

GUIDANCE DOCUMENT

**USING THE COMBINED SESOIL/AT123D MODELS TO DEVELOP SITE-SPECIFIC
IMPACT TO GROUND WATER SOIL REMEDIATION STANDARDS FOR MOBILE
CONTAMINANTS**

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I. Introduction

Contaminated sites with mobile contaminants frequently contain sources of contamination both in the unsaturated soil zone and the ground water. In these cases, a Classification Exception Area (CEA) is often established to allow time for remediation or attenuation of the ground water contamination. Since the default Impact to Ground Water Soil Screening Levels (IGWSSLs) are calculated to immediately protect the ground water against any degradation above the Ground Water Remediation Standards (GWRS), they are more protective than necessary when a ground water CEA is in effect. This guidance document explains how alternative impact to ground water soil remediation standards may be developed for mobile contaminants when both the vadose zone and ground water are contaminated with a chemical of concern. Ground water concentrations are permitted to exceed the GWRS until the expiration of the CEA. The SEVIEW 7 software package (ESCI 2014) contains a combined SESOIL/AT123D model that may be used to simulate the fate of mobile contaminants that are present in both soil and ground water. The model may be used to show that existing contamination in the saturated and unsaturated zone will be attenuated prior to the expiration of the existing CEA at the site. The model must show that ground water concentrations are predicted to fall below the applicable standards at the end of the CEA time period, and that the predicted size of the ground water plume does not become larger than its currently projected extent. This prediction must be confirmed by ground water sampling before case closure.

This guidance document replaces the earlier 2008 guidance titled “Guidance for Using the SESOIL and AT123D Models to Develop Site Specific Impact to Ground Water Soil Remediation Standards”.

This option will primarily be useful for mobile contaminants (e.g. chlorinated solvents), since low mobility contaminants will not be transported out of the soil/ground water system within a reasonable period of time. Sites with coarser-grained soils in the unsaturated zone, such as sand and sandy loam soils, will also provide for more rapid contaminant transport and attenuation. Finally, attenuation is more likely to be adequate when contaminant concentrations in the unsaturated zone are relatively low (i.e. below their respective soil saturation limits). The following conditions apply to the use of this option:

- Ground water quality is currently degraded by contamination migrating from soil at the Area of Concern (AOC).
- When using this guidance, the AOC may not be capped with an impervious or low permeability cap. The SESOIL/AT123D model relies on infiltration, ground water recharge and volatilization in within the AOC order to attenuate chemicals. These processes are inhibited when a site is capped. Any cap used on site must allow natural infiltration of precipitation and volatilization of subsurface contaminant equivalent to what would occur if no cap was present. This is best accomplished by a soil cap that exhibits infiltration properties that are equal to or greater than the soil naturally present on site.

- A receptor evaluation must be conducted. Impacts identified through performance of a Receptor Evaluation must have been addressed in accordance with N.J.A.C. 7:26E-1.10 through 1.16.
- At a minimum, remediation of highly contaminated soil should be performed pursuant to the Technical Requirements for Site Remediation; specifically (1) N.J.A.C. 7:26E-1.10(b), which specifies LNAPL reporting requirements and identifies regulatory timeframes for the initiation of LNAPL recovery, LNAPL delineation, and implementation of interim remedial actions (to the extent practicable), and (2) N.J.A.C. 7:26E-5.1(e), which states that free and residual product must be treated or removed to the extent practicable, or contained when treatment or removal is not practicable. In the vadose zone, NAPL may occur when contaminant concentrations are above the Soil Saturation Limit (C_{sat}); C_{sat} values for select chemicals are found in Table 1. For contaminants that are denser than water, N.J.A.C. 7:26E-2.1(a)14i states that NAPL may be present in ground water when concentrations are greater than one percent of their water solubility.
- In accordance with N.J.A.C. 7:26C-7.9(f), ground water monitoring must demonstrate that contaminant concentrations are below the applicable standards in order to achieve site closure.
- Use of this option assumes that soil and ground water contamination has been appropriately delineated, an adequate ground water monitoring network is installed, and long-term monitoring is performed in accordance with the requirements of the site-specific remedial action permit for ground water.

In 2012, the Department established a Committee to review and update guidance for developing site-specific impact to ground water soil remediation standards. The Committee included Stakeholders and NJDEP staff. This Guidance represents the work of the Committee and it supersedes any previous Department guidance issued on this topic. The following people were on the Committee that prepared this document:

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II. General Guidelines for Running the SESOIL/AT123D model

- The SESOIL/AT123D model simulates the transport of a specified soil concentration distribution in the unsaturated soil zone to assess whether this distribution is acceptable for the IGW pathway. For this reason, the resulting IGWSRS will typically be a depth-dependent concentration distribution, rather than a single number.
- The SESOIL/AT123D model can be used in one of two ways: 1) to model an existing contaminant concentration distribution, to determine if the existing soil contamination is of concern for the IGW pathway, or 2) to model proposed contaminant concentrations that will be left behind after proposed remediation, to determine if the proposed remediation plan is acceptable. In both cases, upon determining an acceptable concentration distribution, the soil concentration on site at a particular depth interval may not exceed the modeled concentration for that particular depth interval. Refer to section III.(11) for further details.
- Contaminants need to be delineated (vertically and horizontally) down to the default Impact to Ground Water Soil Screening Level or site-specific standard. (An example of a site-specific standard would be one obtained from an SPLP test for the contaminant and AOC of interest). A table should be prepared that shows the concentrations measured (including nondetects and concentrations below the standard) at the various depths.
- The ground water plume must be delineated as described in the Technical Regulations at 7:26E-4.3 and the NJDEP Ground Water Technical Guidance Document for Site Investigation, Remedial Investigation and Remedial Action Performance Monitoring: (http://www.nj.gov/dep/srp/guidance/srra/gw_inv_si_ri_ra.pdf), and the Monitored Natural Attenuation Technical Guidance (http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf).
- Since the SESOIL/AT123D model run time is to be matched with the estimated time for ground water remediation to be completed, the duration of the CEA for the site needs to be estimated and will form the basis for the maximum time frame for SESOIL/AT123D modeling. If the duration of the CEA is indefinite, a 30 year time frame shall be used for modeling. The model runtime is set in the SEVIEW 7 toolbar. The number of months of the run should also be entered (in months) in the SESOIL source AT123D “Load” tab (see instructions below).
- The percent soil organic carbon content of both the vadose zone and the contaminated aquifer must be determined when using this guidance document, and the soil texture must be determined in the vadose zone. The default values for these parameters (used in calculating the default IGWSSL values as explained in the Soil Water Partition Equation guidance document), were designed to estimate predicted concentrations of a contaminant in ground water. In contrast, the purpose of this guidance document is to estimate the time required for attenuation of contaminant to occur via transport to and through the contaminated ground water plume. Therefore, the default values for soil

texture and fraction organic carbon are not appropriate for this option. Instructions for the determination of these two parameters are explained in Section III.

- The SESOIL/AT123D model cannot simulate contaminant transport in bedrock or in a confined aquifer. When multiple aquifers are contaminated from releases from the subject site or AOC, the SESOIL/AT123D model may only be used to model the uppermost unconfined aquifer beneath the zone of soil contamination.
- When running scenarios where a clay layer is present, an assessment should be made as to whether the clay layer is continuous and unfractured across the site. If field data suggest that this is the case, then an interval of saturated soil will normally exist above this layer, and will represent the water bearing zone for analysis of the Impact to Ground Water pathway. The SESOIL/AT123D model should be used to model transport down to and within this surficial aquifer. If an aquifer is not observed on top of the clay layer, it is likely to be either fractured or discontinuous, and the SESOIL/AT123D model should be used to simulate transport to the surficial water bearing zone. The clay layer will affect the overall soil texture used in the model if it comprises a significant percentage of the vertical extent of the vadose zone.

III. Setting up the SESOIL model

(1) *Adding a contamination source* - The soil contamination source (AOC) for the site should be set up on the SEVIEW 7 project map by adding a SESOIL source, dragging it to the proper location, and adjusting it to the appropriate size (x and y dimensions) in the “Source size” tab.

(2) *Climate data* - Use climate data from the weather station nearest to the site. Use the climate databases that are included with model software. A list of climate stations by county and municipality is presented in Table 2. The table includes latitude and longitude for the stations. These values may be entered into appropriate mapping applications such as Google[®] maps in order to check nearby climate station locations relative to the site location.

(3) *Chemical properties* - Table 1 lists chemical properties approved by NJDEP for use in the model, which are taken from the NJDEP 2008 Soil Remediation Standards. For metals and cyanide, the Henry’s law constant and diffusion coefficients should be set to zero, and a high value for water solubility (e.g., 100,000 mg/L) should be entered unless the actual species and solubility of the metal are known. Degradation of contaminants may not be included except for hydrocarbons (not including polycyclic aromatic hydrocarbons (PAHs)). For these hydrocarbons (not including PAHs), a one-month half-life rate (biodegradation rate constant of 0.023 days⁻¹) may be used in both the liquid and solid phases. This is based on an assessment of environmental degradation rates by Howard et al (1991). Site-specific values for the soil organic carbon – water partition coefficient (K_{oc}) and the soil-water partition coefficient (K_d) may be determined and used as discussed below.

Site-specific K_d values: As an alternative to the standard K_{oc} and K_d lookup values, a site-specific K_d value may be developed for organic chemicals and metals using the SPLP test (http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf).

As described in the SPLP guidance document, the measured K_d values can be averaged if they vary by less than an order of magnitude; otherwise, the lowest K_d value must be selected. The samples submitted for K_d determination should include the highest contaminant concentration that will be modeled with SESOIL/AT123D. A site-specific K_d value from the SPLP test cannot be used in SESOIL to model concentrations that are higher than those used in the SPLP test due to the potential for the adsorption capacity of the soil to be exceeded at higher concentrations than those tested.

Site-specific K_{oc} value for ionizable phenols: A pH-dependent site-specific K_{oc} value may be developed for these contaminants using the following procedure:

- a. Collect a minimum of 3 soil samples from locations at the site that are representative of the AOC including soil type and contaminant depth.
- b. Measure the soil pH for each sample using standard methods.
- c. Use the soil pH value for each sample to select a soil organic carbon-water partition coefficient (K_{oc}) for the contaminant from Table 3. If the measured soil pH is less than 4.9, use the K_{oc} for pH 4.9. If the measured pH is higher than 8.0, use the K_{oc} value for pH 8.0. If the K_{oc} values vary by less than an order of magnitude, they may be averaged. Otherwise, the minimum K_{oc} value should be used.

This procedure is identical to that described in the soil-water partition equation guidance document.

(4) *Soil Texture* - Determine the appropriate soil texture for the AOC. To establish soil texture, collect soil cores that are representative of the variation in texture that occurs within the AOC. Cores should be collected using a Shelby Tube, direct push sampler, or split spoon. The cores should be collected continuously (every two or four feet depending on the length of the sampling device) from the soil surface to the top of the static water level. Texture analysis should be conducted every two feet or for each distinct soil layer. Break points between the soil layers can be determined via visual inspection of core samples for changes in soil texture and/or appearance.

Gravel should be removed prior to determining soil texture by passing the sample through a 2 mm sieve. Soil aggregates should be crushed to pass through the sieve. The sand, silt and clay percentages should be calculated on the remaining material (the initial sample weight should be determined without the gravel). If the soil contains a large percentage of gravel (or other large particles or debris), water flow in the vadose zone may begin to exhibit characteristics similar to that of fractured bedrock material and ground water recharge may be underestimated. In this situation, use of the SESOIL/AT123D model may not be appropriate. The user shall use professional judgment to determine if the percentage of this material is too great for use of the model.

The soil texture used in the SESOIL model should be a median soil texture, such that the percentage of the vertical soil column height with a texture coarser than or equal to the selected soil texture is equal to the percentage of the soil column finer than or equal to the selected soil texture. For example, if 60% of the vertical soil column is sand, and 40% of the soil column is a loam soil, a sand or sandy loam soil texture may be used.

If it is desired to use more than one soil texture layer, see the next section for selection of appropriate SESOIL soil input parameters.

For additional information on methods for determination of soil texture, see Appendix A.

(5) *SESOIL-specific soil parameters* - When using a single median soil texture (as discussed above), look up the soil parameter values for intrinsic permeability, soil pore disconnectedness index and effective porosity as recommended in the SEVIEW model documentation. These tables are reproduced below. The soil bulk density has only a minor effect on model results and should be set to 1.5 g cm³. The cation exchange capacity is not used in the model and should be set to zero. The Freundlich exponent should be set to one since values for this parameter are not generally available. The soil pH is not used and therefore may be set to 7.0 for all layers. When using a single median soil texture, the same soil properties are to be used for all soil layers in the SESOIL model, with the exception of percent soil organic carbon content, which may be varied (see below).

When using more than one type of soil texture, enter the appropriate intrinsic permeability for each soil layer. SESOIL calculates a weighted mean intrinsic permeability for the entire soil column in order to calculate soil moisture movement, in effect determining a weighted mean soil texture. The following formula is used:

$$k_z = \frac{d}{\sum_{i=1}^n \frac{d_i}{k_i}}$$

where

k_z = depth-weighted average permeability (cm²)

k_i = permeability for layer i (cm²)

d = depth from soil surface to water table (cm)

d_i = thickness of layer i (cm)

The SESOIL model only accepts a single value for disconnectedness index and effective porosity. To determine these values, one of two approaches may be used. The first approach is to determine the depth-weighted intrinsic permeability that SESOIL will use in the simulation, and look up the “effective” soil texture corresponding to that permeability using the table below. That soil texture can then be used to look up the other two parameters using the other two tables. In this manner, the three soil parameters will correspond to the same effective soil texture. The

second approach is to calculate weighted mean values for the effective porosity and disconnectedness index using the formula above, substituting the disconnectedness index and effective porosity for k . Caution should be utilized when using these procedures, especially with widely disparate soil types. If the two approaches yield substantially different values for the soil parameters, professional judgment should be exercised as to the reasonableness of the modeled results, and to whether it is advisable to simulate multiple soil texture layers or to use the SESOIL/AT123D model when this condition exists at the AOC.

**Default Values For Intrinsic Permeability
(Bonazountas and Wagner, 1984)**

USDA Textural Soil Class	Permeability (cm ²)
Clay (very fine)	7.5×10^{-11}
Clay (medium fine)	2.5×10^{-10}
Clay (fine)	6.0×10^{-10}
Silty clay	5.0×10^{-11}
Silty clay loam	8.5×10^{-11}
Clay loam	6.5×10^{-10}
Loam	8.0×10^{-10}
Silt loam	3.5×10^{-10}
Silt	5.0×10^{-11}
Sandy clay	1.5×10^{-9}
Sandy clay loam	2.5×10^{-9}
Sandy loam	2.0×10^{-9}
Loamy sand	5.0×10^{-8}
Sand	1.0×10^{-8}

**Default Values for Soil Pore Disconnectedness Index
(Bonazountas and Wagner, 1984)**

USDA Textural Soil Class	Soil Pore Disconnectedness Index
Clay (very fine)	12
Clay (medium fine)	12
Clay (fine)	12
Silty clay	12
Silty clay loam	10
Clay loam	7.5
Loam	6.5
Silt loam	5.5
Silt	12
Sandy clay	6
Sandy clay loam	4
Sandy loam	4
Loamy sand	3.9
Sand	3.7

**Default Values for Effective Porosity
(Bonazountas and Wagner, 1984)**

USDA Textural Soil Class	Effective Porosity
Clay (very fine)	0.20
Clay (medium fine)	0.20
Clay (fine)	0.22
Silty clay	0.25
Silty clay loam	0.27
Clay loam	0.30
Loam	0.30
Silt loam	0.35
Silt	0.27
Sandy clay	0.24
Sandy clay loam	0.26
Sandy loam	0.25
Loamy sand	0.28
Sand	0.30

In addition to determination of the SESOIL soil parameters indirectly using the procedures described above, it is possible to determine the intrinsic permeability, disconnectedness index and the effective porosity directly through the use of appropriate laboratory tests (Appendix B), although these analyses may be costly and time-consuming.

(6) *Percent soil organic carbon* – This parameter must be measured using soil samples from the site. To determine organic carbon content, a method that uses high temperature dry combustion of the soil followed by measurement of the evolved CO₂ should be used. The Lloyd Kahn method is recommended (USEPA, 1988), but other equivalent methods may be used. See Appendix C for further information. Either a representative percent organic carbon value may be assigned to the entire soil column, or up to four separate values may be used for different depth intervals in the soil column (maximum of four depth intervals). A separate soil layer (not sublayer) must be used in the SESOIL model for each organic carbon value. The following procedure is used to determine a site-specific f_{oc} value. If multiple layers with different organic carbon values are to be used, the procedure is applied to each layer.

1. Collect a minimum of 3 soil samples from locations at the site that are representative of the AOC and the vadose zone underlying the contamination. Samples should not be collected from areas with high levels of organic contamination (greater than 1,000 ppm) because high levels of organic contaminants will contribute to artificially high carbon content.
2. Analyze the samples for soil organic carbon content using the Lloyd Kahn or equivalent method.

3. Use the average percent soil organic carbon content in the SESOIL model (percent organic carbon = fraction organic carbon x 100, or mg/kg organic carbon x 10,000). If the values vary by more than an order of magnitude, they may not be averaged. In this case, the highest percent organic carbon content is used in the model, in order to obtain a conservative estimate of the time needed for contaminant to be eliminated from the soil/ground water system. (In the Partition Equation guidance document, the lowest organic carbon value is used when the samples are not averaged, in order to obtain a conservative estimate of the concentration of contaminant in the leachate.)

Additional soil samples should be collected when soil types vary across the AOC or for larger AOCs.

When entering variable organic carbon contents, the surface layer organic carbon content is entered directly (under the “Soil” tab), and the values for subsequent layers are entered as ratios relative to the surface layer (under the “Application” tab, “Ratios” subtab) as described in the SEVIEW model documentation.

(7) *Sediment washload* - The sediment washload (surface runoff) option is not used unless adequate site-specific information is available for determination of the necessary input parameters.

(8) *Depth to water table* – When the SESOIL model is used, the vadose zone must be divided into layers and/or sublayers from the soil surface to the water table. For this reason, the depth to the water table must be known and documented. The average water table depth should be used if adequate data are available. If data are inadequate to determine the average water table depth, the depth determined during site investigation/delineation may be used.

(9) *Sublayer thickness* - When dividing the vadose zone into layers/sublayers, one foot soil sublayers are recommended to be used with the model, and should cover the entire soil column from the soil surface to the water table. Sublayer thicknesses greater than 1 foot will dilute calculated leachate concentrations in those sublayers and are generally not accepted. Sublayer thicknesses less than one foot may be used, but this will result in somewhat higher leachate concentrations reported by the model for the thinner sublayers in the vadose zone. Smaller sublayer thicknesses are sometimes desirable at the bottom of the soil column in order to correctly model the transport of low mobility contaminants near the water table. However, since this SESOIL/AT123D option will be primarily used for high mobility contaminants, thinner sublayer thicknesses are not necessary. The SESOIL model allows a maximum of 40 sublayers. If the depth to water table is greater than 40 feet, it is recommended that 40 sublayers be used, with the total depth evenly divided over the layers. When setting the number of sublayers, “instantaneous release” of contaminant should be selected on this screen, however this selection does not affect the applied contaminant loadings as explained in this technical guidance.

(10) *Source Size* – The Source Size in the model must be set equal to the size of the AOC. It is set on the project map and on the “Source Size” tab.

(11) *Soil contamination concentrations* - Prepare a table showing results from all soil borings for the AOC arranged in columns, with the SESOIL modeled concentrations in the final column, as illustrated below. The concentrations for the various borings should be the existing concentrations in the soil (if no remediation is proposed), or concentrations that are proposed to be left behind after remediation.

Soil Boring Table/SESOIL model table
Site-specific screening level = 30 mg/kg

Depth Interval (sublayer interval) (ft)	Boring #1	Boring #2	Boring #3	SESOIL model concentrations
0-1	-	-	-	74.1
1-2	-	74.1	-	74.1
2-3	-	-	-	487
3-4	487	-	-	487
4-5	-	-	-	487
5-6	-	nd	-	0
6-7	-	-	-	0
7-8	-	1.2	-	0
8-9	-	-	-	0
9-10	-	27	-	0
10-11	89.5	-	-	89.5
11-12	-	-	283	283
12-13	-	-	669	669
13-14	-	-	-	669
14-15	-	-	226	226
15-16	-	-	-	226
16-17	-	nd	183	183
17-18	342	-	-	342
18-19	-	-	-	342

- = not determined
nd = not detected

Since the SESOIL model is one-dimensional in the unsaturated zone (vertical only), the results from the various soil borings within the AOC must be compiled into one profile for modeling purposes. When entering contaminant concentrations into the SESOIL model (labeled a SESOIL source in SEVIEW 7), a value must be entered at each one foot depth interval between the soil surface and the water table. To fill in the SESOIL modeling column, the highest concentration observed from the various soil borings for a particular depth interval should be entered in the SESOIL model column. If this concentration is below the default or site-specific screening level (e.g. from SPLP results), zero may be entered in the SESOIL column. Note in the above table, that the 1.2 and 27 mg/kg results are below the screening level. Generally, there will be depth intervals for which no sample results are available from any boring (as illustrated in above table).

To fill in these values, inspect the existing concentrations in the SESOIL model column for the vertically closest soil sample results above and below the depth range of interest. The higher of the two results should be used to fill in the missing depth interval. As an example from the above, notice that 487 mg/kg is determined to be the appropriate value for the 2-3 foot depth interval. If contamination above the impact to ground water screening level does not extend to the soil surface or the water table, zeros may be entered above and below the delineated extent of contamination. Note that if delineation does not include samples above or below the boundaries of the contamination, this may result in modeled contamination extending to the water table or to the soil surface, as illustrated in the above example. One exception is for a subsurface discharge at a known depth, such as from an underground storage tank. In this case, contamination does not need to be delineated above the discharge point.

(12) *Ratios* - Except for the soil organic carbon ratio, all other soil property ratios between soil layers should be set to “1”, since layer-specific values for these parameters are not generally available. The soil organic carbon ratios may be varied as discussed above if separate organic carbon contents are determined for some or all of the soil layers.

(13) *Layer Parameters* - The contaminant load parameters POLIN, TRANS, LIG, ISRM and ASL must be set to zero, since they are not used. The VOLF parameter is set to one (volatilization allowed). Check that the factor is set to one for each soil layer, for each month, and for years 1 and 2 (year 2 values are used for the remainder of the SESOIL model run).

(14) *AT123D Load tab* - The x and y release coordinates will be already filled in according to the location and size of the AOC on the SEVIEW 7 project map. The z release coordinates should be set to zero (top of the water table). “Initial Concentration” and “Single Mass Load” are not used (should be set to zero if not greyed out). “Continuous” release is selected, and for “Continuous=0, >1 Varying”, enter the number of months of the run. **THIS SHOULD BE EQUAL TO THE DURATION OF THE CEA FOR THE SITE** and the length of the SESOIL model run. The model time step should be 730 hours (the length of the model time step). The load release rates will be filled in when the SESOIL model is run. For the “Aquifer and Chemical” tab, enter parameters as described for the AT123D model as described in Section IV below.

IV. Setting up the AT123D model

If desired, “Default AT123D Parameters” may be selected and filled in prior to completing the AT123D parameters, because several of the parameters will then already be filled in.

(1) Add one or more “AT123D” sources, representing the existing ground water contamination source. This area would be normally be under the contaminated soil zone, and also include any other areas where a contamination source is located in the ground water. Adjust the location and size of each of these sources by dragging it to the proper location on the project map, and adjusting it to the appropriate size (x, y and z dimensions) in the “Source size” tab.

The measured or estimated contaminated ground water concentrations in each of these source areas must be entered into AT123D. The simplest approach is to use a single AT123D source for the entire ground water contamination source area and use the highest observed ground water concentration as the representative value. While this initial condition is conservative, it may have only a minor effect on the concentrations observed at the end of the simulation run, which will be many years later at the end of the CEA time period and may be more influenced by the soil contamination source, rather than the initial ground water concentration. Alternatively, multiple AT123D sources may be designated in the SEVIEW model in order to allow for entry of different initial concentrations in different areas of the ground water contamination source. The contaminant concentration of each AT123D source should be set at the highest ground water concentration observed for that portion of the source (see example below). Since each AT123D source has a uniform concentration, a complex source area would take many of these sources to achieve detailed resolution of the concentration variations within a plume. Again, since the final concentrations at the end of the model run are of primary interest, how finely the initial ground water conditions are resolved is not likely to be critical, so it is suggested that only a few AT123D sources be used at most. A maximum of 15 sources may be used.

Example ground water source area in AT123D

0.5 µg/L	0.5 µg/L
1 µg/L	
0.5 µg/L	

Note: The remaining instructions in this section are used for AT123D inputs for both the SESOIL source (AT123D Aquifer and Chemical Tab) and each AT123D source that is entered. (The SESOIL source AT123D “LOAD” tab, however, should be filled in using the instructions in item (14) in the previous section.)

(2) *Hydraulic conductivity* - Determine the hydraulic conductivity of the aquifer from field measurements pursuant to the Department’s Monitored Natural Attenuation Technical Guidance Document (http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf). Submit results of slug tests and or pumping tests as an attachment to the submitted documentation.

(3) *Hydraulic gradient* - Determine the hydraulic gradient of the aquifer from field measurements pursuant to the Department’s Monitored Natural Attenuation Technical Guidance Document (http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf). Submit site map with ground water contours as an attachment to submitted documentation.

(4) *Effective porosity* – This parameter may be determined on a site-specific basis. If site specific values are not available, documentation for the SEVIEW modeling package states that a value of 0.25 is commonly used for silt and sand aquifers. This value is acceptable for use in the AT123D model. The SEVIEW documentation also lists ranges of effective porosities for

different aquifer textures that are more up-to-date than those originally reported in the AT123D documentation:

Texture	Effective Porosity
Clay	0.01-0.20 (0.10)
Silt	0.01-0.030 (0.20)
Fine Sand	0.10-0.30 (0.20)
Medium Sand	0.15-0.30 (0.22)
Coarse Sand	0.20-0.35 (0.28)
Gravel	0.10-0.35 (0.22)

The average values (in parentheses) may be used if the aquifer texture is determined and corresponds to one of those listed above.

(5) *Bulk density* – This parameter may be determined site-specifically. If site-specific values are not available, a value of 1,500 kg/m³ may be used. Alternatively, an average value based on aquifer texture (if determined) may be used. Typical values for bulk density relative to soil texture are given in Table I of the AT123D documentation (Yeh 1981):

Texture	Bulk Density (kg/m³)
Sand	1,180~1,580 (1,400)
Silt	1,290~1,800 (1,500)
Clay	1,400~2,200 (1,800)

Average values (in parentheses) from this table may be used for these aquifer materials if the default value of 1,500 kg/m³ is not satisfactory.

(6) *Dispersivities* - Longitudinal dispersivity should be estimated based on the measured plume length using the following equation (Xu and Eckstein 1995):

$$\alpha_L = 0.83(\log_{10} L)^{2.414}$$

where:

α_L = longitudinal dispersivity

L = length of contaminant plume (meters)

Transverse dispersivity should be calculated as 1/10th the longitudinal dispersivity (Gelhar et al. 1992)

Vertical dispersivity should be calculated as 1/100th the longitudinal dispersivity (Gelhar et al. 1992)

(7) *Aquifer dimensions* – If contaminated ground water extends to the bottom of the affected aquifer, aquifer thickness (depth) shall be measured in the field using appropriate methods or shall be determined using available data from the New Jersey Geological Survey or the United

States Geological Survey when appropriate (e.g., assuming aquifer thickness determinations by the NJGS or USGS are at or in close proximity to the subject site). It is recommended that the aquifer thickness be set to “infinite” in the model unless it is known that the vertical extent of the contaminated plume reaches the bottom of the aquifer. In these cases, a finite aquifer thickness should be entered but results should be checked for reasonableness by comparison with an infinite aquifer thickness run. In some cases, it may be difficult to achieve a stable model run with a finite aquifer thickness. Aquifer width should be set to “infinite”.

(8) *Eigenvalues* - Eigenvalues are normally set between 500 and 1,000, but may be set outside this range if an error is reported. In the SEVIEW software package, the default value is 500, which is the recommended value.

(9) *Organic carbon content* - Organic carbon content of the aquifer material must be measured as described above in the SESOIL instructions. The unsaturated zone value used in the SESOIL model may not be used since organic carbon content in the aquifer will generally be lower than that of the vadose zone.

(10) *Chemical Properties* – Should be set to the same values used in the SESOIL model above (Section III(3), above). Note that if the soil partition coefficient, K_d , is directly entered, the units (m^3/kg) are different than the SESOIL K_d parameter (ml/g). The SESOIL K_d must be divided by a factor of 1000 to convert to the AT123D units. Also, the SESOIL water diffusion coefficient (units of cm^2/sec) must be multiplied by a factor of 3,600/10,000 to convert it to AT123D units ($m^2/hour$). (NOTE: In the SEVIEW software package, chemical properties may be carried over from the SESOIL model. If enabled, unit conversion is done automatically when copied into the AT123D model). If a first order decay constant is to be used, it is handled differently than the instructions above for the SESOIL model. The first-order decay coefficient should be set to zero unless first-order biodegradation rate constants (not attenuation or decay constants) have been determined using ground water monitoring data and procedures such as those described by Buscheck and Alcantar (1995). Other relevant references are Newell et al (2002) and USEPA (1998). Attenuation/decay constants are calculated from plots of concentration vs. time at a source area monitoring well, and include all in-situ natural attenuation processes; they are valuable in estimating plume duration, but not biodegradation processes across the extent of the plume. Biodegradation rate constants are estimated through tracer studies or solute transport modeling (incorporating dispersion and retardation/sorption) through iterative variation of the rate constant to achieve calibration with field data within the plume.

(11) *Load parameters, AT123D Source (initial aquifer concentrations)* – An initial concentration in the ground water should be entered for each AT123D source. The “single mass load” parameter should be set to zero if it is not greyed out. Instantaneous release should be selected for each ground water source. The NSOUS variable (labeled as “Continuous=0, >1 Varying”) in the SEVIEW software should be set to zero for AT123D sources. The load release rate window is not used for AT123D ground water contamination sources.

V. Adding Points of Compliance to the Project Map.

In order to complete this task, the ground water plume must be delineated according to guidelines as described in the Technical Regulations at 7:26E-4.3, the NJDEP Ground Water Site

Investigation/Remedial Investigation Technical Guidance Document

(http://www.nj.gov/dep/srp/guidance/srra/gw_inv_si_ri_ra.pdf) and the Ground Water Monitored Natural Attenuation Guidance Document

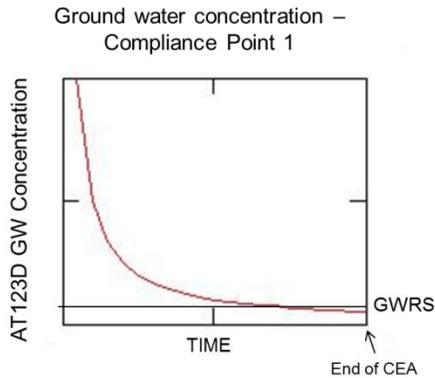
(http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf). Normally, this will have been undertaken as one of the steps necessary to obtain a Classification Exception Area (CEA) for the ground water. The dimensions of the delineated plume will be estimated by the extent of ground water contamination exceeding the GWRS. The plume must include the area directly under the AOC of the contaminated soil.

In SEVIEW 7, ground water concentrations at various points within the plume are monitored by adding “Points of Compliance” to the project map for the site. These should be added in appropriate locations within the ground water plume. For purposes of this guidance, the primary points of concern are along the centerline of the plume that will be generated by the contaminant within the source area AOC being modeled. Locations to be included are as follows:

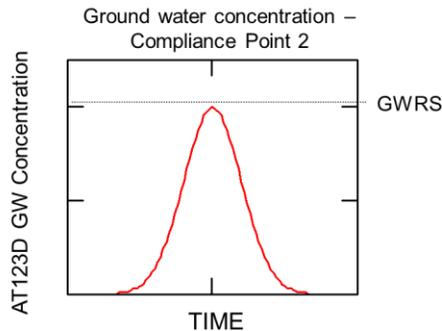
- Compliance Point 1: A location at the centerline of the plume at surface of the water table at the downgradient edge of the AOC.
- Compliance Point 2: A location at the centerline of the plume at the maximum extent of the plume at the surface of the water table.
- If the existing ground water plume is complex or large and/or has ground water sources other than that from the soil AOC, additional points of compliance may be added to monitor intermediate points and the most contaminated areas within the plume.

For all points of compliance, predicted concentrations may be averaged over a 10-foot depth interval, which corresponds to commonly used well screen intervals. To do this for points of compliance along the centerline of the plume, click on the added point of compliance to open the point of compliance window. For the Z-distance, enter 0, 2.5, 5.0, 7.5 and 10 feet. The SEVIEW software will average these five points to obtain a representative concentration for the depth interval. For points of compliance that are monitoring other areas of the plume, five Z values should be entered over a 10-foot depth interval centered around the locations and depths of concern.

The model simulation run should show that contaminant concentrations are below the ground water remediation standards at all points of compliance at the end of the model simulation period, which is normally set for the duration of the CEA. An example figure is shown for Compliance Point 1:



The model simulation run should also show that at Compliance Point 2, the predicted ground water concentrations never exceed the GWRS, as illustrated in the following figure:



If model simulation results are acceptable, the site-specific impact to ground water soil remediation standard is the vertical concentration distribution used in the SESOIL model run. If results are not acceptable, additional remediation may be required. The model may be rerun with a new proposed soil concentration distribution prior to remediation to evaluate whether the additional excavation will be adequate.

VI. SESOIL/AT123D Model Reporting Requirements

A separate report (or separate section of a larger report) should be prepared with a discussion of the model simulation. The SESOIL model table should be submitted showing the measured contaminant concentrations as a function of depth and the modeled SESOIL concentrations. A map of the delineated ground water plume should be submitted, showing how the AT 123D sources are laid out on this plume. A table of the source concentration used for each AT123D source should be provided. Supporting documentation must be provided for the depth to ground water, the vadose zone soil texture, and vadose zone organic carbon. Ground water supporting documentation must be submitted showing the determination of the site-specific hydraulic

conductivity and gradient for the site. The calculation of the longitudinal dispersivity should be included, and data supporting the saturated zone organic carbon content must be supplied. Any other parameters for which default values are not used will also need supporting documentation, such as SPLP data for a site-specific K_d value. In addition, the following model output must be submitted:

1. The four output pages from the SESOIL portion of the model run must be submitted to the Department. These pages show the appropriate model input and output information for the SESOIL source on the project map.
2. The Point of Compliance report from the SEVIEW program should be submitted for each point of compliance.
3. For each Point of Compliance report, the final concentration of the contaminant at the last time step (end of the CEA time period) should be shown. To do this, click twice on the point of compliance graph, and then click again on the graph to bring up the small EXCEL window that shows contaminant concentrations as a function of time. Scroll down to the last time point (end of the CEA), and then print the screen showing the EXCEL window and point of compliance graph together.
4. Electronic submission – The project file (*.prj) containing the simulation run should be submitted to the department.

VII. Ground Water and Soil Monitoring Requirements

A Department approved ground water monitoring program designed to monitor the predictions of the AT123D model must be implemented. If observed ground water concentrations have not decreased as expected at the end of the CEA time period, soil sampling may be required to evaluate whether or contaminated soil is still of concern at the site. Consult the Monitored Natural Attenuation Technical Guidance Document for further details.

VIII. Additional Considerations

Compliance averaging of soil concentrations is not applicable to SESOIL or AT123D modeling at this time.

Table 1

2008 New Jersey DEP Remediation Standards Chemical Properties and Soil Saturation Limits

<i>Chemical</i>	<i>CAS No.</i>	<i>Molecular Wt.</i>	<i>Water Solubility (mg/L)</i>	<i>Henry's Law Constant (atm·m³/mol), 25°C</i>	<i>Henry's Law Constant (dimensionless, 25°C)</i>	<i>K_{oc} (L/kg)</i>	<i>K_d (L/kg)</i>	<i>Water Diffusion Coefficient (cm²/sec)</i>	<i>Air Diffusion Coefficient (cm²/sec)</i>	<i>Impact to Ground Water Soil Saturation Limit (mg/kg)</i>
Acenaphthene	83-32-9	154.21	4.24	1.55E-04	6.36E-03	7.08E+03	NA	7.69E-06	4.21E-02	NA
Acenaphthylene	208-96-8	152.2	16	1.11E-04	4.51E-03	2.76E+03	NA	7.50E-06	4.40E-02	NA
Acetone (2-Propanone)	67-64-1	58.08	1.00E+06	3.88E-05	1.59E-03	5.75E-01	NA	1.14E-05	1.24E-01	155000
Acetophenone	98-86-2	120.15	6.10E+03	1.10E-05	4.51E-04	3.70E+01	NA	8.70E-06	6.00E-02	1390
Acrolein	107-02-8	56.06	2.10E+05	1.20E-04	4.92E-03	1.00E+00	NA	1.20E-05	1.05E-01	32700
Acrylonitrile	107-13-1	53.06	7.40E+04	1.00E-04	4.10E-03	2.00E+00	NA	1.30E-05	1.22E-01	11700
Aldrin	309-00-2	364.91	1.80E-01	1.70E-04	6.97E-03	2.45E+06	NA	4.86E-06	1.32E-02	NA
Aluminum (total)	7429-90-5	26.98	NA	NA	NA	NA	1.50E+03	NA	NA	NA
Anthracene	120-12-7	178.23	4.34E-02	6.50E-05	2.67E-03	2.95E+04	NA	7.74E-06	3.24E-02	NA
Antimony (total)	7440-36-0	121.75	NA	NA	NA	NA	4.50E+01	NA	NA	NA
Arsenic (total)	7440-38-2	74.92	NA	NA	NA	NA	2.60E+01	NA	NA	NA
Atrazine	1912-24-9	215.69	7.00E+01	2.96E-09	1.21E-07	3.60E+02	NA	6.70E-06	2.60E-02	NA
Barium (total)	7440-39-3	137.327	NA	NA	NA	NA	1.70E+01	NA	NA	NA
Benzaldehyde	100-52-7	106.2	3.00E+03	2.67E-05	1.09E-03	2.90E+01	NA	9.10E-06	7.30E-02	634
Benzene	71-43-2	78.11	1.75E+03	5.55E-03	2.28E-01	5.89E+01	NA	9.80E-06	8.80E-02	522
Ben-zidine	92-87-5	184.24	5.00E+02	3.90E-11	1.60E-09	4.70E+01	NA	1.50E-05	3.40E-02	NA
Benzo(a)anthracene (1,2-Benzanthracene)	56-55-3	228.29	9.40E-03	3.35E-06	1.37E-04	3.98E+05	NA	9.00E-06	5.10E-02	NA
Benzo(a)pyrene	50-32-8	252.32	1.62E-03	1.13E-06	4.63E-05	1.02E+06	NA	9.00E-06	4.30E-02	NA
Benzo(b)fluoranthene (3,4-Benzofluoranthene)	205-99-2	252.32	1.50E-03	1.11E-04	4.55E-03	1.23E+06	NA	5.56E-06	2.26E-02	NA
Benzo(ghi)perylene	191-24-2	276.34	2.60E-04	1.40E-07	5.74E-06	3.86E+06	NA	5.30E-06	2.01E-02	NA
Benzo(k)fluoranthene	207-08-9	252.32	8.00E-04	8.29E-07	3.40E-05	1.23E+06	NA	5.56E-06	2.26E-02	NA
Beryllium	7440-41-7	9.012	NA	NA	NA	NA	3.50E+01	NA	NA	NA
1,1'-Biphenyl	92-52-4	154.21	6.00E+00	3.00E-04	1.23E-02	8.56E+03	NA	8.20E-06	4.04E-02	NA
Bis(2-chloroethyl)ether	111-44-4	143.01	1.72E+04	1.80E-05	7.38E-04	1.55E+01	NA	7.53E-06	6.92E-02	3170

<i>Chemical</i>	<i>CAS No.</i>	<i>Molecular Wt.</i>	<i>Water Solubility (mg/L)</i>	<i>Henry's Law Constant (atm·m³/mol), 25°C</i>	<i>Henry's Law Constant (dimensionless, 25°C)</i>	<i>K_{oc} (L/kg)</i>	<i>K_d (L/kg)</i>	<i>Water Diffusion Coefficient (cm²/sec)</i>	<i>Air Diffusion Coefficient (cm²/sec)</i>	<i>Impact to Ground Water Soil Saturation Limit (mg/kg)</i>
Bis(2-chloroisopropyl)ether (2,2'-oxybis(1-chloropropane))	108-60-1	171.07	1.30E+03	7.40E-05	3.03E-03	3.60E+02	NA	6.40E-06	6.02E-02	1140
Bis(2-ethylhexyl)phthalate	117-81-7	390.56	3.40E-01	1.02E-07	4.18E-06	1.51E+07	NA	3.66E-06	3.51E-02	10300
Bromodichloromethane (Dichlorobromomethane)	75-27-4	163.83	6.74E+03	1.60E-03	6.56E-02	5.50E+01	NA	1.06E-05	2.98E-02	1830
Bromoform	75-25-2	252.73	3.10E+03	5.35E-04	2.19E-02	8.71E+01	NA	1.03E-05	1.49E-02	1020
Bromomethane (Methyl bromide)	74-83-9	94.94	1.52E+04	6.24E-03	2.56E-01	1.05E+01	NA	1.21E-05	7.28E-02	3120
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	72.11	2.20E+05	5.60E-05	2.30E-03	1.00E+00	NA	9.80E-06	8.08E-02	34200
Butylbenzyl phthalate	85-68-7	312.36	2.69E+00	1.26E-06	5.17E-05	5.75E+04	NA	4.83E-06	1.74E-02	310
Cadmium	7440-43-9	112.41	NA	NA	NA	NA	2.30E+01	NA	NA	NA
Caprolactam	105-60-2	113.16	3.01E+05	3.66E-09	1.50E-07	6.00E+00	NA	9.00E-06	6.50E-02	NA
Carbazole	86-74-8	167.2	7.48E+00	1.53E-08	6.27E-07	3.39E+03	NA	7.03E-06	3.90E-02	NA
Carbon disulfide	75-15-0	76.14	1.19E+03	3.03E-02	1.24E+00	4.57E+01	NA	1.00E-05	1.04E-01	468
Carbon tetrachloride	56-23-5	153.82	7.93E+02	3.04E-02	1.25E+00	1.74E+02	NA	8.80E-06	7.80E-02	517
Chlordane (alpha and gamma forms summed)	57-74-9	409.8	5.60E-02	4.86E-05	1.99E-03	1.20E+05	NA	4.37E-06	1.18E-02	NA
Chlorobenzene	108-90-7	112.56	4.72E+02	3.70E-03	1.52E-01	2.19E+02	NA	8.70E-06	7.30E-02	288
Chloroethane (Ethyl chloride)	75-00-3	64.51	5.70E+03	8.80E-03	3.61E-01	1.50E+01	NA	1.15E-05	2.71E-01	NA
Chloroform	67-66-3	119.38	7.92E+03	3.67E-03	1.50E-01	3.98E+01	NA	1.00E-05	1.04E-01	1990
Chloromethane (Methyl chloride)	74-87-3	50.49	5.30E+03	8.80E-03	3.61E-01	6.00E+00	NA	6.50E-06	1.26E-01	NA
2-Chlorophenol (o-Chlorophenol)	95-57-8	128.56	2.20E+04	3.91E-04	1.60E-02	3.98E+02	NA	9.46E-06	5.01E-02	20900
Chrysene	218-01-9	228.29	1.60E-03	9.46E-05	3.88E-03	3.98E+05	NA	6.21E-06	2.48E-02	NA
Cobalt (total)	7440-48-4	58.93	NA	NA	NA	NA	4.50E+01	NA	NA	NA
Copper (total)	7440-50-8	63.546	NA	NA	NA	NA	4.30E+02	NA	NA	NA
Cyanide	57-12-5	26	NA	NA	NA	NA	9.90E+00	NA	NA	NA
4,4'-DDD (p,p'-TDE)	72-54-8	320.04	9.00E-02	4.00E-06	1.64E-04	1.00E+06	NA	4.76E-06	1.69E-02	NA
4,4'-DDE (p,p'-DDX)	72-55-9	318.03	1.20E-01	2.10E-05	8.61E-04	4.47E+06	NA	5.87E-06	1.44E-02	NA
4,4'-DDT	50-29-3	354.49	2.50E-02	8.10E-06	3.32E-04	2.63E+06	NA	4.95E-06	1.37E-02	NA
Dibenz(a,h)anthracene	53-70-3	278.33	2.49E-03	1.47E-08	6.03E-07	3.80E+06	NA	5.18E-06	2.02E-02	NA
Dibromochloromethane (Chlorodibromomethane)	124-48-1	208.28	2.60E+03	7.83E-04	3.21E-02	6.31E+01	NA	1.05E-05	1.96E-02	737
1,2-Dibromo-3-chloropropane	96-12-8	236.36	1.20E+03	1.50E-04	6.15E-03	7.90E+01	NA	7.00E-06	2.12E-02	374

<i>Chemical</i>	<i>CAS No.</i>	<i>Molecular Wt.</i>	<i>Water Solubility (mg/L)</i>	<i>Henry's Law Constant (atm·m³/mol), 25°C</i>	<i>Henry's Law Constant (dimensionless, 25°C)</i>	<i>K_{oc} (L/kg)</i>	<i>K_d (L/kg)</i>	<i>Water Diffusion Coefficient (cm²/sec)</i>	<i>Air Diffusion Coefficient (cm²/sec)</i>	<i>Impact to Ground Water Soil Saturation Limit (mg/kg)</i>
1,2-Dibromoethane (Ethylene dibromide)	106-93-4	187.86	4.20E+03	7.40E-04	3.03E-02	4.60E+01	NA	8.10E-06	2.87E-02	1050
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	147	1.56E+02	1.90E-03	7.79E-02	6.17E+02	NA	7.90E-06	6.90E-02	218
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	147	1.30E+02	3.10E-03	1.27E-01	7.08E+02	NA	7.90E-06	6.92E-02	206
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	147	7.38E+01	2.43E-03	9.96E-02	6.17E+02	NA	7.90E-06	6.90E-02	NA
3,3'-Dichlorobenzidine	91-94-1	253.13	3.11E+00	4.00E-09	1.64E-07	7.24E+02	NA	6.74E-06	1.94E-02	NA
Dichlorodifluoromethane (Freon 12)	75-71-8	120.91	2.80E+02	3.40E-01	1.39E+01	6.60E+01	NA	1.00E-05	5.20E-02	NA
1,1-Dichloroethane	75-34-3	98.97	5.06E+03	5.62E-03	2.30E-01	3.16E+01	NA	1.05E-05	7.42E-02	1240
1,2-Dichloroethane	107-06-2	98.96	8.52E+03	9.79E-04	4.01E-02	1.74E+01	NA	9.90E-06	1.04E-01	1640
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	96.94	2.25E+03	2.61E-02	1.07E+00	5.89E+01	NA	1.04E-05	9.00E-02	899
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	96.94	3.50E+03	4.08E-03	1.67E-01	3.55E+01	NA	1.13E-05	7.36E-02	855
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	96.94	6.30E+03	9.38E-03	3.85E-01	5.25E+01	NA	1.19E-05	7.07E-02	1920
2,4-Dichlorophenol	120-83-2	163	4.50E+03	3.16E-06	1.30E-04	1.59E+02	NA	8.77E-06	3.46E-02	NA
1,2-Dichloropropane	78-87-5	112.99	2.80E+03	2.80E-03	1.15E-01	4.37E+01	NA	8.73E-06	7.82E-02	713
1,3-Dichloropropene (total)	542-75-6	110.97	2.80E+03	1.77E-02	7.26E-01	4.57E+01	NA	1.00E-05	6.26E-02	929
Dieldrin	60-57-1	380.91	1.95E-01	1.51E-05	6.19E-04	2.14E+04	NA	4.74E-06	1.25E-02	NA
Diethylphthalate	84-66-2	222.24	1.08E+03	4.50E-07	1.85E-05	2.88E+02	NA	6.35E-06	2.56E-02	788
2,4-Dimethylphenol	105-67-9	122.17	7.87E+03	2.00E-06	8.20E-05	2.09E+02	NA	8.69E-06	5.84E-02	NA
Di-n-butyl phthalate	84-74-2	278.34	1.12E+01	9.38E-10	3.85E-08	3.39E+04	NA	7.86E-06	4.38E-02	761
4,6-Dinitro-2-methylphenol	534-52-1	198.13	2.00E+02	4.30E-07	1.76E-05	1.16E+02	NA	6.90E-06	2.93E-02	NA
2,4-Dinitrophenol	51-28-5	184.11	2.79E+03	4.43E-07	1.82E-05	1.78E-02	NA	9.06E-06	2.73E-02	NA
2,4-Dinitrotoluene	121-14-2	182.14	2.70E+02	9.26E-08	3.80E-06	9.55E+01	NA	7.06E-06	2.03E-01	NA
2,6-Dinitrotoluene	606-20-2	182.14	1.82E+02	7.47E-07	3.06E-05	6.92E+01	NA	7.26E-06	3.27E-02	NA
2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	182.14	2.26E+02	4.20E-07	1.72E-05	8.24E+01	NA	7.16E-06	1.18E-01	NA
Di-n-octyl phthalate	117-84-0	390.56	2.00E-02	6.68E-05	2.74E-03	8.32E+07	NA	3.58E-06	1.51E-02	3330
1,2-Diphenylhydrazine	122-66-7	184.24	6.80E+01	1.50E-06	6.15E-05	7.10E+02	NA	7.40E-06	3.17E-02	NA
Endosulfan I and Endosulfan II (alpha and beta) (summed)	115-29-7	406.93	5.10E-01	1.12E-05	4.59E-04	2.14E+03	NA	4.55E-06	1.15E-02	NA

<i>Chemical</i>	<i>CAS No.</i>	<i>Molecular Wt.</i>	<i>Water Solubility (mg/L)</i>	<i>Henry's Law Constant (atm-m³/mol), 25°C</i>	<i>Henry's Law Constant (dimensionless, 25°C)</i>	<i>K_{oc} (L/kg)</i>	<i>K_d (L/kg)</i>	<i>Water Diffusion Coefficient (cm²/sec)</i>	<i>Air Diffusion Coefficient (cm²/sec)</i>	<i>Impact to Ground Water Soil Saturation Limit (mg/kg)</i>
Endosulfan sulfate	1031-07-8	422.95	6.40E+00	2.10E-03	8.61E-02	1.02E+03	NA	4.40E-06	1.10E-02	NA
Endrin	72-20-8	380.91	2.50E-01	7.52E-06	3.08E-04	1.23E+04	NA	4.74E-06	1.25E-02	NA
Ethylbenzene	100-41-4	106.16	1.69E+02	7.88E-03	3.23E-01	3.63E+02	NA	7.80E-06	7.50E-02	155
Fluoranthene	206-44-0	202.26	2.06E-01	1.61E-05	6.60E-04	1.07E+05	NA	6.35E-06	3.02E-02	NA
Fluorene	86-73-7	166.21	1.98E+00	6.36E-05	2.61E-03	1.38E+04	NA	7.88E-06	3.63E-02	NA
alpha-HCH (alpha-BHC)	319-84-6	290.83	2.00E+00	1.06E-05	4.35E-04	1.23E+03	NA	7.34E-06	1.42E-02	NA
beta-HCH (beta-BHC)	319-85-7	290.83	2.40E-01	7.43E-07	3.05E-05	1.26E+03	NA	7.34E-06	1.42E-02	NA
Heptachlor	76-44-8	373.32	1.80E-01	1.09E-03	4.47E-02	1.41E+06	NA	5.69E-06	1.12E-02	NA
Heptachlor epoxide	1024-57-3	389.4	2.00E-01	9.50E-06	3.90E-04	8.32E+04	NA	4.23E-06	1.32E-02	NA
Hexachlorobenzene	118-74-1	284.78	6.20E+00	1.32E-03	5.41E-02	5.50E+04	NA	5.91E-06	5.42E-02	NA
Hexachloro-1,3-butadiene	87-68-3	260.76	3.23E+00	8.15E-03	3.34E-01	5.37E+04	NA	6.16E-06	5.61E-02	348
Hexachlorocyclopentadiene	77-47-4	272.77	1.80E+00	2.70E-02	1.11E+00	2.00E+05	NA	7.21E-06	1.61E-02	721
Hexachloroethane	67-72-1	236.74	5.00E+01	3.89E-03	1.59E-01	1.78E+03	NA	6.80E-06	2.50E-03	NA
Indeno(1,2,3-cd)pyrene	193-39-5	276.34	2.20E-05	1.60E-06	6.56E-05	3.47E+06	NA	5.66E-06	1.90E-02	NA
Isophorone	78-59-1	138.21	1.20E+04	6.64E-06	2.72E-04	4.68E+01	NA	6.76E-06	6.23E-02	2960
Lead (total)	7439-92-1	207.2	NA	NA	NA	NA	9.00E+02	NA	NA	NA
Lindane (gamma-HCH)(gamma-BHC)	58-89-9	290.83	6.80E+00	1.40E-05	5.74E-04	1.07E+03	NA	7.34E-06	1.42E-02	NA
Manganese (total)	7439-96-5	54.938	NA	NA	NA	NA	6.50E+01	NA	NA	NA
Mercury (total)	7439-97-6		NA	NA	NA	NA	2.00E-01	NA	NA	NA
Methoxychlor	72-43-5	345.65	4.50E-02	1.58E-05	6.48E-04	9.77E+04	NA	4.46E-06	1.56E-02	NA
Methyl acetate	79-20-9	74.08	2.40E+05	1.15E-04	4.72E-03	2.00E+00	NA	1.00E-05	1.04E-01	37900
Methylene chloride (Dichloromethane)	75-09-2	84.93	1.30E+04	2.19E-03	8.98E-02	1.17E+01	NA	1.17E-05	1.01E-01	2440
2-Methylnaphthalene	91-57-6	142.2	2.50E+01	5.2E-04	2.13E-02	6.82E+03	NA	7.75E-06	5.22E-02	NA
2-Methylphenol (o-cresol)	95-48-7	108.14	2.60E+04	1.20E-06	4.92E-05	9.12E+01	NA	8.30E-06	7.40E-02	NA
4-Methylphenol (p-cresol)	106-44-5	108.14	2.20E+04	7.90E-07	3.24E-05	7.40E+01	NA	1.00E-05	7.40E-02	NA
Methyl tert-butyl ether (MTBE)	1634-04-4	88.15	4.80E+04	5.87E-04	2.40E-02	8.00E+00	NA	1.00E-05	1.02E-01	8270
Naphthalene	91-20-3	128.17	3.10E+01	4.83E-04	1.98E-02	2.00E+03	NA	7.50E-06	5.90E-02	NA
Nickel (total)	7440-02-0	58.69	NA	NA	NA	NA	2.40E+01	NA	NA	NA
2-Nitroaniline	88-74-4	138.12	2.90E+02	1.81E-08	7.42E-07	7.40E+01	NA	8.00E-06	7.30E-02	NA
Nitrobenzene	98-95-3	123.11	2.09E+03	2.40E-05	9.84E-04	6.46E+01	NA	8.60E-06	7.60E-02	591

<i>Chemical</i>	<i>CAS No.</i>	<i>Molecular Wt.</i>	<i>Water Solubility (mg/L)</i>	<i>Henry's Law Constant (atm·m³/mol), 25°C</i>	<i>Henry's Law Constant (dimensionless, 25°C)</i>	<i>K_{oc} (L/kg)</i>	<i>K_d (L/kg)</i>	<i>Water Diffusion Coefficient (cm²/sec)</i>	<i>Air Diffusion Coefficient (cm²/sec)</i>	<i>Impact to Ground Water Soil Saturation Limit (mg/kg)</i>
N-Nitrosodimethylamine	62-75-9	74.08	1.00E+06	1.20E-06	4.92E-05	3.00E-01	NA	1.20E-05	1.13E-01	154000
N-Nitrosodi-n-propylamine	621-64-7	130.22	9.89E+03	2.25E-06	9.23E-05	2.40E+01	NA	8.17E-06	5.45E-02	NA
N-Nitrosodiphenylamine	86-30-6	198.23	3.51E+01	5.00E-06	2.05E-04	1.29E+03	NA	6.35E-06	3.12E-02	NA
Pentachlorophenol	87-86-5	266.34	1.95E+03	2.44E-08	1.00E-06	5.10E+03	NA	6.10E-06	5.60E-02	NA
Phenanthrene	85-01-8	178.23	1.10E+00	2.30E-05	9.43E-04	2.65E+04	NA	7.50E-06	3.33E-02	NA
Phenol	108-95-2	94.11	8.28E+04	3.97E-07	1.63E-05	2.88E+01	NA	9.10E-06	8.20E-02	NA
Polychlorinated biphenyls (PCBs)	1336-36-3	Variable	7.00E-01	2.60E-03	1.07E-01	3.09E+05	NA	8.00E-06	1.75E-02	433
Pyrene	129-00-0	202.26	1.35E-01	1.10E-05	4.51E-04	1.05E+05	NA	7.24E-06	2.72E-02	NA
Selenium (total)	7782-49-2	78.96	NA	NA	NA	NA	1.40E+01	NA	NA	NA
Silver (total)	7440-22-4	107.86	NA	NA	NA	NA	2.60E-01	NA	NA	NA
Styrene	100-42-5	104.15	3.10E+02	2.75E-03	1.13E-01	7.76E+02	NA	8.00E-06	7.10E-02	533
Tertiary butyl alcohol (TBA)	75-65-0	74.12	1.00E+06	9.05E-06	3.71E-04	2.00E+00	NA	1.14E-05	9.85E-02	157000
1,1,2,2-Tetrachloroethane	79-34-5		2.97E+03	3.45E-04	1.41E-02	9.33E+01	NA	7.90E-06	7.10E-02	1010
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	165.83	2.00E+02	1.84E-02	7.54E-01	1.55E+02	NA	8.20E-06	7.20E-02	111
Thallium (total)	7440-28-0	204.383	NA	NA	NA	NA	4.80E+01	NA	NA	NA
Toluene	108-88-3	92.14	5.26E+02	6.64E-03	2.72E-01	1.82E+02	NA	8.60E-06	8.70E-02	289
Toxaphene	8001-35-2	414 (average)	7.40E-01	6.00E-06	2.46E-04	2.57E+05	NA	4.34E-06	1.16E-02	NA
1,2,4-Trichlorobenzene	120-82-1	181.45	3.00E+02	1.42E-03	5.82E-02	1.78E+03	NA	8.23E-06	3.00E-02	1120
1,1,1-Trichloroethane	71-55-6	133.42	1.33E+03	1.72E-02	7.05E-01	1.10E+02	NA	8.80E-06	7.80E-02	609
1,1,2-Trichloroethane	79-00-5	133.42	4.42E+03	9.13E-04	3.74E-02	5.01E+01	NA	8.80E-06	7.80E-02	1140
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	131.39	1.10E+03	1.03E-02	4.22E-01	1.66E+02	NA	9.10E-06	7.90E-02	590
Trichlorofluoromethane (Freon 11)	75-69-4	137.37	1.10E+03	9.70E-02	3.98E+00	1.14E+02	NA	1.00E-05	4.26E-02	944
2,4,5-Trichlorophenol	95-95-4	197.45	1.20E+03	4.33E-06	1.78E-04	2.34E+03	NA	7.03E-06	2.91E-02	NA
2,4,6-Trichlorophenol	88-06-2	197.45	8.00E+02	7.79E-06	3.19E-04	9.99E+02	NA	6.25E-06	3.18E-02	NA
Vandium (total)	7440-62-2	50.9415	NA	NA	NA	NA	1.00E+03	NA	NA	NA
Vinyl chloride	75-01-4	62.5	2.76E+03	2.70E-02	1.11E+00	1.86E+01	NA	1.23E-06	1.06E-01	NA
Xylenes (total)	1330-20-7	106.16	1.75E+02	6.73E-03	2.76E-01	3.86E+02	NA	8.44E-06	7.69E-02	168
Zinc (total)	7440-66-6	65.39	NA	NA	NA	NA	2.30E+01	NA	NA	NA

Table 2**Location of SESOIL Climate Stations**

County	Municipality	Climate Station	Latitude	Longitude
Atlantic	Egg Harbor	ATLANTIC CITY AIRPORT	39.450	74.567
Atlantic	Hamilton	MAYS LANDING I W	39.450	74.750
Atlantic	Hammonton Town	HAMMONTON 2 NNE	39.650	74.800
Bergen	Bergenfield	BERGENFIELD	40.924	73.999
Bergen	Cliffside Park	CLIFFSIDE PARK	40.821	73.989
Bergen	Englewood	ENGLEWOOD	40.893	73.973
Bergen	Fair Lawn	FAIR LAWN	40.936	74.120
Bergen	Fort Lee	FORT LEE	40.849	73.974
Bergen	Garfield	GARFIELD	40.880	74.108
Bergen	Lodi	LODI	40.882	74.083
Bergen	Lyndhurst	LYNDHURST	40.808	74.122
Bergen	Mahwah	MAHWAH	41.100	74.167
Bergen	Oradell Boro	NEW MILFORD	40.950	74.033
Bergen	Paramus	PARAMUS	40.945	74.072
Bergen	Ridgewood	RIDGEWOOD	40.979	74.117
Bergen	South Hackensack	HACKENSACK	40.866	74.049
Bergen	Teaneck	TEANECK	40.897	74.016
Bergen	Woodcliff Lake Boro	WOODCLIFF LAKE	41.017	74.050
Bergen	Wyckoff	MIDLAND PARK	40.983	74.150
Burlington	Moorestown	MOORESTOWN	39.967	74.967
Burlington	Shamong	INDIAN MILLS 2W	39.800	74.783
Burlington	South Hampton	PEMBERTON 3 S	39.933	74.700
Burlington	Willingboro	WILLINGBORO	40.028	74.869
Camden	Camden	CAMDEN	39.926	75.120
Camden	Camden	PENNSAUKEN	39.954	75.054
Camden	Cherry Hill	CERRY HILL	39.907	75.004
Camden	Gibbsboro	CAMDEN	39.844	74.964
Camden	Mount Ephram Boro	AUDUBON	39.883	75.083
Cape May	Dennis	BELLEPLAIN ST FOREST	39.250	74.867
Cape May	Lower	CAPE MAY 2 NW	38.950	74.933
Cumberland	Bridgeton	BRIDGETON	39.438	75.231
Cumberland	Millville City	MILLVILLE FAA AP	39.367	75.067
Cumberland	Vineland	VINELAND	39.465	74.997
Essex	Belleville	BELLEVILLE	40.794	74.164
Essex	Bloomfield	BLOOMFIELD	40.807	74.187

County	Municipality	Climate Station	Latitude	Longitude
Essex	East Orange	EAST ORANGE	40.767	74.205
Essex	Essex Fells Boro	ESSEX FELLS SERV BLDG	40.833	74.283
Essex	Irvington	IRVINGTON	40.725	74.231
Essex	Livingston	LIVINGSTON	40.796	74.315
Essex	Maplewood	MAPLEWOOD	40.731	74.273
Essex	Millburn	CANOE BROOK	40.750	74.350
Essex	Millburn	SUMMIT	40.741	74.360
Essex	Montclair	MONTCLAIR	40.813	74.217
Essex	Newark	NEWARK, INTERNATIONAL AIRPORT	40.700	74.167
Essex	Nutley	NUTLEY	40.820	74.159
Essex	Orange	ORANGE	40.770	74.240
Essex	West Orange	WEST ORANGE	40.798	74.239
Gloucester	Glassboro Boro	GLASSBORO	39.700	75.117
Hudson	Bayonne	BAYONNE	40.666	74.119
Hudson	Hoboken	HOBOKEN	40.746	74.035
Hudson	Jersey City	JERSEY CITY	40.733	74.050
Hudson	Kearny	KEARNY	40.762	74.123
Hudson	North Bergen	NORTH BERGEN	40.804	74.012
Hudson	Union City	UNION CITY	40.780	74.024
Hudson	West New York	WEST NEW YORK	40.787	74.014
Hunterdon	East Amwell	WERTSVILLE	40.450	74.800
Hunterdon	Lambertville City	LAMBERTVILLE	40.367	74.950
Hunterdon	Raritan	FLEMINGTON 5 NNW	40.567	74.883
Mercer	East Windsor	HIGHTSTOWN 2 W	40.267	74.567
Mercer	Ewing	EWING	40.270	74.800
Mercer	Ewing	TRENTON	40.274	74.817
Mercer	Princeton	PRINCETON WATERWORKS	40.333	74.667
Middlesex	Carteret	CARTERET	40.583	74.233
Middlesex	East Brunswick	EAST BRUNSWICK	40.430	74.407
Middlesex	East Brunswick	OLD BRIDGE	40.414	74.365
Middlesex	Edison	EDISON	40.504	74.354
Middlesex	North Brunswick	NEW BRUNSWICK 3 SE	40.467	74.433
Middlesex	North Brunswick	NORTH BRUNSWICK	40.447	74.489
Middlesex	Perth Amboy	PERTH AMBOY	40.510	74.270
Middlesex	Sayreville	SAYREVILLE	40.464	74.345
Middlesex	South Plainfield	PLAINFIELD	40.600	74.400
Middlesex	South Plainfield	SOUTH PLAINFIELD	40.580	74.415
Middlesex	Woodbridge	WOODBIDGE	40.558	74.285
Monmouth	Freehold	FREEHOLD	40.267	74.250

County	Municipality	Climate Station	Latitude	Longitude
Monmouth	Long Branch City	LONG BRANCH OAKHURST	40.267	74.000
Morris	Boonton Town	BOONTON I SE	40.900	74.400
Morris	Dover	DOVER	40.890	74.560
Morris	Jefferson	OAK RIDGE RESERVOIR	41.033	74.500
Morris	Parsippany-Troy Hills	MORRIS PLAINS I W	40.833	74.500
Morris	Parsippany-Troy Hills	PARSIPPANY	40.862	74.406
Morris	Rockaway	CHARLOTTEBURG RESVOIR	41.033	74.433
Morris	Rockaway	SPLIT ROCK POND	40.967	74.467
Morris	Roxbury	WEST WHARTON	40.900	74.600
Morris	Washington	LONG VALLEY	40.783	74.783
Morris	Washington	POTTERSVILLE 2 NNW	40.733	74.733
Ocean	Berkeley	TOMS RIVER	39.950	74.217
Ocean	Brick	BRICK	40.052	74.107
Ocean	Lakewood	LAKWOOD	40.084	74.207
Ocean	Tuckerton Boro	TUCKERTON	39.600	74.350
Passaic	Little Falls	LITTLE FALLS	40.883	74.233
Passaic	Passaic	PASSAIC	40.858	74.131
Passaic	Paterson	CLIFTON	40.879	74.144
Passaic	Paterson	PATERSON	40.907	74.150
Passaic	Ringwood Boro	RINGWOOD	41.133	74.267
Passaic	Wanaque Boro	WANAQUE RAYMOND DAM	41.050	74.300
Passaic	West Milford	GREENWOOD LAKE	41.133	74.333
Passaic	West Milford	WEST MILFORD	41.131	74.367
Salem	Woodstown Boro	WOODSTOWN	39.650	75.317
Somerset	Bridgewater	BOUND BROOK 2 W	40.550	74.567
Somerset	Bridgewater	SOMERVILLE 3 NW	40.600	74.633
Somerset	Franklin	SOMERSET	40.479	74.488
Somerset	Hillsboro	BLACKWELLS MILLS	40.467	74.583
Sussex	Branchville Boro	BRANCHVILLE	41.150	74.750
Sussex	Fredon	NEWTON ST PAULS ABBEY	41.033	74.800
Sussex	Hardyston	CANISTEAR RESERVOIR	41.100	74.500
Sussex	Wantage	HIGH POINT PARK	41.300	74.667
Sussex	Wantage	SUSSEX I SE	41.200	74.600
Union	Cranford	CRANFORD	40.650	74.300
Union	Elizabeth	ELIZABETH	40.666	74.178
Union	Hillside	HILLSIDE	40.696	74.230

County	Municipality	Climate Station	Latitude	Longitude
Union	Linden	LINDEN	40.636	74.256
Union	Linden	NORTH PLAINFIELD	40.630	74.247
Union	Rahway	RAHWAY	40.607	74.282
Union	Roselle Park	ROSELLE	40.664	74.263
Union	Scotch Plains	SCOTCH PLAINS	40.655	74.390
Union	Union	UNION	40.699	74.266
Union	Westfield	WESTFIELD	40.658	74.347

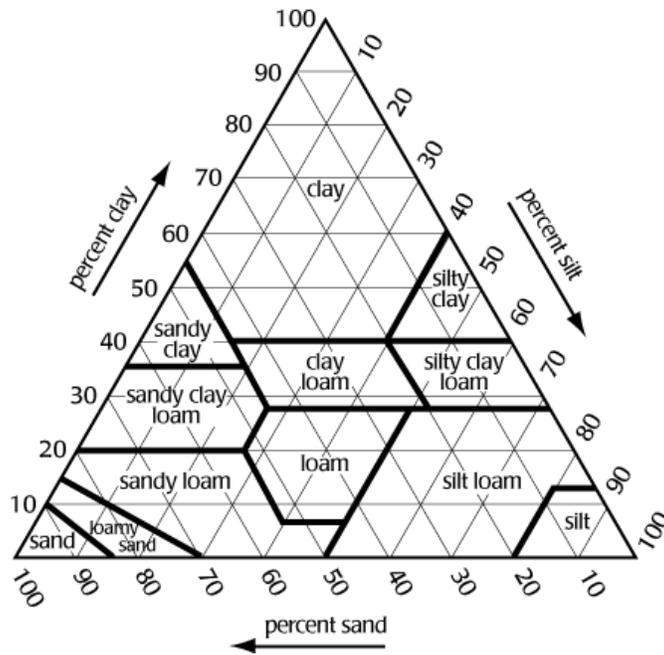
Table 3 **K_{oc} Values (L/kg) for Ionizing Organics as a Function of pH**

pH	Benzoic acid	2-Chlorophenol	2,4-Dichlorophenol	2,4-Dinitrophenol	Pentachlorophenol	2,3,4,5-Tetrachlorophenol	2,3,4,6-Tetrachlorophenol	2,4,5-Trichlorophenol	2,4,6-Trichlorophenol
4.9	5.54E+00	3.98E+02	1.59E+02	2.94E-02	9.05E+03	1.73E+04	4.45E+03	2.37E+03	1.04E+03
5.0	4.64E+00	3.98E+02	1.59E+02	2.55E-02	7.96E+03	1.72E+04	4.15E+03	2.36E+03	1.03E+03
5.1	3.88E+00	3.98E+02	1.59E+02	2.23E-02	6.93E+03	1.70E+04	3.83E+03	2.36E+03	1.02E+03
5.2	3.25E+00	3.98E+02	1.59E+02	1.98E-02	5.97E+03	1.67E+04	3.49E+03	2.35E+03	1.01E+03
5.3	2.72E+00	3.98E+02	1.59E+02	1.78E-02	5.10E+03	1.65E+04	3.14E+03	2.34E+03	9.99E+02
5.4	2.29E+00	3.98E+02	1.58E+02	1.62E-02	4.32E+03	1.61E+04	2.79E+03	2.33E+03	9.82E+02
5.5	1.94E+00	3.97E+02	1.58E+02	1.50E-02	3.65E+03	1.57E+04	2.45E+03	2.32E+03	9.62E+02
5.6	1.65E+00	3.97E+02	1.58E+02	1.40E-02	3.07E+03	1.52E+04	2.13E+03	2.31E+03	9.38E+02
5.7	1.42E+00	3.97E+02	1.58E+02	1.32E-02	2.58E+03	1.47E+04	1.83E+03	2.29E+03	9.10E+02
5.8	1.24E+00	3.97E+02	1.58E+02	1.25E-02	2.18E+03	1.40E+04	1.56E+03	2.27E+03	8.77E+02
5.9	1.09E+00	3.97E+02	1.57E+02	1.20E-02	1.84E+03	1.32E+04	1.32E+03	2.24E+03	8.39E+02
6.0	9.69E-01	3.96E+02	1.57E+02	1.16E-02	1.56E+03	1.24E+04	1.11E+03	2.21E+03	7.96E+02
6.1	8.75E-01	3.96E+02	1.57E+02	1.13E-02	1.33E+03	1.15E+04	9.27E+02	2.17E+03	7.48E+02
6.2	7.99E-01	3.96E+02	1.56E+02	1.10E-02	1.15E+03	1.05E+04	7.75E+02	2.12E+03	6.97E+02
6.3	7.36E-01	3.95E+02	1.55E+02	1.08E-02	9.98E+02	9.51E+03	6.47E+02	2.06E+03	6.44E+02
6.4	6.89E-01	3.94E+02	1.54E+02	1.06E-02	8.77E+02	8.48E+03	5.42E+02	1.99E+03	5.89E+02
6.5	6.51E-01	3.93E+02	1.53E+02	1.05E-02	7.81E+02	7.47E+03	4.55E+02	1.91E+03	5.33E+02
6.6	6.20E-01	3.92E+02	1.52E+02	1.04E-02	7.03E+02	6.49E+03	3.84E+02	1.82E+03	4.80E+02
6.7	5.95E-01	3.90E+02	1.50E+02	1.03E-02	6.40E+02	5.58E+03	3.27E+02	1.71E+03	4.29E+02
6.8	5.76E-01	3.88E+02	1.47E+02	1.02E-02	5.92E+02	4.74E+03	2.80E+02	1.60E+03	3.81E+02
6.9	5.60E-01	3.86E+02	1.45E+02	1.02E-02	5.52E+02	3.99E+03	2.42E+02	1.47E+03	3.38E+02
7.0	5.47E-01	3.83E+02	1.41E+02	1.02E-02	5.21E+02	3.33E+03	2.13E+02	1.34E+03	3.00E+02
7.1	5.38E-01	3.79E+02	1.38E+02	1.02E-02	4.96E+02	2.76E+03	1.88E+02	1.21E+03	2.67E+02
7.2	5.32E-01	3.75E+02	1.33E+02	1.01E-02	4.76E+02	2.28E+03	1.69E+02	1.07E+03	2.39E+02
7.3	5.25E-01	3.69E+02	1.28E+02	1.01E-02	4.61E+02	1.87E+03	1.53E+02	9.43E+02	2.15E+02
7.4	5.19E-01	3.62E+02	1.21E+02	1.01E-02	4.47E+02	1.53E+03	1.41E+02	8.19E+02	1.95E+02
7.5	5.16E-01	3.54E+02	1.14E+02	1.01E-02	4.37E+02	1.25E+03	1.31E+02	7.03E+02	1.78E+02
7.6	5.13E-01	3.44E+02	1.07E+02	1.01E-02	4.29E+02	1.02E+03	1.23E+02	5.99E+02	1.64E+02
7.7	5.09E-01	3.33E+02	9.84E+01	1.00E-02	4.23E+02	8.31E+02	1.17E+02	5.07E+02	1.53E+02
7.8	5.06E-01	3.19E+02	8.97E+01	1.00E-02	4.18E+02	6.79E+02	1.13E+02	4.26E+02	1.44E+02
7.9	5.06E-01	3.04E+02	8.07E+01	1.00E-02	4.14E+02	5.56E+02	1.08E+02	3.57E+02	1.37E+02
8.0	5.06E-01	2.86E+02	7.17E+01	1.00E-02	4.10E+02	4.58E+02	1.05E+02	2.98E+02	1.31E+02

APPENDIX A

Methods for Determination of Soil Texture

A variety of methods exist to determine soil texture. Sieve analysis alone is generally not adequate, because it does not separate the silt and clay fractions. The Department will consider any of the following techniques acceptable: the hydrometer method; sieve analysis for the sand and gravel portions of a given sample with pipette or hydrometer measurements of the silt and clay fractions; rapid sediment analyzers; or electro-resistance multichannel particle size analyzers. The percentages of sand, silt and clay determined by the chosen analysis technique are then compared to the USDA Soil Texture Triangle to determine the soil texture classification (see figure below). Under the USDA classification, sands are considered particles between 0.05 and 2 mm in size, silts are between 0.05 mm and 0.002 mm and clays are less than 0.002 mm in size.



USDA Soil Triangle (Bonazountas and Wagner 1984)

An example Standard Operating Procedure for the hydrometer method from the California Department of Pesticide regulation may be found at

<http://www.cdpr.ca.gov/docs/emon/pubs/sops/meth004.pdf>.

Among the standard methods for determining particle size distribution, two methods from the American Society for Testing and Materials (ASTM) are commonly employed and deserve further discussion.

ASTM Method D422-63 (ASTM 2007a) is a sieve and hydrometer-based method. The sand fraction is determined using a 0.075 mm sieve. Then, the remaining sample is suspended in water and the density of the suspension is measured after the silt has settled, which allows determination of the silt and clay fractions of the sample. This method uses a 0.075 mm cutoff for the sand fraction, rather than the USDA 0.05 mm cutoff. It is recommended, although not required, that a 0.05 mm sieve be substituted. The default hydrometer analysis for this method determines <0.001 mm (colloids) and <0.005 mm fractions, while the USDA clay fraction is <0.002 mm. If the <0.002 mm fraction is not determined directly, it may be estimated by averaging the results from the <0.001 mm and <0.005 mm fractions.

The other ASTM method, F1632-03 (ASTM 2003), is a sieve and pipette-based method. This method has the advantage of properly determining the sand, silt and clay percentages according to the USDA particle size definitions. Sand is first separated using a 0.05 mm sieve. Then, the remaining sample is suspended in water, and the suspended clay is sampled with a pipette after allowing the silt fraction to settle. The clay is determined by weight after drying, and the silt content is then determined by subtracting the sand and clay weight from the total sample weight.

APPENDIX B

Direct Determination of Intrinsic Permeability, Disconnectedness Index and Effective Porosity for the SESOIL Model from Site Soil Samples

While direct determination of SESOIL-specific input parameters is possible, the procedures required are likely to be fairly expensive and time consuming. Methods are available to collect soil core samples and to conduct the appropriate laboratory measurements, but the method results typically require additional measurements and calculations in order to obtain values for the SESOIL input parameters. Therefore, a substantial level of expertise will be required to determine site-specific values for these parameters, and the effort will likely be worthwhile only for larger hazardous waste sites that would exhibit substantial economic savings from determining site-specific values for these parameters.

Generally, intact, undisturbed soil cores will need to be collected from the field and brought into the laboratory. Examples of the procedures required may be found in ASTM method D3550 (ASTM 2007b) and ASTM method D1587 (ASTM 2012).

Pore Disconnectedness Index

The pore disconnectedness index may be determined using the following formula:

$$c = \frac{2 + 3m}{m}$$

where c is the pore disconnectedness index and m is the pore size distribution index (Brooks and Corey 1964). The pore size distribution index, in turn, may be measured from the soil moisture retention curve as the negative slope of the effective degree of saturation versus matric suction on the midpoint of the curve. Standard procedures have not been published for conducting this determination, but the soil moisture retention curve from which the calculation is made may be determined using standard methods such as ASTM D6836 (ASTM 2008a).

Intrinsic Permeability

Intrinsic permeability may be calculated from the saturated hydraulic conductivity of the soil:

$$k = \frac{K\mu}{\rho g}$$

where k is the intrinsic permeability, K is the saturated hydraulic conductivity of the soil, μ is the dynamic viscosity of water, ρ is the density of water and g is the gravitational constant (Freeze and Cherry 1979). To determine saturated hydraulic conductivity, methods such as ASTM D5084 (ASTM 2010) may be used.

Effective Porosity

Obtaining accurate effective porosity values in the field or laboratory has historically been difficult and time consuming. Effective porosity may be thought of as the fractional air content of soil after soil moisture has drained to its field capacity. Field and laboratory methods are available, but field methods are not likely to be practical during site investigation. ASTM D425 ASTM (2008b) is a possible laboratory method to determine effective porosity, but it is not specifically designed for undisturbed soil cores. It is suggested that a modified version of the method be used which allows for the use of undisturbed soil cores. Check with specific laboratories to ascertain whether or not they have developed specific expertise in the determination of this parameter.

APPENDIX C

Determining Organic Carbon Content of Soil

The preferred method to be used for determining fraction organic carbon is the “Lloyd Kahn method” (USEPA 1988) or equivalent. The Lloyd Kahn method was developed by USEPA Region 2 and can be found at the following link:

<http://www.nj.gov/dep/srp/guidance/rs/lloydkahn.pdf>

A similar method is documented on the USEPA Great Lakes website:

http://www.epa.gov/greatlakes/monitoring/sop/chapter_6/LG601.pdf.

The method first removes inorganic carbon via acid treatment. Then, high temperature dry combustion of the sample in the presence of oxygen is conducted using a carbon analyzer, followed by measurement of the evolved CO₂. The primary difference between the Great Lakes method and the Lloyd Kahn method is that the Great Lakes method is more specific in the type of carbon analyzer used.

Schumacher (2002) has compared dry combustion, wet oxidation, furnace (loss on ignition) and hydrogen peroxide treatment techniques for determination of total organic carbon in soils and sediments. The furnace and hydrogen peroxide treatments are best considered to be semiquantitative techniques since they exhibit problems such as incomplete oxidation of organic matter and loss of soil components other than soil organic matter. The wet oxidation technique is more quantitative but also suffers from potential incomplete oxidation of the sample, is subject to interference problems, and requires careful laboratory technique. The author recommends the dry combustion technique because minimal sample preparation is required, complete combustion of the organic carbon is assured, sample analysis time is short, and the method gives more reproducible results. Therefore, the NJDEP has determined that the Lloyd Kahn method (dry combustion) is preferred.

USEPA SW-846 Methods 9060 and 5310 are frequently cited as methods for determination of total organic carbon. However, these methods are designed for water and liquid wastes, and are not relevant to analysis of soil samples.

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