Part 1: INTRODUCTION

This document provides the technical background for the Soil Screening Guidance. The Soil Screening Guidance is a tool that the U.S. Environmental Protection Agency (EPA) developed to help standardize and accelerate the evaluation and cleanup of contaminated soils at sites on the National Priorities List (NPL) with anticipated future residential land use scenarios.[1] This guidance provides a methodology for environmental science/engineering professionals to calculate risk-based, site-specific, soil screening levels (SSLs), for contaminants in soil that may be used to identify areas needing further investigation at NPL sites.

SSLs are not national cleanup standards. SSLs alone do not trigger the need for response actions or define "unacceptable" levels of contaminants in soil. "Screening," for the purposes of this guidance, refers to the process of identifying and defining areas, contaminants, and conditions at a particular site that do not require further Federal attention. Generally, at sites where contaminant concentrations fall below SSLs, no further action or study is warranted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). (Some States have developed screening numbers or methodologies that may be more stringent than SSLs; therefore further study may be warranted under State programs.) Where contaminant concentrations equal or exceed the SSLs, further study or investigation, but not necessarily cleanup, is warranted.

The Soil Screening Guidance provides a framework for screening contaminated soils that encompasses both simple and more detailed approaches for calculating site-specific SSLs, and generic SSLs for use where site-specific data are limited. The *Soil Screening Guidance: User's Guide* (U.S. EPA, 1996) focuses on the application of the simple site-specific approach by providing a step-by-step methodology to calculate site-specific SSLs and plan the sampling necessary to apply them. This Technical Background Document describes the development and technical basis of the methodology presented in the User's Guide. It includes detailed modeling approaches for developing screening levels that can take into account more complex site conditions than the simple site-specific methodology emphasized in the User's Guide. It also provides generic SSLs for the most common contaminants found at NPL sites.

1.1 Background

The Soil Screening Guidance is the result of technical analyses and coordination with numerous stakeholders. The effort began in 1991 when the EPA Administrator charged the Office of Solid Waste and Emergency Response (OSWER) with conducting a 30-day study to outline options for accelerating the rate of cleanups at NPL sites. One of the specific proposals of the study was for OSWER to "examine the means to develop standards or guidelines for contaminated soils." Over the past 4 years, several drafts of the guidance and the accompanying technical background document have had widespread reviews both within and outside EPA. In the Spring of 1995, final drafts were released for public comment and external scientific peer review. Many reviewers' comments contributed significantly to the development of this flexible tool that uses site-specific data in a methodology that can be applied consistently across the nation.

1. Note that the Superfund program defines "soil" as having a particle size under 2 millimeters, while the RCRA program allows for particles under 9 millimeters in size.

1.2 Purpose of SSLs

In identifying and managing risks at sites, EPA considers a spectrum of contaminant concentrations. The level of concern associated with those concentrations depends on the likelihood of exposure to soil contamination at levels of potential concern to human health or to ecological receptors. Figure 1 illustrates the spectrum of soil contamination encountered at Superfund sites and the conceptual range of risk management. At one end are levels of contamination that clearly warrant a response action; at the other end are levels that are below regulatory concern. Appropriate cleanup goals for a particular site may fall anywhere within this range depending on site-specific conditions. Screening levels identify the lower bound of the spectrum -- levels below which there is no concern under CERCLA, provided conditions associated with the SSLs are met.

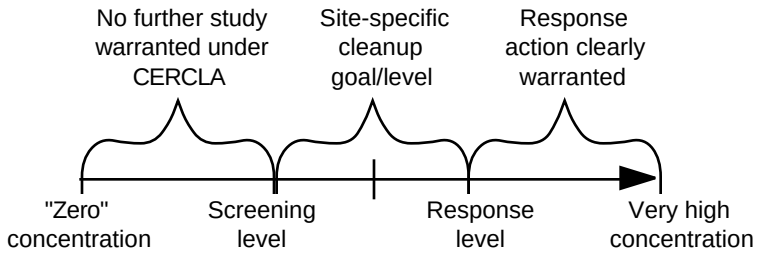

Figure 1. Conceptual Risk Management Spectrum for Contaminated Soil

Although the application of SSLs during site investigations is not mandatory at sites being addressed by CERCLA or RCRA, EPA recommends the use of SSLs as a tool to facilitate prompt identification of contaminants and exposure areas of concern. EPA developed the Soil Screening Guidance to be consistent with and to enhance the current Superfund investigation process and anticipates its primary use during the early stages of a remedial investigation (RI) at NPL sites. It does not replace the Remedial Investigation/Feasibility Study (RI/FS) or risk assessment, but use of screening levels can focus the RI and risk assessment on aspects of the site that are more likely to be a concern under CERCLA. By screening out areas of sites, potential chemicals of concern, or exposure pathways from further investigation, site managers and technical experts can limit the scope of the remedial investigation or risk assessment. SSLs can save resources by helping to determine which areas do not require additional Federal attention early in the process. Furthermore, data gathered during the soil screening process can be used in later Superfund phases, such as the baseline risk assessment, feasibility study, treatability study, and remedial design. This guidance may also be appropriate for use by the removal program when demarcation of soils above residential risk-based numbers coincides with the purpose and scope of the removal action. EPA created the Soil Screening Guidance to be consistent with and to enhance current Superfund processes.

The process presented in this guidance to develop and apply simple, site-specific soil screening levels is likely to be most useful where it is difficult to determine whether areas of soil are contaminated to an extent that warrants further investigation or response (e.g., whether areas of soil at an NPL site require further investigation under CERCLA through an RI/FS). The screening levels have been developed assuming future residential land use assumptions and related exposure scenarios. Although some of the models and methods presented in this guidance could be modified to address exposures

under other land uses, EPA has not yet standardized assumptions for those other uses. Using this guidance for sites where residential land use assumptions do not apply could result in overly conservative screening levels. However, EPA recognizes that some parties responsible for sites with non-residential land use might still benefit from using SSLs as a tool to conduct conservative initial screening.

EPA created the *Soil Screening Guidance: User's Guide* (U.S. EPA, 1996) to be easy to use: it provides a simple step-by-step methodology for calculating SSLs that are specific to the user's site. Applying site-specific screening levels involves developing a conceptual site model (CSM), collecting a few easily obtained site-specific soil parameters (such as the dry bulk density and percent soil moisture), and sampling soil to measure contaminant levels in surface and subsurface soils. Often, much of the information needed to develop the CSM can be derived from previous site investigations (e.g., the preliminary assessment/site inspection [PA/SI]) and, if properly planned, SSL sampling can be accomplished in one mobilization.

SSLs can be used as Preliminary Remediation Goals (PRGs) provided appropriate conditions are met (i.e., conditions found at a specific site are similar to conditions assumed in developing the SSLs). The concept of calculating risk-based soil levels for use as PRGs (or "draft" cleanup levels) was introduced in the *Risk Assessment Guidance for Superfund* (RAGS)*, Volume I, Human Health Evaluation Manual* (HHEM)*, Part B* (U.S. EPA, 1991b). PRGs are risk-based values that provide a reference point for establishing site-specific cleanup levels. The models, equations, and assumptions presented in the Soil Screening Guidance and described herein to address inhalation exposures supersede those described in RAGS HHEM, Part B, for residential soils. **In addition, this guidance presents methodologies to address the leaching of contaminants through soil to an underlying potable aquifer. This pathway should be addressed in the development of PRGs.**

EPA emphasizes that SSLs are **not** cleanup standards. SSLs should not be used as site-specific cleanup levels unless a site-specific nine-criteria evaluation using SSLs as PRGs for soils indicates that a selected remedy achieving the SSLs is protective, compliant with applicable or relevant and appropriate requirements (ARARs), and appropriately balances the other criteria, including cost. PRGs may then be converted into final cleanup levels based on the nine-criteria analysis described in the National Contingency Plan (NCP; Section 300.430 (3)(2)(A)). The directive entitled *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991c) discusses the modification of PRGs to generate cleanup levels.

The generic SSLs provided in Appendix A are calculated from the same equations used in the simple site-specific methodology, but are based on a number of default assumptions chosen to be protective of human health for most site conditions. Generic SSLs can be used in place of site-specific screening levels; however, they are expected to be generally more conservative than site-specific levels. The site manager should weigh the cost of collecting the data necessary to develop site-specific SSLs with the potential for deriving a higher SSL that provides an appropriate level of protection.

1.3 Scope of Soil Screening Guidance

The Soil Screening Guidance incorporates readily obtainable site data into simple, standardized equations to derive site-specific screening levels for selected contaminants and exposure pathways. Key attributes of the Soil Screening Guidance are given in Highlight 1.

Highlight 1: Key Attributes of the Soil Screening Guidance

- Standardized equations are presented to address human exposure pathways in a residential setting consistent with Superfund's concept of "Reasonable Maximum Exposure" (RME).
- Source size (area and depth) can be considered on a site-specific basis using mass-limit models.
- Parameters are identified for which site-specific information is needed to develop site-specific SSLs.
- Default values are provided to calculate generic SSLs where site-specific information is not available.
- SSLs are generally based on a 10^{-6} risk for carcinogens, or a hazard quotient of 1 for noncarcinogens; SSLs for migration to ground water are based on (in order of preference): nonzero maximum contaminant level goals (MCLGs), maximum contaminant levels (MCLs), or the aforementioned risk-based targets.

1.3.1 Exposure Pathways. In a residential setting, potential pathways of exposure to contaminants in soil are as follows (see Figure 2):

- Direct ingestion
- Inhalation of volatiles and fugitive dusts
- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer
- Dermal absorption
- Ingestion of homegrown produce that has been contaminated via plant uptake
- Migration of volatiles into basements

The Soil Screening Guidance addresses each of these pathways to the greatest extent practical. The first three pathways -- direct ingestion, inhalation of volatiles and fugitive dusts, and ingestion of potable ground water, are the most common routes of human exposure to contaminants in the residential setting. These pathways have generally accepted methods, models, and assumptions that lend themselves to a standardized approach. The additional pathways of exposure to soil contaminants, dermal absorption, plant uptake, and migration of volatiles into basements, may also contribute to the risk to human health from exposure to specific contaminants in a residential setting. This guidance addresses these pathways to a limited extent based on available empirical data (see Part 2 for further discussion).

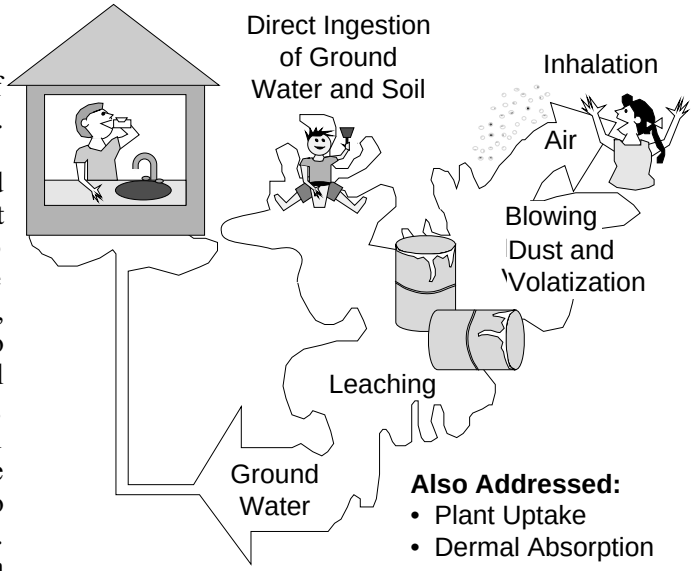

Figure 2. Exposure Pathways Addressed by SSLs.

The Soil Screening Guidance addresses the human exposure pathways listed previously and will be appropriate for most residential settings. The presence of additional pathways or unusual site conditions does not preclude the use of SSLs in areas of the site that are currently residential or likely to be residential in the future. However, the risks associated with these additional pathways or conditions (e.g., fish consumption, raising of livestock, heavy truck traffic on unpaved roads) should be considered in the remedial investigation/feasibility study (RI/FS) to determine whether SSLs are adequately protective.

An ecological assessment should also be performed as part of the RI/FS to evaluate potential risks to ecological receptors.

The Soil Screening Guidance should not be used for areas with radioactive contaminants.

1.3.2 Exposure Assumptions. SSLs are risk-based concentrations derived from equations combining exposure assumptions with EPA toxicity data. The models and assumptions used to calculate SSLs were developed to be consistent with Superfund's concept of "reasonable maximum exposure" (RME) in the residential setting. The Superfund program's method to estimate the RME for chronic exposures on a site-specific basis is to combine an average exposure point concentration with reasonably conservative values for intake and duration in the exposure calculations (U.S. EPA, 1989b; U.S. EPA, 1991a). The default intake and duration assumptions presented in U.S. EPA (1991a) were chosen to represent individuals living in a small town or other nontransient community. (Exposure to members of a more transient community is assumed to be shorter and thus associated with lower risk.) Exposure point concentrations are either measured at the site (e.g., ground water concentrations at a receptor well) or estimated using exposure models with site-specific model inputs. An average concentration term is used in most assessments where the focus is on estimating long-term, chronic exposures. Where the potential for acute toxicity is of concern, exposure estimates based on maximum concentrations may be more appropriate.

The resulting site-specific estimate of RME is then compared with a chemical-specific toxicity criterion such as a reference dose (RfD) or a reference concentration (RfC). EPA recommends using criteria from the Integrated Risk Information System (IRIS) (U.S. EPA, 1995b) and Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1995d), although values from other sources may be used in appropriate cases.

SSLs are concentrations of contaminants in soil that are designed to be protective of exposures in a residential setting. A site-specific risk assessment is an evaluation of the risk posed by exposure to site contaminants in various media. To calculate SSLs, the exposure equations and pathway models are run in reverse to backcalculate an “acceptable level” of a contaminant in soil corresponding to a specific level of risk.

1.3.3 Risk Level. For the ingestion, dermal, and inhalation pathways, toxicity criteria are used to define an acceptable level of contamination in soil, based on a one-in-a-million (10^{-6}) individual excess cancer risk for carcinogens and a hazard quotient (HQ) of 1 for non-carcinogens. SSLs are backcalculated for migration to ground water pathways using ground water concentration limits [nonzero maximum contaminant level goals (MCLGs), maximum contaminant levels (MCLs), or health-based limits (HBLs) (10^{-6} cancer risk or a HQ of 1) where MCLs are not available].

The potential for additive effects has not been "built in" to the SSLs through apportionment. For carcinogens, EPA believes that setting a 10^{-6} risk level for individual chemicals and pathways will generally lead to cumulative risks within the risk range (10^{-4} to 10^{-6}) for the combinations of

chemicals typically found at Superfund sites. For noncarcinogens, additive risks should be considered only for those chemicals with the same toxic endpoint or mechanism of action (see Section 2.1).

1.3.4 SSL Model Assumptions. The models used to calculate inhalation and migration to ground water SSLs were designed for use at an early stage of site investigation when site information may be limited. Because of this constraint, they incorporate a number of simplifying assumptions.

The models assume that the source is infinite. Although the assumption is highly conservative, a finite source model cannot be applied unless there are accurate data regarding source size and volume. EPA believes it to be unlikely that such data will be available from the limited subsurface sampling that is done to apply SSLs. However, EPA also recognizes that infinite source models can violate mass balance (i.e., can release more contaminants than are present) for certain contaminants and site conditions (e.g., small sources). To address this problem, this guidance includes simple models that provide a mass-based limit for the inhalation and migration to ground water SSLs (see Section 2.6). **A site-specific estimate of source depth and area are required to calculate SSLs using these models**.

The infinite source assumption leads to several other simplifying assumptions. Fractionation of contaminant mass between the inhalation and migration to ground water pathways cannot be addressed with infinite source models. For the migration to ground water pathway, an infinite source overrides adsorption in the unsaturated zone or in the aquifer. The models also assume that contamination is evenly distributed throughout the source (i.e., homogeneous) and that no biological or chemical degradation occurs in the soil or in the aquifer. Again, models capable of addressing heterogeneities or degradation processes require collection of site-specific data that is well beyond the scope of the Soil Screening Guidance.

Although the Soil Screening Guidance encourages the use of site-specific data to calculate SSLs, conservative default parameters are provided for use where site-specific data are not available. These defaults are described in Part 2 of this document. Appendix A provides an example set of "generic" SSLs for 110 chemicals that are calculated using these defaults. Because they are designed to be protective of most site conditions across the nation, they are conservative.

A default 0.5 acre source area is used to calculate the generic SSLs. A 30 acre source size was used in the December 1994 guidance. EPA received an overwhelming number of comments that suggest that most contaminated soil sources addressed under the Superfund program are 0.5 acres or smaller. Because of the infinite source assumption, generic SSLs based on a 0.5 acre source size can be protective of larger sources as well (see Appendix A). However, this hypothesis should be examined on a case-by-case basis before applying the generic SSLs to sources larger than 0.5 acre.

1.4 Organization of the Document

Part 2 of this document describes the development of the simple equations used to calculate SSLs. It describes and supports the assumptions behind these equations and presents the results of analyses conducted to develop the SSL methodology. Some of the more sensitive parameters are identified for which site-specific data are likely to have a significant impact. Default values are provided along with their sources and limitations.

Part 3 presents information on other, more complex models that can be used to calculate inhalation and migration to ground water SSLs when more extensive site data are available or can be obtained.

Some of these models can consider a finite source and fractionation between exposure pathways. They also can model more complex site conditions than the simple SSL equations, including conditions that can lead to higher, yet still protective, SSLs (e.g., thick unsaturated zones, biological and chemical degradation, layered soils).

Part 4 provides the technical background for the development of the soil sampling design methodology for SSL application. It addresses methods for surface soil, including a test based on a maximum soil composite sample and the Chen method, which allows decision errors to be controlled. Part 4 also provides simulation results that measure the performance of these methods and sample size tables for different contaminant distributions and compositing schemes. Step-by-step guidance is provided for developing sample designs using each statistical procedure.

Part 5 describes the selection and development of the chemical properties used to calculate SSLs.