State of Alaska

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES REMEDIATION PROGRAM

Cumulative Risk Guidance

January 1, 2006

TABLE OF CONTENTS

TABLE OF CONTENTS 2

PURPOSE AND OVERVIEW 4

BACKGROUND 4

CARCINOGENS 6

NONCARCINOGENS 7

CHEMICALS TO INCLUDE 7
- Petroleum Hydrocarbons 8
- PCBs 8
- Dioxins 8
- Lead 8

ADDING CHEMICALS NOT IN DEC TABLES 9

ACCOUNTING FOR BACKGROUND CONCENTRATIONS 9

ACCOUNTING FOR PETROLEUM HYDROCARBONS 9

CUMULATIVE RISK CALCULATIONS FOR METHOD THREE 11

ADDITIONAL PATHWAYS TO INVESTIGATE 11

CUMULATIVE RISK AND GROUNDWATER 11

ROUNDING IN CUMULATIVE RISK 12

ECOLOGICAL RECEPTORS 13

REFERENCES 14

EXAMPLES 16
- Example 1: Carcinogenic Cumulative Risk 16
- Example 2: Hazard Index 19
- Example 3: Inclusion of Chemicals Not in DEC Tables 22
- Example 4: Cumulative Risk and Method Three 25
- Example 5: Cumulative Risk and Groundwater 28

Appendix A: Worksheet for Calculating Cumulative Risk 32

Appendix B: Method Two Risk-Based Concentrations 33

Appendix C: Risks Associated with Table C Levels 33

PURPOSE AND OVERVIEW

The Alaska Department of Environmental Conservation (DEC) has developed rules for determining the necessity for and degree of cleanup required to protect human health, safety, and welfare and the environment at contaminated sites under the Contaminated Sites Program (CS). These regulations are found at 18 AAC 75, Article 3. The purpose of this Guidance is to clarify DEC policy for calculating cumulative risk.

If applying cleanup levels under methods two, three, or four or applying groundwater cleanup levels, a responsible party must ensure that cumulative carcinogenic risk and hazard index standards are not exceeded. Under 18 AAC 75.325(g), if using method two or three for applicable soil cleanup levels or applying groundwater cleanup levels, a responsible person shall ensure that, "…after completing site cleanup, the risk from hazardous substances does not exceed a cumulative carcinogenic risk standard of 1 in 100,000 across all exposure pathways and a cumulative noncarcinogenic risk standard at a hazard index of 1 across all exposure pathways."

Under 18 AAC 75.325(h), a responsible person proposing an alternative cleanup level under method four shall ensure that, "…the risk from hazardous substances does not exceed a cumulative carcinogenic risk standard of 1 in 100,000 across all exposure pathways and a cumulative noncarcinogenic risk standard at a hazard index of 1 for all exposure pathways."

Under method four and 18 AAC 75.325(h), "…the department may consider a risk standard consistent with the range acceptable under 40 C.F.R. 300.430, revised as of July 1, 2002." This risk range applies to carcinogens only. Under 40 C.F.R. 300.430, an acceptable risk standard is an excess cancer risk to an individual of 1 in 10,000 to 1 in 1,000,000. Consideration of the risk standard mentioned above will be based on site-specific conditions, land use, hazardous substance characteristics, statutory compliance, protection of human health, safety, and welfare, and the environment, ability of cleanup to be implemented, long-term and short-term effectiveness, use of treatment technologies, public comment, and cost.

This guidance clarifies the steps involved in calculating cumulative risk and gives examples to demonstrate the process. This guidance is specific to methods two and three although method four is addressed in areas as a reference. For calculating cumulative risk under method four, please refer to the *Risk Assessment Procedures Manual* (2000).

BACKGROUND

Cumulative risk is defined as the sum of risks resulting from multiple sources and pathways to which humans are exposed. When more than one hazardous substance is present at a site or multiple exposure pathways exist, the cleanup levels in Table B1 of 18 AAC 75.341 and Table C of 18 AAC 75.345 may need to be adjusted downward. The cumulative cancer risk remaining at the site when cleanup is completed must be equal to or less than 1 in 100,000 (1×10^{-5}) and the cumulative noncarcinogenic hazard index (HI)

must be equal to or less than 1. Tables B1 and B2 of 18 AAC 75.341 and Table C of 18 AAC 75.345 are hereinafter referred to simply as "Table B1," "Table B2," and "Table C," respectively.

The approach for calculating cumulative risk is as follows:

1. Develop a site specific conceptual site model (CSM) showing completed exposure pathways that need to be evaluated.

2. For each contaminant, record the exposure media, exposure route, concentration to remain on-site following cleanup, and pathway specific risk-based concentration (RBC).

3. Indicate whether the contaminant is considered a carcinogen, noncarcinogen, or both.

4. For each carcinogen, risk is calculated by dividing the site concentration remaining on-site by the applicable RBC and multiplying by the risk management level of $1x10^{-5}$. Cumulative carcinogenic risk is the summation of all the risks from each exposure pathway and exposure route (see Equation 1).

$$\text{Cumulative Risk} = \Sigma[(\text{Concentration} \div \text{RBC}) \times 10^{-5}] \qquad \textbf{Eq. 1}$$

5. For each noncarcinogen, the hazard quotient (HQ) is calculated by dividing the site concentration remaining on-site by the applicable RBC and multiplying by the risk management level of 1. The hazard index (HI) is the summation of all HQs across all pathways that are affecting the same target organ or system endpoint (see Equation 2).

$$\text{HI} = \Sigma[(\text{Concentration} \div \text{RBC}) \times 1] \qquad \textbf{Eq. 2}$$

A site-specific CSM should be used to identify complete exposure pathways on-site and will help address data quality objectives. A CSM should include the source of contamination, release/transport mechanisms, contact media (i.e. soil, air, or groundwater), exposure route (i.e. **direct contact**, inhalation,) and receptor (i.e. current/future resident, subsistence user, or biota). Methods two and three soil cleanup levels are assumed to be protective of inhalation of volatilization from soil to ambient air, **direct contact with** soil, and ingestion of groundwater. All other pathways that are shown to be complete based on the site-specific CSM should be investigated. These pathways can be addressed under method four.

Each contaminant detected above one-tenth of the Tables B1 inhalation or **direct contact** or Table C cleanup levels must be included in cumulative risk calculations. For these contaminants, record the exposure media, exposure route, concentration to remain on-site following cleanup, and the RBC. Appendix A is an example worksheet that can be used to organize the above information for calculating cumulative risk.

It is important to note that the cumulative risk standard must be met following site cleanup. For soil, the site concentration to be used in cumulative risk calculations is the maximum concentration, unless the department approves an appropriate statistical method, in which case compliance will be based on the mean soil concentration at the 95th percent upper confidence limit, under 18 AAC 75.380(c)(1). For groundwater, the site concentration is the maximum concentration, as described in 18 AAC 75.380(c)(2).

The RBC for method two soil inhalation and **direct contact** pathways can be found in Appendix B. RBCs correspond to the concentration in soil that would cause an adverse effect through the inhalation or ingestion routes of exposure. RBCs are calculated using the equations presented in DEC's *Cleanup Levels Guidance* (2002) and takes into account default exposure and soil/aquifer data as well as toxicological data specific to the compound of interest. Note the RBC may be different from the cleanup level in Table B1. Some cleanup levels in Table B1 are capped at the soil saturation concentration and therefore correspond to a risk or HQ lower than the department standard. Also, some contaminants have both carcinogenic and noncarcinogenic effect and the cleanup level listed in the aforementioned table corresponds to the lowest concentration causing an effect. For example, aldrin causes both carcinogenic and non-carcinogenic effects when exposure is through the **direct contact** route. The cleanup level is in Table B1 corresponds with the carcinogenic effect because it is caused at a lower concentration than the non-carcinogenic effect.

The RBC for groundwater and method three alternative cleanup levels for soil must be calculated on a site-specific basis using DEC's *Cleanup Levels Guidance* (2002).

Contaminants are generally divided into two basic groups, those that have a carcinogenic effect and those that have a noncarcinogenic effect. Cumulative carcinogenic risk and noncarcinogenic hazard index are calculated separately. Some compounds can cause both effects and are included in both cumulative risk calculations.

CARCINOGENS

Risks from exposure to carcinogens are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (EPA, 1989). Under 18 AAC 75.990(12), DEC defines a carcinogen as "…a substance that meets the criteria of a Group A or Group B carcinogen according to EPA's *Guidelines for Carcinogen Risk Assessment*. Cumulative carcinogenic risk is the summation of all risks from each exposure pathway and exposure route. The cumulative carcinogenic risk equation is shown in Equation 1. Unless demonstrated otherwise, cancer risks resulting from exposure to two or more carcinogens are assumed to be additive. The cumulative carcinogenic risk equation assumes that there are no synergistic or antagonistic chemical interactions. See Example 1 on how to calculate cumulative carcinogenic risk.

NONCARCINOGENS

Under 18 AAC 75.990(69), DEC defines a noncarcinogen as "…a hazardous substance with adverse health effects on humans other than cancer." The noncarcinogenic HQ represents the ratio of estimated intake of a chemical to the estimated intake at which there are no observed adverse effects. The HI is the summation of all of the HQs for all pathways and exposure routes that affect the same target organ or system endpoint.

For noncarcinogens, the health threats resulting from exposure to two or more hazardous substances with similar types of toxic response are assumed to be additive. However, many noncarcinogens have varying toxic effects and therefore assuming that these effects are additive may not be valid.

Noncarcinogenic compounds affect different target organs or systems by different mechanisms of toxicity. To accurately assess the possible effects of noncarcinogenic compounds, HI can be segregated by target organ or system endpoint and mechanism of toxicity consistent with EPA's *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A) – Interim Final* (1989) and *Guidelines for the Health Risk Assessment of Chemical Mixtures* (1986). Since the mechanism of toxicity is not well understood for many compounds, the department will generally accept segregation of the HI by target organ alone.

See Example 2 to calculate the HI from exposure to contaminated soil.

CHEMICALS TO INCLUDE

Contaminants detected at greater than or equal to one-tenth of the table values are included in cumulative risk calculations. For method two and three cleanups, 18 AAC 75.340(k) states that chemicals in soil detected at one-tenth or more of the Tables B1 ingestion and inhalation cleanup levels must be included when calculating cumulative risk. One-tenth of the ingestion or inhalation value listed in Table B1 for the appropriate climate zone is used as the criteria for which compounds will be included in cumulative risk calculations.

When conducting a method four risk assessment, compounds found at levels that correspond to greater than the risk based benchmarks of 1×10^{-6} risk or HQ of 0.1 will be retained for further analysis and are therefore included in the cumulative risk calculations. See Section 4.2.3 of DEC's *Risk Assessment Procedures Manual* (2000), for more information.

Petroleum Hydrocarbons

The department has decided not to include GRO, DRO, and RRO in cumulative risk calculations. See the section on *Accounting for Petroleum Hydrocarbons* for more information.

PCBs

Polychlorinated biphenyls (PCBs) are included in cumulative risk calculations although the cleanup levels are determined site-specifically, based on land use, or through a site-specific risk assessment. If separate congener or Aroclor concentrations are presented, the appropriate toxicological data can be used to calculate cancer risk. At the time of this document, EPA's *Integrated Risk Information System* (IRIS) has individual assessments for three different Aroclors: Aroclor 1016, Aroclor 1248, and Aroclor 1254. If PCBs are presented as a total concentration, the highest cancer slope factor and reference dose should be used.

Dioxins

Risks to dioxins are calculated based on a 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxicity equivalent (TEQ) approach and should be included in cumulative risk calculations. Toxicity equivalency factors (TEFs) are used to compare the relative toxicity of individual dioxin-like compounds to the more toxic TCDD. Included in this calculation are dioxins, furans, and dioxin-like PCBs. The TEQ approach is based on the assumption that dioxin and dioxin-like compounds act through the same mechanism of toxicity. The TEF for TCDD is equal to one, whereas the TEF values for all other dioxins and dioxin-like compounds are equal to less than one. The TEQ is defined as the product of the concentration of an individual dioxin-like compound and the corresponding TEF for that compound. The total TEQ is the sum of the TEQ for each of the congeners in a given mixture.

$$\text{Total TEQ} = \Sigma\,(C_i * TEF_i) \qquad \textbf{Eq. 3}$$

Once the total TEQ is calculated, this value can be compared to the dioxin slope factor and the risk can be calculated. The most up-to-date toxicological data and TEFs should be used when calculating risk to dioxins.

Lead

Lead contamination in soil or groundwater is not included in cumulative risk calculations. EPA found it inappropriate to apply a reference dose or cancer slope factor to lead (IRIS, 1988). The residential lead soil cleanup level in Table B1 is based on the Integrated Exposure Uptake Biokinetic (IEUBK) model. Soil cleanup levels for lead are site-specific, based on land use, and groundwater cleanup levels are presented in Table C. In addition, an alternative cleanup level may be proposed under a site-specific risk assessment. See Notes to Tables B1 and B2 for more details.

Please contact DEC's risk assessor for more information on how PCBs, dioxins, and lead are handled in cumulative risk calculations.

ADDING CHEMICALS NOT IN DEC TABLES

When encountering chemicals on-site that are not included in Tables B1, B2, or C, the first step is to establish RBCs using the equations presented in DEC's *Cleanup Levels Guidance* (2002). The RBC will correspond to the route-specific cleanup level equations (inhalation and ingestion). Toxicity and chemical data specific to the compound of concern will be needed. Toxicity data can be obtained from EPA's IRIS, EPA's *Health Effects Assessment Summary Tables* (1997), or other accepted source. Chemical data can be obtained from an accepted chemistry source.

Once a RBC is determined, the compound can be included in cumulative risk calculations using the same methods presented above. Example 3 shows how to include a contaminant that is not found in DEC tables in cumulative risk calculations.

ACCOUNTING FOR BACKGROUND CONCENTRATIONS

DEC's *Technical Guidance Document on Determination of Background Concentrations* (1998) is used for determining if compounds found on-site are attributable to background levels. If a chemical found at the site is shown to be solely attributable to the background concentration, then the chemical is not included in the cumulative risk calculations.

ACCOUNTING FOR PETROLEUM HYDROCARBONS

Individual risks from each petroleum fraction must be calculated; however, they are not included in a cumulative risk calculation with other petroleum fractions or with other chemicals in the tables, as explained below.

Each petroleum fraction is a mixture of many different chemicals. The Total Petroleum Hydrocarbon Criteria Working Group identified indicator contaminants within petroleum that can be evaluated individually. There is toxicological information available for each indicator compound. This information can be used to determine cleanup and risk levels. These indicator chemicals can be found in DEC's *Underground Storage Tanks Procedures Manual* (2002) and *Guidance for Cleanup of Petroleum Contaminated Sites* (2000) and are presented in the table below.

The carcinogenic risk of petroleum can be adequately evaluated by determining the risk from carcinogenic polyaromatic hydrocarbons (PAHs). Using the same rationale, noncarcinogenic effects of petroleum can be evaluated by calculating the HI for the indicator contaminants listed in Tables B1 and C. Therefore, the department believes that calculating cumulative risk for the indicator contaminants, in addition to other contaminants on-site, is protective of the cumulative risk to petroleum exposure.

The department understands that there are petroleum constituents that will not be evaluated using this method. For many of these constituents the toxicity of the compounds has not yet been determined or there is minimal risk due to exposure. Petroleum is a chemical mixture. Under EPA's *Guidelines for the Health Risk Assessment of Chemical Mixtures* (1986), the most preferred method for evaluating the risk to chemical mixtures is to use toxicological data for the mixture itself. Many mixtures have different toxicological properties than their constituents. At this time, there is not enough toxicological data available to calculate risk to the full petroleum fractions other than using a surrogate approach to determine toxicity. The department will continue to investigate this issue to provide a protective method of evaluating risk.

INDICATOR COMPOUNDS **FOR PETROLEUM CONTAMINATED SITES**	
! *Volatiles (BTEX)* Benzene Toluene Ethylbenzene Total xylene ! *Polynuclear Aromatic Hydrocarbons (PAHs)** - **Carcinogens**** Acenaphthylene Benzo(a)anthracene Benzo(a)pyrene Chrysene Indeno(1,2,3-cd)pyrene Benzo(k)fluoranthene Benzo(b)fluroranthene Benzo(a)anthracene Dibenzo(a,h)anthracene • *Polynuclear Aromatic Hydrocarbons (PAHs)** - **Noncarcinogens** Anthracene Acenaphthene Benzo(g,h,i)perylene Phenanthrene Pyrene Naphthalene Fluorene	! *Metals as required on a case by case basis* Arsenic Barium Cadmium Chromium Lead Nickel Vanadium ! *Others as needed on a case by case basis* Ethylene dibromide (EDB) 1,2-dichloroethane (EDC) Methyl tert-butyl ether (MTBE) Volatile chlorinated solvents

CUMULATIVE RISK CALCULATIONS FOR METHOD THREE

If alternative cleanup levels have been developed under method three, the risk or HQ from each constituent and the cumulative risk is calculated similar to that mentioned above. The site concentration following cleanup is divided by the RBC and the quotient is multiplied by the target risk standard. The RBC for method three cleanup levels must be calculated and not obtained from the Appendix A spreadsheet. To calculate the RBC for method three alternative cleanup levels, use the equations presented in DEC's *Cleanup Levels Guidance* (2002) and the site-specific data used to calculate alternative cleanup levels. Also, an internet accessible method three web calculator is available at http://www.dec.state.ak.us/spar/cs/webcalc/. The web calculator calculates the cumulative risk associated with soil where alternative cleanup levels have been proposed under method three. Example 4 shows how to calculate cumulative risk at a site that will apply method three alternative cleanup levels.

ADDITIONAL PATHWAYS TO INVESTIGATE

When developing site-specific alternative cleanup levels, exposure pathways other than those specified in Tables B1, B2 and C may be complete based on the site-specific conceptual site model. Tables B1, B2 and C include the following exposure routes: **direct contact with** soil**, which is protective of ingestion and dermal exposure to soil**, inhalation of volatilization from soil to ambient air, and ingestion of groundwater. In general, ingestion of fugitive dust is deemed a protected exposure routes under the ingestion of soil pathway. **This may not be the case where there is dust is generated by human activity or where chromium is present**. All completed pathways must be included in cumulative risk calculations including those pathways not addressed in Tables B1 and C. For example, in addition to the pathways identified above, volatilization to indoor air or ingestion of subsistence foods may also be complete pathways. If these pathways are complete they must be considered in the cumulative risk calculations. The site specific CSM will designate which exposure pathways are completed and, therefore, which are included in cumulative risk calculations.

CUMULATIVE RISK AND GROUNDWATER

Table C groundwater cleanup levels are expected to be protective of the ingestion of groundwater. Unless it is shown that the groundwater at the site is not used for human consumption, it should be assumed that the ingestion of groundwater pathway is complete. Chemicals found at one-tenth the Table C values need to be included in the cumulative risk calculations.

Table C values were developed using EPA's maximum contaminant levels (MCLs), maximum contaminant level goal (MCLGs), or health based limits (HBLs). HBLs are based on toxicological data and risk to human health. MCLs and MCLGs incorporate other factors including feasibility and cost into determining the levels. All Table C values, regardless of how they were developed, are assumed to be protective of human health.

The HQ and carcinogenic risks associated with ingestion of groundwater at Table C levels are shown in Appendix C. For some chemicals, the cleanup level in Table C exceeds the cumulative risk standard. The following compounds exceed the cancer risk standard of 1×10^{-5} when set at the Table C levels:

arsenic,
benzo(a)pyrene, beryllium, bromodichloromethane, chlordane, chlorodibromomethane, 1,4-dichlorobenzene, 3,3-dichlorobenzidine, 1,1-dichloroethylene, 1,3-dichloropropene, heptachlor,

heptachlor epoxide, hexachlorobenzene,
toxaphene,
vinyl chloride,
n-nitrosodi-n-propylamine.

The following compounds exceed the HQ of 1.0 when set at the Table C levels:
arsenic,
2-chlorophenol,
hexachloro-1,3-butadiene,
hexachloroethane.

In these cases, the cumulative risk at the site should be calculated by both including these chemicals and not including these chemicals. Decisions to set cleanup levels at either the Table C values or values that correspond to less than or equal to the cumulative risk standards will be made based on DEC delegated authority. Example 4 shows how to calculate cumulative risk when there is groundwater contamination.

ROUNDING IN CUMULATIVE RISK

Under 18 AAC 75.325(g), a responsible person must ensure that, after completing site cleanup using methods two or three, the risk from hazardous substances does not exceed a cumulative carcinogenic risk standard of 1 in 100,00 across all exposure pathways and a cumulative noncarcinogenic risk standard at a hazard index of 1 for all exposure pathways. Similarly, under 18 AAC 75.325(h), a responsible person proposing an alternative cleanup level for soil or groundwater based on a site-specific risk assessment under method four must ensure that the risk from hazardous substances does not exceed the cumulative carcinogenic risk standard of 1 in 100,000 across all exposure pathways and the cumulative noncarcinogenic risk standard at a hazard index of 1 for all exposure pathways.

Both risk estimates, the Incremental Lifetime Cancer Risk and the Hazard Index should be expressed using one significant figure for clean ups under methods two, three and four. Standard rounding procedures must be adhered to such that:

- Starting from the leftmost significant digit, move to the right until you have as many digits as you are allowed to keep. Then look to the immediate right and note the number present.
- If the number to the right is a 5, 6, 7, 8, or 9, round the last significant digit up one. If the number to the right is a 4, 3, 2, 1, or 0, keep the last significant digit the same.

Therefore, the rounding procedures and cumulative risk standards are consistent between methods two, three, and four.

ECOLOGICAL RECEPTORS

The noncarcinogenic HI is calculated for ecological receptors. The ecological noncarcinogenic risk management level is set at a HI of 1. Carcinogens are not considered to be of concern for ecological receptors. The HI is the sum of HQs across multiple exposure routes and exposure pathways (see Equation 4). The HQ is calculated by dividing the dose by a risk-based ecological benchmark.

$$HI = \Sigma \text{ Dose} \div \text{Benchmark} \qquad \textbf{Eq. 4}$$

If the HI exceeds 1, the individual HQs should be retained for further evaluation. See the *Risk Assessment Procedures Manual* (2000) for additional information.

REFERENCES

Alaska Department of Environmental Conservation. 2001. *Guidance on Use of 10X Rule and Risk Assessment to Develop Groundwater Cleanup Levels* (2001). Contaminated Sites Remediation Program.

Alaska Department of Environmental Conservation. 2002 *Oil and Hazardous Substances Pollution Control Regulations 18AAC 75, Articles 3 and 9.*

Alaska Department of Environmental Conservation. 2002. *Underground Storage Tanks Procedures Manual.*

Alaska Department of Environmental Conservation. 2002. *Cleanup Levels Guidance* . Contaminated Sites Program.

Alaska Department of Environmental Conservation. 2000. *Guidance for Cleanup of Petroleum Contaminated Sites*. Contaminated Sites Remediation Program.

Alaska Department of Environmental Conservation. 2000. *Risk Assessment Procedures Manual.* Contaminated Sites Remediation Program.

Alaska Department of Environmental Conservation. 1998. *Technical Guidance Document on Determination of Background Concentrations.* Contaminated Sites Remediation Program.

Total Petroleum Hydrocarbon Criteria Working Group. 1997. *Volume 4, Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH)*. Amherst Scientific Publishers, Amherst, MA.

United States Environmental Protection Agency. 1997. *Health Effects Assessment Summary Tables: FY 1997 Update*. EPA/540/R-97-036. Office of Emergency and Remedial Response, Washington, DC.

United States Environmental Protection Agency. 1996. *Soil Screening Guidance: Technical Background Document.* EPA/540/R-95/128. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency. 1996. *Soil Screening Guidance: User's Guide.* 9355.4-23. Office of Solid Waste and Emergency Response, Washington DC.

United States Environmental Protection Agency. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A).* EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, DC.

United States Environmental Protection Agency. 1988. *Integrated Risk Information System: Lead and Compounds (Inorganic). http://www.epa.gov/iris/subst/0277.htm.* Office of Research and Development, Washington, DC.

United States Environmental Protection Agency. 1987. *Integrated Risk Information System: Dibromochloromethane. http://www.epa.gov/iris/subst/0222.htm.* Office of Research and Development, Washington, DC.

United States Environmental Protection Agency. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. EPA/630/R-98/002. Office of Research and Development, Washington, DC.

EXAMPLES

Example 1: Carcinogenic Cumulative Risk

This example assumes soil is contaminated at a site located in the Arctic zone. Method two was used to develop cleanup levels. The chemicals of concern in the soil are benzene, arsenic, tetrachloroethylene (PCE), and toluene. For this example, the inhalation and ingestion pathways are all complete based on the site-specific conceptual site model. Also, it is assumed that arsenic is solely attributable to the source and not any background level.

The steps to calculate carcinogenic cumulative risk are as follows:

1) Develop a site specific conceptual site model (CSM).

2) Record the contaminant, exposure media, exposure route, site concentration to remain on-site following cleanup, and pathway-specific RBC for carcinogenic and/or noncarcinogenic effects.

3) Calculate the carcinogenic risk for each contaminant across each exposure pathway and sum all of the exposure pathways to calculate the cumulative risk.
   (a) Calculate the risk associated with each contaminant separated by exposure route (inhalation or ingestion).
   (b) Sum the risks from all contaminants for each exposure route.
   (c) Sum risks for all complete exposure routes.

The contaminants, concentrations, and RBCs at the site in this example are shown below. Because the site cleanup follows method two, the RBC can be obtained from the Human Health Risk-Based Concentrations spreadsheet found in Appendix B.

Chemicals of Concern	Exposure Media	Route of Exposure	Site Conc (mg/kg)	RBC (mg/kg)	C/NC[1]
Benzene	Soil	Inhalation	5.2	14	C
		Direct Contact	5.2	204	C
Arsenic	Soil	Direct Contact	1.8	7.5	C
		Direct Contact	1.8	41.	NC
PCE	Soil	Inhalation	80	157	C
		Direct Contact	80	216	C
		Direct Contact	80	1370	NC
Toluene	Soil	Inhalation	180	2160	NC
		Direct Contact	180	27400	NC

[1] – C/NC = Carcinogen or Noncarcinogen

Cumulative carcinogenic risk is the sum of all cancer risks for all contaminants on-site summed across all exposure pathways and all exposure routes. The carcinogenic cumulative risk standard is set at 1 in 100,000 (1×10^{-5}).

To calculate the carcinogenic cumulative risk, the risk associated with each chemical of concern is calculated for each exposure route and pathway. The risk is calculated by dividing the site concentration by the RBC and multiplying by the target risk level of 1×10^{-5}.

As noted above, benzene and PCE have carcinogenic effects through the inhalation route of exposure and benzene, arsenic and PCE have carcinogenic effects through the ingestion route of exposure. Toluene has no carcinogenic effects and therefore is not included in the cumulative carcinogenic risk calculation. Summarized below are the calculated risks for each exposure route.

Carcinogens: Inhalation				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**Risk at Site Conc[1]**
Benzene	5.2	12.9	[5.2/12,9] **5.2/14**	4×10^{-6}
Arsenic	1.8	--	--	--
PCE	80	157	80/157	5×10^{-6}

Carcinogens: Direct Contact				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**Risk at Site Conc[1]**
Benzene	5.2	204	5.2/204	3×10^{-7}
Arsenic	1.8	7.5	1.8/6.8	3×10^{-6}
PCE	80	216	80/216	4×10^{-6}

[1] – Risk at Site Concentration = (Site Concentration ÷ RBC) x 10^{-5}

As shown, the risk from *each* contaminant for the inhalation and ingestion routes is below the carcinogenic risk standard of 1×10^{-5}. The next step is to sum all the risks associated with each exposure route.

Carcinogens: Total Inhalation Risk				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**Risk at Site Conc[1]**
Benzene	5.2	12.9	[5.2/12,9] **5.2/14**	4.0×10^{-6}
Arsenic	1.8	--	--	--

PCE	40	157	40/157	[5.1 x 10^{-6}] **5 x 10^{-6}**
Total Inhalation Risk				[9.1 x 10^{-6}] **9 x 10^{-6}**

Carcinogens: Total Direct Contact Risk				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**Risk at Site Conc[1]**
Benzene	5.2	204	5.2/204	[2.5 x 10^{-7}] **3 x 10^{-7}**
Arsenic	1.8	7.5	[1.8/7.5] **1.8/6.8**	[2.43 x 10^{-6}] **3 x 10^{-6}**
PCE	40	216	40/216	[3.7 x 10^{-6}] **4 x 10^{-6}**
Total Ingestion Risk				**[6.4 x 10^{-6}]** 7 x 10^{-6}

[1] – Risk at Site Concentration = (Site Concentration ÷ RBC) x 10^{-5}

The risk from all contaminants through the inhalation route or the direct contact route is below the risk standard of 1 in 100,000. The next step is to sum the total risks across all exposure routes.

Cumulative Risk = Total Inhalation Risk + Total Direct Contact Risk
= 9 x 10^{-6} + 7 x 10^{-6}
= 1.6 x 10^{-5}
= 2 x 10^{-5} rounded to one significant figure

Since the cumulative carcinogenic risk is greater than 1 x 10^{-5}, the concentrations of one or more of the chemicals of concern will have to be reduced so that the overall risk at the site is below the carcinogenic risk standard, even though all contaminants are below the Table B1 Cleanup Levels.

Example 2: Hazard Index

This example will build onto Example 1. Therefore, the CSM and table indicating contaminants, site concentrations left on-site, and RBCs will also apply to this example.

To calculate the HI, all chemicals on-site that have a noncarcinogenic effect must be included in the calculation. Some of these chemicals may also have a carcinogenic effect but they need to be additionally evaluated for toxicant effects in the HI calculation.

The steps to calculate a HI are as follows:

1) Develop a site specific conceptual site model (CSM).

2) Record the contaminant, exposure media, exposure pathway, site concentration to remain on-site following cleanup, and RBC for carcinogenic and/or noncarcinogenic effects.

3) Calculate the HQ for each contaminant across each exposure pathway and sum all of the exposure pathways to calculate the HI.
   (a) Determine the contaminant specific target organ or system endpoint for each exposure route.
   (b) Calculate the HQ for each contaminant separated by exposure route.
   (c) Assign the appropriate HQ to each target organ or system endpoint.
   (d) Sum the HQ for each target organ or system endpoint.

For this example, steps 1 and 2 have been completed in Example 1. The next step in calculating the HI is to investigate the target organ or system endpoint for each chemical. EPA's IRIS database (http://www.epa.gov/iris/) lists some target organs affected by each compound. Other acceptable references, such as EPA's *Health Effects Assessment Summary Tables* (HEAST) or the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles can also be used. The affected endpoints are grouped by inhalation and **direct contact** routes.

Below are the compounds from Example 1 and the target organ or system endpoint that is affected.

Compound	**Endpoint or System**
Arsenic	
- Oral Route	vascular
Toluene	
- Oral Route	liver, kidney
- Inhalation Route	neurological
PCE	
- Oral Route	liver

Next, the HQ for each contaminant on-site with a noncarcinogenic effect is calculated by dividing the site concentration remaining on-site by the RBC. The HQs for this example are shown below.

Noncarcinogens: Inhalation				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**HQ at Site Conc[1]**
Arsenic	1.8	--	--	--
Toluene	180	2160	180/2160	8E-02
PCE	80	--	--	--

Noncarcinogens: Direct Contact				
Chemicals of Concern	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**Site Conc / RBC**	**HQ at Site Conc[1]**
Arsenic	1.8	41.1	1.8/41	4E-02
Toluene	180	27400	180/27400	1E-02
PCE	80	1370	80/1370	6E-02

[1] – Risk at Site Concentration = (Site Concentration ÷ RBC) x 1

As shown, the risk from *each* chemical has a HQ below one. The next step is to assign the appropriate HQ to each endpoint. For instance, the liver and kidney are affected by exposure to toluene from the route of ingestion. Therefore, we can assign the toluene ingestion route HQ to the liver and kidney endpoints.

HQ Summary by Target Organ			
Target Organ	**Compound**	**Exposure Route**	**HQ**
Liver	Toluene	Direct Contact	1E-02
	PCE	Direct Contact	6E-02
Kidney	Toluene	Direct Contact	1E-02
Neurological	Toluene	Direct Contact	8E-02
Vascular	Arsenic	Direct Contact	4E-02

Now sum the HQ from each compound by target organ or system endpoint. In our example the HI for each target organ endpoint is as follows:

HI by Target Organ	
Target Organ	**HI**
Liver	7E-02
Kidney	1E-02
Neurological	8E-02
Vascular	4E-02

The HI for each target organ is below the target of 1. Therefore, the cleanup levels at the site do not exceed a the HI standard.

The HI can be calculated without segregating the HI by endpoints. Although addition of the HQ for dissimilar endpoints is not scientifically supported, if the HI for all endpoints is less than one it can be assumed that, if the HI for similar endpoints were calculated, it too would be below 1. If the HI is found to be greater than one at this step evaluation similar to that shown above would be necessary.

Example 3: Inclusion of Chemicals Not in DEC Tables

Example 3 will continue to build on Examples 1 and 2. Assume that in addition to the chemicals listed in the Examples 1 and 2, dibromochloromethane is also found in the soil. This contaminant is not included in DEC Table B1. To include the contaminant in cumulative risk calculations, follow the steps below.

1) Obtain compound specific toxicological and chemical data from approved sources.

2) Use toxicological and chemical data and the equations presented in DEC's *Cleanup Levels Guidance* (2002) to calculate RBCs.

3) Follow the steps indicated in Examples 1 and 2 on how to calculate carcinogenic cumulative risk and the noncarcinogenic HI.

Toxicological and chemical data for the compound of concern can be obtained from many sources. Some approved sources are listed in DEC's *Risk Assessment Procedures Manual* (2000). Toxicological data can be obtained from EPA's IRIS or HEAST databases or other approved resource. Chemical data can come from various resources including EPA's Region IX Preliminary Remediation Goal (PRG) tables, Region III RBC tables, or chemistry books. For this example EPA's IRIS database and Region IX PRG tables were used as sources of data.

Based on EPA's IRIS database, it is discovered that dibromochloromethane has both carcinogenic and noncarcinogenic effects. To calculate risk-based inhalation and ingestion concentrations for dibromochloromethane, chemical specific parameters and toxicological data are needed. IRIS can be used to retrieve the slope factor (SF_o), inhalation unit risk factor (URF), oral reference dose (RfD), or inhalation reference concentration (RfC). Region IX PRG Tables were used to obtain the chemical specific data needed. This information includes the unitless Henry Law constant (H'), diffusivity in air (D_i), diffusivity in water (D_w), organic carbon partition coefficient (K_{oc}), and solubility (S). The information retrieved from these databases is shown in the following table.

If a drinking water MCL is available, that number should be used as the Table C value in calculating the soil migration to groundwater cleanup level. For this compound, there is no MCL available and a risk-based value will be used.

Chemical and Toxicological Data for Dibromochloromethane		
Variable	**Value**	**Reference**
SF_o	0.084 $(mg/kg\text{-}d)^{-1}$	IRIS
URF	--	IRIS
RfD	0.002 (mg/kg-d)	IRIS
RfC	--	IRIS
H'	0.035	Region IX PRG
D_I	0.096 (cm^2/s)	Region IX PRG
D_w	0.00005 (cm^2/s)	Region IX PRG
K_{oc}	470 (cm^3/g)	Region IX PRG
S	4400 (mg/L)	Region IX PRG

Using the data above and the equations presented in DEC's *Cleanup Levels Guidance* (2002), RBCs for carcinogenic and noncarcinogenic effects for each route (ingestion and inhalation) can be calculated. As shown above, there is only a need to investigate the ingestion pathway for dibromochloromethane because there is no URF or RfC for the inhalation route associated with this compound. Using these equations, the RBCs are as follows:

RBC Summary				
Chemical of Concern	**C/NC**	**Route of Exposure**	**RBC (mg/kg)**	**Reference**
Dibromochloromethane	C	Direct Contact	133	Eq. 4[1]
	NC	Direct Contact	274	Eq. 3[1]

[1] – Equations from DEC's *Cleanup Levels Guidance*

Now that RBCs have been calculated for dibromochloromethane, the risks and HQs can be calculated. These values can be included in the cumulative risk calculations. At this point, cumulative risk can be completed as done previously in Examples 1 and 2. For this example, the HI is calculated without segregating by target organ.

Carcinogenic Risks			
Chemicals of Concern	**Site Conc. (mg/kg)**	**Risk-based Cleanup Level (mg/kg)**	**Risk at Site Conc[1]**
Direct Contact			
Benzene	5.2	204	2.5×10^{-7}
Arsenic	1.8	7.5	2.4×10^{-6}
PCE	80	216	3.7×10^{-6}
Dibromochloromethane	*15*	*133*	1.1×10^{-6}
Total Direct ContactRisk			$\mathbf{7.5 \times 10^{-6}}$
Inhalation			
Benzene	5.2	12.9	4.0×10^{-6}
PCE	80	157	5.1×10^{-6}
Total Inhalation Risk			$\mathbf{9.1 \times 10^{-6}}$
Total Carcinogenic Risk			$\mathbf{1.7 \times 10^{-5}}$

[1] – Risk at Site Concentration = (Site Concentration ÷ RBC) x 10^{-5}

Noncarcinogenic HI			
Chemicals of Concern	**Site Conc. (mg/kg)**	**Risk-based Cleanup Level (mg/kg)**	**HQ at Site Conc[2]**
Direct Contact			
Arsenic	1.8	41.1	4E-02
Toluene	180	27400	1E-02
PCE	80	1370	6E-02
Dibromochloromethane	*15*	*274*	*5E-02*
Direct ContactHI			***2E-01***
Inhalation			
Toluene	180	2160	*8E-02*
Inhalation HI			***8E-02***
Total HI			***2E-01***

[2] – Risk at Site Concentration = (Site Concentration ÷ RBC) x 1

The concentrations on-site exceed the cumulative carcinogenic risk of 1×10^{-5} but not the noncarcinogenic HI of 1. Therefore, the concentrations of one or more of the chemicals of concern will have to be reduced so that the overall risk at the site is below the cumulative carcinogenic risk standard.

Example 4: Cumulative Risk and Method Three

Sites that undergo method three soil cleanups also need to ensure that the cumulative risk standards are not exceeded following cleanup. The steps involved in calculating cumulative risk are the same as those presented earlier for method two cleanups. They are as follows:

1) Develop a site specific conceptual site model (CSM).

2) Record the contaminant, exposure media, exposure pathway, site concentration to remain on-site following cleanup, and RBC for carcinogenic and/or noncarcinogenic effects.

3) Calculate the risk or HQ for each exposure route and sum all of the exposure pathways to calculate the cumulative carcinogenic risk or noncarcinogenic HI.

The difference in calculating cumulative risk for sites undergoing method three cleanups versus method two is the applicable RBC for method three must be calculated using the site-specific data.

For this example, assume there is soil contamination in the Over 40-inch climate zone. Based on a site-specific CSM, groundwater is not a current or future source of drinking water and ten times the Table C value has been applied appropriately. The site is located in an industrial park that is zoned commercial. The commercial/industrial land use exposure scenario has been applied appropriately. Alternative cleanup levels for the ingestion and inhalation pathways have been developed using method three calculations. The compounds of concern and the site concentrations to remain on-site following cleanup are shown in the table below.

Contaminant	*Site Concentration*	*Units*
Chromium +6	100	mg/kg
Ethylbenzene	50	mg/kg
Toluene	48	mg/kg

RBCs that correspond to commercial/industrial exposure scenarios must be calculated for each contaminant of concern. To calculate the RBC for Cr^{+6} at the site, use Equation 3 for ingestion of noncarcinogenic contaminants from DEC's *Cleanup Levels Guidance* (2002) and solve for the cleanup level. This calculated cleanup level corresponds to the RBC for the site. To calculate the RBCs for ethylbenzene and toluene use Equation 3 from that guidance document for ingestion of noncarcinogenic contaminants and Equation 7 from the document for the inhalation of noncarcinogenic volatile contaminants. Appendix B of the guidance document shows the default

commercial/industrial exposure parameters. Below is an example to calculate the RBC for Cr^{+6} using the commercial/industrial exposure scenario.

Equation 3[1] - Ingestion of Cr^{+6}

$$\text{Cleanup Level (mg/kg)} = \text{RBC} = \frac{\text{THQ x BW x AT x 365 d/yr}}{(1/\text{RfD}) \times 10^{-6}\ \text{kg/mg} \times \text{EF} \times \text{ED} \times \text{IR}}$$

THQ = 1
BW = 70 kg
AT = 25 years
RfD = 0.003 mg/kg-d

EF = 250 days
ED = 25 years
IR = 50 mg/kg
Cr^{+6} RBC = 10,220 mg/kg

1 - DEC's *Cleanup Levels Guidance* (2002)

The following is a complete list of contaminants at the site and the associated RBCs.

Chemicals of Concern	**Exposure Media**	**Route of Exposure**	**Site Conc (mg/kg)**	**RBC (mg/kg)**	**C/NC[1]**
Cr^{+6}	Soil	Direct Contact	100	6,130	NC
Ethylbenzene	Soil	Inhalation	50	4,424	NC
		Direct Contact	50	204,400	NC
Toluene	Soil	Inhalation	48	1,430	NC
		Direct Contact	48	408,800	NC

[1] – C/NC = Carcinogen or Noncarcinogen

At this point, the cumulative risk at the site can be calculated as shown in the previous examples. The following table shows the cumulative carcinogenic risk and HI at the site following cleanup.

Contaminant	**Route of Exposure**	**Site Con.**	**RBC**	**Risk/HQ**
Noncarcinogens				
Cr^{+6}	Direct Contact	100	6,130	2E-02
Ethylbenzene	Inhalation	50	4,424	1E-02
	Direct Contact	50	204,400	2×10^{-4}
Toluene	Inhalation	48	1,430	3E-02

	Direct Contact	48	408,800	1×10^{-4}
HI				**6E-02**

The concentrations on-site do not exceed cumulative risk standards and the cleanup levels are appropriate at the site.

Example 5: Cumulative Risk and Groundwater

For this example, assume there is soil and groundwater contamination at a bulk fuel tank farm located in an Under 40-inch climate zone. Assume that method two cleanup levels were proposed for this site. In the site-specific CSM, ingestion of soil, inhalation of volatilization from soil, and ingestion of groundwater are the complete exposure pathways.

The following table shows the soil contamination to remain on-site following cleanup.

Contaminant	*Site Concentration*	*Units*
Benzene	0.02	mg/kg
Ethylbenzene	0.25	mg/kg
Toluene	5.4	mg/kg
Xylenes	78	mg/kg
Pyrene	300	mg/kg
RRO	4000	mg/kg
DRO	250	mg/kg
GRO	300	mg/kg

Xylene and pyrene are the only contaminants on-site that need to be included in the cumulative risk calculations. RRO, DRO, and GRO are not included in cumulative risk calculations and the other contaminants will remain on-site at levels below one-tenth of the Table B1 inhalation or ingestion values. Following the procedures listed in Example 2, the HI from soil contamination at this site is shown in the table below. Xylene and pyrene have no carcinogenic effect and therefore the carcinogenic risk is not calculated.

Contaminant	**Route of Exposure**	**Site Conc. (mg/kg)**	**RBC (mg/kg)**	**HQ**
Noncarcinogens				
Xylene	Ingestion	78	203000	4×10^{-4}
Pyrene	Ingestion	300	3040	1E-01
HI				**1E-01**

In addition to the risk due to exposure to contaminated soil, the risk due to ingestion of contaminated groundwater must be included in the cumulative risk calculation. The contaminants detected in groundwater and the concentration to remain following remediation are found in the table below.

Contaminant	**Site Conc. (mg/L)**	**Table C (mg/L)**
Benzene	0.005	0.005
Ethylbenzene	0.10	0.7
Toluene	0.075	1
Xylenes	0.25	10
RRO	0.00801	1.1
DRO	0.046	1.5
GRO	0.0019	1.3

Benzene and ethylbenzene are the only contaminants on-site that need to be included in the cumulative risk calculations. RRO, DRO, and GRO are not included in cumulative risk calculations and the other contaminants remain on-site at levels below one-tenth of the Table C values.

Benzene will be cleaned-up to the Table C value. Therefore, the risk associated with the Table C value for benzene can be obtained from Appendix C. Benzene in groundwater at 0.005 mg/L corresponds to a cancer risk of 3×10^{-6}.

Ethylbenzene is above 1/10 of the Table C value and therefore should be included in the cumulative risk calculation. The value to remain on-site is below the Table C value and therefore the risk associated with ethylbenzene should be calculated using DEC's *Cleanup Levels Guidance* (2002). Ethylbenzene has noncarcinogenic effects when ingested and therefore the HQ associated with 0.10 mg/L in groundwater can be calculated using Equation 1 of the above mentioned guidance document.

Equation 1[1]-

$$\text{Cleanup Level (mg/L)} = \frac{\text{THQ} \times \text{RfD} \times \text{BW} \times \text{AT} \times 365\ \text{d/yr}}{\text{IR} \times \text{EF} \times \text{ED} \times \text{A}}$$

1- DEC's *Cleanup Levels Guidance* (2002)

RfD = 0.1 mg/kg-d
BW = 70 kg
AT = 70 yrs
IR = 2 L/d
EF = 350 d/yr
ED = 30 y
A = 1

Solving for THQ (target hazard quotient) and inputting 0.10 mg/L as the cleanup level and 0.1 mg/kg-d for the RfD, the HQ associated with ethylbenzene ingestion in groundwater at this site can be calculated. The HQ is 1E-02.

The risks and hazard quotients associated with the ingestion of groundwater need to be added to the cumulative risk calculations for the exposure to soil, see table below.

Contaminant	Route of Exposure	Media	Site Conc.	Risk/HQ
Carcinogen				
Benzene	Ingestion	Groundwater	0.005 mg/L	$3. \times 10^{-6}$
Cancer Risk				**3×10^{-6}**
Noncarcinogens				
Xylene	Ingestion	Soil	78 mg/kg	4E-04
Pyrene	Ingestion	Soil	300 mg/kg	1E-01
Ethylbenzene	Ingestion	Groundwater	0.10 mg/L	1E-02
HI				1E-01

Both the carcinogenic cumulative risk standard and the HI standard are not exceeded at this site.

APPENDICES

Appendix A: Worksheet for Calculating Cumulative Risk

Worksheet for Calculating Cumulative Risk

Chemicals of Concern	Exposure Media	Exposure Route	Site Conc.	RBC	Units (mg/kg or mg/L)

Appendix B: Method Two Risk-Based Concentrations

Human Health Method Two Risk –Based Concentrations

		Artic Zone				Under 40 inch zone				Over 40-Inch Zone			
		Inhalation		Direct Contact		Inhalation		Direct Contact		Inhalation		Direct Contact	
CAS #	**Chemical Name**	**C**	**NC**	**C**	**NC**	**C**	**NC**	**C**	**NC**	**C**	**NC**	**C**	**NC**
83-32-9	Acenapthene				8.2E+03				6.1E+03				5.0E+03
208-96-8	Acenapthylene				8.2E+03				6.1E+03				5.0E+03
67-64-1	Acetone		3.2E+04		1.2E+05		2.1E+04		9.1E+04		1.6E+04		8.3E+03
309-00-2	Aldrin	3.5E+01		7.0E-01	4.1E+00	2.4E+01		5.0E-01	3.0E+00	1.8E+01		4.0E-01	2.5E+00
120-12-7	Anthracene				4.1E+04				3.0E+04				2.5E+04
7440-36-0	Antimony				5.5E+01				4.1E+01				3.3E+01
7440-38-2	Arsenic			6.8E+00	4.1E+01			5.1E+00	3.0E+01			4.1E+00	2.5E+01
740-39-3	Barium				9.6E+03				7.1E+03				5.8E+03
71-43-2	Benzene	1.4E+01	1.4E+02	5.5E+02	2.0E+02	9.2E+00	9.2E+01	1.5E+02	4.1E+02	6.8E+00	6.9E+01	1.2E+02	3.3E+02
56-55-3	Benzo(a)anthracene			1.1E+01				8.1E+00				6.6E+00	
50-32-8	Benzo(a)pyrene			1.1E+00				8.1E-01				6.6E-01	
205-99-2	Benzo(b)flouranthene			1.1E+01				8.1E+00				6.6E+00	
191-24-2	Benzo(g,h,i)perylene				4.1E+03				3.0E+03				2.5E+03
207-08-9	Benzo(k)fluoranthene			1.1E+02				8.1E+01				6.6E+01	
65-85-0	Benzoic acid				5.5E+05				4.1E+05				3.3E+05
7440-41-7	Beryllium			2.6E+00	2.7E+02			1.9E+00	2.0E+02			1.6E+00	1.7E+02
111-44-4	Bis(2-cloroethyl)ether	4.8E+00		1.0E+01		3.2E+00		7.5E+00		2.4E+00		6.2E+00	
117-81-7	Bis(2-ethylhexyl)phthalate			6.1E+02	2.7E+03			4.5E+02	2.0E+03			3.7E+02	1.7E+03
75-27-4	Bromodichloromethane			1.8E+02	2.7E+03			1.3E+02	2.0E+03			1.1E+02	1.7E+03
75-25-2	Bromoform	7.3E+02	2.4E+03	1.4E+03	2.7E+03	4.9E+02	1.6E+03	1.1E+03	2.0E+03	3.7E+02	1.2E+03	8.6E+02	1.7E+03
71-36-3	Butanol				1.4E+04				1.0E+04				8.3E+03
85-68-7	Butyl benzyl phthalate				2.7E+04				2.0E+04				1.7E+04
7440-43-9	Cadmium				6.8E+01				5.1E+01				4.1E+01

		Artic Zone				Under 40 inch zone				Over 40-Inch Zone			
		Inhalation		Direct Contact		Inhalation		Direct Contact		Inhalation		Direct Contact	
86-74-8	Carbazole			4.3E+02				3.2E+02				2.6E+02	
75-15-0	Carbon disulfide		1.7E+03		1.4E+04		1.2E+03		1.0E+04		8.7E+02		8.3E+03
56-23-5	Carbon Tetrachloride	5.1E+00		8.6E+01	9.6E+01	3.4E+00		6.4E+01	7.1E+01	2.6E+00		5.2E+01	5.8E+01
57-74-9	Chlordane	7.5E+02	2.3E+03	2.8E+01	6.8E+01	5.0E+02	1.5E+03	2.1E+01	5.1E+01	3.8E+02	1.1E+03	1.7E+01	4.1E+01
108-90-7	Chlorobenzene		1.6E+02		2.7E+03		1.1E+02		2.0E+03		8.1E+01		1.7E+03
124-48-1	Chlorodibromomethane			1.3E+02	2.7E+03			9.9E+01	2.0E+03			8.1E+01	1.7E+03
67-66-3	Chloroform	4.8E+00		1.8E+03	1.4E+03	3.2E+00		1.4E+03	1.0E+03	2.4E+00		1.1E+03	8.3E+02
91-58-7	2-Chloronaphthalene		2.5E+04		1.1E+04		1.7E+04		8.1E+03		1.2E+04		6.6E+03
95-57-8	2-Chlorophenol				6.8E+02				5.1E+02				4.2E+02
7440-47-3	Chromium				4.1E+02				3.0E+02				2.5E+02
16065-83-1	Chromium +3				2.1E+05				1.5E+05				1.2E+05
18540-29-9	Chromium +6				4.1E+02				3.0E+02				2.5E+02
218-01-9	Chrysene			1.1E+03				8.1E+02				6.6E+02	
57-12-5	Cyanide				2.7E+03				2.7E+03				
94-75-7	2,4 D				1.4E+03				1.0E+03				8.3E+02
72-54-8	DDD			4.3E+01				3.2E+01				2.6E+01	
72-55-9	DDE			3.0E+01				2.2E+01				1.8E+01	
50-29-3	DDT			3.0E+01	6.8E+01	5.3E+03		2.2E+01	5.1E+01			1.8E+01	4.1E+01
53-70-3	Dibenzo(a,h)anthracene			1.1E+00				8.1E-01				6.6E-01	
132-64-9	Dibenzofuran		4.9E+03		2.7E+02		3.3E+03		2.0E+02		2.5E+03		1.7E+02
541-73-1	1,3-Dichlorobenzene		1.8E+03		4.1E+03		1.2E+03		3.0E+03		8.9E+02		2.5E+03
106-46-7	1,4-Dichlorobenzene		1.2E+04	4.7E+02			8.0E+03	3.5E+02			6.0E+03	2.8E+02	
95-50-1	1,2-Dichlorobenzene		3.4E+03		1.2E+04		2.3E+03		9.1E+03		1.7E+03		7.5E+03
91-94-1	3,3-Dichlorobenzidine			1.9E+01				1.4E+01				1.1E+01	
75-71-8	Dichlorodifluoromethane		4.9E+02		2.7E+05		3.3E+02		2.0E+04		2.4E+02		1.7E+04
107-06-2	1,2-Dichloroethane	7.1E+00		1.2E+02		4.8E+00		9.1E+01		3.5E+00		7.5E+01	
75-34-3	1,1-Dichloroethane		2.3E+03		1.4E+04		1.6E+03		1.0E+04		1.2E+03		8.3E+03
156-59-2	cis-1,2-Dichloroethylene				1.4E+03				1.0E+03				8.3E+02
156-60-5	trans-1,2-Dichloroethylene				2.7E+03				2.0E+03				1.7E+03

		Artic Zone				Under 40 inch zone				Over 40-Inch Zone			
		Inhalation		Direct Contact		Inhalation		Direct Contact		Inhalation		Direct Contact	
75-35-4	1.1-Dichloroethylene	1.3E+00		1.9E+01	1.2E+03	9.0E-01		1.4E+01	9.1E+02	7.0E-01		1.1E+01	7.5E+02
120-83-2	2,4-Dichlorophenol				4.1E+02				3.0E+02				2.5E+02
78-87-5	1,2-Dichloropropane		2.5E+01	1.7E+02			1.7E+01	1.7E+01	1.2E+02		1.2E+01	1.0E+02	
542-75-6	1,3-Dichloropropene	9.6E+01	3.3E+02	1.1E+02	4.1E+03	2.1E+01	7.2E+01	8.3E+01	3.0E+03	1.1E+01	3.6E+01	6.8E+01	2.5E+03
60-57-1	Dieldrin	1.2E+01		7.0E-01	6.8E+00	7.9E+00		5.0E-01	5.1E+00	5.9E+00		4.0E-01	4.1E+00
84-66-2	Diethyl phthalate				1.1E+05				8.1E+04				6.6E+04
131-11-3	Dimethyl phthalate				1.4E+06				1.0E+06				8.3E+05
105-67-9	2,4-Dimethylphenol				2.7E+03				2.0E+03				1.7E+03
84-74-2	Di-n-butyl-phthalate				1.4E+04				1.0E+04				8.3E+03
51-28-5	2,4-Dinitrophenol				2.7E+02				2.0E+02				1.7E+02
606-20-2	2,6Dinitrotoluene			1.3E+01	1.4E+02			9.3E+00	1.0E+02			7.6E+00	8.3E+01
121-14-2	2,4-Dinitrotoluene			1.3E+01	2.7E+02			9.3E+00	2.0E+02			7.6E+00	1.7E+02
117-84-0	Di-n-octyl-phthalate				2.7E+03				2.0E+03				1.7E+03
123-91-1	1,4-Dioxane	8.0E+02		1.0E+03		5.4E+02		7.6E+02		4.0E+02		6.2E+02	
115-29-7	Endosulfan				8.2E+02				6.1E+02				5.0E+02
72-20-8	Endrin				4.1E+01				3.0E+01				2.5E+01
100-41-4	Ethylbenzene		6.7E+03		1.4E+04		4.5E+03		1.0E+04		3.4E+03		8.3E+03
106-93-4	Ethylene Dibromide	7.3E-01	1.6E+02	5.6E+00	1.2E+03	4.9E-01	1.1E+02	4.2E+00	9.1E+02	3.7E-01	8.1E+01	3.4E+00	7.5E+02
107-21-1	Ethylene glycol				2.7E+05				2.0E+05				1.7E+05
206-44-0	Fluoranthene				5.5E+03				4.1E+03				3.3E+03
86-73-7	Fluorene				5.5E+03				4.1E+03				3.3E+03
76-44-8	Heptachlor	1.2E+00		2.5E+00	6.8E+01	8.0E-01		1.8E+00	5.1E+01	6.0E-01		1.5E+00	4.2E+01
1024-57-3	Heptachlor epoxide	5.0E+01		9.4E-01	1.8E+00	3.3E+01		6.9E-01	1.3E+00	2.5E+01		5.7E-01	1.1E+00
87-68-3	Hexachloro-1,3-butadiene	8.2E+01		1.4E+02	2.7E+01	5.5E+01		1.1E+02	2.0E+01	4.1E+01		8.7E+01	1.7E+01
118-74-1	Hexachlorobenzene	1.0E+01		7.0E+00	1.1E+02	6.7E+00		5.2E+00	8.1E+01	5.0E+00		4.2E+00	6.6E+01
319-84-6	alpha-Hexachlorocyclohexane			1.6E+00	6.8E+01			1.2E+00	5.1E+01			9.6E-01	4.1E+01
319-85-7	geta-Hexachlorocyclohexane			5.5E+00	2.7E+01			4.1E+00	2.0E+01			3.4E+00	1.7E+01

		Artic Zone				Under 40 inch zone				Over 40-Inch Zone			
		Inhalation		Direct Contact		Inhalation		Direct Contact		Inhalation		Direct Contact	
58-89-9	gamma-Hexachlorocyclohexane (Lindane)			7.7E+00	4.1E+01			5.7E+00	3.0E+01			4.6E+00	2.5E+01
77-47-4	Hexachlorocyclopentadiene		1.1E+01		8.2E+02		7.2E+00		6.1E+02		5.3E+00		5.0E+02
67-72-1	Hexachloroethane	5.8E+02		8.0E+02	1.4E+02	3.9E+02		5.9E+02	1.0E+02	2.9E+02		4.9E+02	8.3E+01
193-39-5	Indeno(1,2,3-c,d)pyrene			1.1E+01				8.1E+00				6.6E+00	
78-59-1	Isophorone			9.0E+03	2.7E+04			6.6E+03	2.0E+04			5.4E+03	1.7E+04
98-82-8	Isopropyl benzene		1.1E+04		1.4E+04		7.3E+03		1.0E+04		5.5E+03		8.3E+03
7439-97-6	Mercury		2.6E+01				1.8E+01				1.3E+01		
1634-04-4	Mert-tert-butyl ether	9.8E+02	3.3E+04	6.2E+03	1.2E+05	6.6E+02	2.2E+04	4.6E+03	8.7E+04	4.9E+02	1.6E+04	3.8E+03	7.1E+04
72-43-5	Methoxychlor				6.8E+02				5.1E+02				4.1E+02
74-83-9	Methyl Bromide		2.1E+01		1.9E+02		1.4E+01		1.4E+02		1.1E+01		1.2E+02
78-93-3	Methyl ethyl ketone		2.3E+05		8.2E+04		1.6E+05		6.1E+04		1.2E+05		5.0E+04
74-95-3	Methylene bromide		3.1E+02		1.4E+03		2.1E+02		1.0E+03		1.5E+02		8.3E+02
75-09-2	Methylene chloride	2.7E+02	1.6E+04	1.5E+03	8.2E+03	1.8E+02	1.1E+04	1.1E+03	6.1E+03	1.4E+02	8.2E+03	9.1E+02	5.0E+03
91-57-6	2-Methylnapthalene				5.5E+02				4.1E+02				3.3E+02
95-48-7	2-Methylphenol				6.8E+03				5.1E+03				4.1E+03
91-20-3	Napthalene		1.8E+02		2.7E+03		1.2E+02		2.0E+03		9.2E+01		1.7E+03
7440-02-0	Nickel						2.7E+03				2.0E+03		1.7E+03
98-95-3	Nitrobenzene		1.3E+02		6.8E+01		9.0E+01		5.1E+01		6.7E+01		4.1E+01
621-64-7	n-Nitrosodi-n-propylamine			1.2E+00				9.0E-01				7.4E-01	
86-30-6	n-Nitrosodiphenylamine			1.7E+03	2.7E+03			1.3E+03	2.0E+03			1.1E+03	1.7E+03
106-47-8	p-Chloroaniline				5.5E+02				4.1E+02				3.3E+02
87-86-5	Pentachlorophenol			5.2E+01	4.1E+03			3.9E+01	3.0E+03			3.2E+01	2.5E+03
85-01-8	Phenanthrene				4.1E+04				3.0E+04				2.5E+04
108-95-2	Phenol				4.1E+04				3.0E+04				2.5E+04
133-63-63	Polychlorinated biphenyls (PCBs)			3.9E+00	2.7E+00			2.9E+00	2.0E+00			2.4E+00	1.7E+00
57-55-6	Propylene glycol				6.8E+04				5.1E+04				4.1E+04
129-00-0	Pyrene				4.1E+03				3.0E+03				2.5E+03

		Artic Zone				Under 40 inch zone				Over 40-Inch Zone			
		Inhalation		Direct Contact		Inhalation		Direct Contact		Inhalation		Direct Contact	
	Selenium												
7440-22-4	Silver				6.8E+02				5.1E+02				4.2E+02
100-42-5	Styrene		1.5E+04		2.7E+04		1.0E+04		2.0E+04				1.7E+04
79-34-5	**1,1,2,2-Tetrachloroethane**	8.1E+00		5.6E+01		5.4E+00		4.2E+01		4.1E+00		3.4E+01	
127-18-4	Tetrachloroethylene	1.6E+02		2.2E+02	1.4E+03	1.1E+02		1.6E+02	1.0E+03	7.9E+01		1.3E+02	8.3E+02
108-88-3	Toluene		2.2E+03		2.7E+04		1.5E+03		2.0E+04		1.1E+03		1.7E+04
8001-35-2	Toxaphene	9.2E+02		1.0E+01		6.2E+02		7.5E+00		4.6E+02		6.2E+00	
120-82-1	1,2,4-Trichlorobenzene		9.5E+03		1.4E+03		6.4E+03		1.0E+03		4.8E+03		8.3E+02
71-55-6	1,1,1-Trichloroethane		3.6E+03				2.4E+03				1.8E+03		
79-00-5	1,1,2-Trichloroethane	1.5E+01		2.0E+02	5.5E+02	1.0E+01		1.5E+02	4.1E+02	7.7E+00		1.2E+02	3.3E+02
79-01-6	Trichloroethylene	6.4E+01		1.0E+03		4.3E+01		7.6E+02		3.2E+01		6.2E+02	
88-06-2	2,4,6-Trichlorophenol	2.3E+03		7.7E+02		1.5E+03		5.7E+02		1.1E+03		4.7E+02	
95-95-4	2,4,5-Trichlorophenol				1.4E+04				1.0E+04				8.3E+03
93-72-1	2(2,4,5)-Trichlorophenoxy-propionic acid				1.1E+03				8.1E+02				6.6E+02
96-18-4	1,2,3-Trichloropropane	7.3E-01	8.8E+01	5.6E+02	8.2E+02	4.9E-01	5.9E+01	4.2E+02	6.1E+02	3.7E-01	4.4E+01	3.4E+02	5.0E+02
76-13-1	Trichlorotrifluoroethane (Freon 113)		8.5E+04		4.1E+06		7.7E+04		3.0E+06		5.7E+04		2.5E+06
95-63-6	1,2,4-Trimethylbenzene		1.3E+02		6.8E+03		8.6E+01		5.1E+03		6.4E+01		4.1E+03
108-67-8	1,3,5-Trimethylbenzene		5.5E+01		6.8E+03		3.7E+01		5.1E+03		2.7E+01		4.1E+03
7440-62-2	Vanadium				9.6E+02				7.1E+02				
108-05-4	Vinyl Acetate		2.3E+03		1.4E+05		1.5E+03		1.0E+05		1.1E+03		8.3E+04
75-01-4	Vinyl Chloride	6.4E+00	2.4E+02	7.5E+00	4.1E+02	4.3E+00	1.6E+02	5.5E+00	3.0E+02	3.2E+00	1.2E+02	4.5E+00	2.5E+02
1330-20-7	Xylenes		8.5E+02		2.7E+05		5.7E+02		2.0E+05		4.3E+02		1.7E+05
7440-66-6	Zinc				4.1E+04				3.0E+04				2.5E+04

Appendix C: Risks Associated with Table C Levels

Risk and HQ at Table C Levels

Contaminant	GW Cleanup Level (mg/l)	RfD (mg/kg-d)	Sfo (mg/kg-d)$^{-1}$	Risk at Cleanup[1]	HQ at Cleanup[2]
Acenaphthene	2.2	0.06			1.0
Acenaphthylene	2.2	0.06			1.0
Acetone	3.65	0.1			1.0
Aldrin	0.00005	0.00003	17	1.0E-05	0.05
Anthracene	11	0.3			1.0
Antimony	0.006	0.0004			0.4
Arsenic	0.01	0.0003	1.5	2.0E-08	3.3E-04
	[0.05]			[8.8E-04]	[4.6]
Barium	2	0.07			0.8
Benzene	0.005		0.055	3.2E-06	
Benzo(a)anthracene	.0012	0.7	None	1.0 E-06	
Benzo(b)fluoranthene	0.001		0.73	8.6E-06	
Benzo(k)fluoranthene	0.01		0.073	8.6E-06	
Benzoic acid	146	4			1.0
Benzo(a)pyrene	0.0002		7.3	1.7E-05	
Benzo (g,h,i) perylene	1.1	0.03			1.0
Beryllium	0.004	0.002			0.055
Bis(2-chlorethyl)ether	0.00077		1.1	9.9E-06	
Bis(2-ethylhexyl)phthalate	0.006	0.02	0.014	9.9E-07	0.01
Bromodichloromethane	0.1	0.02	0.062	7.3E-05	0.1
Bromoform	0.1	0.02	0.0079	9.3E-06	0.1
Butanol	3.65	0.1			1.0
Butyl benzyl phthalate	7.3	0.2			1.0
Cadmium	0.005	0.001			0.1
Carbazole	0.04		0.02	9.4E-06	
Carbon disulfide	3.65	0.1			1.0
Carbon tetrachloride	0.005	0.0007	0.13	7.6E-06	0.2
Chlordane	0.002	0.0001	0.35	8.2E-06	0.9
Chloroaniline, p-	0.15	0.004			1.0
Chlorobenzene	0.1	0.02			0.1
Chlorodibromomethane	0.06	0.02	0.084	5.9E-05	0.1
Chloroform	0.1	0.01	0.0061	7.2E-06	0.3
2-Chloronaphthalene	2.9	0.08			1.0
Chlorophenol, 2-	0.2	0.005			1.1
Chromium	0.1	0.003			0.9
Chromium +3	55	1.5			1.0
Chromium +6	0.1	0.003			0.9
Chrysene	0.1		0.0073	8.6E-06	

Contaminant	GW Cleanup Level (mg/l)	RfD (mg/kg-d)	Sfo (mg/kg-d)$^{-1}$	Risk at Cleanup[1]	HQ at Cleanup[2]
Copper	1.3	0.04			0.9
Cyanide	0.2	0.02			0.3
DDD	0.0036		0.24	1.0E-05	
DDE	0.0025		0.34	1.0E-05	
DDT	0.0025	0.0005	0.34	1.0E-05	0.1
Dibenzo(a,h)anthracene	0.0001		7.3	8.6E-06	
Di-n-butyl phthalate	3.65	0.1			1.0
Dichlorobenzene, 1,2-	0.6	0.09			0.2
1,3 Dichlorobenzene	1.1	0.03			1.0
Dichlorobenzene, 1,4-	0.075		0.024	2.1E-05	
Dichlorobenzidine, 3,3-	0.002		0.45	1.1E-05	
Dichloroethane, 1,1-	3.65	0.1			1.0
Dichloroethane, 1,2-	0.005		0.091	5.3E-06	
Dichloroethylene, 1,1-	0.007	0.009	0.6	4.9E-05	0.02
cis-1,2-dichloroethylene	0.07	0.01			0.2
trans-1,2-Dichloroethylene	0.1	0.02			0.1
Dichlorophenol, 2,4-	0.1	0.003			0.9
2,4 D (2-(2,4-dichlorophenoxy)acetic acid)	0.07	0.01			0.2
Dichloropropane, 1,2-	0.005		0.068	4.0E-06	
Dichloropropene, 1,3-	0.009	0.03	0.1	1.1E-05	0.01
Dieldrin	0.00005	0.00005	16	9.4E-06	0.03
Diethyl phthalate	29	0.8			1.0
Dimethylphenol, 2,4-	0.7	0.02			1.0
Dinitrophenol, 2,4-	0.07	0.002			1.0
Dinitrotoluene, 2,4-	0.00125	0.002	0.68	1.0E-05	0.02
Dinitrotoluene, 2,6-	0.00125	0.001	0.68	1.0E-05	0.03
Di-n-octyl phthalate	0.7	0.02			1.0
1.4 Dioxane	0.077		0.011	0.00001	
Dioxin		0.00000003			0.00
Endosulfan	0.2	0.006			0.9
Endrin	0.002	0.0003			0.2
Ethylbenzene	0.7	0.1			0.2
Ethylene Dibromide	0.00005	0.009	2	0.000001	0.0002
Ethylene Glycol	73	2			1
Fluoranthene	1.46	0.04			1.0
Fluorene	1.46	0.04			1.0
Heptachlor	0.0004	0.0005	4.5	2.1E-05	0.02
Heptachlor epoxide	0.0002	0.000013	9.1	2.1E-05	0.4
Hexachlorobenzene	0.001	0.0008	1.6	1.9E-05	0.03
Hexachloro-1,3-butadiene	0.01	0.0002	0.078	9.2E-06	1.4
HCH, a-	0.0001		6.3	7.4E-06	

Contaminant	GW Cleanup Level (mg/l)	RfD (mg/kg-d)	Sfo (mg/kg-d)$^{-1}$	Risk at Cleanup[1]	HQ at Cleanup[2]
HCH, b-	0.00047		1.8	9.9E-06	
HCH, g- (lindane)	0.0002	0.0003	1.3	3.1E-06	0.02
Hexachlorocyclopentadiene	0.05	0.007			0.2
Hexachloroethane	0.06	0.001	0.014	9.9E-06	1.6
Indeno(1,2,3-c,d)pyrene	0.001		0.73	8.6E-06	
Isophorone	0.9	0.2	0.00095	1.0E-05	0.1
Lead	0.015				
Mercury	0.002				
Methoxychlor	0.04	0.005			0.2
Methyl bromide	0.05	0.0014			1.0
Mehylene bromide	0.365	0.01			1
Methylene chloride	0.005	0.06	0.0075	4.4E-07	0.002
Methyl ethyl ketone (2- Butanone)	22	0.6			1
Methyl tert-butyl ether (MTBE)	0.47	0.9	0.0018	0.00001	0.01
2-Methylnaphthalene	0.73	0.02			1
Methylphenol, 2- (o-cresol)	1.8	0.05			1.0
Naphthalene	0.7	0.02	0.003	2.5E-05	1.0
Nickel	0.1	0.02			0.1
Nitrobenzene	0.018	0.0005			1.0
N-Nitrosodi-n-propylamine	0.17		7	1.4E-02	
N-Nitrosodiphenylamine	0.0001		0.0049	5.8E-09	
Pentachlorophenol	0.001	0.03	0.12	1.4E-06	0.001
Phenanthrene	11	0.3			1
Phenol	22	0.6			1.0
Propylene Glycol	18	0.5			1
PCBs	0.0005				
Pyrene	1.1	0.03			1.0
Selenium	0.05	0.005			0.3
Silver	0.18	0.005			1.0
Styrene	0.1	0.2			0.014
Tetrachloroethane, 1,1,2,2-	0.004		0.2	9.4E-06	
Tetrachloroethylene	0.005	0.01	0.052	3.1E-06	0.014
Thallium	0.002				
Toluene	1	0.2			0.14
Toxaphene	0.003		1.1	3.9E-05	
Trichlorobenzene, 1,2,4-	0.07	0.01			0.2
Trichloroethane, 1,1,1-	0.2				
Trichloroethane, 1,1,2-	0.005	0.004	0.057	3.3E-06	0.03
Trichloroethylene	0.005				
Trichlorophenol, 2,4,5-	3.65	0.1			1.0

Contaminant	GW Cleanup Level (mg/l)	RfD (mg/kg-d)	Sfo (mg/kg-d)$^{-1}$	Risk at Cleanup[1]	HQ at Cleanup[2]
Trichlorophenol, 2,4,6-	0.077		0.011	9.9E-06	
1,2,3, Trichloropropane	0.04	0.006	0.02	0.000009	0.2
2-(2,4,5-Trichlorophenoxy) propionic acid (Silvex)	0.05	0.008			0.2
Trichlorotriflouroethane (Freon 113)	1100	30			
1,2,4-Trimethylbenzene	1.83				
1,3.5-Trimethylbenzene	1.83	0.05			1
Vanadium	0.26	0.007			1.0
Vinyl acetate	36.5	1			1.0
Vinyl chloride	0.002	0.003	0.1	2.3E-06	0.02
Xylenes	10	2			0.1
Zinc	11	0.3			1.0
GRO	1.3				
DRO	1.5				
RRO	1.1				
GRO - Aliphatics	1.3	5			0.01
GRO - Aromatics	7.3	0.2			1.0
DRO - Aliphatics	0.1	0.1			0.03
DRO - Aromatics	1.5	0.04			1.0
RRO - Aliphatics		2			0.00
RRO - Aromatics	1.1	0.03			1.0

1 - Equation 2 from *Cleanup Levels Guidance* (2002)
2 - Equation 1 from Cleanup Levels Guidance (2002)