RISK-BASED CLOSURE

1. Introduction

This document discusses the protocol for conducting a risk assessment to implement closure of hazardous waste management unit (HWMU) in accordance with Title 9 of the Virginia Administrative Code, Section 20-60-10 et seq. (Formerly the Virginia Hazardous Waste Management Regulations).

1. Risk-Based Evaluation In order to estimate the risk for chemicals of concern (COCs) a risk assessment will be conducted according to the Virginia DEQ document titled "Guidance for development of health based cleanup goals using decision tree/REAMS program (herein after "Virginia Risk Guidance") (November 1, 1994) prepared by Old Dominion University and the approved closure plan. The risk assessment report will contain the following sections:

- site evaluation,
- development of a site conceptual model,
- identification of contaminants of concern,
- identification of media and exposure pathways,
- toxicity assessment,
- estimation of contaminant concentration at the point of exposure, and
- summary of health risks.

The submission instructions contained in Appendix IX of the Virginia Risk Guidance will be reviewed prior to submitting the report to confirm that all necessary risk issues have been addressed. The risk goals/performance standards will be a hazard index of 1.0 for non-carcinogens and an individual carcinogenic risk of 1E-06 and cumulative carcinogenic risk of 1E-04.

Compliance with the closure standard will be verified by comparing the calculated individual and cumulative risk/hazard for all the contaminants of concern (COC) that failed background comparison to the risk-based performance standards.

The risk assessment will be conducted assuming a future residential/industrial use of the property. The methodology/equation for estimating the exposure concentration is presented in subsequent sections.

The initial step in the risk assessment will be to develop a site conceptual exposure model (SCEM) which depicts all potential exposure routes and media for the site and the receptors which may be exposed. The procedure for identification of contaminants of concern for health based is presented in Section 2.

Once the SCEM is completed, the exposure assumptions outlined in the Virginia Risk Guidance will be employed to estimate the health risks and develop a cleanup criteria. Information will also be taken as needed from U.S. EPA documents and databases (e.g., the Risk Assessment Guidance for Superfund (RAGS), and the Integrated Risk Information System (IRIS)). The chemical intake equations and exposure parameter assumptions used to calculate estimate risks (obtained from Virginia risk assessment guidance/REAMS) are shown in Tables 1 through 4. Additional details on the approach and assumptions used for each potential exposure pathway are provided below.

As a part of the Risk Exposure and Analysis Modeling System (REAMS) evaluation, fate and transport modeling is necessary to demonstrate that the residual soil concentrations of contaminants of concern would not result in contamination of other environmental media of concern including the groundwater underneath the closure unit. The SESOL module evaluates likelihood for the transport of contaminants to other media and estimates the transfer load. For this purpose, representative soil sample(s) will be collected around the unit (subjected to closure) for analysis of the physical properties listed on page 62 of the REAMS document. Specifically, site-specific soil data will include at a minimum bulk density and porosity. Weather data to be used in the REAMS model will be obtained from the State Climatology Office in Charlottesville.

2. Identification of Contaminants of Concern

Contaminants of concern includes those constituents detected during the closure soil sampling which may be related to past waste management practices and whose concentrations statistically exceeded background levels. Please note that if the concentration of inorganic contaminants detected in the soil did not exceed the background levels, no further risk-based evaluation will be required. Only those inorganic constituents of concern having concentrations that are statistically greater than background concentrations and all detected organic contaminants will be subject to REAMS evaluation to estimate the risks.

3. Exposure Assessment

The exposure assessment will identify transport mechanisms for the contaminants of concern that may potentially impact human receptors. The results of this assessment will be used to document the current and future exposure potential posed by the site.

With regard to soil, the following exposure assumptions will apply. Initially, a residential exposure will be assumed for the purpose of attempting to document unrestricted closure of the soil. If the risk for potential residential exposure does not exceed the performance standards, unrestricted closure of soil will be documented/accepted. If the site cannot be clean closed for residential use, then the option to pursue restricted closure (commercial/industrial) will be exercised. Closure to commercial/industrial scenario will require the facility to enact a deed restriction that eliminates the possibility of future residential use of the site. The requirements for establishing such a deed restriction are detailed in VDEQ's Guidelines for Developing Health-Based Cleanup Goals Using Risk Assessment at A Hazardous Waste Site

Facility for Restricted Industrial Use, dated June 1995.

Exposure routes will include ingestion, dermal absorption, and inhalation of vapors and dust particles.

With regard to groundwater, REAMS fate and transport modeling[1] will be required to assess residual soil contamination impacts to the groundwater. If the groundwater does not qualify for clean closure, the scope of future groundwater monitoring will be discussed with VDEQ. The groundwater exposure routes to be evaluated include ingestion, dermal absorption, and inhalation of volatiles emitted from the contaminated groundwater.

The exposure assumptions presented in the following sections are based on residential exposure. These constitute a reasonable maximum exposure scenario (RME), an exposure which is unlikely to occur but is reasonably possible. The exposure pathways for residential exposure include ingestion of soil, dermal contact with soil, inhalation of resuspended soil particulates, and inhalation of volatile organic compounds. Potential exposure to groundwater at the site will be evaluated

3.1.1 Ingestion of Soil

The equation for potential chemical intake by soil ingestion for residential scenario on site is included in Table 1. This scenario also assumes that weather or other conditions (e.g., frozen ground/ snow /other cover) do not affect exposure and that all soil ingested is from contaminated areas of the site. These assumptions are protective of human health and the environment.

3.1.2 Dermal Contact with Soil

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[1] REAMS includes the unsaturated zone fate and transport model SESOIL. The purpose of running the model is two fold: a) determine whether the contaminants will reach the groundwater table in next 30 years. b) calculate the risk associated with the estimated concentration in the groundwater. For constituents with a promulgated MCL, the estimated concentration will be directly compared against the MCL. However, prior to running the SESOIL model the facility should obtain all the information identified on page 62, of the Virginia guidance document. The closure report must include evaluation of model results (concentrations reaching the groundwater) and a copy of SESOIL output file.

The equation for calculating the potential absorbed chemical dose by dermal contact with contaminated soil is provided in table 1. This scenario assumes that weather or other conditions (e.g., frozen ground/ snow or other cover) do not affect exposure, that contaminated soil remains on the skin long enough for the COCs to be absorbed and that all soil adhering to the skin is from contaminated areas of the site.

The skin surface areas (SA) used in the dermal pathway have been identified in REAMS guidance as 4,860 cm^2 for adults, which is the 50th percentile value for the arms, hands and lower legs (U.S. EPA, 1989b - See Attachment A).

A skin-soil adherence factor of 1.45 mg/cm^2 will be used in the dermal intake calculations. The U.S. EPA guidance for dermal exposure assessment (Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B) states that a range of values from 0.1 mg/cm^2 to 1.5 mg/cm^2 per event appear possible for dermal adherence factors (AF). In order to estimate the amount of a particular COC which may potentially be absorbed through the skin, chemical-specific dermal absorption factors (ABS_{derm}) are used.

3.1.3 Inhalation of Resuspended Soil

The equation for potential chemical intake by inhalation of resuspended contaminated soil is included in Table 1. An inhalation rate of 0.83 m^3/hr will be used as specified in the Virginia Risk Guidance. This scenario assumes that the concentration of COCs in indoor dust will be equal to that in outdoor soil and that weather or other conditions, (e.g., frozen ground/snow or other cover) do not affect resuspension or exposure.

However, an appropriate model or equations in table-1, will be used to estimate the potential amount of respirable particulate matter generated by wind erosion. The estimated generation rate for eroded particulate matter will then be used derive an ambient air particulate concentration. Documentation for these models will be presented to the Department.

3.1.4 Inhalation of Volatilized COCs in Soil

Since the COCs have appreciable vapor pressures, they are expected to volatilize from soil. Inhalation of COCs as volatilized vapors is considered for this risk assessment. The equations in Table-1 will be considered for estimating the intake for this condition.

4. Toxicity Assessment

The two principle indices of toxicity used in risk assessment are the reference dose (RfD) and the cancer slope factor (SF). An RfD is the intake or dose per unit of body weight (mg/kg-day) that is unlikely to result in toxic (non-carcinogenic) effects to human populations, including sensitive subgroups (e.g., the very young or elderly). The RfD allows for the existence of a threshold dose below which no adverse effects occur.

The SF is used to express the cancer risk attributable to a discrete unit of intake; that is, the cancer risk per milligram ingested per kilogram of bodyweight per day ($[mg/kg\text{-}day]^{-1}$). The SF is an estimate of the upper-bound probability of an individual developing cancer as a result of exposure to a particular carcinogen. Unlike the RfD, the SF assumes that there is no threshold dose below which the probability of developing cancer is zero. Note that SFs are only developed for those chemicals which have been shown to be carcinogens in man or in at least several animal species. A carcinogenic weight of evidence rating is used to describe the strength of the experimental evidence for carcinogenicity. The U.S. EPA has developed SFs for most chemicals with weight of evidence ratings of "A" (known human carcinogen) or "B" (probable human carcinogen).

RfDs and SFs are derived by the U.S. EPA for the most toxic chemicals generally associated with chemical releases to the environment for which adequate toxicological data are available. If both the carcinogenic and non-carcinogenic effects of a particular compound are significant, both values may be established. However, in most cases only one value is available.

4.1 Inhalation and oral RfDs and SFs -

SFs pertinent to the oral and inhalation exposure pathways will be obtained from U.S. EPA's IRIS database. The IRIS (Integrated Risk Information System) on-line database was established by the U.S. EPA to provide risk assessors with peer reviewed toxicological data on chemicals commonly encountered at environmental sites of contamination. If data is not available from IRIS, it will be obtained from the Health Effects Assessment Summary Tables (HEAST), a compilation of toxicity values produced by the USEPA on a quarterly basis. The hierarchy presented in Appendix III of Virginia Risk guidance will be followed for using these sources.

4.2 Dermal RfDs and SFs -

Chemical specific oral-route absorption values (ABS_{oral}) are used to adjust the oral RfD or SF, which is computed from an administered dose, for use in the dermal exposure pathway. This correction is necessary due to the differences in absorption between the skin and the gastrointestinal tract. By correcting the administered-dose oral RfD or SF for the fraction expected to be absorbed in the gut, a dermal absorption factor can be used to estimate the correct dose received through the skin.

5. Evaluation of Risks

Using the toxicity criteria and identified exposure pathways discussed above, and the procedures described in the VDEQ guidance document (REAMS, November 1994), the risks presented by the COC will be estimated. The estimated risks will consider the effects from multiple constituents and all routes of exposure. The risk goals will be a total cumulative hazard index of 1.0 for multiple noncarcinogens and a total cumulative carcinogenic risk of 1E-04 for multiple carcinogens. However, the risk from each individual carcinogen shall not exceed 1E-06 (i.e., one case of cancer per 1,000,000 population).

5.1 Estimation of exposure concentration

For the contaminants detected at the site, an exposure point concentration (EPC) for each exposure pathway will be calculated for each contaminant by estimating the 95th upper confidence limit (UCL) on the arithmetic mean of the concentrations. If the calculated 95th UCL is greater than the maximum detected concentration, then the maximum detected concentration will be used as the EPC. The risks for contaminants will be calculated as per the equations and assumptions described in Table 1 through Table 4. If for a contaminant both carcinogenic and noncarcinogenic risk-based cleanup goal exists, the lower of the two will be used as a pathway specific to estimate the risk.

5.2. Risk Estimation

Health risk assessments are based on the relationship between risk, dose and toxicity:

$$Risk = Dose * Toxicity$$

Since dose is the product of the contaminant concentration multiplied by exposure (the intake), equation (1) becomes:

$$Risk = Intake\ rate * Contaminant\ conc. * Toxicity$$

(Please note that the term CDI in attached tables 1-4, includes intake rate and contaminant conc)

To estimate the intake, the exposure equations and assumptions discussed in Section 1, are used. The intake estimates for each route of exposure are then combined with the RfDs or SFs to determine the resulting risk.

For Carcinogens Risk:

$$Cancer\ Risk = (Intake_{oral} * Cont.\ conc. * SF_{oral})$$

$$+ (Intake_{inhal} * Cont.\ conc. * SF_{inhal}) + (Intake_{derm} * Cont.\ conc. * SF_{derm})$$

For Noncarcinogens:

$$Hazard\ Index = (Intake_{oral} * Cont.conc. * \frac{1}{RfD_{oral}}) + (Intake_{inhal} * Cont.conc. * \frac{1}{RfD_{inhal}})$$
$$+ (Intake_{derm} * Cont.conc. * \frac{1}{RfD_{derm}})$$

where, taking into account all COCs and relevant exposure pathways, the excess cancer risk is 10^{-6} or the hazard index is 1.0.

Using REAMS software a maximum acceptable contaminant concentrations will be calculated which meets the cumulative risk criteria. This process will be used in this risk assessment to derive the health-based cleanup criteria for the site. If the estimated risks satisfy the risk based performance standards, the soils/groundwater will be considered clean closed.

Table 1
Risk Assessment Algorithm for Carcinogenic Exposure

Exposure Route	[illegible]	
	Residential Exposure	[illegible]
Ground Water		
Ingestion	$\dfrac{CW \times IRW_{adj} \times EF}{AT_c}$	$\dfrac{CW \times IRW_a \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation	$\dfrac{CW \times IRA_{adj} \times EF \times K}{AT_c}$	$\dfrac{CW \times IRA_a \times EF_o \times ED_o \times K}{BW_a \times AT_c}$
Dermal	$\dfrac{CW \times SAW_{adj} \times PC \times ET \times EF \times CF}{AT_c}$	$\dfrac{CW \times SAW_a \times PC \times ET \times EF_o \times ED_o \times CF}{BW_a \times AT_c}$
Soil		
Ingestion	$\dfrac{CS \times IRS_{adj} \times CF \times FI \times EF}{AT_c}$	$\dfrac{CS \times IR \times CF \times FI \times EF_o \times ED_o}{BW_a \times AT_c}$
Dermal	$\dfrac{CS \times CF \times SAS_{adj} \times AF \times ABS \times EF}{AT_c}$	$\dfrac{CS \times CF \times SAS_a \times AF \times ABS \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation of vaporizing VOCs from soil	$\dfrac{CS \times 1/VF \times IRA_{adj} \times ET \times EF}{At_c}$	$\dfrac{CS \times 1/VF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation of emitting particles from soil	$\dfrac{CS \times 1/PEF \times IRA_{adj} \times ET \times EF}{AT_c}$	$\dfrac{CS \times 1/PEF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_c}$

Table 2
Risk Assessment Algorithm for Non-carcinogenic Exposure

Exposure Route	[illegible]	[illegible]
Ground Water		
Ingestion	$\frac{CW \times IRW_c \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CW \times IRW_a \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation	$\frac{CW \times IRA_c \times EF \times ED_c \times K}{BW_c \times AT_n}$	$\frac{CW \times IRA_a \times EF_o \times ED_o \times K}{BW_a \times AT_n}$
Dermal	$\frac{CW \times SAW_c \times PC \times ET \times EF \times ED_c \times CF}{BW_c \times AT_n}$	$\frac{CW \times SAW_a \times PC \times ET \times EF_o \times ED_o \times CF}{BW_a \times AT_n}$
Soil		
Ingestion	$\frac{CS \times IRS_c \times CF \times FI \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times IRS_a \times CF \times FI \times EF_o \times ED_o}{BW_a \times AT_n}$
Dermal	$\frac{CS \times CF \times SA_c \times AF \times ABS \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times CF \times SA \times AF \times ABS \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation of vaporizing VOCs from soil	$\frac{CS \times 1/VF \times IRA_c \times ET \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times 1/VF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation of emitting particles from soil	$\frac{CS \times 1/PEF \times IRA_c \times ET \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times 1/PEF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_n}$

Note: Occupational noncarcinogenic risk assessment is based on adult exposure

Table 3
Age Adjusted Factors

$$IRA_{adj} = \frac{ED_c \times IRA_c}{Bw_c} + \frac{(ED_{tot} - ED_c) \times IRA_a}{BW_a}$$

$$IRW_{adj} = \frac{ED_c \times IRW_c}{Bw_c} + \frac{(ED_{tot} - ED_c) \times IRW_a}{BW_a}$$

$$SAW_{adj} = \frac{ED_c \times SAW_c}{Bw_c} + \frac{(ED_{tot} - ED_c) \times SAW_a}{BW_a}$$

$$IRS_{adj} = \frac{ED_c \times IRS_c}{Bw_c} + \frac{(ED_{tot} - ED_c) \times IRS_a}{BW_a}$$

$$SAS_{adj} = \frac{ED_c \times Sa_c}{Bw_c} + \frac{(ED_{tot} - ED_c) \times SA_a}{BW_a}$$

Note regarding age adjusted factor:

Because contact rate with tap water, ambient air, and residential soil are different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age adjusted factor. These factors approximate the integrated exposure from birth until age 30 by combining contact rates, body weights, and exposure durations for two age groups - small children and adults.

Table 4
Exposure Variables Included in Tables 1, 2, and 3

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ABS	Absorption factor	-	User specified	
AF	Adherence factor	-	1.45	a, c
AT_c	Averaging time carcinogens	days	25550	
AT_n	Averaging time non-carcinogens	days	ED x 365	
BW_a	Body weight adult	kg	70	c
BW_c	Body weight child	kg	15	c
CF	Conversion factor	-	0.000001	-
CS	Chemical concentration in soil	mg/Kg-day	User specified	
CW	Chemical concentration in water	mg/L	User specified	
ED_C	Exposure duration child	years	6	c
ED_{total} ED	Exposure duration for carcinogen total or Residential	years	30	c
ED_O	Exposure duration occupational	years	25	c
EF	Exposure frequency residential	days	350	c
ET	Exposure Time General/Occupational Groundwater Surface Water - ingestion Surface water - dermal Air -inhalation	hrs/day	8.0 0.2 2.6 2.6 24.0	c, d
FI	Fraction ingested Residential Occupational	-	1.0 0.5	b
IRA_a	Inhalation rate air adult	m^3/day	20	b
IRA_{adj}	Inhalation rate - air adjusted	-	11.66	
IRA_c	Inhalation rate child	m^3/day	12	b
IR	Ingestion rate food Fruit/veggies Fish	kg/day	0.28 0.122 0.054	c,d

Symbol	Term	Unit	Value	Reference
IRS_a	Ingestion rate soil adult	mg/day	100	b
IRS_c	Ingestion rate soil child	mg/day	200	b
IRS_{adj}	Ingestion - soil adjusted	-	114.29	
IRW_a	Ingestion rate water adult	L/day	2	b
IRW_{adj}	Ingestion -water adjusted	L-y/kg-d	1.09	
IRW_c	Ingestion rate water child	L/day	1	b
K	Volatilization factor, water to air	-	0.5	
PC	Permeability constant	cm/hr	User specified	b
PEF	Particulate emission factor	m^3/kg	6.789926E08	f
SAW_c	Surface area child groundwater dermal surface water dermal	cm^2	7500	b,e
SAS_a SAS_c	Surface area soil occupational - adult child	cm^2/event	4500 1875	e
SAS_{adj}	Surface area soil ajusted	cm^2/event	2290	
SAW_a	Surface area for water contact adult	cm^2	820	b
SAW_{adj}	Surface area for water contact	cm^2/event	9200	
VF	Volatilazation factor, soil to air	m^3/kg	User specified	-

References:

a. Risk Assessment Guidance for Superfund, Volume I, EPA/540/1-89/002, December 1989.

b. Region III values

c. Exposure Factors handbook, EPA/600/8-89/043, July 1989

d. Human health evaluation manual supplemental guidance, OSWER Directive 9285.6-03. March 25, 1991.

e. Dermal exposure Assessment, Principles and Applications, Interim Report. EPA/600/8-91/011b. January 1992.

f. Technical Background Document for Draft Soil Screening Level Guidance. Office of Solid Waste and Emergency Response. EPA/540/R-94/101. December 1994.