating from the source areas as part of daily living. Subsequent exposure of the receptor occurs upon inhalation of the ambient air.

Exposure to volatile organic compounds released from soil is expected to be minimal given the low concentrations of volatiles found in the surface soil. There are sites where subsurface soil contains higher concentrations of volatile organic compounds, however, the exposures to subsurface soil are limited in durations ~~and given the vapor pressures of these compounds, the volatilization would be expected to be rapid as well, thereby minimizing inhalation of volatile emissions~~.

A qualitative comparison of volatile organic chemical concentrations in soil and draft soil screening levels based on intermedia transfer (from soil to air) was completed to determine if additional analysis of this potential exposure pathway was warranted. Concentrations of volatile organics in soil were greatest in samples collected at the Goss Cove Landfill. Maximum concentrations of various organic compounds and corresponding soil screening levels (EPA, Region III March 1995) are as follows:

Chemical	Maximum (mg/kg)	SSL (mg/kg)
Acetone	23	62,000
Ethylbenzene	69	260
Methylene chloride	38	7
Toluene	15	520
Xylenes	480	320

As shown above, the maximum concentrations of two of the chemicals were noted to slightly exceed the SSLs (i.e., by less than a factor of 6). The SSLs are based on residential land use and lifetime exposure scenarios and are therefor relatively conservative. These chemicals are confined to the subsurface, and hence potential exposures would only be anticipated under a construction scenario.

Any construction activities in areas containing higher concentrations of volatile organics will be conducted using appropriate respiratory protection measures as warranted by health and safety protocols. No exceedances of SSLs were observed for the remaining sites. Exposure to volatile emissions is has been considered only at Site 8 (Goss Cove Landfill) at the Nautilus Museum where ambient air samples were collected and analyzed.

Direct Contact with Soil/Sediment. Receptors may come into direct contact with soil affected by the release of chemicals from the source areas. During the receptor's period of contact, the individual may be exposed via inadvertent ingestion of a small amount of soil or via dermal absorption of certain contaminants from the soil.

Direct Contact with Groundwater. It is possible that an excavation (for construction, utility maintenance, etc.) could be deep enough to come into contact with the shallow groundwater. In such an instance, workers could be exposed to the groundwater via dermal contact. In addition, it has been assumed (at the direction of EPA) that the site could be developed for future residential land use. Under such a hypothetical scenario, direct dermal contact with groundwater, groundwater ingestion, and inhalation of volatiles could occur.

~~It is highly unlikely that any of the sites under consideration in this RI will be developed for residential land use. Therefore, onsite routine contact with groundwater (via ingestion, inhalation of volatiles, and/or dermal contact) in a residential setting is not considered to be a potential route of exposure.~~

~~The groundwater at the site flows into the Thames River, and therefore there are no potential downgradient groundwater users who could be exposed on a routine basis in a residential setting. The location of existing offsite wells is shown on Drawing Number 4. Based on measured water levels and water levels inferred from bedrock topography, no wells exist downgradient of any identified source areas. One well (OSW29) was located near the tennis courts at the Area A Landfill, however, that property is now part of the Subase, the well has been sealed, and a building has been constructed at that location. Well 2WMW22D is located at the northern edge of the Subase, and could be considered to be upgradient of offsite wells OSW11, 14, or 15. Although no water level readings are available to confirm this, the monitoring well samples collected from this well contained various phenol compounds at concentrations well below health-based levels of concern (health advisories and Region III screening values). All metals concentration in the unfiltered samples from this well were also below MCLs or Region III screening values. In addition, the base itself is served by a surface water source in an adjacent drainage basin. Therefore routine exposures to groundwater via ingestion, inhalation of volatile emissions during showering, or dermal contact in a residential setting are not considered further in this risk assessment.~~

Direct Contact with Surface Water. Receptors may also come into direct contact with surface water containing chemicals in a dissolved phase. In most cases, this exposure would be of short duration (unless swimming is involved), and individuals may be exposed via dermal contact and/or incidental ingestion. Swimming was considered a potential exposure route for North Lake and Goss Cove. Water skiing was considered for the Thames River.

Ingestion of Shellfish. Finally, persons could be exposed to potentially site related contaminants when ingesting shellfish harvested from the Thames River. It was assumed that local residents consume shellfish collected in the vicinity of the site. ~~However, since hi~~Harvesting is actually controlled by commercial interests that move the shellfish to depuration beds in other water bodies prior to sale and combine them with shellfish taken from other water bodies~~.~~ Therefore, evaluation of this exposure scenario is considered to be highly conservative.

3.3.3.4 Potential Receptors

Several potential receptors have been identified under both current and future land use conditions. These receptors were identified by analyzing the interaction of current land use practices and the identified sources of contamination.

Several receptor groups have been defined for this risk assessment. The original receptors identified in the Work Plan (Atlantic Environmental Services Inc., May 1993) have been modified slightly to conform to current guidance and to provide some consistency between sites. These receptors are as follows:

- Full-time employees - Adult military or civilian personnel assigned to work 40 hours/week at a particular facility.

- Utility workers - Adult civilian personnel who may be involved in maintenance/installation of underground utilities.

- Construction workers - Adult civilian personnel who may be involved in a short-term, one-time construction project at a site.

- Occasional visitors - Adult civilian or military personnel who infrequently visit a site for activities such as inspection, mowing, etc.

- Local residents (adults) - Persons living in the vicinity of the base who could be exposed while on site for activities such as auctions or visiting the Nautilus Museum, or exposed while off site in their homes via inhalation of fugitive dust. Also includes local residents who may consume locally harvested shellfish ~~or finfish~~ or who may waterski, etc., in the Thames River.

- Adult recreational user - Civilian or military personnel involved in recreational activities such as tennis, jogging, or picnicking on or near a site.

- Child recreational user - Dependent children or local (offsite) residents playing on or near a site, including swimming (North Lake ~~and Goss Cove, only~~), exploring, tennis, etc.

- Future adult and child residents - persons residing at the base assuming that the facility is closed and developed for residential purposes.

One or more of these receptor groups are evaluated quantitatively for each of the sites under investigation in this report. Table 3-10 contains a matrix summary of the particular combinations developed with the aide of information presented in the Phase I RI report as well as additional data on exposure media.

Future adult and child resident receptors have been included in the baseline risk assessment at the direction of the EPA. These receptors are purely hypothetical and are included only to provide an indication of potential risks if the facility were developed for residential use. Such a scenario is considered unlikely given the critical nature of the facility with respect to support of the submarine fleet, and hence national defense.

Two variations of the receptors are considered, as per USEPA Region I guidance. The first is identified as a central tendency exposure (CTE) receptor, which is developed using both regional guidance (USEPA Region I, August 1994) and professional judgment regarding site-specific conditions. The second class of receptor is called the reasonable maximum exposure (RME), and was developed to evaluate potential worst-case ~~but still likely to occur~~ exposures as per USEPA guidance (USEPA, December 1989; USEPA Region I, August 1994).

3.3.3.5 Potentially Complete Exposure Pathways

An exposure pathway is considered to be complete if it is determined that there is 1) a source or release of chemicals from a source; 2) an exposure point where contact can occur; and 3) an exposure route by which contaminants are taken into the human body. This section summarizes the potentially complete exposure pathways that are quantitatively evaluated in the risk assessment and provides the rationale for

TABLE 3-10

SUMMARY OF RECEPTORS BY SITE
NSB-NLON, GROTON, CONNECTICUT

Site	Utility Workers	Full-Time Employees	Construction Workers	Occasional Visitors	Local Adult Residents		Recreational User		Future Residents	
					Onsite	Offsite	Adult	Child	Adult	Child
1 - CBU Drum Storage Area			X	X					X	X
2 - Area A Landfill	X	X	X	X	X	X	X	X	X	X
2 - Area A Wetlands			X					X	X	X
2 - Area A Weapons Center		X	X						X	X
2 - Area A Downstream	X							X	X	X
4 - Rubble Fill at Bunker A86	X			X					X	X
6 - DRMO	X	X	X	X	X	X			X	X
7 - Torpedo Shops	X	X	X						X	X
8 - Goss Cove Landfill	X	X	X	X	X			X	X	X
13 - Lower Subase	X	X	X						X	X
14 - OBDANE				X					X	X
15 - Spent Acid Storage/Disposal Area	X		X						X	X
Thames River						X				

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those pathways that are not. Table 3-11 presents a summary of the potentially complete exposure pathways (as well as the hypothetical exposure pathways) and receptors.

3.3.3.6 Quantification of Exposure

Estimates of exposure are based on the contaminant concentrations at the exposure points and on scenario-specific assumptions and intake parameters. The models and equations used to quantify intakes are described in this section and have been obtained from a variety of USEPA guidance documents which are cited in the specific intake estimation sections that follow.

Exposures are dependent on the predicted concentrations of chemicals in environmental media and local land use practices, and both are subject to change over time. This results in a large number of possible combinations of receptors, media, exposure pathways, and concentrations. Table 3-11 presented a summary of the complete exposure pathways to be evaluated in the quantitative risk assessment. These scenarios are applicable under both current and future land use conditions.

Exposure model parameters are presented in Tables 3-12, 3-13, and 3-14 for on or off base local residents, potential future residents, and for adult civilian and military personnel, respectively. The parameters are based on those presented in the Work Plan (Atlantic Environmental Services, Inc., May 1993), but have been modified to be in conformance with current USEPA guidance. All parameters are referenced in footnotes on each table. These parameters are used in the equations presented in this section, along with the exposure point concentrations presented in the site-specific sections, to calculate intakes, which will be used to determine risks. Individual chemical intakes for each receptor/exposure route combination are presented in the spreadsheets in Appendices F.4 through F.16.

<u>Air Exposure Via Inhalation</u>. The amount of a chemical a receptor takes in as a result of respiration is determined using the concentration of the contaminant in air. Intakes of both particulates and vapors/gases are calculated using the same equation, as follows (USEPA, December 1989):

$$Intake_{ai} = (C_{ai})(IR)(ET)(EF)(ED)/(BW)(AT)$$

where:	$Intake_{ai}$	=	intake of chemical "i" from air (PM10 or vapor) inhalation (mg/kg/day)
	C_{ai}	=	concentration of chemical "i" in PM10 fraction or air (mg/m^3)
	IR	=	inhalation rate (m^3/hr)
	ET	=	exposure time (hours/day)

TABLE 3-11

SUMMARY OF EXPOSURE ROUTES EVALUATED QUANTITATIVELY NSB-NLON, GROTON, CONNECTICUT

Receptors	Exposure Routes
Potentially Complete Exposure Pathways	
Utility Workers/Construction Workers	• Soil Ingestion (subsurface and surface) • Soil Dermal Contact (subsurface and surface) • Inhalation of Dust (subsurface and surface) • Dermal Contact with Groundwater
Full-Time Employees/Occasional Visitors/Adult Recreational Users/Local Residents-Onsite	• Soil Ingestion (surface) • Soil Dermal Contact (surface) • Inhalation of Dust (surface) • Inhalation of Air
Local Residents Offsite	• Surface Water Ingestion ~~(skiing)~~ water • Surface Water Dermal Contact ~~(skiing)~~ water • Shellfish~~/Finfish~~ Ingestion • Inhalation of Dust (surface)
Child Recreational Users	• Soil Ingestion (surface) • Soil Dermal Contact (surface) • Inhalation of Dust (surface) • Surface Water Ingestion (swimming) • Surface Water Dermal Contact (swimming) • Sediment Ingestion (swimming) • Sediment Dermal Contact (swimming)
Incomplete Exposure Pathways	
Future Residents (Adults and Children)	• Soil Ingestion (surface) • Soil Dermal Contact (surface) • Inhalation of Dust (surface) • Direct Ingestion of Groundwater • Dermal Contact with Groundwater while Showering/Bathing • Inhalation of Volatiles in Groundwater while Showering/Bathing

TABLE 3-12

EXPOSURE PARAMETERS FOR OFFSITE RESIDENTS
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Adult Residents - Onsite Exposure		Adult Residents - Offsite Exposure		Adult Recreational User		Child Recreational User	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Soil Ingestion	Exposure Concentration (mg/kg)	95 % UCL[2]	95 % UCL[2]	NA[1]	NA	95 % UCL[2]	95 % UCL[2]	95 % UCL[2]	95 % UCL[2]
	Ingestion Rate (mg/day)	100[2]	50[2]	NA	NA	100[2]	50[2]	100[4]	50[4]
	Exposure Frequency (day/yr)	26[4]	26[4]	NA	NA	120[4]	52[4]	56 - Woods 28 - Wetlands[4]	56 - Woods 28 - Wetlands[4]
	Exposure Duration (yr)	30[2]	9[2]	NA	NA	25[2]	6[4]	6[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	NA	NA	70[2]	70[2]	40[5]	40[5]
Soil Dermal Contact	Exposure Concentration (mg/kg)	95 % UCL	95 % UCL	NA	NA	95 % UCL	95 % UCL	95 % UCL	95 % UCL
	Body Surface Area (cm^2)	20000[3]	20000[3]	NA	NA	20000[3]	20000[3]	10500[6]	10500[6]
	Fraction Exposed (forearms, head, hands)	0.19[6]	0.19[6]	NA	NA	0.19[6]	0.19[6]	0.30[6]	0.30[6]
	Adherence Factor (mg/cm^2)	1.0[3]	0.2[3]	NA	NA	1.0[3]	0.2[3]	1.0[3]	0.2[3]
	Exposure Frequency (day/yr)	26[4]	26[4]	NA	NA	120[4]	52[4]	56 - Woods 28 - Wetlands[4]	56 - Woods 28 - Wetlands[4]
	Exposure Duration (yr)	30[2]	9[2]	NA	NA	25[2]	6[4]	6[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	NA	NA	70[2]	70[2]	40[5]	40[5]
Inhalation of Dust/Air	PM10 Exposure Concentration (mg/m^3)	0.018 x UCL[4]	0.018 x UCL[4]	0.004 x UCL[4]	0.004 x UCL[4]	0.004 x UCL[4]	0.004 x UCL[4]	0.018 x UCL[4]	0.018 x UCL[4]
	Inhalation Rate (m^3/hr)	0.8[6]	0.8[6]	0.8[6]	0.8[6]	2.5[6]	2.5[6]	3.2[6]	3.2[6]
	Exposure Time (hr/day)	2.5[4]	2.5[4]	24[2]	24[2]	1[4]	1[4]	2[4]	1[4]
	Exposure Frequency (day/yr)	26[4]	26[4]	350[2]	234[2]	120[4]	52[4]	56 - Woods 28 - Wetlands[4] 26 - Indoors	56 - Woods 28 - Wetlands[4] 26 - Indoors
	Exposure Duration (yr)	30[2]	9[2]	30[2]	9[2]	26[4]	6[4]	6[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	40[5]	40[5]

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TABLE 3-12 (Continued)
EXPOSURE PARAMETERS FOR OFFSITE RESIDENTS
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Adult Residents - Onsite Exposure		Adult Residents - Offsite Exposure		Adult Recreational User		Child Recreational User	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Dermal Contact with Surface Water (Adult-skiing; child-swimming)	Exposure Concentration (mg/L)	NA	NA	Maximum	95% UCL[2]	NA	NA	Maximum[7]	95% UCL[2]
	Body Surface Area (cm^2)	NA	NA	20000[6]	20000[6]	NA	NA	10500[6]	10500[6]
	Fraction Exposed (forearms, hands)	NA	NA	1.0	1.0	NA	NA	1.0[4]	1.0[4]
	Exposure Time (hr/day)	NA	NA	2.6[6]	2.6[6]	NA	NA	4[4]	2[4]
	Exposure Frequency (day/yr)	NA	NA	16[4]	8[4]	NA	NA	55[4]	55[4]
	Exposure Duration (yr)	NA	NA	30[2]	9[2]	NA	NA	6[4]	6[4]
	Body Weight (kg)	NA	NA	70[2]	70[2]	NA	NA	40[5]	40[5]
Ingestion of Surface Water (Adult-skiing; child-swimming)	Exposure Concentration (mg/L)	NA	NA	Maximum[6]	95% UCL[2]	NA	NA	Maximum[6]	95% UCL[2]
	Ingestion Rate (L/hr)	NA	NA	0.05[7]	0.05[7]	NA	NA	0.05[6]	0.05[6]
	Exposure Time (hr/day)	NA	NA	2.6[6]	2.6[6]	NA	NA	4[4]	2[4]
	Exposure Frequency (day/yr)	NA	NA	16[4]	8[4]	NA	NA	55[4]	55[4]
	Exposure Duration (yr)	NA	NA	30[2]	9[2]	NA	NA	6[4]	6[4]
	Body Weight (kg)	NA	NA	70[2]	70[2]	NA	NA	40[5]	40[5]
Fishing Shellfish Ingestion	Exposure Concentration (mg/day)	NA	NA	95% UCL[2]	95% UCL[2]	NA	NA	NA	NA
	Ingestion Rage (kg/day)	NA	NA	0.055[2]	0.003[2]	NA	NA	NA	NA
	Exposure Frequency (day/yr)	NA	NA	350[2]	234[2]	NA	NA	NA	NA
	Exposure Duration (yr)	NA	NA	30[2]	9[2]	NA	NA	NA	NA
	Body Weight (kg)	NA	NA	70[2]	70[2]	NA	NA	NA	NA

1 NA - Exposure route not evaluated.
2 USEPA Region I, August 1994.
3 USEPA, January 1992.
4 Based on Phase I RI (Atlantic, August 1992).
5 Average body weight, child ages 6-12 (USEPA, May 1989).
6 USEPA, May 1989.
7 USEPA Region I, June 1989.
8 USEPA, April 1988.

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TABLE 3-13

EXPOSURE PARAMETERS FOR POTENTIAL FUTURE ONSITE RESIDENTS NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Adult		Child	
		RME	CTE	RME	CTE
Soil Ingestion	Exposure Concentration (mg/kg)	95% UCL[1]	95% UCL[1]	95% UCL[1]	95% UCL[1]
	Ingestion Rate (mg/day)	100[1]	50[1]	200[1]	100[1]
	Exposure Frequency (day/yr)	150[1]	150[1]	150[1]	150[1]
	Exposure Duration (yr)	24[1]	7[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]
Soil Dermal Contact	Exposure Concentration (mg/kg)	95% UCL[1]	95% UCL[1]	95% UCL[1]	95% UCL[1]
	Body Surface Area (cm^2)	20000[2]	20000[2]	6980[2]	6980[2]
	Fraction Exposed (forearms, head, hands)	0.19[3]	0.19[3]	0.30[3]	0.30[3]
	Adherence Factor (mg/cm^2)	1.0[2]	0.2[2]	1.0[2]	0.2[2]
	Exposure Frequency (day/yr)	150[1]	150[1]	150[1]	150[1]
	Exposure Duration (yr)	24[1]	7[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]
Inhalation of Dust/Air	PM10 Exposure Concentration (mg/m_3)	0.018 x UCL[4]	0.018 x UCL[4]	0.018 x UCL[4]	0.018 x UCL[4]
	Inhalation Rate (m^3/hr)	0.8[1]	0.8[1]	0.8[1]	0.8[1]
	Exposure Time (hr/day)	24	24	24	24
	Exposure Frequency (day/yr)	350[1]	234[1]	350[1]	234[1]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]
Ingestion of Groundwater	Exposure Concentration (mg/L)	Maximum[5]	95% UCL[1]	Maximum [5]	95% UCL[1]
	Ingestion Rate (L/day)	2[1]	1.4[1]	1[3]	0.8[3]
	Exposure Frequency (day/yr)	350[1]	350[1]	350[1]	350[1]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]

TABLE 3-13 (Continued)
EXPOSURE PARAMETERS FOR POTENTIAL FUTURE ONSITE RESIDENTS
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Adult		Child	
		RME	CTE	RME	CTE
Dermal Contact with Groundwater while Showering/ Bathing	Exposure Concentration (mg/L)	Maximum[6]	95% UCL[1]	Maximum[6]	95% UCL[1]
	Body Surface Area (cm^2)	20000[2]	20000[2]	6980[2]	6980[2]
	Fraction Exposed (whole body)	1.0	1.0	1.0	1.0
	Exposure Time (min/day)	15[2]	10[2]	15[2]	10[2]
	Exposure Frequency (day/yr)	350[1]	350[1]	350[1]	350[1]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]
Inhalation of Volatiles while Showering/ Bathing	Volatile Chemical Generation Rate ($\mu g/m^3$ min)	[6]	[6]	[6]	[6]
	Inhalation Rate (L/min)	10[3]	10[3]	10[3]	10[3]
	Shower Duration (min)	15[2]	10[2]	15[2]	10[2]
	Total Time in Bathroom (min)	20[8]	15[8]	20[8]	15[8]
	Air Exchange Rate (min^{-1})	0.0083[7]	0.0083[7]	0.0083[7]	0.0083[7]
	Exposure Frequency (day^{-1})	0.96[9]	0.96[9]	0.96[9]	0.96[9]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]

1 USEPA, Region I, August 1994.
2 USEPA, January 1992.
3 USEPA, May 1989.
4 Based on Phase I RI (Atlantic, August 1992).
5 USEPA, April 1988.
6 Foster & Chrostowski, 1987. Chemical-specific value calculated using maximum concentration for RME and 95% UCL for CTE.
7 Foster & Chrostowski, 1987.
8 Professional judgement.
9 One shower/day, 350 days/yr.

TABLE 3-14

EXPOSURE PARAMETERS FOR ADULT PERSONNEL
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Utility Workers		Employee		Construction Worker		Occasional Visitor	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Soil Ingestion	Exposure Concentration (mg/kg)	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]
	Ingestion Rate (mg/day)	480[2]	480[4]	100[2]	50[2]	480[2]	480[4]	100[2]	50[2]
	Exposure Frequency (day/yr)	3.5[4]	1[4]	250[2]	150[2]	120[4]	80[4]	24[4]	12[4]
	Exposure Duration (yr)	25[2]	25[4]	25[2]	6[4]	1[4]	1[4]	25[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]
Soil Dermal Contact	Exposure Concentration (mg/kg)	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]
	Body Surface Area (cm^2)	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]
	Fraction Exposed (forearms, head, hands)	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]
	Adherence Factor (mg/cm^2)	1.0[3]	0.2[3]	1.0[3]	0.2[3]	1.0[3]	0.2[3]	1.0[3]	0.2[3]
	Exposure Frequency (day/yr)	3.5[4]	1[4]	250[2]	150[2]	120[4]	80[4]	24[4]	12[4]
	Exposure Duration (yr)	25[2]	25[4]	25[2]	6[4]	1[4]	1[4]	25[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]

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TABLE 3-13 (Continued)
EXPOSURE PARAMETERS FOR POTENTIAL FUTURE ONSITE RESIDENTS
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Adult		Child	
		RME	CTE	RME	CTE
Dermal Contact with Groundwater while Showering/ Bathing	Exposure Concentration (mg/L)	Maximum[6]	95% UCL[1]	Maximum[6]	95% UCL[1]
	Body Surface Area (cm^2)	20000[2]	20000[2]	6980[2]	6980[2]
	Fraction Exposed (whole body)	1.0	1.0	1.0	1.0
	Exposure Time (min/day)	15[2]	10[2]	15[2]	10[2]
	Exposure Frequency (day/yr)	350[1]	350[1]	350[1]	350[1]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]
Inhalation of Volatiles while Showering/ Bathing	Volatile Chemical Generation Rate ($\mu g/m^3$ min)	[6]	[6]	[6]	[6]
	Inhalation Rate (L/min)	10[3]	10[3]	10[3]	10[3]
	Shower Duration (min)	15[2]	10[2]	15[2]	10[2]
	Total Time in Bathroom (min)	20[8]	15[8]	20[8]	15[8]
	Air Exchange Rate (min^{-1})	0.0083[7]	0.0083[7]	0.0083[7]	0.0083[7]
	Exposure Frequency (day^{-1})	0.96[8]	0.96[8]	0.96[8]	0.96[8]
	Exposure Duration (yr)	30[1]	9[1]	6[1]	2[1]
	Body Weight (kg)	70[1]	70[1]	15[1]	15[1]

1 USEPA, Region I, August 1994.
2 USEPA, January 1992.
3 USEPA, May 1989.
4 Based on Phase I RI (Atlantic, August 1992).
5 USEPA, April 1988.
6 Foster & Chrostowski, 1987. Chemical-specific value calculated using maximum concentration for RME and 95% UCL for CTE.
7 Foster & Chrostowski, 1987.
8 Professional judgement.
9 One shower/day, 350 days/yr.

TABLE 3-14

EXPOSURE PARAMETERS FOR ADULT PERSONNEL
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Utility Workers		Employee		Construction Worker		Occasional Visitor	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Soil Ingestion	Exposure Concentration (mg/kg)	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]
	Ingestion Rate (mg/day)	480[2]	480[4]	100[2]	50[2]	480[2]	480[4]	100[2]	50[2]
	Exposure Frequency (day/yr)	3.5[4]	1[4]	250[2]	150[2]	120[4]	80[4]	24[4]	12[4]
	Exposure Duration (yr)	25[2]	25[4]	25[2]	6[4]	1[4]	1[4]	25[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]
Soil Dermal Contact	Exposure Concentration (mg/kg)	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]	95% UCL[2]
	Body Surface Area (cm^2)	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]	20000[3]
	Fraction Exposed (forearms, head, hands)	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]	0.19[5]
	Adherence Factor (mg/cm^2)	1.0[3]	0.2[3]	1.0[3]	0.2[3]	1.0[3]	0.2[3]	1.0[3]	0.2[3]
	Exposure Frequency (day/yr)	3.5[4]	1[4]	250[2]	150[2]	120[4]	80[4]	24[4]	12[4]
	Exposure Duration (yr)	25[2]	25[4]	25[2]	6[4]	1[4]	1[4]	25[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]

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TABLE 3-14 (Continued)
EXPOSURE PARAMETERS FOR ADULT PERSONNEL
NSB-NLON, GROTON, CONNECTICUT

Exposure Scenario	Parameter (units)	Utility Workers		Employee		Construction Worker		Occasional Visitor	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Inhalation of Dust/Air	PM10 Exposure Concentration (mg/m^3)	0.09 x UCL[4]	0.09 x UCL[4]	0.018 x UCL[4]	0.018 x UCL[4]	0.09 x UCL[4]	0.09 x UCL[4]	0.018 x UCL[4]	0.018 x UCL[4]
	Inhalation Rate (m^3/hr)	3.9[5]	3.9[5]	2.5[5]	2.5[5]	3.9[5]	3.9[5]	0.8[5]	0.8[5]
	Exposure Time (hr/day)	8[4]	8[4]	8[4]	8[4]	8[4]	8[4]	8[4]	8[4]
	Exposure Frequency (day/yr)	3.5[4]	1[4]	250[2]	150[2]	120[4]	80[4]	24[4]	12[4]
	Exposure Duration (yr)	25[2]	25[4]	25[2]	6[4]	1[4]	1[4]	25[4]	6[4]
	Body Weight (kg)	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]	70[2]
Dermal Contact with Groundwater	Exposure Concentration (mg/L)	Maximum[6]	95% UCL[6]	NA[1]	NA	95% UCL[6]	95% UCL[6]	NA	NA
	Body Surface Area (cm^2)	20000[3]	20000[3]	NA	NA	20000[3]	20000[3]	NA	NA
	Fraction Exposed (forearms, hands)	0.11[5]	0.11[5]	NA	NA	0.11[5]	0.11[5]	NA	NA
	Exposure Time (hr/day)	8[4]	8[4]	NA	NA	8[4]	8[4]	NA	NA
	Exposure Frequency (day/yr)	3.5[4]	1[4]	NA	NA	120[4]	80[4]	NA	NA
	Exposure Duration (yr)	25[2]	25[4]	NA	NA	1[4]	1[4]	NA	NA
	Body Weight (kg)	70[2]	70[2]	NA	NA	70[2]	70[2]	NA	NA

1 NA - Exposure route not evaluated.
2 USEPA Region I, August 1994.
3 USEPA, January 1992.
4 Based on Phase I RI (Atlantic, August 1992).
5 USEPA, May 1989.
6 USEPA Region I, June 1989.

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EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT=ED*365 days/yr;
		for carcinogens, AT=70yr*365 days/yr

The concentrations of chemicals in dust were developed using PM10 modeling completed in the Phase I RI (Atlantic Environmental Services, Inc., August 1992). The air concentration term (C_{si}) is calculated by multiplying the PM10 fraction in air by the chemical concentration in the soil. The following conversion factors were used in the Phase I RI (Atlantic Environmental Services, Inc., August 1992):

- For activities involving construction - 0.09 mg/m^3.
- For onsite exposures, no soil disturbance - 0.018 mg/m^3.
- For offsite, downwind exposures - 0.004 mg/m^3.

Exposure times range from one hour per day for the adult recreational users to 24 hours per day for RME potential local and onsite future residents in their homes. Exposure frequencies range from 1 day per year for a CTE utility worker to 350 days per year for the RME adult resident potential future residents. All exposure factors for each of the two the identified receptor groups are outlined in Tables 3-12 through 3-14.

Incidental Ingestion of Soil/Sediment. The estimation of intake of contaminants in soil is determined using the predicted concentration of a contaminant in the location of interest. This pathway is evaluated for both children and adults. Children represent a critical subpopulation of concern for whom this exposure pathway may be significant. USEPA guidance (December 1989) suggests that children may be exposed through the soil ingestion pathway from ages one through six.; however, because future residential land use is not considered at these sites exposed Two receptor groups for children are considered, potential future child residents exposed from ages one to six (under the RME) and children to be between the ages of 6 and 12 who and are involved in transient recreational activities such as exploring or wading. Intakes associated with soil ingestion are calculated using the following equation:

$$Intake_{si} = (C_{si})(IR)(FI)(EF)(ED)/(BW)(AT)$$

where:	$Intake_{si}$	=	intake of contaminant "i" from soil or sediment (mg/kg/day)
	C_{si}	=	concentration of contaminant "i" in soil or sediment (mg/kg)

IR	=	ingestion rate (mg/day)
FI	=	fraction ingested from contaminated source (decimal fraction)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED*365 days/yr;
		for carcinogens, AT = 70 yr*365 days/yr

For adults and older children not involved in construction activities, ingestion rates are considered to range from 50 mg/day (adults under CTE conditions) to ~~100~~ 200 mg/day (potential future child residents for the RME). An ingestion rate of 480 mg/day is considered for construction personnel (USEPA, March 25, 1991). Exposure frequencies range from 1 day/year for the CTE utility worker to 250 days/year for the RME full-time employee.

Dermal Contact with Soil/Sediment. The estimation of intake of a contaminant in soil via absorption through the skin is determined using the predicted concentration in the soil at the location of concern. Evaluation of the dermal absorption pathway is performed for both children and adults. As with soil ingestion, exposure of children represents a critical subpopulation of interest for the exposure assessment. Again, soil dermal contact by a child is assumed to occur between the ages ~~six and twelve~~ of one and six (RME potential future child residents) and six and twelve (child recreational users). Dermal absorption from potentially contaminated areas is calculated using the following equation:

$$Intake_{si} = (C_{si})(SA)(AF)(ABS)(CF)(EF)(ED) \ / \ (BW)(AT)$$

where:	$Intake_{si}$	=	amount of chemical "i" absorbed during contact with soil/sediment (mg/kg/day)
	C_{si}	=	concentration of chemical "i" in soil/sediment (mg/kg)
	SA	=	skin surface area available for contact (cm^2/event)
	AF	=	skin adherence factor (mg/cm^2)
	ABS	=	absorption factor (decimal fraction)
	CF	=	conversion factor (10^{-6} kg/mg)
	EF	=	exposure frequency (days/yr)
	ED	=	exposure duration (yr)
	BW	=	body weight (kg)

AT	=	averaging time (days);
		for noncarcinogens, AT = ED*365 days/yr;
		for carcinogens, AT = 70 yr*365 days/yr

Dermal contact with soil by adults and children is assumed to occur at the same exposure frequency as soil ingestion. Exposed surface areas of 19 percent of the total body surface area (to account for forearms, head, and hands) for the adults and 30 percent of the total body surface area (to account for forearms, head, hands, and feet) for the children were selected based on default clothing scenarios expressed in the USEPA dermal exposure guidance (USEPA, August 1992). Soil adherence factors were selected from the published range of 0.2 to 1.0 mg/cm^2 (USEPA, January 1992).

Dermal Contact with Groundwater/Surface Water. Because the groundwater and surface waters at the base are not used for potable supplies, only limited exposure scenarios are considered under current site conditions. Potential future residents are assumed to use groundwater for domestic purposes (i.e., bathing, showering, washing dishes). This scenario assumes that a residential development is constructed on the site and potable wells are installed. It is also possible under future land use conditions that deep excavations at the base for activities such as utility maintenance and construction could result in a dermal exposure to the shallow groundwater (that contained in the overburden). Dermal contact with surface waters could result upon swimming in North Lake or when children are exploring in areas such as the Area A Wetland. In addition, local residents may waterski in the Thames River.

The following equation will be used to assess exposures resulting from dermal contact with water (USEPA, December 1989):

$$Intake_{wi} = (C_{wi})(AV)(PC_i)(ET)(EF)(ED) \ / \ (BW)(AT)$$

where:	$Intake_{wi}$	=	intake of chemical "i" from water (mg/kg/day)
	C_{wi}	=	concentration of chemical "i" in water (mg/L)
	AV	=	skin surface area available for contact (cm^2)
	PC_i	=	dermal permeability constant of chemical "i" in water (cm/hr)
	ET	=	exposure time (hr/day)
	EF	=	exposure frequency (days/yr)
	ED	=	exposure duration (yr)

BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED*365 days/yr;
		for carcinogens, AT = 70yr*365 days/yr

The dermal permeability constants are chemical-specific, and are those reported in USEPA's dermal risk assessment guidance (USEPA, January 1992). Potential future residents are assumed to be exposed to groundwater 350 days per year (USEPA Region I, 1994) at exposure durations ranging from 2 years for the CTE child resident to 30 years for the RME adult resident. Whole body contact is assumed for future residents. Groundwater exposure times for adult construction and utility personnel are 8 hours per day for 1 to 120 days per year for the CTE utility worker and the RME construction worker, respectively. Exposure durations are 1 year for the construction worker and 25 years for the utility worker. Adults are assumed to be exposed only on their forearms and hands, for a total area of 2200 cm^2. For children playing or swimming, exposures are evaluated as 2 to 4 hours per day for 55 days per year over a 6 year period. Children involved in recreational activities are assumed to experience whole body exposure, for a total surface area of 10500 cm^2.

Local adult residents may also be exposed while waterskiing on the Thames River. Small children are not considered in this scenario given the size, tidal flows, etc., of the River. In the vicinity of the Base, the banks are heavily industrialized and/or steep, and therefore not conducive to swimming by young children. Adults waterskiing may experience whole body exposure up to an estimated 16 days/year for 30 years, for 2.6 hours/day.

Incidental Ingestion of Groundwater/Surface Water. Potential future residents (adults and children) may be exposed to groundwater via direct ingestion. Direct contact with surface waters while swimming or exploring could also result in the inadvertent ingestion of small amounts of water. Children are the most likely receptors for incidental ingestion of surface water. Their exposures are evaluated using the following equations (USEPA, December 1989):

$$Intake_{wi} = (C_{wi})(IR)(EF)(ED) \ / \ (BW)(AT) \qquad \text{for groundwater}$$

$$Intake_{wi} = (C_{wi})(IR)(ET)(EF)(ED) \ / \ (BW)(AT) \qquad \text{for surface water}$$

where:	$Intake_{wi}$	=	intake of chemical "i" from water (mg/kg/day)
	C_{wi}	=	concentration of chemical "i" in water (mg/L)
	IR	=	ingestion rate for groundwater (L/day)

		ingestion rate for surface water (L/hr)
ET	=	exposure time for surface water (hr/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED*365 days/yr;
		for carcinogens, AT = 70 yr*365 days/yr

Exposure times, frequencies, and durations are the same as described above for dermal contact. ~~The ingestion rate is assumed to be 0.05 L/hr.~~ Ingestion rates for potential future residents range from 0.8 L/day (CTE child resident) to 2 L/day (RME adult resident). The ingestion rate for a child recreational user exposed to surface water was set at 0.05 L/hr (EPA, Region I, June 1989).

Inhalation of Volatiles in Groundwater. For potential future residents, additional exposures may occur via inhalation during showering, bathing, washing dishes, etc. Inhalation exposures were estimated using a mass transfer model developed specifically for this exposure route, in combination with an air intake estimation model. The mass transfer model accounts for inhalation that occurs during a shower and after a shower while the receptor remains in the closed bathroom. The method employed is as follows (USEPA, December 1989; Foster and Chrostowski, 1987):

$$Intake_{w} = (S)(IR)(K)(EF)(ED) \;/\; (BW)(AT)(R_e)(CF)$$

and

$$K = D_s + \frac{\exp\,(R_e \times D_t)}{R_e} - \frac{\exp R_e \times (D_s - D_t)}{R_e}$$

where:	$Intake_{w}$	=	intake of chemical "i" from water (mg/kg-day)
	S	=	volatile chemical generation rate ($\mu g/m^3$-min)
	IR	=	inhalation rate (L/min)
	EF	=	exposure frequency (days/year)
	ED	=	exposure duration (years)
	BW	=	body weight (kg)
	AT	=	averaging time or period of exposure (days)
	R_e	=	air exchange rate (min^{-1})
	K	=	mass transfer coefficient

D_s = shower duration (min)

D_t = total time in bathroom (min)

CF = conversion factor (1E + 6 μg-L/mg-m^3)

The volatile chemical generation rate was estimated using the Foster and Chroetowski mass transfer model, which is based on two-phase film theory. The model employs contaminant-specific mass transfer coefficients, Henry's Law constants, droplet diameter, drop time, viscosity, temperature, etc.

The inhalation rate was specified at 10 L/min for the future adult and child resident. The exposure frequency was specified as 0.96/day (i.e., one shower/day, 350 days/year). Exposure durations range from 2 years for the CTE child resident to 30 years for the RME adult resident. The air exchange rate was specified as 0.0083/min, shower durations were set at 10 minutes for the CTE and 15 minutes for the RME, and an additional 5 minutes was added to the shower duration time to estimate the total time spent in the bathroom.

Ingestion of Shellfish~~/Finfish~~. Indirect~~contact with water~~ exposure may also occur via the ingestion of shellfish ~~or finfish~~ harvested from the Thames River. It is possible, though unlikely, that local residents could be exposed to shellfish from this area, although all harvesting is supposedly controlled by commercial concerns which remove the shellfish to offsite depuration beds, where they are combined with shellfish from other areas, prior to sale. The following model will be used to assess potential exposures resulting from ingestion of shellfish from the Thames River (USEPA, December 1989):

$$Intake_{fi} = (C_{fi})(IR)(EF)(ED) \ / \ (BW)(AT)$$

where:

$Intake_{fi}$	=	intake of chemical "i" from shellfish (mg/kg/day)
C_{fi}	=	concentration of chemical "i" in shellfish (mg/kg)
IR	=	ingestion rate (kg/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED*365 days/yr;
		for carcinogens, AT = 70 yr*365 days/yr

Default ingestion rates specified by USEPA Region I (USEPA Region I, August 1994) were used for the CTE and RME resident receptors, as follows:

- 0.055 kg/day for 350 days/yr for 30 years for the RME resident adult
- 0.003 kg/day for 234 days/yr for 9 years for the CTE resident adult

Actual shellfish concentrations were available for oysters and clams, which are the only two species of potential commercial interest in the river.

3.3.4 Risk Characterization

This section provides a characterization of the potential human health risks associated with the potential exposure to chemicals of concern at NSB-NLON. Section 3.3.4.1 outlines the methods used to estimate the type and magnitude of health risks, and site-specific sections in Chapters 5.0 through 17.0 present the results for the current and potential future land use conditions for the individual sites. Section 3.3.5 contains a discussion of the uncertainties associated with all aspects of the process.

3.3.4.1 Risk Characterization Methodology

Potential human health risks resulting from exposure to chemicals of concern are estimated using algorithms established by the United States Environmental Protection Agency (USEPA). The methods described by the USEPA are protective of human health and are likely to overestimate (rather than underestimate) risk. The USEPA methodology uses specific algorithms to calculate risk as a function of chemical concentration, human exposure parameters, and toxicity.

Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also exhibit noncarcinogenic effects. Potential impacts are then characterized for both types of health effects.

Chemical Carcinogens. Risks attributable to exposure to chemical carcinogens are estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. At low doses, the incremental lifetime cancer risk (ILCR) is determined as follows (USEPA, December 1989):

$$ILCR_i = (Intake_i)(CSF_i)$$

where: $ILCR_i$ = Incremental Lifetime Cancer Risk for chemical "i", expressed as a unitless probability

$Intake_i$	=	Intake of chemical "i" (mg/kg/day)
CSF_i	=	Cancer Slope Factor of chemical "i" $(mg/kg/day)^{-1}$

Risks below 1E-6 (1/1E-6, or a risk less than 1 in 1 million) are generally considered to be acceptable by the USEPA, and risks greater than 1E-4 (1 in 10,000) are generally considered to be unacceptable by the agency.

When carcinogenic risks exceed 1E-2 using the above methodology, the USEPA (December 1989) specifies that the one-hit model be used, as follows:

$$ILCR_i = 1 - \exp(-Intake_i)(CSF_i)$$

Risks are estimated for all carcinogenic compounds regardless of the class designation (A, B, or C).

Noncarcinogens. The hazards associated with the effects of noncarcinogenic chemicals are evaluated by comparing an exposure level or intake to a Reference Dose (RfD). The ratio of the intake to the RfD is called the Hazard Quotient (HQ) and is defined as follows (USEPA, December 1989):

$$HQ_i = \frac{Intake}{RfD_i}$$

where:	HQ_i	=	Hazard Quotient for chemical "i" (unitless)
	$Intake_i$	=	Intake of chemical "i" (mg/kg/day)
	RfD_i	=	Reference Dose of chemical "i" (mg/kg/day)

If the ratio of the intake to the RfD exceeds unity, there exists a potential for noncarcinogenic (toxic) effects to occur. A Hazard Index (HI) is generated by summing the individual HQs for all the chemicals of concern. If the value of the HI exceeds unity, there is a potential for noncarcinogenic health effects associated with that particular chemical mixture, and therefore it is necessary to segregate the HQs by target organ effects. The HQ should not be construed as a probability in the manner of the ILCR, but rather a numerical indicator of the extent to which a predicted intake exceeds or is less than an RfD.

3.3.5 Uncertainties Analysis

There is uncertainty associated with all aspects of the baseline human health risk assessment presented in the preceding sections. This section will present a summary of these uncertainties, with a discussion of how they may affect the final risk numbers discussed in Sections 5.0 through 17.0.

There is uncertainty associated with all steps of the risk assessment process. Uncertainty in the selection of chemicals of concern is associated with the current status of the predictive data bases and the procedures used to include or exclude constituents as chemicals of concern. Uncertainty associated with the exposure assessment includes the values used as input variables for a given intake route, the methods used and the assumptions made to determine exposure point concentrations, and the predictions regarding future land use and population characteristics. Uncertainty in the toxicity assessment includes the quality of the existing data to support dose-response relationships, and the weight-of-evidence used for determining the carcinogenicity of chemicals of concern. Uncertainty in risk characterization includes that associated with exposure to multiple chemicals and the cumulative uncertainty from combining conservative assumptions made in earlier activities.

While there are various sources of uncertainty, as described above, the direction of uncertainty can be influenced by the assumptions made throughout the risk assessment, including selection of chemicals of concern and selection of values for dose response relationships. Throughout the entire risk assessment, assumptions were made so that the final calculated risks would be overestimated because of the safety factors built into the assumptions. Thus, the resultant uncertainty in the numerical risk assessments is in how much lower the actual risks are.

Generally, risk assessments carry two types of uncertainty -- measurement and informational uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements. For example, this type of uncertainty is associated with analytical data collected for each site. The risk assessment reflects the accumulated variances of the individual values used.

Informational uncertainty stems from inadequate availability of information needed to complete the toxicity and exposure assessments. Often, this gap is significant, such as the absence of information on the effects of human exposure to low doses of a chemical, on the biological mechanism of action of a chemical, or the behavior of a chemical in soil.

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration of

uncertainties, limitations, and assumptions inherent in the process can be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions made are protective of sensitive subpopulations or the maximum exposed individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, thereby producing a much larger uncertainty for the final results. This uncertainty is biased toward overpredicting both carcinogenic and noncarcinogenic risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

This interpretation is especially relevant when the risks exceed the point-of-departure for defining "acceptable" risk. For example, when risks calculated using a high degree of uncertainty are below an "acceptable" risk level (i.e., 10^{-6}), the interpretation of no significant risk is straightforward. However, when risks calculated using a high degree of uncertainty are above an "acceptable" risk level (i.e., 10^{-4}), a conclusion can be difficult unless uncertainty is considered.

Recent USEPA guidance on risk assessment (USEPA, February 26, 1992; USEPA Region I, August 1994) requires risk assessors to use exposure and toxicity assumptions from the "high end" and the "central tendency" of their distributions. These values correspond to the RME and central tendency (CT) scenarios.

3.3.5.1 Uncertainty in Selection of Chemicals of Concern

There is a minor amount of uncertainty associated with the final risk values based on the selection of chemicals of concern to be used in the quantitative risk assessment. However, the use of predetermined screening values based on conservative land use scenarios (i.e., residential land use for soil and sediment, and ingestion/inhalation for groundwater/surface water) in combination with the reduction of the values for carcinogens to correspond to a 1E-7 cancer risk should ensure that the most significant contributors to risk from a site are evaluated. The elimination of chemicals that are present at concentrations that correspond to a less than 1E-7 cancer risk and less than 0.1 hazard index should not affect the final conclusions regarding contaminants that could cause a potential health concern.

There are additional chemicals (e.g., dibenzofuran and cobalt) for which there are no available health criteria for which Region III could calculate appropriate risk-based screening concentrations. These compounds are not, therefore, included as chemicals of concern for this assessment. The elimination of these particular compounds from the quantitative risk assessment should not change the conclusions of the report.

3.3.5.2 Uncertainty in the Exposure Assessment

Uncertainty in the exposure assessment arises for the methods used to calculate exposure point concentrations, determination of land use conditions, the selection of receptors, and the selection of exposure parameters. Each of these is discussed below.

Determination of Land Use. The current land use patterns were well established by Atlantic Environmental, Inc., during the Phase I RI. Detailed interviews with base personnel were used to establish the potentially exposed populations and the activities that could bring them into contact with contaminated media. In addition, planned construction projects were identified.

One issue associated with land use that was not considered was the potential conversion of the base (particularly the sites under consideration in the RI) to residential uses at some time in the future. This scenario is considered to be highly unlikely given the dispersed population patterns surrounding the base currently and the heavily industrialized nature of the facility at the current time. These factors make a future industrial land use scenario much more likely, at least for the foreseeable future. Therefore, land use is not considered to add significantly to the uncertainty of this risk assessment.

Calculation of Exposure Point Concentrations. For most media at most sites, less than ten samples were available. This makes the estimation of the upper 95 percent confidence limit on the mean highly uncertain, and therefore, the maximum detected chemical concentrations were often used. As a result, the estimations of risk are most likely to be overstated, because persons are not likely to spend the entire defined exposure periods at the single point location of maximum concentration.

For some sites, the risk evaluation focused on one or more smaller areas of concern. These boundaries are somewhat artificial, and originated as investigations of something perhaps like a tank or are simply gross geographical boundaries. Exposures may or may not occur in these particular areas, and therefore risks could be under- or overestimated.

Exposure Routes and Receptor Identification. Based on the work performed by Atlantic Environmental, Inc., exposure routes and receptor groups were fairly well-defined. In this report, an attempt was made to simplify the various groups identified, as well as to determine a single set of exposure parameters to apply to each group. This may either under- or over-estimate the risks, with the final result dependent on how well the receptors were defined.

Selection of Exposure Parameters. Each exposure factor selected for use in this risk assessment has some associated uncertainty. Generally, exposure factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of exposure, the USEPA guidelines on the RME receptor were used, which generally consist of the 95th percentile for most parameters. Therefore, the selected values for the RME receptor represent the upper bound of the observed or expected habits of the majority of the population.

Generally, the uncertainty can be assessed quantitatively for a number of assumptions made in determining factors for calculating exposures and intakes. Many of these parameters were determined from statistical analyses on human population characteristics. Often the data base used to summarize a particular exposure parameter (i.e., body weight) is quite large. Consequently, the values chosen for such variables in the RME scenario have low uncertainty. For many parameters for which limited information exists (i.e., dermal absorption of organic chemicals from soil), there is greater uncertainty. However, there are often sufficient data to estimate these parameters with low uncertainty.

Many of the quantities used to calculate exposures and risks in this report are selected from a distribution of possible values. For the RME scenario, the value representing the 95th percentile is generally selected for each parameter to ensure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions, but does not indicate what a more average or typical exposure might be, or what risk range might be expected for individuals in the exposed population. To address these issues, the USEPA has suggested the use of the CTE receptor, whose intake variables are set at approximately the 50th percentile of the distribution. The risks for this receptor seek to incorporate the range of uncertainty associated with various intake assumptions. Many of the parameters were estimated using professional judgment, although USEPA Region I provides some default parameters (USEPA Region I, August 1994).

3.3.5.3 Uncertainty in the Toxicological Evaluation

Uncertainty associated with the toxicity assessment is associated with hazard assessment and dose-response evaluations for the chemicals of concern. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will also induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using the USEPA methods. Positive animal cancer test data suggest that humans contain tissue(s) that may also manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment

of noncancer effects, however, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans.

Uncertainty in hazard assessment arises from the nature and quality of the animal and human data. Uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when pharmacokinetic data indicate a similar fate in humans and animals; when postulated mechanisms of toxicity are similar for humans and animals; and when the chemical of concern is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose-response evaluation includes the determination of a slope factor for the carcinogenic assessment and derivation of an RfD or Reference Concentration (RfC) for the noncarcinogenic assessment. Uncertainty is introduced from interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Uncertainty also results from intraspecies variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal, but the human population of concern may reflect a great deal of heterogeneity including unusual sensitivity or tolerance to the chemical of concern. Even toxicity data from human occupational exposure reflect a bias because only those individuals sufficiently healthy to attend work regularly (the "healthy worker effect") and those not unusually sensitive to the chemical are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study from which the quantitative estimate is derived and the data base. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty in carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a nonthreshold assumption of carcinogenesis. There is evidence to suggest, however, that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Williams and Weisburger, 1991); therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD or RfC to mitigate poor quality of the key study or gaps in the data base. Additional uncertainty for noncancer effects arises from the use of an effect level in the estimation of an RfD or RfC, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises in estimation of an RfD

or RfC for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less-than-chronic study. Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors that normally range between 3 and 10. The resulting combination of uncertainty and modifying factors may reach 1,000 or more.

Class C carcinogens are classified as possible human carcinogens because the evidence for their carcinogenicity in animals is limited. The inclusion of these compounds in the estimation of total carcinogenic risk adds to the uncertainty of the final risk numbers by potentially overestimating the human health effects.

Another source of uncertainty in this risk assessment is the lack of cancer slope factors for compounds identified by the USEPA as possible human carcinogens (Class C compounds). The only Class C compounds identified as potential chemicals of concern at this site are 2-methylphenol, 1,1,2,2-tetrachloroethane, and 1,1-dichloroethene. It is unlikely that the evaluation of these particular compounds as potential carcinogens would change the conclusions of the carcinogenic risk evaluations.

Another potential source of uncertainty in the toxicity assessment is the extrapolation of Reference Concentrations to Reference Doses without use of an inhalation absorption factor. Typically, CERCLA risk assessments require the conversion of an air concentration to an internal dose. So while this conversion is not thought to add significantly to the uncertainty in a risk assessment, it is not recommended unless the primary literature is consulted first.

The derivation of dermal RfDs and CSFs from oral values may cause uncertainty. This is particularly the case when no gastrointestinal absorption rates are available in the literature or when only qualitative statements regarding absorption are available.

Uncertainty also arises in the dose-response assessment for values derived for several principal chemicals of concern by using studies with limitations. For example, Class B2 PAHs for which no toxicity data are available are evaluated using benzo(a)pyrene toxicity data with estimated orders of potential potency for the average and RME receptors. This may either underestimate or overestimate the carcinogenic risks associated with PAHs.

The carcinogenicity of arsenic via ingestion is not confirmed by the available data. However, the USEPA has proposed an oral unit risk factor that was used for all oral and dermal exposures to arsenic at this site. Since arsenic is a major risk driver, the risks may be overstated.

3.3.5.4 Uncertainty in the Risk Characterization

Uncertainty in risk characterization results primarily from assumptions made regarding additivity of effects from exposure to multiple compounds from various exposure routes. High uncertainty exists when summing cancer risks for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often compounds affect different organs, have different mechanisms of action, and differ in their fate in the body, so additivity may not be an appropriate assumption. However, the assumption of additivity is made to provide a conservative estimate of risk.

In addition, the risk characterization does not consider antagonistic or synergistic effects. Little or no information is available to determine the potential for antagonism or synergism for the chemicals of concern. Therefore, this uncertainty cannot be discussed for its impact on the risk assessment, since it may either underestimate or overestimate potential human health risk.

Finally, the screening step for selection of chemicals of concern made some use of surrogate compounds to complete the screening step. For instance, acenaphthene values were used for acenaphthylene, endosulfan was used for endosulfan sulfate, endrin was used for endrin aldehyde and endrin ketone, naphthalene was used for 2-methylnaphthalene, and anthracene was used for phenanthrene.