

# POLLUTE

Version 8

## Example 17: Landfill with Composite Primary Liner



© 2021 GAEA Technologies Ltd.

**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**

# POLLUTE

Version 8

© 2021 GAEA Technologies Ltd.

All rights reserved. No parts of this work may be reproduced in any form or by any means - graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems - without the written permission of GAEA Technologies.

Products that are referred to in this document may be either trademarks and/or registered trademarks of the respective owners. GAEA Technologies makes no claim to these trademarks.

While every precaution has been taken in the preparation of this document, GAEA Technologies assumes no responsibility for errors or omissions, or for damages resulting from the use of information contained in this document or from the use of programs that may accompany it. In no event shall GAEA Technologies be liable for any loss of profit or any other commercial damage caused or alleged to have been caused directly or indirectly by this document.

Printed: September 2021 in Canada.

## Description

This example demonstrates how to create a landfill with a composite primary liner, primary and secondary leachate collection systems, and a compacted clay secondary liner. The composite primary liner is composed of a 60 mil (1.5 mm) geomembrane in good contact with a 0.9 m thick compacted clay liner. Small holes with an area of 0.1 cm<sup>2</sup> and a frequency of 2.5 per hectare (1 per acre) are assumed for the geomembrane. The method proposed by Giroud et al (1992) is used to calculate the flow (leakage) through the composite liner, these calculations are performed automatically by POLLUTE. Below the composite primary liner is a 0.3 m thick granular secondary leachate collection system, overlying a 0.9 m thick compacted clay secondary liner. There is a 3 m thick aquitard under the secondary liner, which overlies a 3 m thick aquifer.

The landfill has a length (L) of 200 m in the direction parallel to groundwater flow in the underlying aquifer. Consideration is being given to a volatile organic contaminant with an initial source concentration of 1500 µg/L, which is assumed to remain constant with time over the time period being examined in this example. The leachate head on the composite primary liner is assumed to be constant at 0.3 m, the head on the secondary liner is assumed to be 0.3 m, and the groundwater level relative to the top of the aquifer is assumed to be 3 m (i.e., at the top of the aquitard).

The flow in the aquifer must be established based on hydrogeologic data and is represented in terms of the horizontal Darcy velocity (the "Base Outflow Velocity") in the aquifer at the down-gradient edge of the landfill (see Example 3 for more discussion of Base Outflow Velocity and Aquifer thickness).

The parameters used for this example are listed below:

Property	Symbol	Value	Units
Geomembrane Contact		Good	-
Geomembrane Holes		Circles	-
Hole Area		0.1	cm <sup>2</sup>
Hole Frequency		1	/acre
Geomembrane Thickness		60	mil
Geomembrane Diffusion Coef.		3.0x10 <sup>-5</sup>	m <sup>2</sup> /a
Source Concentration	c <sub>0</sub>	1500	µg/L
Source Type		Constant	-
Landfill Length	L	200	m
Leachate Head on Primary Liner		0.3	m
Leachate Head on Secondary Liner		0.3	m
Groundwater level in Aquifer		3	m
Clay Thickness	H	0.9	m
Clay Diffusion Coef.	D	0.02	m <sup>2</sup> /a
Clay Distribution Coef.	K <sub>d</sub>	0.5	mL/g
Clay Hydraulic Conductivity	k	1.0x10 <sup>-9</sup>	m/s
Clay Porosity	n	0.35	-
Clay Dry Density		1.9	g/cm <sup>3</sup>
Collection System Thickness	H	0.3	m
Collection System Dispersion Coef.		100	m <sup>2</sup> /a
Collection System Density		1.9	g/cm <sup>3</sup>
Collection System Distr. Coef.	K <sub>d</sub>	0	mL/g
Collection System Porosity	n	0.3	-
Aquitard Thickness	H	3	m

Aquitard Hydraulic Conductivity	k	$1.0 \times 10^{-5}$	m/s
Aquitard Diffusion Coef.	D	0.02	$\text{m}^2/\text{a}$
Aquitard Dry Density		1.9	$\text{g}/\text{cm}^3$
Aquitard Distribution Coef.	$K_d$	0	$\text{mL}/\text{g}$
Aquitard Porosity	n	0.35	-
Aquifer Thickness	h	3	m
Aquifer Porosity	$n_b$	0.3	-
Base Outflow Velocity	$v_b$	10	m/s

## Data Entry

Open the Examples project and open Case 17. The data for this type of model is entered differently than the previous models, since it was created using the Primary and Secondary Liner Landfill template.

### General Tab

The screenshot displays the 'General Information' section of the software interface. The 'Model Title' is 'Case 17. Landfill with composite primary liners.' and the 'Units' are set to 'Metric'. The 'Laplace Transform Parameters' section shows TAU: 7, N: 20, SIG: 0, and RNU: 2. The 'Run Parameters' section shows 'Output Units' with 'Time Units' set to 'yr', 'Depth Units' set to 'm', and 'Concentration Units' set to 'µg/L'. The 'All Depths' and 'Concentrations at Specified Times' options are selected. A table lists the specified times and units:

Time	Units
10	year
20	year
30	year
50	year
100	year

The 'General Information' section also shows a list of layers with checkboxes for their inclusion in the model:

Layer	Checked
Waste	
Primary Collection System	
Primary Geomembrane	<input checked="" type="checkbox"/>
Primary Clay Liner	<input checked="" type="checkbox"/>
Secondary Collection System	
Secondary Geomembrane	<input type="checkbox"/>
Secondary Clay Liner	<input checked="" type="checkbox"/>
Aquitard	<input checked="" type="checkbox"/>
Aquifer	<input checked="" type="checkbox"/>

On the General tab the layers present in the model can be specified. In this example, the model

consists of a primary geomembrane, primary liner, secondary liner, aquitard, and aquifer.

### Source & Hydraulic Heads

The screenshot shows the 'Source & Hydraulic Heads' tab in a software interface. The 'Source' section includes input fields for Concentration (1500 µg/L), Landfill Length (200 m), and Landfill Width (0). The 'Source Type' is set to 'Constant Concentration'. The 'Hydraulic Heads' section includes input fields for Leachate Head on Primary Liner (0.3 m), Leachate Head on Secondary Liner (0.3 m), and Groundwater level relative to top of Aquifer (3 m).

This tab is used to specify the source information and hydraulic heads. In this example the source has a constant concentration of 1500 µg/L and a landfill length of 200 m. The heads specified for the liners and the groundwater level are relative to the aquifer.

### Collection System

The screenshot shows the 'Collection System' tab in a software interface. The 'Secondary Collection System' section includes a text field for Name (Collection System), a 'Change Symbol' button, and input fields for Number of Sublayers (1), Thickness (0.3 m), Density (1.9 kg/m³), Diffusion Coef (100 m²/a), Distribution Coef (0.01 m/s), Porosity (0.3), and Phase Parameter (1).

The parameters for the secondary leachate collection system are specified on the Collection System tab.

## Geomembranes


The screenshot shows the 'Geomembranes' tab in a software interface. The 'Primary Geomembrane' section includes a 'Name' field set to 'Geomembrane', a 'Change Symbol' button, and input fields for 'Number of Sublayers' (1), 'Thickness' (60 mil), 'Diffusion Coef' (3E-5 m<sup>2</sup>/a), and 'Phase Parameter' (1). The 'Leakage Method' section has three radio buttons: 'LEAK, Rowe et al 2004', 'Giroud & Bonaparte 1992' (selected), and 'Equivalent K'. The 'Giroud & Bonaparte, 1992' sub-section contains 'Contact' (Good selected), 'Hole Type' (Circle selected), and 'Permeation' (No selected). It also has 'Hole Frequency' (2.5 hectare) and 'Hole Area' (0.1 cm<sup>2</sup>) fields. A 'Calculate Leakage' button and a 'Darcy Velocity' field are at the bottom.

The Geomembranes tab is used to specify the parameters for the primary geomembrane and the method to calculate the leakage through the geomembrane. In this example, the leakage through the geomembrane will use the method proposed by Giroud & Bonaparte.

## Clay Liners

**Primary Clay Liner**

Name:



Number of Sublayers:

Thickness:

Density:

Conductivity K:


Diffusion Coef:

Distribution Coef:

Porosity:

**Secondary Clay Liner**

Name:



Number of Sublayers:

Thickness:

Density:

Conductivity K:

Diffusion Coef:

Distribution Coef:


Porosity:

The parameters for the primary and secondary clay liners are specified on the Clay Liners tab.

## Aquitard

**Aquitard**

Name:



Number of Sublayers:

Thickness:

Density:

Conductivity K:

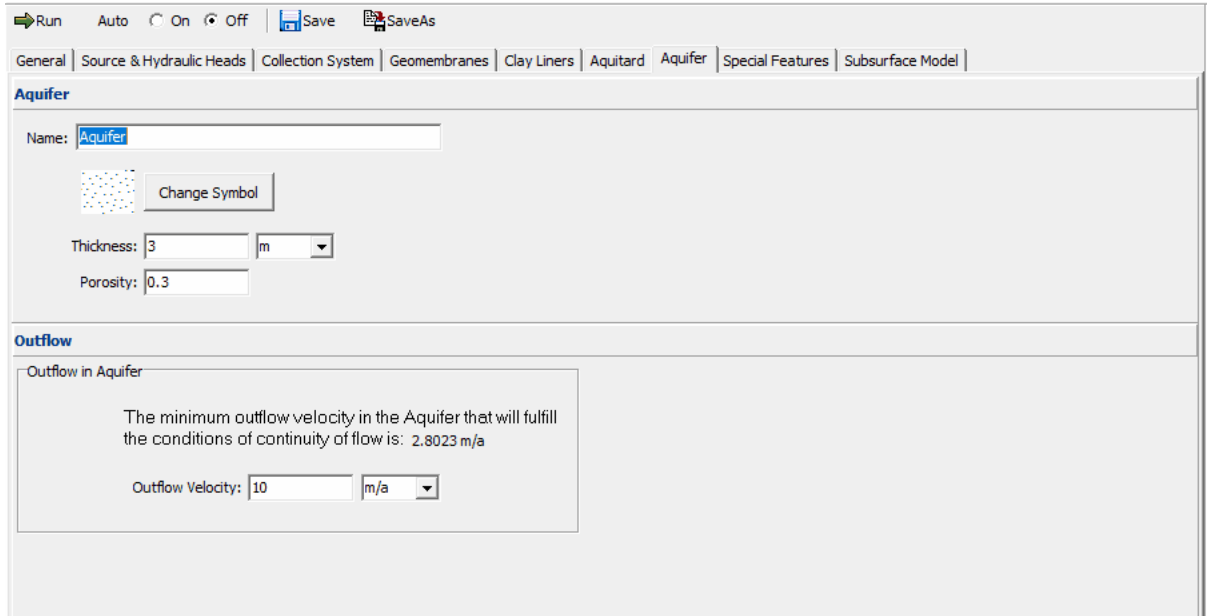
Diffusion Coef:

Distribution Coef:

Porosity:

The parameters for the aquitard are specified on the Aquitard tab.

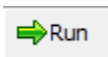
## Aquifer



The screenshot shows a software interface for configuring an aquifer. At the top, there is a toolbar with icons for Run, Auto, On, Off, Save, and SaveAs. Below the toolbar is a menu bar with tabs: General, Source & Hydraulic Heads, Collection System, Geomembranes, Clay Liners, Aquitard, Aquifer, Special Features, and Subsurface Model. The 'Aquifer' tab is selected. The 'Aquifer' section contains a 'Name' field with the value 'Aquifer', a 'Change Symbol' button, a 'Thickness' field with the value '3' and a unit dropdown set to 'm', and a 'Porosity' field with the value '0.3'. Below this is the 'Outflow' section, which includes a text box stating: 'The minimum outflow velocity in the Aquifer that will fulfill the conditions of continuity of flow is: 2.8023 m/a'. Below the text box is an 'Outflow Velocity' field with the value '10' and a unit dropdown set to 'm/a'.

The parameters for the aquifer are specified on the Aquifer tab. The outflow velocity in the aquifer can be specified on the bottom of the tab. The minimum outflow velocity for the model will be calculated and shown.

## Model Execution



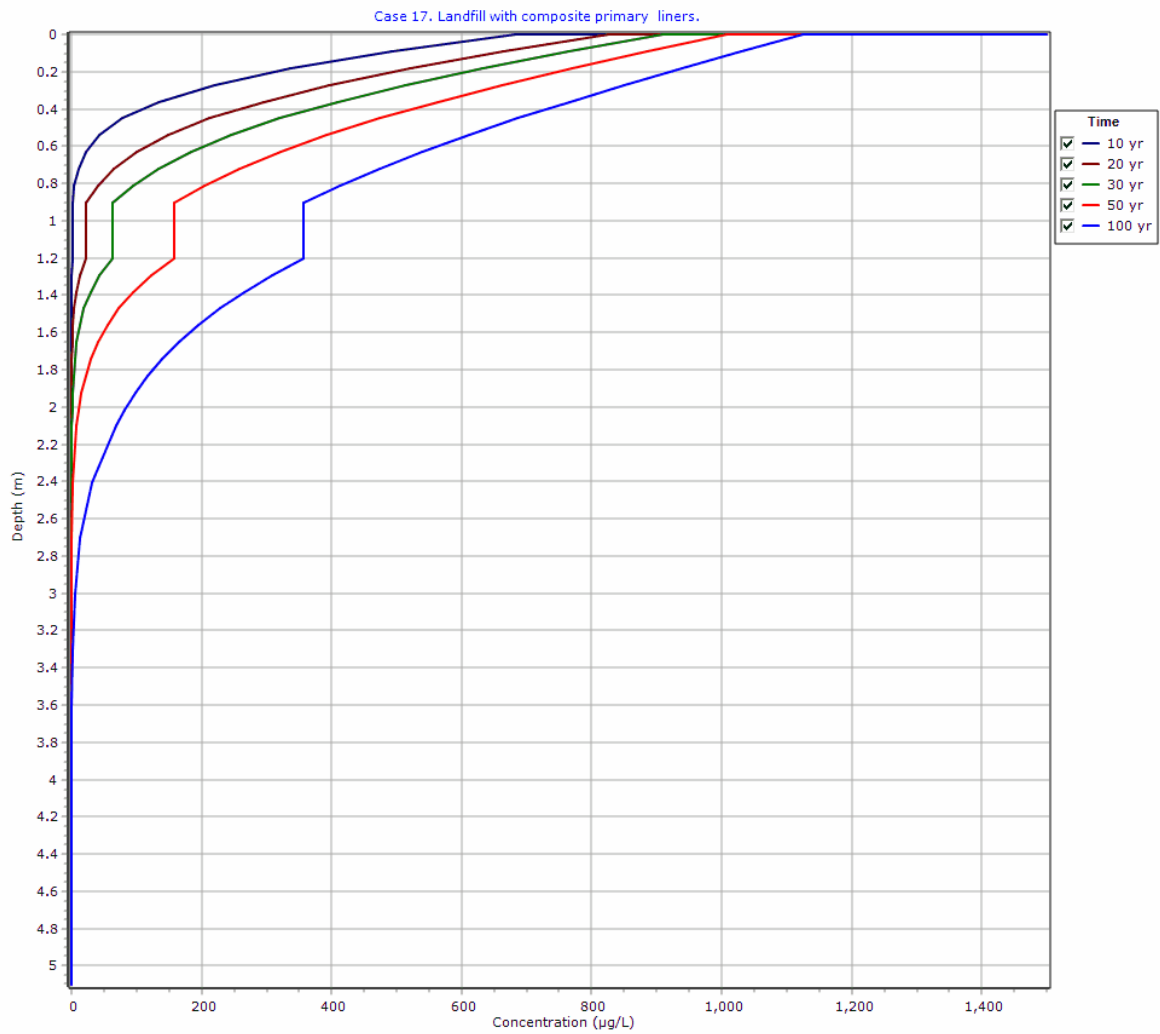
To run the model and calculate the concentrations press the Run button on the toolbar.

## Model Output

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

### Depth vs Concentration





**Output Listing**

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

**POLLUTEv8**

Version 8.00 Beta  
 Copyright (c) 2021  
 GAEA Technologies Ltd., R.K. Rowe and J.R. Booker

**Case 17. Landfill with composite primary liners.**

**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
Geomembrane	60 mil	1	3E-5 m <sup>2</sup> /a	1	0 mL/g	950 kg/m <sup>3</sup>
Clay Liner	0.9 m	10	0.02 m <sup>2</sup> /a	0.35	0.5 mL/g	1.9 g/cm <sup>3</sup>
Collection System	0.3 m	1	100 m <sup>2</sup> /a	0.3	0 m <sup>3</sup> /kg	1.9 kg/m <sup>3</sup>
Clay Liner	0.9 m	10	0.02 m <sup>2</sup> /a	0.35	0.5 m <sup>3</sup> /kg	1.9 kg/m <sup>3</sup>
Aquitard	3 m	10	0.02 m <sup>2</sup> /a	0.3	0.5 m <sup>3</sup> /kg	1.9 kg/m <sup>3</sup>

### Boundary Conditions

#### Constant Concentration

Source Concentration = 1500 µg/L

#### Fixed Outflow Bottom Boundary

Landfill Length = 200 m  
 Landfill Width = 0 m  
 Base Thickness = 3 m  
 Base Porosity = 0.3  
 Base Outflow Velocity = 10 m/a

### Velocity and Sink Profile

Time Period	Minimum Depth	Maximum Depth	Vertical Velocity	Horizontal Outflow	Phase Parameter
01	0 m	0.001524 m	3.9744E-5 m/a	0 m/a	1
	0.001524 m	0.9 m	3.9744E-5 m/a	0 m/a	1
	0.9 m	1.2 m	3.9744E-5 m/a	0 m/a	1
	1.2 m	2.1 m	3.9744E-5 m/a	0 m/a	1
	2.1 m	5.1 m	3.9744E-5 m/a	0 m/a	1

### Laplace Transform Parameters

TAU = 7   N = 20   SIG = 0   RNU = 2

### Calculated Concentrations at Selected Times and Depths

Time yr	Depth m	Concentration µg/L
10	0.000E+00	1.500E+03
	1.524E-03	6.823E+02
	9.152E-02	4.917E+02
	1.815E-01	3.370E+02
	2.715E-01	2.190E+02
	3.615E-01	1.345E+02
	4.515E-01	7.798E+01
	5.415E-01	4.256E+01
	6.315E-01	2.181E+01
	7.215E-01	1.044E+01
8.115E-01	4.532E+00	
9.015E-01	1.486E+00	

	1.202E+00	1.485E+00
	1.292E+00	5.762E-01
	1.382E+00	2.090E-01
	1.472E+00	7.081E-02
	1.562E+00	2.239E-02
	1.652E+00	6.608E-03
	1.742E+00	1.819E-03
	1.832E+00	4.665E-04
	1.922E+00	1.115E-04
	2.012E+00	2.487E-05
	2.102E+00	5.395E-06
	2.402E+00	1.203E-08
	2.702E+00	6.039E-11
	3.002E+00	6.877E-12
	3.302E+00	7.519E-13
	3.602E+00	6.479E-14
	3.902E+00	4.344E-15
	4.202E+00	2.236E-16
	4.502E+00	8.703E-18
	4.802E+00	2.517E-19
	5.102E+00	8.435E-22
20	0.000E+00	1.500E+03
	1.524E-03	8.260E+02
	9.152E-02	6.636E+02
	1.815E-01	5.199E+02
	2.715E-01	3.968E+02
	3.615E-01	2.946E+02
	4.515E-01	2.126E+02
	5.415E-01	1.488E+02
	6.315E-01	1.007E+02
	7.215E-01	6.553E+01
	8.115E-01	4.031E+01
	9.015E-01	2.239E+01
	1.202E+00	2.238E+01
	1.292E+00	1.332E+01
	1.382E+00	7.670E+00
	1.472E+00	4.275E+00
	1.562E+00	2.305E+00
	1.652E+00	1.202E+00
	1.742E+00	6.060E-01
	1.832E+00	2.954E-01
	1.922E+00	1.393E-01
	2.012E+00	6.381E-02
	2.102E+00	2.913E-02
	2.402E+00	1.208E-03
	2.702E+00	3.221E-05
	3.002E+00	5.508E-07
	3.302E+00	6.278E-09
	3.602E+00	1.246E-10
	3.902E+00	2.172E-11

	4.202E+00	4.988E-12
	4.502E+00	1.028E-12
	4.802E+00	1.848E-13
	5.102E+00	6.496E-15
30	0.000E+00	1.500E+03
	1.524E-03	9.088E+02
	9.152E-02	7.644E+02
	1.815E-01	6.322E+02
	2.715E-01	5.137E+02
	3.615E-01	4.098E+02
	4.515E-01	3.205E+02
	5.415E-01	2.455E+02
	6.315E-01	1.837E+02
	7.215E-01	1.337E+02
	8.115E-01	9.389E+01
	9.015E-01	6.252E+01
	1.202E+00	6.250E+01
	1.292E+00	4.317E+01
	1.382E+00	2.919E+01
	1.472E+00	1.932E+01
	1.562E+00	1.252E+01
	1.652E+00	7.934E+00
	1.742E+00	4.920E+00
	1.832E+00	2.986E+00
	1.922E+00	1.776E+00
	2.012E+00	1.040E+00
	2.102E+00	6.088E-01
	2.402E+00	6.824E-02
	2.702E+00	5.728E-03
	3.002E+00	3.587E-04
	3.302E+00	1.671E-05
	3.602E+00	5.782E-07
	3.902E+00	1.516E-08
	4.202E+00	4.244E-10
	4.502E+00	5.379E-11
	4.802E+00	1.512E-11
	5.102E+00	9.861E-13
50	0.000E+00	1.500E+03
	1.524E-03	1.007E+03
	9.152E-02	8.850E+02
	1.815E-01	7.698E+02
	2.715E-01	6.623E+02
	3.615E-01	5.634E+02
	4.515E-01	4.734E+02
	5.415E-01	3.926E+02
	6.315E-01	3.210E+02
	7.215E-01	2.583E+02
	8.115E-01	2.039E+02
	9.015E-01	1.573E+02
	1.202E+00	1.573E+02

	1.292E+00	1.231E+02
	1.382E+00	9.522E+01
	1.472E+00	7.273E+01
	1.562E+00	5.486E+01
	1.652E+00	4.087E+01
	1.742E+00	3.008E+01
	1.832E+00	2.189E+01
	1.922E+00	1.576E+01
	2.012E+00	1.127E+01
	2.102E+00	8.056E+00
	2.402E+00	2.028E+00
	2.702E+00	4.309E-01
	3.002E+00	7.706E-02
	3.302E+00	1.158E-02
	3.602E+00	1.459E-03
	3.902E+00	1.539E-04
	4.202E+00	1.358E-05
	4.502E+00	1.003E-06
	4.802E+00	6.204E-08
	5.102E+00	6.335E-10
100	0.000E+00	1.500E+03
	1.524E-03	1.124E+03
	9.152E-02	1.030E+03
	1.815E-01	9.383E+02
	2.715E-01	8.503E+02
	3.615E-01	7.662E+02
	4.515E-01	6.862E+02
	5.415E-01	6.106E+02
	6.315E-01	5.398E+02
	7.215E-01	4.738E+02
	8.115E-01	4.127E+02
	9.015E-01	3.567E+02
	1.202E+00	3.566E+02
	1.292E+00	3.092E+02
	1.382E+00	2.666E+02
	1.472E+00	2.285E+02
	1.562E+00	1.948E+02
	1.652E+00	1.652E+02
	1.742E+00	1.393E+02
	1.832E+00	1.170E+02
	1.922E+00	9.780E+01
	2.012E+00	8.154E+01
	2.102E+00	6.789E+01
	2.402E+00	3.197E+01
	2.702E+00	1.387E+01
	3.002E+00	5.537E+00
	3.302E+00	2.031E+00
	3.602E+00	6.839E-01
	3.902E+00	2.112E-01
	4.202E+00	5.978E-02

	4.502E+00	1.548E-02
	4.802E+00	3.554E-03
	5.102E+00	1.703E-04

**NOTICE**

Although this program has been tested and experience would indicate that it is accurate within the limits given by the assumptions of the theory used, we make no warranty as to workability of this software or any other licensed material. No warranties either expressed or implied (including warranties of fitness) shall apply. No responsibility is assumed for any errors, mistakes or misrepresentations that may occur from the use of this computer program. The user accepts full responsibility for assessing the validity and applicability of the results obtained with this program for any specific case.