GUIDANCE DOCUMENT

USING THE SESOIL TRANSPORT MODEL TO ASSESS THE IMPACT TO GROUND WATER PATHWAY

Revised December 2008

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Introduction

At sites where a discharge has occurred and ground water has not yet been contaminated, the person responsible for conducting the remediation is required to ensure that ground water quality is not impacted. When clean soil exists between the soil contamination and the seasonal high water table, the Seasonal Soil Compartment Model (SESOIL) may be used to determine whether current levels of soil contamination may impact the ground water in the future.

The SESOIL model is most useful when a contaminant has low mobility, or has a higher mobility but is either present at low concentrations or has a low toxicity. If the contaminant has low mobility the contaminant will not migrate to the water table even under long simulation times. If the contaminant is present at low concentrations or has a low toxicity, then the contaminant may reach the water table, but concentrations in the leachate at the bottom of the unsaturated soil zone may not be sufficient to impact the ground water at levels that exceed the Ground Water Quality Criteria. Under such conditions, existing soil contamination may be shown to not pose a threat to ground water demonstrating that the impact to ground water pathway is not of concern. Alternatively, the model may be used to calculate the acceptable IGW soil remediation standard. See the Appendix for background information on the SESOIL model.

While the original SESOIL code is available free of charge from the USEPA, it lacks a user interface. Commercially available software packages contain both the source code and interfaces to assist users in the selection and preparation of input data and for viewing and presenting model output.

For use on contaminated sites in New Jersey, the Department has assigned default input parameter values. When adjusting the default scenario for site-specific purposes, the Department has set restrictions on how the model may be used, what input parameters may be changed, and what restrictions are imposed on their modification. Guidance on the use of SESOIL and restrictions on the various input parameters is described below.

When using SESOIL, free and residual product must be remediated pursuant to the Technical Rules, N.J.A.C. 7:26E-6.1(d). If soil pH has been significantly altered beyond the natural pH for the soil, this model may not be used for metals. If the site contains fill material significantly coarser than sand, excess infiltration may result and this model should not be used.

If the modeling indicates that the existing soil contamination does not pose a threat to ground water, or if a site is remediated to a site specific criterion determined using this model, no further action for the impact to ground water pathway is required. No monitoring, deed notices or other restrictions are necessary.

I. Running the SESOIL model

The following instructions should be used to run the SESOIL model. The parameters are grouped in order of normal data entry when running the SESOIL user interface.

(1) Use SESOIL model version 6.2 or later.

(2) Run the model in the monthly mode.

(3) Use climate data from the weather station nearest to the site. Use the climate databases that are included with model software.

(4) Use chemical properties for the model as specified below:

Use default values for water solubility, Henry's law constant, and diffusion coefficients from the Basis and Background document of the Inhalation Soil Cleanup Standards. Chemical properties may be found in the following chemical properties table:

http://www/nj/gov/dep/srp/guidance/rs/chemproperties.pdf

For metals and cyanide, a high water solubility (e.g., 100,000 mg/L) should be entered unless the actual species and solubility of the metal are known, and the Henry's law constant and diffusion coefficients should be set to zero.

Default K_{oc} values for organic chemicals and default K_d values for metals are provided in the chemicals properties table.

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. Volatile organic compounds may not be evaluated with this test, as discussed in the NJDEP SPLP guidance document:

http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf

For ionizable phenols, a pH-dependant site-specific K_{oc} value may be developed as described in the NJDEP Soil Water Partition Coefficient Guidance:

http://www.nj.gov/dep/srp/guidance/rs/partition_equation.pdf

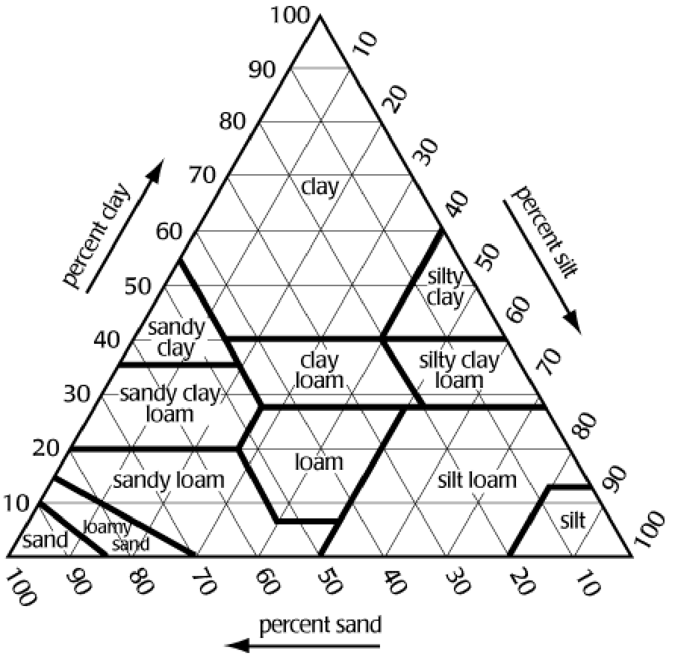
Degradation of contaminants may not be included except for benzene, toluene, ethylbenzene and xylene (BTEX). For BTEX contaminants use a 1 month half life biodegradation rate (biodegradation rate constant of 0.023 days^{-1}) in both the liquid and solid phases if aerobic conditions (>4% oxygen) can be demonstrated in the vadose zone.

Hydrolysis rate constants may not be used.

(5) Use sand as the soil texture unless a site-specific soil texture has been determined. Use default soil properties for intrinsic permeability, soil pore disconnectedness index and effective porosity as contained in the model documentation for the appropriate soil texture (See tables below). The soil bulk density must be set to 1.5 g cm^3. The cation exchange capacity must be set to zero. The Freundlich exponent must be set to one. The soil pH is not used and should be set to 7.0 for all layers. The default soil organic carbon content must be set to 0.2 percent. The same soil properties must be used for all existing soil layers, with the exception of soil organic

carbon content. Use the following procedures to determine site-specific soil texture and soil organic carbon content:

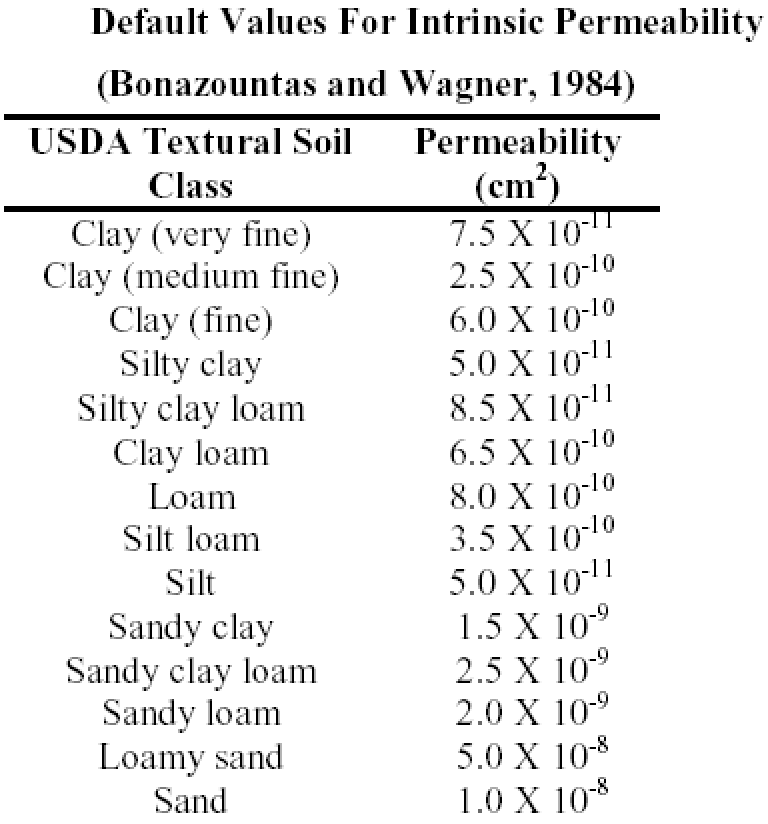
To establish soil texture, collect soil cores that are representative of the variation in texture that occurs within the area of concern. Cores should be collected using a Shelby Tube, direct push sampler, or split spoon. The cores should be collected continuously (every two or four feet depending on 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 A variety of methods exist to determine 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

The soil texture to be used in the SESOIL model should be a median soil texture, such that the percentage of the soil vertical profile 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.

A site-specific organic carbon content may be determined. Follow the procedure described in the Inhalation Soil Cleanup Standards. If a variable organic carbon content with depth is to be determined, the procedure for determining organic carbon content must be followed for each depth interval that is to be assigned a particular organic carbon content. 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 model documentation.



Default Values For Intrinsic Permeability

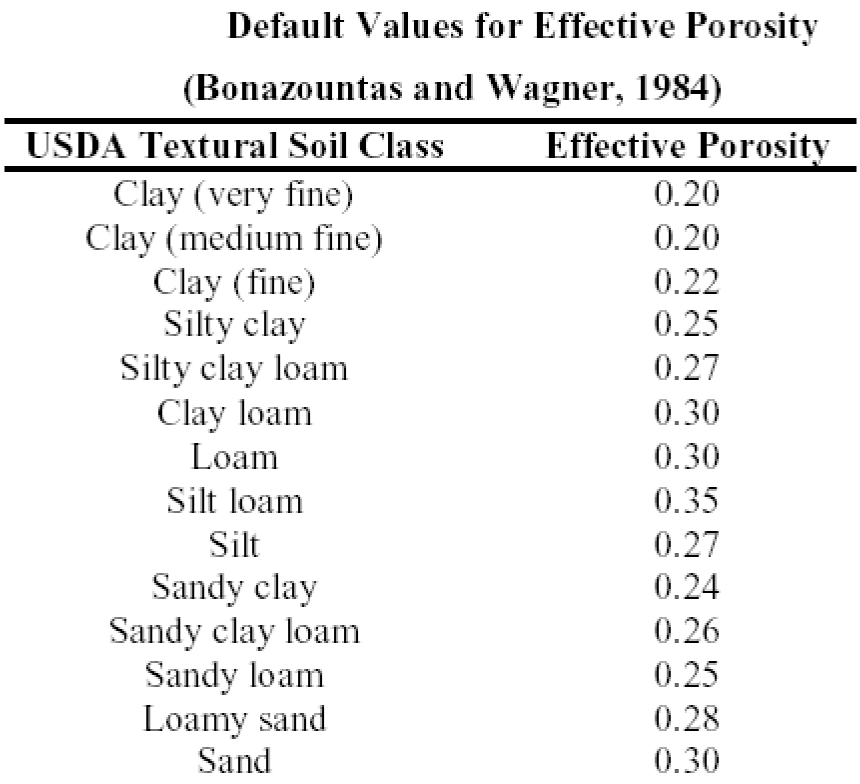
(Bonazountas and Wagner, 1984)

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

(6) The sediment washload option must not be used.

(7) One foot soil sublayers must be used with the model, and should cover the entire soil column from the soil surface to the water table. If the depth to water table is greater than 40 feet, use 40 sublayers, with the total depth evenly divided over the layers.

(8) The “Load area” or “Application Area” in the model must be set equal to the size of the Area of Concern. Enter the appropriate latitude of the site, and select “instantaneous release” of contaminant at Time 0 of the simulation.

(9) Contaminant concentrations (either existing concentrations or proposed remediation standards) must be entered as initial concentrations in the appropriate soil layers.

(10) With one exception, all ratios of soil properties between soil layers must be set to “1”. The exception to this is that soil organic carbon ratios may be variable as discussed above.

(11) The contaminant load parameters POLIN, TRANS, LIG, ISRM and ASL must be set to zero. The VOLF parameter must be set to zero unless soil texture has been determined, in which case it is set to one.

(12) Set the model run time at 100 years for low mobility contaminants. For all other contaminants, the model run time must be long enough to achieve peak concentrations in ground water.

II. Using SESOIL model results to determine compliance with the impact to ground water pathway

(1) Print out all summary output pages provided by the model software.

(2) Compare the time-dependant concentration of the contaminant in the soil moisture in the deepest soil layer to the Leachate Criterion (LC) to determine compliance with ground water criteria. The Leachate Criterion is determined following procedures described in the impact to ground water SPLP Guidance Document. If the model predicts that the concentration will not exceed the LC, then the soil contaminant concentration distribution used in the model (either existing concentrations or proposed remediation criterion) will not pose a threat ground water demonstrating that not further action for the impact to ground water pathway. Acceptable ground water conditions are illustrated in Figures (1) and (2) below.

(3) For mobile contaminants, the peak predicted concentration should not exceed the LC (Figure 1). If this is the case, the modeled contaminant distribution will not pose a threat ground water demonstrating that no further action for the impact to ground water pathway.

(4) For contaminants that are immobile or exhibit low mobility, the SESOIL results should indicate a ground water concentration that does not exceed the LC for at least 100 years (as shown in Figure 2). Department has decided that protection of the ground water for 100 years is acceptable, since low mobility contaminants would be expected to become irreversibly adsorbed or degraded during this time period.

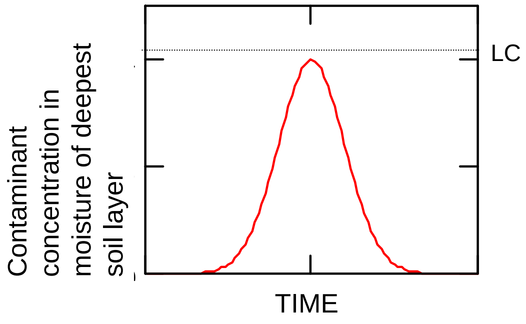


Figure 1

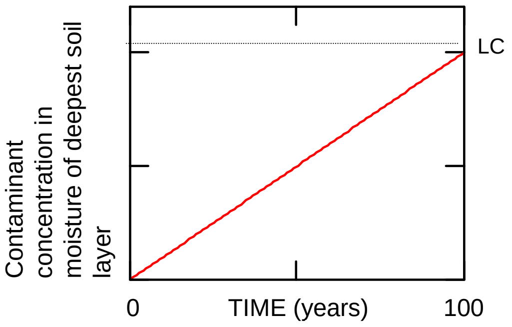


Figure 2

(5) If the model predicts that the ground water concentration will exceed the LC, then soil remediation is necessary or the SESOIL model may be rerun to identify the concentration distribution of the contaminant in soil that will not result in an exceedance of the LC. This identified soil concentration distribution will not pose a

threat ground water demonstrating that no further action for the impact to ground water pathway**.**

III. Submission requirements

Submit the following information for the SESOIL runs to the Department:

1. The value of all input parameters, and their source, if other than default values are used;

2. Output of the soil moisture concentration for the bottom soil sublayer as a function of time. Graphical output is preferred; and

3. Other output summaries as provided by the software.

APPENDIX

Background Information on the SESOIL Model

The SESOIL model was originally formulated by Arthur D. Little and Associates for the USEPA (Bonazountas and Wagner, 1984). Since that time it has been revised and updated several times (Bonazountas et al., 1997). The model now has over a 20 year history and has been subject to several laboratory and field validation studies (Bonazountas et al., 1997; Melancon et al., 1986; Sanders, 1995).

The SESOIL model has become fairly well established and has been accepted by several state agencies and the USEPA for calculating remediation standards. Some of the states routinely using SESOIL exclusively or SESOIL with AT123D (a ground water transport model) are Oregon, New Hampshire, Wisconsin, Massachusetts and Hawaii. The models may be useful for site-specific remediation standard calculations when 1) there is a clean zone of soil between the contamination and the water table, or 2) when ground water plume modeling is desired.

The SESOIL model accounts for the contaminant processes of advection, volatilization, degradation, and surface runoff (Bonazountas and Wagner, 1984, Bonazountas et al., 1997). Precipitation is generated using a statistical formula that incorporates monthly New Jersey climate data. Water transport is calculated via the statistical water balance dynamics theory of Eagleson (1978). The model includes the mechanisms of runoff, infiltration, evapotranspiration, and ground water recharge. The capillary fringe effect is also included. Contaminant transport downward is calculated via advection using the retardation factor. The factor allows calculation of the distance of contaminant transport during each time step. The soil column is considered to be layered into several compartments. Contaminant entering a soil compartment is considered to be immediately mixed through the entire compartment. Vapor phase transport is also modeled (upward direction only) to allow calculation of contaminant volatilization. Various options for contaminant degradation are also included. However, with one exception, the Department does not allow for contaminant degradation. The exception applies to benzene, toluene, ethylbenzenes and xylene, which may degrade rapidly in the vadose zone under certain conditions (DeVaull et al., 2002; Howard et al., 1991). Under these conditions, a default half-life of 1 month may be used in SESOIL provided aerobic conditions in the vadose zone can be demonstrated.

REFERENCES

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