POLLUTE

Version 8

Example 11: Time-varying Source Concentration

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GAEA Technologies Ltd,

221 Laurel Street
Cambridge, Ontario
Canada
N3H 3Y6

Tel: (613) 900-1950

Email:
sales@gaeatech.com
support@gaeatech.com

www.gaeatech.com

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Description

In this example there is a time-varying source concentration history and diffusive transport of a conservative species (i.e., no sorption) from a landfill. Time zero corresponds to the excavation of a landfill cell, the cell then filled quickly with water to a depth of 6 m. No waste was added to the cell for 7 years. The landfill is situated in a clay that contains chloride in its pore water at a concentration of 120 mg/L. During the 7 years that the cell contained water the chloride began to diffused out of the clay pore water and into the cell water. Between the years 7 and 10, waste was added to the cell and the source concentration of chloride increased linearly with time reaching a peak value at year 10 of 2100 mg/L. The source concentration of chloride then remained relatively constant between the years 10 and 13. During the years 13 to 15 the source concentration decreased linearly with time to a value of 1180 mg/L at year 15. The source concentration then remained relatively constant again from years 15 to 19. This example will calculate the predicted chloride distribution with depth at year 19.

There is no leachate collection system in the landfill, and the water level in the waste corresponds to the natural water level. The hydraulic gradient is zero, and hence the Darcy velocity is zero. And the clay is sufficiently thick that it can be assumed to be infinite for the time period under consideration.

When using the Variable Properties special feature it is possible to independently specify the diffusion coefficient (D_m) and the dispersivity. In this example the dispersivity is assumed to be zero since there is no flow. Clearly if there is no flow then the value of the dispersivity is not relevant since the coefficient of hydrodynamic dispersion (D) is then calculated by:

$$D = D_m + \alpha * v_a / n$$

The Reference Height of Leachate for this example is the same as the depth of water in the cell (i.e., 6 m). In this example the source concentration is assigned specific values at various times by setting the value of the Reference Height of Leachate very large. Setting the Reference Height of Leachate very large will ensure that the source concentration remains constant during that time interval.

Following are the parameters used in this example:

Property	Symbol	Value	Units
Darcy Velocity	v_a	0	m/a
Diffusion Coefficient	D_m	0.00663	m^2/a
Distribution Coefficient	K_d	0	cm^3/g
Dispersivity		0	m
Soil Porosity	n	0.37	-
Dry Density		1.6	g/cm^3
Soil Layer Thickness		infinite	m
Thickness of Interest	H_r	1.5	m
Number of Sub-layers		15	-
Source Concentration	c_0	variable	mg/L
Ref. Height of Leachate	H_r	6	m
Volume of Leachate Collected	Q_c	0	m/a

When using the Variable Properties special feature the accuracy of the solution is dependent on the number of sub-layers used.

This example is for a hypothetical landfill and is used to illustrate how to prepare an input file and run an analysis using the Variable Properties option. The example is not a prescription for modeling contaminant migration from a landfill. Each landfill has its own unique

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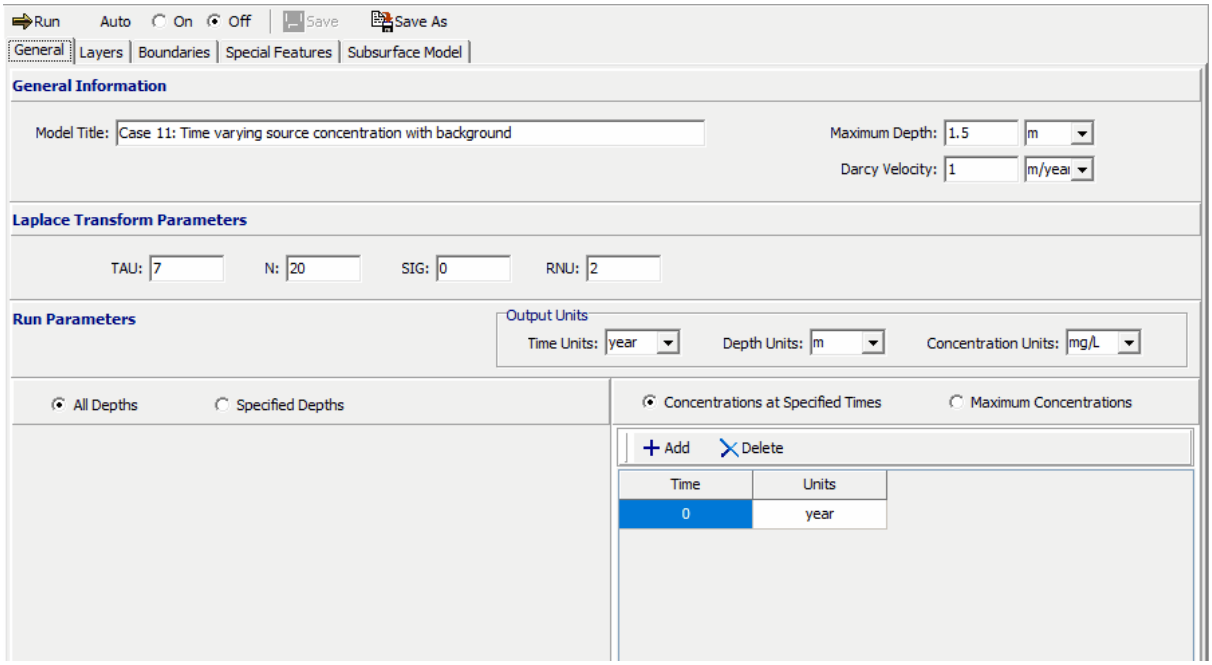
characteristics and no general prescription can be made. The Variable Properties option should only by used by someone with the hydrogeologic and engineering background necessary to appreciate the subtleties associated withthe physical situation and the steps necessary for appropriate modeling of this physical situation.

Data Entry

Open the Examples project and open Case 11.

General Tab



In the General tab the Darcy velocity can not be specified if the Time-varying Properties special feature is used. Any Darcy velocity entered will be ignored. When the time-varying properties special feature is used the times to calculate the concentrations are specified in the Time-Varying Properties sub-tab of the Special Features tab..

Layers Tab

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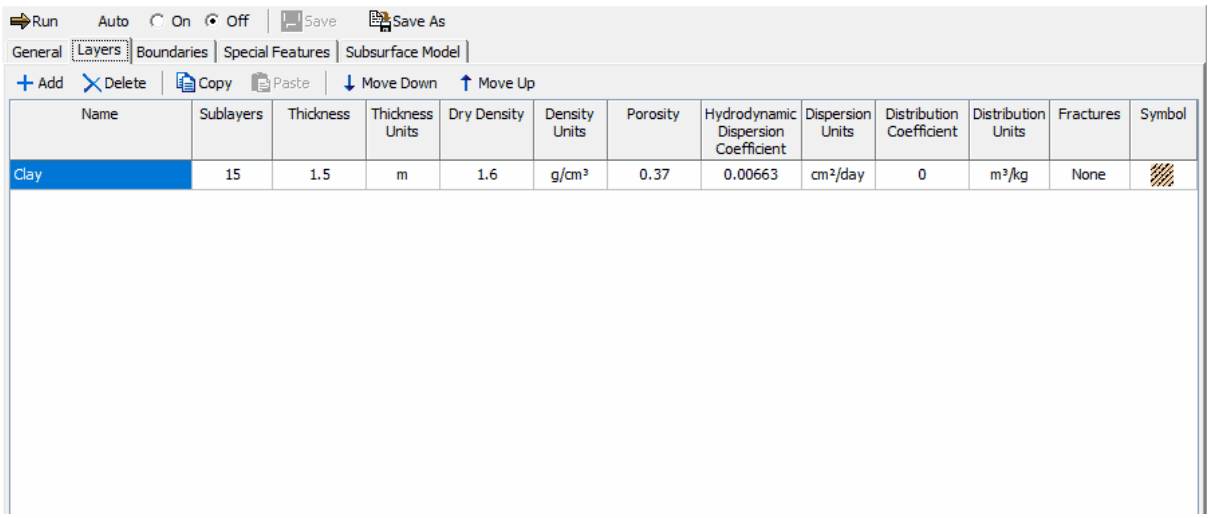
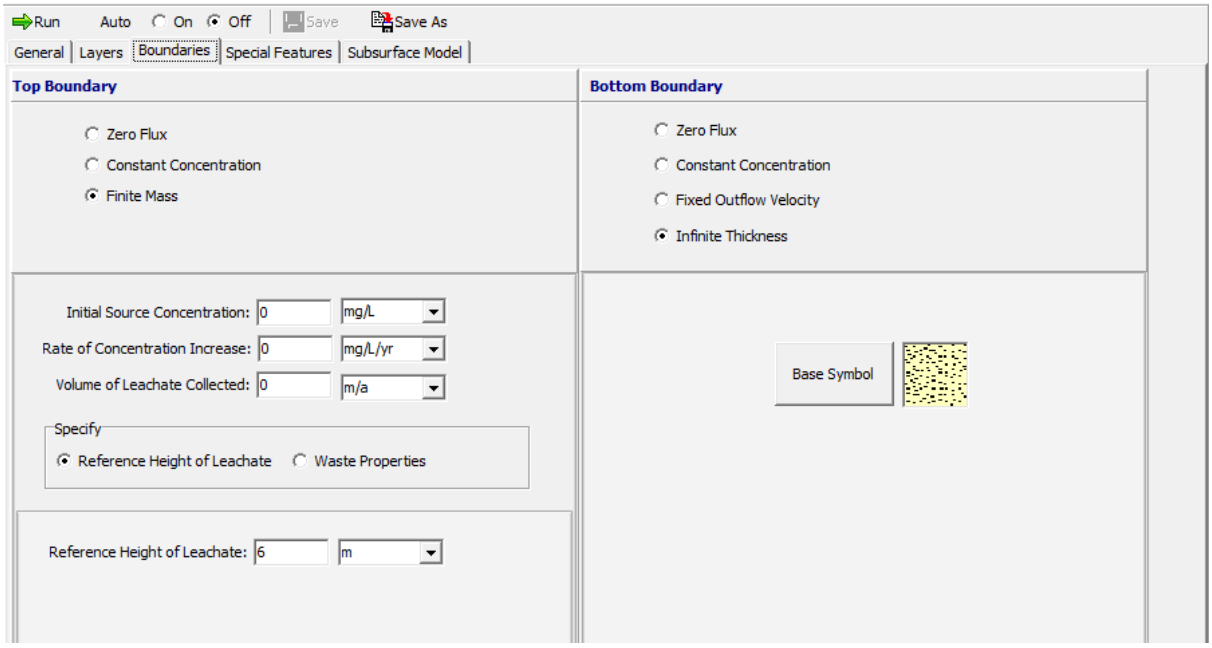


The layer data for the layer can be specified on the Layers tab. Although the clay layer is assumed to be infinite, the concentrations for only the top 1.5 m will be calculated. This is the depth interval where the contaminant plume is expected.

Boundaries Tab



In this example, the top boundary has a finite mass and the bottom boundary is represented by a layer of infinite thickness. If the Time-varying Properties special feature has been selected, any parameters entered for the Finite Mass tab will be ignored and the will be entered in the Time-Varying Properties sub-tab of the Special Features tab.

Special Features

The initial concentration profile and time-varying properties for this example are specified using the Special Features tab.

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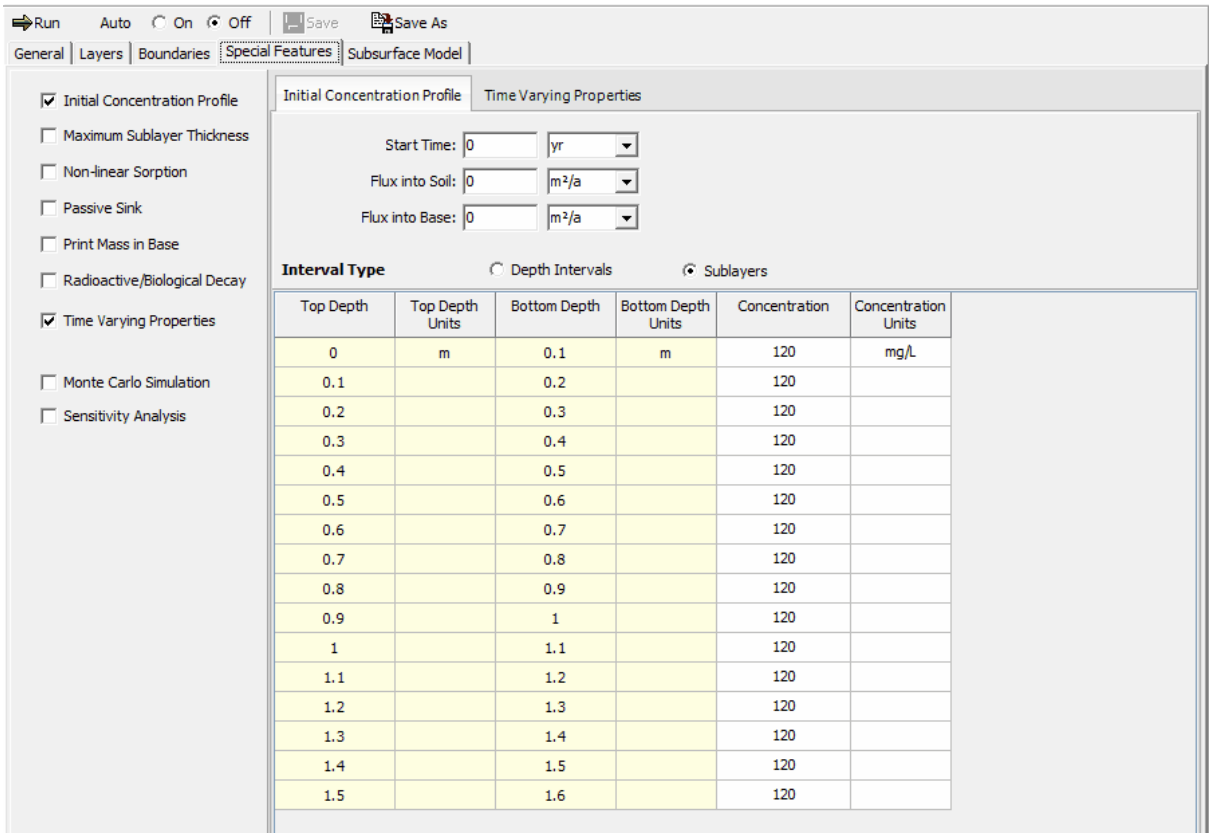
Initial Concentration Profile

To specify the initial concentration profile, check the Initial Concentration Profile box on the Special Features tab. The Concentration Profile sub-tab can be used to specify the type of profile as either Depth Intervals or Sublayers. The concentration profile can be specified as a constant for given depth intervals or as a different value for every sublayer. In this example the background concentration is uniform with depth, and can be specified as a constant 120 mg/L over 1 depth interval.



Top Depth	Top Depth Units	Bottom Depth	Bottom Depth Units	Concentration	Concentration Units
0	m	0.1	m	120	mg/L
0.1		0.2		120	
0.2		0.3		120	
0.3		0.4		120	
0.4		0.5		120	
0.5		0.6		120	
0.6		0.7		120	
0.7		0.8		120	
0.8		0.9		120	
0.9		1		120	
1		1.1		120	
1.1		1.2		120	
1.2		1.3		120	
1.3		1.4		120	
1.4		1.5		120	
1.5		1.6		120	

Time Varying Properties

To specify the time-varying properties, check the Time-Varying Properties box on the Special Features tab. The Time-Varying Data sub-tab can be used to the time periods and whether there are variable layer properties and variable decay. In this example there are 5 time periods viz. 0 to 7 years, 7 to 10 years, 10 to 13 years, 13 to 15 years, and 15 to 19 years.

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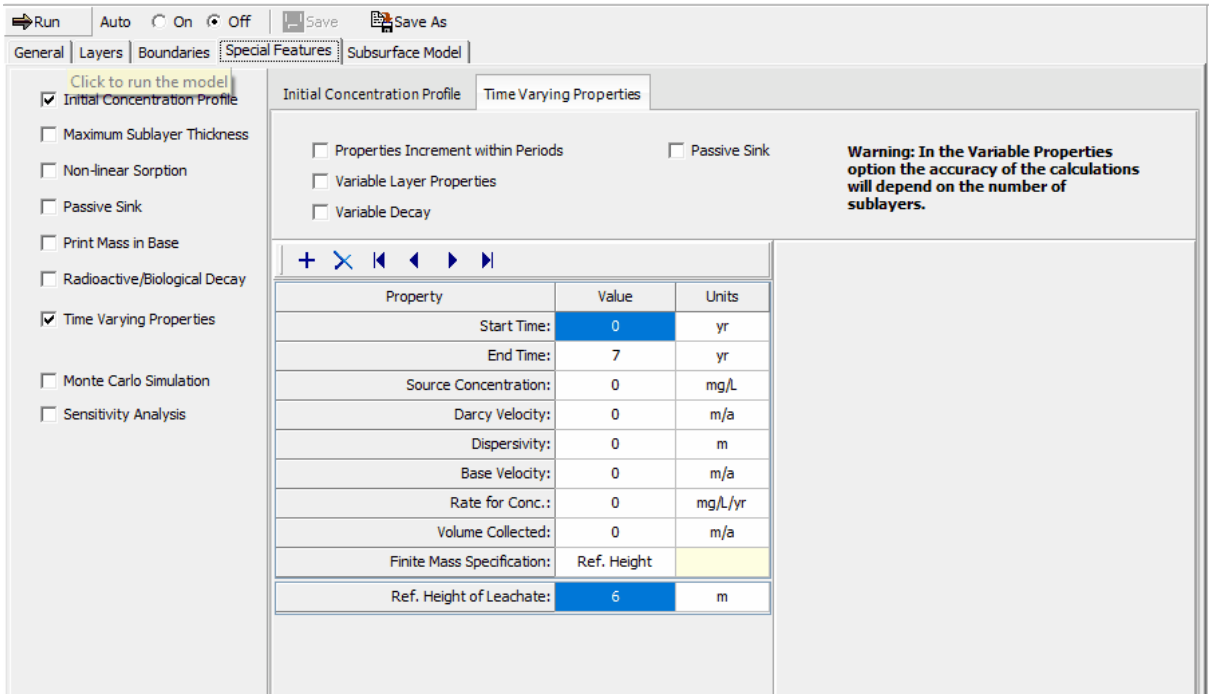
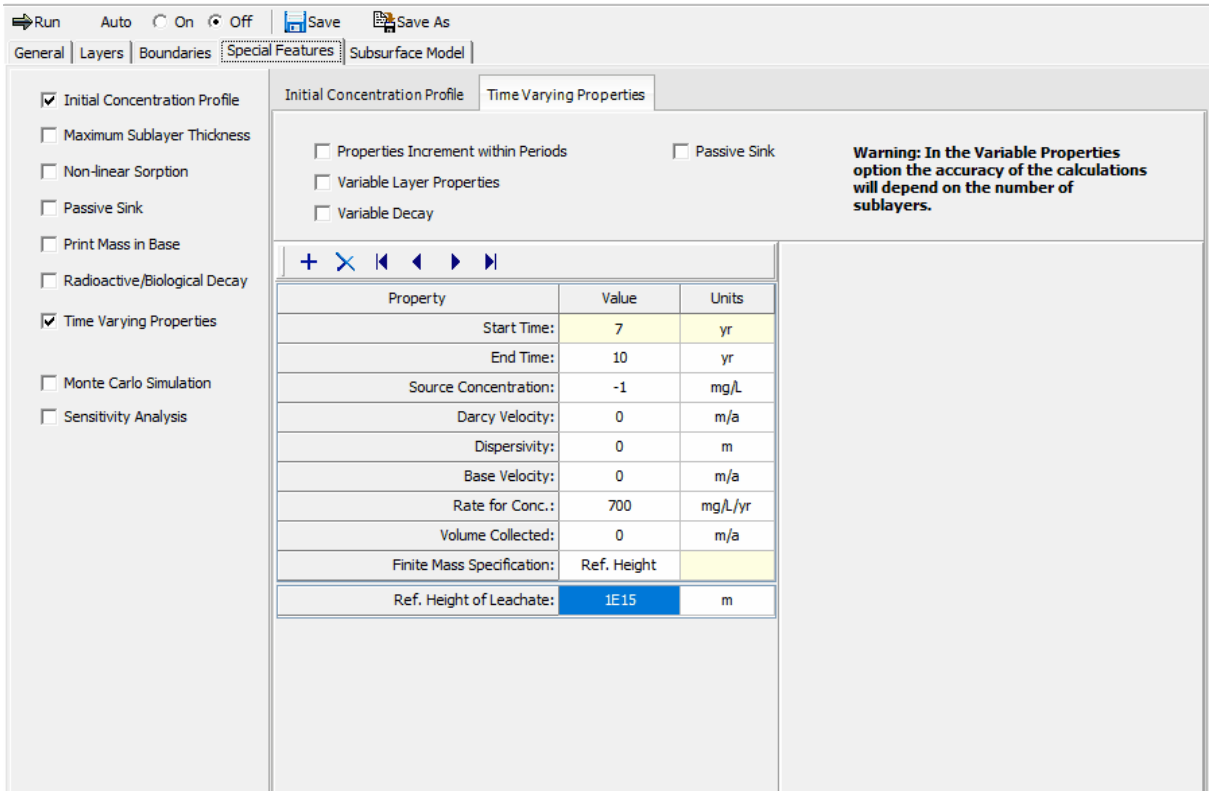


In the first time period, specifying only one time increment means that the concentrations will only be calculated at the end time (i.e., 7 years).The beginning source concentration is zero, since fresh water is initially filling the cell.



The data for time period two can be specified by clicking on the Next button. This time period is from 7

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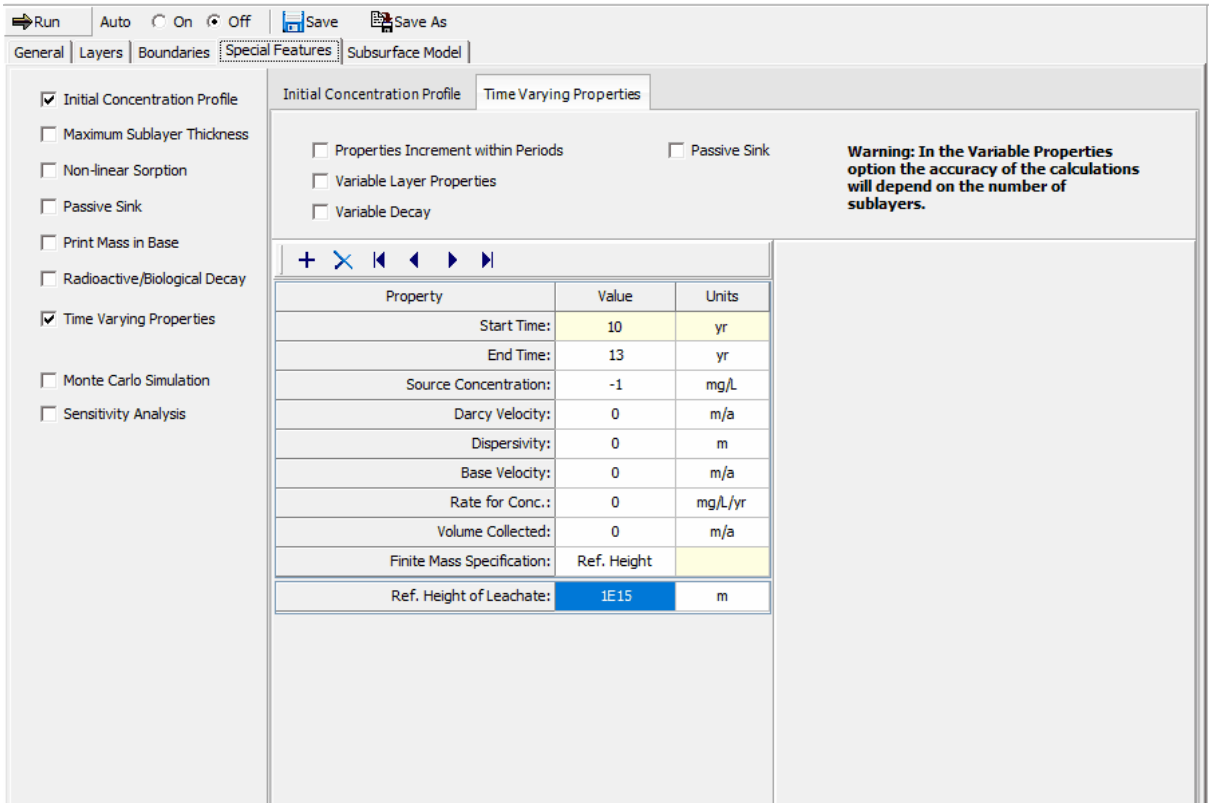
to 10 years. Between the years 7 and 10 the source concentration increases linearly with time at a rate of 700 mg/L per year. Only one time increment is necessary, since we are not interested in calculating the concentrations at any intermediate times. Specifying the source concentration as -1 causes the calculated concentration at the end of the previous period to be used as the concentration at the beginning of this period. The Leachate Reference Height is set very high in order to ignore the effects of source depletion.



Next the data for time period three should be entered, this time period is from 10 to 13 years. During the 3 years between 10 and 13 years the source concentration remains constant. Specifying the beginning concentration as -1 indicates to use the calculated concentration at the end of the previous time period as the concentration at the start of this time period. The Leachate Reference Height is set very high in order to ignore the effects of source depletion.

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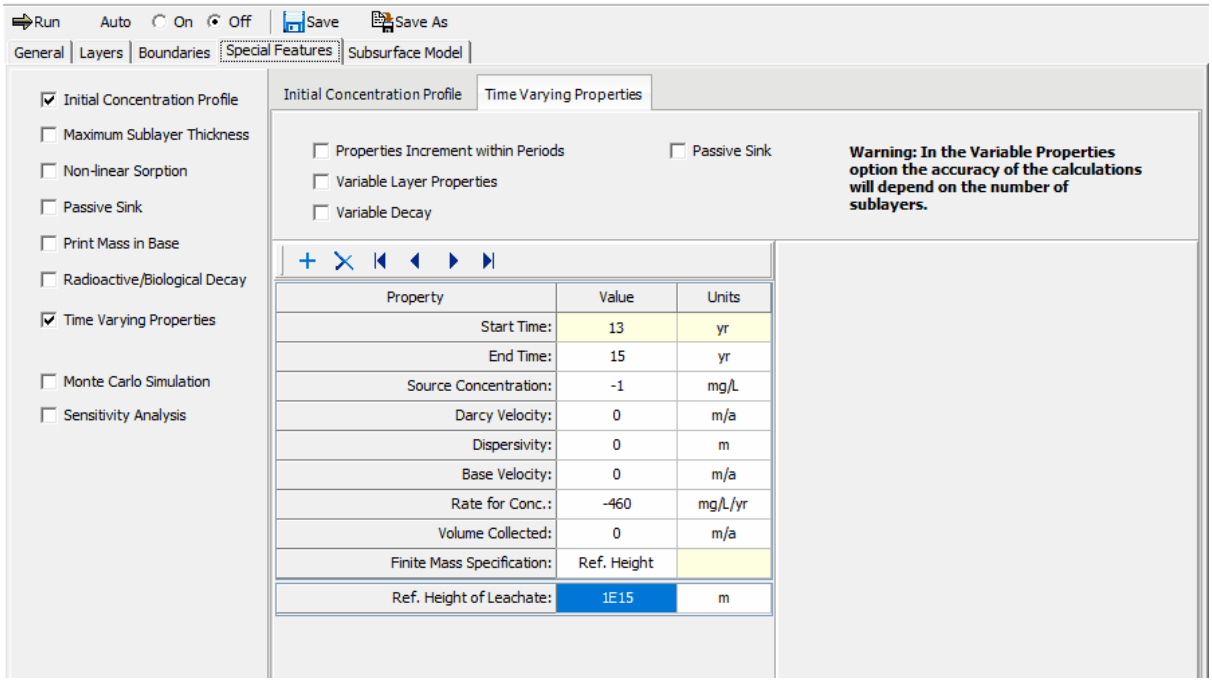
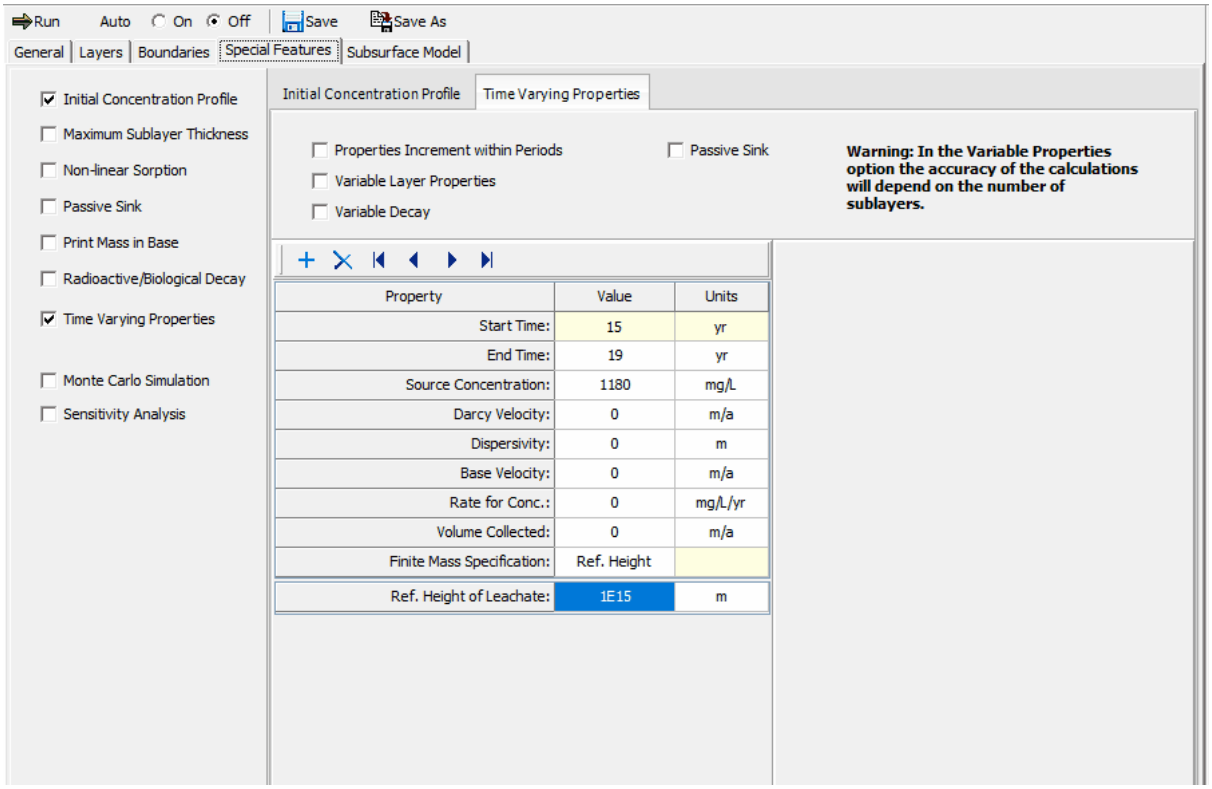


Next the data for time period four should be entered, this time period is from 13 to 15 years. Between the years 13 and 15 the source concentration decreases linearly with time at the rate of 460 mg/L per year. Specifying the beginning concentration as -1 indicates to use the calculated concentration at the end of the previous time period as the concentration at the start of this time period. The Leachate Reference Height is set very high in order to ignore the effects of source depletion.



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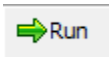
Data for the last time period can be entered by clicking on the Next button, this time period is from 15 to 19 years. For the 4 years between 15 and 19 the source concentration is assumed to remain constant at 1180 mg/L. The Leachate Reference Height is set very high in order to ignore the effects of depletion of the source.

Model Execution



To run the model and calculate the concentrations press the Run button on the toolbar.

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Model Output

After the model has been executed, the output for the model will be displayed.

Depth vs Concentration

The Depth vs Concentration chart can be displayed by selecting the Depth vs Concentration item for the Chart Type.

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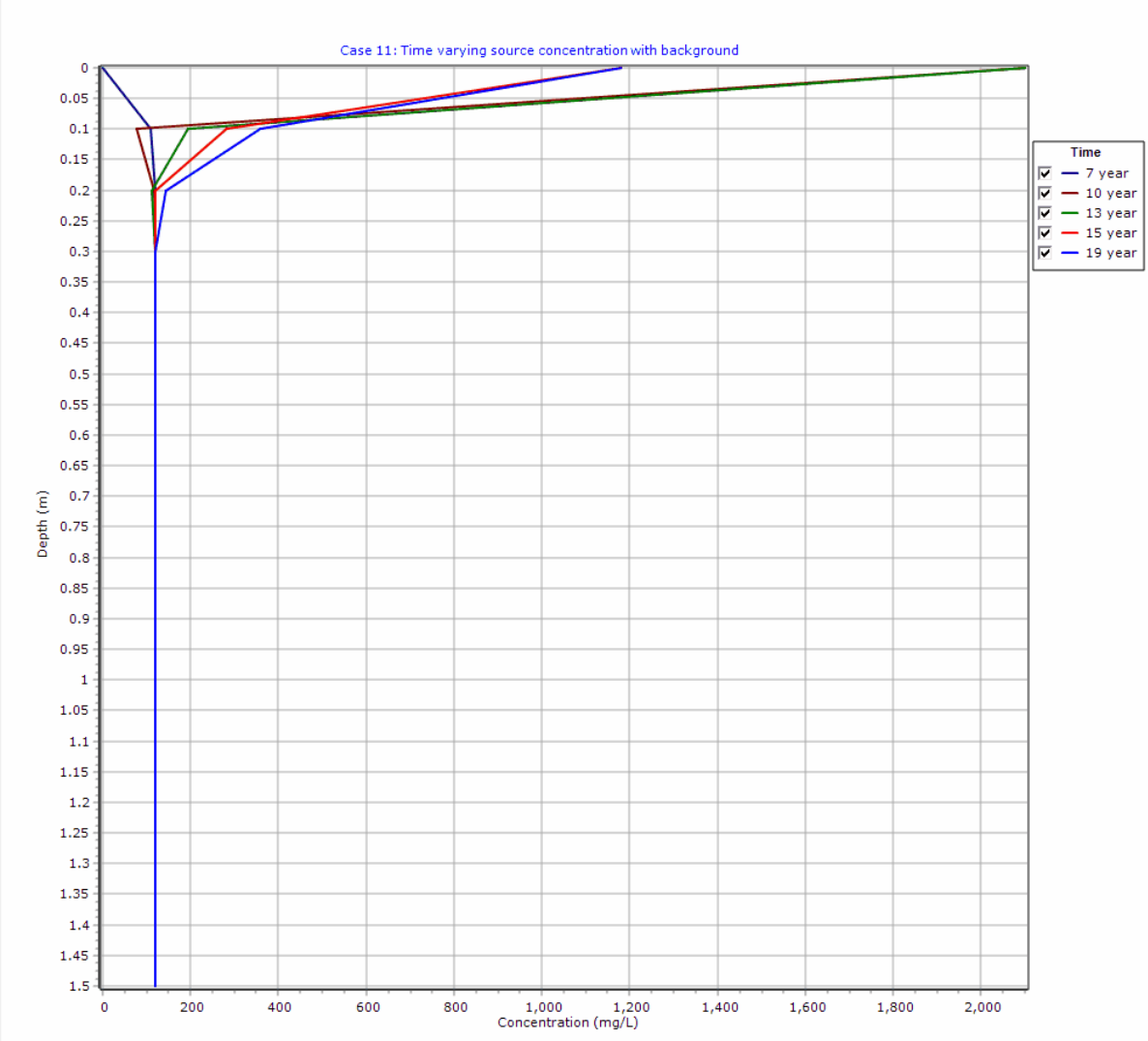

Output Listing

To display the output as a text listing that will show the calculated concentrations as numbers, click on the List tab.

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Case 11: Time varying source concentration with background

THE VARIABLE VELOCITY AND/OR CONCENTRATION OPTION HAS BEEN USED. NOTE THAT THE ACCURACY OF THE CALCULATIONS WITH THIS OPTION WILL DEPEND ON THE NUMBER OF SUBLAYERS USED.

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Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Clay	1.5 m	15	0.00663 cm²/day	0.37	0 m³/kg	1.6 g/cm³

Boundary Conditions

Finite Mass Top Boundary

Infinite Thickness Bottom Boundary

INITIAL CONCENTRATION PROFILE

Time = 0 yr
Flux into Soil = 0 m²/a
Flux into Base = 0 m²/a

Top Depth	Bottom Depth	Concentration
0 m	0.1 m	120 mg/L
0.1 m	0.2 m	120 mg/L
0.2 m	0.3 m	120 mg/L
0.3 m	0.4 m	120 mg/L
0.4 m	0.5 m	120 mg/L
0.5 m	0.6 m	120 mg/L
0.6 m	0.7 m	120 mg/L
0.7 m	0.8 m	120 mg/L
0.8 m	0.9 m	120 mg/L
0.9 m	1 m	120 mg/L
1 m	1.1 m	120 mg/L
1.1 m	1.2 m	120 mg/L
1.2 m	1.3 m	120 mg/L
1.3 m	1.4 m	120 mg/L
1.4 m	1.5 m	120 mg/L
1.5 m	1.6 m	120 mg/L

Variation in Properties with Time

Time Periods with the same Source and Velocity

Period	Start Time	No. of Steps	Time Step	Source Conc	Rate of Change	Height of Leachate	Volume Collected
1	0 yr	1	7 yr	0 mg/L	0	6 m	0 m/a
2	7 yr	1	3 yr	-1 mg/L	700	1E15 m	0 m/a
3	10 yr	1	3 yr	-1 mg/L	0	1E15 m	0 m/a
4	13 yr	1	2 yr	-1 mg/L	-460	1E15 m	0 m/a
5	15 yr	1	4 yr	1180 mg/L	0	1E15 m	0 m/a

Period	Start Time	End Time	Proportion Mass	Dispersivity	Base Velocity
1	0 yr	7 yr	0 m/a	0 m	0 m/a
2	7 yr	10 yr	0 m/a	0 m	0 m/a
3	10 yr	13 yr	0 m/a	0 m	0 m/a
4	13 yr	15 yr	0 m/a	0 m	0 m/a
5	15 yr	19 yr	0 m/a	0 m	0 m/a

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Laplace Transform Parameters

TAU = 7 N = 20 SIG = 0 RNU = 2

Calculated Concentrations at Selected Times and Depths

Time year	Depth m	Concentration mg/L
7	0.000E+00	3.429E-01
	1.000E-01	1.097E+02
	2.000E-01	1.199E+02
	3.000E-01	1.200E+02
	4.000E-01	1.200E+02
	5.000E-01	1.200E+02
	6.000E-01	1.200E+02
	7.000E-01	1.200E+02
	8.000E-01	1.200E+02
	9.000E-01	1.200E+02
	1.000E+00	1.200E+02
	1.100E+00	1.200E+02
	1.200E+00	1.200E+02
	1.300E+00	1.200E+02
	1.400E+00	1.200E+02
	1.500E+00	1.200E+02
10	0.000E+00	2.100E+03
	1.000E-01	7.684E+01
	2.000E-01	1.182E+02
	3.000E-01	1.200E+02
	4.000E-01	1.200E+02
	5.000E-01	1.200E+02
	6.000E-01	1.200E+02
	7.000E-01	1.200E+02
	8.000E-01	1.200E+02
	9.000E-01	1.200E+02
	1.000E+00	1.200E+02
	1.100E+00	1.200E+02
	1.200E+00	1.200E+02
	1.300E+00	1.200E+02
	1.400E+00	1.200E+02
	1.500E+00	1.200E+02
13	0.000E+00	2.100E+03
	1.000E-01	1.935E+02
	2.000E-01	1.117E+02
	3.000E-01	1.197E+02
	4.000E-01	1.200E+02
	5.000E-01	1.200E+02
	6.000E-01	1.200E+02
	7.000E-01	1.200E+02
	8.000E-01	1.200E+02

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	9.000E-01	1.200E+02
	1.000E+00	1.200E+02
	1.100E+00	1.200E+02
	1.200E+00	1.200E+02
	1.300E+00	1.200E+02
	1.400E+00	1.200E+02
	1.500E+00	1.200E+02
15	0.000E+00	1.180E+03
	1.000E-01	2.810E+02
	2.000E-01	1.212E+02
	3.000E-01	1.187E+02
	4.000E-01	1.200E+02
	5.000E-01	1.200E+02
	6.000E-01	1.200E+02
	7.000E-01	1.200E+02
	8.000E-01	1.200E+02
	9.000E-01	1.200E+02
	1.000E+00	1.200E+02
	1.100E+00	1.200E+02
	1.200E+00	1.200E+02
	1.300E+00	1.200E+02
	1.400E+00	1.200E+02
	1.500E+00	1.200E+02
19	0.000E+00	1.180E+03
	1.000E-01	3.584E+02
	2.000E-01	1.442E+02
	3.000E-01	1.196E+02
	4.000E-01	1.198E+02
	5.000E-01	1.200E+02
	6.000E-01	1.200E+02
	7.000E-01	1.200E+02
	8.000E-01	1.200E+02
	9.000E-01	1.200E+02
	1.000E+00	1.200E+02
	1.100E+00	1.200E+02
	1.200E+00	1.200E+02
	1.300E+00	1.200E+02
	1.400E+00	1.200E+02
	1.500E+00	1.200E+02

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