POLLUTE

Version 8

Example 3: Advective Diffusive Transport

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Description

In this example the input data file from Case 2 will be edited to include advective transport and a permeable base stratum (aquifer) with a fixed outflow. The hydrogeology is comprised of a 4 m thick aquitard layer with a constant contaminant concentration in the landfill source at the top, and a 20 m thick underlying aquifer at the base.

Although the aquifer is 20 m thick it is generally unrealistic to model dilution (mixing) of contaminant through the full thickness. The actual thickness that should be modelled depends on the hydrogeologic conditions, the length of monitoring screens, and the local regulations. In this example dilution (mixing) of the contaminant will only be considered in the upper 3m of the aquifer, and hence the aquifer thickness used is h = 3 m.

Since the aquifer (i.e., the contaminant receptor) is being modelled as a boundary condition the actual deposit thickness that is explicitly modelled is the 4 m thick aquitard, and the concentration given in the output at the 4 m depth is the concentration in the upper 3 m of the aquifer. It is assumed that this is uniformly distributed in the 3 m and that no contaminant moved lower than 3 m into the aquifer (if the aquifer thickness, h, were to be increased, the concentration in the aquifer would drop).

In the underlying aquifer the inflow of water beneath the up gradient edge of the landfill is given by a Darcy velocity of 20 m/a.

The “base velocity” is the outflow velocity beneath the down-gradient edge of the landfill and corresponds to the inflow velocity (20 m/a) at the up gradient edge plus the inflow from the landfill.

Based on continuity of flow the initial flow in the aquifer, q_{in}, is given by the inflow velocity (v_{in} = 20 m/a in this example) multiplied by the thickness of the aquifer being considered (h = 3 m in this example) and the width of the landfill (the landfill dimension perpendicular to the direction of groundwater flow, W = 300 m in this example), thus:

$$q_{in} = v_{in} * h * W = 20 * 3 * 300 = 18000 \text{ m}^2/\text{a}$$

The flow into the aquifer from the landfill, q_a, is the downward Darcy velocity (v_a = 0.1 m/a in this case) multiplied by the length (L = 200 m) and width (W = 300 m) of the landfill, thus:

$$q_a = v_a * L * W = 0.1 * 200 * 300 = 6000 \text{ m}^3/\text{a}$$

Hence the outflow at the down-gradient edge of the landfill is:

$$q_{out} = q_{in} + q_a = 18000 + 6000 = 24000 \text{ m}^3/\text{a}$$

And the “Base Outflow Velocity”, v_b, is the outflow divided by the width of the landfill (W = 300 m) and the thickness of the aquifer being considered (h = 3 m), therefore:

$$v_b = q_{out} / (W * h) = 24000 / (3 * 300) = 26.67 \text{ m/a}$$

The following parameter are assumed for the example:

Property	**Symbol**	**Value**	**Units**
Darcy Velocity	v_a	0.1	m/a
Diffusion Coefficient	D	0.01	m^2/a
Distribution Coefficient	K_d	0	cm^3/g
Soil Porosity	n	0.4	-
Dry Density		1.5	g/cm^3

Soil Layer Thickness	H	4	m
Number of Sub-layers		4	-
Source Concentration	c_b	1	g/L
Landfill Length	L	200	m
Landfill Width	W	300	m
Thickness of Aquifer	h	3	m
Porosity of Aquifer	n_b	0.3	
Base Outflow Velocity	v_b	26.67	m/a

The landfill length (L) is measured in the direction parallel to groundwater flow. And the landfill width (W) is the direction perpendicular to groundwater flow, since this is not a 3D analysis this parameter has no effect on the results.

Warning: The evaluation of the base flow velocity, v_b, requires consideration of the local hydrogeology and the potential effect of the proposed landfill on flow conditions. For some situations, the aquitard has sufficiently low hydraulic conductivity and the aquifer has sufficiently high transmissivity that simple hand continuity calculations as indicated above are appropriate. In other cases some more sophisticated flow models may be required. The parameters used in any modeling should be selected by a hydrogeologist/engineer with sufficient knowledge and experience to understand the existing flow system and the flow system that is likely to exist after the landfill construction.

Note: The concentration at 4 m is the concentration at the bottom of the aquitard and in the 3 m thick aquifer part of the aquifer beneath the landfill. This example was selected to have a downward flow (v_a = 0.1 m/a) so large that advection controls and in fact for the constant source boundary condition it is possible to calculate the peak impact in the aquifer from a simple hand calculation, viz.

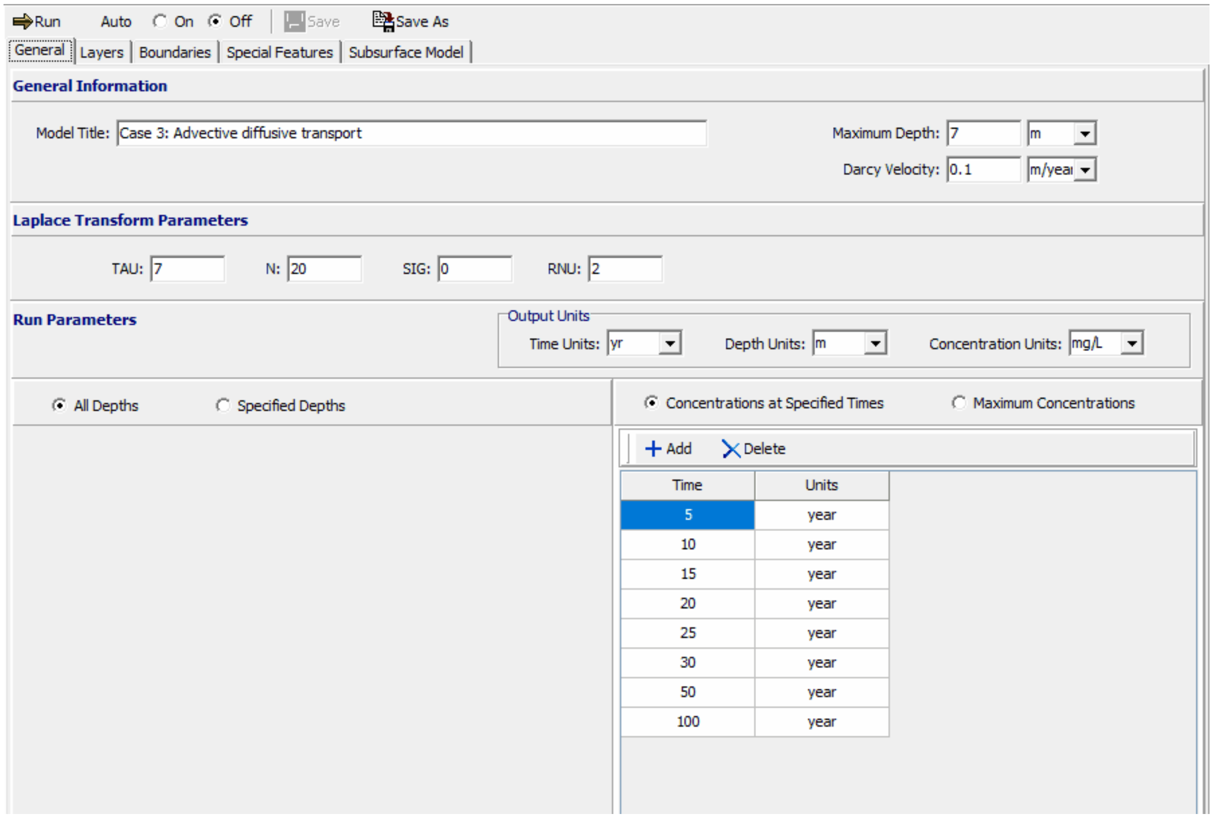
$c_{max} = q_a * c_o / q_{out} = 6000 * 1 / 24000 = 0.25$ g/L

[As an exercise the user may wish to repeat the calculation for va = 0.005 m/a, vb = 20.34 m/a. Based on the simple hand calculation above, this would give cmax = 0.0164 g/L = 16.4 mg/L.]

Data Entry

Open the Examples project and open Case 3.

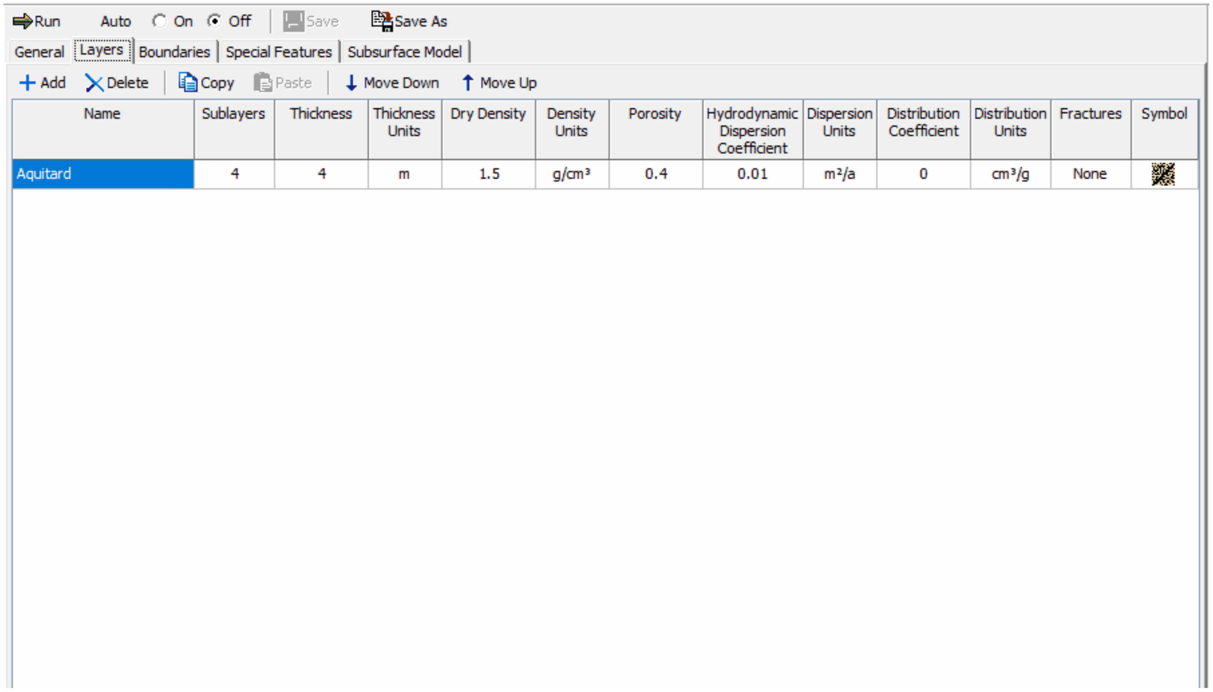
General Tab



On the General tab above the Darcy velocity of 0.1 m/a can be specified. The run parameters for this model is the same as that in Case 2.

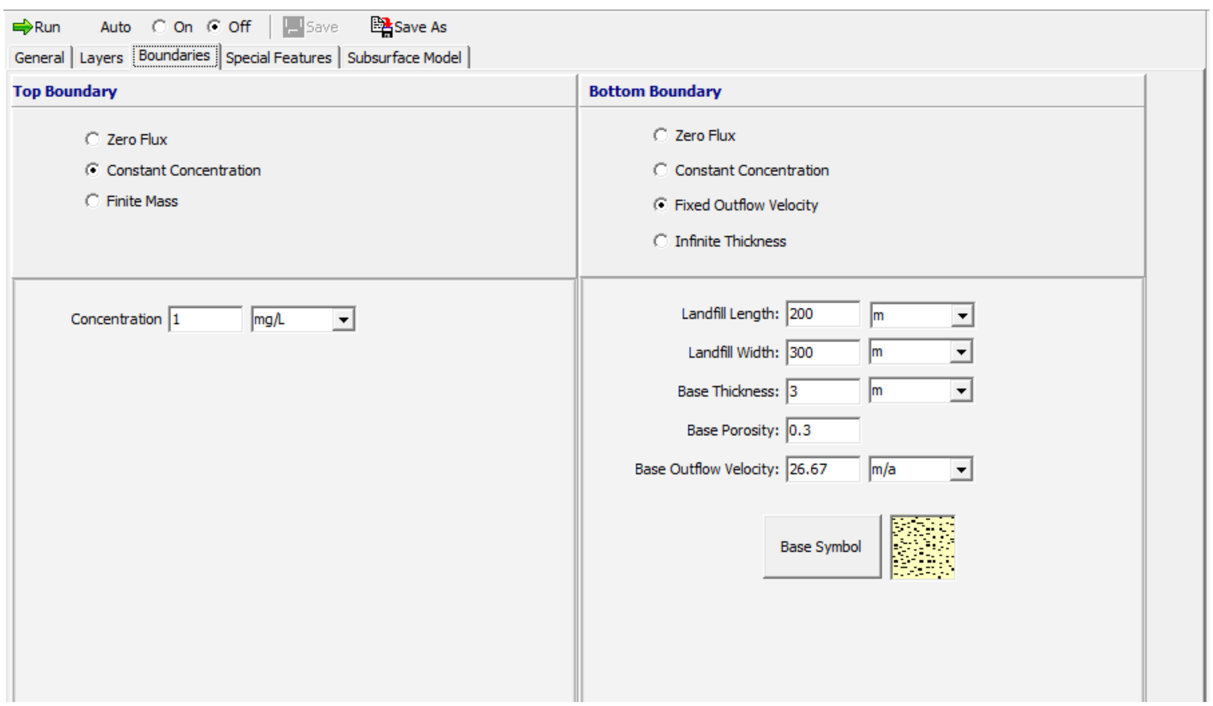
The run parameters for this model are specified at the bottom of the tab. In this example the automatic search for the peak base concentration option is going to be used. The search depth will be 4 m (the bottom of the layer) and the lower and upper time limits will be 25 and 400 years.

Layers Tab



The layer data for this model is the same as that in Case 2.

Boundaries Tab



The boundary conditions for the model can be specified on the Boundaries tab. In this example, the top boundary has a constant concentration of 1 and the bottom boundary is represented as an aquifer with a fixed outflow velocity as shown on the Boundary Condition form below.

Model Execution

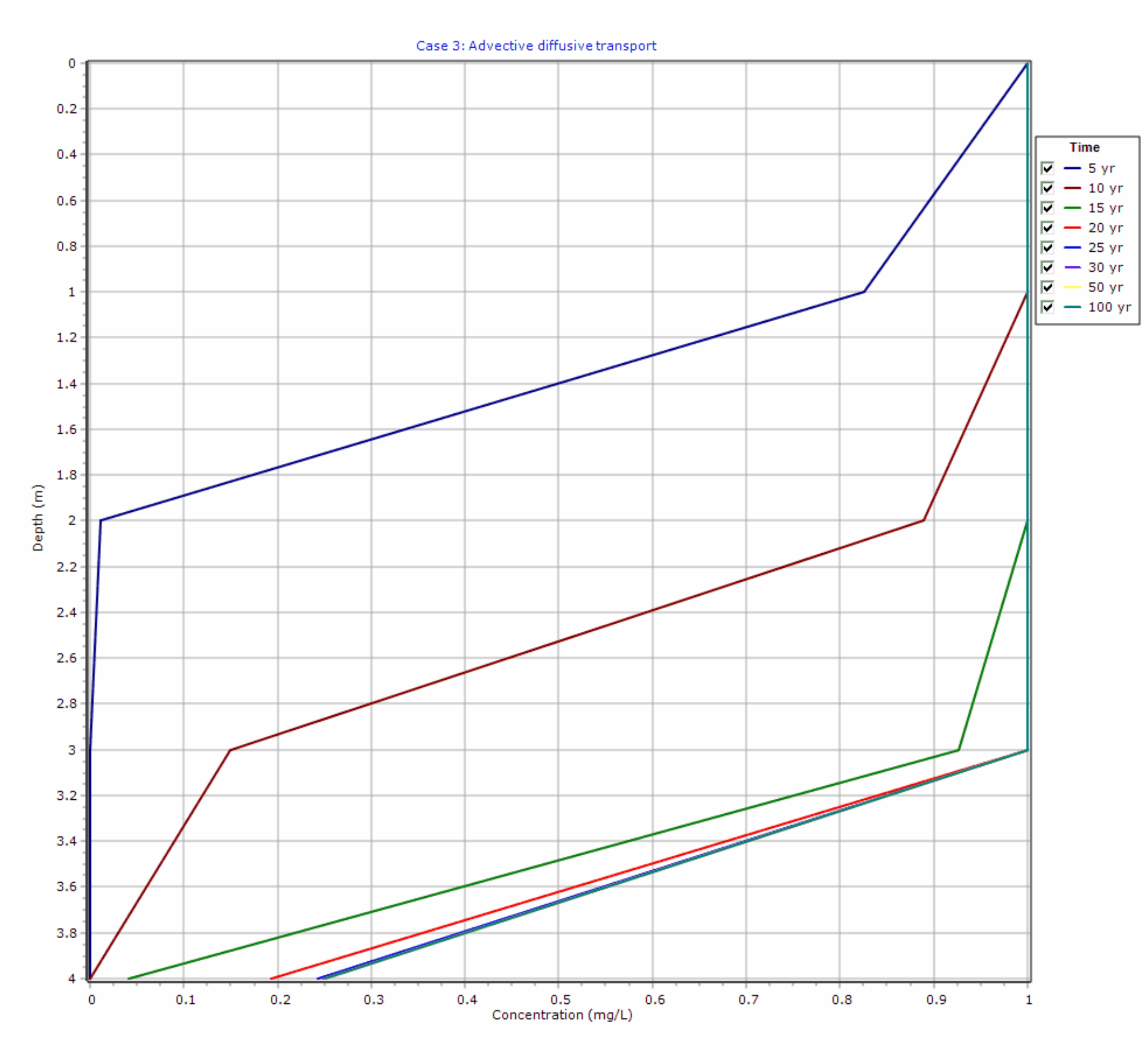
To run the model and calculate the concentrations press the Run button on the toolbar.

Model Output

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

Concentration vs Depth

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



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 3: Advective diffusive transport

THE DARCY VELOCITY (Flux) THROUGH THE LAYERS Va = 0.1 m/year

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Aquitard	4 m	4	0.01 m^2/a	0.4	0 cm^3/g	1.5 g/cm^3

Boundary Conditions

Constant Concentration

Source Concentration = 1 mg/L

Fixed Outflow Bottom Boundary

Landfill Length = 200 m
Landfill Width = 300 m
Base Thickness = 3 m
Base Porosity = 0.3
Base Outflow Velocity = 26.67 m/a

Laplace Transform Parameters

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

Calculated Concentrations at Selected Times and Depths

Time yr	Depth m	Concentration mg/L
5	0.000E+00	1.000E+00
	1.000E+00	8.257E-01
	2.000E+00	1.116E-02
	3.000E+00	2.255E-08
	4.000E+00	6.655E-11
10	0.000E+00	1.000E+00
	1.000E+00	9.998E-01
	2.000E+00	8.892E-01
	3.000E+00	1.490E-01
	4.000E+00	2.805E-05
15	0.000E+00	1.000E+00
	1.000E+00	1.000E+00
	2.000E+00	9.995E-01
	3.000E+00	9.271E-01
	4.000E+00	4.101E-02
20	0.000E+00	1.000E+00
	1.000E+00	1.000E+00
	2.000E+00	1.000E+00
	3.000E+00	9.994E-01
	4.000E+00	1.930E-01
25	0.000E+00	1.000E+00
	1.000E+00	1.000E+00

	2.000E+00	1.000E+00
	3.000E+00	1.000E+00
	4.000E+00	2.426E-01
30	0.000E+00	1.000E+00
	1.000E+00	1.000E+00
	2.000E+00	1.000E+00
	3.000E+00	1.000E+00
	4.000E+00	2.491E-01
50	0.000E+00	1.000E+00
	1.000E+00	1.000E+00
	2.000E+00	1.000E+00
	3.000E+00	1.000E+00
	4.000E+00	2.500E-01
100	0.000E+00	1.000E+00
	1.000E+00	1.000E+00
	2.000E+00	1.000E+00
	3.000E+00	1.000E+00
	4.000E+00	2.500E-01

NOTICE