GUIDANCE DOCUMENT

INHALATION STANDARDS COMPLIANCE

DEVELOPMENT OF ALTERNATIVE REMEDIATION STANDARDS FOR THE INHALATION PATHWAY

June 2008

Table of Contents

I. Introduction

A. Inhalation Exposure Pathway Soil Remediation Standards

The Inhalation Exposure Pathway Soil Remediation Standards (InhSRS) were developed using the USEPA Soil Screening Guidance and Supplement (1996, 2001), as well as standard USEPA models. This was done for contaminants in both their volatile and particulate forms, where applicable. Appendix A of this document presents the InhSRS.

Out of 136 total regulated contaminants, the inhalation exposure pathway determines the soil remediation standard for 32 residential standards and 48 non-residential standards compared to the ingestion/dermal exposure pathway (impact to ground water soil remediation standards are determined on a site-specific basis, therefore a similar comparison cannot be made). These contaminants and their respective standards are listed in Appendix B of this document.

B. Inhalation Exposure Pathway Alternative Remediation Standards

The Brownfield and Contaminated Site Remediation Act (N.J.S.A. 58:10B-1 et seq.) requires the New Jersey Department of Environmental Protection (Department) to consider site-specific factors in determining alternative remediation standards (ARS). These site-specific factors may vary from those used by the Department in the development of the adopted soil remediation standards pursuant to this section. ARSs for the inhalation exposure pathway are to be developed pursuant to N.J.A.C. 7:26D-7.

In addition, the Department has developed a spreadsheet calculator that will allow the input of site-specific conditions that will calculate an appropriate ARS. This Inhalation Exposure Pathway Alternative Remediation Standard Calculator may be found at http://www.nj.gov/dep/srp/guidance/rs. Instructions for using this spreadsheet calculator are found in Appendix J of this document.

The Department will also review other proposed approaches incorporating different models, assumptions, and information on a case by case basis. If the Department approves of their use, these may then be used to develop an acceptable ARS. However, the Department reserves the right to unilaterally determine the acceptability of these proposals.

Be advised that the Department will continue to evaluate other factors for potential use in the ARS process. The Department will also monitor those variables it currently allows to be used to develop ARS and will, if appropriate, preclude their future use.

An acceptable ARS will effectively function as the InhSRS that it replaces for that particular site. Specifically, such an ARS would be used in determining whether an area is contaminated. The ARS would be used in the compliance process just as an InhSRS would be.

The methodologies for calculating an actual inhalation exposure pathway ARS are described below in Appendix I. If the Inhalation Exposure Pathway Alternative Remediation Standard Calculator is used to derive a proposed ARS, it is required that a screenshot of the output be submitted to assist the Departmental review of the result (see Section III for additional information regarding submittal requirements).

C. Compliance

Compliance is defined to be the process whereby the analytical data from a site are compared against the appropriate soil remediation standards and a determination made whether those standards have been exceeded. Appropriate InhSRS are either the promulgated standard or an ARS developed specifically for the site. Compliance with the InhSRS does not preclude the need to evaluate compliance with the ingestion/dermal exposure pathway and the impact to ground water pathway.

Specific to the inhalation exposure pathway, compliance shall be determined by compliance averaging. The compliance averaging process is described starting in Section II.

D. Preliminary Assessment/Site Investigation

If an appropriate InhSRS is exceeded at any sampled location during the preliminary assessment/site investigation stage (PA/SI), complete horizontal and vertical delineation as defined by the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, is required.

Compliance with the InhSRS during the PA/SI is determined on a single-point ("bright line") basis. Compliance averaging is not appropriate until the remedial investigation is completed.

If the person responsible for conducting the remediation chooses, contamination detected during the PA/SI can be remediated using single-point compliance. If this option is chosen, post-remedial action samples will be required to demonstrate compliance with the applicable InhSRS.

E. Remedial Investigation

As part of the remedial investigation (RI), complete horizontal and vertical delineation shall be accomplished prior to evaluating compliance with the inhalation exposure pathway. It is critical that an appropriate sampling program pursuant to the Technical Requirements for Site Remediation be conducted. Pursuant to N.J.A.C. 7:26E-3.4(a), sampling shall be biased towards the areas of contamination, and shall not include excessive sampling of uncontaminated areas. For the purposes of this document, "excessive sampling" is considered as more than the minimum needed to complete the delineation as defined by N.J.A.C. 7:26E.

Once delineation is completed, it is necessary to determine compliance with the most restrictive standard to ascertain whether a remedial action (RA) is required. Compliance shall be determined by the methods described in Section II, below. Alternatively, the person responsible for conducting the remediation may choose to determine compliance on a single-point basis provided that a remedial action is undertaken, in order to preclude the need to apply the methods described in Section II.

F. Remedial Action

No further remediation will be required at a site based on the inhalation exposure pathway if the compliance evaluation indicates that there are no exceedances of the appropriate InhSRS. This does not preclude the need for additional remediation based on the ingestion/dermal exposure pathway and the impact to ground water pathway. For example, if compliance averaging indicates no need for remediation based on the inhalation exposure pathway, but exceedances exist for an applicable standard for at least one of the other pathways, then remediation still needs to be evaluated under those pathways. If the compliance evaluation indicates that there are

exceedances of the appropriate InhSRS, then remedial actions must be considered for the area under evaluation pursuant to N.J.A.C. 7:26E-5.

After the remedial action is completed, if compliance with the most stringent standard is not achieved, at a minimum, an institutional control will be required. Also, institutional controls are required for certain ARS, regardless of the remedial action performed. See Appendix I for additional information.

II. Compliance Process

For the inhalation exposure pathway, the compliance process after the PA/SI will be typically based on averaging, rather than single-point compliance. The justification for doing so is the recognition that what a person inhales is not derived from a single location, but is rather an integration of many onsite upwind locations. The models used to develop the InhSRS are based on this concept as well (see the Inhalation Exposure Pathway Basis and Background document for additional information).

A. Determining contaminants of concern

The first step in determining compliance for the inhalation exposure pathway is to determine which contaminants are above levels of regulatory concern. Table 1A (residential standards) and Table 1B (non-residential standards) of N.J.A.C. 7:26D shall be used to perform this evaluation. Once the contaminants of potential regulatory concern are determined, those standards that are based on the inhalation exposure pathway need to be addressed for compliance using this guidance document.

The most common contaminants encountered at Site Remediation Program (SRP) sites at concentrations requiring remediation for which the inhalation exposure pathway determines the soil remediation standard are:

Benzene
Carbon tetrachloride

Chloroform
1,1-DCA
1,2-DCA
1,1-DCE
Naphthalene
PCE
TCE
Vinyl Chloride

If the contaminant is not of regulatory concern using the inhalation exposure pathway compliance methodology, the person responsible for conducting the remediation is still required to evaluate the contaminant for compliance with the ingestion/dermal exposure pathway and the impact to ground water pathway. It is important to note that single-point compliance is the compliance mechanism for both the ingestion/dermal exposure pathway and the impact to ground water pathway. Therefore, any single exceedance of the applicable standard shall require remedial action.

If there are exceedances of either of these pathways, remedial actions and/or institutional controls will be required. For example, the most restrictive soil remediation standard for benzene is the residential InhSRS of 2 mg/kg; the most restrictive ingestion/dermal soil remediation standard for benzene is the residential value of 3 mg/kg. If there are exceedances of the 2 mg/kg InhSRS, even if the compliance evaluation indicated that the inhalation exposure pathway was not of concern, it is likely that there will be exceedances of the 3 mg/kg ingestion/dermal exposure pathway standard that will need to be addressed.

Furthermore, for situations in which the most restrictive soil remediation standard is established by either the ingestion/dermal exposure pathway or the impact to ground water pathway, the person responsible for conducting the remediation shall ensure that the implemented remedial action must also be protective of the inhalation exposure pathway. This also applies to ARSs established for those pathways.

B. Functional areas

Compliance for the InhSRS employs a fixed area approach ("functional area"). This approach will be applicable to both the volatile and particulate contaminant standards. The fixed area approach divides the site into "functional areas" of fixed size which correspond to the areas of typical residential and non-residential sites. The functional areas are only required to evaluate contaminated areas of the site. The purpose of the functional area is to determine the samples to be included in the compliance averaging process. For example, if the site is five acres in size, but contamination is limited to only two acres, only this two acre portion of the site requires evaluation. To determine whether to use the residential or non-residential functional area, land use should be taken into account. It is then determined whether there is an exceedance of the remediation goal within each individual functional area.

1. Size of functional area

The functional area for residential exposure scenarios will be the default residential lot size of 0.5 acre. In the case of the non-residential exposure scenarios, the functional area will be two (2) acres, the default non-residential site lot size.

The size of the functional area can be increased up to 50% for the last functional area evaluated for a site:

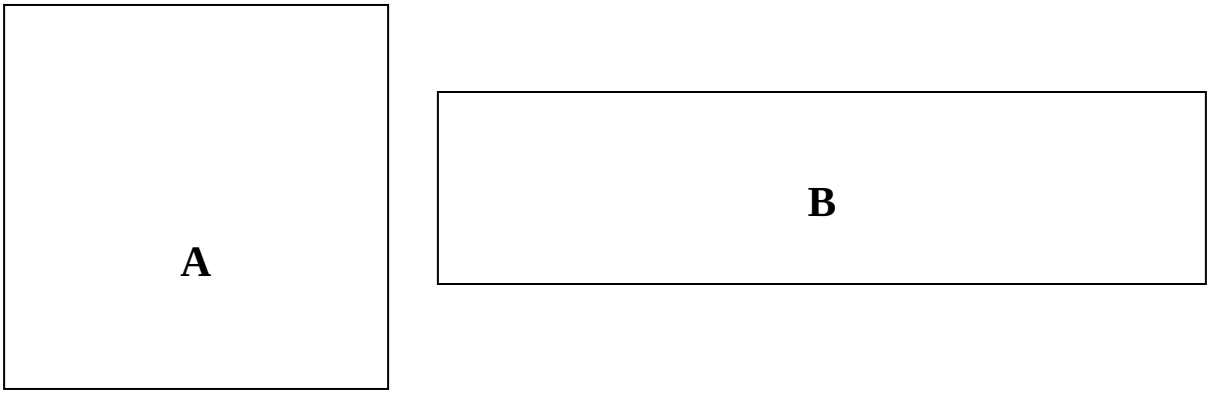
- Residential site - default = 0.5 acres
  - Site size is 0.75 acres, the entire site can be evaluated as one functional area.
  - Site size is 1.2 acres, would require two functional areas, the first being 0.5 acres, the second 0.7 acres

- Non-residential site - default = 2.0 acres
  - Site size is 2.3 acres, the entire site can be evaluated as one functional area.
  - Site size is 4.3 acres, would require two functional areas, the first being 2.0 acres, and the second 2.3 acres.

Similarly, if the site size is less than 0.5 acres for a residential site or less than 2 acres for a non-residential site, the default functional area is applied, and the applicable residential or non-residential InhSRS applied.

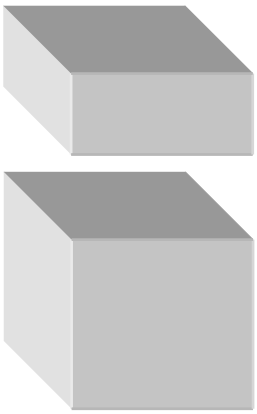
2. Shape of functional area

The preferential shape of the functional area shall be square (Figure A) but can vary somewhat based on site configuration and contamination distribution. However, it is preferred that the length of the functional area be kept to no more than four times the width (Figure B).



3. Vertical definition of functional area

In all cases, there is a surface zone of 0 to 2 feet below ground surface (bgs) and a subsurface zone (greater than 2 feet bgs) associated with the site being evaluated. It should be noted that the surface zone will encompass both surface samples (0.0 to 0.5 ft) as well as any other samples taken at 2 feet of depth or less. The final vertical depth for the subsurface zone shall be determined pursuant to the delineation requirements set forth in N.J.A.C. 7:26E (Technical Requirements for Site Remediation). Note that, based on the contaminant distribution pattern in both the surface and subsurface zones, the functional areas within the subsurface vertical zone may need to be placed and evaluated distinctly from the comparable functional areas within the surface vertical zone.



Surface (0 to 2 feet bgs) vertical zone

Subsurface (greater than 2 feet bgs) vertical zone

4. Evaluation of functional area

In all cases, each individual contaminant detected in either of the two vertical zones (surface, subsurface) is evaluated by comparing the 95% upper confidence limit (UCL) of the mean (or, if necessary, the arithmetic mean value) of the selected data against the applicable standard. The data to be selected shall include those required to delineate the area of concern(s) (AOC) encompassed by the functional area. Data below regulatory concern other than those needed to delineate the AOC would not be included. Data from AOCs that are not of regulatory concern also would not be included.

The 95% UCL of the mean approach is used by the United States Environmental Protection Agency (EPA) for situations where, from a statistical perspective, there is a limited amount of data for a given area of concern or site (the arithmetic mean value is used when an insufficient number of data points exists to determine a statistically valid 95% UCL of the mean based on the statistical program being used - this is explained in Section II.D, below). All data necessary for delineation within a given functional area and vertical zone are utilized in the evaluation. As indicated previously, the placement of the initially assessed functional area shall be biased to the worst case contaminant concentrations.

Each functional area of the site may need to be evaluated separately. For instance, a 10-acre non-residential site may be evaluated using five (5) functional areas. However, if the analysis of the worst case functional area indicates no regulatory concern, the remaining functional areas do not have to be evaluated from the perspective of the inhalation exposure pathway. A similar

approach could be applied to a 1.5 acre residential site using potentially three (3) functional areas of 0.5 acre size.

The determination of the 95% UCL of the mean shall be accomplished with a program that can properly evaluate non-detect results if needed. The use of the most current version of the EPA program ProUCL (ProUCL; currently Version 4.00.02) is recommended by the Department for the evaluation.

C. ProUCL Version 4.00.02

1. Background

The EPA maintains the statistical program ProUCL. This statistical software program can be used to compute upper limits including the 95% UCL. The ProUCL software package provides several statistical methods that can be used on data sets with non-detect observations potentially having multiple detection limits (DLs). Information about the program and download directions can be found at http://www.epa.gov/nerlesd1/tsc/software.htm (for Department personnel, directions for downloading and installing the program will be provided by email). This program is available to the public at no cost to the user.

2. Instructions for use of the program

ProUCL provides an online help file that explains the program and how to use it. Basic directions for entering data and calculating the 95% UCL of the mean are outlined in Appendix D of this document.

3. Minimum number of distinct sample values and total sample points to be used in ProUCL

Based on its evaluation of the ProUCL program, the Department has identified that a minimum of three distinct sample values must be present in the data set in order for the program to function properly. In addition, because the calculated result is more robust with more samples, the Department is establishing that the minimum number of samples to be inputted into the program is seven data points. In those cases where there are two or fewer distinct sample values or six or

fewer total sample points, compliance shall be determined by calculating the average for the data set.

4. Evaluation of ProUCL results

ProUCL will identify the recommended 95% UCL of the mean for the data set under evaluation. The result is identified as the "Potential UCL to Use" on the output table. This is the 95% UCL of the mean that should be used for evaluation of the inhalation exposure pathway. An example of an output table from ProUCL is provided as Appendix E of this document.

The Department has identified two circumstances in which the "Potential UCL to Use" requires further explanation.

- If ProUCL identifies more than one potential UCL to use, the Department has determined that the lower value shall be used in the evaluation of the inhalation exposure pathway.

- If the calculated 95% UCL of the mean is greater than all values in the data set, the Department has determined that the maximum sample value in the data set shall be used for evaluation of the inhalation exposure pathway.

D. <u>Method to determine the arithmetic mean value</u>

To determine the arithmetic mean value of the data set, add up all the sample values, and divide by the total number of samples. For non-detect (ND) values, enter zero (0) as the value. The rationale for entering zero is two-fold: (a) there is a preference to not ascribe a data value where there is no evidence that such a datum exists, and (b) to be consistent with the guidance provided by the ProUCL software that one-half of the detection level (i.e., "DL/2") not be used for non-detect values. The Department is aware that the median value may be the option selected preferentially by statisticians (as opposed to the arithmetic mean value), however, the Department is using the arithmetic mean value as a measure of conservatism to avoid the allowance of hot spots to go unremediated.

E. Offsite compliance

If delineation indicates that contamination has migrated offsite at any depth, then delineation and compliance with the InhSRS shall be determined by applying the most restrictive InhSRS to the offsite contaminated area. The contaminated offsite area shall be addressed separately and the 95% UCL of the mean of the offsite area compared to the most restrictive InhSRS, irrespective of its current land use. With this exception, compliance for the inhalation exposure pathway for the offsite area shall be evaluated as outlined in Section II.B through II.D, above.

If the functional area compliance evaluation for the offsite area indicates that there are no exceedances of the most stringent InhSRS in the worst case area, then no further remediation of the offsite contamination is required for the inhalation exposure pathway. This does not preclude the need for additional remediation for the offsite area being evaluated based on the ingestion/dermal exposure pathway or the impact to ground water pathway. If the compliance evaluation for the offsite functional area indicates that there is an exceedance of the most restrictive InhSRS, a remedial action will be required; this may involve removal, treatment, or establishment of an institutional control, with or without an engineering control.

F. Non-residential particulate InhSRS

A unique aspect of the Department approach relative to the USEPA was the inclusion of a vehicular traffic component in the non-residential exposure scenario. Doing so created the unusual condition whereby the non-residential exposure scenario particulate standard was more conservative (i.e., lower) than the residential exposure scenario particulate standard. The reason for this is that the residential exposure scenario particulate standard is generated based solely by wind action, whereas the non-residential exposure scenario particulate standard is the product of both the wind and vehicular traffic. There are 39 contaminants for which this occurs; of these 39 contaminants, the InhSRS is more conservative than the ingestion/dermal exposure pathway standard for only six contaminants. Appendix C presents the contaminants for which the non-residential particulate standard is more conservative than the residential particulate standard. As seen in Appendix C, it is unlikely to encounter acenaphthylene, benzo(ghi)perylene, cobalt, manganese, or phenanthrene at concentrations in exceedance of their respective InhSRS. The non-residential InhSRS and the ingestion/dermal exposure pathway residential standard for the

sixth, cadmium, are equal (78 mg/kg). However, because the compliance mechanism for the ingestion/dermal exposure pathway is single-point compliance, the need for a remedial action would be determined by the ingestion/dermal exposure pathway.

G. Unconditional/Conditional no further action

Once the data have been evaluated by either compliance averaging (or by determining the arithmetic mean value), it is necessary to determine whether the site is in full compliance with the applicable InhSRS or whether additional remediation is required.

If the site is in full compliance with the applicable unrestricted use InhSRS, the person responsible for conducting the remediation can request unconditional no further action (NFA) for the site with no institutional or engineering controls. Again, this does not preclude the need to evaluate compliance with the ingestion/dermal exposure pathway or the impact to ground water pathway.

If the site is not in full compliance with the applicable unrestricted use InhSRS, the person responsible for conducting the remediation must either propose to perform additional remedial actions to try to achieve full compliance and an unconditional NFA, or request conditional NFA with establishment of an institutional control with or without engineering controls.

The following decision matrix is provided to assist with this process. The decision matrix is based on two presumptions: the inhalation exposure pathway is the only pathway requiring evaluation (i.e., there are no exceedances of the applicable standards for either the ingestion/dermal exposure pathway or the impact to ground water pathway), and the person responsible for conducting the remediation is not going to conduct any additional remedial actions involving removal or treatment of contaminated soils.

1. Determine whether Unconditional or Conditional NFA is the desired end point.
    a. Unconditional NFA - through compliance, determine that all contaminants are at or below the applicable unrestricted use standard. The site is no longer of regulatory concern to the Department.

b. Conditional NFA - through compliance, determine that the unrestricted use standard is not achieved. An institutional control is required, with or without engineering control(s).

2. For Conditional NFA - determine relevant contaminant(s).
   a. If the most restrictive standard is determined by the residential exposure scenario.
      i. Residential site, institutional control and engineering control are required.
      ii. Non-residential site, only an institutional control is required. If the non-residential standard is also exceeded, then an engineering control is also required.

   b. If the most restrictive standard is determined by the non-residential exposure scenario (occurs for particulates in non-residential scenario).
      i. Non-residential site, institutional control and engineering control are required.
      ii. Residential site, neither an institutional control nor an engineering control is required. However, if the residential standard is also exceeded, both an institutional control and an engineering control are required.

   c. If the relevant standard is determined by the ARS process and the ARS requires the use of an institutional control pursuant to N.J.A.C. 7:26D, then the need for this institutional control supercedes 1 and 2a and 2b, above.

      The ARS options that require an institutional control are: changes to percent vegetative cover (V) and vehicle traffic (TC; traffic count). Refer to Appendix I, below, as well as the Inhalation Exposure Pathway Basis and Background document, Section VI, for more information on the need for institutional controls for ARSs.

      To assist in determining inhalation exposure pathway ARSs for contaminants, the Department has provided an electronic spreadsheet calculator. This Inhalation Exposure Pathway Alternative Remediation Standard Calculator may be found at http://www.nj.gov/dep/srp/guidance/rs. Instructions for using this spreadsheet calculator are found in Appendix J of this document.

Another ARS option is the recreational land use scenario. This constitutes an example of using a new model to derive an ARS. As such, it must be proposed to the Department for review and potential approval.

H. Completing additional remedial actions and re-determining compliance

If the results of the compliance evaluation indicate that the inhalation exposure pathway exceeds the most restrictive standard, and therefore an institutional control (and possibly an engineering control) will be required, the person responsible for conducting the remediation can conduct additional remedial actions to remove or treat the remaining soil contamination. This can involve removing/treating some or all of the remaining soil contamination.

1. Following the remedial action, if all soil samples are at or below the most restrictive InhSRS, then no further action is required for the inhalation exposure pathway.

2. Following the remedial action, if not all soil samples are at or below the most restrictive InhSRS, then compliance shall be demonstrated by calculating a new 95% UCL of the mean or by determining the arithmetic mean value, as appropriate.

3. Samples to be used in the recalculation shall always include all values from the original SI and RI that were used as part of the original compliance calculations, and were not removed or treated as part of the remedial action. This will include both detected and ND values pursuant to Section II.B.4, above.

   In addition, for those areas where removal occurred, the contaminated sample values shall be replaced in the new calculation by either:

   a. The results of all post-excavation samples, if such samples were collected pursuant to N.J.A.C. 7:26E; or

b. If post-excavation samples were not collected pursuant to N.J.A.C 7:26E, the contaminated sample points in the excavated area may be replaced by an identical number of ND values in the compliance calculation.

For those areas where treatment occurred, the sample values from within the treated area may be replaced in the new calculation by the results of all post-treatment samples that are collected from within the treated area.

III. Submittal Requirements

A. If the Inhalation Exposure Pathway Alternative Remediation Standard Calculator is used to derive a proposed ARS, it is required that a screenshot of the output be submitted to assist the Departmental review of the result. A separate screenshot is required for each ARS proposed. The screenshot must contain all input variables that have been altered, as well as the calculated ARS values.

B. The following information shall be submitted for Department review of compliance with the inhalation exposure pathway. Please note that the electronic submittals required below are different than those required as part of N.J.A.C. 7:26E-3.13(c)3v, N.J.A.C. 7:26E-4.8(c)3, and N.J.A.C. 7:26E-6.6(b)8.

1. Tables of data used to evaluate the inhalation exposure pathway (both as hard copy and Microsoft Excel-compatible electronic spreadsheet or table). Required whether calculating 95% UCL of the mean or arithmetic mean value.

   i. Data shall include contaminant(s) of concern, sample identification, sample depth interval, vertical zone (surface or sub-surface), functional area identification (if more than one functional area involved), concentration(s), and method detection limit(s) for ND values only.

ii. The data shall be arranged by contaminant. For each contaminant, arrange the data by surface and subsurface. For each contaminant within each vertical zone, arrange by functional area.

An example of a data submission is provided in Appendix F.

2. From ProUCL 4:

   i. The input data table for each functional area, in both hard copy and electronic form, with an explanation of the data columns. This will be a file with the extension ".WST." Examples of ProUCL input data tables are given in each of the examples, below, and in Appendix G and Appendix H.

   ii. The output 95% UCL of the mean calculation summary in both hard copy and electronic form. This will be a file with the extension ".OST." If multiple 95% UCLs are recommended, the lowest (least restrictive) value shall be selected. See Appendix E for an example of the output 95% UCL of the mean calculation summary.

   iii. In order for Department staff to verify the information provided, it is essential that the file names for the WST and OST files for a given functional area are the same.

3. The following maps:

   i. Contaminant isopleth maps, to assist in determining whether the functional area(s) for each contaminant for each depth zone was properly placed.

   ii. A functional area map for each contaminant, including the sample location points and data results, for each surface and subsurface functional area. If functional areas for different contaminants completely overlap, it is not necessary to submit separate maps for each functional area.

4. Any additional data used for the calculation of the 95% UCL of the mean or the calculation of the arithmetic mean value for evaluation of the inhalation exposure pathway.

B. The above information shall be provided to the Department in the next report required to be submitted to the Department (Remedial Investigation Report (RIR), Remedial Action Progress Reports (RAPR), or Remedial Action Report (RAR)). The report shall also include a justification of the following:

1. Functional area(s) selected, including placement and shape.

2. ProUCL 95% UCL of the mean selected, if multiple values recommended.

3. Non-ProUCL value selected (if applicable - use of different statistical program, use of arithmetic mean value).

4. A conclusion regarding whether the functional area(s)/site is in compliance for the inhalation exposure pathway, or additional remediation is required.

IV. Examples

The following examples are illustrative of the concepts used in this guidance document or are from existing cases within the Site Remediation Program. These encompass varying levels of complexity for the compliance evaluation, ranging from determining the arithmetic mean value for a single contaminant in only the surface zone, to multiple contaminants in both surface and subsurface zones with differing aerial locations for the functional areas.

A. Example 1 - basic example of functional area use, use of 95 % UCL of the mean

Example 1 involves a 1.5 acre non-residential site. 10 soil samples were collected. Contamination extends to the property boundary, and delineation has been completed

horizontally and vertically. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the surface (0 to 2 feet bgs) zone. Table 1 shows the data set associated with this example. Note that Table 1 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 1 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 1	
Benzene	d_Benzene
0.33	0
1.28	1
0.42	0
0.4	0
2.33	1
1.54	1
2.11	1
0.33	0
0.877	1
1.16	0

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 1.5 acres in size. The applicable functional area is 2.0 acres; therefore the entire site will be considered the functional area.

3. **Organize the data set**

   Because only one contaminant is being evaluated, and only one vertical zone (surface), the data do not require any specific organization.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because there are more than six (6) samples, compliance will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are present in the data, the ProUCL program was run using the "With NDs option."

6. **Evaluate results**

   The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

   ProUCL calculated two potential values for the 95% UCL of the mean for benzene: 1.597 mg/kg and 1.783 mg/kg. Based on the Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose the 95% UCL of the mean for benzene of 1.597 mg/kg. Based on this calculated 95% UCL, the site is in compliance for benzene. No further action is required for this site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

B. <u>Example 2 - multiple vertical zones example</u>

Example 2 involves a 1.5 acre non-residential site. A total of 20 soil samples were collected - 10 in the surface (0 to 2 feet bgs) zone and 10 in the subsurface (greater than 2 feet bgs) zone. Delineation has been completed within the boundaries of the site horizontally and vertically. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation

standards and for which inhalation is the most restrictive pathway. Contamination is detected in both in both the surface and subsurface zones. Table 2 shows the data set associated with this example. Note that Table 2 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 2 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 2

Benzene Surface	d_Benzene Surface		Benzene Subsurface	d_Benzene Subsurface
0.33	0		3.5	1
1.28	1		16.9	1
0.42	0		1.2	1
0.4	0		0.91	1
2.33	1		10.5	1
1.54	1		9.4	1
2.11	1		8.4	1
0.33	0		1.02	1
0.877	1		0.76	1
1.16	0		21.3	1

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 1.5 acres in size. The applicable functional area is 2.0 acres; therefore the entire site will be considered the functional area. Two separate functional areas are required to evaluate the site, one for the surface zone and one for the subsurface zone.

3. **Organize the data set**

   Only one contaminant is being evaluated, but both surface and subsurface zones are being evaluated, so it is necessary to organize the data by surface and subsurface.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because there are exceedances in both the surface zone and the subsurface zone, and there are more than six (6) samples located in each zone, compliance for both zones will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are present in the surface zone data, the ProUCL program was run using the "With NDs option" for the surface zone data. Because NDs are not present in the subsurface zone data, the ProUCL program was run using the "Full option" for the subsurface zone data.

6. **Evaluate results**

   The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

   For the surface (0 to 2 feet bgs) zone, ProUCL calculated two potential values for the 95% UCL of the mean for benzene: 1.597 mg/kg and 1.783 mg/kg. Based on Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose the 95% UCL of the mean for benzene of 1.597 mg/kg. Based on this calculated 95% UCL, the surface zone at this site is in compliance for benzene. No further action is required for this site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

   For the subsurface (greater than 2 feet bgs) zone, ProUCL calculated that the 95% UCL of the mean for benzene is 11.62 mg/kg. Based on this calculated 95% UCL, both the

residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for the subsurface zone at this site, assuming no additional treatment or excavation is conducted.

C. Example 3 - multiple functional area example

Example 3 involves a 4.0 acre non-residential site. A total of 20 soil samples were collected. Delineation has been completed within the boundaries of the site horizontally and vertically. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the surface (0 to 2 feet bgs) zone. Table 3 shows the data set associated with this example. Note that Table 3 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 3 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 3

Functional Area 1			Functional Area 2	
Benzene Surface	d_Benzene Surface		Benzene Surface	d_Benzene Surface
3.5	1		0.33	0
16.9	1		1.28	1
1.2	1		0.42	0
0.91	1		0.4	0
10.5	1		2.33	1
9.4	1		1.54	1
8.4	1		2.11	1
1.02	1		0.33	0
0.76	1		0.877	1
21.3	1		1.16	0

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 4.0 acres in size. The applicable functional area is 2.0 acres; therefore two separate functional areas are required to evaluate the site, each 2.0 acres in size.

3. **Organize the data set**

   Only one contaminant is being evaluated, however, two functional areas are required. Therefore, the data are organized by functional area, with the functional areas located such that the worst-case contamination is contained within the first functional area (Functional Area 1). If the calculated 95% UCL of the mean of Functional Area 1 exceeds either the residential or non-residential standard for benzene, then it will be necessary to evaluate the second functional area (Functional Area 2).

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because there are exceedances in both functional areas, and there are more than six (6) samples located in each functional area, compliance for functional areas will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are not present in the data for Functional Area 1, the ProUCL program was run using the "Full option" for the Functional Area 1 data. Because NDs are present in the data for Functional Area 2, the ProUCL program was run using the "With NDs option" for the Functional Area 2 data.

6. **Evaluate results**

   The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for

benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

For Functional Area 1, ProUCL calculated that the 95% UCL of the mean for benzene is 11.62 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for this portion of the site, assuming no additional treatment or excavation is conducted. Additionally, it is necessary to evaluate Functional Area 2.

For Functional Area 2, ProUCL calculated two potential values for the 95% UCL of the mean for benzene: 1.597 mg/kg and 1.783 mg/kg. Based on Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose the 95% UCL of the mean for benzene of 1.597 mg/kg. Based on this calculated 95% UCL, this portion of the site is in compliance for benzene. No further action is required for this portion of the site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

D. Example 4 - functional area fails, but compliance achieved by delineation

Example 4 involves a 3.0 acre non-residential site. A total of 10 soil samples were collected. Delineation has been completed within the boundaries of the site horizontally and vertically. Contamination is limited to only a 2.0 acre portion of the site. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the surface (0 to 2 feet bgs) zone. Table 4 shows the data set associated with this example. Note that Table 4 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 4 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 4	
Benzene	d_Benzene
3.5	1
16.9	1
1.2	1
0.91	1
10.5	1
9.4	1
8.4	1
1.02	1
0.76	1
21.3	1

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 3.0 acres in size. The applicable functional area is 2.0 acres.

3. **Organize the data set**

   Because only one contaminant is being evaluated, and only one vertical zone (surface), the data do not require any specific organization.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because there are more than six (6) samples, compliance will be evaluated by calculation of the 95% UCL.

5. Run Program or Run Analysis

Because NDs are not present in the data, the ProUCL program was run using the "Full option."

6. Evaluate results

The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

ProUCL calculated that the 95% UCL of the mean for benzene is 11.62 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for this portion of the site, assuming no additional treatment or excavation is conducted.

The portion of the site outside of the evaluated functional area has already been determined to be in compliance with the InhSRS based on the remedial investigation delineation sample results. Therefore there is no need conduct further compliance evaluation for this portion of the site.

E. Example 5 - increased functional area size example

Example 5 involves a 4.5 acre non-residential site. A total of 25 soil samples were collected. Delineation has been completed within the boundaries of the site horizontally and vertically. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the surface (0 to 2 feet bgs) zone. Table 5 shows the data set associated with this example. Note that Table 5 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 5 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 5			
Functional Area 1		Functional Area 2	
Benzene Surface FA1	d_Benzene Surface FA1	Benzene Surface FA2	d_Benzene Surface FA2
3.5	1	0.33	0
16.9	1	1.28	1
1.2	1	0.42	0
0.91	1	0.4	0
10.5	1	2.33	1
9. 4	1	1. 54	1
8.4	1	2.11	1
1.02	1	0.33	0
0.76	1	0.877	1
21.3	1	1.16	0
		1.58	0
		1.22	1
		1.37	0
		0.16	1
		0.83	0

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 4.5 acres in size. The applicable functional area is 2.0 acres; therefore two separate functional areas are required to evaluate the site. The first functional area will be 2.0 acres in size. Based on Section II.B.1, above, the second functional area will be 2.5 acres in size.

3. **Organize the data set**

   Only one contaminant is being evaluated, however, two functional areas are required. Therefore, the data are organized by functional area, with the functional areas located such that the worst-case contamination is contained within the first functional area (Functional Area 1); this functional area will be 2.0 acres in size. If the calculated 95% UCL of the mean of Functional Area 1 exceeds either the residential or non-residential standard for benzene, then it will be necessary to evaluate the second functional area (Functional Area 2); this functional area will be 2.5 acres in size.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because there are exceedances in both functional areas, and there are more than six (6) samples located in each functional area, compliance for functional areas will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are not present in the data for Functional Area 1, the ProUCL program was run using the "Full option" for the Functional Area 1 data. Because NDs are present in the data for Functional Area 2, the ProUCL program was run using the "With NDs option" for the Functional Area 2 data.

6. **Evaluate results**

   The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

   For Functional Area 1, ProUCL calculated that the 95% UCL of the mean for benzene is 11.62 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for this portion of the site, assuming no additional treatment or excavation is conducted. Additionally, it is necessary to evaluate Functional Area 2.

For Functional Area 2, ProUCL calculated two potential values for the 95% UCL of the mean for benzene: 1.156 mg/kg and 1.457 mg/kg. Based on Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose the 95% UCL of the mean for benzene of 1.156 mg/kg. Based on this calculated 95% UCL, Functional Area 2 is in compliance for benzene. No further action is required for this portion of the site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

F. Example 6 - offsite contamination, use of arithmetic mean example

Example 6 involves a 4.0 acre non-residential site, with contamination that has migrated offsite. The impacted offsite area is 0.5 acres. A total of 25 soil samples were collected, 20 onsite and five (5) offsite. Delineation has been completed horizontally and vertically onsite and offsite. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the surface (0 to 2 feet bgs) zone. Table 6 shows the data set associated with this example. Note that Table 6 has been adapted from the ProUCL format. As explained in Appendix D, the first column of Table 6 ("Benzene") contains the actual results values, and the second column ("d_Benzene") indicates whether the result value represents a detected (1) or non-detected (0) value.

Table 6

Functional Area 1		Functional Area 2		Offsite (Functional Area 3)	
Benzene Surface FA1	d_Benzene Surface FA1	Benzene Surface FA2	d_Benzene Surface FA2	Benzene Offsite	d_Benzene Offsite
3.5	1	0.33	0	0.83	0
16.9	1	1.28	1	2.97	1
1.2	1	0.42	0	1.58	1
0.91	1	0.4	0	0.16	0
10.5	1	2.33	1	2.82	1
9.4	1	1.54	1		

Table 6						
Functional Area 1			Functional Area 2		Offsite (Functional Area 3)	
8.4	1		2.11	1		
1.02	1		0.33	0		
0.76	1		0.877	1		
21.3	1		1.16	0		

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 4.0 acres in size, with contamination that has migrated offsite. The impacted offsite area is 0.5 acres.

   The applicable onsite functional area is 2.0 acres; as noted in Section II.E, above, the offsite contamination is evaluated as a stand-alone functional area. Therefore, three separate functional areas are required to evaluate the site, two onsite functional areas 2.0 acres in size, and one offsite functional area 0.5 acres in size.

3. **Organize the data set**

   Only one contaminant is being evaluated, however, three functional areas are required - two onsite and one offsite. Therefore, the data are organized by functional area, with the functional areas located such that the worst-case contamination is contained within the first onsite functional area (Functional Area 1); this functional area will be 2.0 acres in size. If the calculated 95% UCL of the mean of Functional Area 1 exceeds either the residential or non-residential standard for benzene, then it will be necessary to evaluate the second onsite functional area (Functional Area 2); this functional area will also be 2.0 acres in size. The offsite (third) functional area requires evaluation regardless of the evaluation results of the two onsite functional areas; this functional area will be 0.5 acres in size.

4. **Enter data into ProUCL or determine the arithmetic mean value**

There are exceedances in all three functional areas. Because there are more than six (6) samples in each of the two onsite functional areas (Functional Area 1, Functional Area 2), compliance for both will be evaluated by calculation of the 95% UCL. However, because the offsite functional area (Functional Area 3) contains only five (5) data points, the arithmetic mean value will be calculated.

5. **Run Program or Run Analysis**

Because NDs are not present in the data for Functional Area 1, the ProUCL program was run using the "Full option" for the Functional Area 1 data. Because NDs are present in the data for Functional Area 2, the ProUCL program was run using the "With NDs option" for the Functional Area 2 data. Because NDs are present in the data for Functional Area 3 (offsite area), based on the Department policy described in Section II.D, above, zero (0) was substituted for the ND values when calculating the arithmetic mean value.

6. **Evaluate results**

The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

For Functional Area 1, ProUCL calculated that the 95% UCL of the mean for benzene is 11.62 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for this portion of the site, assuming no additional treatment or excavation is conducted. Additionally, it is necessary to evaluate Functional Area 2.

For Functional Area 2, ProUCL calculated two potential values for the 95% UCL of the mean for benzene: 1.597 mg/kg and 1.783 mg/kg. Based on Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose

the 95% UCL of the mean for benzene of 1.597 mg/kg. Based on this calculated 95% UCL, this portion of the site is in compliance for benzene. No further action is required for this portion of the site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

For Functional Area 3 (offsite area), because there are only five values, the arithmetic mean value is calculated and used to determine compliance. The calculated arithmetic mean value for benzene is 1.47 mg/kg. Based on this arithmetic mean value, Functional Area 3 (offsite area) is in compliance for benzene. No further action is required for the contamination that has migrated offsite relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

G. Example 7 - existing case, gasoline service station

Example 7 involves a non-residential site (operating gasoline service station) with volatile organic soil contamination. The site is approximately 0.28 acres (12,000 square feet) in size and all contamination has been completely delineated to the most restrictive standard both horizontally and vertically. Benzene is the only contaminant exceeding its inhalation exposure pathway soil remediation standards and for which inhalation is the most restrictive pathway. Contamination is restricted to the subsurface (greater than 2 feet bgs) zone.

Table 7

Benzene Subsurface	d_Benzene Subsurface		Benzene Subsurface	d_Benzene Subsurface		Benzene Subsurface	d_Benzene Subsurface
1.4	1		0.3	0		0.3	0
2.4	1		0.3	0		0.3	0
5.5	1		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0

Table 7							
Benzene Subsurface	d_Benzene Subsurface		Benzene Subsurface	d_Benzene Subsurface		Benzene Subsurface	d_Benzene Subsurface
0.3	0		0.3	0		0.3	0
0.3	0		1.15	1		0.3	0
0.3	0		0.3	0		0.3	0
2.0	1		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0		0.3	0		0.3	0
0.3	0						

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Benzene is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 0.28 acres in size. The applicable functional area is 2.0 acres; therefore the site would be considered the functional area.

3. **Organize the data set**

   Because only one contaminant is being evaluated, and only one vertical zone (subsurface), the data do not require any specific organization. See Table 7 for the data set associated with this example. Note that Table 7 has been adapted from the ProUCL format.

4. Enter data into ProUCL or determine the arithmetic mean value

Because there are more than six (6) samples, compliance will be evaluated by calculation of the 95% UCL.

5. Run Program or Run Analysis

Because NDs are present in the data, the ProUCL program was run using the "With NDs option."

6. Evaluate results

The residential InhSRS for benzene is 2 mg/kg, and the non-residential InhSRS for benzene is 5 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for benzene is 3 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for benzene is 14 mg/kg.

ProUCL calculated two potential values for the 95% UCL of the mean for benzene for the subsurface zone: 1.442 mg/kg and 2.135 mg/kg. Based on the Department policy described in Section II.C.4, above, the person responsible for conducting the remediation should choose the 95% UCL of the mean for benzene of 1.442 mg/kg. Based on this calculated 95% UCL, the site is in compliance for benzene. No further action is required for this site relative to the inhalation exposure pathway. However, because there is an exceedance of the most conservative ingestion/dermal exposure pathway standard, further compliance evaluation is needed for this pathway. Additionally, the impact to ground water pathway may still require compliance evaluation as well.

H. Example 8 - existing case, cadmium contamination example

Example 8 involves a non-residential (manufacturing) site with cadmium contamination. The site is approximately 12 acres in size and all contamination has been completely delineated onsite to the most restrictive standard both horizontally and vertically. Contamination is detected in both the surface (0 to 2 feet bgs) and subsurface (greater than 2 feet bgs) zones. The non-residential inhalation standard for Cd (78 mg/kg) is more stringent than the residential inhalation

standard (1,000 mg/kg). See Table 8 (Appendix G) for the data set for this example. Note that Table 8 has been adapted from the ProUCL format.

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   Cadmium is the only contaminant for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 12 acres in size. The applicable functional area is 2.0 acres. The surface zone contamination is restricted to an area less than two acres in size, and therefore can be addressed by one functional area. The subsurface zone contamination is dispersed over an area approximately 2.0 acres, and therefore shall be evaluated using one functional area.

3. **Organize the data set**

   Only one contaminant is being evaluated, therefore the data are organized by surface and subsurface. A total of two functional areas are required: one for the surface zone and one for the subsurface zone.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Because the surface zone contains only six (6) samples, compliance for this functional area will be determined by calculating the arithmetic mean value. Because the subsurface zone contains more than six (6) samples, compliance for this zone will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are present in the surface zone data, based on the Department policy described in Section II.D, above, zero (0) was substituted for the ND values when calculating the arithmetic mean value for the surface zone data. Because NDs are not present in the

subsurface zone data, the ProUCL program was run using the "Full option" for the subsurface zone data.

6. Evaluate results

The residential InhSRS for cadmium is 1,000 mg/kg. The non-residential InhSRS is 78 mg/kg, and is the applicable InhSRS for this evaluation. The residential ingestion/dermal exposure pathway soil remediation standard for cadmium is 78 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for cadmium is 1,100 mg/kg.

For the surface zone, because there are only six values, the arithmetic mean value is calculated and used to determine compliance. The calculated arithmetic mean value for cadmium is 693.0 mg/kg. Based on this arithmetic mean value, the non-residential InhSRS is exceeded, and therefore both an institutional and engineering control are required for the surface zone at this site, assuming no additional treatment or excavation is conducted.

For the subsurface zone, ProUCL calculated that the 95% UCL of the mean for cadmium is 2,660 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS are exceeded, and therefore both an institutional and engineering control are required for the subsurface zone at this site, assuming no additional treatment or excavation is conducted.

The residential and non-residential ingestion/dermal exposure pathway soil remediation standards are also exceeded in both the surface and subsurface zones. Therefore, both an institutional and engineering control are required. Additionally, the impact to ground water pathway may still require compliance evaluation as well.

I. Example 9 - existing case, multiple contaminants, multiple depths example

Example 9 involves a non-residential (manufacturing) site with volatile and semi-volatile soil contamination. The site is approximately 1.5 acres in size and all contamination has been completely delineated onsite to the most restrictive standard both horizontally and vertically.

Contamination is detected in both the surface (0 to 2 feet bgs) and subsurface (greater than 2 feet bgs) zones. See Table 9 (Appendix H) for the data set for this example. Note that Table 9 has been adapted from the ProUCL format.

1. **Determine contaminants for which the most restrictive standard is exceeded, and whether the standard is from the inhalation exposure pathway**

   1,4-dichlorobenzene and naphthalene are the only contaminants for which the InhSRS is the most restrictive standard for the direct contact pathway.

2. **Evaluation of the functional area**

   The site is non-residential and 1.5 acres in size. The applicable functional area is 2.0 acres; therefore the entire site will be considered the functional area.

3. **Organize the data set**

   Two contaminants are being evaluated, and both are detected in both of the vertical zones. The data are organized by contaminant, and then by surface and subsurface.

4. **Enter data into ProUCL or determine the arithmetic mean value**

   Both contaminants exceed their respective InhSRS in both the surface and subsurface zones. Because there are more than six (6) samples located in both the surface zone and subsurface zone for both 1,4-dichlorobenzene and naphthalene, compliance for both contaminants in both zones will be evaluated by calculation of the 95% UCL.

5. **Run Program or Run Analysis**

   Because NDs are present in the data for each contaminant for each functional area, the ProUCL program was run using the "With NDs option."

6. **Evaluate results**

   The residential InhSRS for 1,4-dichlorobenzene is 5 mg/kg, and the non-residential InhSRS for 1,4-dichlorobenzene is 13 mg/kg. The residential InhSRS for naphthalene is 6 mg/kg, and the non-residential InhSRS for naphthalene is 17 mg/kg. The residential

ingestion/dermal exposure pathway soil remediation standard for 1,4-dichlorobenzene is 610 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for 1,4-dichlorobenzene is 6,800 mg/kg. The residential ingestion/dermal exposure pathway soil remediation standard for naphthalene is 2,400 mg/kg, and the non-residential ingestion/dermal exposure pathway soil remediation standard for naphthalene is 25,000 mg/kg.

1,4-Dichlorobenzene

For the surface (0 to 2 feet bgs) zone, ProUCL calculated that the 95% UCL of the mean for 1,4-dichlorobenzene is 2.526 mg/kg. Based on this calculated 95% UCL, the site is in compliance for 1,4-Dichlorobenzene. No further action is required for this site relative to both the inhalation exposure and ingestion/dermal exposure pathways. However, the impact to ground water pathway may still require compliance evaluation.

For the subsurface (greater than 2 feet bgs) zone, ProUCL calculated that the 95% UCL of the mean for 1,4-dichlorobenzene is 27.74 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential InhSRS for benzene are exceeded, and therefore both an institutional and engineering control are required to address the 1,4-dichlorobenzene contamination in the subsurface zone at this site, assuming no additional treatment or excavation is conducted. There are no exceedances of either the residential or non-residential ingestion/dermal exposure pathway soil remediation standard for 1,4-dichlorobenzene, therefore no further action is required for 1,4-dichlorobenzene for the ingestion/dermal exposure pathway for the subsurface zone. However, the impact to ground water pathway may still require compliance evaluation as well.

Naphthalene

For the surface (0 to 2 feet bgs) zone, ProUCL calculated that the 95% UCL of the mean for naphthalene is 305.2 mg/kg. Based on this calculated 95% UCL, the site is not in compliance for naphthalene. Based on this calculated 95% UCL, both the residential and non-residential InhSRS for naphthalene are exceeded, and therefore both an institutional and engineering control are required to address the naphthalene contamination in the

surface zone at this site, assuming no additional treatment or excavation is conducted. Neither the residential nor non-residential ingestion/dermal exposure pathway soil remediation standard for naphthalene is exceeded, therefore no further action is required for naphthalene in the surface zone at this site for the ingestion/dermal exposure pathway. However, the impact to ground water pathway may still require compliance evaluation.

For the subsurface (greater than 2 feet bgs) zone, ProUCL calculated that the 95% UCL of the mean for naphthalene is 878.9 mg/kg. Based on this calculated 95% UCL, both the residential and non-residential for naphthalene InhSRS are exceeded, and therefore both an institutional and engineering control are required to address the naphthalene contamination in the subsurface zone at this site, assuming no additional treatment or excavation is conducted. The residential ingestion/dermal exposure pathway soil remediation standard for naphthalene is exceeded in the subsurface zone, however, the non-residential ingestion/dermal exposure pathway soil remediation standard for naphthalene is not exceeded. Therefore, an institutional control without an engineering control is required for the subsurface zone at this site for the ingestion/dermal exposure pathway. Additionally, the impact to ground water pathway may still require compliance evaluation.

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APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Acenaphthene (PAH)	83-32-9	0.2	NR[1]	A[2], B[3]	300,000	C[4], P[5]
Acenaphthylene (PAH)	208-96-8	0.2	NR	A, B	300,000	C, P
Acetone (2-Propanone)	67-64-1	0.01	NR	A, B, D[6]	NR	A, B, D
Acetophenone	98-86-2	0.2	2	NC[7], V[8]	5	NC, V
Acrolein	107-02-8	0.5	0.5	NC, V	1	NC, V
Acrylonitrile	107-13-1	0.5	0.9	C, V	3	C, V
Aldrin	309-00-2	0.002	5	C, V	14	C, V
Aluminum	7429-90-5	20	NR	B, NV[9]	NR	B, NV
Anthracene (PAH)	120-12-7	0.2	380,000	C, P	30,000	C, P
Antimony	7440-36-0	6	360,000	NC, P	23,000	NC, P
Arsenic	7440-38-2	1	980	C, P	76	C, P
Atrazine [+ (11)]	1912-24-9	0.2	NR	A, B	NR	A, B
Barium	7440-39-3	20	910,000	NC, P	59,000	NC, P
Benzaldehyde	100-52-7	0.2	NR	A, B	NR	A, B
Benzene	71-43-2	0.005	2	C, V	5	C, V
Benzidine	92-87-5	0.7	(0.004)[10]	C, V	(0.01)	C, V
Benzo(a)anthracene (1,2-Benzanthracene) (PAH)	56-55-3	0.2	38,000	C, P	3,000	C, P

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Benzo(a)pyrene (PAH)	50-32-8	0.2	3,800	C, P	300	C, P
Benzo(b)fluoranthene (3,4-Benzofluoranthene) (PAH)	205-99-2	0.2	3,8000	C, P	3,000	C, P
Benzo(ghi)perylene (PAH)	191-24-2	0.2	380,000	C, P	30,000	C, P
Benzo(k)fluoranthene (PAH)	207-08-9	0.2	38,000	C, P	3,000	C, P
Beryllium	7440-41-7	0.5	1,800	C, P	140	C, P
1,1'-Biphenyl	92-52-4	0.2	NR	A, B	NR	A, B
Bis(2-chloroethyl)ether	111-44-4	0.2	0.6	C, V	2	C, V
Bis(2-chloroisopropyl)ether	108-60-1	0.2	23	C, V	67	C, V
Bis(2-ethylhexyl) phthalate	117-81-7	0.2	NR	A, B	140,000	C, P
Bromodichloromethane (Dichlorobromomethane)	75-27-4	0.005	1	C, V	3	C, V
Bromoform	75-25-2	0.005	98	C, V	280	C, V
Bromomethane (Methyl bromide)	74-83-9	0.005	25	NC, V	59	NC, V
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	0.01	NR	A, B	NR	A, B
Butyl benzyl phthalate [+]	85-68-7	0.2	NR	A, B	NR	A, B
Cadmium	7440-43-9	0.5	1000	C, P	78	C, P
Caprolactam	105-60-2	0.2	NR	A, B	NR	A, B
Carbazole	86-74-8	0.2	740,000	C, P	58,000	C, P

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Carbon disulfide	75-15-0	0.5	NR	A, B	NR	A, B
Carbon tetrachloride	56-23-5	0.005	0.6	C, V	2	C, V
Chlordane (alpha and gamma)	57-74-9	0.002	42,000	C, P	3,300	C, P
Chlorobenzene	108-90-7	0.005	NR	A, B	NR	A, B
Chloroethane (Ethyl chloride)	75-00-3	0.005	NR	A, B	NR	A, B
Chloroform	67-66-3	0.005	0.6	C, V	2	C, V
Chloromethane (Methyl chloride)	74-87-3	0.005	4	C, V	12	C, V
2-Chlorophenol (o-Chlorophenol)	95-57-8	0.2	910	NC, V	2,200	NC, V
Chrysene (PAH)	218-01-9	0.2	380,000	C, P	30,000	C, P
Cobalt	7440-48-4	5	9,100	NC, P	590	NC, P
Copper	7440-50-8	3	NR	B	280,000	NC, P
Cyanide	57-12-5	3	NR	B, NV	NR	B, NV
4,4'-DDD	72-54-8	0.003	61,000	C, P	4,800	C, P
4,4'-DDE	72-55-9	0.003	670	C, V	3,400	C, P
4,4'-DDT	50-29-3	0.003	44,000	C, P	3,400	C, P
Dibenz(a,h)anthracene (PAH)	53-70-3	0.2	3,500	C, P	270	C, P
Dibromochloromethane (Chlorodibromomethane) [+]	124-48-1	0.005	3	C, V	8	C, V
1,2-Dibromo-3-chloropropane	96-12-8	0.005	0.08	C, V	0.2	C, V

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
1,2-Dibromoethane	106-93-4	0.005	0.1	C, V	0.3	C, V
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	0.005	NR	A, B	NR	A, B
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	0.005	NR	A, B	NR	A, B
1,4-Dichlorobenzene (p-Dichlorobenzene) [+]	106-46-7	0.005	5	C, V	13	C, V
3,3'-Dichlorobenzidine	91-94-1	0.2	3	C, V	960	C, P
Dichlorodifluoromethane	75-71-8	0.005	490	NC, V	NR	A, B
1,1-Dichloroethane	75-34-3	0.005	8	C, V	24	C, V
1,2-Dichloroethane	107-06-2	0.005	0.9	C, V	3	C, V
1,1-Dichloroethene [+]	75-35-4	0.005	61	NC, V	150	NC, V
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	0.005	230	NC, V	560	NC, V
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	0.005	300	NC, V	720	NC, V
2,4-Dichlorophenol	120-83-2	0.2	NR	A, B	NR	A, B
1,2-Dichloropropane	78-87-5	0.005	2	C, V	5	C, V
1,3-Dichloropropene (cis and trans)	542-75-6	0.005	2	C, V	7	C, V
Dieldrin	60-57-1	0.003	1	C, V	3	C, V
Diethyl phthalate	84-66-2	0.2	NR	A, B	NR	A, B, D
2,4-Dimethyl phenol	105-67-9	0.2	NR	A, B	NR	A, B

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Di-n-butyl phthalate	84-74-2	0.2	NR	A, B, D	NR	A, B, D
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	534-52-1	0.3	730,000	NC, P	47,000	NC, P
2,4-Dinitrophenol	51-28-5	0.3	NR	A, B	820,000	NC, P
2,4-Dinitrotoluene	121-14-2	0.2	6	C, V	16	C, V
2,6-Dinitrotoluene	606-20-2	0.2	2	C, V	7	C, V
2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	NE (12)	NE	NE	NE	NE
Di-n-octyl phthalate	117-84-0	0.2	NR	A, B, D	NR	A, B, D
1,2-Diphenylhydrazine	122-66-7	0.7	5	C, V	13	C, V
Endosulfan I and Endosulfan II (alpha and beta)	115-29-7	0.003	NR	A, B	NR	A, B
Endosulfan sulfate	1031-07-8	0.003	NR	A, B	NR	A, B
Endrin	72-20-8	0.003	NR	A, B	120,000	NC, P
Ethyl benzene	100-41-4	0.005	NR	A, B	NR	A, B
Fluoranthene (PAH)	206-44-0	0.2	NR	A, B	300,000	C, P
Fluorene (PAH)	86-73-7	0.2	NR	A, B	300,000	C, P
alpha-HCH (alpha-BHC)	319-84-6	0.002	0.7	C, V	2	C, V
beta-HCH (beta-BHC) +	319-85-7	0.002	8,000	C, P	620	C, P
Heptachlor	76-44-8	0.002	6	C, V	18	C, V

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Heptachlor epoxide	1024-57-3	0.002	5	C, V	13	C, V
Hexachlorobenzene	118-74-1	0.2	1	C, V	4	C, V
Hexachloro-1,3-butadiene +	87-68-3	0.2	12	C, V	35	C, V
Hexachlorocyclopentadiene	77-47-4	0.2	45	NC, V	110	NC, V
Hexachloroethane +	67-72-1	0.2	83	C, V	82,000	C, P
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	0.2	38,000	C, P	3000	C, P
Isophorone +	78-59-1	0.2	NR	A, B	NR	A, B
Lead	7439-92-1	1	44,000	NC, P	12,000	NC, P
Lindane (gamma-HCH) (gamma-BHC)	58-89-9	0.002	3	C, V	10	C, V
Manganese	7439-96-5	2	91,000	NC, P	5,900	NC, P
Mercury	7439-97-6	0.1	27	NC, V	65	NC, V
Methoxychlor	72-43-5	0.02	NR	A, B	NR	A, B
Methyl acetate	79-20-9	0.005	NR	A, B	NR	A, B
Methylene chloride (Dichloromethane)	75-09-2	0.005	34	C, V	97	C, V
2-Methylnaphthalene	91-57-6	0.17	NR	A, B	300,000	C, P
2-Methylphenol (o-Creosol) +	95-48-7	0.2	NR	A, B	NR	A, B
4-Methylphenol (p-Creosol) +	106-44-5	0.2	NR	A, B	NR	A, B
Methyl tert-butyl ether (MTBE) +	1634-04-4	0.005	110	C, V	320	C, V

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Naphthalene [+]	91-20-3	0.2	6	C, V	17	C, V
Nickel (Soluble salts)	7440-02-0	4	360,000	NC, P	23,000	NC, P
2-Nitroaniline	88-74-4	0.3	39	NC, V	23,000	NC, P
Nitrobenzene	98-95-3	0.2	160	NC, V	390	NC, V
N-Nitrosodimethylamine	62-75-9	0.7	(0.02)	C, V	(0.05)	C, V
N-Nitrosodi-n-propylamine	621-64-7	0.2	0.2	C, V	0.5	C, V
N-Nitrosodiphenylamine	86-30-6	0.2	NR	A, B	130,000	C, P
Pentachlorophenol	87-86-5	0.3	590	C, V	1,700	C, V
Phenanthrene (PAH)	85-01-8	0.2	NR	A, B	300,000	C, P
Phenol	108-95-2	0.2	NR	A, B	NR	A, B
Polychlorinated biphenyls (PCBs)	1336-36-3	0.03	20	C, V	57	C, V
Pyrene (PAH)	129-00-0	0.2	NR	A, B	300,000	C, P
Selenium	7782-49-2	4	NR	B, NV	NR	B, NV
Silver	7440-22-4	1	NR	B, NV	NR	B, NV
Styrene	100-42-5	0.005	90	C, V	260	C, V
Tertiary butyl alcohol (TBA) [+]	75-65-0	0.1	4,800	NC, V	11,000	NC, V
1,1,2,2-Tetrachloroethane [+]	79-34-5	0.005	1	C, V	3	C, V
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	0.005	2	C, V	5	C, V

APPENDIX A: Inhalation Exposure Pathway Soil Remediation Standards						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Thallium	7440-28-0	3	360,000	NC, P	23,000	NC, P
Toluene	108-88-3	0.005	NR	A, B	NR	A, B
Toxaphene	8001-35-2	0.2	70	C, V	200	C, V
1,2,4-Trichlorobenzene	120-82-1	0.005	NR	A, B	NR	A, B
1,1,1-Trichloroethane [+]	71-55-6	0.005	NR	A, B	NR	A, B
1,1,2-Trichloroethane	79-00-5	0.005	2	C, V	6	C, V
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	0.005	7	C, V	20	C, V
Trichlorofluoromethane	75-69-4	0.005	NR	A, B	NR	A, B
2,4,5-Trichlorophenol	95-95-4	0.2	NR	A, B	NR	A, B
2,4,6-Trichlorophenol	88-06-2	0.2	340	C, V	960	C, V
Vanadium	7440-62-2	5	NR	B, NV	470,000	NC, P
Vinyl chloride	75-01-4	0.005	0.7	C, V	2	C, V
Xylenes	1330-20-7	0.005	NR	A, B	NR	A, B
Zinc	7440-66-6	6	NR	B, NV	110,000	NC, P

(1) NR means the chemical is not regulated by the Department for the inhalation exposure pathway and for the specified exposure scenario. The reasons are identified in the "Notes" in the adjacent column.

(2) A means the health based soil remediation standard for a volatile compound exceeds Csat.

(3) B means that the calculated health based soil remediation standard for a compound in a particulate phase exceeds one million parts per million.

(4) C means the chemical was evaluated as a carcinogen.

(5) P means the chemical was evaluated as a particulate.

(6) D means that the calculated health based soil remediation standard for a volatile compound exceeds one million parts per million.

(7) NC means the chemical was evaluated as a noncarcinogen.

(8) V means the chemical was evaluated as a volatile.

(9) NV means the chemical is nonvolatile.

(10) Values within parentheses denote standards that defer to the PQLs.

(11) + = Compound evaluated under Department C-Carcinogen policy.

(12) NE = Mixture of 2,4-Dinitrotoluene/2,6-Dinitrotoluene not evaluated for inhalation exposure pathway. Instead, two contaminants evaluated individually.

APPENDIX B: Comparison of inhalation exposure pathway standards to ingestion/dermal exposure pathway standards

COMPARISON OF INHALATION EXPOSURE PATHWAY STANDARDS TO INGESTION/DERMAL EXPOSURE PATHWAY STANDARDS - only lists those contaminants where the InhSRS is the most conservative

	Chemical	Soil PQL	Csat	RESIDENTIAL			NON-RESIDENTIAL		
				Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?
1	Acenaphthylene	0.2	90.75				300,000		Yes
2	Acetophenone	0.2	1,387.06	2	6,100	Yes	5	68,000	Yes
3	Acrolein	0.5	32,743.98	0.5	39	Yes	1	570	Yes
4	Acrylonitrile	0.5	11,679.07	0.9	1	Yes	3	6	Yes
5	Anthracene	0.2	2.57	380,000	17,000		30,000	180,000	Yes
6	Barium	20		910,000	16,000		59,000	230,000	Yes
7	Benzene	0.005	522.36	2	3	Yes	5	14	Yes
8	Benzo(ghi)perylene	0.2	2.01	380,000		Yes	30,000		Yes
9	Beryllium	0.5		1,800	16		140	230	Yes
10	Bis(2-chloroethyl)ether	0.2	3,172.06	0.6	0.4		2	2	Yes*
11	Bis(2-chloroisopropyl)ether	0.2	1,135.81	23	2,400	Yes	67	27,000	Yes
12	Bromodichloromethane (Dichlorobromomethane)	0.005	1,827.92	1	10	Yes	3	51	Yes
13	Bromoform	0.005	1,023.50	98	81		280	400	Yes
14	Bromomethane (Methyl bromide)	0.005	3,116.81	25	110	Yes	59	1,600	Yes
15	Cadmium	0.5		1,000	78		78	1,100	Yes
16	Carbon tetrachloride	0.005	516.51	0.6	7	Yes	2	35	Yes
17	4-Chloroaniline (p-Chloroaniline)	0.2	1,513.34	26	9		74	2,700	Yes
18	Chloroform	0.005	1,987.39	0.6	780	Yes	2	11,000	Yes
19	Chloromethane (Methyl chloride)	0.005	1,105.74	4		Yes	12		Yes
20	2-Chlorophenol (o-Chlorophenol)	0.2	20,487.57	910	310		2,200	3,400	Yes

APPENDIX B: Comparison of inhalation exposure pathway standards to ingestion/dermal exposure pathway standards

COMPARISON OF INHALATION EXPOSURE PATHWAY STANDARDS TO INGESTION/DERMAL EXPOSURE PATHWAY STANDARDS - only lists those contaminants where the InhSRS is the most conservative

	Chemical	Soil PQL	Csat	RESIDENTIAL			NON-RESIDENTIAL		
				Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?
21	Cobalt	5		9,100	1,600		590	23,000	Yes
22	Dibromochloromethane (Chlorodibromomethane)	0.005	736.8	3	8	Yes	8	38	Yes
23	1,2-Dibromo-3-chloropropane	0.005	374.49	0.08	0.3	Yes	0.2	1	Yes
24	1,4-Dichlorobenzene (p-Dichlorobenzene)	0.005	103.27	5	610	Yes	13	6,800	Yes
25	Dichlorodifluoromethane	0.005	548.28	490	16,000	Yes		230,000	
26	1,1-Dichloroethane	0.005	1,235.31	8	510	Yes	24	7,400	Yes
27	1,2-Dichloroethane	0.005	1,643.89	0.9	5	Yes	3	26	Yes
28	1,1-Dichloroethene	0.005	898.95	61	11		150	160	Yes
29	cis-1,2-Dichloroethene	0.005	855.31	230	780	Yes	560	11,000	Yes
30	trans-1,2-Dichloroethene	0.005	1,918.56	300	1,300	Yes	720	19,000	Yes
31	1,2-Dichloropropane	0.005	712.69	2	9	Yes	5	47	Yes
32	1,3-Dichloropropene (cis and trans)	0.005	929.19	2	6	Yes	7	32	Yes
33	Hexachlorocyclopentadiene	0.2	720.52	45	370	Yes	110	4,100	Yes
34	Manganese	2		91,000	11,000		5,900	160,000	Yes
35	Mercury	0.1		27	23		65	340	Yes
36	Methylene chloride (Dichloromethane)	0.005	2,437.62	34	46	Yes	97	230	Yes
37	Methyl tert-butyl ether (MTBE)	0.005	8,266.24	110	780	Yes	320	11,000	Yes
38	Naphthalene	0.2	128.83	6	2,400	Yes	17	25,000	Yes
39	Nickel (Soluble salts)	4		360,000	1,600		23,000	23,000	Yes*
40	2-Nitroaniline	0.3	87.39	39		Yes	23,000		Yes

APPENDIX B: Comparison of inhalation exposure pathway standards to ingestion/dermal exposure pathway standards

COMPARISON OF INHALATION EXPOSURE PATHWAY STANDARDS TO INGESTION/DERMAL EXPOSURE PATHWAY STANDARDS - only lists those contaminants where the InhSRS is the most conservative

	Chemical	Soil PQL	Csat	RESIDENTIAL			NON-RESIDENTIAL		
				Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation Driver?
41	Phenanthrene	0.2	58.54				300,000		Yes
42	Styrene	0.005	532.86	90	16,000	Yes	260	230,000	Yes
43	Tertiary butyl alcohol (TBA)	0.1	157,377.85	4,800	1,400		11,000	20,000	Yes
44	1,1,2,2-Tetrachloroethane	0.005	1,014.63	1	10	Yes	3	150	Yes
45	Tetrachloroethene (PCE)	0.005	110.76	2	8	Yes	5	39	Yes
46	1,1,2-Trichloroethane	0.005	1,140.45	2	31	Yes	6	440	Yes
47	Trichloroethene (TCE)	0.005	589.57	7	21	Yes	20	100	Yes
48	Vinyl chloride	0.005	893.5	0.7	2	Yes	2	8	Yes
49	Zinc	6			23,000		110,000	340,000	Yes

Yes* = Inhalation criterion and Ingestion/Dermal criterion are equal.

APPENDIX C: Non-residential InhSRS more conservative then residential InhSRS

The following table indicates those contaminants for which the non-residential InhSRS is more conservative than the residential InhSRS. Blank spaces indicate that no standards have been developed. Additionally, shaded values indicate that the InhSRS is the most conservative standard when compared to the ingestion/dermal exposure pathway soil remediation standards:

Contaminant	Residential (mg/kg)	Non-residential (mg/kg)
Acenaphthene		300,000
Acenaphthylene		300,000
Anthracene	380,000	30,000
Antimony	360,000	23,000
Arsenic	980	76
Barium	910,000	59,000
Benzo(a)anthracene (1,2-Benzanthracene)	38,000	3,000
Benzo(a)pyrene	3,800	300
Benzo(b)fluoranthene (3,4-Benzofluoranthene)	38,000	3,000
Benzo(ghi)perylene	380,000	30,000
Benzo(k)fluoranthene	38,000	3,000
Beryllium	1,800	140
Bis(2-ethylhexyl) phthalate		140,000
Cadmium	1,000	78
Carbazole	740,000	58,000
Chlordane (alpha and gamma)	42,000	3,300
Chrysene	380,000	30,000
Cobalt	9,100	590
Copper		280,000
4,4'-DDD	61,000	4,800
4,4'-DDT	44,000	3,400
Dibenz(a,h)anthracene	3,500	270
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	730,000	47,000
2,4-Dinitrophenol		820,000
Endrin		120,000
Fluoranthene		300,000
Fluorene		300,000
beta-HCH (beta-BHC)	8,000	620
Indeno(1,2,3-cd)pyrene	38,000	3,000
Lead	44,000	12,000
Manganese	91,000	5,900
2-Methylnaphthalene		300,000
Nickel (Soluble salts)	360,000	23,000

Contaminant	Residential (mg/kg)	Non-residential (mg/kg)
N-Nitrosodiphenylamine		130,000
Phenanthrene		300,000
Pyrene		300,000
Thallium	360,000	23,000
Vanadium		470,000
Zinc		110,000

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APPENDIX D: Instructions for using ProUCL version 4.00.02

1. Open ProUCL 4

2. The first step is to name the data column with a description that summarizes the data set. To name the column, left click on the gray box over the column number. This will select the column and it will change color to blue. Next, right click on the box over the column number. A new box appears with the title header name. Left click on this box and inset the data set name, then click ok.

3. If your data set includes non-detect values (ND values), name the adjacent column to the right in the same manner with "d_" or "D_" (the underscore is required) followed by exactly the same data set name. This column will differentiate between detected and ND values results and must start with the "d_" or "D_". Note that the program will not recognize that these two columns are associated if the data set names are different.

   If your data set does not include ND values, it is not necessary to include the second column.

4. Begin entering the data in the column below the name. Each row is numbered for data entry. For non-detect data enter the detection limit. This shall include data assigned the "U" laboratory qualifier ("undetected").

5. In the adjacent column under the "d_" or "D_" header name, enter "1" for a detected concentration and enter "0" for a non-detected concentration. This column should only contain the values "0" or "1".

6. When all data have been entered, left click on UCL at the top of the page. A box will appear with the titles "Full" and "With NDs". From this box, left click on "Full" for a data set with all detected concentrations or left click on "With NDs" for a data set with non-detected concentrations.

7. A new box will appear with five (5) options. Left click on option "All".

8. A "Select variables" box will appear. In this box, left click on the data set you would like to evaluate. Data sets will be located on the left side of the screen under "Variables". Move the data set(s) to be evaluated to the right hand side of the box under the heading "Selected" by left clicking on the arrows. The next step is to left click on OK after all data sets for evaluation have been moved to the right side of the screen.

9. At this point, the data set(s) will be evaluated and the results shown on the screen.

10. ProUCL evaluates all results and selects the appropriate 95% UCL of the mean at the bottom of the results set under the heading "Potential UCL to Use". This is the 95% UCL of the mean that shall be used for your data set.

APPENDIX E: Example of ProUCL Output Table

The following output table file (*.OST) was created using ProUCL v.4.00.02, with the settings "With NDs" and "All." Refer to Appendix D for an explanation of these terms.

	General UCL Statistics for Data Sets with Non-Detects		
User Selected Options			
From File	E:\Input.wst		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
X			
General Statistics			
Number of Valid Data	18	Number of Detected Data	16
Number of Distinct Detected Data	16	Number of Non-Detect Data	2
		Percent Non-Detects	11.11%
Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.0428	Minimum Detected	-3.151
Maximum Detected	287	Maximum Detected	5.659
Mean of Detected	40.54	Mean of Detected	1.601
SD of Detected	72.61	SD of Detected	2.841
Minimum Non-Detect	0.01	Minimum Non-Detect	-4.605
Maximum Non-Detect	0.01	Maximum Non-Detect	-4.605

UCL Statistics			
Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.595	Shapiro Wilk Test Statistic	0.902
5% Shapiro Wilk Critical Value	0.887	5% Shapiro Wilk Critical Value	0.887
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	36.03	Mean	0.834
SD	69.46	SD	3.479
95% DL/2 (t) UCL	64.51	95% H-Stat (DL/2) UCL	214724
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	30.65	Mean in Log Scale	0.879
SD	73.1	SD in Log Scale	3.403
95% MLE (t) UCL	60.62	Mean in Original Scale	36.04
95% MLE (Tiku) UCL	58.76	SD in Original Scale	69.46
		95% Percentile Bootstrap UCL	65.52
		95% BCA Bootstrap UCL	77.72
Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.305	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	132.9		
nu star	9.757		
A-D Test Statistic	0.535	**Nonparametric Statistics**	
5% A-D Critical Value	0.833	Kaplan-Meier (KM) Method	

K-S Test Statistic	0.833	Mean	36.04
5% K-S Critical Value	0.232	SD	67.5
Data appear Gamma Distributed at 5% Significance Level		SE of Mean	16.43
		95% KM (t) UCL	64.62
Assuming Gamma Distribution		95% KM (z) UCL	63.07
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	64.52
Minimum	1E-09	95% KM (bootstrap t) UCL	115.9
Maximum	287	95% KM (BCA) UCL	65.07
Mean	36.03	95% KM (Percentile Bootstrap) UCL	65.28
Median	9.72	95% KM (Chebyshev) UCL	107.7
SD	69.46	97.5% KM (Chebyshev) UCL	138.7
k star	0.178	99% KM (Chebyshev) UCL	199.5
Theta star	202.5		
Nu star	6.407	Potential UCLs to Use	
AppChi2	1.851	95% KM (Chebyshev) UCL	107.7
95% Gamma Approximate UCL	124.7		
95% Adjusted Gamma UCL	141.9		
Note: DL/2 is not a recommended method.			

APPENDIX F: Example of data submission

Contaminant	Sample ID	Depth (ft bgs)	Vertical Zone	Functional Area	Concentration (mg/kg)	MDL (NDs only)
Cadmium	21-1	01.0-01.5	Surface	FA1Surface	10.5	
Cadmium	21-2	01.0-01.5	Surface	FA1Surface	777	
Cadmium	24A-15	01.5-02.0	Surface	FA1Surface	0.49	
Cadmium	DSB-12	01.5-02.0	Surface	FA1Surface	ND	0.4
Cadmium	DSB-13	01.5-02.0	Surface	FA1Surface	ND	0.4
Cadmium	DSB-14	01.5-02.0	Surface	FA1Surface	3,370	
Cadmium	08-17	12.5-13.0	Subsurface	FA1Subsurface	ND	0.4
Cadmium	08-29	02.5-03.0	Subsurface	FA1Subsurface	ND	0.4
Cadmium	08-29	04.5-05.0	Subsurface	FA1Subsurface	2	
Cadmium	08-29	05.5-06.0	Subsurface	FA1Subsurface	ND	0.4
Cadmium	11-12	07.0-07.5	Subsurface	FA1Subsurface	2.3	
Cadmium	11-12	07.5-08.0	Subsurface	FA1Subsurface	9.2	
Cadmium	11-12	09.0-09.5	Subsurface	FA1Subsurface	ND	0.4
Cadmium	11-15	03.5-04.0	Subsurface	FA1Subsurface	769	
Cadmium	P6-3	02.0-02.5	Subsurface	FA1Subsurface	ND	0.4
Cadmium	27-1	01.0-01.5	Surface	FA2Surface	ND	0.4
Cadmium	27-2	01.0-01.5	Surface	FA2Surface	ND	0.4
Cadmium	06-01	07.0-07.5	Subsurface	FA2Subsurface	ND	0.4
Cadmium	08-25	02.0-02.5	Subsurface	FA2Subsurface	6.91	
Cadmium	08-25	07.5-08.0	Subsurface	FA2Subsurface	ND	0.4
Cadmium	08-26	02.0-02.5	Subsurface	FA2Subsurface	0.179	
Cadmium	08-27	07.5-08.0	Subsurface	FA2Subsurface	0.06	
Cadmium	08-27	11.5-12.0	Subsurface	FA2Subsurface	ND	0.4
Cadmium	08-28	08.0-08.5	Subsurface	FA2Subsurface	ND	0.4

APPENDIX G: Data input table for Example 8

Table 8 (data input for Example 8)				
Cadmium Surface	d_Cadmium Surface		Cadmium Subsurface	d_Cadmium Subsurface
10.5	1		2.3	1
0.4	0		9.2	1
3,370	1		0.4	0
0.49	1		769	1
0.4	0		2.2	1
777	1		0.4	0
			1.8	1
			0.4	0
			0.4	0
			1.5	1
			0.4	0
			0.4	0
			0.447	1
			1.26	1
			536	1
			2,060	1
			0.4	0
			0.8	1
			256	1
			28,000	1
			883	1
			0.4	0
			1.58	1
			1,030	1
			18	1

Table 8 (data input for Example 8)				
Cadmium Surface	d_Cadmium Surface		Cadmium Subsurface	d_Cadmium Subsurface
			465	1
			525	1
			1,510	1
			4,320	1
			0.4	0
			0.307	1
			466	1
			648	1
			516	1
			11	1
			2,550	1
			0.48	1
			467	1
			0.4	0
			56	1
			19.4	1
			0.68	1
			3.8	1
			18.2	1
			43	1
			129	1
			11.6	1
			0.4	0
			0.4	0
			0.4	0
			1.9	1
			2	1

Table 8 (data input for Example 8)				
Cadmium Surface	d_Cadmium Surface		Cadmium Subsurface	d_Cadmium Subsurface
			0.4	0
			0.4	0
			0.6	1
			2.3	1
			1.1	1
			0.4	0
			34	1
			34	1
			14.3	1
			0.4	0
			5.1	1
			0.4	0
			0.81	1
			4.5	1
			3.5	1
			8.6	1
			19.8	1
			0.4	0
			1.5	1
			2.1	1
			0.4	0
			35.1	1
			65.1	1
			133	1
			0.4	0
			0.4	0
			0.4	0

Table 8 (data input for Example 8)				
Cadmium Surface	d_Cadmium Surface		Cadmium Subsurface	d_Cadmium Subsurface
			0.4	0
			0.4	0
			0.4	0
			0.4	0
			0.4	0

APPENDIX H: Data input table for Example 9

Table 9 (data input for Example 9)

1,4-Dichloro-benzene Surface	d_1,4-Dichloro-benzene Surface	Naphthalene Surface	d_Naphthalene Surface	1,4-Dichloro-benzene Subsurface	d_1,4-Dichloro-benzene Subsurface	Naphthalene Subsurface	d_Naphthalene Subsurface
1.02	0	113	1	3.5	1	73.6	1
6.25	1	68.9	1	16.9	1	112	1
8.03	1	287	1	1.2	1	0.12	1
1.03	0	0.054	1	0.91	1	0.15	1
0.778	0	0.01	0	20.2	1	96.8	1
1.6	0	0.94	1	55.7	1	2770	1
3.07	1	0.736	1	15.3	1	1.5	1
2.1	1	1550	1	1.02	1	749	1
3.48	1	512	1	0.76	1	1.62	1
4.5	1	29	1	57.5	1	2.53	1
0.33	0	0.01	0	1.7	1	0.185	1
1.28	1	0.176	1	1.15	1	1.75	1
0.42	0	41.6	1	3.4	1	6220	1
0.4	0	18.5	1	1.57	1	411	1
2.56	1	24.1	1	5.03	1	62.7	1
1.97	1	30.7	1	0.2	1	0.08	1
2.11	1	0.541	1	0.2	1	564	1
0.33	0	32.6	1	8.93	1	4.77	1
0.877	1	0.723	1	41.5	1	9.56	1
2.17	1	0.0428	1	0.709	1	1.5	1
1.15	0	1.47	1	0.12	1	336	1
1.63	1	5.81	1	11	1	234	1
1.24	1	52.1	1	0.2	0	0.04	1
3.16	1	0.115	1	0.3	0	0.03	1
2.32	1	12.3	1	2.87	1	0.159	1
1.3	1	30.4	1	3.42	1	4.5	1
0.3	0	0.189	1	5.84	1	0.753	1
0.4	0	237	1	0.4	0	270	1
1.39	1	85.9	1	0.3	0	4000	1

Table 9 (data input for Example 9)

1,4-Dichloro-benzene Surface	d_1,4-Dichloro-benzene Surface	Naphthalene Surface	d_Naphthalene Surface	1,4-Dichloro-benzene Subsurface	d_1,4-Dichloro-benzene Subsurface	Naphthalene Subsurface	d_Naphthalene Subsurface
1.15	0	0.537	0	0.4	0	120	1
0.67	1	8.6	1	0.564	1	22.7	1
0.33	0	1.8	1	0.424	1	0.34	1
2.77	1	86.9	1	3.75	0	0.295	1
1.66	1	98.2	1	1.6	0	26.5	1
1.11	1			0.067	1	3.1	1
1.31	1			0.27	0	0.226	0
1.16	0			2.5	1	1.05	1
1.77	1			0.582	1	432	1
5.27	1			1.96	1	136	1
5.92	1			12.4	1	0.45	1
				1.58	0	0.39	1
				1.22	1	10.5	1
				1.37	0	57.1	1
				0.16	1	0.745	1
				0.83	0	61.5	1
				1.55	1	0.643	1
				0.4	0	8.42	1
				0.3	0	73.5	1
				0.4	0	3.6	1
				0.19	1	31	1
				0.177	1	429	1
				1.83	1	1.84	1
				0.2	0	8.5	1
				0.4	0	0.191	0
				0.367	1	4.9	0
				0.148	1	0.272	0
				0.154	1	38.4	1
				0.28	1	1.3	1
				76.4	1	2.28	1
				3.83	1	3.69	1

Table 9 (data input for Example 9)

1,4-Dichloro-benzene Surface	d_1,4-Dichloro-benzene Surface	Naphthalene Surface	d_Naphthalene Surface	1,4-Dichloro-benzene Subsurface	d_1,4-Dichloro-benzene Subsurface	Naphthalene Subsurface	d_Naphthalene Subsurface
				0.285	1	0.136	1
				0.4	0	0.203	1
				0.318	1	1.74	1
				0.25	1	499	1
				0.46	1	1.12	1
				2.45	1	0.625	1
				11	1	0.066	1
				37.8	1	24	1
				5.61	1	208	1
				0.195	1	155	1
				3.85	1	11	1
				5.24	1	785	1
				64.5	1	42	1
				0.383	1	0.296	1
				0.12	0	0.361	1
				0.91	1	196	1
				0.843	1	13.4	1
				4.84	1	0.131	1
				1.7	1	0.023	1
				1.57	0	0.143	1
				0.93	1	0.492	1
				2	1	1.24	1
				1.85	1	0.37	1
				0.72	0	27	1
				0.533	1	238	1
				0.666	1	19.1	1
				0.164	1	166	1
				0.33	0	1560	1
				7.1	1	1.58	1
				0.81	0	1090	1
				0.796	1	4470	1

Table 9 (data input for Example 9)

1,4-Dichloro-benzene Surface	d_1,4-Dichloro-benzene Surface	Naphthalene Surface	d_Naphthalene Surface	1,4-Dichloro-benzene Subsurface	d_1,4-Dichloro-benzene Subsurface	Naphthalene Subsurface	d_Naphthalene Subsurface
				14.8	1	1.5	1
				22.3	1	0.476	0
				3.72	1	2.34	1
				4.8	1	7.13	1
				264	1		

APPENDIX I: Methodology for developing Alternative Remediation Standards for the Inhalation Exposure Pathway Soil Remediation Standards

1. Volatile Contaminants
   A. Variables which can be changed - for volatile contaminants, only a limited number of variables are allowed to be changed to accommodate site-specific conditions:

      i. Depth Range of Contamination – The EPA SSG methodology (USEPA, 1996a) used to develop remediation standards assumes an infinite depth of contamination. If the depth of contamination is known, this may be incorporated into development of alternative remediation standards. An assumption of finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a greater remediation standard. Use the following procedure:

         (1) Determine the actual depth range of contamination by sampling conducted pursuant to the Technical Requirements for Site Remediation, N.J.A.C. 7:26E-4.

         (2) Use the actual depth range of contamination in the Jury model that is included in the EMSOFT software package to derive a site-specific volatilization factor (VF) following the methodology in Appendix K of this document. The EMSOFT software package is available for download at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2862.

         (3) Substitute the derived site-specific volatilization factor into Equations 1 and 2 to calculate an alternative inhalation remediation standard.

         (4) The Department will not require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on depth range of contamination.

ii. Organic Carbon (f_{oc}) - The organic carbon content of the soil is used with a contaminant's K_{oc} value to determine the extent the contaminant is adsorbed to soil. In general, the soil remediation standard is linearly related to the organic carbon content (for example, a doubling of the organic carbon content of the soil will double the calculated remediation standard, making it greater). Use the following procedure:

(1) Collect a minimum of 3 samples from different locations at the site that are representative of each area of concern including soil type(s) and sample depth equivalent to the location of contamination. Samples may not be collected from areas with high levels of organic contamination (greater than 1,000 ppm), since they will contribute to an artificially high organic carbon content. Additional soil samples should be collected and submitted for testing to calculate a refined site-specific remediation standard if further investigation reveals a contaminated area significantly larger than the original area investigated during the earlier phases of case processing. The number of samples should be based on the size of the area of concern pursuant to the Technical Requirements for Site Remediation, N.J.A.C. 7:26E.

(2) Analyze samples for soil organic carbon content using the Lloyd Kahn method (USEPA, 1988).

(3) Use the average soil organic content as f_{oc} in the soil-water partition coefficient equation (Equation 5 of the Inhalation Exposure Pathway Basis and Background document) to develop a site-specific K_d value. If f_{oc} values at a given area of concern vary by more than an order of magnitude, they may not be averaged to calculate a site-specific K_d value. In this case, the lowest f_{oc} value must be used to determine the K_d value for the soil in the area of concern.

(4) Use the site-specific K_d value in Equation 4 of the Inhalation Exposure Pathway Basis and Background document to calculate a site-specific value for apparent diffusivity, D_A.

(5) Use the site-specific value for apparent diffusivity, D_A, in Equation 3 of the Inhalation Exposure Pathway Basis and Background document to calculate a site-specific volatilization factor, VF.

(6) Substitute the site-specific volatilization factor into Equations 1 and 2 to calculate an alternative inhalation remediation standard.

(7) The Department will not require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on soil organic carbon content.

B. Variables which cannot be changed - for volatile contaminants, the following variables can **not** be changed to develop an ARS:

i. Total Soil Porosity (n) - The Department uses 0.41 because it is the value for sandy loam soil, which is the default soil texture for New Jersey. The USEPA uses a default of 0.43 for loam soil. Site-specific porosity values are difficult to obtain in the field, and laboratory measurements of this parameter are not advised since the integrity of the soil structure is lost during sampling unless special techniques are used.

ii. Water-filled & Air-filled Soil Porosity (Volumetric soil water content) (θ_w & θ_a) – Experimentally determining site-specific air and water contents of a soil at a particular site is difficult, because of long-term and short-term variations in soil moisture. Long-term variations occur due to seasonal changes and short-term variations occur due to weather events. For this reason the SSG User's guide does not recommend using field results to adjust these parameters. Therefore, adjustment of these parameters will not be allowed without consultation with and approval by the Department. The value for air-filled porosity (θ_a) is 0.18 L_{air}/L_{soil}, and the value for water-filled porosity (θ_w) is 0.23 L_{water}/L_{soil}.

iii. Dry Soil Bulk Density (ρ_b) - Dry soil bulk densities vary over a relatively small range, from about 1.3 to 1.8 g/cc (Carsel et al., 1988). The USEPA default value of 1.5 g/cm^3 was used because it agrees with the value listed for a sandy loam soil texture. Remediation standards are only slightly affected by the value for this parameter.

iv. Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values (1996a).

v. Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).

vi. Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).

2. Particulate Contaminants

A. Variables which can be changed - for particulate contaminants, a limited number of variables are allowed to be changed to accommodate site-specific conditions:

i. Residential Scenario

(1) Vegetative Cover - For the residential exposure scenario, the default of 50% vegetative cover is employed because it represents a reasonable compromise between no cover and a totally vegetated site. This parameter can be varied to reflect a site-specific condition and an appropriate ARS subsequently calculated. Use the following procedure:

(i) Measure the actual amount of vegetative cover to determine the fraction of vegetative cover (V) on the site. An example of an acceptable vegetative cover would be areas of continuous grass where there is no bare ground.

(ii) Use the measured fraction of vegetative cover (V) in Equation 11 of the Inhalation Exposure Pathway Basis and Background document to calculate the particulate emission factor (PEF).

(iii) Use the calculated particulate emission factor (PEF) in Equation 9 or 10 of the Inhalation Exposure Pathway Basis and Background document to calculate the particulate contaminant carcinogenic (Inh_pSRS_c) or noncarcinogenic (Inh_pSRS_n) soil remediation standard for the inhalation exposure pathway, respectively.

(iv) The Department will require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on an actual amount of vegetative cover to ensure that the basis for the ARS is maintained.

ii. Non-residential Scenario

(1) Number of Vehicle Trips per Day For Non-residential Sites - A number different than 33 vehicle trips per day can be used, but must reflect the current or expected vehicle activity level at a given site, whichever is greater. For future use, the entire site is assumed to be unpaved. Use the following procedure:

(i) Determine the daily traffic count for an unpaved area (TC). The number of vehicle trips per day will be calculated by dividing the weekly total by the number of days of site operation for that week.

(ii) Use the measured daily traffic count for an unpaved area (TC) in Equation 20 of the Inhalation Exposure Pathway Basis and Background document to calculate the particulate emission rate for site traffic ($ER_{traffic}$).

(iii) Use the calculated particulate soil remediation standards ($ER_{traffic}$) in Equation 19 of the Inhalation Exposure Pathway Basis and Background

document to calculate the particulate emission factor from site activity (PEFs).

(iv) Use the calculated particulate emission factor from site activity (PEF_s) in Equation 18 of the Inhalation Exposure Pathway Basis and Background document to calculate the exposure dose calculation (DOSE).

(v) Use the calculated exposure dose calculation (DOSE) in Equation 14 or 15 of the Inhalation Exposure Pathway Basis and Background document to calculate the particulate contaminant carcinogenic (InhpSRSc) or the particulate contaminant noncarcinogenic (Inh_pSRS_n) soil remediation standard for the inhalation exposure pathway, respectively.

(vi) The Department will require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on actual vehicle activity to ensure that the basis for the ARS is maintained.

B. Variables which cannot be changed - for particulate contaminants, the following variables can **not** be changed to develop an ARS. Many of the variables are used as defaults in other Federal and State calculations. Those variables that are not calculation-defaults would require widespread technical support:

i. Residential Scenarios

(1) Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values (1996a).

(2) Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).

(3) Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).

(4) Inhalation rate - The Department default inhalation rate for an industrial scenario is 20 cubic meters per day (USEPA 1997b). This is based on the recommended inhalation rate of 2.5 m^3/hr for an outdoor worker undergoing heavy activities (USEPA 2001).

(5) Body weight - The default body weight for an industrial scenario is 70 kg (USEPA 2001).

ii. Non-residential Scenarios

(1) Surface material moisture content - The default surface material moisture content from AP-42 (USEPA 1998a) is 0.2%. It may not be adjusted because of the difficulty in determining a representative measure for the entire site.

(2) Mean vehicle weight - The default mean vehicle weight assumed is 6,886 pounds (3.1 metric tons (Mg)). This is based on the study conducted by Boile (2006). A site-specific vehicle weight value is too variable and will not be readily amendable to enforcement.

(3) Number of days with greater than 0.01 inches of precipitation - The Department used 121.3 days with 0.01 inch (0.254 mm) of measurable precipitation as its default. This value represents Newark's 30-year average of precipitation days annually. The average number of precipitation days for Atlantic City and Philadelphia are 111.5 and 115.4 days, respectively, over the same 30-year period. The number of precipitation days with 0.01 inch or greater were taken from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data Summaries (NOAA, 2002a; NOAA, 2002b; NOAA, 2002c). There is no point in changing the number of days with precipitation or other meteorological data because the Newark meteorological data produces the least

conservative soil standard. Newark meteorological data was used in all of the InhSRS to offset some of the conservatism inherent in the air dispersion modeling.

(4) Frequency of traffic - The frequency of traffic is the number of days per year that vehicular traffic occurs at a site. A value of 225 days assumes that on-site traffic occurs five days a week, 50 weeks per year. Traffic is assumed not to occur on weekends or during holidays (10 days/year), and poor weather days.

(5) Averaging time - The averaging time for contaminants that are carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 25 years. These are USEPA default values (USEPA 2001).

(6) Exposure frequency - The exposure frequency also assumes 225 days per year. A value of 225 days assumes a five-day work week for 50 weeks per year. Furthermore, exposure is assumed not to occur during holidays, vacation, and sick time, accounting for another 25 days during the year. These are USEPA default values (USEPA 2001).

(7) Exposure duration - The exposure duration for non-residential sites is 25 years. This is a USEPA default value (USEPA 2001).

(8) Inhalation rate - The Department default inhalation rate for an industrial scenario is 20 cubic meters per day (USEPA 1997b). This is based on the recommended inhalation rate of 2.5 m^3/hr for an outdoor worker undergoing heavy activities (USEPA 2001).

(9) Body weight - The default body weight for an industrial scenario is 70 kg (USEPA 2001).

3. Alternative Remediation Standards Based on Recreational Land Use

   An alternative remediation standard for both volatile and/or particulate contaminants may be based on use of the site for recreational purposes. Recreational purposes are site-specific uses that do not reflect either a residential or non-residential land use scenario. Alternative standards may be based on site-specific land use scenarios that effect the amount of time that people are likely to spend at a site that is designated for recreational use. There are two basic types of recreational land use scenarios, active and passive, that may be considered. Examples of active recreational land use are sports playing fields and playgrounds. Examples of passive recreational land use are walking or bike trails. The approval of an alternative remediation standard for recreational land use will be contingent on the use of proper institutional controls to ensure the continued use of the site for the proposed recreational use.

APPENDIX J: Instructions for use of the Inhalation Exposure Pathway Alternative Remediation Standard Calculator

The following instructions are also available within the Inhalation Exposure Pathway Alternative Remediation Standard Calculator.

The calculator runs in Microsoft Excel. Once the spreadsheet is opened:

1. Click on the "Calculate Inhalation ARS" button.

2. The Alternative Remediation Standard calculator will open.

3. Select the contaminant of concern.

4. Pursuant to N.J.A.C. 7:26D-Appendix 4, inputs that can be varied are:
   a. Fraction of organic carbon (foc) - volatile equations; residential and non-residential exposure scenarios.
   b. Percent vegetative cover (V) - particulate equations; residential exposure scenario only.
   c. Number of vehicles per day (TC) - particulate equations; non-residential exposure scenario only.
   d. Depth Range of Contamination - volatile equations; residential and non-residential exposure scenarios. Enter Depth Range of Contamination and other pertinent information into the EMSOFT software package (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2862). EMSOFT outputs a site-specific "Time Averaged Volatilization Flux" (J) value. This J value is input into the Inhalation ARS Calculator and used to calculate a new Volatilization Factor (VF). See Appendix K of this document for additional instructions for using the EMSOFT program.

5. More than one input variable can be changed at one time.

6. Other factors that are impacted by the change in input variable will be highlighted on the screen (i.e., changing the fraction of organic carbon also changes the Csat value; the Csat value on the screen will change and be highlighted).

7. Calculated values for residential (green) and non-residential (purple) exposure scenarios will appear on the right side of the screen.
   a. Values are calculated using volatile/particulate and carcinogenic/noncarcinogenic equations.
   b. The applicable alternative remediation standard for each exposure scenario is the last value given.
   c. The applicable alternative remediation standard will also state which equation yielded the value (i.e., "Particulate, Carcinogenic").

8. If the same input variables will be used to calculate alternative remediation standards for multiple contaminants, there is no need to reset the input variables for each contaminant. Simply click on the next contaminant from the list on the right side of the screen.

   The exception to this is Depth Range of Contamination: chemical-specific information is required to calculate the new VF using EMSOFT, therefore this value must be re-entered using that chemical-specific information.

9. To reset all input variables to default values, click on the "Reset Values" button.

10. To exit the calculator, click on the "Exit" button. You will return to the start/instruction screen.

APPENDIX K: Calculation of an Alternative Remediation Standard using the EMSOFT Model and a Finite Contamination Thickness

Introduction

The generic remediation guidance uses a simplified form of the model of Jury et al. (1990), which assumes an infinite depth of contamination. The full version of this model allows for a finite depth range to be specified (Jury et al., 1990). Assuming a finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a higher remediation standard. Calculation of an Alternative Remediation Standard using the Jury model is likely to be worthwhile (result in a higher criteria) if the thickness of the contaminated zone is not extensive. To calculate this site-specific standard, the EMSOFT software package is recommended. The package is available on the Internet from USEPA's National Center for Environmental Assessment (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2862). Software documentation (in PDF format) may also downloaded from the site.

Theoretical basis

For volatile organic chemicals (dimensionless Henry's law constant >> 2.5 x 10^{-5}), volatilization from the soil surface is limited only by the diffusion rate through the soil, with no restriction imposed by the stagnant air layer at the soil surface (Jury et al., 1984). If soil moisture advection is not considered, and if a chemical is assumed to be present from the soil surface to an infinite depth, the volatilization flux equation can be expressed as follows (Jury et al., 1984):

$$J = C_0 (D_A / \pi \times t)^{1/2} \quad (1)$$

where J is the volatilization flux (mg/cm^2/day) as a function of time t (days), C_0 is the concentration of contaminant at time zero on a volume basis (mg/cm3), and D_A is the soil diffusion coefficient (cm^2/day, from Equation 6 of the USEPA Soil Screening Guidance [EPA SSG] document). An average volatilization flux may be calculated by integrating Equation 1 from time 0 to time t, to give cumulative flux, and dividing by the time interval:

$$\frac{\int_0^t C_0 (D_A / \pi \times t)^{1/2}}{t} \quad (2)$$

The solution to this equation is

$$2C_0 \sqrt{D_A / \pi \times t} \quad (3)$$

If Equation 3 is normalized for concentration by dividing C_0 (which has units of mg/cm^3) by the initial concentration on a weight basis (C_S , which has units of mg/g), the equation is transformed to

$$2\rho_b \sqrt{D_A / \pi \times t} \quad (4)$$

where Equation 4 now represents the average volatilization flux per unit concentration of contaminant on a weight basis, and ρ_b is the bulk density of the soil as described in the EPA SSG document (g/cm^3). Note that Equation 4 is equivalent to the inverse of the second factor of Equation 6 in the EPA SSG document. Thus, the average volatilization flux using the Jury model can be used along with the inverse of the mean concentration at the center of a square source (g/m^2/s per kg/m^3 – see Q/C factor of Equation 6 in the EPA SSG document) to calculate the volatilization factor.

While the above derivation was carried out using a simplified form of the Jury model, the average volatilization flux from the full Jury model can be used in the same manner. The full version of the Jury model (Jury et al., 1990) considers a finite source of contaminant located in a depth range of L to $L + W$, where L is the depth of the top of the contamination, and W is the

thickness of the contamination. Advection of soil moisture, due to precipitation infiltration, may also be considered, as well as degradation of the contaminant. These additional features in the full version of the model may result in a significantly lower average volatilization flux, and in turn, a higher calculated remediation standard. The full version of the Jury model may be evaluated using the EMSOFT program, available without charge on the Internet (USEPA, 1997).

Calculation of Alternative Remediation Standard using EMSOFT

Calculating an alternative inhalation soil remediation standard for volatile organic chemicals requires three steps:

1. Calculation of the time-averaged volatilization flux of contaminant from the soil using the model of Jury et al.

2. Calculation of the Volatilization Factor (VF) from the time-averaged volatilization flux.

3. Calculation of the soil remediation criteria using the exposure assumptions assumed during calculation of the remediation standards.

Step 1: Running the Jury model (using the EMSOFT software package) to obtain the time-averaged volatilization flux.

Several types of output are available from the program. For purposes of the NJDEP remediation criteria, the time-averaged flux output is all that is necessary. The program should be run for the exposure period of interest (30 years, or 10,958 days). Chemical degradation is not allowed for these calculations. A 1 mg/kg concentration of contaminant must be used, in order to correctly calculate the volatilization factor.

1. Begin execution of the EMSOFT program by double-clicking on EMSOFT.BAT

2. A title screen comes up. Click on the OK button.

3. If you have previously saved a chemical input file (*.CHM) or a complete input scenario (*.DAT) file that you wish to use, click on the appropriate selection box and the desired file name, and then click on OK. If you will be entering new data, simply click on OK.

4. Select the time-averaged flux box by clicking on it. Then click on the Time period for averaging.... box and enter 10,958 days. For depths D1 and D2, first click on the data entry box, then enter the depth to groundwater, in cm. Then click on OK. If depth to groundwater is not known, enter a depth below the location of the contamination.

5. Enter the chemical data by clicking on each selection box and entering the appropriate values (see following table). If you wish to save this chemical data in a file for future use, click on the selection box, click on the name entry box (leave the .CHM part alone), and enter the name. Then click on OK.

Parameter	Value
Organic carbon partition coefficient (mL/g, or L/kg)	Chemical specific[a]
Henry's law constant (dimensionless)	Chemical specific[a]
Air diffusion coefficient (cm^2/day)	Chemical specific[a,b]
Aqueous diffusion coefficient (cm^2/day)	Chemical specific[a,b]
Half-life (days)	1,000,000[c]
Number of contaminant layers	1[c]

[a] Use values from Appendix E of the Inhalation Exposure Pathway Basis and Background document.

[b] Multiply the DEP values (cm^2/s) by 86,400 s/day to obtain units of cm^2/day.

[c] This parameter value may not be changed.

6. Enter the soil properties and physical constants, using the following table as guidance, then click on OK:

Parameter	Value
Fraction organic carbon	0.002[d]
Porosity (v/v, dimensionless)	0.41[e]
Water content (v/v, dimensionless)	0.23[e]
Bulk density (g/cm3)	1.5[e]
Porewater flux (cm/day)	0.08[f]
Boundary layer thickness (cm)	0.5[e]

[d] This may be adjusted using site-specific measurements (see text).

[e] This parameter value may not be changed.

[f] This parameter value may not be changed without consultation with the Department. Corresponds to New Jersey annual infiltration rate (see Appendix D of the Inhalation Exposure Pathway Basis and Background document).

7. Enter layer properties using the following table, then click on OK:

Parameter	Value
Cover thickness (cm)	Site-specific[g]
Layer thickness (cm)	Site-specific[h]
Contaminant concentration (mg/kg)	1[i]

[g] Enter the shallowest depth at which contamination is observed (cm). If contamination extends to the soil surface, enter 0.

[h] Enter the thickness, in cm, of the contaminated soil. This is the lowest depth at which contamination is observed minus the shallowest depth at which contamination is observed.

[i] This value may not be changed.

8. If you wish to save the entire input scenario and/or the output data in a file, check the appropriate box, click on the name entry box, and enter the desired name (leave the .DAT and .OUT part of the name intact). Then click on OK.

9. The program then calculates the time-averaged volatilization flux (average surface flux). Write down the value shown. Then click on OK.

Step 2: Calculate the Volatilization Factor (VF)

1. Convert the time-averaged volatilization flux (mg/cm^2/day) to units of gm/m^2/sec. To do this, multiply by 10,000 cm^2/m^2, divide by 86,400 sec/day, and divide by 1,000 mg/g.

2. Divide the converted value by 10^{-6} to give the normalized volume-based flux, J (gm/m^2/sec).

3. Calculate the VF as follows:

$$VF = \frac{Q / C}{J}$$

where Q/C is either 90.4 (g/m^2/sec)/(kg/m^3) (residential sites) or 138.7 (g/m^2/sec)/(kg/m^3) (non-residential sites), and VF is the volatilization factor (m^3/kg).

Step 3: Calculate the site-specific soil remediation criteria using the above VF value

Use Equation 1 or 2 from the Inhalation Exposure Pathway Basis and Background document for this exposure pathway.

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