PROTOCOL FOR VCP REMEDIATION GOAL LOOKUP TABLES
NEBRASKA VOLUNTARY CLEANUP PROGRAM

1.0 INTRODUCTION

This guidance describes the protocol employed by Nebraska Department of Environmental Quality (NDEQ) to establish chemical-specific and media-specific remediation goals (RGs) for soil and groundwater protective of human health and the environment. NDEQ created this document to support a consistent and streamlined decision-making process for sites managed under the Nebraska Voluntary Cleanup Program (VCP). The goal is to use this guidance as one tool to identify RGs for a site in the VCP. The RGs are referred to throughout this document as "VCP RGs."

The protocol described in this guidance reflects approaches and procedures for establishing RGs that NDEQ, other state agencies, and the U.S. Environmental Protection Agency (EPA) use in existing programs to assess potential human health risks posed by potential exposure to environmental contamination. The bases of this approach are the EPA guidance and directives established to support the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). In addition, this document relies on Nebraska standards promulgated under Title 117 - Nebraska Surface Water Quality Standards (NDEQ 2000) and Title 118 - Ground Water Quality Standards and Use Classification (NDEQ 2001). This protocol resulted from discussions between NDEQ and Nebraska Health and Human Services Systems (NHHSS) personnel. It should be noted that the VCP RGs developed in this document are not static, but "living" benchmarks that will be modified accordingly—typically annually or as significant new exposure and toxicological information becomes available.

Complexities of contaminated sites vary widely in physical and contaminant characteristics, exposure factors, and resultant risks and hazards. This protocol aims to provide an acceptable level of protectiveness and flexibility that will promote high-quality, effective, and efficient cleanups by:

- Streamlining decision-making
- Framing a consistent approach

- Ensuring remedial action that protects human health and the environment
- Providing flexibility either to use risk-based lookup tables or to develop site-specific risk-based cleanup goals
- Considering land use
- Maintaining consistency with NDEQ and EPA guidance.

The remaining sections of this guidance include an overview of the protocol (Section 2.0), the tiered approach for establishing VCP RGs (Section 3.0), the procedures used for developing the VCP RG lookup tables (Section 4.0), a guide to interpreting the VCP RG lookup tables (Section 5.0), and a summary of the technical documentation supporting the VCP RG lookup tables, including the assumptions used to calculate the VCP RGs (Section 6.0). The VCP RG lookup tables are included as Attachment A.

2.0 OVERVIEW

The following sections describe various aspects of the VCP RG protocol approach, including the three tiers of the VCP RG approach, as discussed in Section 2.1. This protocol focuses on Tier 2 values, referred to as VCP RGs, but also presents the Tier 1 and Tier 3 options. Section 2.2 outlines specific issues related to non-cancer hazards and carcinogenic risks, including the target non-cancer hazard and carcinogenic risks prescribed for individual and multiple contaminants undergoing a Tier 2 evaluation. Finally, specific requirements for ecological receptors are discussed in Section 2.3.

2.1 VCP Remediation Goal Protocol

The VCP RG protocol is based on a three-tiered approach: (1) determine if contamination identified on site is greater than background levels (Tier 1); (2) use a set of VCP RG lookup tables (Tier 2); and (3) develop site-specific VCP RGs (Tier 3). The Tier 2 approach is similar to methodologies followed to develop RGs by EPA Region 3 (Risk-Based Concentrations [RBCs], EPA 2004a), Region 6 (Human Health Medium-Specific Screening Levels [HHMSSLs], EPA 2004b), and Region 9 (Preliminary Remediation Goals [PRGs], EPA 2002a); many other state voluntary cleanup programs that use risk-based lookup tables; and the Tier 1 lookup tables in NDEQ's Risk-Based Corrective Action (RBCA) at Petroleum Release Sites: Tier 1/Tier 2 Assessments (NDEQ 2002). The Tier 3 approach is similar to other approaches used under existing EPA and NDEQ guidance. These approaches range from: (1) completing a baseline risk assessment in accordance with EPA's *Risk Assessment Guidance for Superfund (RAGS)* Part A (EPA 1989); to (2) modifying only certain exposure pathways and assumptions to reflect site-specific conditions; to (3) using site-specific values for fate and transport parameters consistent with the Tier 2 approach in NDEQ's RBCA at Petroleum Release Sites (NDEQ 2002).

2.2 Noncarcinogenic Hazards and Carcinogenic Risks

VCP RGs are based on the assumption of exposure due to site-related contamination that will result in acceptable risk to human health and the environment. Long-term or chronic exposure to contaminated media is considered in the VCP RGs. The human health risks defined are related to both carcinogenic risks and noncarcinogenic hazards. In some cases, a contaminant may exhibit both noncarcinogenic and carcinogenic toxicity. The VCP RG would then be based on the lower of the target contaminant concentrations resulting from the analysis of noncarcinogenic hazard or carcinogenic risk.

For estimating noncarcinogenic hazard, a threshold exposure is estimated based on a clinically-determined critical toxicological effect such as liver, kidney, or central nervous system disorders or damage. This threshold exposure is referred to as the reference dose (RfD) for oral exposure or reference concentration (RfC) for inhalation exposure. The general assumption is that exposure below the RfD or RfC will pose no appreciable risk of adverse effects on human health, including the health of sensitive populations, during a lifetime. Exposures above the RfD or RfC may result in an unacceptable risk of adverse health effects. The ratio between the exposure and the RfD or RfC is known as the Hazard Quotient (HQ). For residential VCP RGs, an HQ less than or equal to 0.25 is considered acceptable, and an HQ greater than 0.25 is considered unacceptable. For industrial VCP RGs, an HQ less than or equal to 1.0 is considered acceptable, and an HQ greater than 1.0 is considered unacceptable. When a receptor or organism (in this case, a person) is exposed to multiple contaminants producing noncarcinogenic effects, the sum of HQs calculated for an exposure pathway (the way a contaminant comes in contact with an organism—e.g., ingestion, inhalation) or receptor is referred to as the Hazard Index (HI). For both residential and industrial VCP RGs, a target organ-specific HI exceeding 1.0 is not acceptable. See Section 4.3 for further information on HQs and HIs.

For carcinogenic risks, human and animal data are used to estimate the probability of increasing potential for developing cancer due to chronic exposure to contaminated media. The chemical-specific oral slope factor (SF) or inhalation unit risk (IUR) represents the carcinogenic risk factor: the higher the SF or IUR, the greater the potential for that contaminant to cause a cancer over a lifetime. This SF (along with an estimated dose) or IUR is used to calculate a probability of excess cancers occurring over a lifetime. The probability is expressed as an excess probability of an *individual* (not a population) developing cancer over a lifetime as a result of exposure to the chemical that causes carcinogenic effects. This incremental or excess individual lifetime cancer risk exceeds the background cancer risk (for example, it is expressed as one excess cancer incidence per 1,000,000 population [1 in 1,000,000] or 1×10^{-6}). EPA's National Contingency Plan (NCP) has established 1×10^{-6} as a point of departure for determining remediation decisions when applicable, relevant, and appropriate regulations are not available. EPA has also noted that remedial action should result in an acceptable risk range of 1×10^{-4} to 1×10^{-6} (EPA 1990a). EPA's policy is that action is generally not warranted unless the cumulative cancer risk to an individual is exceeds 1×10^{-4}. For residential VCP RGs, a cancer risk level less than or equal to 1×10^{-6} is considered acceptable for individual chemical carcinogenic risks, and a cancer risk level greater than 1×10^{-6} is considered unacceptable for individual chemical carcinogenic risks. For industrial VCP RGs, a cancer risk level less than or equal to 1×10^{-5} is considered acceptable for individual chemical carcinogenic risks, and a cancer risk level greater than 1×10^{-5} is considered unacceptable for individual chemical carcinogenic risks. When a receptor or organism (in this case, a person) is exposed to multiple contaminants producing carcinogenic effects, the sum of cancer risk levels calculated for an exposure pathway or receptor is a cumulative cancer risk level. For residential VCP RGs, a combined, cumulative cancer risk level exceeding 1×10^{-5} is not acceptable. For industrial VCP RGs, a combined, cumulative cancer risk level exceeding 1×10^{-4} is not acceptable. See Section 4.2 for further information on cancer risk levels.

2.3 Ecological Receptors

The VCP RG lookup tables used in Tier 2 are not designed to protect ecological receptors. EPA and other agencies have not yet developed a comprehensive set of lookup tables for ecological VCP RGs because ecological settings are so complex. Development of VCP RGs for ecological receptors therefore first requires reasonable support for assuming a complete exposure pathway exists for these receptors. Under the VCP, the participant is required to answer a series of questions about significant ecological receptors at or adjacent to the site. These questions address the site's proximity to sensitive habitats, known ecological receptors in the area, presence of threatened or endangered species near the site, and other information on ecological receptors. These questions are listed below:

- If contamination is present at the site, is all soil contamination below 15 feet?
- Is less than 0.25 acre of contiguous undeveloped land on or within 500 feet of any area of the site?
- Are any of the following contaminants present: chlorinated dioxins or furans, polychlorinated biphenyl mixtures, dichlorodiphenyltrichloroethane, dichlorodiphenyldichloroethene, dichlorodiphenyldichloroethane, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene?
- For sites that do not contain any contaminants listed above, are more than 1.5 acres of contiguous undeveloped land on or within 500 feet of any area of the site?
- Does the site have any features that would obviously eliminate specific exposure pathways, such as paving or other permanent barriers?
- Does the site contain or is it likely to contain special-status species or habitats?
- Does groundwater from the site discharge to a water body or wetland?

The VCP participant should provide answers to these questions to NDEQ, which will review them with assistance from other appropriate state or federal agencies, such as Nebraska Game & Parks Commission, Nebraska Health and Human Services System, EPA, and the US Fish & Wildlife Service. If a site is found to have a viable ecological population and a chemical of potential concern (COPC) is present, the participant should conduct an ecological risk assessment at the site in accordance with EPA's Ecological Risk Assessment Guidance for Superfund (EPA 1997b). The risk assessment is then used to establish VCP RGs under direction of NDEQ. Site-specific ecological VCP RGs then will be developed using the exposure assumptions from this assessment. For surface water, the VCP RGs should be consistent with Title 117 - Nebraska Surface Water Quality Standards, Chapter 4, Section 003, Aquatic Life (NDEQ 2000).

3.0 TIERED APPROACH

The following sections describe the three-tiered approach to establishing VCP RGs for contaminated sites. The protocol assumes that before the tiered approach is applied to any VCP site, the site has been thoroughly characterized according to information outlined in VCP guidance. This site characterization includes identifying the nature and extent of contamination, defining the land use (current and future), determining groundwater use, and identifying potential receptors. Also necessary is development of a conceptual site model that clearly identifies all contaminant sources and their migration pathways, as well as potential receptors (i.e., residents, industrial workers). Note that for simplicity, throughout this document and the VCP RG lookup tables, industrial-commercial workers and the industrial-commercial land use scenario will be referred to "industrial" instead of "industrial-commercial."

3.1 Tier 1

The Tier 1 evaluation compares contaminants identified on site with site-specific background levels. Background samples are a baseline measurement to assess the degree of contamination at a site. It should be determined whether background samples are truly uncontaminated; if COPCs are detected in the background samples, an assessment should determine whether they are anthropogenic (human-made) in origin and not site-related, present at naturally occurring levels, or actual site contaminants.

A basic assumption for Tier 1 is that contaminants found at a site are related to site activities and are not considered background. The background evaluation focuses on inorganic contaminants, as most organic compounds found at contaminated sites are not naturally occurring (although they may be ubiquitous) and may also include certain contaminants naturally enriched in various environments. As part of the site investigation, site-specific background levels for soil and groundwater should be established. Analytical results for site soil should be compared to soils of similar soil type, and analytical results for site groundwater should be compared to groundwater from the same waterbearing unit. Note that contaminants associated with a site that are identified in groundwater will be required to comply with Nebraska Title 118 – Ground Water Standards and Use Classification.

NDEQ recognizes that a number of naturally occurring inorganic contaminants are present at sites in varying concentrations. These contaminants may include metals (lead, arsenic, chromium, and others) and other inorganics (such as chloride and natural nitrate). In addition, organic contaminants may be present due to their widespread human uses and could be considered as anthropogenic contamination. Tier 1 is designed to address primarily background contaminant situations; anthropogenic concentrations should not be screened out at Tier 1 and need to be carried through Tier 2.

The VCP participant should evaluate analytical results of contaminant concentrations found at the site to determine if they are within the range of background conditions. Any contaminant found at or below inorganic background levels is not considered a COPC and does not need to be included in the remedial action plan for the site. To determine whether a contaminant is above background, the participant should follow the procedures outlined in EPA's "Guidance for Comparing Background and Chemical Concentrations in Soils at Superfund Sites" (EPA 2001), American Society for Testing and Materials (ASTM) D6312-98 "Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs" (ASTM 1998), or a functional equivalent. A contaminant found above inorganic background levels via direct comparison or appropriate statistics is a COPC. VCP RGs are required for all COPCs.

3.2 Tier 2

At completion of the Tier 1 evaluation, contaminants found at concentrations above background levels have been identified as COPCs for the site. The Tier 2 evaluation compares concentrations of COPCs found on site with VCP RGs in lookup tables to determine if concentrations in soils or groundwater exceed the VCP RGs. The user may calculate the upper confidence limit of the arithmetic mean for each COPC and use this value to compare with the appropriate VCP RG. This calculation may be completed using EPA's ProUCL Software, available at http://www.epa.gov/nerlesd1/tsc/form.htm. If the upper confidence limit of the arithmetic mean for contaminant concentrations are found at concentrations above the VCP RGs, the participant has two alternatives: either remediate the site to the values in the VCP RG lookup tables or develop a site-specific VCP RG under Tier 3. If a COPC is not on the VCP RG lookup tables, the participant should contact NDEQ so that NDEQ can determine an appropriate VCP RG.

For each organic COPC, the soil's saturation concentration should be calculated. At the soil saturation concentration, the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the contaminant may be present as a pure liquid phase (if the contaminant is liquid at ambient soil temperatures) or pure solid phase (if the contaminant is solid at ambient soil temperatures). If the soil saturation concentration is lower than the risk-based VCP RG, the saturation concentration is used as the VCP RG.

VCP RGs are risk-based values designed to be protective of human health and the environment.

- For residential land use scenarios, the VCP RG in soil is set at an excess cancer risk level of 1×10^{-6} for individual chemical carcinogenic risks and a cancer risk level of 1×10^{-5} for the cumulative carcinogenic effects of multiple chemical carcinogenic risks. For individual chemical noncarcinogenic hazards, the VCP RG in soil is set at an HQ value of 0.25 and a target organ-specific HI of 1.0 for the combined effects of multiple chemical noncarcinogenic hazards. The required cancer risk levels are further discussed in Section 4.2, and the required HQ and HI are further discussed in Section 4.3. Note that where the background concentration for a COPC exceeds an excess cancer risk level of 1×10^{-6} or an HQ value of 0.25, the background concentration becomes the VCP RG.

- For industrial land use scenarios, the VCP RG in soil is set at an excess cancer risk level of 1×10^{-5} for individual chemical carcinogenic risks and a cancer risk level of 1×10^{-4} for the cumulative carcinogenic effects of multiple chemical carcinogenic risks. The participant should contact NDEQ if more than 10 chemicals with carcinogenic effects are present, which would exceed the target risk level of 1×10^{-4}. For noncarcinogenic hazards, the VCP RG in soil is set at an HQ value of 1.0 and a target organ-specific HI of 1.0 for the combined effects of multiple chemical noncarcinogenic hazards. The required cancer risk levels are further discussed in Section 4.2, and the required HQ and HI are further discussed in Section 4.3. Note that where the background concentration for a COPC exceeds an excess cancer risk level of 1×10^{-5} or an HQ value of 1.0, the background concentration becomes the VCP RG. If the participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial.

The VCP RG lookup tables are for protection of human health only, not for ecological receptors. Parameter values for all exposure assumptions are discussed in more detail in Section 6.0. The VCP RG lookup tables are included as Attachment A.

3.3 Tier 3

Tier 3 requires NDEQ's oversight of the entire process. Under Tier 3, the participant can develop site-specific, risk-based VCP RGs that are protective of human health. This site-specific approach may consist of a complete baseline risk assessment, modification of certain exposure pathways and assumptions to reflect site-specific conditions, or use of site-specific values for fate and transport parameters consistent with the Tier 2 approach in NDEQ's RBCA at Petroleum Release Sites (NDEQ 2002).

Tier 3 provides the participant an option to determine VCP RGs using models, formulas, risk and exposure assessment methods, and approaches other than those specified under Tier 2. Tier 3 can involve considerably more effort than Tiers 1 and 2, since the evaluation can be more complex.

Performing a Tier 3 analysis may necessitate expanding the site investigation and the risk assessment, or including sophisticated contaminant fate and transport modeling. The following is a list of possible information that may be required to support a Tier 3 VCP RG.

- Additional geologic or hydrogeologic data
- Data required to support the accuracy of predictive fate and transport models
- Data to support alternative assumptions for exposure pathways and receptor models
- Data to support an alternative exposure point or point of compliance
- Data to support alternative future land uses.

The approach to developing Tier 3 VCP RGs should be consistent with EPA's *Risk Assessment Guidance for Superfund (RAGS): Volume I – Human Health Evaluation Manual.* Part B, Development of Risk-based Preliminary Remediation Goals (EPA1991a) and other relevant EPA and NDEQ guidance (such as NDEQ's RBCA at Petroleum Release Sites: Tier 1/Tier 2 Assessments [NDEQ 2002]).

4.0 DEVELOPMENT OF VCP REMEDIATION GOAL LOOKUP TABLES

The assumptions for the VCP RG lookup tables are largely based on default values, as outlined in EPA's current risk assessment guidance and NDEQ guidance:

- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA 2002b);
- *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (HHEM).* Part B, Development of Risk-Based Preliminary Remediation Goals (EPA 1991a) and Part E, Supplemental Guidance for Dermal Risk Assessment (EPA 2004e);
- RBCA at Petroleum Release Sites: Tier 1/Tier 2 Assessments – Appendixes D and E (NDEQ 2002)
- Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (EPA 2002c).

However, to be consistent with current NDEQ guidance and policies, and to reflect current conditions in Nebraska, some assumptions in the guidance above should be modified. For ease of discussion, these assumptions have been differentiated into groups.

The remainder of this section specifies and justifies the assumptions for developing human health VCP RG lookup tables under Tier 2 for the VCP; VCP RG lookup tables are presented in Attachment A.

4.1 Exposed Populations

Soil VCP RGs are developed for two exposure populations based on land use: (1) residents and (2) industrial workers. These two groups are most likely to be exposed to contamination released from a site in the VCP. Moreover, children are included in the residential population, thereby assuring protection of sensitive receptors. Other populations were considered, such as trespassers, recreationalists, or construction workers. However, the resident or industrial worker is exposed for a longer duration than these other populations and therefore is at higher risk of COPC exposure. Also, RAGS Part A (EPA 1989) identifies residential, commercial/industrial, and recreational land use as the land use categories most often applicable at Superfund sites. As mentioned above, recreationalists undergo less exposure than residents, so the receptors chosen for the VCP RG lookup tables include residents (children and adults) and industrial workers.

Groundwater VCP RGs are based on Title 118 – Ground Water Quality Standards and Use Classification – Appendix A, which considers exposure to residents (the most sensitive population group) (NDEQ 2001).

Exposure pathways considered in the VCP RG lookup tables are as shown in Table 1.

TABLE 1

RECEPTORS AND EXPOSURE PATHWAYS CONSIDERED IN THE VCP REMEDIATION GOAL LOOKUP TABLES

Exposure Medium	Exposure Pathway	Land Use	Receptor
Soil	Incidental ingestion	Residential	Age-adjusted – carcinogenic risks Child – noncarcinogenic effects
	Inhalation of volatiles and particulates	Residential	Adult – carcinogenic risks Adult – noncarcinogenic effects
	Dermal contact	Residential	Age-adjusted – carcinogenic risks Child – noncarcinogenic effects
	Incidental ingestion	Industrial	Worker
	Inhalation of volatiles and particulates	Industrial	Worker
	Dermal contact	Industrial	Worker
	Soil-to-groundwater	Residential	Age-adjusted – carcinogenic risks Adult – noncarcinogenic effects
Groundwater	Ingestion	Residential	Age-adjusted – carcinogenic risks Adult – noncarcinogenic effects
	Inhalation	Residential	Adult – carcinogenic risks Adult – noncarcinogenic effects
	Dermal contact	Residential	Age-adjusted – carcinogenic risks Adult – noncarcinogenic effects

4.2 Target Cancer Risk

The target cancer risk, a probability of an excess cancer over a lifetime, is set at different levels for soils based on two distinct populations: residential and industrial workers. The residential population is assumed to include sensitive populations such as elderly residents and children. The selected receptor-specific target cancer risk levels provide a high level of protection for the most sensitive populations that would be exposed almost exclusively in a residential setting. Importantly, target risk levels for individual and combined carcinogenic effects for both types of land use are within the acceptable target cancer risk range of 1 x 10^{-4} to 1 x 10^{-6} used by the federal Superfund and Resource Conservation and Recovery Act (RCRA) programs.

To protect the residential exposure groups, the target cancer risk for exposure to individual chemical carcinogenic risks in soils is set at one excess cancer in 1,000,000 population, or

1×10^{-6}. The target cancer risk level for the cumulative effects of multiple chemicals' carcinogenic risk is 1×10^{-5} for residential land use. If more than 10 chemicals with carcinogenic effects are present for residential land use scenarios, NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1×10^{-5} goal is met. Note that even if the cumulative risk level of 1×10^{-5} is met, each individual chemical must still meet a 1×10^{-6} risk level.

Since the industrial worker population is not anticipated to include the elderly and children, its target cancer risk is one excess cancer in 100,000 population, or 1×10^{-5}. The target cancer risk level for the cumulative effects of multiple chemical carcinogenic risks is 1×10^{-4} for industrial land use. If more than 10 chemicals with carcinogenic effects are present for industrial land use scenarios, NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1×10^{-4} goal is met. Note that even if the cumulative risk level of 1×10^{-4} is met, each individual chemical must still meet a 1×10^{-5} risk level. As discussed earlier, if a participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial.

Exposure to groundwater is not usually population-specific as is exposure to soils. Therefore, instead of setting the target cancer risk by exposed populations, VCP RGs for exposure to groundwater will be identified consistent with the approach outlined in Title 118 – Ground Water Standards and Use Classification – Appendix A (NDEQ 2001). The receptor is assumed an adult resident, and the target cancer risk for those compounds without Title 118 numerical standards is 1×10^{-6}. Absent a standard, however, VCP RGs are calculated in a manner similar to that for soils. This is discussed in more detail in Section 4.6.

4.3 Target Hazard Index

The target HQ, established for individual chemical noncarcinogenic hazards, and the HI, which is the sum of the HQ for combined effects of individual noncarcinogenic hazards, are set at different levels for soils based on two distinct populations: residential and industrial workers. The residential population is assumed to include sensitive populations such as elderly residents and children. The selected receptor-specific target HQs and HIs provide a high level of protection for the most sensitive populations that would be exposed almost exclusively in a residential setting. It should be noted that the federal Superfund and RCRA programs identify a target HI of 1.0 as the goal for combined effects of individual chemical noncarcinogenic hazards.

To protect the residential exposure groups, the HQ for exposure to individual chemicals with noncarcinogenic effects in soils is set at 0.25. An HQ of 0.25 for exposure to soils provides a level of conservatism for sites with multiple chemical noncarcinogenic hazards. The target organ-specific HI for the cumulative effects of multiple chemical noncarcinogenic hazards is 1.0 for residential land use. If more than four chemicals with noncarcinogenic effects are present for residential land use scenarios, the participant should refer to Attachment D of this document, "Target Organs for Noncarcinogenic Effects of Various Contaminants," which provides information on target organs compiled for the States of Illinois and Florida risk-based corrective action programs. The number of contaminants affecting each target organ should be determined. If more than four chemicals with noncarcinogenic effects affect a single target organ or multiple target organs (thereby exceeding the target organ-specific HI of 1.0), NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1.0 goal is met. Note that even if the cumulative HI of 1.0 is met, each individual chemical must still meet an HQ of 0.25. If a COPC is present but not listed in the VCP RG lookup tables (and not on the list presented in Attachment D), the participant should contact NDEQ to determine if target organ effects are applicable for the contaminant.

For industrial land use scenarios, the VCP RG in soil is set to a target HQ of 1.0. This value is less conservative than the residential target, but still considered protective of industrial workers. The target organ-specific HI for the cumulative effects of multiple chemical noncarcinogenic hazards is 1.0 for industrial land use. If more than one chemical with noncarcinogenic effects is present for industrial land use scenarios, the participant should refer to Attachment D of this document, "Target Organs for Noncarcinogenic Effects of Various Contaminants," which provides information on target organs compiled for the States of Illinois and Florida risk-based corrective action programs. The number of contaminants affecting each target organ should be determined. If more than one chemical with noncarcinogenic effects affects a single target organ or multiple target organs (thereby exceeding the target organ-specific HI of 1.0), NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1.0 goal is met. As discussed earlier, if a participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial. If a COPC is present but not listed in the VCP RG lookup tables (and not on the list presented in Attachment D), the participant should contact NDEQ to determine if target organ effects are applicable for the contaminant.

As with the target cancer risk discussed above, VCP RGs for exposure to groundwater will be identified consistent with the approach outlined in Title 118 – Ground Water Standards and Use Classification – Appendix A (NDEQ 2001). The receptor is assumed an adult resident, and a target HQ of 0.25 will be used for those compounds without Title 118 numerical standards. This HQ value will correspond to a concentration expected to result in no adverse health effect for longer-term or lifetime exposure, as discussed in Title 118, Appendix A. Absent a standard, however, VCP RGs are calculated in a manner similar to that for soils (e.g., childhood exposures are considered). This is discussed in more detail in Section 4.6.

4.4 Surface Water

All surface water values for human exposure will be consistent with Title 117 - Nebraska Surface Water Quality Standards, Chapter 4, Section 004 – Water Supply (NDEQ 2000). Note that values protective of ecological receptors will be determined separately.

4.5 Soil Exposure

Multiple exposure pathways are considered when establishing a VCP RG for soil. VCP RGs for soil are based on three major pathways: incidental ingestion, dermal contact, and inhalation. The incidental ingestion pathway assumes a higher incidental ingestion rate of soil for children than adults; it estimates protective concentrations in soil considering these ingestion rates combined with toxicity factors, risk levels/hazard indices, and other exposure factors (e.g., duration of exposure).

The dermal contact pathway takes into account receptor-specific contact rates and the same considerations used for incidental soil ingestion. In addition, chemical-specific absorption fractions and chemical-specific modifications of oral toxicity factors for dermally absorbed contaminant doses are used.

The soil inhalation pathway takes into account either inhalation of COPCs volatilizing from the soils (volatile compounds only) or inhalation of airborne particulates or dusts. Chemical-specific volatilization factors from soil (VF_s) are used to estimate exposure from volatile COPCs, defined as contaminants with a Henry's law constant greater than 1×10^{-5} atmosphere - cubic meter per mole (atm-m^3 / mole) and a molecular weight (MW) less than 200 grams per mole (g/mole). For the purposes of the VCP RG tables, only volatile organic compounds (VOC) are considered "volatile;" inorganics are not. To estimate the inhalation of particulates from non-volatile COPCs, a particle emission factor (PEF) is used. EPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA 2002b) provides a procedure to calculate PEFs for various locations. To calculate a default PEF for Nebraska, specific data provided for Lincoln, Nebraska, were used.

As discussed earlier, the soil's saturation concentration is also calculated for each COPC. If the soil saturation concentration is lower than the above risk-based VCP RG, the saturation concentration is used as the VCP RG.

4.6 Groundwater Exposure

All groundwater exposure values are set consistent with Title 118 – Ground Water Standards and Use Classification – Appendix A (NDEQ 2001), which establishes a groundwater and remedial action classification process to protect groundwater for appropriate uses. For groundwater pollution occurrences, Title 118 identifies three remedial action classes (RAC): RAC-1, RAC-2, and RAC-3— defined in Appendix A as:

- RAC-1 — This category includes groundwaters of Class GA and a portion of Class GB, a 500-foot radius around all private drinking water supply wells. In addition, RAC-1 shall be assigned automatically when a public or private drinking water supply well has been contaminated. RAC-1 shall receive the most extensive remedial action measures.

- RAC-2 — This category includes groundwaters of Class GB (except for the portion of Class GB placed in RAC-1) and Class GC(R).

- RAC-3 — This category includes, but is not limited to, groundwaters of Class GC— except for Class GC(R) that were placed in RAC-2. RAC-3 shall receive the least extensive remedial action measures.

The definitions of the groundwater classes GA, GB, and GC are provided in Chapter 7 of Title 118. Under Title 118, Appendix A, the VCP RGs for RAC-1 and RAC-2 are set at the maximum contaminant levels (MCL) in Chapter 4. Absent an established MCL, EPA's Ambient Water Quality Criteria, Health Advisories, and other documents are used to set the VCP RG.

For COPCs without a regulatory standard, the level is set at one of the following under Title 118: the concentration estimated to result in an excess lifetime cancer risk of 1×10^{-6}; a concentration expected to result in no adverse health effect for longer term or lifetime exposures; or a laboratory detection limit (if higher and within an acceptable range). For RAC-3, cleanup of readily removable contaminants (e.g., free product) is required; other impacts to beneficial use may be considered (e.g., wetland systems), and monitoring may also be necessary.

Note that the VCP RG protocol modifies the approach taken under Title 118, Appendix A. Instead of using only the ingestion pathway to determine the risk-based value, it also includes the inhalation pathway for volatile COPCs, as well as the dermal pathway for appropriate compounds (See Section 6.6). Further, the VCP RG protocol uses an HQ of 0.25 for noncarcinogenic hazards. Procedures to calculate this VCP RG follow those provided in the supporting documentation for EPA Region 9 PRGs and the EPA dermal guidance (EPA 2004e) and are described in more detail in Section 6.6. Note that VCP RGs based on dermal exposure to groundwater are ~~not~~ derived only for COPCs considered likely to exceed the risk for groundwater ingestion and inhalation exposures, as discussed in RAGS Part E, Exhibit B.

4.7 Soil-to-Groundwater

The VCP RGs include soil concentrations that preclude migration of soil contamination to underlying groundwater (which would cause contamination threatening human health and the environment). This approach assumes that contaminants are leached from the soil, migrate to the groundwater, and eventually enter a receptor well. For RAC-1 and RAC-2 sites, the receptor is assumed at the source area. For RAC-3 sites, the VCP RG should ensure no free product development on the groundwater table or no soil saturation.

The calculations follow the recommendations outlined in EPA's Soil Screening Guidance (EPA 1996a,b; 2002b) and assume a dilution attenuation factor (DAF) of 20. DAF represents the reduction in concentration that occurs as soil leachate moves through soil and groundwater, as a result of adsorption, degradation, and dilution by clean groundwater. DAF is defined as the ratio of soil leachate concentration to receptor point concentration. A DAF of 20, as used here, assumes that there is a 20-fold reduction in contaminant concentration between the soil sampling location and the receptor well location. This DAF value is based on the assumption of a 0.5 acre source and applies to most sites in the VCP program. For sites where little or no attenuation might be expected (e.g., shallow groundwater table with on-site receptor well, fractured media, karst topography, or source size greater than 30 acres), the applicant should contact the Department to address the need for a lower RG based on a DAF=1.

4.8 Soil Depth

Soil VCP RGs for exposure through direct contact pathways apply to soil depths to which a receptor will likely be exposed at the site. For a residential receptor, this is the upper 10 feet—assumption being that potential basement construction may bring soil from this depth to the surface. For an industrial receptor, this is the upper 15 feet—assuming that construction or maintenance of a utility line could occur at this depth and exposure then would occur. However, please note that cleanup to the appropriate RGs to these depths may not be necessary in all cases (e.g., no basements or deep utilities to be constructed). In such cases, having 2 – 3 feet of clean soil or fill beneath the structure may eliminate exposures through direct contact pathways. The NDEQ should be consulted in such instances.

4.9 Indoor Air

Intrusion of volatile contaminants from the subsurface into buildings is a pathway of concern for NDEQ. To determine if remedial action may be required for this medium, VCP uses the protocols in the recent draft EPA vapor intrusion guidance “Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils” (EPA 2002c). Intrusion of volatile contaminants may be of concern at sites meeting the following criteria:

- Volatile COPCs are located 100 feet below ground level (bgl) or less.
- Volatile COPCs are located in proximity to existing or future buildings (within 100 feet horizontally).

If these criteria are met, the participant should use the recent draft EPA vapor intrusion guidance to determine if the site could pose a risk to human health. The participant should use a target risk level of 1×10^{-6} for residential land use and 1×10^{-5} for industrial land use. An HI of 1.0 should be used for both residential and industrial land use. If the participant identifies contaminant concentrations that may pose unacceptable risk or hazard, he or she should contact NDEQ to determine the appropriate VCP RG for this pathway.

5.0 READING THE VCP REMEDIATION GOAL LOOKUP TABLES

This section provides an overview of the VCP RG lookup tables. Since the approach taken to develop these tables was similar to the approach taken by EPA Region 9 in developing its PRGs, large portions of the text in the following two sections are taken from the EPA Region 9 PRG supporting documentation (EPA 2002a). The VCP RG lookup tables are presented in Attachment A, and the supporting tables are presented in Attachment B.

5.1 General Considerations

With the exceptions described below, VCP RGs are contaminant concentrations that correspond to fixed levels of risk and hazard in soil and groundwater—cancer risk of either 1×10^{-6} for residential or 1×10^{-5} for industrial, or a noncarcinogenic HQ of either 0.25 for residential or 1.0 for industrial. For most cases in which a contaminant causes both cancer and non-cancer (systemic) effects, the cancer risk estimate will call for more stringent criteria, and consequently this value appears in the printed copy of the VCP RG lookup tables. VCP RG concentrations that equate to the calculated cancer risk are indicated by "ca." VCP RG concentrations that equate to the calculated HQ for noncarcinogenic concerns are indicated by "nc." Note that for groundwater and soil-to-groundwater RGs, a “m” designation indicates that the value is based on a MCL from Title 118.

NDEQ recommends calculation of both cancer- and non-cancer-based VCP RGs; the lower of the carcinogenic and noncarcinogenic VCP RG should then be used as the final value. Both carcinogenic and noncarcinogenic VCP RGs, as well as the lower of the two, are listed in Attachment A, Tables A-1.

In general, concentrations in the VCP RG lookup tables are risk-based, but two important exceptions for soil exist: (1) for some contaminants, VCP RGs are based on the soil saturation equation ("sat") and (2) for relatively less toxic inorganic and semivolatile contaminants, a non-risk-based "ceiling limit" concentration is given as $1 \times 10^{+5}$ milligram per kilogram (mg/kg) ("max"). The risk-based values for these same contaminants are also available along with the VCP RGs if the participant wants to view the risk-based concentrations before applying “sat” or “max.” For more information on why the “sat” value and not a risk-based value is presented for several volatile contaminants in the VCP RG lookup tables, see Section 6.5.

Applying a "ceiling limit" to contaminants for reasons other than exceeding the saturation limit is not universally accepted. It has been argued that all values should be risk-based to allow for scaling (for example, if the risk-based VCP RG is set at an HQ = 1.0, and the participant would like to set the HQ to 0.1 to take into account multiple contaminants, this is as simple as multiplying the risk-based VCP RG by 1/10th). If scaling is necessary, VCP RG participants can make this adjustment by referring to the VCP RG lookup tables where risk-based soil concentrations are presented for all contaminants (see soil calculations, "combined" pathways column). Participants should contact NDEQ prior to conducting any scaling.

Though applying a ceiling limit is not universally accepted, NDEQ has opted to continue applying a "max" soil concentration to the VCP RG lookup tables for the following reasons:

- Risk-based VCP RGs for some contaminants in soil exceed unity (>1,000,000 mg/kg), which is not possible.
- The ceiling limit of 1 x 10^{+5} mg/kg is equivalent to a contaminant representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may not be accurate due to presence of the foreign contaminant itself (e.g., soil adherence, windborne dispersion may have changed).
- VCP RGs currently do not address short-term exposures (e.g., pica children [children who ingest unusually large amounts of non-food items, e.g., soil] and construction workers). Though extremely high soil VCP RGs are likely to represent relatively non-toxic contaminants, such high values might not be justified if more toxicological data were available for evaluating short-term and/or acute exposures. In other words, if more data regarding the acute toxicity of various compounds were available and considered, extremely high soil concentrations (e.g., > 1 x 10^{+5} mg/kg) may be found unprotective. Therefore, application of the "max" soil concentration is intended to address this issue.

5.2 Toxicity Values

Several issues impact toxicity values used to establish VCP RGs discussed in this section. A variety of sources are available for toxicity values, and this section identifies the toxicity source hierarchy used.

Hierarchy of Toxicity Values

Toxicity values, known as noncarcinogenic RfDs and RfCs, and carcinogenic SFs and IURs, were obtained from the following hierarchy of sources:

- Level 1: EPA's Integrated Risk Information System (IRIS) (EPA 2004c) values—indicated by "i" in the VCP RG lookup tables.

- Level 2: EPA's National Center for Environmental Assessment (NCEA) provisional peer-reviewed toxicity values (PPRTV) (EPA 2004d)—indicated by "p" in the VCP RG lookup tables. Other NCEA values follow the PPTRVs in the hierarchy and are indicated by "n" in the VCP RG lookup tables.

- Level 3: EPA's Health Effects Assessment Summary Tables (HEAST) (EPA 1997a)—indicated by "h" in the VCP RG lookup tables—and other sources (e.g., California EPA toxicity values, Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels). Values withdrawn from IRIS or HEAST and under review are indicated by "x"; values obtained from other sources are indicated by "o."

Note that the toxicity factor hierarchy prescribed above reflects the new EPA hierarchy (EPA 2003).

Inhalation Toxicity Factors

Consistent with current U.S. EPA methodology, the VCP RG inhalation equations use RfCs and IUFs instead of inhalation RfDs and SFs. A number of uncertainties are involved in making the lung surface area and/or pharmacokinetic adjustments required to estimate an internal dose from the inhalation pathway (e.g., inhalation RfD). In addition, considering possible route-of-entry effects of various contaminants, route-to-route extrapolations are not performed for the toxicity factors in the VCP RG lookup tables. Therefore, the VCP RG lookup tables to not contain any inhalation values obtained using route-to-route extrapolation methods.

Dermal Toxicity Factors

For many contaminants, a scientifically defensible database does not exist for adjusting the oral SF and/or RfD to estimate a dermal toxicity value. The approach taken to modify the toxicity factors for dermal exposure was consistent with EPA dermal guidance (EPA 2004e).

5.3 Chemical/Physical Parameters

Chemical/physical parameters presented in Attachment B, Table B-1 were taken directly from the chemical/physical properties table listed in the EPA Region 9 PRG table. While MWs were estimated in the Region 9 PRG table, actual MWs were obtained from ChemFinder (Cambridge Software 2004). The Region 9 PRG tables present chemical/physical properties for VOCs only.

Since groundwater-to-soil VCP RGs are calculated in the VCP RG lookup tables, additional chemical/physical data (soil-water partition coefficient [K_d], soil-organic carbon-water partition coefficient [K_{oc}], and Henry's Law Constant [H]) were necessary and were obtained from EPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Appendix C (EPA 2002b). K_d/K_{oc} and H values for organics were obtained from Exhibit C-1 of this document; K_d values for inorganics (assuming a pH of 6.8) were obtained from Exhibit C-4 of this document. As H values for inorganics were not available in this 2002 Soil Screening Guidance document, the Texas Risk Reduction Program Rule chemical/physical properties (Texas Commission on Environmental Quality [TCEQ] 2004) were reviewed to ensure that all inorganics listed in Exhibit C-4 of the 2002 Soil Screening supplemental guidance document had a H value of zero. This was true for all inorganics listed except mercury (mercury has a H value listed in Exhibit C-1 of the EPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites; this H value for mercury was used in the VCP RG lookup tables).

As the groundwater dermal pathway is not included in the Region 9 PRG tables, additional chemical/physical parameters necessary for evaluation of this pathway were obtained from the EPA dermal guidance (EPA 2004e). Specifically, predicted dermal permeability (Kp) values, as well as calculated values for time to reach steady state (t_star), fraction absorbed (FA), event duration (tau_event), and ratio of the permeability coefficient through the stratum corneum to the permeability coefficient across the viable epidermis (B) were obtained from Appendix B of the dermal guidance (EPA 2004e). Values for organics were obtained from Exhibit B-3 of Appendix B, and values for inorganics were obtained from Exhibit B-4 of Appendix B.

5.4 VCP Remediation Goals Derived with Special Considerations

Most VCP RGs are readily derived via the various equations contained herein. However, for some contaminants, the standard equations do not apply, and/or adjustments to the toxicity values are recommended. These special case contaminants are discussed below. Note that each of these special considerations is consistent with the approaches taken by EPA Region 9 in their PRG table (EPA 2002a).

Cadmium

The VCP RGs for cadmium are based on the oral RfD for water that is slightly more conservative (by a factor of 2) than the RfD for food; the more conservative RfD for cadmium was used. However, reasonable arguments could be made for applying the RfD for food (instead of the oral RfD for water) for some media such as soils.

The water RfD for cadmium assumes a 5% oral absorption factor. The assumption of an oral absorption factor of 5% for cadmium leads to an estimated dermal RfD of 2.5×10^{-5} mg/kg-day. The VCP RG calculations incorporate these adjustments per recent guidance (EPA 2004e).

Chromium VI

For chromium VI, IRIS shows an IUF of 1.2×10^{-2} (microgram per cubic meter)$^{-1}$ $(\mu g/m^3)^{-1}$. However, the supporting documentation in the IRIS file states that these toxicity values are based on an assumed 1:6 ratio of chromium VI:chromium III. Because of this assumption, these cancer toxicity values were presented in the VCP RG lookup tables as "total chromium" numbers. In the VCP RG lookup tables, chromium VI-specific values are also included. These are derived by multiplying the "total chromium" value by 7, yielding a unit risk factor of 8.4×10^{-2} $(\mu g/m^3)^{-1}$.

Lead

Derivations of residential VCP RGs for lead are based on pharmacokinetic models. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model is designed to predict the probable blood lead concentrations for children 0 to 84 months old who have been exposed to lead through various sources (air, water, soil, dust, diet and *in utero* contributions from the mother) (EPA 1994a,b). The IEUBK model may also be used to estimate the risk or probability that a child's blood lead concentration will exceed a certain level of concern (typically 10 µg/dL). The IEUBK Model was used to calculate VCP RGs such that there would be no more than a 5% probability that a residential child or fetus exposed to lead contamination would exceed a blood lead level of 10 µg/dL, to be consistent with EPA's health protection goal for lead.

Manganese

The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. The author of the IRIS assessment for manganese recommends subtracting the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. The explanatory text in IRIS further recommends using a modifying factor of 3 when calculating hazards associated with non-food sources due to a number of uncertainties discussed in the IRIS file for manganese, leading to a RfD of 0.024 mg/kg-day. This modified RfD is applied in the derivation of the VCP RGs for soil and groundwater.

Thallium

IRIS has many toxicity factors for the different salts of thallium. But because analytical data packages typically report "thallium," it was decided to report a VCP RG for "thallium" by basing the adjustment contained in the IRIS file for thallium sulfate on the MW of thallium. The adjusted oral RfD for plain thallium is 6.6×10^{-5} mg/kg-day, which is used to calculate the thallium VCP RG.

Vinyl Chloride

In EPA's reassessment of vinyl chloride toxicity, IRIS presents two cancer SFs for vinyl chloride: one intended for evaluating adult risks and a second (more protective) value that takes into account the unique susceptibility of developing infants and young children. For residential VCP RGs, the VCP RG lookup tables apply the more conservative cancer potency factor that addresses exposures to both children and adults, whereas for the industrial VCP RGs, the adult only cancer SF is applied.

Because of the age-dependent vulnerability associated with vinyl chloride exposures, and due to the method applied to derive the cancer slope factor for vinyl chloride, an assumption of a 70-year exposure over the lifetime is assumed for residential exposures—consistent with the way the toxicity value for vinyl chloride was derived. Therefore, instead of the usual exposure assumption of 6 years as a child and 24 years as an adult assumed for carcinogenic risks, the exposure assumption for vinyl chloride has been revised to 6 years as a child and 64 years as adult. Since most of the cancer risk is associated with the first 30 years of exposure to vinyl chloride, little real difference exists between a 30-year exposure assumption (typically assumed for Superfund risk assessments) and the 70-year exposure assumption in calculating the VCP RG for vinyl chloride.

5.5 Soil-to-Groundwater Approach

The soil-to-groundwater RGs were developed using a default DAF of 20 to account for natural processes that reduce contaminant concentrations in the subsurface. In general, if VCP RGs are not exceeded for the migration to groundwater pathway, this pathway may be eliminated from further investigation.

5.6 Miscellaneous

VOCs are indicated by "1" in the VOC column of the VCP RG lookup tables and are defined in Section 4.5 of this document. Three borderline contaminants (dibromochloromethane, 1,2-dibromochloropropane, and pyrene) that do not strictly meet these criteria of volatility have also been included based on professional judgment.

VOCs are evaluated for potential volatilization from soil and water to air but not for dermal exposure to soil per EPA guidance. Chemical-specific dermal absorption values for contaminants in soil and dust are presented for arsenic, cadmium, chlordane, 2,4-dichlorophenoxyacetic acid (2,4-D), 4,4′- Dichlorodiphenyldichloroethane (DDD), 4,4′- Dichlorodiphenyldichloroethene (DDE), 4,4′- Dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexanes (HCH), tetrachlorodibenxo-p-dioxin (TCDD), polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and pentachlorophenols as recommended in the *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual.* Part E, Supplemental Guidance for Dermal Risk Assessment Interim Guidance” (EPA 2004e). Otherwise, default dermal absorption fractions are assumed at 0.10 for semivolatile organic compounds (SVOC).

6.0 TECHNICAL SUPPORT DOCUMENTATION

VCP RGs consider human exposure hazards to contaminants from contact with contaminated soils and groundwater. The following section describes the approach taken to calculate exposures to soils via incidental ingestion, dermal contact, and inhalation; soil-to-groundwater; and exposures to groundwater via ingestion, dermal contact, and inhalation. The results of the calculations for each pathway are presented in Attachment B, Tables B-2 through B-4.

6.1 Soils - Incidental Ingestion

Calculation of risk-based VCP RGs for incidental ingestion of soil is based on methods presented in RAGS (EPA 1991a) and “Soil Screening Guidance” (EPA 1996a, b; 2001). Briefly, these methods back-calculate a soil concentration level from a target risk (for carcinogenic risks) or HQ (for noncarcinogenic hazards).

A number of studies have shown that inadvertent ingestion of soil is common among children six years old and younger (Calabrese and others 1989; Davis and others 1990; Van Wijnen, Clausing, and Brunekreef 1990). To take into account the higher soil intake rate for children, two different approaches are used to estimate soil VCP RGs, depending on whether the adverse health effect is cancer or some effect other than cancer. For carcinogenic risks, the method for calculating soil VCP RGs uses an age-adjusted soil ingestion factor that considers the difference in daily soil ingestion rates, body weights, and exposure duration for children from 0 to 6 years old and others from 7 to 30 years old. This health-protective approach is chosen to take into account the higher daily rates of soil ingestion in children, as well as the longer duration of exposure anticipated for a long-term resident. For more on this method, see RAGS (EPA 1991a).

For noncarcinogenic concerns, the more protective method of calculating a soil VCP RG is to evaluate childhood exposures separately from adult exposures. In other words, an age-adjustment factor is not applied as for carcinogenic risks. This approach is considered conservative because it combines the higher 6-year exposure for children with chronic toxicity criteria. NDEQ has adopted this approach for calculating soil VCP RGs for noncarcinogenic health concerns.

6.2 Soils - Vapor and Particulate Inhalation

EPA toxicity criteria indicate that risks from exposure to some contaminants via inhalation far outweigh the risk via incidental ingestion; therefore, soil VCP RGs have been designed to address this pathway as well. The models used to calculate VCP RGs for inhalation of volatiles and particulates are updates of risk assessment methods presented in RAGS: Part B (EPA 1991a) and are identical to the Soil Screening Guidance Technical Background Document and User's Guide (EPA 1996a, b).

Note that the soil-to-air pathway evaluated in the VCP RG calculations is based on direct inhalation exposures that result from volatilization or particulate emissions of contaminants from soil to outdoor air. The soil VCP RG calculations currently do not evaluate potential for volatile contaminants in soil to migrate indoors.

To address the soil-to-outdoor air pathways, the VCP RG calculations incorporate VF_s values for volatile contaminants and PEFs for non-volatile contaminants. These factors relate soil contaminant concentrations to air contaminant concentrations that may be inhaled on site. The VF_s and PEF equations can be divided into two separate models: an emission model to estimate emissions of the contaminant from the soil and a dispersion model to simulate the dispersion of the contaminant in the atmosphere.

The box model in RAGS: Part B (EPA 1991a) has been replaced with an air dispersion factor (Q/C) derived from a modeling exercise using meteorological data from 29 locations across the U.S.—because the box model may not apply to a broad range of site types and meteorology, and does not use state-of-the-art techniques developed for regulatory dispersion modeling. The dispersion model for both volatiles and particulates is the AREA-ST, an updated version of the Office of Air Quality Planning and Standards, Industrial Source Complex Model, ISC2. For the VCP RGs, the Q/C term of 81.64 g/m^2-sec/kg/m^3 for Lincoln, Nebraska, was used for both the VF_s and PEF equations.

A default source size of 0.5 acre was chosen for the VCP RG calculations. For unusual site conditions of an area source substantially larger than the default source area assumed here, an alternative Q/C can be applied (see EPA 1996a, b).

Volatilization Factor for Soils

VOCs were screened for inhalation exposures using chemical-specific, calculated VF_s values. Note that VF_s values are provided in Attachment B, Table B-1. The emission terms used in the VF_s calculations are chemical-specific and were calculated from physical-chemical information originally obtained from several sources. The priority of these sources was as follows: Soil

Screening Guidance (EPA 1996a, b), “Superfund Chemical Data Matrix” (EPA 1996c), *Handbook of Environmental Fate and Exposure Data for Organic Chemicals* (Howard 1991), *Subsurface Contamination Reference Guide* (EPA 1990b), and *Superfund Exposure Assessment Manual* (SEAM) (EPA 1988). When a choice was necessary between a measured and a modeled value (e.g., K_{oc}), modeled values were used. In cases where Diffusivity Coefficients (D_i) were not provided in existing literature, D_i values were calculated using Fuller's Method described in SEAM (EPA 1988). A surrogate term was required for some contaminants that lacked physico-contaminant information. In these cases, a proxy contaminant of similar structure was used that may overestimate or underestimate the VCP RG for soils. Note that chemical/physical information for VOCs was obtained directly from the EPA Region 9 PRG tables (EPA 2002a).

The VF_s equation described herein forms the basis for deriving generic soil VCP RGs for the inhalation pathway. The following parameters in the standardized equation can be replaced with site-specific data to develop a simple site-specific VCP RG:

- Source area
- Average soil moisture content
- Average fraction organic carbon content
- Dry soil bulk density.

The basic principle of the VF_s model (Henry’s Law) is applicable only if the soil contaminant concentration is at or below soil saturation “sat.” Above the soil saturation limit, the model cannot predict an accurate VF_s-based VCP RG. How these particular cases are handled depends on whether the contaminant is liquid or solid at ambient soil temperatures (see Section 6.5).

Note that soil inhalation VCP RGs are not calculated for inorganics, even if they fit the volatility cutoffs (H >1E-05 atm-m^3/mole; MW<200 g/mole). No soil inhalation or particulate values are calculated for these compounds. These volatile inorganic contaminants are flagged with “n/a” in the VOC column in Table A-1.

Particulate Emission Factor for Soils

Inhalation of contaminants adsorbed to respirable particles (PM_{10}) were assessed using a default PEF equal to 1.2E+9 m^3/kg that relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The generic PEF was derived using default values listed in the PEF equation herein. The relationship is derived by Cowherd and others (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (e.g., years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures.

Note that the generic PEF evaluates windborne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here.

The impact of the PEF on the resultant VCP RG concentration (that combines soil exposure pathways for incidental ingestion, dermal contact, and inhalation) may be assessed by viewing the pathway-specific soil concentrations available with the VCP RGs. The PEF equation detailed herein forms the basis for deriving a generic PEF for the inhalation pathway. For more details regarding specific parameters used in the PEF model, the reader is referred to “Soil Screening Guidance: Technical Background Document” (EPA 1996a).

6.3 Soils - Dermal Exposure

Dermal Contact Assumptions

Exposure factors for dermal contact with soil are based on recommendations in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual.* Part E, Supplemental Guidance for Dermal Risk Assessment. Interim Guidance. (EPA 2004e).

Dermal Absorption

Chemical-specific dermal absorption values (ABS_d) recommended by the Superfund Dermal Workgroup were applied when available. Chemical-specific values are included for the following contaminants: arsenic, cadmium, chlordane, 2,4-D, DDT, DDD, DDE, lindane and other hexachlorocyclohexanes, TCDD, PAHs, PCBs, and pentachlorophenols. The Supplemental Guidance for Dermal Risk Assessment (EPA 2004e) recommends a default dermal absorption factor for SVOCs of 10% as a screening method for most SVOCs without dermal absorption factors. Default dermal absorption values for other contaminants (VOCs and inorganics) are not recommended in this new guidance.

6.4 Soils - Migration to Groundwater

The methodology for calculating VCP RGs for the migration to groundwater was developed to identify contaminant concentrations in soil with potential to contaminate groundwater. Migration of contaminants from soil to groundwater can be envisioned as a two-stage process: (1) release of contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well. The soil-to-groundwater VCP RG methodology considers both of these fate and transport mechanisms.

Soil-to-groundwater VCP RGs are back-calculated from acceptable groundwater concentrations (i.e., MCLs per Title 118, or risk-based VCP RGs for the remaining compounds). First, the acceptable groundwater concentration is multiplied by a dilution factor to obtain a target leachate concentration. For example, if the dilution factor is 20 and the acceptable groundwater concentration is 0.05 mg/L, the target soil leachate concentration would be 1.0 mg/L. The partition equation presented herein is then used to calculate the total soil concentration (i.e., VCP RG) corresponding to this soil leachate concentration.

The soil-to-groundwater VCP RG methodology was designed for use during the early stages of a site evaluation when information about subsurface conditions may be limited. Because of this constraint, the methodology is based on conservative, simplifying assumptions about the release and transport of contaminants in the subsurface. For further information, the reader is referred to the Soil Screening Guidance documents (EPA 1996a, b; 2002b).

6.5 Soil Saturation Limit

The soil saturation concentration “sat” corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., non-aqueous phase liquids (NAPL) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures. The “sat” equation included herein is used to calculate “sat” for each volatile contaminant. As an update to RAGS Part B (EPA 1991a), this equation takes into account the amount of contaminant in the vapor phase in soil in addition to the amount dissolved in the soil's pore water and sorbed to soil particles.

Chemical-specific "sat" concentrations should be compared with each VF_s-based VCP RG because a basic principle of the VCP RG volatilization model is not applicable when free-phase contaminants are present. How these cases are handled depends on whether the contaminant is liquid or solid at ambient temperatures. Note that contaminants that are solids at ambient temperatures are indicated in the VCP RG lookup tables. Liquid contaminants with a VF_s-based VCP RG that exceeds the "sat" concentration are set equal to "sat," whereas for solids (e.g., PAHs), soil screening decisions are based on the appropriate VCP RGs for other pathways of concern at the site (e.g., incidental ingestion).

6.6 Groundwater – Ingestion, Inhalation, and Dermal

Calculation of VCP RGs for ingestion and inhalation of contaminants in domestic water is based on the methodology presented in RAGS Part B (EPA 1991a); calculation of VCP RGs for dermal contact with contaminants in domestic water is based on the methodology presented in RAGS Part E (EPA 2004e). Ingestion of drinking water is an appropriate pathway for all contaminants. For the purposes of this guidance, however, inhalation of volatile chemicals from water is considered routinely only for those contaminants defined as VOCs (see Section 4.5). For volatile contaminants, an upper-bound volatilization factor (VF_w) is used that is based on all uses of household water (e.g., showering, laundering, and dish washing). Certain assumptions were made—that, for example, the volume of water used in a residence for a family of four is 720 L/day, the volume of the dwelling is 150,000 L, the dwelling occupies 900 square feet, and the air exchange rate is 0.25 air changes/hour (Andelman 1990 in RAGS Part B [EPA 1991a]). Additional assumption was that the average transfer efficiency weighted by water use is 50 percent (i.e., half of the concentration of each contaminant in water will be transferred into air by all water uses). Note: the range of transfer efficiencies extends from 30% for toilets to 90% for dishwashers.

Calculation of VCP RGs for dermal exposure to domestic water is based on the methodology presented in RAGS Part E (EPA 2004e). As recommended in the guidance, only contaminants identified as having a groundwater dermal dose contributing more than 10% of the dose from the water ingestion pathway (identified in the rightmost column as "Y" in Exhibits B-3 and B-4 of Appendix B of the dermal guidance) were considered significant enough to be evaluated for the dermal groundwater pathway. Equations provided in Appendix D of the dermal guidance were used along with default parameters recommended in the guidance. However, exposure parameters recommended in the dermal guidance were not used for parameters where the NDEQ approach differed from that recommended by EPA (e.g., EPA recommends a THQ of 1 for residential while NDEQ uses a THQ of 0.25). In these cases, the NDEQ-recommended exposure factors were used.

6.7 Default Exposure Factors

Default exposure factors were obtained primarily from RAGS Supplemental Guidance Standard Default Exposure Factors (EPA 1991b), and more recent information from EPA's Office of Solid Waste and Emergency Response (OSWER) and EPA's Office of Research and Development (ORD). Default values are identified in Table 2. Note that for the dermal groundwater pathway in particular, names of some standard exposure parameters were altered slightly for incorporation into the Excel model. For example, the EPA dermal guidance (EPA 2004e) specifies "t^*" and "τ" (or "τ_{event}"), while these parameters were named "t_star" and "t_event," respectively, in the model. These alterations were made because Excel views "*" as a multiplication symbol and does not differentiate between "τ" and "t." Therefore, effort was made to name the default parameters as close to the accepted terms as possible, within the confines of the Excel model.

Because contact rates may differ for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors ("adj"). Use of age-adjusted factors is especially important for soil ingestion exposures, which are higher during childhood and decrease with age. Age-adjusted factors were used for groundwater ingestion (when a Title 118 MCL was not available) and dermal exposures as well. These factors approximate the integrated exposure from birth until age 30, combining contact rates, body weights, and exposure durations for two age groups—small children and adults. Age-adjusted factors were obtained from RAGS Part B (EPA 1991a) or developed by analogy (see derivations below).

<u>Incidental Ingestion of Soil ([mg-yr]/[kg-day]):</u>

$$IFS_{adj} = \frac{ED_c \; x \; IRS_c}{BW_c} + \frac{(ED_a - ED_c) \; x \; IRS_a}{BW_a}$$

Dermal Contact with Soil ([mg-yr]/[kg-day]):

$$DCFS_{adj} = \frac{ED_c \text{ x } AF \text{ x } SA_{c-s}}{BW_c} + \frac{(ED_a - ED_c) \text{ x } AF \text{ x } SA_{a\ r-s}}{BW_a}$$

Groundwater Ingestion ([L-yr]/[kg-day]):

$$IFW_{adj} = \frac{ED_c \ x \ IRW_c}{BW_c} + \frac{(ED_a - ED_c) \ x \ IRW_a}{BW_a}$$

Dermal Contact with Groundwater ([kg]/[cm²-event]):

$$DCFW_{adj} = \frac{BW_c}{EV \text{ x } ED_c \text{ x } EF_r \text{ x } SA_{c-w}} + \frac{BW_a}{EV \text{ x } ED_a \text{ x } EF_r \text{ x } SA_{a\ r-w}}$$

Noncarcinogenic hazards are evaluated in children separately from adults. No age-adjustment factor is used in this case. The focus on children is considered protective because of the higher daily intake rates of soil and groundwater by children and their lower body weights.

The standardized equations used to calculate the VCP RGs are described in detail in Attachment C.

Table 2
Standard Default Factors

Symbol	Definition	Units	Default Value	Reference
ABS_d	Dermal absorption factor	unitless	Chemical-specific	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Arsenic	unitless	0.03	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Cadmium	unitless	0.001	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Chlordane	unitless	0.04	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	2,4-D	unitless	0.05	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)

Symbol	Definition	Units	Default Value	Reference
	DDT, DDD, and DDE	unitless	0.03	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Hexachlorocyclohexanes	unitless	0.04	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	TCDD	unitless	0.03	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	PAHs	unitless	0.13	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	PCBs	unitless	0.14	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Pentachlorophenols	unitless	0.25	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Semivolatile organics	unitless	0.1	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Volatile organics	unitless	---	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Inorganics	unitless	---	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
ABS_{GI}	Gastrointestinal absorption efficiency (listed here and adjusted only if <50%, per EPA dermal guidance)	unitless	Chemical-specific	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Antimony	unitless	0.15	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Barium	unitless	0.07	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Beryllium	unitless	0.007	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Cadmium	unitless	0.05	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Chromium (III)	unitless	0.013	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Chromium (VI)	unitless	0.025	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Manganese	unitless	0.04	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Mercuric chloride	unitless	0.07	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Nickel	unitless	0.04	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Silver	unitless	0.04	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
	Vanadium	unitless	0.026	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
AF_{a-r}	Adherence factor for soils, adult resident (geometric mean for gardening scenario)	mg/cm^2	0.07	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
AF_{a-w}	Adherence factor for soils, adult worker (geometric mean for utility worker scenario)	mg/cm^2	0.2	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
AF_c	Adherence factor for	mg/cm^2	0.2	RAGS (Part E), EPA 2004e

Symbol	Definition	Units	Default Value	Reference
	soils, child (geometric mean for children playing in wet soil scenario)			(EPA/540/R-99/005)
AT_c	Averaging time, carcinogens	days	25,550	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
AT_n	Averaging time, noncarcinogens	days	ED x 365	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
BW_a	Body weight, adult	kg	70	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
BW_c	Body weight, child	kg	15	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
CF_1	Conversion factor 1	mg/kg	1E+06	---
CF_2	Conversion factor 2	µg/mg	1E+03	---
$DCFS_{adj}$	Age-adjusted soil dermal factor	mg-year/kg-day	361 (calculated)	By analogy to RAGS (Part B)
$DCFW_{adj}$	Age-adjusted water dermal factor	kg/cm^2-event	1.45E-06 (calculated)	By analogy to RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
ED_c	Exposure duration, child	years	6	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
ED_a	Exposure duration, adult resident	years	30[a]	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
ED_w	Exposure duration, industrial	years	25	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
EF_r	Exposure frequency, residential	days/year	350	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
EF_w	Exposure frequency, industrial	days/year	250	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
EV	Event frequency	event/day	1	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
IFS_{adj}	Age-adjusted soil ingestion factor	mg-year/kg-day	114 (calculated)	By analogy to RAGS (Part B), EPA 1991b (OSWER No. 9285.7-01B)
IFW_{adj}	Age-adjusted water ingestion factor	L-year/kg-day	1.1 (calculated)	By analogy to RAGS (Part B)), EPA 1991b (OSWER No. 9285.7-01B)
IRS_a	Soil ingestion rate, adult	mg/day	100	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
IRS_c	Soil ingestion rate, child	mg/day	200	Exposure Factors, EPA 1991b (OSWER No. 9285.6-03)
IRS_w	Soil ingestion rate, industrial	mg/day	100	Soil Screening Guidance, EPA 2002b
IRW_a	Drinking water ingestion rate, adult	L/day	2	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
IRW_c	Drinking water ingestion rate, child	L/day	1	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
IUR	Inhalation unit risk	$(\mu g/m^3)^{-1}$	Chemical-specific	IRIS, HEAST, or NCEA[b]
PEF	Particulate emission factor	m^3/kg	1.2E+09 (calculated)	Soil Screening Guidance, EPA 1996a; EPA 1996b
RfC	Inhalation reference concentration	mg/m^3	Chemical-specific	IRIS, HEAST, or NCEA[b]
RfD_o	Reference dose, oral	mg/kg-day	Chemical-specific	IRIS, HEAST, or NCEA[b]
SA_{a-r-s}	Exposed surface area for soil/dust, adult resident	cm^2/day	5,700	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
SA_{a-w-s}	Exposed surface area for	cm^2/day	3,300	RAGS (Part E), EPA 2004e

Symbol	Definition	Units	Default Value	Reference
	soil/dust, adult worker			(EPA/540/R-99/005)
$SA_{c\text{-}s}$	Exposed surface area for child in soil	cm^2/day	2,800	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
$SA_{a-r\text{-}w}$	Exposed surface area for water contact, adult resident	cm^2	18,000	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
$SA_{c\text{-}w}$	Exposed surface area for water contact, child	cm^2	6,600	RAGS (Part E), EPA 2004e (EPA/540/R-99/005)
Sat	Soil saturation concentration	mg/kg	Chemical-specific (calculated)	Soil Screening Guidance, EPA 1996a; EPA 1996b
SF_o	Oral cancer slope factor	$(mg/kg\text{-}day)^{-1}$	Chemical-specific	IRIS, HEAST, or NCEA[b]
THQ_r	Target hazard quotient, residential	unitless	0.25	Nebraska Department of Environmental Quality
THQ_w	Target hazard quotient, industrial	unitless	1	Nebraska Department of Environmental Quality
TR_r	Target cancer risk, residential	unitless	1E-06	Nebraska Department of Environmental Quality
TR_w	Target cancer risk, industrial	unitless	1E-05	Nebraska Department of Environmental Quality
VF_s	Volatilization factor for soil	m^3/kg	Chemical-specific (calculated)	Soil Screening Guidance, EPA 1996a; 1996b
VF_w	Volatilization factor for water	L/m^3	0.5	RAGS (Part B), EPA 1991a (Publication 9285.7-01B)

Footnotes:

[a] Exposure duration for lifetime residents is assumed 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years).

[b] IRIS – Intregrated Risk Information System (EPA 2004c), HEAST – Health Effects Assessment Tables (EPA 1997a), and NCEA National Center for Environmental Assessment.

cm^2	square centimeter
cm^2/day	square centimeters per day
event/day	event per day
kg	kilogram
kg/cm^2-event	kilograms per square centimeter per event
L/day	liters per day
L/m^3	liters per cubic meter
m^3/day	cubic meters per day
m^3/kg	cubic meters per kilogram
mg/cm^2	milligrams per cubic centimeter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram body weight per day
mg/m^3	milligrams per cubic meter
mg-year/kg-day	milligrams per year per kilogram per day
µg/m^3	micrograms per cubic meter
µg/mg	micrograms per milligram

7.0 SUMMARY

This document describes the protocol followed to develop VCP RGs. The protocol provides an adequate level of protection to residential, recreational, industrial, and construction worker populations. Where possible, the values are specific to Nebraska through the use of, for example, Title 118 for groundwater values and Nebraska-specific PEFs. Overall, this approach protects human health and the environment and allows maximum flexibility to VCP participants.

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