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TECHNICAL MEMORANDUM REGARDING GENERAL HEALTH RISK ASSESSMENT APPROACH MILLINGTON SUPPACT TN

11/15/1996

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TECHNICAL MEMORANDUM

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DATE: November 15, 1996

RE: General Human Health Risk Assessment (HHRA) Approach for NSA Memphis

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This memorandum discusses the general HHRA approach for NSA Memphis. It is proposed that this text not be reproduced in subsequent HHRAs, which would include only site-specific information and reference this memorandum, reducing the bulk necessary to present site-specific risk information to risk managers. Deviations from these general methods would be justified and discussed in site-specific HHRAs.

1 BASELINE RISK ASSESSMENT

1.1 Introduction

A baseline risk assessment (BRA) establishes a baseline of risk to facilitate risk management decisions. Risk is the estimated potential for toxic effects on actual or hypothetical human or ecological receptors, while baseline risk refers to risk arising from exposures to chemicals assuming site conditions remain unchanged. BRAs are used by risk managers to decide if remedial actions are necessary and to determine the extent of remediation necessary to reduce the risk to acceptable levels. Generally, a BRA is divided into two sections, one assessing human health risk, and a second addressing ecological risk. This section addresses generally applied HHRA methods, while ecological risk assessment methods will be addressed in the site-specific assessments. Data management and analysis methods which will be used to reach the conclusions of site-specific HHRAs are discussed below. The following sections describe the methods, procedures, considerations, toxicological information, and related uncertainties possibly affecting HHRAs at NSA Memphis.

1.2 Background

The site background will be summarized in this section of the site-specific HHRAs.

2 General Guidance

HHRAs will generally be prepared in accordance with the guidelines set forth in the following documents, although some may not apply to every site:

- *Provisional Guidance for Quantitative Risk Assessment of PAHs*, U.S. Environmental Protection Agency, ECAO-CIN-842, EPA/600/BP92/001C, July 1993.

- *Risk Assessment Guidance for Superfund (RAGS), Volume I — Human Health Evaluation Manual, Part A*, U.S. Environmental Protection Agency/Office of Emergency and Remedial Response (OERR), EPA/540/1-89/002, December 1989 (Interim).

- *RAGS, Volume I — Human Health Evaluation Manual, (Part B, Development of Risk-Based Preliminary Remediation Goals)*, USEPA/OERR, EPA/540/R92/003, December 1991 (Interim).

- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance — Standard Default Exposure Factors — Interim Final,* EPA/OERR, Office of Solid Waste and Emergency Response (OSWER) Directive: 9285.6-03, March 25, 1991. (RAGS Supplement).

- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance-Dermal Risk Assessment — Interim Guidance,* EPA/OERR, August 18, 1992. (Supplemental Dermal Guidance).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Development of Health-Based Preliminary Remediation Goals, Remedial Goal Options (RGO) and Remediation Levels* (Supplemental RGO Guidance).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Provisional Guidance of Quantitative Risk Assessment of PAHs* (EPA Document EPA/600/R-93-089 July 1993).

- *Supplemental Guidance to RAGS: Calculating the Concentration Term*, May 1992.

- USEPA Region III *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Table*, March 18, 1994, (RBC Screening Tables).

- USEPA Region III *Risk-Based Concentration Table*, January 1995, and subsequent versions (USEPA 1995).

2.1 Objectives

The objectives of the BRA will be to:

- Characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media.

- Identify potential receptors and quantify their potential exposures under current and future conditions for all affected environmental media.

- Qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium.

- Characterize the baseline carcinogenic and noncarcinogenic risks associated with exposure to environmental media at the site(s) under current and future land use conditions.

- Evaluate the uncertainties related to exposure predictions, toxicological data, and resulting carcinogenic risk and noncarcinogenic hazard estimations.

- Establish Remedial Goal Options (RGOs) for chemicals of concern (COC) in each environmental medium based on risk/hazard to facilitate risk management decision-making.

The value of the risk assessment as a basis for making remedial decisions and determining whether detected site concentrations have the potential for toxic effects or increased cancer incidences depends upon adequately characterizing chemical contamination. Variables considered in characterizing the study area and its associated risk will include the amount, type, and location of sources; the pathways of exposure (media type and migration routes); and the

type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors). Sampling activities typically consist of collecting surface (0 to 1-foot interval) and subsurface soil samples, and groundwater samples from monitoring wells installed in various water-bearing zones.

2.2 Organization

A human health risk assessment, as defined by RAGS Part A, includes the following steps:

- *Site characterization*: evaluation of data regarding site geography, geology, hydrogeology, climate, and demographics.

- *Data collection*: analysis of environmental media samples, including background/reference samples.

- *Data evaluation*: statistical analysis of analytical data to identify the nature and extent of contamination and to establish a preliminary list of COPCs based on risk-based and background screening. This list will subsequently be refined to identify COCs.

- *Exposure assessment*: identification of potential receptors under current and predicted conditions and potential exposure pathways, and calculation/quantitation of exposure point concentrations and chemical intakes.

- *Toxicity assessment*: qualitative evaluation of the adverse effects of the COPCs, and quantitative estimate of the relationship between exposure and severity or probability of effect.

- *Risk characterization*: combination of the output of the exposure and the toxicity assessments to quantify the total noncancer and cancer risk to the hypothetical receptors.

- *Uncertainty*: discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium - and exposure pathway-specific influences.

- *Risk/hazard summary*: presentation and discussion of the results of the quantification of exposure (risk and hazard) for the potential receptors and their exposure pathways identified under the current and future conditions.

- *RGOs*: computation of exposure concentrations corresponding to risk projections within the USEPA target risk range of 1E-6 to 1E-4 for carcinogenic COCs and hazard quotient goals of 0.1, 1, and 3 for noncarcinogenic COCs.

3 Site Characterization

When performing a HHRA, environmental media data are compiled to determine potential site-related chemicals and exposures as outlined in RAGS Part A. The steps identifying COPCs are discussed below.

3.1 Data Sources

The number of samples collected from each medium will be detailed in this section of the site-specific HHRAs, and tables will show which sample designations will be included and how data are grouped (when applicable). In addition, the analytical methods, the name of the analyzing laboratory, and data quality objectives will be referenced at this point in the HHRA.

3.2 Data Validation

Data validation is an after-the-fact, independent, systematic process of evaluating data and comparing them to established criteria to confirm they are of the technical quality necessary to support the decisions made in the RFI process. Parameters specific to the data are reviewed to determine whether they meet the stipulated DQOs. The quality objectives address five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To

verify that these objectives are met, field measurements, sampling and handling procedures, laboratory analysis and reporting, and nonconformances and discrepancies in the data are examined to determine compliance with appropriate and applicable procedures.

Data for NSA Memphis will be validated in accordance with the methods outlined in the *Comprehensive RFI Work Plan* (E/A&H, 1994b). The data validation report will be referenced in this section of the HHRA.

3.3 Management of Site-Related Data

All environmental sampling data will be evaluated for suitability for use in the quantitative BRA. Data obtained via the following methods will be considered inappropriate:

- Analytical methods that are not specific for a particular chemical, such as total organic carbon, total organic halogen, or TPH (design parameter samples).

- Field screening instruments including total organic vapor monitoring units and organic vapor analyzers.

Additional data excluded will be detailed in the site-specific HHRAs.

Limitations of analytical results will be addressed in HHRAs by including estimated concentration values for reported nondetects. A nondetect indicates that the analyte was not detected above the practical quantitation limit of the sample ("U" qualified results), which is determined by the analytical method, the instrument used, and possible matrix interferences. However, a nondetected analyte could exist at a concentration between zero and the quantitation limit. For this reason, one-half the "U" value could serve as an unbiased estimate of the nondetect. Because the estimated values of "J" qualified hits are frequently much lower than the sample quantitation limits of "U" qualified nondetects for organic compounds, one-half of

each "U" value will be compared to one-half of the lowest hit (normally "J" qualified) at the same site. The lesser of these two values will be used as the best estimate of the concentration potentially present below the sample quantitation limit, and will be inserted into the adjusted dataset. For inorganic chemicals, the rule is simpler: One-half of each "U" value will be used to represent the concentration of the corresponding sample when compiling the adjusted dataset. If two nondetects are reported for any one location (a result of QA/QC samples), one-half the lesser of the "U" values will be compared to the lowest hit at the site (for organics, as above) or applied directly (for inorganics) to estimate a concentration value to be used in the NSA Memphis risk calculations. If a parameter is not detected at a site, neither data management method will be applied, and the parameter will not be considered in screening or formal assessment.

Once the dataset is complete, statistical methods will be used to evaluate the analytical results to (1) identify COPCs and (2) establish exposure point concentrations (EPCs) at potential receptor locations. The statistical methods used in data evaluation are discussed below. The rationale used to develop this methodology and the statistical techniques is based on the following sources:

- RAGS Part A
- *Supplemental Guidance to RAGS: Calculating the Concentration Term*, May 1992
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987)

Microsoft Fox Pro and Borland[1] Quattro Pro will typically be used for data management and statistical calculations. For each set of data used to describe the concentration of chemicals in a contaminated area, the following information will be tabulated in accordance with RAGS: frequency of detection, range of quantitation limits, range of detected values, and average of

1 *References to specific software products are not to be construed as an endorsement by the U.S. Navy or E/A&H.*

detected concentrations. For datasets of 10 or more, the upper confidence limit (UCL) on the mean of log-transformed values of the concentration will be presented. In accordance with RAGS, the lesser of either the maximum concentration detected or the UCL will be used to quantify potential exposure, as detailed in Section 4, Exposure Assessment.

3.4 Selection of COPCs

The substances detected (chemicals present in site samples, or CPSSs) will be screened to develop a list or group of COPCs. COPCs are, therefore, chemicals selected by comparison to screening concentrations, intrinsic toxicological properties, persistence, fate and transport characteristics, and cross-media transport potential. The nature and general extent of CPSSs will be referenced in this section of the site-specific HHRAs. To reduce the list of CPSSs and focus the risk assessment on COPCs, the following two comparisons will be performed.

3.4.1 Comparison of Site-Related Data to Risk-Based Screening Concentrations

The maximum concentrations of CPSSs detected during sampling will be compared to risk-based screening values. These values will be obtained from *Risk Based Screening Concentrations*, USEPA Region III, January through June, 1996 (and subsequent versions). As stated in the EPA Region III document, a risk goal of 1E-6 will be used to calculate screening concentrations for carcinogens. RBCs will be adjusted to reflect a target HQ of 0.1 for noncarcinogens, in accordance with USEPA Region IV *Supplemental Guidance to RAGS Bulletin 1* (USEPA, November 1995). Groundwater results will be compared to tap water screening values, and reported soil concentrations will be compared to residential soil screening values. CPSSs with maximum detected concentrations exceeding their corresponding concentrations, goals, levels, and/or standards will be evaluated further and compared to reference background concentrations. In addition, surrogate screening values based on toxicological similarities will be used if no screening value are available in USEPA's table, and surrogate screening values will be noted where applied.

The maximum concentration reported for each carcinogenic polycyclic aromatic hydrocarbon (PAH) will be compared to its corresponding screening value. In addition, all carcinogenic PAH concentrations reported at that location will be converted to the benzo(a)pyrene equivalent concentration (BEQ), which will be compared to the screening value for benzo(a)pyrene. PAH conversions will be performed using current Toxic Equivalency Factors (TEFs) for PAHs in accordance with USEPA Region IV *Supplemental Guidance to RAGS Bulletin 2* (USEPA, November 1995).

3.4.2 Comparison of Site-Related Data to Background Concentrations

Background data for NSA Memphis will be referenced in this section, or background reference concentrations from E/A&H's August 27, 1996 *Reference Concentrations* technical memorandum will be used. Following comparison to risk- and hazard-based screening values, CPSSs whose maximum detected concentrations exceeded corresponding background reference concentrations will be formally assessed in the HHRA, unless otherwise noted.

The maximum reported concentration of a CPSS will be compared to its reference background concentration (when applicable). This comparison helps account for naturally occurring elements, such as beryllium, manganese, and arsenic. Thus, risk and/or hazard associated with naturally occurring elements are not addressed where their concentrations are similar to corresponding background.

In the HHRA, if the maximum concentration of a CPSS is determined to be less than either two-times mean background or the risk-based screening values, then the CPSS will not be considered further unless deemed appropriate based on chemical-specific characteristics (e.g., degradation product with greater toxicity).

3.4.3 Elimination of Essential Elements: Calcium, Iron, Magnesium, Potassium, and Sodium

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out if it is present at concentrations that are not associated with adverse health effects. Based on RAGS, the lack of risk-related data, and USEPA Region IV's recommendations, the following essential nutrients will not be included in HHRAs: calcium, iron, magnesium, potassium, and sodium.

Risk information usually obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) is necessary to calculate risk and hazard estimates (and risk-based screening values). This information is based on toxicological and epidemiological data which are critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk information (or surrogate risk information) is not always available for all CPSSs, so their risk and/or hazard will not be calculated. The results of the screening process will be tabulated in the HHRA. No risk-based screening values are available for TPH and chemical-specific analyses were performed on site samples, so exposure will not be quantified for this group of compounds. TPH constituents would be included in the chemical-specific analyses.

3.4.4 Summary of COPCs

The results of the screening evaluations will be tabulated on a medium-specific basis in the site-specific HHRAs.

3.5 Estimation of Risk and Hazard

COPCs will be identified, and exposure will be estimated for these compounds. Risk/hazard will be subsequently calculated based on exposure estimates, then exposure scenarios (e.g., soil exposure during commercial land use) exceeding USEPA acceptable limits will be identified.

An exposure scenario of concern will be identified as a scenario with incremental excess lifetime cancer risk (ILCR) estimated greater than 1E-4 or a hazard index (HI) estimated greater than 1. In the next step, COPCs exceeding 1E-6 ILCR or a HQ greater than 0.1 in a scenario of concern are retained as COCs. Section 5, Toxicity Assessment, discusses cancer risk thresholds and noncancer toxicity in detail.

4 Exposure Assessment

This section of the HHRAs will determine the magnitude of contact that a potential receptor may have with site-related COPCs. Exposure assessment involves four stages:

- Characterizing the physical setting and land use of the site.
- Identifying COPC release and migration pathway(s).
- Identifying the potential receptors, under various land use or site condition scenarios, and the pathways through which they might be exposed.
- Quantifying the intake rates, or contact rates, of COPCs.

4.1 Exposure Setting and Land Use

The site setting and land use will be detailed or referenced in this section of the site-specific HHRAs. This information is used to develop appropriate exposure estimates for different land use assumptions. If the future use of the area in question is known, this information will be used to define exposure assumptions used when calculating risk (e.g., sites known to be commercially zoned will not be assessed for residential land use).

4.2 Potentially Exposed Populations

This section will describe who may be exposed to contaminants in environmental media. The populations typically addressed will be one or a combination of the following: current site workers, hypothetical current site trespassers, as well as hypothetical future site residents. Because current site workers at most sites within NSA Memphis would be expected to have limited contact with contaminated media at most sites, worker-related exposure may be addressed exclusively for maximally exposed site workers, assuming the future worker scenario would be protective of both current and future site workers. Specifics will be discussed in this section of the site-specific HHRAs.

4.3 Exposure Pathways

This section will summarize how potential human receptors may be exposed to site media. In general, soil matrix-related pathways will include incidental ingestion and dermal contact. Ingestion and inhalation of volatilized contaminants will be typical groundwater exposure pathways. The hypothetical future scenarios will assume continuous, uniform exposure to current surface soil conditions and the use of site groundwater as a potable water source, unless otherwise noted in the site-specific HHRA. A table in the site-specific HHRA will justify and summarize exposure pathways and potential human receptors.

4.4 Exposure Point Concentrations

The EPC is the estimated concentration of a contaminant in an exposure medium that will be contacted by a real or hypothetical receptor. Determining the exposure point concentration depends on factors such as:

- Availability of data
- Amount of data available to perform statistical analysis
- Reference concentrations not attributed to site impacts
- Location of the potential receptor

USEPA Region IV guidance calls for assuming lognormal distributions for environmental data and the calculation of 95% UCL on the mean for use in exposure quantification. Applying the UCL is generally inappropriate with less than 10 samples. Therefore, the maximum concentrations detected will be used for all datasets with less than 10 samples. In general, outliers have been included when calculating the UCL because high values seldom appear as outliers for a lognormal distribution. Including outliers increases the overall uncertainty of the calculated risks and conservatively biases exposure estimates.

For sample sets of 10 and greater, the UCL will be calculated for a lognormal distribution as follows:

$$UCL = e^{\left(\bar{a}+0.5s_a^2 + \frac{H_{0.95}\ x\ s_a}{\sqrt{n-1}}\right)}$$

where:

$\bar{a}$	=	$\Sigma a/n$ = sample arithmetic mean of the log-transformed data, a = ln(x)
s_a	=	sample standard deviation of the log-transformed data
n	=	number of samples in the data set
$H_{0.95}$	=	value for computing the one-sided upper 95% confidence limit on the lognormal mean from standard statistical tables (Gilbert, 1987)

EPCs and UCLs will be summarized and tabulated when applicable in the site-specific HHRA.

4.5 Quantification of Exposure

This section describes the models, equations, and intake model variables used to quantify doses or intakes of the COPCs for the surface soil and groundwater exposure pathways. The models are designed to estimate route- and medium-specific factors, which are multiplied by the EPC

to estimate chronic daily doses. The intake model variables generally reflect 50th or 95th percentile values which, when applied to the EPC, ensure that the estimated intakes represent the reasonable maximum exposure (RME, which is considered 95th percentile). Formulae are derived from RAGS, Part A unless otherwise indicated. Table 1 lists intake model variables used to compute chronic daily intake (CDI) for potential receptors exposed to surface soil and/or groundwater contaminants.

Because NSA Memphis is part of BRAC, future site use cannot be determined with any certainty. Therefore, the conservative assumptions will be used to account for any reasonable future use. Current reuse plans will be referenced and discussed in the site-specific HHRAs. NSA Memphis media analytical results and exposure methods have been formatted to allow exposure estimates to be fine-tuned based on actual conditions as base reuse plans materialize, and this information will be used on a site-specific basis, if known.

In accordance with USEPA's recommendations, the adult and child intake variables will be combined to estimate exposure to carcinogens. This factor is referred to as the lifetime weighted average, or LWA. The LWA considers the difference in daily ingestion rates for soil and drinking water, body weights, and exposure durations for children (ages 1 to 6) and adults (ages 7 to 31). The exposure frequency is assumed to be identical for the adult and child exposure groups, and an example is shown after the equations are presented below.

Before quantifying soil exposure, it will first be necessary to derive the appropriate fraction ingested (or contacted) (FI/FC) from contaminated area factors for each applicable COPC. These factors will be derived by evaluating the spatial distribution of COPCs. The FI/FC will be computed by estimating the maximum area of a hot spot and dividing it by the total site area. These computations will be performed conservatively to account for uncertainty associated with contaminant distributions.

Table 1
Parameters Used to Estimate CDI

Pathway Parameters	Resident Adult	Resident Child	Adult Worker	Trespassing Child (age 7-16)	Units
Surface Soil Ingestion and Dermal Contact					
Ingestion Rate (soil)	100[a]	200[a]	50[a]	100[a]	mg/day
Ingestion Rate (water)	2	1	1	NA	L/day
Exposure Frequency	350[b]	350[b]	250[b]	52[f]	days/year
Exposure Duration	24[c]	6[c]	25[c]	10[g]	years
Dermal Contact Area	4,100[a]	2,900[a]	4,100[a]	4,100[a]	cm^2
Skin Adherence Factor	1	1	1	1	mg/cm^2
Absorption Factor	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	unitless
Oral Absorption Efficiency	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	unitless
Conversion Factor	1E-6	1E-6	1E-6	1E-6	kg/mg
Body Weight	70[a]	15[a]	70[a]	45[a]	kg
Averaging Time, Noncancer	8,760[d]	2,190[d]	9,125[d]	3,650[d]	days
Averaging Time, Cancer	25,550[e]	25,550[e]	25,550[e]	25,550[e]	days

Notes:
a — USEPA (1989a) *Risk Assessment Guidance for Superfund Vol. I, Human Health Evaluation Manual (Part A).*
b — USEPA (1991b) *Risk Assessment Guidance for Superfund Vol. I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final*, OSWER Directive: 9285.6-03.EPA/600/8-89/043.
c — USEPA (1991a), *Risk Assessment Guidance for Superfund: Vol. I — Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*, OSWER Directive 9285.7-01B.
d — Calculated as the product of ED (years) x 365 days/year.
e — Calculated as the product of 70 years (assumed lifetime) x 365 days per year.
f — Assuming one day per week exposure.
g — Assuming trespassing occurs during the 10-year adolescent/teenage period.
NA — Not applicable.

The FI/FC factors modify the hot spot concentrations to more closely approximate site-wide exposure conditions. When the UCL is used as EPC, no FI/FC adjustments will be made. In addition, CPSSs not eliminated from the HHRAs based on the screening comparisons described in Section 3.4 may be eliminated as a COPC because the UCL concentration does not exceed the corresponding background concentration or RBC. This will be discussed on a site-specific basis.

4.5.1 Surface Soil Pathway Exposure

Ingestion of COPCs in Surface Soil

Except CDI for a site resident's exposure to carcinogens, the following equation is used to estimate the ingestion of COPCs in soil:

$$CDI_s = (EPC_s)(IR)(EF)(ED)(F)(FI)/(BW)(AT)$$

where:

CDI_s = ingested dose (mg/kg-day)

EPC_s = exposure point concentration of contaminant in soil (mg/kg)

IR = ingestion rate (milligrams per day [mg/day])

EF = exposure frequency (days/year)

ED = exposure duration (years)

F = conversion factor (1E-6 kg/mg)

FI = fraction ingested from contaminated source (unitless)

BW = body weight (kg)

AT = averaging time (days)

The LWA is used to calculate carcinogenic CDI for site residents. An example of the LWA calculation is shown below for the soil ingestion pathway, and LWAs are similarly calculated for subsequent equations.

$$LWA = [(IR_a \times ED_a)/BW_a] + [(IR_c \times ED_c)/BW_c]$$

where:

LWA = lifetime weighted average

IR = ingestion rate (milligrams per day [mg/day])

ED = exposure duration (years)

BW = body weight (kg)

$_a$ = adult

$_c$ = child

Consequently, CDI for carcinogens would be calculated as follows for site residents:

$$CDI_s = (EPC_s)(EF)(LWA)(F)(FI)/(AT)$$

where:

CDI_s = ingested dose (mg/kg-day)

EPC_s = exposure point concentration of contaminant in soil (mg/kg)

EF = exposure frequency (days/year)

F = conversion factor (1E-6 kg/mg)

FI = fraction ingested from contaminated source (unitless)

AT = averaging time (days)

LWA = lifetime weighted average

Dermal Contact with COPCs in Surface Soil

The following equation is used to estimate intake due to dermal contact with COPCs in soil:

$$CDI_{sd} = (EPC_s)(CF)(EF)(ED)(F)(FC)(ABS)(AF)/(BW)(AT)$$

where:

CDI_{sd} = dermal dose (mg/kg-day)

EPC_s = exposure point concentration of contaminant in soil (mg/kg)

CF = contact factor (cm^2)

EF = exposure frequency (days/year)

ED = exposure duration (years)

F = conversion factor (1E-6 kg/mg)

FC = fraction contacted from contaminated source (unitless)

ABS = absorption factor (unitless value, specific to organic versus inorganic compounds)

AF = adherence factor (milligrams per square centimeter [mg/cm^2])

BW = body weight (kg)

AT = averaging time (days)

4.5.2 Groundwater Pathway Exposure

Ingestion and Inhalation of COPCs in Groundwater

The following equation is used to estimate the ingestion and/or inhalation of COPCs in groundwater:

$$CDI_w = (EPC_w)(IR)(EF)(ED)(FI)/(BW)(AT)$$

where:

CDI_w = ingested/inhaled dose (mg/kg-day)

EPC_w = exposure point concentration of contaminant in water (milligrams per liter [mg/L])

IR = ingestion rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

FI = fraction ingested from contaminated source (unitless)

BW = body weight (kg)

AT = averaging time (days)

HHRAs are comprised of many tables, and intake tables serve only as an intermediate check when reviewing the document. The CDI equations above can be solved assuming a concentration of 1, and the result can be used as a universal multiplier. Multipliers were developed for each typical land use scenario and are shown in Table 2. Consequently, a significant number of the tables in HHRAs can be eliminated. An example of the abbreviated CDI method is shown below:

$$CDI = (EPC)(M)$$

where:

CDI = chronic daily intake (mg/kg-day)

EPC = exposure point concentration (mg/kg or mg/L)

M = multiplier specific to the exposure scenario, land use, and potential receptor selected

Table 2
Multipliers* Used to Estimate Chronic Daily Intake

		Soil		Groundwater
		Ingestion	*Dermal Contact*	*Ingestion*
Exposure Pathway	**Exposure Type**	**All Chemicals**	**Organics****	**All Chemicals*****
Resident	Noncarcinogens (adult)	1.37E-06	5.62E-07	2.74E-02
	Noncarcinogens (child)	1.28E-05	1.85E-06	6.39E-02
	Carcinogens (LWA)	1.57E-06	3.51E-07	1.49E-02
Trespasser	Noncarcinogens	3.17E-07	1.30E-07	NA
(age 7-16)	Carcinogens	4.52E-08	1.85E-08	NA
Site-Worker	Noncarcinogens	4.89E-07	4.01E-07	9.78E-03
	Carcinogens	1.75E-07	1.43E-07	3.49E-03

Notes:

LWA = Lifetime weighted average

* = The product of the multiplier and the exposure point concentration equals the chronic daily intake for a given chemical assuming a reasonable maximal exposure scenario

** = The multiplier for inorganics is multiplied by a factor of 0.1 to account for the dermal absorption factor of 0.001 for inorganics; the multiplier for organic compounds includes the 0.01 factor.

*** = The ingestion intake is also used to address inhalation risk in accordance with USEPA's Supplemental Guidance To RAGS Bulletin 3; ingestion risk is approximately equal to risk posed by dermal and inhalation exposure while showering, and this is applied to volatile organic compounds only.

NA = Not applicable

Because multipliers can be reviewed separately, CDI will be incorporated into the risk and hazard equations and will not be presented in separate tables.

5 Toxicity Assessment

5.1 Carcinogenicity and Noncancer Effects

USEPA has established a classification system for rating the potential carcinogenicity of environmental contaminants based on the weight of scientific evidence. The cancer classes are described below. Cancer weight-of-evidence class "A" (human carcinogens) means that human toxicological data have shown a proven correlation between exposure and the onset of cancer (in varying forms). The "B1" classification indicates some human exposure studies have implicated the compound as a probable carcinogen. Weight-of-evidence class "B2" indicates a possible human carcinogen based on confirmatory carcinogenic laboratory animal data. Weight-of-evidence class "C" identifies possible human carcinogens, and class "D" indicates a compound not classifiable with respect to its carcinogenic potential. A class "A" compound posing risk higher than USEPA's acceptable risk range has more weight than would a class "C" compound. There is more uncertainty in the lower classifications, so the weight-of-evidence should be used by risk managers when making risk management decisions based on cancer risk.

USEPA has established slope factors (SF) for carcinogenic compounds. The SF is defined as a "plausible upper-bound estimate of the probability of a response (cancer) per unit intake of a chemical over a lifetime" (RAGS, Part A). Upper-bound estimates are more likely to overestimate cancer potential.

In addition to potential carcinogenic effects, most substances also can produce other toxic responses at doses greater than experimentally derived threshold concentrations. USEPA has derived reference dose (RfD) values for these substances. A chronic RfD is defined as, "an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure concentration for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." These

toxicological values are used in risk formulae to assess the upper-bound level of cancer risk and noncancer hazard associated with exposure to a given chemical concentration.

For carcinogens, the potential risk posed by a chemical is computed by multiplying the CDI (as mg/kg-day) by the SF (in reciprocal mg/kg-day). The HQ (for noncarcinogens) is computed by dividing the CDI by the RfD. USEPA has set standard limits (or points of departure) for carcinogens and noncarcinogens to evaluate whether significant risk is posed by a chemical (or combination of chemicals). For carcinogens, the point-of-departure range is 1E-6, with a generally accepted range of 1E-6 to 1E-4. These risk values correlate with one in 10,000 (1E-4) and one in 1 million (1E-6) excess cancer incidence resulting from exposure to toxic compounds from outside the body.

For noncarcinogens, other toxic effects are generally considered possible if the HQ (or sum of HQs for a pathway-hazard index) exceeds the threshold value of 1. Although both cancer risk and noncancer hazard are generally additive only if the target organ is common to multiple chemicals, a most conservative estimate of each may be obtained by summing the individual risks or hazards, regardless of target organ. Site-specific HHRAs for NSA Memphis will take the universal summation approach for each class of toxicant. Details regarding the risk formulae applied to site data are provided in Section 6, Risk Characterization.

Critical studies used in establishing toxicity classifications by USEPA are shown in the IRIS database, which is the primary source for information necessary to estimate risk. HEAST, Fiscal Year 1995 is the secondary source for this information. In addition, USEPA's National Center for Environmental Assessment (NCEA) will be used as a source when necessary. In accordance with RAGS, a table will summarize toxicological data in the site-specific HHRAs in the form of RfDs and SFs obtained for COPCs identified in site media, as well uncertainty/modifying factors, target organs, and cancer classes (where available).

5.2 Evaluating Dermal Exposure and the Resulting Toxicity

In accordance with USEPA Region IV's *Supplemental Guidance to RAGS Bulletin 2*, dermal RfD values and SFs are derived from the corresponding oral values. As described in the supplemental guidance, the oral RfD is multiplied by an oral absorption efficiency factor (OAF), expressed as a decimal. The resulting dermal RfD is based on the absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than administered (intake) doses. For the same reasons, a dermal SF is derived by dividing the oral SF by the OAF. The oral SF is divided rather than multiplied because SFs are expressed as reciprocal doses.

Appendix A of RAGS, Part A states that in the absence of specific data, an assumption of 5% oral absorption would be relatively conservative. *Supplemental Guidance to RAGS: Region IV Bulletin 2* indicates that in the absence of specific data, USEPA Region IV suggests an oral absorption factor of 80% for volatile organics, 50% for semivolatile organics, and 20% for inorganic chemicals. These percentages (or associated fractions) will be used in the site-specific HHRAs

5.3 Toxicity Profiles for COPCs

In accordance with RAGS, toxicological summary paragraphs will be included in the body of the HHRA text for all COPCs. Most information for the profiles will be gleaned from IRIS and HEAST. Another source of information will be NCEA. Any additional references will be noted specifically in the text. The profiles will summarize adverse effects of COPCs and the amount associated with such effects.

6 Risk Characterization

Risk characterization combines the exposure assessment and toxicity assessment results to yield qualitative and quantitative expressions of risk and/or hazard for the exposed receptors. The quantitative component expresses the probability of developing cancer, or a threshold comparison of the estimated dose with a reference dose for noncancer effects. These quantitative estimates

are developed for individual chemicals, exposure pathways, transfer media, and source media, and for each receptor for all media to which one may be exposed. The qualitative component usually involves comparing COC concentrations in media with established criteria or standards for chemicals for which there are no corresponding toxicity values. The risk characterization helps guide risk-management decisions.

Generally, the risk characterization will follow the methodology prescribed by RAGS Part A, as modified by more recent information and supplemental guidance cited in the earlier sections of this memorandum. *The USEPA methods are designed to be health-protective and tend to overestimate risk rather than underestimate it. The risk results, therefore, are generally overly conservative, because risk characterization involves summing the overestimated risk estimates.*

6.1 Risk Characterization Methodology

Potential excess risks to humans following exposure to COPCs will be estimated using methods established by USEPA, when available. As discussed above, these methods are health-protective and are likely to overestimate risk. Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also pose a noncarcinogenic hazard. The potential human health effects associated with chemicals that produce carcinogenic and other toxic effects will be characterized separately, as discussed below.

6.1.1 Carcinogenic Effects of Chemicals

The risk attributed to exposure to carcinogens is estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (EPA, 1989a):

$$ILCR=(CDI)(SF)$$

where:

ILCR	=	incremental lifetime excess cancer risk, a unitless expression of the probability of developing cancer, adjusted for reference incidence
CDI	=	chronic daily intake, averaged over 70 years (mg/kg-day)
SF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

For a given pathway with simultaneous exposure of a receptor to several carcinogens, the following equation is used to sum cancer risks:

$$Risk_p = ILCR(chem_1) + ILCR(chem_2) + \ldots ILCR(chem_i)$$

where:

$Risk_p$	=	total pathway risk of cancer incidence
$ILCR(chem_i)$	=	incremental lifetime excess cancer risk for a specific chemical

Cancer risk for a given receptor across pathways and across media is summed in the same manner.

6.1.2 Noncarcinogenic Effects of Chemicals

The risks associated with the noncarcinogenic effects of chemicals are evaluated by comparing an exposure level or intake with a reference dose. The HQ, defined as the ratio of intake to RfD, is defined as (RAGS, Part A):

$$HQ = CDI/RfD$$

where:

HQ	=	hazard quotient (unitless)
CDI	=	intake of chemical (mg/kg-day)
RfD	=	reference dose (mg/kg-day)

Chemical noncarcinogenic effects are evaluated on a chronic basis, using chronic RFD values. An HQ of 1 indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be a concern for potential adverse health effects.

In the case of simultaneous exposure of a receptor to several chemicals, an HI will be calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \ldots HQ_i$$

where:

HI	=	Hazard Index (unitless)
HQ	=	Hazard Quotient (unitless)

Risk and hazard projections will be summarized in tabular format on a medium- and exposure pathway-specific basis in the HHRAs.

6.2 Surface Soil Pathways

Generally, the incidental ingestion and dermal contact pathways will be characterized for surface soil. Surface soil onsite will be evaluated under scenarios and exposure pathways outlined in the site-specific HHRAs.

6.3 Groundwater Pathways

Groundwater pathways will typically consist of ingestion and inhalation of volatilized chemicals in groundwater. The site-specific HHRAs will detail the pathways which will be addressed. Most groundwater pathways are not complete because municipal water supplies are used, and this will be discussed in the HHRAs.

6.4 COCs Identified

COCs will be identified based on cumulative (all pathway) risk and hazard projected for the sites. USEPA has established a generally acceptable risk range of 1E-4 to 1E-6, and an HI threshold of 1.0. Any COPC that is carried through the risk assessment process and found to contribute to a scenario with an ILCR in excess of 1E-4 or HI greater than 1 for any of the exposure scenarios evaluated in this risk assessment, and has an individual exposure pathway risk greater than 1E-6 or exposure pathway HQ greater than 0.1, will be referred to as a COC. A table will present the COCs identified in site-specific HHRAs.

7 Risk Uncertainty

This section will discuss the uncertainty and variability inherent in the risk assessment process in addition to site-, medium-, and exposure pathway-specific influences. Overall, uncertainties associated with the initial stages of the risk assessment process become magnified when they are combined with other uncertainties. It is not possible to eliminate all uncertainties; however, recognizing the uncertainties is fundamental to understanding and subsequently using risk assessment results.

Where chronic RME estimates of risk/hazard indicated a significant threat (e.g., ILCR greater than 1E-4) would be posed to human health, central tendency (CT) analysis may be performed. RME estimates are based on the upper bound (90th or 95th percentile) exposure assumptions, while CT estimates are based on the 50th percentile (mean or median) values. CT exposure scenarios are constructed consistent with standard CT exposure assumptions provided in *Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure-Draft* (USEPA, November 1993). CT exposure assumptions will be presented in the site-specific HHRAs, when applicable.

8 Risk Summary

Risk estimates will be presented and summarized in table form in the site-specific HHRAs.

9 Remedial Goal Options

RGOs are chemical concentrations computed to equate with specific risk and/or hazard goals that may be established for a particular site. As previously discussed, COCs are identified as any COPC that significantly contributes to a scenario of concern. A pathway having a combined ILCR greater than 1E-4 or an HI greater than 1 is defined as a scenario of concern, and an individual chemical which contributes either 1E-6 ILCR or 0.1 HI to one exposure pathway is considered to significantly contribute to the scenario ILCR or HI. Based on this method, COCs may be identified, requiring RGO calculation. Inclusion in the RGO table does not necessarily indicate that remedial action will be required to address a specific chemical. Instead, RGOs are provided to facilitate risk-management decisions.

In accordance with USEPA Supplemental RGO Guidance, RGOs will be calculated at 1E-4, 1E-5, and 1E-6 risk levels for carcinogenic COCs and HI goals of 3, 1, and 0.1 for noncarcinogenic COCs. RGOs will be based on specific scenarios which will be identified in the site-specific HHRAs.