

POLLUTE

Version 8

Example 14: Primary and Secondary Collection



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Description

In this example a landfill with both a primary and a secondary leachate collection system is modelled using the Passive Sink special feature. The landfill contains a finite mass of a conservative contaminant species, and is underlain by an aquifer with fixed outflow. A passive sink is used to model the secondary leachate collection system, which is assumed to be composed of a 0.3 m thick granular layer. The Darcy velocity is assumed to be 0.01 m/a downward from the landfill to the secondary leachate collection system, and 0.0 m/a between the secondary leachate collection system and the aquifer (i.e., the water table is assumed to be at the base of the secondary leachate collection system).

The analysis starts at time zero which corresponds to the completion of the landfill and the development of a peak leachate concentration (c_o) of 1000 mg/L. It is assumed that the average waste thickness is 6.25 m with a density of 600 kg/m³, and that the contaminant represents 0.2% of the total mass of the waste. Thus the total mass of contaminant per unit area of landfill is:

$$m_{tc} = 0.002 * 600 * 6.25 = 7.5 \text{ kg/m}^2$$

The Reference Height of Leachate (H_r) is then calculated by dividing the total mass of contaminant per unit area (m_{tc}) by the contaminant concentration (c_o).

$$H_r = 0.002 * 600 * 6.25 / 1 = 7.5 \text{ m}$$

It is also assumed that the peak concentration in the landfill is reached relatively early in the life of the landfill, and that the analysis starts at this time. Consequently there is no increase in concentration with time and the Rate of Increase in Concentration (cr) with time is zero.

The average infiltration through the cover (q_o) is assumed to be 0.3 m/a. If the average exfiltration through the base of the landfill (v_a) is 0.01 m/a, then the Volume of Leachate Collected is:

$$Q_c = q_o - v_a = 0.3 - 0.01 = 0.29 \text{ m/a}$$

The strata beneath the landfill consists of a 1 m clay layer, a 0.3 m granular layer (i.e., secondary leachate collection system), a 2 m aquitard layer, underlain by a 1 m thick aquifer. The landfill is assumed to be 200 m long in the direction parallel to the groundwater flow in the aquifer. At the up gradient edge of the landfill the inflow in the aquifer is given by a Darcy velocity of 4 m/a.

The outflow Darcy velocity at the down gradient edge of the landfill (v_b) is then by multiplying the landfill length (200 m) by the Darcy velocity below the secondary leachate collection system (0.0 m/a) and adding the inflow, viz:

$$v_b = 4 + 200 / 1 * v_a = 4 \text{ m/a}$$

When using the Passive Sink Properties special feature the deposit is divided into layers which can have vertical and horizontal flows. In the example 3 layers are necessary, the first is from the base of the landfill to the top of the secondary leachate collection system, the second is the secondary leachate collection system, and the third is from the base of the secondary leachate collection system to the aquifer. In the first layer there is a vertical downwards Darcy velocity of 0.01 m/a and no horizontal flow. The second layer has a horizontal flow which is equal to the difference in Darcy velocity between the layers above and below, multiplied by the landfill length and divided by the layer thickness, viz:

$$v_s = (v_{a1} - v_{a2}) * L / h = (0.01 - 0.0) * 200 / 0.3 = 6.67 \text{ m/a}$$

In the third layer there is no vertical or horizontal advective flow, there will however still be diffusive flow.

Following are the parameters used in this example:

Property	Symbol	Value	Units
Darcy Velocity	v_a	variable	m/a
Sink Outflow Velocity	v_s	variable	m/a
Diffusion Coefficient	D	variable	m ² /a
Distribution Coefficient	K_d	0	cm ³ /g
Soil Porosity	n	0.4	-
Granular Layer Porosity	<u>n</u>	0.3	-
Dry Density		1.5	g/cm ³
Layer 1 Thickness	H	1	m
Layer 2 Thickness	H	0.3	m
Layer 3 Thickness	H	2	m
Source Concentration	c_0	1000	mg/L
Ref. Height of Leachate	H_r	7.5	m
Vol. of Leachate Collected	Q_c	0.29	m/a
Landfill Length	L	200	m
Landfill Width	W	1	m
Aquifer Thickness	h	1	m
Aquifer Porosity	n_b	0.3	-
Aquifer Outflow Velocity	v_b	4	m/a

This example is for a hypothetical landfill and is used to illustrate how to prepare an input file and run an analysis using the Passive Sink option. The example is not a prescription for modeling contaminant migration during operation of a landfill. Each landfill has its own unique characteristics and no general prescription can be made. The Passive Sink option should only be used by someone with the hydro-geotechnical background necessary to appreciate the subtleties associated with the physical situation and the steps necessary for appropriate modeling of this physical situation.

Data Entry

Open the Examples project and open Case 14.

General Tab

Run Auto On Off Save Save As

General Layers Boundaries Special Features Subsurface Model

General Information

Model Title: Case 14: Primary and Secondary Leachate Collection

Maximum Depth: 4.3 m

Darcy Velocity: 1 m/year

Laplace Transform Parameters

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

Run Parameters

Output Units

Time Units: year Depth Units: m Concentration Units: mg/L

☒ All Depths ☐ Specified Depths

☒ Concentrations at Specified Times ☐ Maximum Concentrations

+ Add X Delete

Time	Units
10	year
25	year
50	year
100	year
150	year

The general data for this example can be specified on the General tab. In this example the Darcy velocity will be ignored, the Darcy velocity will be read during the input of the Passive Sink parameters. The concentrations can either be calculated at specified times or the time of the maximum concentration can be found. In this example the concentrations will be calculated at 10, 25, 50, 100, and 150 years.

Layers Tab

Run Auto On Off Save Save As

General Layers Boundaries Special Features Subsurface Model

+ A Click to run the model Copy Paste Move Down Move Up

Name	Sublayers	Thickness	Thickness Units	Dry Density	Density Units	Porosity	Hydrodynamic Dispersion Coefficient	Dispersion Units	Distribution Coefficient	Distribution Units	Fractures	Symbol
Clay	4	1	m	1.5	g/cm ³	0.4	0.02	m ² /a	0	m ³ /kg	None	
Collection System	4	0.3	m	1.5	g/cm ³	0.3	10	m ² /a	0	m ³ /kg	None	
Aquitard	4	2	m	1.5	g/cm ³	0.4	0.02	m ² /a	0	m ³ /kg	None	

The layer data for the 3 layers can be specified on the Layers tab.

Boundaries Tab

The screenshot shows the 'Boundaries' tab in a software application. The interface is divided into two main sections: 'Top Boundary' and 'Bottom Boundary'.

Top Boundary:

- Radio buttons: ☐ Zero Flux, ☐ Constant Concentration, ☒ Finite Mass.
- Initial Source Concentration: 1000 mg/L
- Rate of Concentration Increase: 0 mg/L/yr
- Volume of Leachate Collected: 0.29 m/a
- Specify: ☒ Reference Height of Leachate, ☐ Waste Properties
- Reference Height of Leachate: 7.5 m

Bottom Boundary:

- Radio buttons: ☐ Zero Flux, ☐ Constant Concentration, ☒ Fixed Outflow Velocity, ☐ Infinite Thickness.
- Landfill Length: 200 m
- Landfill Width: 1 m
- Base Thickness: 1 m
- Base Porosity: 0.3
- Base Outflow Velocity: 4 m/a
- Base Symbol: [Yellow textured square icon]

The boundary conditions for the model can be specified on the Boundaries tab. In this example the top boundary has a finite mass and the bottom boundary is represented by a fixed outflow aquifer.

Special Features

The passive sink data for this model can be entered using the Passive Sink feature on the Special Features tab.

Passive Sink

When the Passive Sink option is selected the depths and whether there is a phase change or inflow can be specified. In this example there are 3 depth intervals. The first depth interval is for the clay liner, the second for the secondary leachate collection system, and the third for the aquitard.

Run Auto On Off Save Save As

General Layers Boundaries **Special Features** Subsurface Model

☐ Initial Concentration Profile
☐ Maximum Sublayer Thickness
☐ Non-linear Sorption
☒ Passive Sink
☐ Print Mass in Base
☐ Radioactive/Biological Decay
☐ Time Varying Properties
☐ Monte Carlo Simulation
☐ Sensitivity Analysis

Passive Sink

Inflow Rate
☒ No ☐ Yes

Phase Change
☒ No ☐ Yes

Interval Type
☒ Depth Intervals ☐ Layers

+ Add X Delete

Top Depth	Top Depth Units	Bottom Depth	Bottom Depth Units	Darcy Velocity	Darcy Velocity Units	Rate of Removal	Rate of Removal Units
0	m	1	m	0.01	m/a	0	m/a
1	m	1.3	m	0.01	m/a	6.67	m/a
1.3	m	3.3	m	0	m/a	0	m/a

Model Execution



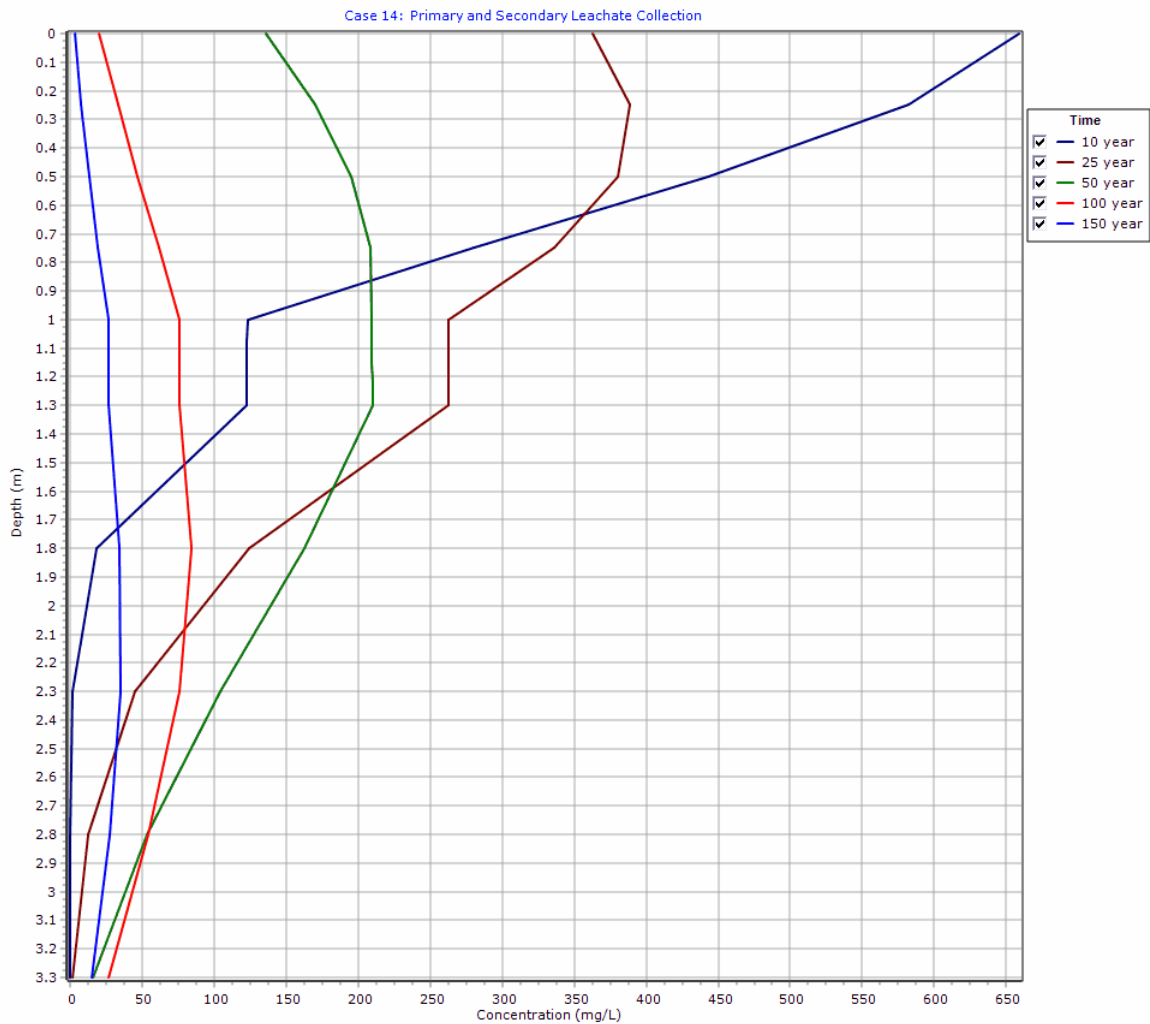
To run the model and calculate the concentrations press the Run button on the toolbar.

Model Output

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

Depth vs Concentration

The Depth vs Concentration chart can be displayed by selecting the Depth vs Concentration 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 14: Primary and Secondary Leachate Collection

THE PASSIVE SINK OPTION HAS BEEN USED. NOTE THE USER IS RESPONSIBLE FOR ENSURING THAT VELOCITY CHANGES ARE CONSISTENT WITH THE PASSIVE SINK.

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distribution Coefficient	Dry Density
Clay	1 m	4	0.02 m ² /a	0.4	0 m ³ /kg	1.5 g/cm ³
Collection System	0.3 m	4	10 m ² /a	0.3	0 m ³ /kg	1.5 g/cm ³
Aquitard	2 m	4	0.02 m ² /a	0.4	0 m ³ /kg	1.5 g/cm ³

Boundary Conditions

Finite Mass Top Boundary

Initial Concentration = 1000 mg/L
 Rate of Increase = 0 mg/L/yr
 Volume of Leachate Collected = 0.29 m/a
 Thickness of Waste = 0 m
 Waste Density = 0 g/cm³
 Proportion of Mass = 0
 Volumetric Water Content = 0
 Conversion Rate Half Life = 0 year
 Reference Height of Leachate = 7.5 m

Fixed Outflow Bottom Boundary

Landfill Length = 200 m
 Landfill Width = 1 m
 Base Thickness = 1 m
 Base Porosity = 0.3
 Base Outflow Velocity = 4 m/a

Velocity and Sink Profile

Time Period	Minimum Depth	Maximum Depth	Vertical Velocity	Horizontal Outflow
01	0 m	1 m	0.01 m/a	0 m/a
	1 m	1.3 m	0.01 m/a	6.67 m/a
	1.3 m	3.3 m	0 m/a	0 m/a

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
10	0.000E+00	6.589E+02
	2.500E-01	5.818E+02
	5.000E-01	4.425E+02
	7.500E-01	2.803E+02
	1.000E+00	1.231E+02
	1.075E+00	1.230E+02
	1.150E+00	1.229E+02
	1.225E+00	1.228E+02

	1.300E+00	1.228E+02
	1.800E+00	1.873E+01
	2.300E+00	1.587E+00
	2.800E+00	7.432E-02
	3.300E+00	5.162E-04
25	0.000E+00	3.627E+02
	2.500E-01	3.891E+02
	5.000E-01	3.801E+02
	7.500E-01	3.364E+02
	1.000E+00	2.632E+02
	1.075E+00	2.631E+02
	1.150E+00	2.631E+02
	1.225E+00	2.630E+02
	1.300E+00	2.630E+02
	1.800E+00	1.245E+02
	2.300E+00	4.525E+01
	2.800E+00	1.254E+01
	3.300E+00	1.337E+00
50	0.000E+00	1.363E+02
	2.500E-01	1.698E+02
	5.000E-01	1.948E+02
	7.500E-01	2.086E+02
	1.000E+00	2.097E+02
	1.075E+00	2.097E+02
	1.150E+00	2.098E+02
	1.225E+00	2.098E+02
	1.300E+00	2.098E+02
	1.800E+00	1.627E+02
	2.300E+00	1.040E+02
	2.800E+00	5.353E+01
	3.300E+00	1.598E+01
100	0.000E+00	2.019E+01
	2.500E-01	3.310E+01
	5.000E-01	4.699E+01
	7.500E-01	6.133E+01
	1.000E+00	7.553E+01
	1.075E+00	7.554E+01
	1.150E+00	7.556E+01
	1.225E+00	7.558E+01
	1.300E+00	7.560E+01
	1.800E+00	8.454E+01
	2.300E+00	7.584E+01
	2.800E+00	5.456E+01
	3.300E+00	2.635E+01
150	0.000E+00	3.300E+00
	2.500E-01	7.810E+00
	5.000E-01	1.322E+01
	7.500E-01	1.948E+01
	1.000E+00	2.649E+01
	1.075E+00	2.649E+01

	1.150E+00	2.650E+01
	1.225E+00	2.651E+01
	1.300E+00	2.652E+01
	1.800E+00	3.452E+01
	2.300E+00	3.469E+01
	2.800E+00	2.753E+01
	3.300E+00	1.491E+01

NOTICE

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