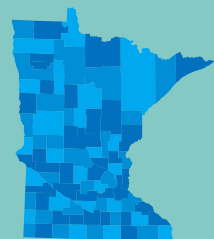


March 2025

Soil Reference Value Technical Support Document

Environmental Analysis and Outcomes Division



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Revision History

April 2022

- Minor text cleanup throughout the document for readability
- Addition of text in Section 3.1. Methodology related to acute SRVs
- Addition of text in Section 6. Site-Specific Soil Background related to derivation of site-specific BTVs

March 2025

Minnesota Pollution Control Agency

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Document number: c-r1-05

- Minor text and reference format edits for improved readability and flow
- Revision of toxicity value hierarchy in Section 3.3. Toxicity Values
- Updates to the acute RfDs in Section 3.3. Toxicity Values related to Table 3
- Addition of information in Section 4. Risk Evaluations and Risk Assessments related to conceptual site model, exposure, and sampling
- Revision of sample concentration use in Section 4.8. Risk Characterization related to chronic risks
- Updates to toxicity data for copper, cyanide, nickel, and pentachlorophenol, along with minor text edits in Appendix A

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Acronyms

ADAF	Age Dependent Adjustment Factor
ATSDR	Agency for Toxic Substances and Disease Registry
B[a]P	Benzo[a]pyrene
bgs	Below Ground Surface
BMDL	Benchmark dose lower confidence limit
BTV	Background Threshold Value
Cal EPA	California Environmental Protection Agency
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
cPAH	Carcinogenic Polycyclic Aromatic Hydrocarbon
Csat	Soil Saturation Limit
CSF	Cancer Slope Factor
CTE	Central Tendency Exposure
ELCR	Excess Lifetime Cancer Risk
HBV	Health Based Value
HEAST	Health Effects Assessment Summary Table
HI	Hazard Index
HQ	Hazard Quotient
HRL	Health Risk Limit
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk
LOAEL	Lowest Observed Adverse Effect Level
MDH	Minnesota Department of Health
MOA	Mode of Action
MPCA	Minnesota Pollution Control Agency
MRL	Minimum Risk Limit
NOAEL	No Observed Adverse Effect Level
OEHHA	Office of Environmental Health Hazard Assessment
OPP	Office of Pesticide Programs
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PEF	Potency Equivalency Factor
PF	Particulate Emission Factor
PPRTV	Provisional Peer Reviewed Toxicity Value
QA/QC	Quality Assurance/Quality Control
RAA	Risk Assessment Advice
RDA	Recommended Daily Allowance

RfC	Reference Concentration
RfD	Reference Dose
RME	Reasonable Maximum Exposure
RPF	Relative Potency Factor
RSC	Relative Source Contribution
RSL	Regional Screening Level
SRV	Soil Reference Value
SSBV	Site-Specific Background Value
SSCV	Site-Specific Cleanup Value
SSG	Soil Screening Guidance
SVOC	Semi-Volatile Organic Compound
TCDD	2,3,7,8-Tetrachlorodibenzo-p-Dioxin
TEF	Toxicity Equivalency Factor
TSD	Technical Support Document
UCL	Upper Confidence Limit
UF	Uncertainty Factor
U.S. EPA	U.S. Environmental Protection Agency
VF	Volatilization Factor
VOC	Volatile Organic Compound
WHO	World Health Organization

1.Introduction

This document provides technical support for the Minnesota Pollution Control Agency's (MPCA) soil reference values (SRVs). *The intended audience is toxicologists and risk assessors.*

SRVs are a screening tool that may be used to evaluate potential human health risks from exposure to contaminated soil. They are derived based on the U.S. Environmental Protection Agency's (U.S. EPA) Superfund methodology using exposure assumptions based on specific land use categories depicting a specific land use scenario and set of receptors (people).

Generic SRVs are intended to be used as screening values. Exceedance of a generic SRV indicates further investigation and/or data evaluation should be conducted to determine if there is actual risk present. In some cases, it may be appropriate to derive site-specific cleanup values (SSCVs) to use instead of the generic SRVs.

This SRV Technical Support Document (TSD) includes:

- Description of land use categories
- Methodology and exposure assumptions used to derive SRVs
- Recommendations regarding the use of SRVs
- General information about site-specific risk assessments
- General information about site-specific soil background concentrations

The SRV TSD is intended to be used in conjunction with the [SRV spreadsheet](#).

It is not intended to replace program-specific soil investigation guidance.

All references in this document to chemical concentrations in soil are based on dry weight.

SRVs do not assess risks associated with soil contaminants leaching into groundwater or intrusion of soil contaminant vapors into buildings. Risks associated with these pathways are evaluated using other risk-based values: Soil Leaching Values and Intrusion Screening Values.

2. Land Use Categories

To evaluate potential risks at sites with contaminated soil, land use categories have been developed depicting specific scenarios and receptors (people). Land use categories characterize two things:

- The expected frequency and duration of exposure to soil contaminants.
- Accessible and potentially accessible zone depths that a receptor is expected to access.

Land use categories are summarized below and in **Table 1**, and are depicted in **Figures 1** through **3**.

2.1. Residential/Recreational Land Use Category

The Residential/Recreational land use category includes single family homes; multi-family housing; facilities that house or care for potentially sensitive populations, such as long-term care facilities, correctional housing, hospitals, child care centers, churches, and schools; and land used for recreational purposes, ranging from playgrounds and sports fields to wildlife areas. The general exposure assumptions associated with this land use category include use of the property by all ages, with expected contact with soil in the accessible zone and varying degrees of contact with soil in the potentially accessible zone, depending on the specific scenario (**Figures 1** and **2**). One set of SRVs – Residential/Recreational SRVs – applies to all of these scenarios.

2.2. Commercial/Industrial Land Use Category

The Commercial/Industrial land use category includes warehouses, offices, manufacturing facilities, restaurants, retail stores, entertainment venues, hotels, and other similar uses. The *Commercial* land use category includes use of the property by all ages, although children are not expected to spend a significant amount of time at the property. The *Industrial* land use category includes use of the property by adult workers. In both scenarios, people are expected to have a lesser degree of contact with soil as compared to the Residential/Recreational land use category (**Figure 3**). One set of generic SRVs – Commercial/Industrial SRVs – applies to all of these scenarios.

2.3. Accessible Zone and Potentially Accessible Zone

As depicted on **Figures 1** through **3**, both the Residential/Recreational and Commercial/Industrial land use categories include the concept of an *Accessible Zone* (0 to 4 feet below ground surface (bgs) in greenspace areas) and *Potentially Accessible Zone* (4 to 12 feet bgs in greenspace areas) to describe different soil depths that a receptor is expected to access. Although these defined zones are intended to be appropriate for use at most sites, there may be cases where site-specific factors, such as the type and concentration of contaminants present, or the way a site is used, support the use of a different depth for the Accessible Zone, such as an Accessible Zone that extends less than or greater than 4 feet bgs. In these cases, the MPCA program will use professional judgment to determine an appropriate depth for the Accessible Zone. The SRV TSD is not intended to be used as program-specific guidance. The inclusion of the land use categories in the SRV TSD is to establish the typical exposure scenarios used to derive generic SRVs and to describe the rationale for the depth of the Accessible Zone and Potentially Accessible Zone. Please refer to MPCA program-specific guidance to determine how to perform a soil investigation for that specific program, including how SRVs will be used. Appropriate institutional controls will be included in program-specific guidance.

2.4. Impervious Surfaces and Utility Corridors

Impervious surfaces and utility corridors are generally present on all developed sites regardless of land use category. The application of SRVs to soil beneath an impervious surface or within a utility trench is based on a common approach for all land use categories.

An ***impervious surface*** refers to a constructed building slab or pavement (e.g. roads, parking lots, sidewalks, driveways, trails). Two feet of soil that meets the SRVs for the applicable land use category or SSCVs should be present under all newly constructed pavements and buildings (**Figure 4**). This protects people from exposure to contaminated soil due to future degradation of pavements or during routine maintenance activities.

The MPCA program may require a vertical buffer of more than 2 feet beneath a new building or pavement if warranted based on site-specific conditions, to ensure people are adequately protected.

Soil used to backfill a *utility corridor* should meet the SRVs for the surrounding land use category or SSCVs (**Figure 5**). This protects workers from exposure to contaminated soil when working in the utility corridor and also protects people from being exposed to contaminated soil brought to the surface during utility work.

Table 1: Land use categories.

Land use category	Land use sub-category	Exposure	Examples	Accessible zone depth	Potentially accessible zone depth
Residential/Recreational	Single Family Homes (Figure 1)	Used by all ages People are expected to contact soil in the accessible zone and are able to conduct significant digging in the potentially accessible zone	Lawns surrounding single family homes	4 feet	12 feet
	Multi-Family Housing and facilities that house or care for potentially sensitive populations (Figure 1)	Used by all ages People are expected to contact soil in the accessible zone, with potential contact with deeper soil during digging conducted by others (e.g. landowner)	Lawns, yards, or landscaping surrounding multi-family housing, long-term care facilities, correctional housing, hospitals, child care centers, churches, schools	4 feet	12 feet
	Recreational (Figure 2)	Used by all ages People are expected to contact soil in the accessible zone, with lesser potential contact with deeper soil	Wildlife areas; local, state or national forests; erodible trails; playgrounds; sports fields; beaches; campgrounds	4 feet Maximum soil depth for erodible trails is 2 feet measured from the trail disturb zone determined by trail use	12 feet
Commercial/Industrial	(Figure 3)	Commercial - used by all ages, children are not expected to spend a significant amount of time at site Industrial - used by adult worker People are expected to contact soil in the accessible zone, with lesser potential contact with deeper soil	Lawns, yards, or landscaping surrounding warehouses; offices; manufacturing facilities; restaurants, retail stores, hotels, etc.	4 feet	12 feet

Figure 1. Greenspace at single-family homes, multi-family housing, and other facilities that house or care for potentially sensitive populations.

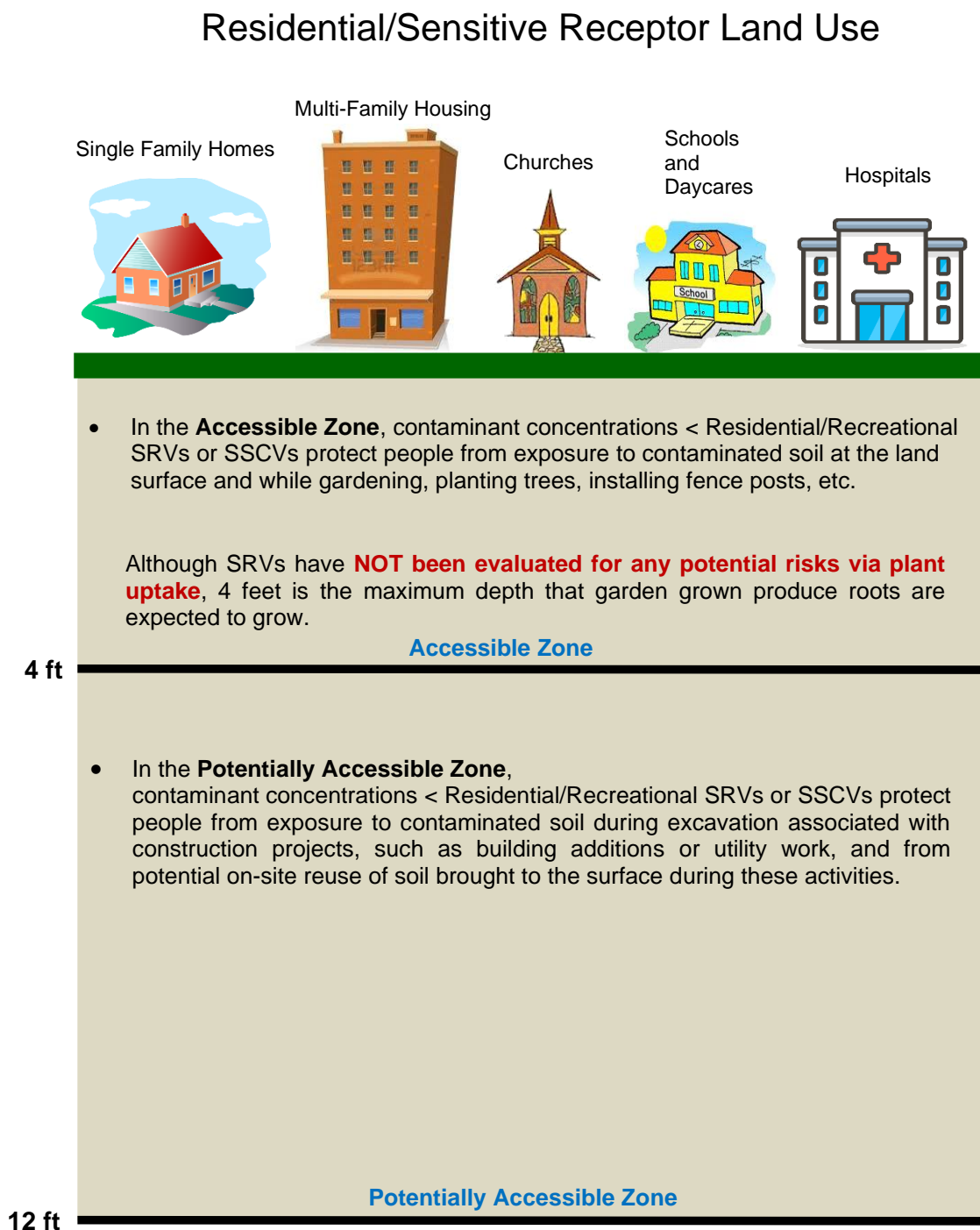


Figure 2. Greenspace at recreational areas.

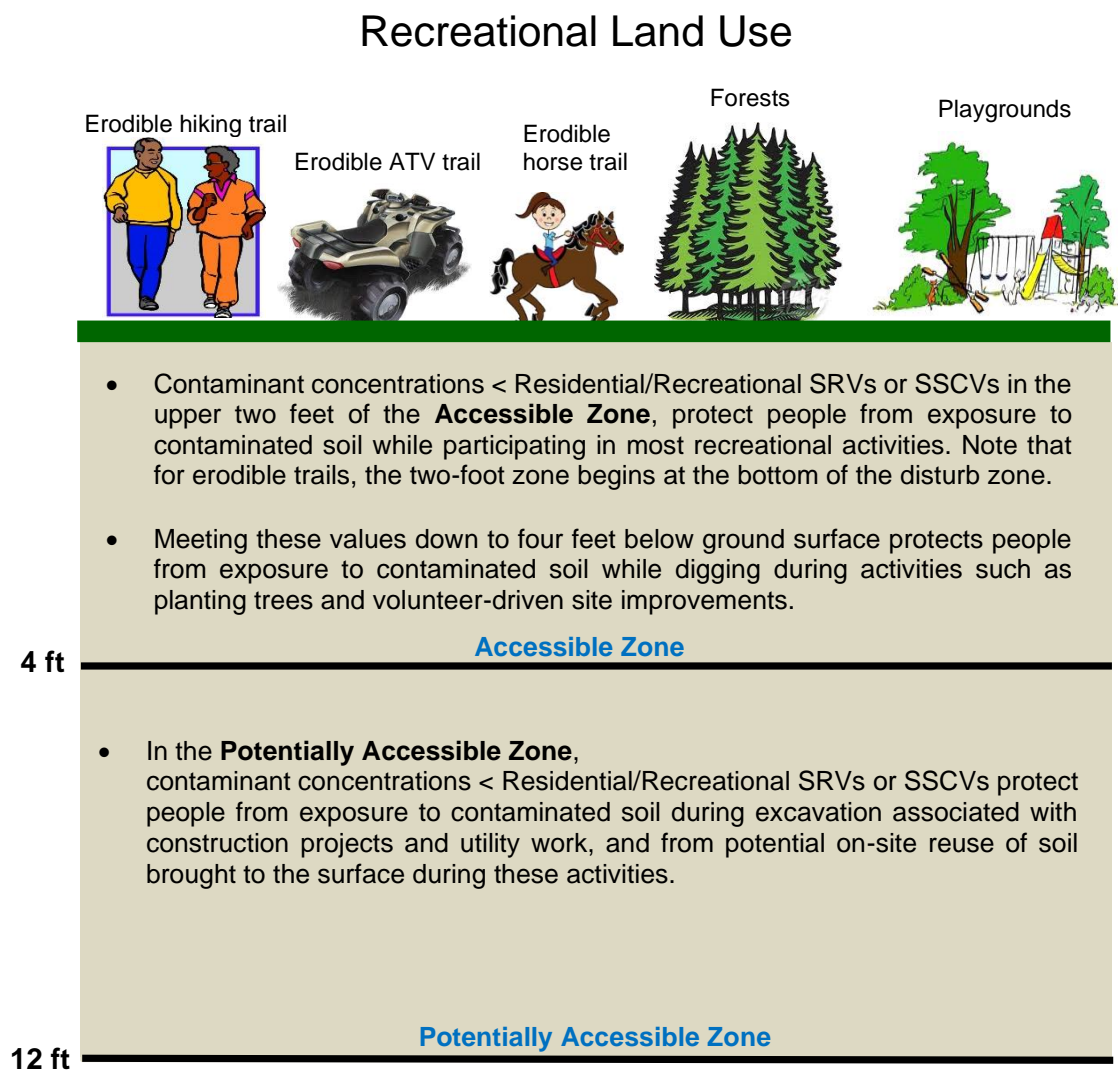


Figure 3. Greenspace at commercial/industrial properties.

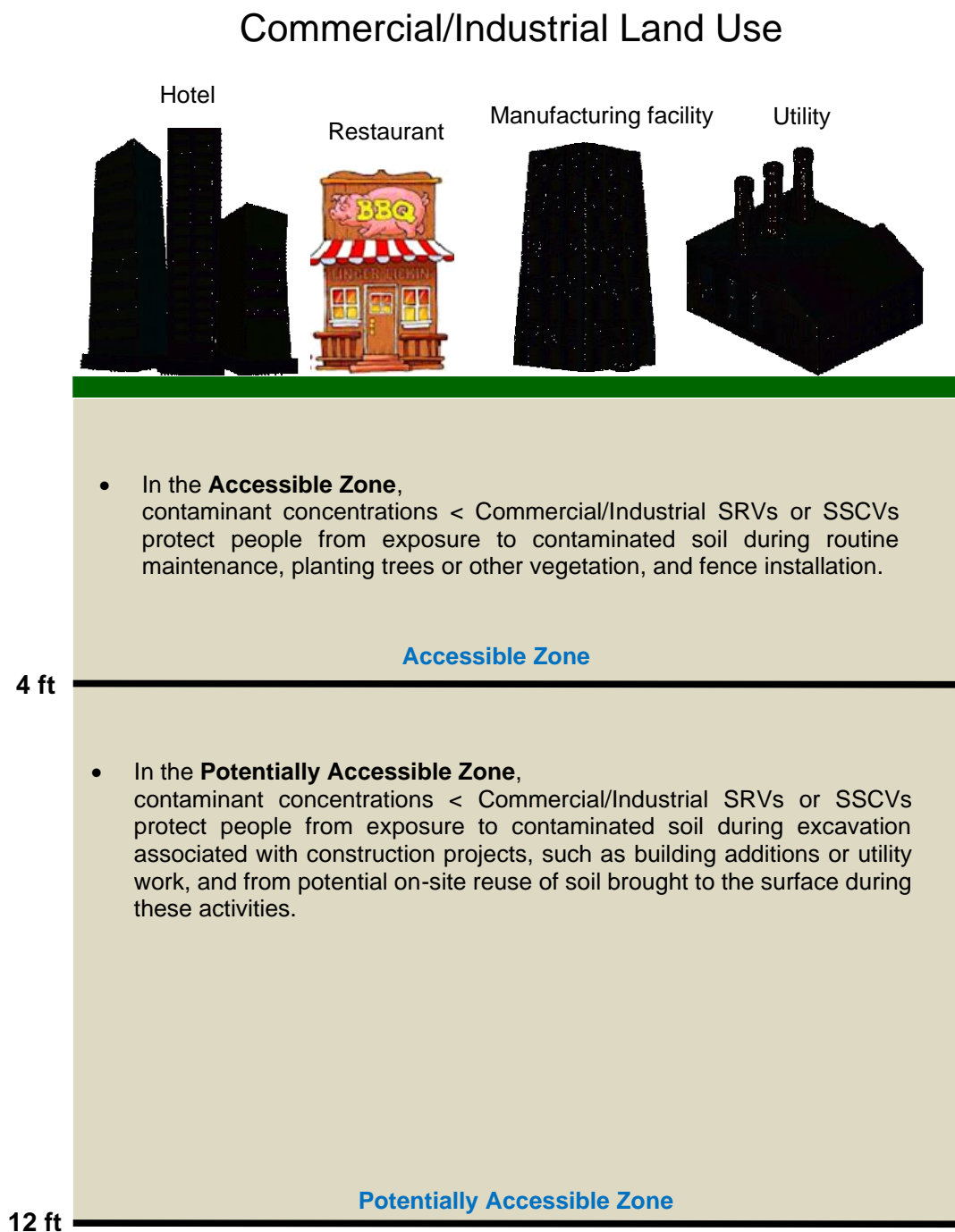


Figure 4. Impervious surfaces.

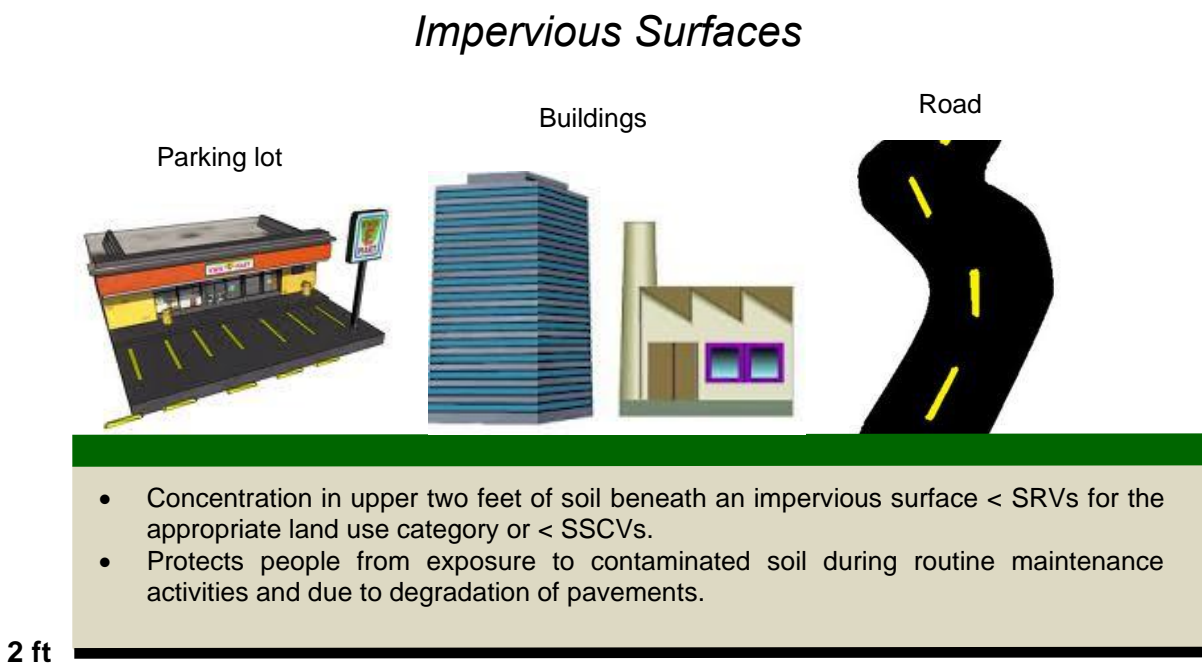
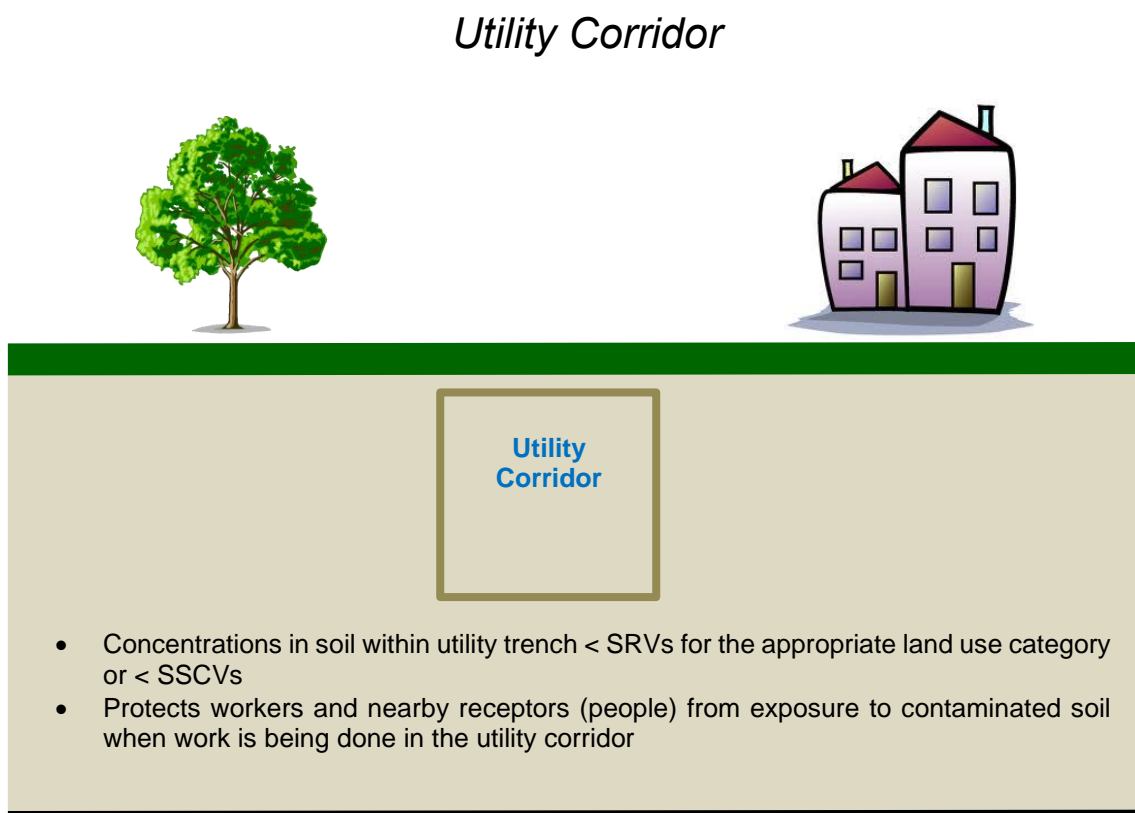


Figure 5. Utility corridor.



3. Derivation of Soil Reference Values

SRVs are intended to be risk-based screening values. They were derived using the following:

- **Methodology** from the U.S. EPA's Superfund Program
- **Exposure parameters** depicting exposure to contaminated soil in a specific land use category
- **Toxicity values** reflecting the toxicity of contaminants
- **Chemical-specific parameters** characterizing a contaminant's chemical and physical properties

Details regarding the derivation of SRVs for each land use category, including methodology, exposure parameters, toxicity values and chemical-specific parameters are in the SRV spreadsheet. This section provides general information regarding the derivation of the SRVs and is intended to be used in conjunction with the SRV spreadsheet. For additional information not covered in this guidance or the SRV spreadsheet, please refer to the following the U.S. EPA guidance:

- U.S. EPA (1989) [Risk Assessment Guidance for Superfund Volume 1 Human Health Evaluation Manual \(Part A\)](#)
- U.S. EPA (1991) [Risk Assessment Guidance for Superfund Volume 1 – Human Health Evaluation Manual \(Part B, Development of Risk-based Preliminary Remediation Goals\)](#)
- U.S. EPA (1996) [Soil Screening Guidance: User's Guide](#)
- U.S. EPA (2002a) [Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites](#)
- U.S. EPA (2004) [Risk Assessment Guidance for Superfund, Part E](#)
- U.S. EPA (2005) [Supplemental Guidance for Assessing Susceptibility from Early-Life Exposures to Carcinogens](#)
- U.S. EPA (2008) [Children's Specific Exposure Factor Handbook](#)
- U.S. EPA (2011) [Exposure Factor Handbook](#)
- U.S. EPA (2014) [Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Parameters memo](#)
- U.S. EPA (2024a) [Regional Screening Levels User's Guide](#)

3.1. Methodology

SRVs were derived using the U.S. EPA's Superfund methodology for deriving U.S. EPA's regional screening levels (RSLs) for evaluating potential risks from contaminated soils (U.S. EPA 1996, U.S. EPA 2002a, U.S. EPA 2024a). The U.S. EPA's methodology is based on the reasonable maximum exposure (RME) concept which uses upper-bound estimates for the most sensitive exposure parameters and central tendency estimates for less sensitive exposure parameters. Upper bound estimates of the average exposure point concentrations are compared to the soil screening values. RME is intended to be protective of the entire population, including sensitive individuals, while still being reasonable.

SRVs were derived to represent chronic, long-term exposures to a contaminant. Acute, one-time event exposure SRVs have been developed for a small number of contaminants where acute exposure is of concern. The acute SRVs were derived to determine levels potentially associated with significant health effects in toddlers ingesting a large quantity of soil during a single event. This behavior is referred to as soil pica.

Chronic, long term exposures are evaluated by deriving two SRVs:

- One SRV to assess cancer risks

- One SRV to assess non-cancer chronic risks

Acute, shorter term exposures are evaluated by deriving one non-cancer acute SRV.

Soil saturation limit (C_{sat}) is derived for any volatile contaminant that is present as a liquid at ambient soil temperatures. It is not derived for contaminants that are present as solids at ambient temperature. C_{sat} represents the concentration of a contaminant in soil at which soil pore water and pore air are saturated with the chemical and the absorptive limit of the soil particles has been reached. Above C_{sat} a contaminant may be present in free phase.

The U.S. EPA has established a maximum contaminant limit/theoretical ceiling limit of 100,000 mg/kg which is equivalent to a chemical representing 10% by weight of a soil sample. Concentrations at or higher than the maximum contaminant limit may violate the assumptions used to derive SRVs.

Final chronic SRVs are set at the lowest of the following values:

- Cancer SRV
- Non-cancer Chronic SRV
- Soil Saturation Concentration (C_{sat})
- Maximum Contaminant Limit

Methodologies used to derive cancer, non-cancer chronic, and acute SRVs are described below. Equations and specific exposure parameters used to derive these SRVs and C_{sat} are provided in the [SRV spreadsheet](#).

3.1.1. Cancer SRV

Cancer SRVs include three routes of human exposure to soil:

- Incidental soil ingestion
- Dermal contact with soil
- Inhalation of fugitive soil dust and soil vapors

They do not include ingestion due to plant uptake of contaminants.

Cancer SRVs were derived assuming a lifetime daily dose over 70 years and a receptor exposure duration associated with a specific land use category. Age-specific exposure parameters (such as body weight and surface area) were used for the following age brackets: 0 to 2 years, 2 to 16 years and 16 to 26 years.

Two methods were used to account for early life sensitivity:

- Chemical-specific adjustment factors
- Default age-dependent adjustment factors (ADAFs)

Chemical-specific adjustment factors were used when available. Default ADAFs were applied to contaminants determined to be a linear carcinogen (MDH 2020). Although the U.S. EPA only applies default ADAFs to linear carcinogens with mutagenic mode of actions (MOAs), the Minnesota Department of Health (MDH) has determined that it is appropriate to apply ADAFs to all linear carcinogens regardless of the MOA.

Risks were characterized by using an excess lifetime cancer risk (ELCR) representing the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogen. An ELCR of 1E-05 or one additional case of cancer in 100,000 has been established as an acceptable risk level.

Individual contaminant soil concentrations resulting in a cancer risk estimate equal to or less than an ELCR of 1E-05 are considered to be acceptable.

Cancer equations, exposure parameters and ADAFs for specific land use categories are provided in the [SRV spreadsheet](#).

3.1.2. Non-Cancer Chronic SRV

Similarly to cancer SRVs, non-cancer chronic SRVs include the same routes of exposure and *do not* include plant uptake of contaminants. They were derived based on exposure parameters applicable to specific land use categories.

A relative source contribution (RSC) factor of 0.2 was used to derive the generic SRVs. The use of this RSC accounts for the following:

- Exposure to the same contaminant in other media such as groundwater, surface water or air. Using 0.2 assumes 20% of the total exposure a receptor experiences to a specific contaminant will come from soil and the rest of that total exposure from other media.
- Exposure to the same contaminant in different land use categories that a receptor may frequent such as school, home and work.
- Potential additive risks from multiple contaminants present at a site.

Individual contaminant soil concentrations resulting in a non-cancer risk estimate equal to or less than a hazard quotient (HQ) of 1 are considered acceptable.

Non-cancer chronic equations and exposure parameters for specific land use categories are provided in the [SRV spreadsheet](#).

Vinyl chloride – a special case

As recommended by the U.S. EPA, vinyl chloride SRV is derived differently than the other SRVs due to additional cancer risks to children (U.S. EPA 2000). Even a short amount of exposure to vinyl chloride results in potential risks to children. The U.S. EPA provides two cancer toxicity values for vinyl chloride that represent the following exposures:

- Continuous lifetime exposures from birth
- Continuous lifetime exposure during adulthood

Since cancer effects observed from exposures during early life stages are different than effects observed from exposures during adulthood, it is not appropriate to prorate the early life risk over a longer duration. Instead, when deriving a Residential cancer SRV for vinyl chloride, the U.S. EPA recommends summing:

- Early life cancer risk
- Prorated child cancer risk
- Prorated adult cancer risk

Due to the additional early life cancer risks to children, the Commercial/Industrial SRV is not reasonably protective of children exposed to vinyl chloride in a Commercial/Industrial setting and may underestimate the potential risk to children. The Residential/Recreational SRV should be used if children are expected to be present.

3.2. Exposure Parameters

SRVs for each land use category were derived using exposure parameters specific to that land use category. Exposure parameters were chosen based on the age of receptor expected to be present and their likely activities. Consistent with the RME concept, upper-bound estimates were used for the most sensitive exposure parameters and central tendency for those less sensitive. The majority of the exposure parameters used are those recommended in U.S. EPA guidance, including [Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors](#) (memo) (U.S. EPA 2014), [Soil Screening Guidance: User's Guide](#) (U.S. EPA 1996), and [Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites](#) (U.S. EPA's SSG) (U.S. EPA 2002a). The different types of exposure parameters used to derive the SRVs are discussed below. A detailed list of the specific exposure parameters used for each land use category is provided in the [SRV spreadsheet](#).

3.2.1. Exposure Duration

Exposure duration represents the number of years a receptor is likely to be exposed to soil at a specific land use category. This is a sensitive exposure parameter; therefore, an upper bound estimate is used. The appropriate estimate to use depends on the land use category. For example, for the Commercial/Industrial land use category the upper bound estimate of exposure duration is 25 years to account for the possibility of a worker working for the same employer for 25 years. All exposure durations for land use categories included in U.S. EPA (2014) memo were used as recommended. Exposure duration values used for each land use category are listed in the [SRV spreadsheet](#).

3.2.2. Exposure Frequency

Exposure frequency represents the frequency of receptor exposure to soil via the following routes of exposure: ingestion, dermal contact, and inhalation of fugitive dust and volatiles. This is a sensitive exposure parameter; therefore, an upper bound estimate is used. Exposure frequencies for land use categories included in the U.S. EPA's Soil Screening Guidance (SSG) were modified to reflect the climate in Minnesota.

The appropriate exposure frequency depends on the following:

- Type of receptor, as reflected in the land use category
 - Residential/Recreational
 - Commercial/Industrial
- Exposure route
 - Ingestion
 - Dermal contact
 - Inhalation via fugitive dust
 - Inhalation via vapors
- Type of contaminant present
 - Volatile organic compounds (VOCs)
 - Non-VOCs

According to frost data from the Minnesota Department of Transportation and snow cover data from the Minnesota Office of Climatology, there is an average of 100 days per year when the ground is frozen and covered by 1 inch or more of snow. During these days, it is not likely a receptor will be exposed to outdoor soil via ingestion, dermal contact or inhalation of fugitive dust or vapors. However, a receptor may still be exposed to soil via ingestion of soil present in indoor dust during this 100-day time period.

Whether the contaminant is a VOC or non-VOC determines the appropriateness of including the dermal exposure route. VOCs will be depleted from the upper 2 cm of the soil surface; therefore, dermal exposure to VOCs will not occur unless a receptor is digging in the soil. If digging does occur, it is likely that in most cases dermal exposure to VOCs will not be significant because the VOCs will quickly evaporate from the soil and the receptor's skin. However, there are three chemicals for which the dermal pathway is included despite their volatility, as it has been determined to be a significant route of exposure: chlordane, polychlorinated biphenyls (PCBs) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents.

Table 2 provides the rationale used to determine when the exposure frequency should be reduced by 100 days and whether the specific exposure routes should be included for VOCs and non-VOCs. Since the 100 days per year reduction is representative of a receptor that frequents the land use category year-round (*i.e.*, 365 days), this number needs to be reduced if a receptor is present at a land use category on a less frequent basis. For example, workers are estimated to work 5 days per week. The 100 days of frozen and snow-covered ground would need to be reduced to represent only the frozen and snow covered days that occur during the time the worker spends at work. Specific exposure frequencies for each land use category are listed in the [SRV spreadsheet](#).

Table 2. Exposure frequency modifications.

Exposure route	VOC	Non-VOC
Ingestion	<i>Eliminate 100 days/year</i> Although ingestion exposure will occur both indoor and outdoor, VOCs will not be present in indoor dust due to their volatile nature	<i>Do NOT eliminate 100 days/year</i> Ingestion exposure will occur both indoor and outdoor and non-VOCs will be present in indoor dust
Dermal Contact	<i>NOT included for VOCs</i> Dermal contact is not considered to be a significant route of exposure for VOCs due to their volatile nature	<i>Eliminate 100 days/year</i> Dermal contact is considered to only be a significant route of exposure outdoors and will not occur when the ground is frozen and snow cover is greater than 1 inch
Inhalation – Fugitive Dust	<i>NOT included for VOCs</i> Inhalation of fugitive dust is not considered to be a significant route for exposure for VOCs due to their volatile nature	<i>Eliminate 100 days/year</i> Fugitive dust is not expected to be present outdoors when the ground is frozen and snow cover is greater than 1 inch
Inhalation – Vapors	<i>Eliminate 100 days/year</i> Vapors are not expected to be present outdoors when the ground is frozen and snow cover is greater than 1 inch	<i>Eliminate 100 days/year</i> Vapors are not expected to be present outdoors when the ground is frozen and snow cover is greater than 1 inch

3.2.3. Exposure Time for Inhalation Pathway

Exposure time represents the number of hours a receptor is likely to be exposed to soil at a specific land use category. Exposure time is 24 hours for the Residential/Recreational land use category consistent with U.S. EPA (2014) default exposure factors. For the Commercial/Industrial land use category, exposure time is adjusted to 10 hours a day based on MDH recommendation (MPCA 2024c). Although the U.S. EPA uses an exposure time of 8 hours a day for this scenario (U.S. EPA 2014), the MDH recommends using 10 hours to be protective of workers who are present at a site longer than 8 hours a day.

3.2.4. Body Weight

Body weight represents the weight of the receptor that is likely to be present at a specific land use category. This is a less sensitive exposure parameter; therefore, a central tendency estimate is used. All

body weights were calculated using the same data used by U.S. EPA (2014) memo. Specific body weights and the calculations for each land use category are listed in the [SRV spreadsheet](#).

3.2.5. Ingestion Rate

Ingestion rate is the amount of soil a receptor is expected to incidentally ingest when participating in activities associated with the land use category. This is a sensitive exposure parameter; therefore, an upper bound estimate is used. All ingestion rates for land use categories included in U.S. EPA (2014) memo are used as recommended. Specific ingestion rates used for each land use category are listed in the [SRV spreadsheet](#).

3.2.6. Surface Area

Surface area is the amount of a receptor's exposed skin during dermal contact with the soil. This is a less sensitive exposure parameter; therefore, a central tendency estimate is used. Surface area estimates were calculated using the same data used by U.S. EPA (2014). Specific surface areas and the calculations used are listed in the [SRV spreadsheet](#).

3.2.7. Adherence Factor

Adherence factor is the amount of soil expected to adhere to a receptor's exposed skin during dermal contact with the soil. The adherence factor is a sensitive exposure parameter that depends significantly on the type of activity a receptor is engaging in. To fit with the RME scenario, the U.S. EPA recommends using a central tendency value for an activity that is likely to result in more soil adherence, such as an adult gardening or a child playing in wet soil. Adherence factor estimates for all land use categories included in U.S. EPA (2014) memo were used as recommended. Specific adherence factor values for each land use category are listed in the [SRV spreadsheet](#).

3.2.8. Volatilization Factor

The volatilization factor (VF) estimates the amount of a contaminant present in vapor that may be inhaled by a receptor. It relates the amount of contamination present in the soil to the amount that may be present in vapors released from subsurface soil. There is no consideration for vapors that may be present in the upper 2 cm of the soil because any vapor in this interval would be released to the air rapidly. The U.S. EPA includes two different VFs that can be used to derive SRVs: standard VF and mass limit VF, both based on the same model. The standard VF uses chemical-specific parameters but continues to include vapor exposure even after the starting material has been depleted, violating mass balance laws. The mass limit VF includes a thickness parameter that prevents mass balance violations but does not use any chemical-specific parameters. The U.S. EPA recommends deriving two SRVs: one using the standard VF and one using the mass limit VF. The final SRV is set to whichever value is greater. Both methods are upper end estimates of the potential vapor exposure a receptor may experience. Calculation of both VFs results in a more reasonable and adequately protective estimate of potential inhalation risk.

Standard VF

All of the default parameters recommended in U.S. EPA's SSG were used to calculate the standard VF. The chemical-specific parameters used in the calculation are discussed in **Section 3.4. Chemical-Specific Parameters**. The inverse of the mean concentration at the center of a 0.5 acre square source was used.

Mass Limit VF

All of the default parameters recommended in U.S. EPA's SSG were used to calculate the mass limit VF. A default contamination thickness (average thickness of source) parameter is not given because the U.S.

EPA recommends this be determined according to the site. MPCA has established a standard default thickness of 12 feet based on the following rationale:

- The average thickness of contamination present at most sites is not greater than 12 feet.
- Setting a thickness parameter close to the greatest depth that a receptor is expected to access (12 feet bgs) will adequately protect a receptor that is accessing the soil as well as a receptor located above the soil surface in most cases.
- MPCA programs are responsible to know if their specific site fits within the exposure parameters used to derive the generic SRVs. If site-specific data indicate a potential volatilization issue that does not fit these SRVs--such as the presence of a specific type of contaminant, especially high concentration of a contaminant or current and potential site use--the program is responsible for determining whether the generic SRVs are inappropriate to use.

T Parameter

The T parameter in both volatilization factors has been determined to represent the time interval over which the soil contaminant volatilizes. An estimate of the flux from the volatilized contaminant that reaches the air above the soil is averaged over T. This parameter *does not* represent exposure duration. Thirty years has been used for all volatilization factor T parameters as a reasonable and adequately protective estimate of the volatilization time interval. If this T does not appear reasonable for the specific contaminants at a site, the program may request the assistance of a MPCA risk assessor to establish a site-specific T parameter.

3.2.9. Particulate Emission Factor

The particulate emission factor (PF) estimates the concentration of a contaminant in fugitive dust that may be inhaled by a receptor. It relates the amount of a contaminant present in soil to the amount that may be present in fugitive dust. Only wind-borne dust is included in the PF. Emissions from traffic and mechanical disturbances are not included. All of the default parameters provided in U.S. EPA's SSG were used to calculate the PF except for the fraction of vegetative cover for the Commercial/Industrial land use category. A value of zero was used for vegetative cover in the Commercial/Industrial land use category based on the potential absence of vegetative cover at this type of site. The inverse of the mean concentration at the center of a 0.5 acre square source was used.

3.3. Toxicity Values

Toxicity values provide an estimate of a contaminant's toxicity and are used to determine an acceptable level of contamination in soil. SRVs use three types of toxicity values:

- Cancer toxicity values used to derive cancer SRVs
- Non-cancer chronic toxicity values used to derive non-cancer chronic SRVs
- Acute toxicity values used to derive acute non-cancer SRVs

Specific types of toxicity values are listed below.

- **Cancer** – estimates the increased cancer risk from a lifetime of exposure to a contaminant via oral or inhalation routes of exposure
 - **Cancer Slope Factor (CSF)** – estimates cancer risk from oral and dermal (there are typically no dermal toxicity values) routes of exposures
 - **Inhalation Unit Risk (IUR)** – estimates cancer risk from inhalation route of exposure

- **Non-cancer Chronic** – estimate of a continuous oral or inhalation exposure to the human population that is likely to not result in an appreciable risk
 - **Chronic Reference Dose (RfD)** – estimates non-cancer risk from oral and dermal (there are typically no dermal toxicity values) routes of exposures
 - **Chronic Reference Concentration (RfC)** – estimates non-cancer risk from inhalation route of exposure
- **Non-cancer Acute** – estimate of an acceptable exposure to a child deliberately ingesting soil during a single event
 - **Acute Reference Dose (RfD)** – estimates non-cancer risk from oral exposure

Toxicity values used for specific contaminants are listed in the [SRV spreadsheet](#).

3.3.1. Toxicity Value Hierarchy

The following hierarchy is generally followed to determine appropriate toxicity values to use for deriving non-cancer chronic SRVs. In some cases, the hierarchy is not followed if rationale exists to support a deviation from it for a specific contaminant. Non-cancer acute toxicity value sources are discussed in **Appendix A**. Website information for toxicity value sources is provided in the [SRV spreadsheet](#).

- MDH's Health Risk Limits (HRL), Health Based Values (HBV) or Risk Assessment Advice (RAA)
- U.S. EPA's Integrated Risk Information System's (IRIS) or Office of Pesticide Programs' (OPP) Reference Dose (RfD), Reference Concentration (RfC), Cancer Slope Factor (CSF) and Inhalation Unit Risk (IUR)
- U.S. EPA's Superfund Provisional Peer Reviewed Toxicity Values (PPRTVs) including Reference Dose (RfD), Reference Concentration (RfC), Cancer Slope Factor (CSF) and Inhalation Unit Risk (IUR)
- Agency for Toxic Substances and Disease Registry's (ATSDR) Minimal Risk Levels (MRLs)
- California Environmental Protection Agency Office of Environmental Health Hazard Assessment's (OEHHA) Reference Exposure Levels and Cancer Potency Values
- U.S. EPA's Superfund Provisional Peer Reviewed Screening Toxicity Values (available in the appendix of PPRTV Derivation Support Documents for individual chemicals) including Reference Dose (RfD), Reference Concentration (RfC), Cancer Slope Factor (CSF) and Inhalation Unit Risk (IUR)
- U.S. EPA's Superfund Health Effects Assessment Summary Table's (HEAST) Reference Dose (RfD), Reference Concentration (RfC), Cancer Slope Factor (CSF) and Inhalation Unit Risk (IUR)
- Other sources such as other states that derive their own toxicity values may be used if 1) an appropriate dataset was used, 2) the derivation was based on current methodologies and 3) it was subject to peer review.

3.3.2. Acute Toxicity Values

Acute non-cancer SRVs based on ingestion were derived for chemicals that are known to pose an acute risk from soil exposure. Since acute non-cancer RfDs are not as readily available as chronic RfDs, an evaluation was conducted to determine the most appropriate toxicity value to use. Evaluations conducted are summarized in **Appendix A**. Acute non-cancer RfDs are listed in **Table 3**.

Table 3. Acute RfDs.

Chemicals	Acute RfDs (mg/kg-event)
Arsenic	0.005
Barium	0.2 (Ch)
Cadmium	0.007
Copper	0.142 (Ch)
Cyanide	0.0056
Fluoride	0.5
Nickel	0.2
Pentachlorophenol	0.004
Phenol	1.0

Ch = Chronic RfD used since acute was less than chronic RfD

3.3.3. Benzo[a]pyrene Equivalents

MPCA issued a policy for analyzing a list of 25 carcinogenic PAHs (cPAHs), identified as probable or possible human carcinogens by the California Environmental Protection Agency (Cal EPA), to evaluate human health risks in specific sites (Cal EPA 1999, Cal EPA 2011, MPCA 2011). These include sites with combustion-related contamination, reuse of stormwater pond sediments, the need for environmental forensics, and human health risk assessments for cPAHs that are currently identified or have been previously identified.

Toxicity data does not exist for all individual cPAHs, they are instead evaluated according to how potent they are in relation to a reference contaminant, benzo[a]pyrene (B[a]P). Assuming B[a]P has a toxicity of 1, other cPAHs are assigned a potency equivalency factors (PEF) to indicate how toxic they are in comparison to B[a]P. A list of PEFs for the 25 cPAHs is provided in the [SRV spreadsheet](#).

Site soil concentrations of individual cPAHs are multiplied by the corresponding PEF values to obtain an individual B[a]P equivalent concentration. These individual B[a]P equivalent concentrations are summed for all cPAHs to calculate a total B[a]P equivalent concentration that is compared to the appropriate SRV. The [SRV spreadsheet](#) (BaP equivalents tab) includes a table that calculates the B[a]P equivalent for a soil sample when the user inputs concentrations of cPAHs detected in that sample. Refer to the table for a list of cPAHs that are included in the B[a]P equivalent concentration.

The MDH published guidance on calculating B[a]P equivalents and recommends a revised method to evaluate cPAHs using relative potency factors (RPF) instead of PEF previously used, and an alternative surrogate mixture method using 7X the concentration of B[a]P (MDH 2016).

Note: This section only pertains to cPAHs, which are evaluated by using B[a]P equivalents. Non-carcinogenic PAHs are evaluated individually and are not included in the total B[a]P equivalent concentration.

3.3.4. 2,3,7,8 - Tetrachlorodibenzo-p-Dioxin Equivalents

Both the MDH and the U.S. EPA recommend using the World Health Organization's (WHO) toxicity equivalency factors (TEFs) to evaluate dioxin-like compounds (MDH 2009, U.S. EPA 2010, Van den Berg et al. 200). Toxicity data do not exist for all individual dioxin-like compounds; instead, they are evaluated according to their potency relative to the reference contaminant, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).

Assuming TCDD has a toxicity of 1, other dioxin-like compounds are assigned a TEF to indicate how toxic they are in comparison to TCDD. A list of TEFs for dioxin-like compounds is provided in the [SRV spreadsheet](#).

Site soil concentrations of individual dioxin-like compounds are multiplied by the corresponding TEF value to obtain an individual TCDD equivalent concentration. These individual TCDD equivalent concentrations are summed for all dioxin-like compounds to calculate a total TCDD equivalent concentration that is compared to the appropriate SRV. The [SRV spreadsheet](#) (TCDD equivalent tab) includes a table that calculates the TCDD equivalent for a soil sample when the user inputs concentrations of dioxin-like compounds detected in that sample. Refer to the table for a list of the dioxin-like compounds that are included in the TCDD equivalent concentration.

3.4. Chemical-Specific Parameters

The following chemical-specific parameters were used in the derivation of the SRVs. Please refer to the [SRV spreadsheet](#) for a detailed list of the specific parameters that were used for a specific chemical. **Table 4** lists the hierarchies for the chemical-specific parameters, which are modeled after the hierarchies the U.S. EPA uses for their RSLs.

- **Dermal Absorption Factor** – estimates amount of a chemical that is absorbed through the skin.
- **Gastrointestinal Absorption Factor** – estimates amount of a chemical that is absorbed by the gastrointestinal system.
- **Relative Bioavailability** – estimates amount of a chemical that is available inside an organism to cause an adverse effect. Consideration of relative bioavailability is generally limited to site-specific risk assessments except in cases where there are sufficient data to provide a reasonable value to be used in the calculation of a generic SRV.
- **Diffusivity in Air** – estimates diffusion of a chemical into air.
- **Diffusivity in Water** – estimates diffusion of a chemical into water.
- **Soil Organic Carbon Partition Coefficient** – estimates to what degree a chemical will bind to the organic carbon fraction of soil.
- **Henry's Law Constant** – estimates vapor release from chemicals in soil. Ratio of a chemical's vapor pressure in air to its solubility in water. The larger the ratio, the more volatile a chemical is. When the Henry's Law constant is greater than $1\text{E-}05 \text{ atm-m}^3/\text{mol}$, it is expected that vapors will be released from the chemical into the air.
- **Vapor Pressure** – estimates vapor release from chemicals in soil. The larger the vapor pressure, the more volatile a chemical is. When vapor pressure is greater than 1 mm Hg, it is expected that vapors will be released from the chemical into the air.
- **Solubility** – estimates amount of chemical that can be dissolved in water.

Consistent with U.S. EPA's definition (U.S. EPA 2024a), a chemical is considered volatile if:

- Its Henry's Law Constant is greater than $1\text{E-}05 \text{ atm-m}^3/\text{mol}$
or
- Its vapor pressure is greater than 1 mm Hg

The one exception is *mercury*, which is considered volatile despite not meeting the above criteria.

Table 4. Chemical-specific parameter hierarchies.

Priority	Dermal absorption	Relative bioavailability	Gastrointestinal absorption	Air diffusion	Water diffusion	Koc ^{1, 4}	Henry's law constant ^{3, 4}	Vapor pressure ⁴	Solubility ⁴
1	EPA 2004	CSR	EPA 2004	WATER9	WATER9	EPI Suite Est ²	PHYSPROP Exp	PHYSPROP Exp	PHYSPROP Exp
2	EPA 2024b	EPA 1996				SSSG	EPI Suite Exp	EPI Suite Exp	EPI Suite Exp
3						YAWS Est	YAWS Exp	PHYSPROP Ext	CRC
4						EPI Suite Exp	PHYSPROP Ext	PHYSPROP Est	YAWS Exp
5						YAWS Exp	PHYSPROP Est	EPI Suite Est	Perry
6							EPI Suite Est, group		Lange
7							EPI Suite Est, bond		PHYSPROP Est
8									YAWS Est
9									EPI Suite Est

¹ - Not applicable to inorganics; exception – use the Koc listed in U.S. EPA's RSL User's Guide for benzoic acid, 2,4-dichlorophenol, pentachlorophenol, 2,3,4,6-tetrachlorophenol, 2,4,5-trichlorophenol and 2,4,6-trichlorophenol (U.S. EPA 2024a).

² - For estimated Koc use the MCI method first, then the log Kow method.

³ - For estimated Henry's Law use the GROUP method first, then the BOND method.

⁴ - For PFAS, chemical specific parameters were obtained based on a different hierarchy. Refer to the SRV spreadsheet for more information.

EPA 2004 - U.S. EPA (2004) Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment).

EPA 2024b - U.S. EPA (2024b) Regional screening level (RSL) tables.

CSR - Chemical-specific reference that specifies a relative bioavailability (*e.g.*, ATSDR profile).

EPA 1996 - EPA's Soil Screening Guidance: User's Manual.

WATER9 - EPA's WATER9.

EPI Suite Est - Estimated Values, U.S. EPA and Toxics and Syracuse Research Corporation (SRC), Estimation Interface (EPI) Suite.

SSSG - U.S. EPA (2002a) Supplemental Soil Screening Guidance.

YAWS Est - YAWS Estimated Values, Yaws C.L. (2003), YAWS Handbook of Thermodynamic and Physical Properties of Chemical Compounds.

EPI Suite Exp - Experimental Values, U.S. EPA and Toxics and Syracuse Research Corporation (SRC), Estimation Interface (EPI) Suite.

YAWS Exp - YAWS Experimental Values, Yaws C.L. (2003), YAWS Handbook of Thermodynamic and Physical Properties of Chemical Compounds.

PHYSPROP Exp - Experimental values, Syracuse Research Corporation (SRC), 2005, PHYSPROP Database.

PHYSPROP Ext - Extrapolated values, Syracuse Research Corporation (SRC), 2005, PHYSPROP Database.

PHYSPROP Est - Estimated values, Syracuse Research Corporation (SRC), 2005, PHYSPROP Database.

EPI Suite Est, bond - Estimated Values, bond method, U.S. EPA and Toxics and Syracuse Research Corporation (SRC), Estimation Interface (EPI) Suite.

EPI Suite Est, group - Estimated Values, group method, U.S. EPA and Toxics and Syracuse Research Corporation (SRC), Estimation Interface (EPI) Suite.

CRC - CRC Handbook of Chemistry and Physics.

Perry - Green, Don W., Perry, Robert H. (2008), Perry's Chemical Engineer's Handbook.

Lange - Speight, James G. (2005), Lange's Handbook of Chemistry.

4. Risk Evaluations and Risk Assessments

Risk evaluations and risk assessments evaluate whether contaminants present in media--in this case, soil--are a potential risk to people using the area with the contaminated soil. This section includes the minimum requirements for using the SRVs in a risk evaluation or site-specific risk assessment. **It is not intended to replace program-specific guidance.**

- **Risk evaluations** use the generic SRVs applicable to the appropriate land use category, as listed in the [SRV spreadsheet](#).
- **Site-specific risk assessments** use SSCVs for soil established using site-specific information.

Generally, a **risk evaluation** is conducted first before considering whether it is necessary to conduct a **site-specific risk assessment**.

The same basic principles and steps that apply to both risk evaluations and site-specific risk assessments are described in this section. The process used to establish SSCVs and any other items specific to a site-specific risk assessment are addressed in general terms in **Section 5. Site-Specific Soil Cleanup Values** and **Section 6. Site-Specific Soil Background** of this TSD. These topics are not the focus of this SRV TSD. If a site-specific risk assessment is being considered, please contact MPCA project staff for guidance.

4.1. Acute, Subchronic or Short-Term Risks

SRVs evaluate cancer and chronic non-cancer risks, and acute non-cancer risks for a limited number of chemicals, as listed in the SRV spreadsheet. Any other potential acute, subchronic or short-term risks associated with a site should be evaluated using a site-specific risk assessment.

4.2. Land Use Category and Contaminants of Potential Concern

Site uses should be clearly identified to determine which land use category is appropriate to use and to identify contaminants of potential concern (COPC). Any contaminants associated with site uses or that have been detected at the site should be included as COPC.

4.3. Conceptual Site Model

A conceptual site model is an overview of what has and is occurring at a site. It includes the source of contamination, fate and transport of contamination, receptors that may be exposed to contamination and potential exposure pathways. At a minimum, the following items should be included for soil:

- Source of contaminants and release, and current release status
- Type of contaminants and impacted environmental media
- Site geological and hydrogeological settings
- Locations, concentrations and volumes of soil contamination
- Soil contaminant migration pathways
- Soil exposure pathways
- Potential receptors on and/or off site

4.4. Background Values

In general, if the exposure point concentration or exposure area maximum concentration is equal to or less than site background concentrations, the contaminant may not represent a release to the environment and may not be considered a contaminant of concern (COC).

Ten of the SRVs derived based on exposure parameters and toxicity values resulted in generic SRVs that were estimated as being potentially below typical non-anthropogenic background soil concentrations (*i.e.*, aluminum, arsenic, barium, chromium, cobalt, iron, thallium, vanadium, B[a]P, and TCDD). An evaluation was conducted to determine if each SRV was below typical soil background concentrations and, if necessary and possible, to establish appropriate typical background values ([Background Threshold Values](#) or BTVs) that could be used instead of the generic SRV (MPCA 2021). If a BTV was established for a specific chemical, it will be listed in the SRV spreadsheet in place of the health-based SRV.

In some cases, it may be appropriate to establish a site-specific background value (SSBV) for a particular contaminant. Published background concentrations, based on a sufficient number of samples and up-to-date quality assurance/quality control (QA/QC) procedures, are expected to accurately represent non-anthropogenic background concentrations and may be considered when appropriate. For some soil contaminants, existing published background concentrations may be based on insufficient sample size, outdated QA/QC procedures, and/or may not accurately represent non-anthropogenic background concentrations for the area. In these cases, site-specific background data are preferred.

4.5. Exposure Pathways and Receptors

All potential soil exposure pathways and receptors must be identified. For an exposure pathway to be complete, the following three conditions must exist:

- Source of contamination
- Exposure route
- Potential receptor(s)

Possible routes of human health exposure to contaminants in soil include:

- **Incidental soil ingestion**
- *Ingestion via produce*
- *Ingestion via food chain*
- **Dermal contact with soil**
- **Inhalation via fugitive dust**
- **Inhalation via volatilization - outdoor air**
- *Inhalation via volatilization - indoor air*

Routes of exposure included in the derivation of SRVs are **bolded**. Routes of exposure not included in the derivation of SRVs are shown in italics. The inhalation via volatilization - indoor air route of exposure is evaluated during a vapor intrusion investigation. If any of the other italicized routes of exposure apply to a site, a site-specific risk assessment may be required.

Potential receptors that may be exposed to site soil contamination should be identified. It is also important to identify the most sensitive receptor that may be exposed.

Remedial action may not be necessary for released COPCs if, for example, no current or potential future completed exposure pathways exist.

4.6. Exposure Concentrations

An **exposure concentration** represents the amount of the contaminant present where a receptor contacts contaminated soil. There are two types of exposure concentrations:

- **Exposure point concentration**
- **Exposure area concentration**

An exposure *point* concentration:

- Represents a contaminant concentration at a single sample location.
- Sample locations may be biased to represent potential high concentrations near a point of release or to evaluate spatial variability or limits of contaminated soil.
- Can be used to evaluate **acute** exposures.
- Relies on **discrete soil samples** with one exposure concentration based on maximum concentrations. It is not appropriate to use composite or incremental soil sampling results when evaluating an exposure point concentration.
- Represents depth to which a person may be exposed.

An exposure *area* concentration:

- Evaluates chronic, subchronic and short-term exposures.
- Uses only samples located within the boundaries of a defined exposure area being evaluated.
- Relies on soil samples that are from areas with similar contamination and a similar range of concentrations, without significant spatial trends or pattern of concentrations. It is not appropriate to include data from samples of uncontaminated soil or hot spots.
- Represents the area and depth to which the potential receptor may be exposed. The area must reasonably reflect a person's potential exposure across the entire site.
- Averages sample data over the entire exposure area. A sufficient sample density is necessary when evaluating an exposure area concentration. Composite or incremental soil sampling may be appropriate for non-volatile contaminants.

Due to the possible transport of contamination off site, exposure areas or points may be located on or off site. Information regarding site use should be taken into consideration when determining appropriate exposure area and exposure point concentrations.

Hot spots refer to areas containing significantly higher concentrations of contamination than surrounding areas. These areas may have been subject to larger releases or contaminated in different ways than other areas of the site. All hot spots should be defined as distinct exposure areas and evaluated separately.

4.6.1. Area and Time Weighted Exposure Concentrations

An exposure concentration is intended to be a spatial average and is assumed to be equal to the temporal average based on the following assumptions:

- Soil concentrations remain constant over time (*e.g.*, there is no mechanism decreasing contaminant concentrations over time such as biodegradation).
- Samples represent a uniform, random distribution of soil samples over the entire exposure area.
- A receptor is equally likely to be exposed to any exposure points within the exposure area.

Rationale and data should be provided for any adjustments made to an exposure concentration.

In some cases, the spatial average exposure concentration is not equal to the temporal average exposure concentration. It may be appropriate to use area or time weighted exposure concentrations if detailed

site-specific exposure pattern information is available. This approach requires the approval of a MPCA risk assessor as well as the program.

Area Weighted Exposure Concentration

For cases where samples (contaminant concentrations) are not evenly spaced over the exposure area but a receptor's exposure is equally likely over the entire exposure area, an area weighted average exposure concentration can be calculated.

Time Weighted Exposure Concentration

For cases where a receptor is not equally likely to be exposed over the entire exposure area but the samples are evenly spaced over the exposure area, a time weighted average exposure concentration can be calculated.

4.6.2. Soil Concentration Modeling

Data from actual sampling is the most accurate method of determining an exposure concentration and is always preferred. In some cases, modeling may be appropriate if the site situation does not allow sampling.

4.6.3. Rounding Exposure Concentrations

When it is necessary to round an exposure concentration to compare to an SRV or BTV, the concentration should be rounded up or down following the accepted mathematical procedure. The last digit in the concentration past the last digit in the SRV is rounded down if it is less than 5 and rounded up if it is equal to or greater than 5. For example:

- If a concentration of 10.2 mg/kg is being compared to an SRV or BTV of 10 mg/kg, the 10.2 would be rounded to 10 mg/kg and would not be considered an exceedance.
- If a concentration of 10.5 mg/kg is being compared to an SRV or BTV of 10 mg/kg, the 10.5 would be rounded up to 11 mg/kg and be considered an exceedance.

4.7. Sampling

This section provides general information about the collection of soil samples and the evaluation of soil data in the context of using the SRVs in a risk evaluation. The information provided is not meant to replace program-specific sampling guidance.

Data obtained from sampling are used to estimate an exposure concentration, which is used to evaluate potential risks. Appropriately designed sampling accomplishes the following:

- Determines presence or absence of contamination
- Identifies contaminants present
- Delineates both lateral and vertical extent of contamination
- Determines release locations and mechanisms
- Determines the highest contaminant concentrations
- Defines how contaminant concentrations vary with location and depth
- Identifies hot spots
- Provides background concentrations

The default soil depth to which a receptor is likely to be exposed will vary according to the land use category. To evaluate potential risks from ingestion, dermal contact, or inhalation via fugitive dust (the exposure pathways addressed by the SRVs), soil samples should be obtained from the surface to the depth at which a receptor is likely to have exposure. If a situation exists on site that does not meet the assumptions used to establish the default depth of exposure for a given land use category, soil samples should be obtained from the site-specific exposure depth.

When VOCs or Semi-Volatile Organic Compounds (SVOC) are present, exposure concentrations to evaluate potential outdoor inhalation risk from vapor should be calculated using subsurface samples obtained from an appropriate depth based on the specific contaminant present and site characteristics.

4.7.1. Sampling Design

Two types of sampling designs commonly used are target (judgmental) and probabilistic sampling. In target sampling, locations are selected based on site information and professional judgment. In probabilistic sampling, locations are selected based on a random statistical model. Probabilistic models commonly used are: simple random, systematic/grid and stratified sampling.

Target sampling is used when professional judgement is applied to select specific sample locations based on site-specific information, which is a non-random and biased sampling approach. Simple random sampling is used when the population being sampled is homogeneous without potential hot spots. Sample locations are selected on a random basis, so they are not necessarily uniformly distributed across the site. Systematic/grid sampling is often used when little information is available about a site or to fully characterize a site. Sample locations are evenly distributed throughout the site using a grid. Stratified sampling separates a site into homogeneous groups or strata based on soil characteristics, site knowledge and professional judgment. Each stratum is sampled independently using an appropriate method, most commonly systematic/grid. These sampling designs are discussed in greater detail in U.S. EPA's [Guidance on Choosing a Sampling Design for Environmental Data Collection](#) (U.S. EPA 2002b).

The type of sampling that will be most effective to adequately characterize a site will depend on sampling objectives, how much information is available regarding contaminant releases and site-specific characteristics. For most situations, a combination of two sampling methods, target and stratified, are recommended.

4.7.2. Composite Sampling

Composite sampling should first be approved by the MPCA program to avoid potential wasted effort. If any of the following conditions apply, composite sampling should **not** be conducted:

- VOCs are being analyzed
- Soil samples are from different soil types
- Contaminant pattern is unknown or variable
- Matrix interference among contaminants is likely
- Acute risks are being evaluated

Maximum contaminant concentrations should be used to evaluate risks when using results from composite sampling.

4.7.3. Laboratory Analysis

Laboratory analysis should be conducted for all COPCs and results calculated on a total, dry weight basis. Appropriate QA/QC procedures and methods with detection limits below the SRVs should be used.

For general considerations when designing a sampling plan please refer to the following [MPCA guidance](#): Laboratory Quality Control and Data Policy (MPCA 2024a); Laboratory Data Review Checklist (MPCA 2018); Quality Assurance Project Plan Guidance (MPCA 2024b); and Data Quality Objectives (MPCA 2012). Additional information can be found on U.S. EPA's Hazardous Waste Test Methods / SW-846 [website](#) (U.S. EPA 2007).

There is inherent uncertainty in the reported results from laboratory analytical testing. This is a result of sampling technique, the chosen aliquot of sample to be analyzed by the laboratory, and laboratory analysis methods. Due to this uncertainty, a 20% variance as a decrease or increase from the reported results of analytical testing of inorganics is generally acknowledged. For example, if the actual soil concentration is 100 mg/kg, the analytical results could be reported somewhere between 80 to 120 mg/kg.

4.7.4. Non-Detects

The Kaplan Meier method available through U.S. EPA's ProUCL software is recommended for evaluating non-detect data, including TCDD and B[a]P equivalents. Detailed instructions are provided in **Appendix C**. An entity may choose not to evaluate non-detect data, although this is likely to result in a more conservative estimate of potential risks.

4.7.5. Data Presentation

Sampling data should be presented in a clear and concise manner in tables and include the following information and statistics (when possible) to characterize potential human health risks:

- Sample date, identification and depth
- Results of each individual sample
- Reporting limits and method detection limits
- Number of observations
- Frequency of detection
- Maximum
- **Minimum**
- **Median**
- **Arithmetic mean and standard deviation**
- **95% upper confidence limit (95% UCL) of the mean (for defined areas of contaminations or exposure areas)**
- **Identification of samples designated with J to reflect an estimated concentration**

It is not appropriate to report the **bolded** items in the above list for composite or incremental samples. Maximum concentrations should be used for composite or incremental samples.

U.S. EPA's ProUCL software can be used to determine the 95% UCL of the mean (U.S. EPA 2016). Detailed instructions of how to calculate a 95% UCL of the mean are provided in **Appendix B**. This calculation can only be accomplished on datasets consisting of eight or more samples.

4.8. Risk Characterization

Risk characterization determines if there is a possibility that human health risks may exist at a site.

Risk Evaluation

In most cases, the appropriate first step to evaluate contaminated soil is to perform a risk evaluation. This is accomplished by comparing site contaminant concentrations to their respective generic SRVs for the appropriate land use category, as listed on the [SRV spreadsheet](#). Details regarding how to conduct a risk evaluation are provided in this section.

Site-Specific Risk Assessment

If risk evaluation results indicate there may be a potential risk present, a site-specific risk assessment may be conducted to establish SSCVs and/or SSBVs. SSCVs and SSBVs are addressed in general terms in **Section 5. Site-Specific Soil Cleanup Values** and **Section 6. Site-Specific Soil Background** of this TSD, but these topics are not the focus of this document. If a site-specific risk assessment is being considered, please contact MPCA project staff for guidance.

4.8.1. Acute Risks

An **exposure point** concentration (discrete sample) is used to evaluate acute risks. The maximum concentration of a contaminant should be compared to the acute SRV or BTV provided in the [SRV spreadsheet](#). It is **not** appropriate to use composite or incremental sampling to evaluate acute risks. Acute SRVs are only provided for the Residential/Recreational land use category and only for a small number of contaminants.

Potential acute risks for contaminants that are not listed in the SRV spreadsheet and lack sufficient toxicity data to derive a site-specific SRV should be evaluated qualitatively.

4.8.2. Chronic Risks

In practice, **maximum** concentration is commonly applied to evaluate chronic risks when comparing composite or incremental sampling concentrations to SRVs, or comparing concentrations to BTVs. The approach is protective to ensure considering the highest exposure.

An exposure area concentration (averaged over the entire exposure area) may also be used to evaluate chronic risks, particularly for discrete samples. **Section 4.6. Exposure Concentrations** defined exposure areas used for calculating an averaged exposure area concentration, as well as relevant information to apply exposure area. The 95% UCL of the mean of the discrete samples can be compared to the chronic SRV for the appropriate land use category, as listed in the [SRV spreadsheet](#). The 95% UCL of the mean may be calculated using U.S. EPA's ProUCL software (U.S. EPA 2016). **Appendix B** provides instructions regarding calculation of the 95% UCL of the mean using ProUCL. If the 95% UCL is greater than the maximum concentration, insufficient samples may have been obtained. In this case, if additional samples are not an option, the maximum concentration should be used.

Potential chronic risks for contaminants that are not listed in the SRV spreadsheet and lack sufficient toxicity data to derive a site-specific SRV should be evaluated qualitatively.

Table 5 indicates how to interpret the chronic SRV spreadsheet results. If soil exposure concentrations are equal to or below the chronic SRV, it indicates potential risks are not a concern. If soil exposure concentrations exceed the chronic SRV, it indicates risks may exist and warrant further investigation to determine their presence. Background values (BTVs) should only be used for comparison with soil exposure concentrations when the BTV of the contaminant exceeds its SRV.

Table 5. Comparison of soil concentrations with chronic SRVs or BTVs.

NO Exceedances ^{1, 2}	Exceedances ^{1, 3}
Risks are <u>NOT</u> likely to exist under current conditions	Risks <u>MAY</u> be present and should be evaluated further
For non-cancer risks, the HQ of the contaminant is = or < 1	For non-cancer risks, the HQ of the contaminant is > 1
For cancer risks, the ELCR of the contaminant is = or < 1E-05	For cancer risks, the ELCR of the contaminant is > 1E-05

1 – Assumes additive risks are not a concern.

2 – No Exceedance is defined as maximum concentrations being equal to or less than an SRV or BTV, or a contaminant 95% UCL of the mean concentration being equal to or less than an SRV.

3 – Exceedance is defined as maximum concentration being greater than an SRV or BTV, or a contaminant 95% UCL of mean concentration being greater than an SRV.

4.8.3. Additive Risks

In general, it is not necessary to perform a separate evaluation for additive risks when conducting a risk evaluation using the SRV spreadsheet. SRVs are derived using an RSC of 0.2 and an ELCR of 1E-05 making them reasonably protective of potential additive non-cancer and cancer risks at the majority of sites. If there is a site-specific characteristic that a MPCA program identifies as being a potential additive risk concern, an additive risk evaluation may be required as part of a risk evaluation.

Although MPCA does not include background concentrations or reporting limits in calculations of additive risk in the SRV spreadsheet, they do need to be taken into consideration when evaluating for additive risks (U.S. EPA 2018).

4.9. Uncertainty

A thorough explanation of the uncertainties involved in the risk evaluation should be provided. Uncertainties that could have a significant effect on the outcome of the risk evaluation (either an under or over estimate of risks) may exist for two reasons:

- Lack of knowledge of the site, which can be reduced by additional sampling, research or knowledge, such as site-specific or scientific information
- Natural variability, such as variation in ingestion rates among people

There are many uncertainties involved in the risk evaluation. Some examples are exposure assumptions, toxicity information, contaminant speciation, variances in sampling and laboratory analysis, and professional judgment.

4.10. Conclusion

A concise summary of the risk evaluation should be provided indicating whether an unacceptable human health risk exists on site. This summary should include:

- Quantitative results from the SRV spreadsheet, *e.g.*, whether contaminant concentrations exceed their respective SRVs and BTVs
- Qualitative discussion of potential risks associated with contaminants lacking toxicity data
- Quantitative and/or qualitative discussion of uncertainty and how it may impact results

If all contaminant concentrations are below the SRVs and BTVs for the appropriate land use category, it can be concluded that response actions to address unacceptable human health risks from contaminated soil at the site may not be needed.

If there are contaminant concentrations above the SRVs and BTVs for the appropriate land use category, this does **not** necessarily indicate there is human health risk at the site. It may indicate a need for further investigation and/or evaluation to determine if there may be human health risk at the site.

If a **risk evaluation** using the generic SRVs has been completed and there is a need to investigate further to determine the presence or absence of risk to a receptor, options include:

- Collection of additional soil samples to further characterize exposure concentrations.
- Completion of a site-specific risk assessment to establish SSCVs or SSBVs, with assistance from MPCA staff.

5.Site-Specific Soil Cleanup Values

This section provides general information about SSCVs. SSCVs may be developed to evaluate potential risks to human health from contaminated soil when the generic SRVs may not be representative of risk exposure pathways at a site. They are determined based on site-specific information including the current planned use of the site by people, the resulting probable maximum exposure levels, and potential exposure pathways. Site-specific **soil exposure parameters, soil properties and contaminant speciation in soil are also taken into consideration**. SSCVs are established as part of a site-specific risk assessment, which is typically conducted after a risk evaluation using generic SRVs has been completed and potential human health risks identified.

A site-specific risk assessment may be less or more detailed depending on what factors influence the potential human health risks at a site and how much information an entity conducting the assessment chooses to include. For example, although site-specific soil properties can be used to determine SSCVs, it is not necessary to include them. Instead, the SSCVs could be determined based on site-specific soil exposure parameters only.

If site concentrations have exceeded the generic SRVs and/or BTVs, SSCVs may be established based on additional site-specific information. This can be accomplished in two different ways:

- Derive **site-specific SRVs** based on modification of the allowed parameters and use those SRVs as the SSCVs.
- Derive multiple site-specific SRVs using different modifications of the allowed parameters to show a **range of potential SRVs** and use this information along with other site-specific factors to establish SSCVs.

The modifications that can be made include exposure parameters, physical properties and chemical-specific information.

As previously stated in **Section 3. Derivation of Soil Reference Values**, generic SRVs are derived based on the RME concept, which is intended to protect the entire population. Site-specific SRVs could also be derived using the central tendency exposure (CTE) concept, which is intended to represent an average exposure of a population. Although a CTE does not provide protection for the entire population as an RME does, this information provides an additional line of evidence that can be used in a site-specific risk assessment to determine appropriate SSCVs.

Please contact MPCA program staff if a site-specific risk assessment is planned. Such an effort requires coordination between the entity performing the risk assessment and the MPCA project staff and risk assessor.

6. Site-Specific Soil Background

This section provides general information about site-specific soil background concentrations in the context of conducting a site-specific risk assessment. Unlike situations where default published background concentrations are applied (refer to **Section 4.4. Background Values**), existing published background concentrations for certain soil contaminants may lack an adequate number of samples, utilize outdated QA/QC procedures, and/or fail to accurately represent non-anthropogenic background concentrations for a specific site. In such cases, a targeted evaluation for the background concentrations of a particular chemical is necessary to depict site conditions.

Background concentrations of chemicals found in soil vary depending on the local geology and physical and chemical properties of the soil. They are heterogeneous both laterally and vertically and over small and large areas. Although certain background values (BTVs) have been calculated for purposes of screening, chemical background concentrations are more accurately described as a range, rather than a single fixed value, due to this variation. It is important to consider these factors when evaluating whether observed concentrations are a result of a release or background.

For the purposes of this document, background is defined as the amount of a contaminant present in the soil that is not attributable to local anthropogenic sources, such as a release. Some inorganics are present in lower or higher concentrations in soil due to local geological characteristics. Certain organics, such as B[a]P and TCDD, may be present at low concentrations in soil not due to local anthropogenic sources or an onsite release, but because of their potential origin from regional sources and land use. The persistence in surface soils and ability to be transported by air deposition over long distances can also contribute to their presence.

In general, if the exposure point concentration or exposure area maximum concentration is equal to or less than site background concentrations, further release investigation or response actions related to the contaminant, as well as further consideration as a COC, may not be necessary.

BTVs representing statewide typical background concentrations for contaminants with health-based SRVs calculated to be below soil background concentrations are listed in the [SRV spreadsheet](#). Maximum site concentrations should first be compared to BTVs. If the maximum site concentration exceeds a BTV, there are two options to investigate further:

- Compare site dataset to BTV using the proportions test.
- Determine site-specific background and compare to site data.

In some situations, it may be appropriate to derive *lower* site-specific background than the statewide BTV. For example, if background site-specific data are available that show the background concentrations are below the established BTV or if, based on knowledge of the site, lower background is expected and confirmed through sampling.

Please contact MPCA program staff if site-specific background values are to be established. Such an effort requires coordination between the entity performing the evaluation and the MPCA project staff and risk assessor.

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Appendix A: Derivation of Acute RfDs

Arsenic

Acute arsenic toxicity results in gastrointestinal symptoms including nausea, vomiting and diarrhea, and facial edema as the critical effects. Both symptoms subside when exposure is removed. Acute exposure may also lead to other effects: respiratory effects including respiratory distress, hemorrhagic bronchitis and pulmonary edema; cardiac effects including altered myocardial depolarization (prolonged QT interval, nonspecific ST segment changes), cardiac arrhythmias and ischemic heart disease; and neurological effects including headache, lethargy, mental confusion, hallucination, seizures and coma (ATSDR 2007).

It is appropriate to use the case study from Mizuta et al. (1956) to assess health risks of acute arsenic exposure, which is based on gastrointestinal effects observed in 220 humans poisoning from contaminated soy sauce (ATSDR 2007). Exposure duration lasted two to three weeks, with an estimated arsenic intake of 0.05 mg/kg-day. An uncertainty factor (UF) of 10 was applied to account for the use of a lowest observed adverse effect level (LOAEL) instead of a no observed adverse effect level (NOAEL). This results in an *acute Reference Dose (RfD)* of 0.005 mg/kg-event.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological profile for Arsenic. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. <https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=22&tid=3>

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Barium

Acute barium toxicity usually begins with gastrointestinal symptoms including abdominal pain, vomiting, diarrhea and weakness. Toxicity may progress with more severe symptoms including: severe gastrointestinal hemorrhage, decreased blood potassium levels, cardiac arrhythmias, abnormal sensations that may begin in the mouth and spread to the extremities, muscle paralysis, complete quadriplegia, respiratory paralysis and death (Nordberg et al. 2007, ATSDR 2007, WHO & IPCS 1991). It is not clear from the literature whether gastrointestinal effects always occur prior to the more severe effects (Lewi et al. 1964, ATSDR 2007).

Several cases of accidental and intentional barium poisoning have been reported, whereas an associated effect level has rarely been established. Nordberg et al. (2007) reported a lowest effect level of 3 mg/kg, based on a dose of 200 to 500 mg of barium and an adult weight of 70 kg.

The effect level of 3 mg/kg from Nordberg et al. (2007) is appropriate to evaluate health risks from acute barium exposure. An UF of 10 is applied to account for the use of a LOAEL instead of a NOAEL since it has been reported that paralysis has been observed prior to any gastrointestinal effects. An additional UF of 10 is applied to account for intraspecies variability. This results in an acute RfD of 0.03 mg/kg-event, which is lower than the U.S. EPA's chronic RfD of 0.2 mg/kg-day (U.S. EPA 2005). As it is generally not advisable to set an acute RfD lower than a chronic RfD, the *acute RfD will be set at the U.S. EPA's chronic RfD of 0.2 mg/kg-event*.

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Cadmium

Acute cadmium toxicity begins with gastrointestinal symptoms including nausea, vomiting, salivation, abdominal pain, cramps and diarrhea. No fatalities were reported in the literature and rapid recovery is experienced due to the low absorption rate of cadmium (ATSDR 2012, Norberg et al. 2007).

There are cases of accidental cadmium poisoning reported in the literature as a result of cadmium plated utensils, metal pitchers, ice cube trays, food molds, solder, pipes, beverage taps and refrigerators (Frant and Kleeman 1941, Lauwerys 1979, Norberg et al. 2007, ATSDR 2012). Nordberg et al. (1973) identified an effect dose of 0.07 mg/kg based on an accidental poisoning case involving cadmium contamination of a soft drink machine, as reported in ATSDR (2012).

The acute effect level of 0.07 mg/kg from Nordberg et al. (1973) is appropriate to evaluate health risks from cadmium exposure. An UF of 3 is used to account for LOAEL to NOAEL with a less severe, transient effect and an UF of 3 is used to account for intraspecies variability. The result is an *acute RfD of 0.007 mg/kg-event*.

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Copper

Copper is an essential nutrient required for physiological processes in human body, typically obtained through dietary intake and supplements. However, acute oral exposure to copper has been identified for gastrointestinal toxicity in humans, manifesting as symptoms including nausea, vomiting, abdominal pain and delayed gastric emptying.

Several studies have investigated the dose-response relationship for acute copper toxicity through bolus dosing or copper-containing water consumption (Pizarro et al. 1999; Araya et al. 2001; Gotteland et al. 2001; Olivares et al. 2001; Pizarro et al. 2001; Araya et al. 2003a; Araya et al. 2003b). The reported LOAELs across these studies range from 0.012 to 0.1 mg Cu/kg/day. Among these, Pizarro et al. (1999) study provides the most comprehensive information to determine acute toxicity threshold. Sixty healthy women were recruited, consuming copper sulfate in drinking water for 2 weeks. The copper concentrations in both dietary sources and drinking water were quantified. Observed gastrointestinal symptoms included abdominal pain, nausea, and vomiting.

The ATSDR (2024) utilized dose-response data from Pizarro et al. (1999) to derive a benchmark dose lower confidence limit associated with 10% extra risk (BMDL₁₀), calculated as 0.055 mg Cu/kg/day. A partial UF of 3 is applied to address human variability, as toxicokinetic differences among individuals are unlikely to directly influence toxic effects on the gastrointestinal tract. This results in an acute RfD of 0.02 mg Cu/kg/day, reflecting copper administration with dietary background. However, this value is below the recommended daily allowance (RDA) for copper of 0.09 mg/kg-day, as established by WHO (1996), making it potentially inappropriate for ensuring adequate nutritional intake. Additionally, the value is lower than the Cal EPA's chronic RfD of 0.142 mg/kg-day (Cal EPA 2008). As it is generally not advisable to set an acute RfD lower than a chronic RfD, *the acute RfD will be set to the Cal EPA's chronic RfD of 0.142 mg/kg-event.*

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Cyanide

Acute cyanide toxicity induces dyspnea, palpitations, hypotension, convulsions, and vomiting. Respiratory failure may ultimately lead to death. The neurological system is particularly vulnerable to the effects of acute cyanide oral exposure (ATSDR 2024).

Although cyanide poisoning has been widely studied, no lowest effect levels have been reported in the literature. ATSDR (2024) reports an average fatal dose of 1.52 mg/kg for humans based on case studies of poisonings. The lowest fatal dose of 0.56 mg/kg was estimated by Gettler and Baine (1938).

It is appropriate to use the lowest fatal dose of 0.56 mg/kg from Gettler and Baine (1938) to assess health risks from acute cyanide exposure. An UF of 10 is applied to account for a severe lethal effect and an UF of 10 is applied to account for intraspecies variability. This results in an acute *RfD* of 0.0056 mg/kg-event.

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Fluoride

Acute fluoride toxicity begins with gastrointestinal symptoms, including nausea, vomiting, weakness, diarrhea, muscle twitching and excess salivation. Rapid recovery generally takes place once the exposure is eliminated (Hoffman et al. 1980, ATSDR 2003).

Reports of accidental fluoride poisoning via drinking water, resulting from malfunctioning fluoridators, have been reported in the literature. Hoffman et al. (1980) reported that doses of 70 to 140 mg/kg induced gastrointestinal symptoms in children. Vogt et al. (1982) estimated that a dose of 0.7 to 1.3 mg/kg caused nausea in adults, while 2 to 3 mg/kg caused vomiting. Two studies investigated fluoride poisoning cases reported to poison control centers. Augenstien et al. (1991) estimated an effect dose ranging from 2 to 4 mg/kg, with a lethal dose range of 6 to 83 mg/kg. Spoerke et al. (1980) estimated an effect dose of 50 to 225 mg/kg. The Centers for Disease Control (CDC 1995) established that a dose of 5 mg/kg necessitates emergency treatment, as calculated by Whitford (1990).

It is appropriate to derive acute *RfD* for fluoride based on CDC's recommended dose of 5 mg/kg as the threshold for seeking medical attention. While other lower potential lethal doses have been reported by poison control centers, these doses remain unverifiable. An UF of 10 is applied to account for a use of a LOAEL instead of a NOAEL. It is assumed that intraspecies variability was considered when establishing the dose threshold for medical treatment. This results in an acute *RfD* of 5 mg/kg-event.

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Whitford GM. 1990. The physiological and toxicological characteristics of fluoride. *J Dent Res*. 69 Spec No:539-49; discussion 556-7.

Nickel

Acute nickel toxicity results in nausea, vomiting, abdominal cramps, giddiness, lassitude, headache, and cough (ATSDR 2024, Sunderman et al. 1988). While nickel is an essential trace element for several species, its nutritional importance in humans has not been well studied. Nickel is present in a wide variety of foods. There is no evidence to suggest that typical dietary intake of nickel causes adverse effects. However, two studies have reported nickel ingestion from food may lead to contact dermatitis in sensitive individuals (Cronin et al. 1980, Gawkrödger et al. 1986, ATSDR 2005).

Sunderman et al. (1988) reported nausea, vomiting, abdominal cramps, giddiness, lassitude, headache and cough in adult workers exposed to 7 to 36 mg/kg in drinking water. Ten of these workers required hospitalization.

It is appropriate to use the lowest effect dose of 7 mg/kg from Sunderman et al. (1988) to derive acute RfD for nickel exposure. An UF of 3 is applied to account for the use of a LOAEL instead of a NOAEL and an UF of 10 to account for intraspecies variability. While 10 out of 20 workers required hospitalization, it is assumed that their exposure was greater than that of the other subjects who did not require hospitalization. Thus, the UF of 10 for intraspecies variability appears to adequately address this uncertainty. This results in an *acute RfD of 0.2 mg/kg-event*.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2024. Toxicological Profile for Nickel. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. <https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=245&tid=44>

Cronin E, DiMichiel AD, Brown SS. 1980. Oral challenge in nickel-sensitive women with hand eczema. In: Brown SS, Sunderman FW, eds. *Nickel toxicology*. New York, NY: Academic Press, 149-152.

Gawkrödger DJ, Cook SW, Fell GS, Huner JA. 1986. Nickel dermatitis: the reaction or oral nickel challenge. *Br. J. Dermatol.*, 115(1):33-38.

Sunderman FW, Dingle B, Hopfer SM, and Swift T. 1988. Acute nickel toxicity in electroplating workers whom accidentally ingested a solution of nickel sulfate and nickel chloride. *Am. J. Ind. Med.* 14(3):257-266.

Pentachlorophenol

There are limited reports regarding acute toxicity in humans following ingestion of pentachlorophenol. Existing case studies lack detailed exposure data and information regarding possible co-exposure to other chemicals. Symptoms associated with these cases include: hyperthermia generated by uncoupling of oxidative phosphorylation, aplastic anemia, hepatic enlargement, dermal toxicity, chloracne and death (ATSDR 2022).

Animal studies report symptoms of vomiting, hyperpyrexia and elevated blood pressure, heart rate and respiration rate following acute exposures to pentachlorophenol. ATSDR 2022 established an acute oral MRL of 0.005 mg/kg-day, based on delayed ossification of skulls in rat pups. Similar developmental effects have been observed in other animal studies.

The MDH has derived an acute RfD of 0.004 mg/kg/day (MDH 2015). UF factors applied include 3 for interspecies variability, 10 for intraspecies variability, 3 for a LOAEL to NOAEL and 3 for database uncertainty. Additivity endpoints include developmental and thyroid (endocrine disrupting). It is appropriate to use the MDH's *acute RfD of 0.004 mg/kg-event* in health risk assessment.

References

- Agency for Toxic Substances and Disease Registry (ATSDR). 2022. Toxicological Profile for Pentachlorophenol. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. <https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=402&tid=70>
- Minnesota Department of Health (MDH). 2015. Toxicological Summary for Pentachlorophenol (PCP). <http://www.health.state.mn.us/divs/eh/risk/guidance/gw/table.html>.

Phenol

Acute phenol toxicity results in mouth sores, burning mouth, dark urine, diarrhea, and, in some cases, death (ATSDR 2008, Baker et al. 1978).

Bennett et al. (1950) identified a lethal dose of 230 mg/kg. The U.S. EPA (2002) reported estimated lethal oral doses in a range between 14 and 930 mg/kg for adults. Baker et al. (1978) reported the lowest effect level of 0.14 to 3.4 mg/kg-day, though exposure data in this study was uncertain. A study conducted on cases at a poison control center reported a lowest effect dose for a child of 98 mg/kg (Spiller et al. 1993). ATSDR (2008) established an acute oral MRL of 1 mg/kg-day based on decreased maternal weight gain in a rat study, using divided gavage dosing protocol to mitigate the enhanced toxicity associated with gavage compared to drinking water exposure.

It is appropriate to apply the acute MRL derivation from ATSDR (2008) to evaluate health risks from oral phenol exposure. A BMDL of 152 mg/kg-day was derived using EPA Benchmark Dose Software. An UF of 10 was used for intraspecies variability and another UF of 10 was used for interspecies. This result in an *acute RfD of 1 mg/kg-event*.

References

- Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological profile for Phenol. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. <https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=148&tid=27>
- Baker EL, Landrigan PJ, Bertozzi PE, Field PH, Basteys BJ, Skinner HG. 1978. Phenol poisoning due to contaminated drinking water. Arch. Environ. Health, 33(2):89-94.

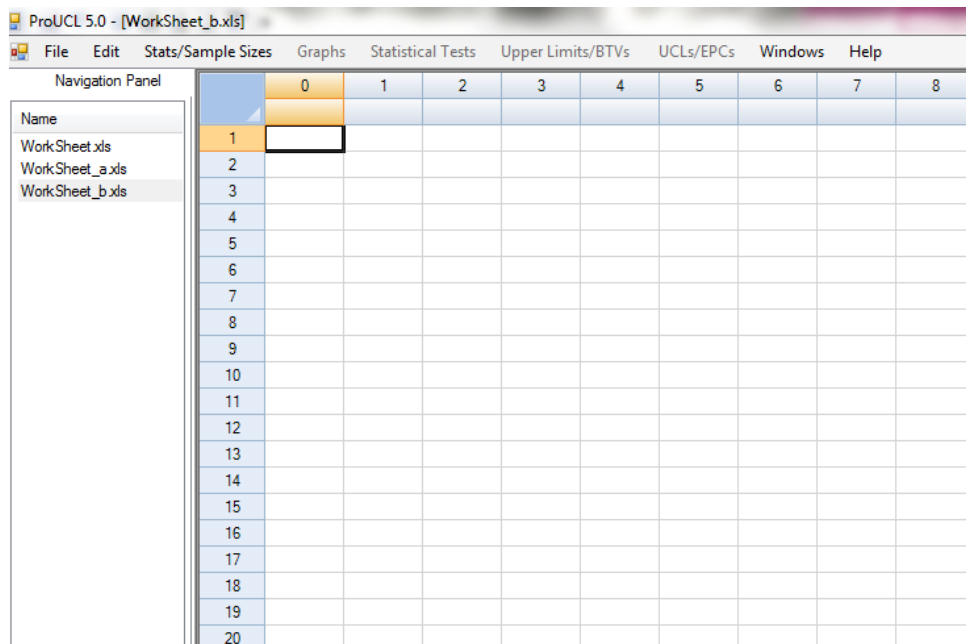
Bennett IL Jr, James DF, Golden A. 1950. Severe acidosis due to phenol poisoning; report of two cases. *Ann. Intern. Med.*, 32(2):324-327.

Spiller HA, Quadrani-Kushner DA, Cleveland P. 1993. A five year evaluation of acute exposures to phenol disinfectant (26%). *Clin Toxicol.* 31(2):307-313.

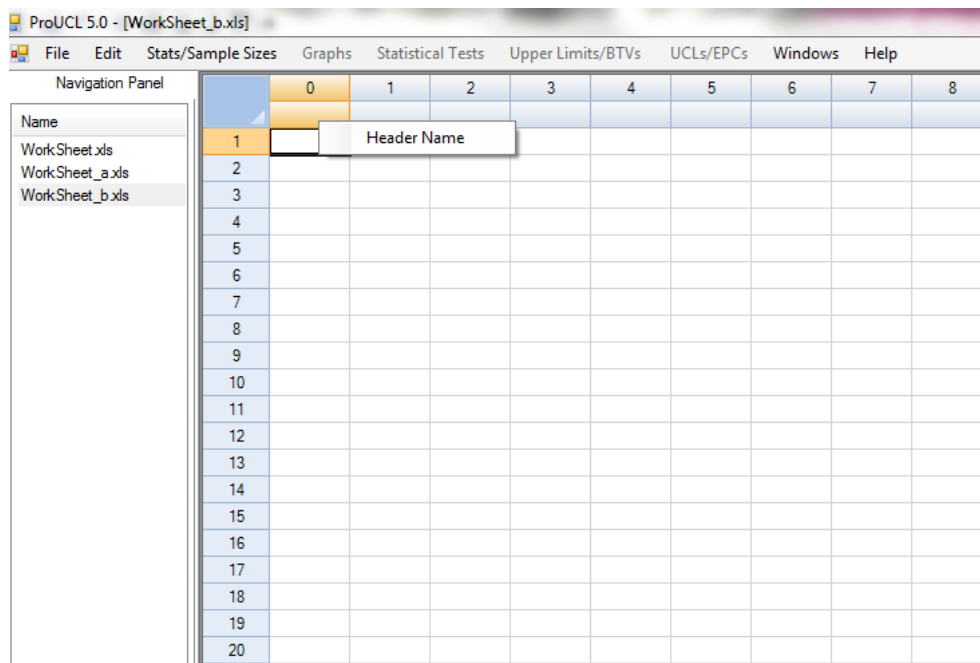
U.S. EPA. 2002. Toxicological review of phenol: In support of summary information on the Integrated Risk Information System (IRIS). Washington D.C: U.S. Environmental Protection Agency.

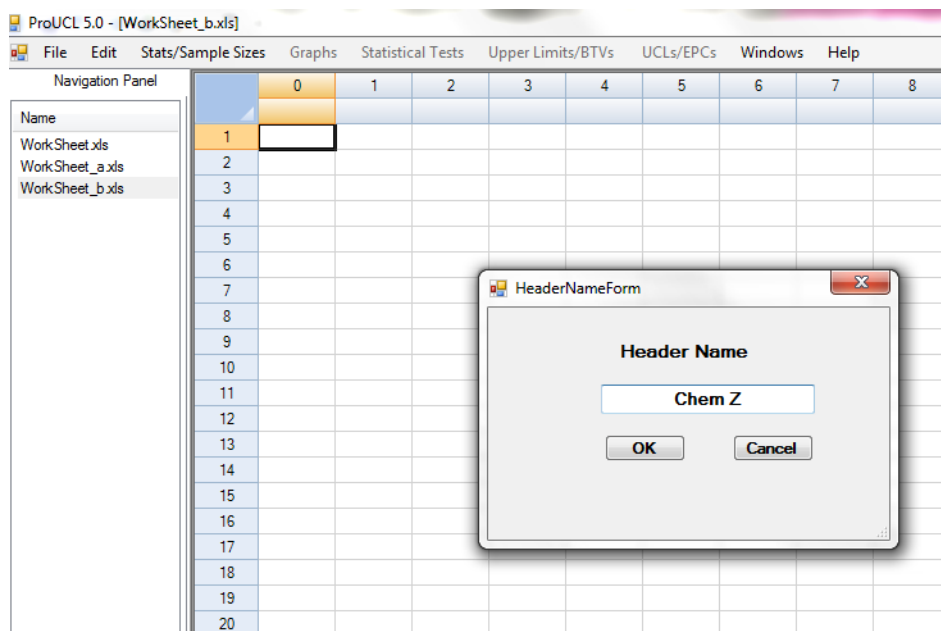
Appendix B: Calculating 95% UCL of the Mean

1. In ProUCL, open a new worksheet by choosing “File”, then “New”.

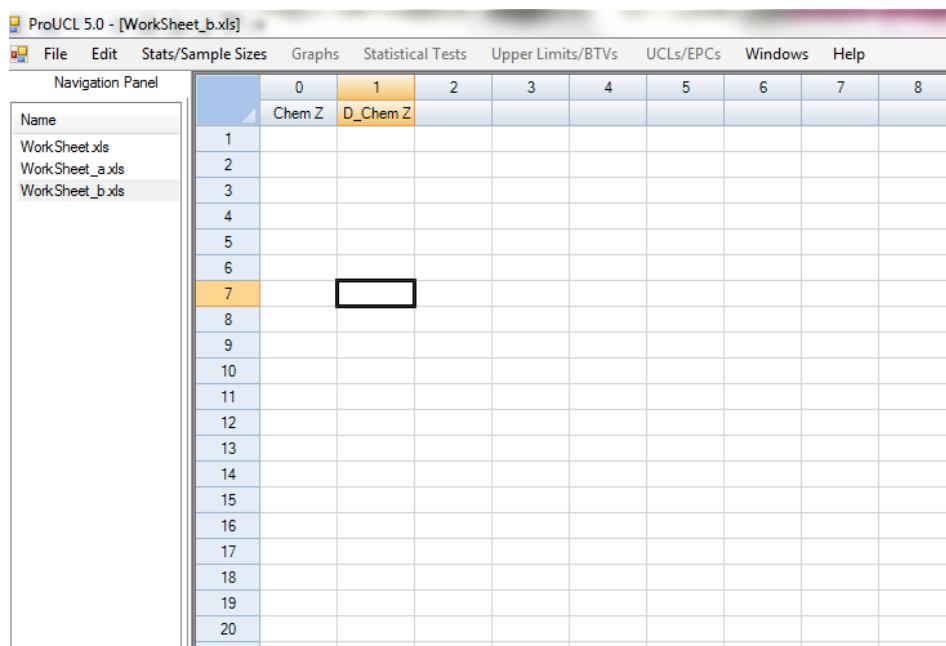


2. Name the first column to identify the contaminant by clicking on the header and choosing “Header Name”. The “HeaderNameForm” window will open. Enter the contaminant name (Chem Z) and click “OK”.





3. If your data contains non-detect values, name the second column with the same name as the first column with a "D_" attached to the beginning.
 - a. If your data does **not** contain any non-detect values, do **not** name the second column.



4. Enter the data into the first column ("Chem Z"). If the data you received from the lab is under the laboratory reporting limit but greater than the detection limit (J-flagged or estimated values), enter the estimated value into the worksheet treating it as a detected concentration. Enter the detection limit for all other non-detect values.
 - a. The dataset must contain at least eight samples to calculate the 95% UCL of the mean.
 - b. If you do not have any non-detect values, you only need to enter the data into the first column. You do **not** need to enter anything into the second column. Make sure there is no header name on the second column. If there is a header name, you can eliminate it by deleting the title using the same process used to enter the title.

ProUCL 5.0 - [WorkSheet_b.xls]

File Edit Stats/Sample Sizes Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help									
Navigation Panel									
Name	0	1	2	3	4	5	6	7	8
WorkSheet.xls	Chem Z	D_Chem Z							
WorkSheet_a.xls	1	10							
WorkSheet_b.xls	2	11.1							
	3	9.5							
	4	8.6							
	5	7							
	6	5.5							
	7	12							
	8	13.2							
	9	18.4							
	10	20.1							
	11	5							
	12	6.5							
	13	11							
	14	10.7							
	15	9.1							
	16								
	17								
	18								
	19								
	20								

5. If any of the values in column one are non-detect values entered in as the detection limit, fill in the second column as described below:
 - a. Enter a “0” for a non-detect (based on detection limit rather than an actual sample concentration).
 - b. Enter a “1” for a detected value (based on an actual sample concentration).

ProUCL 5.0 - [WorkSheet_b.xls]

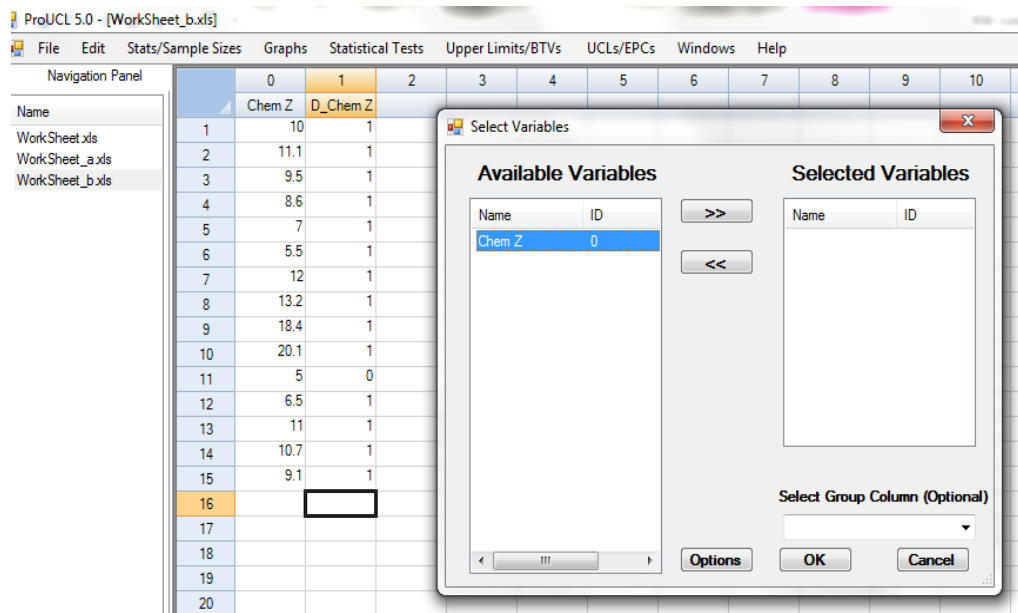
File Edit Stats/Sample Sizes Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help									
Navigation Panel									
Name	0	1	2	3	4	5	6	7	8
Chem Z	D_Chem Z								
1	10	1							
2	11.1	1							
3	9.5	1							
4	8.6	1							
5	7	1							
6	5.5	1							
7	12	1							
8	13.2	1							
9	18.4	1							
10	20.1	1							
11	5	0							
12	6.5	1							
13	11	1							
14	10.7	1							
15	9.1	1							
16									
17									
18									
19									
20									

6. Choose “UCLs/EPCs”, then “All”.

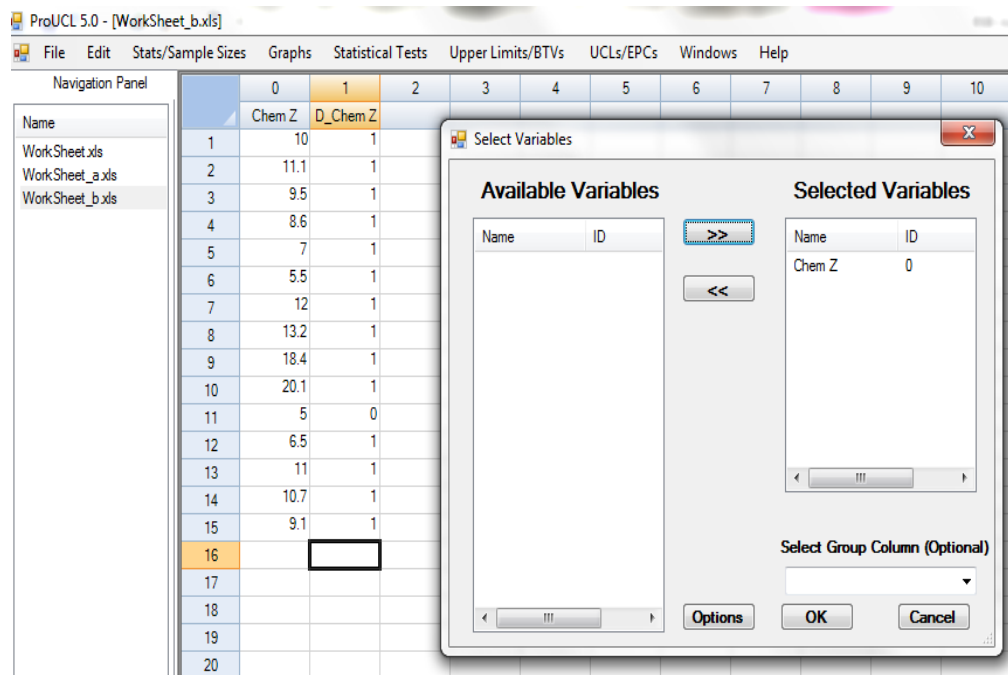
ProUCL 5.0 - [WorkSheet_b.xls]

File Edit Stats/Sample Sizes Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help									
Navigation Panel									
Name	0	1	2	3	4	5	6	7	8
Chem Z	D_Chem Z								
1	10	1							
2	11.1	1							
3	9.5	1							
4	8.6	1							
5	7	1							
6	5.5	1							
7	12	1							
8	13.2	1							
9	18.4	1							
10	20.1	1							
11	5	0							
12	6.5	1							
13	11	1							
14	10.7	1							
15	9.1	1							
16									
17									
18									
19									
20									

7. The “Select Variables” window will open.



8. Select the dataset you want to calculate the 95% UCL of the mean for by highlighting it under the “Available Variables” list and clicking the “>>” button to move it to the “Selected Variables” list. You can calculate 95% UCL of means for more than one dataset at once.



9. Press “OK”.

10. ProUCL will return a list of possible 95% UCL of mean values based on the data's distribution. There is a suggested 95% UCL of the mean listed at the end of the output (inside green circle below). Users must evaluate the results presented to determine the most appropriate 95% UCL of the mean to use based on the data and the ProUCL calculations.

ProUCL 5.0 - [UCLsNoNDsAll.xls]

File Edit BIS Simulator Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help

Navigation Panel

	A	B	C	D	E	F	G	H	I	J	K	L
Name	UCL Statistics for Uncensored Full Data Sets											
WorkSheet.xls												
WorkSheet_a.xls	User Selected Options											
WorkSheet_b.xls	Date/Time of Computation 4/18/2016 2:18:44 PM											
UCLsNoNDsAll.xls	From File WorkSheet_b.xls											
	Full Precision OFF											
	Confidence Coefficient 95%											
	Number of Bootstrap Operations 2000											
	Chem Z											
	General Statistics											
	Total Number of Observations				15	Number of Distinct Observations				15		
						Number of Missing Observations				0		
	Minimum				5	Mean				10.51		
	Maximum				20.1	Median				10		
	SD				4.268	Std. Error of Mean				1.102		
	Coefficient of Variation				0.406	Skewness				1.041		
	Normal GOF Test											
	Shapiro Wilk Test Statistic				0.907	Shapiro Wilk GOF Test						
	5% Shapiro Wilk Critical Value				0.881	Data appear Normal at 5% Significance Level						
	Lilliefors Test Statistic				0.179	Lilliefors GOF Test						
	5% Lilliefors Critical Value				0.229	Data appear Normal at 5% Significance Level						
	Data appear Normal at 5% Significance Level											
	Assuming Normal Distribution											
	95% Normal UCL					95% UCLs (Adjusted for Skewness)						
	95% Student's-t UCL				12.45	95% Adjusted-CLT UCL (Chen-1995)				12.64		
						95% Modified-t UCL (Johnson-1978)				12.5		
	Gamma GOF Test											
	A-D Test Statistic				0.275	Anderson-Darling Gamma GOF Test						
	5% A-D Critical Value				0.738	Detected data appear Gamma Distributed at 5% Significance Level						
	K-S Test Statistic				0.127	Kolmogorov-Smirnov Gamma GOF Test						
	5% K-S Critical Value				0.222	Detected data appear Gamma Distributed at 5% Significance Level						
	Detected data appear Gamma Distributed at 5% Significance Level											

ProUCL 5.0 - [UCLsNoNDsAll.xls]													
File Edit BIS Simulator Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help													
Navigation Panel													
Name	40	A	B	C	D	E	F	G	H	I	J	K	L
	41	Gamma Statistics											
WorkSheet.xls	42	k hat (MLE)				7.04	k star (bias corrected MLE)				5.676		
WorkSheet_a.xls	43	Theta hat (MLE)				1.493	Theta star (bias corrected MLE)				1.852		
WorkSheet_b.xls	44	nu hat (MLE)				211.2	nu star (bias corrected)				170.3		
UCLsNoNDsAll.xls	45	MLE Mean (bias corrected)				10.51	MLE Sd (bias corrected)				4.413		
	46	Adjusted Level of Significance				0.0324	Approximate Chi Square Value (0.05)				141.1		
	47						Adjusted Chi Square Value				137.8		
	48	Assuming Gamma Distribution											
	49	95% Approximate Gamma UCL (use when n>=50))				12.69	95% Adjusted Gamma UCL (use when n<50)				12.99		
	50												
	51	Lognormal GOF Test											
	52	Shapiro Wilk Test Statistic				0.968	Shapiro Wilk Lognormal GOF Test						
	53	5% Shapiro Wilk Critical Value				0.881	Data appear Lognormal at 5% Significance Level						
	54	Lilliefors Test Statistic				0.107	Lilliefors Lognormal GOF Test						
	55	5% Lilliefors Critical Value				0.229	Data appear Lognormal at 5% Significance Level						
	56	Data appear Lognormal at 5% Significance Level											
	57												
	58	Lognormal Statistics											
	59	Minimum of Logged Data				1.609	Mean of logged Data				2.28		
	60	Maximum of Logged Data				3.001	SD of logged Data				0.394		
	61												
	62	Assuming Lognormal Distribution											
	63	95% H-UCL				12.99	90% Chebyshev (MVUE) UCL				13.77		
	64	95% Chebyshev (MVUE) UCL				15.25	97.5% Chebyshev (MVUE) UCL				17.31		
	65	99% Chebyshev (MVUE) UCL				21.34							
	66												
	67	Nonparametric Distribution Free UCL Statistics											
	68	Data appear to follow a Discernible Distribution at 5% Significance Level											
	69												
	70	Nonparametric Distribution Free UCLs											
	71	95% CLT UCL				12.33	95% Jackknife UCL				12.45		
	72	95% Standard Bootstrap UCL				12.27	95% Bootstrap-t UCL				13.04		
	73	95% Hall's Bootstrap UCL				14.35	95% Percentile Bootstrap UCL				12.37		
	74	95% BCA Bootstrap UCL				12.52							
	75	90% Chebyshev(Mean, Sd) UCL				13.82	95% Chebyshev(Mean, Sd) UCL				15.32		
	76	97.5% Chebyshev(Mean, Sd) UCL				17.4	99% Chebyshev(Mean, Sd) UCL				21.48		
	77												
	78	Suggested UCL to Use											
	79	95% Student's-t UCL				12.45							
	80												
	81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
	82	These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)											
	83	and Singh and Singh (2003). However, simulation results will not cover all Real World data sets.											

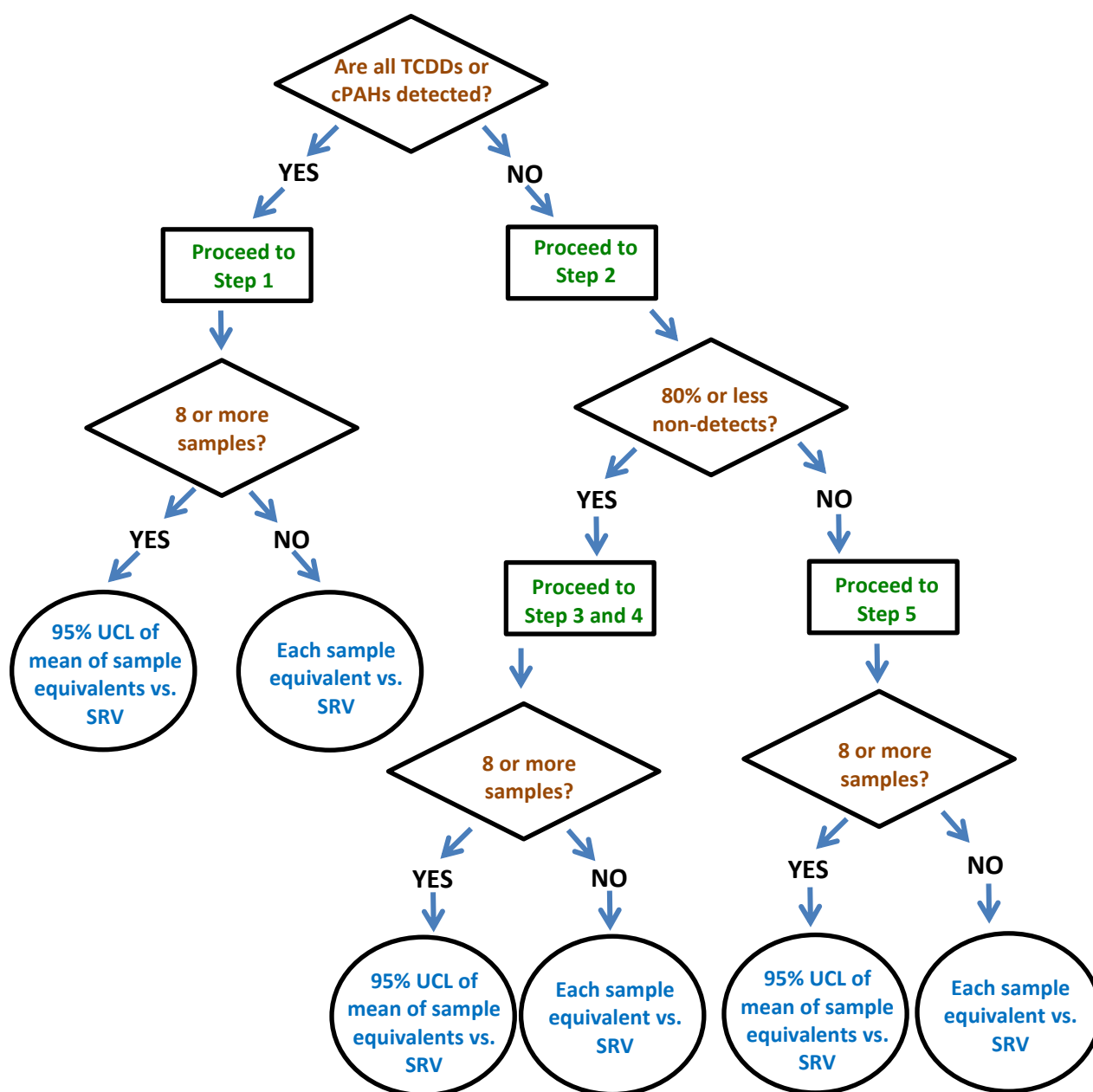
Appendix C: Calculating TCDD and B[a]P Equivalents

A party can choose **not** to use Kaplan Meier with non-detect data, although this is likely to result in a more conservative estimate of potential risks. Other situations where it would not be necessary to calculate B[a]P or TCDD equivalents include:

- Detected concentrations exceed applicable SRV, BTV or SSCV
- Equivalents concentration based on reporting limits do not exceed SRV, BTV or SSCV

Follow the instructions below to calculate TCDD equivalents for dioxin-like compounds and B[a]P equivalents for cPAHs using ProUCL and the Kaplan Meier method for non-detect data. Please refer to Figure C-1 for a flowchart depicting the process.

Figure C-1. Calculating TCDD and B[a]P Equivalents Flowchart.



Step 1 - No non-detect data present

- **If all of the cPAHs have been detected follow the instructions below in Step 1. If not, proceed to Step 2.** You will need to calculate a B[a]P and TCDD equivalent concentration for each individual discrete sample. Use the SRV spreadsheet to calculate the following (MPCA 2022):
 1. Potency equivalent factor (PEF) for each of the **cPAHs** analyzed in each sample using the “BaP Equivalents” worksheet.
 - a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.
 - c. The “Potency Equivalency Factors (PEF)” column contains the PEF that the site concentration is multiplied by to calculate the individual cPAH B[a]P equivalent concentration.
 - d. There are a series of two columns titled “Site Concentration” and “BaP Equivalent” (starts with columns E and F and ends with AQ and AR).
 - e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 5).
 - f. Enter the site concentration for the cPAH into the “Site Concentration” column and the “BaP Equivalent” concentration will automatically be calculated (multiplies the site concentration by the cPAH PEF).
 - g. If you have eight or more samples.
 - i. Enter the individual sample “Total BaP equivalents” (row 31) into ProUCL and calculate the 95% UCL of the mean using the instructions in **Appendix B**.
 - ii. Compare the 95% UCL of the mean of your samples to the BaP SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
 - h. If you have less than eight samples.
 - i. When you do not have eight or more samples, you cannot calculate the 95% UCL of the mean and compare it to the SRV. In this case you will need to compare each “sample equivalent” to the SRV.
 - ii. Compare the individual sample equivalent concentration from the “Total BaP Equivalents” column (row 31) to the B[a]P SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
 2. Toxicity equivalence factor (TEF) for each of the **TCDDs** analyzed in each sample using the “TCDD Equivalents” worksheet.
 - a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.

- c. The “Toxicity Equivalency Factor (TEF)” column contains the TEF that the site concentration is multiplied by to calculate the individual TCDD equivalent concentration.
- d. There are a series of two columns titled “Site Concentration” and “TCDD Equivalent” (starts with columns C and D and ends with AO and AP).
- e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 4).
- f. Enter the site concentration for the TCDD into the “Site Concentration” column and the “TCDD Equivalent” concentration will automatically be calculated (multiplies the site concentration by the TCDD TEF).
- g. If you have more than eight samples:
 - i. Enter the individual sample “Total TCDD equivalents” (row 37) into ProUCL and calculate the 95% UCL of the mean using the instructions in **Appendix B**.
 - ii. Compare the 95% UCL of the mean of your samples to the TCDD SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
- h. If you have less than eight samples:
 - i. When you do not have eight or more samples, you cannot calculate the 95% UCL of the mean and compare it to the SRV. In this case you will need to compare each “sample equivalent” to the SRV.
 - ii. Compare the individual sample equivalent concentration from the “Total TCDD Equivalents” column (row 37) to the TCDD SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).

Step 2 - Non-detect data present

- Determine the percentage of cPAH non-detects by dividing the number of non-detects in each sample by the total number of cPAHs sampled and then multiplying by 100. For example, if you sampled all 17 cPAHs and results indicated 10 non-detects, you would perform the following calculation to determine the percentage of non-detects: $10/17 \times 100 = 59\%$ non-detects.
 1. **If you have 80% or less non-detect data, the Kaplan Meier (KM) method should be used to calculate the KM Mean, proceed to Steps 3 and 4.**
 2. **If you have greater than 80% non-detect data, the Kaplan Meier method should NOT be used, proceed to step 5.**

Step 3 - 80% or less non-detect data

- You will need to calculate a B[a]P and TCDD equivalent concentration for each individual discrete sample. Use the SRV spreadsheet to calculate the following:
 1. Potency equivalent factor (PEF) for each of the **cPAHs** analyzed in each sample using the “BaP Equivalents” worksheet.
 - a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.

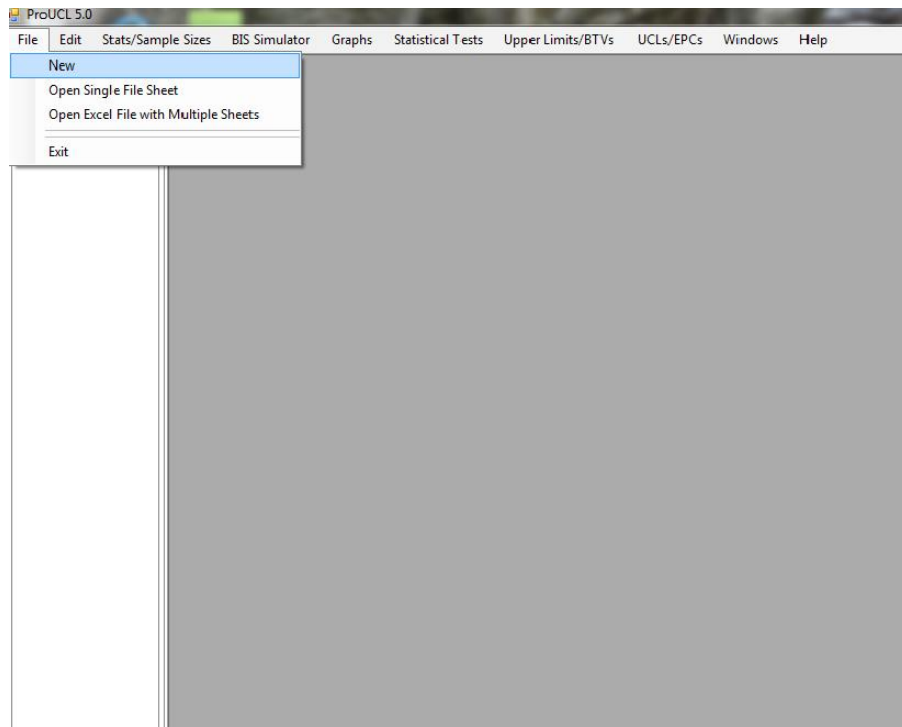
- c. The “Potency Equivalency Factors (PEF)” column contains the PEF that the site concentration is multiplied by to calculate the individual cPAH BaP equivalent concentration.
 - d. There are a series of two columns titled “Site Concentration” and “BaP Equivalent” (starts with columns E and F and ends with AQ and AR)
 - e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 5).
 - f. Enter the site concentration for the cPAH into the “Site Concentration” column and the “BaP Equivalent” concentration will automatically be calculated (multiplies the site concentration by the cPAH PEF). If the data you received from the lab is under the laboratory reporting limit but greater than the detection limit (I flagged or estimated values), enter the estimated value into the spreadsheet treating it like it is a detected concentration. Enter the reporting limit or method detection limit for all non-detect cPAHs.
 Note: The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and can provide an estimate of the detected concentration. It does not provide information about compounds reported as not detected. There is a possibility of false negatives for compounds that are not detected.
 - g. B[a]P equivalent concentrations will automatically calculate and be displayed in the “BaP Equivalent” columns. The spreadsheet automatically multiplies the “Potency Equivalency Factor” column by the “Site Concentration” column.
 - h. Proceed to **Step 4** to calculate the BaP equivalent concentration using the Kaplan Meier method.
2. TCDD equivalent concentration for each of the **TCDDs** analyzed in each sample using the “TCDD Equivalents” worksheet.
 - a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.
 - c. The “Toxicity Equivalency Factor (TEF)” column contains the TEF that the site concentration is multiplied by to calculate the individual TCDD equivalent concentration.
 - d. There are a series of two columns titled “Site Concentration” and “TCDD Equivalent” (starts with columns C and D and ends with AO and AP).
 - e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 4).
 - f. Enter the site concentration for the TCDD into the “Site Concentration” column and the “TCDD Equivalent” concentration will automatically be calculated (multiplies the site concentration by the TCDD TEF). If the data you received from the lab is under the laboratory reporting limit but greater than the detection limit (I flagged or estimated values), enter the estimated value into the spreadsheet treating it like it is a detected concentration. Enter the reporting limit (or method detection limit if one is available) for all non-detect TCDDs.

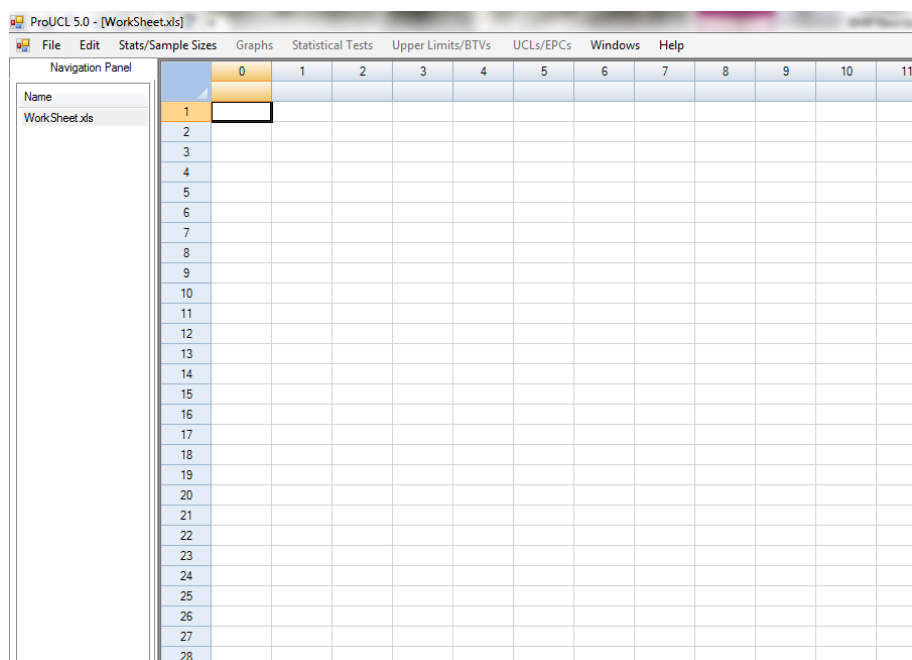
Note: The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and can provide an estimate of the detected concentration. It does not provide information about compounds reported as not detected. There is a possibility of false negatives for compounds that are not detected.

- g. TCDD equivalent concentrations will automatically calculate and be displayed in the “TCDD Equivalent” columns. The spreadsheet automatically multiplies the “Toxicity Equivalent Factor” column by the “Site Concentration” column.
- h. Proceed to **Step 4** to calculate the TCDD equivalent concentration using the Kaplan Meier method.

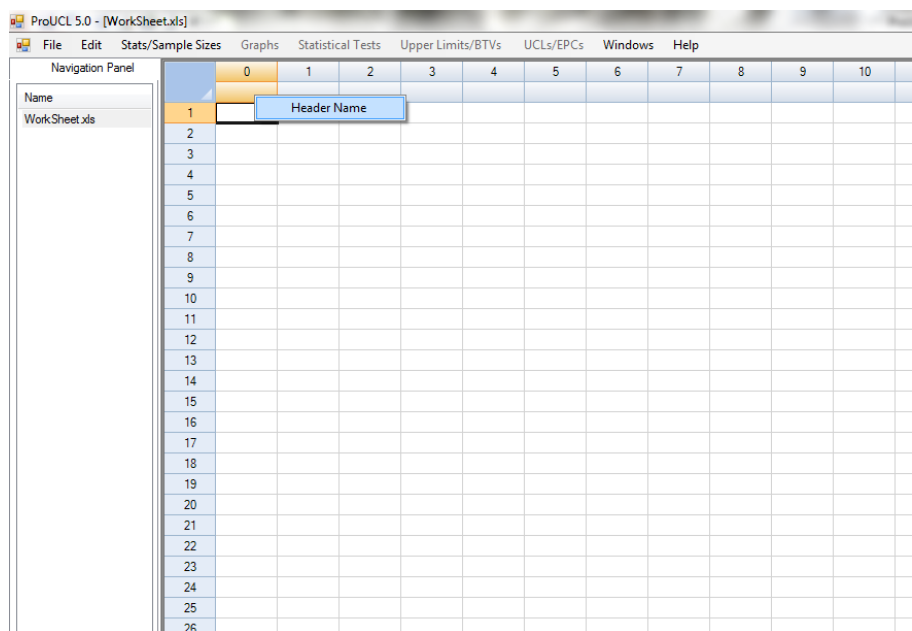
Step 4 - Kaplan Meier method

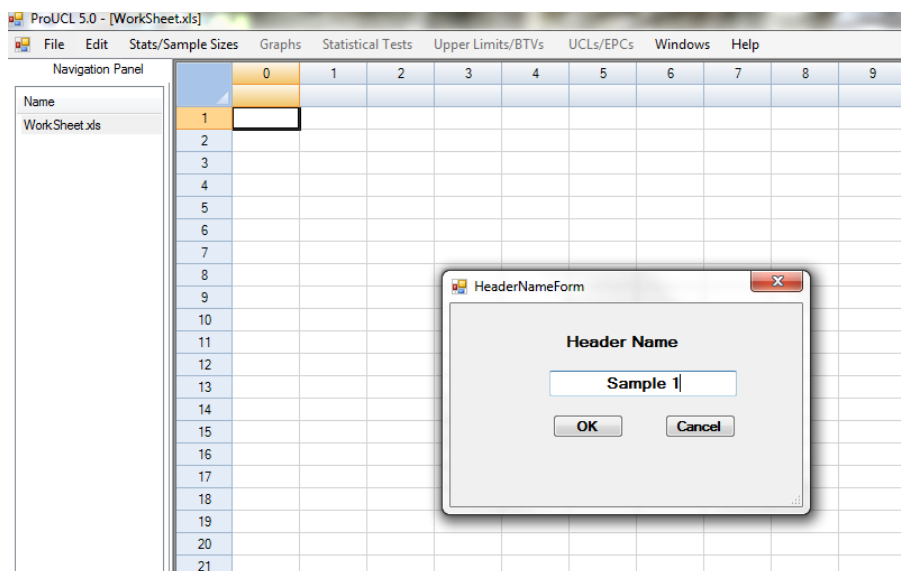
- Use U.S. EPA’s ProUCL software to calculate the Kaplan Meier mean (KM Mean) B[a]P and/or TCDD equivalent concentration.
 1. U.S. EPA’s ProUCL software is available to download for free (U.S. EPA 2016).
 2. In ProUCL, open a new worksheet by choosing “File”, then “New”.



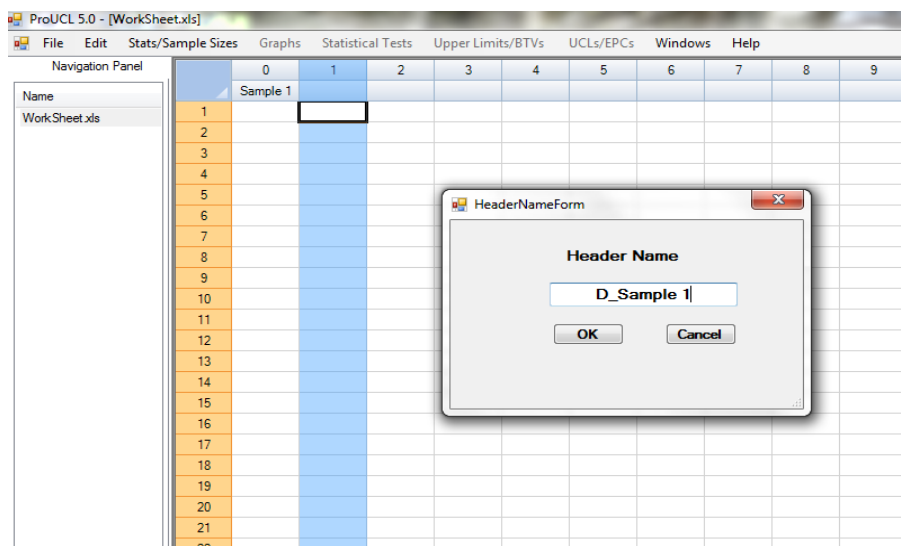


3. Name the first column to identify the sample (ex. "Sample 1") by clicking on the header and choosing "Header Name". The "HeaderNameForm" window will open. Enter the title of that column and click "OK".





4. Name the second column with a “D_” in front of the name you gave the first column (ex. “D_Sample 1”) by clicking on the header and choosing “Header Name”. The “HeaderNameForm” window will open. Enter the title of that column and click “OK”.



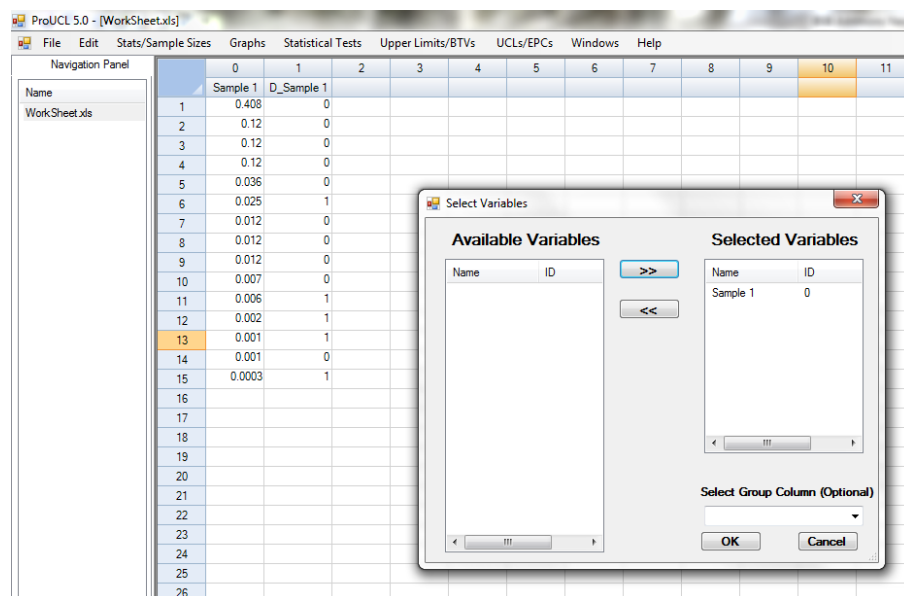
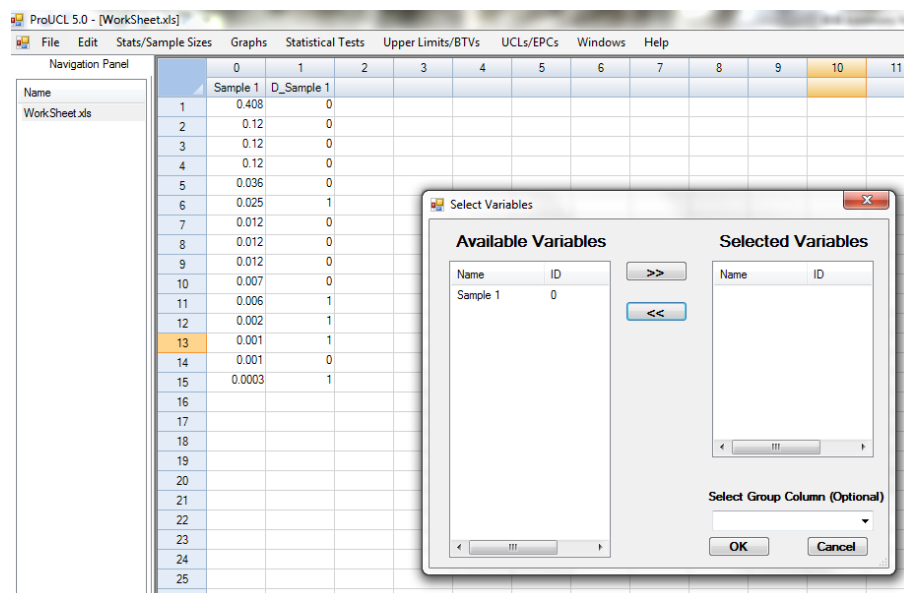
5. Enter the individual cPAH or TCDD data from the “SRV spreadsheet” into the first column (ex. “Sample 1”) in ProUCL.
 - a. For B[a]P equivalents, enter any data under the “BaP Equivalents” worksheet for individual cPAHs from the SRV spreadsheet (rows 6 through 30) into the first column (ex. “Sample 1”) in ProUCL.
 - b. For TCDD equivalents, enter any data under the “TCDD Equivalents” worksheet for the individual TCDDs from the SRV spreadsheet (rows 6 through 36) into the first column (ex. “Sample 1”) in ProUCL.
6. Under the second column (ex. “D_Sample 1”), enter a “0” if the sample concentration is non-detect data (based on a reporting limit or method detection limit if one is available rather than an actual sample concentration) and a “1” if it is a detected concentration.

- Repeat this procedure for each additional sample listed in the “SRV spreadsheet” using additional columns across the spreadsheet (ex. “Sample 2” would be entered into columns 2 and 3 in the ProUCL spreadsheet).

	0	1	2	3	4	5	6	7	8	9
	Sample 1	D_Sample 1								
1	0.408	0								
2	0.12	0								
3	0.12	0								
4	0.12	0								
5	0.036	0								
6	0.025	1								
7	0.012	0								
8	0.012	0								
9	0.012	0								
10	0.007	0								
11	0.006	1								
12	0.002	1								
13	0.001	1								
14	0.001	0								
15	0.0003	1								
16										
17										
18										
19										
20										
21										

- Under “Stats/Sample Sizes”, chose “General Statistics”, “With NDs”, “Raw Statistics”. The “Select Variables” window will open. Click the “>>” button to choose the data you want to use to calculate the “General Statistics”. You can choose all of your samples at the same time. Click “OK” to run the calculation.

	0	1	2	3	4	5	6	7	8	9
2	0.12	0								
3	0.12	0								
4	0.12	0								
5	0.036	0								
6	0.025	1								
7	0.012	0								
8	0.012	0								
9	0.012	0								
10	0.007	0								
11	0.006	1								
12	0.002	1								
13	0.001	1								
14	0.001	0								
15	0.0003	1								
16										
17										
18										
19										
20										
21										



9. ProUCL will calculate “General Statistics” including the Kaplan Meier mean which is the value you will use to compare to the SRVs (see “KM Mean” in the blue circle below).

ProUCL 5.0 - [WND_Raw_Stats.xls]

File Edit BIS Simulator Graphs Statistical Tests Upper Limits/BTVs UCLs/EPCs Windows Help

Navigation Panel

Name

WorkSheet.xls

WND_Raw_Stats.xls

General Statistics on Uncensored Data											
1											
2	Date/Time of Computation	5/4/2016 11:29:22 AM									
3	User Selected Options										
4	From File	WorkSheet.xls									
5	Full Precision	OFF									
6	From File: WorkSheet.xls										
7											
8											
9	General Statistics for Censored Datasets (with NDs) using Kaplan Meier Method										
10											
11	Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD
12	Sample 1	15	0	5	10	66.67%	0.001	0.408	0.00423	5.036E-5	0.00721
13											
14	General Statistics for Raw Dataset using Detected Data Only										
15											
16	Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness
17	Sample 1	5	0	3.0000E-4	0.025	0.00686	0.002	1.0770E-4	0.0104	0.00252	2.002
18											
19	Percentiles using all Detects (Ds) and Non-Detects (NDs)										
20											
21	Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile
22	Sample 1	15	0	0.001	0.0018	0.004	0.012	0.078	0.12	0.12	0.206
23											

10. Multiply the “KM Mean” from ProUCL (value in blue circle above) by the number of cPAHs and/or TCDDs that were analyzed for and included in the calculation. Enter this value into the “SRV spreadsheet”, “Total BaP Equivalents – Kaplan Meier” (row 32) and/or “TCDD Equivalents – Kaplan Meier” (row 38) under the appropriate sample (ex. “Sample 1”). For example: If 15 cPAHs were analyzed for, the calculation would be $15 * 0.00423 = 0.0635$ mg/kg.

- a. If the laboratory reports the three fluoranthenes (benzo[b]fluoranthene, benzo[j]fluoranthene and benzo[k]fluoranthene) as total fluoranthenes count this as one cPAH. If the laboratory reports two of the fluoranthenes (benzo[b]fluoranthene and benzo[j]fluoranthene) as benzo[b,j]fluoranthene, count this as 1 cPAH.

11. If you have eight or more samples:

- a. Enter the individual sample “Total BaP Equivalents – Kaplan Meier” (row 32) and/or “Total TCDD equivalents – Kaplan Meier” (row 38) into ProUCL and calculate the 95% UCL of the mean using the instructions in **Appendix A**.
- b. Compare the 95% UCL of the mean of your samples to the B[a]P equivalent and/or TCDD equivalent SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).

12. If you have less than eight samples:

- a. When you do not have eight or more samples, you cannot calculate the 95% UCL of the mean and compare it to the SRV. In this case you will need to compare each “sample equivalent” to the SRV.
- b. Compare the individual sample equivalent concentration from the “Total BaP Equivalents – Kaplan Meier” column (row 32) and/or “Total TCDD equivalents – Kaplan Meier” column (row 38) to the B[a]P equivalent and/or TCDD equivalent SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).

Step 5 - Greater than 80% non-detect data

- When a dataset has greater than 80% non-detect data, Kaplan Meier is no better than stating the B[a]P equivalent or TCDD equivalent concentration is somewhere between the B[a]P equivalent or TCDD equivalent concentration calculated when replacing the non-detect data with the full method detection limit and when replacing the non-detect data with zeros. Use the “SRV spreadsheet” to calculate the PEF for each of the cPAHs and/or TCDDs analyzed.
 1. Determine if appropriate reporting limits have been used by comparing the reporting limits used for your samples (found in the laboratory report) to those listed in the **Table C-1** for cPAHs and **Table C-2** for TCDD equivalents below.
 - a. If the reporting limit used by the laboratory for a cPAH and/or TCDD is equal to or less than the reporting limit in the table, appropriate reporting limits were used for that cPAH and/or TCDD. All cPAHs and/or TCDDs need to be checked. If all cPAHs and TCDDs have been analyzed using appropriate reporting limits, skip to **number 2** below to calculate total **B[a]P equivalents** and/or **number 3** to calculate total **TCDD equivalents**.
 - b. If any of the cPAHs and/or TCDDs did not use an appropriate reporting limit, you cannot calculate B[a]P and/or TCDD equivalents using the instructions in numbers 2 and 3 below. In this case, you will need to either re-analyze your samples for the cPAHs and/or TCDDs that did not have appropriate reporting limits or obtain new samples. The laboratory will be able to help you decide which one makes sense in your case.
 - i. If the laboratory is able to re-run the sample and obtain a lower reporting limit, equal to or less than that in **Table C-1** and **Table C-2**, it might be beneficial to run your sample again for that cPAH and/or TCDD.
 - ii. If the laboratory had to dilute your sample resulting in an increase in the reporting limit for a cPAH and/or TCDD, you will probably need to obtain new samples.
 2. Use the SRV spreadsheet to calculate the PEF for each of the **cPAHs** analyzed in each sample using the “BaP Equivalent” worksheet.
 - a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.
 - c. The “Potency Equivalency Factors (PEF)” column contains the PEF that the site concentration is multiplied by to calculate the individual cPAH B[a]P equivalent concentration.
 - d. There are a series of two columns titled “Site Concentration” and “BaP Equivalent” (starts with columns E and F and ends with AQ and AR).
 - e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 5).
 - f. Enter the site concentration for the cPAH into the “Site Concentration” column and the “BaP Equivalent” concentration will automatically be calculated (multiplies the site concentration by the cPAH PEF). If the data you received from the lab is under the laboratory reporting limit but greater than the method detection limit (J flagged or estimated values), enter the estimated value into the

spreadsheet treating it like it is a detected concentration. Enter one-half the reporting limit or method detection limit for all non-detect cPAHs.

Note: The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and can provide an estimate of the detected concentration. It does not provide information about compounds reported as not detected. There is a possibility of false negatives for compounds that are not detected.

- g. If you have more than eight samples:
 - i. Enter the individual sample “Total BaP equivalents” (row 31) into ProUCL and calculate the 95% UCL of the mean using the instructions in **Appendix B**.
 - ii. Compare the 95% UCL of the mean of your samples to the B[a]P SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
 - h. If you have less than eight samples:
 - i. When you do not have eight or more samples, you cannot calculate the 95% UCL of the mean and compare it to the SRV. In this case you will need to compare each “sample equivalent” to the SRV.
 - ii. Compare the individual sample equivalent concentration from the “Total BaP Equivalents” column (row 31) to the B[a]P SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
3. Use the SRV spreadsheet to calculate the toxicity equivalence factor (TEF) for each of the **TCDDs** analyzed in each sample using the “TCDD Equivalents” worksheet.
- a. The spreadsheet is arranged to accommodate a total of 20 individual discrete samples.
 - b. If you have more than 20 samples you can either use another copy of the SRV spreadsheet or request a copy of the SRV spreadsheet with columns for the number of additional samples necessary.
 - c. The “Toxicity Equivalency Factor (TEF)” column contains the TEF that the site concentration is multiplied by to calculate the individual TCDD equivalent concentration.
 - d. There are a series of two columns titled “Site Concentration” and “TCDD Equivalent” (starts with columns C and D and ends with AO and AP).
 - e. Enter the sample number or identification in the column that has “Enter Sample ID” (row 4).
 - f. Enter the site concentration for the TCDD into the “Site Concentration” column and the “TCDD Equivalent” concentration will automatically be calculated (multiplies the site concentration by the TCDD TEF). If the data you received from the lab is under the laboratory reporting limit but greater than the method detection limit (J flagged or estimated values), enter the estimated value into the spreadsheet treating it like it is a detected concentration. Enter one-half of the reporting limit or method detection limit for all non-detect TCDDs.

Note: The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and can provide an estimate of the

detected concentration. It does not provide information about compounds reported as not detected. There is a possibility of false negatives for compounds that are not detected.

- g. If you have more than eight samples:
 - i. Enter the individual sample “Total TCDD equivalents” (row 37) into ProUCL and calculate the 95% UCL of the mean using the instructions in **Appendix B**.
 - ii. Compare the 95% UCL of the mean of your samples to the TCDD SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).
- h. If you have less than eight samples:
 - i. When you do not have eight or more samples, you cannot calculate the 95% UCL of the mean and compare it to the SRV. In this case you will need to compare each “sample equivalent” to the SRV.
 - ii. Compare the individual sample equivalent concentration from the “Total TCDD Equivalents” column (row 37) to the TCDD SRV of the applicable land use category (Residential/Recreational or Commercial/Industrial).

Note: It is not appropriate to use the method detection limit if the lab does not meet the reporting limits listed in **Table C-1** and **Table C-2**. If the lab cannot meet the reporting limits, this indicates there was an issue with the analysis which needs to be investigated and resolved.

Table C-1. Carcinogenic PAH reporting limits

Carcinogenic PAH (cPAH)	Potency equivalent factor (PEF)	Appropriate maximum reporting limit mg/kg *
Benz[a]anthracene	0.1	0.01
Benzo[b]fluoranthene	0.1	0.03
Benzo[j]fluoranthene	0.1	0.03
Benzo[k]fluoranthene	0.1	0.03
Benzo[a]pyrene	1	0.01
Chrysene	0.01	0.01
Dibenz[a,h]acridine	0.1	0.01
Dibenz[a,h]anthracene	0.56	0.01
7H-Dibenzo[c,g]carbazole	1	0.01
Dibenzo[a,e]pyrene	1	0.01
Dibenzo[a,h]pyrene	10	0.01
Dibenzo[a,i]pyrene	10	0.01
Dibenzo[a,l]pyrene	10	0.01
7,12-Dimethylbenzanthracene	34	0.01
Indeno[1,2,3,-c,d]pyrene	0.1	0.01
3-Methylcholanthrene	3	0.01
5-Methylchrysene	1	0.01

* Laboratory reporting limits listed will need to be corrected for dry weight.

Table C-2. TCDD reporting limits

TCDD	Potency equivalent factor (PEF)	Appropriate maximum reporting limit pg/g *
<i>Dioxins</i>		
2,3,7,8-TCDD	1	0.060
Other TCDD	0	0.060
1,2,3,7,8-PeCDD	1	0.060
Other PeCDD	0	0.060
1,2,3,4,7,8-HxCDD	0.1	0.060
1,2,3,6,7,8-HxCDD	0.1	0.060
1,2,3,7,8,9-HxCDD	0.1	0.060
Other HxCDD	0	0.060
1,2,3,4,6,7,8-HpCDD	0.01	0.060
Other HpCDD	0	0.060
1,2,3,4,6,7,8,9-OCDD	0.0003	0.060
<i>Furans</i>		
2,3,7,8-TCDF	0.1	0.060
Other TCDF	0	0.060
1,2,3,7,8-PeCDF	0.03	0.060
2,3,4,7,8-PeCDF	0.3	0.060
Other PeCDF	0	0.060

TCDD	Potency equivalent factor (PEF)	Appropriate maximum reporting limit pg/g *
1,2,3,4,7,8-HxCDF	0.1	0.060
1,2,3,6,7,8-HxCDF	0.1	0.060
2,3,4,6,7,8-HxCDF	0.1	0.060
1,2,3,7,8,9-HxCDF	0.1	0.060
Other HxCDF	0	0.060
1,2,3,4,6,7,8-HpCDF	0.01	0.060
1,2,3,4,7,8,9-HpCDF	0.01	0.060
Other HpCDF	0	0.060
1,2,3,4,6,7,8,9-OCDF	0.0003	0.060
PCBs		
3,3',4,4'-TeCB (PCB 77)	0.0001	0.090
3,4,4',5-TeCB (PCB 81)	0.0003	0.10
2,3,3',4,4'-PeCB (PCB 105)	0.00003	0.15
2,3,4,4',5-PeCB (PCB 114)	0.00003	0.19
2,3',4,4',5-PeCB (PCB 118)	0.00003	0.19
2',3,4,4',5-PeCB (PCB 123)	0.00003	0.19
3,3',4,4',5-PeCB (PCB 126)	0.1	0.20
2,3,3',4,4',5-HxCB (PCB 156)	0.00003	0.081
2,3,3',4,4',5'-HxCB (PCB 157)	0.00003	0.081
2,3',4,4',5,5'-HxCB (PCB 167)	0.00003	0.064
3,3',4,4',5,5'-HxCB (PCB 169)	0.03	0.070
2,3,3',4,4',5,5'-HpCB (PCB 189)	0.00003	0.11

* Laboratory reporting limits listed will need to be corrected for dry weight.