POLLUTE

Version 8

Example 1: Subtitle D Landfill

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Description

This example illustrates the use of the program to model a U.S. RCRA Subtitle D landfill. The landfill consists of a composite liner and a primary leachate collection system. The composite 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 cm2 and a frequency of 1 per acre (2.5 per hectare) 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 the program.

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 liner is assumed to be constant at 0.3 m.

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.

The parameters used for this example are listed below:

Property	Symbol	Value	Units
Geomembrane Contact		Good	-
Geomembrane Holes		Circles	-
Hole Area		0.1	cm2
Hole Frequency		1	/acre
Source Concentration	co	1500	µg/L
Source Type		Constant	-
Landfill Length	L	200	m
Leachate Head on Liner		0.3	m
Geomembrane Thickness		60	mil
Geomembrane Diffusion Coef.		3.0x10-5	m^2/a
Clay Thickness	H_s	0.9	m
Clay Diffusion Coef.	D	0.02	m^2/a
Distribution Coefficient	K_d	0.5	mL/g
Soil Porosity	n	0.35	-
Dry Density		1.9	g/cm^3
Aquifer Thickness	h	3	m
Aquifer Porosity	n_b	0.3	-
Base Outflow Velocity	v_b	10	m/a

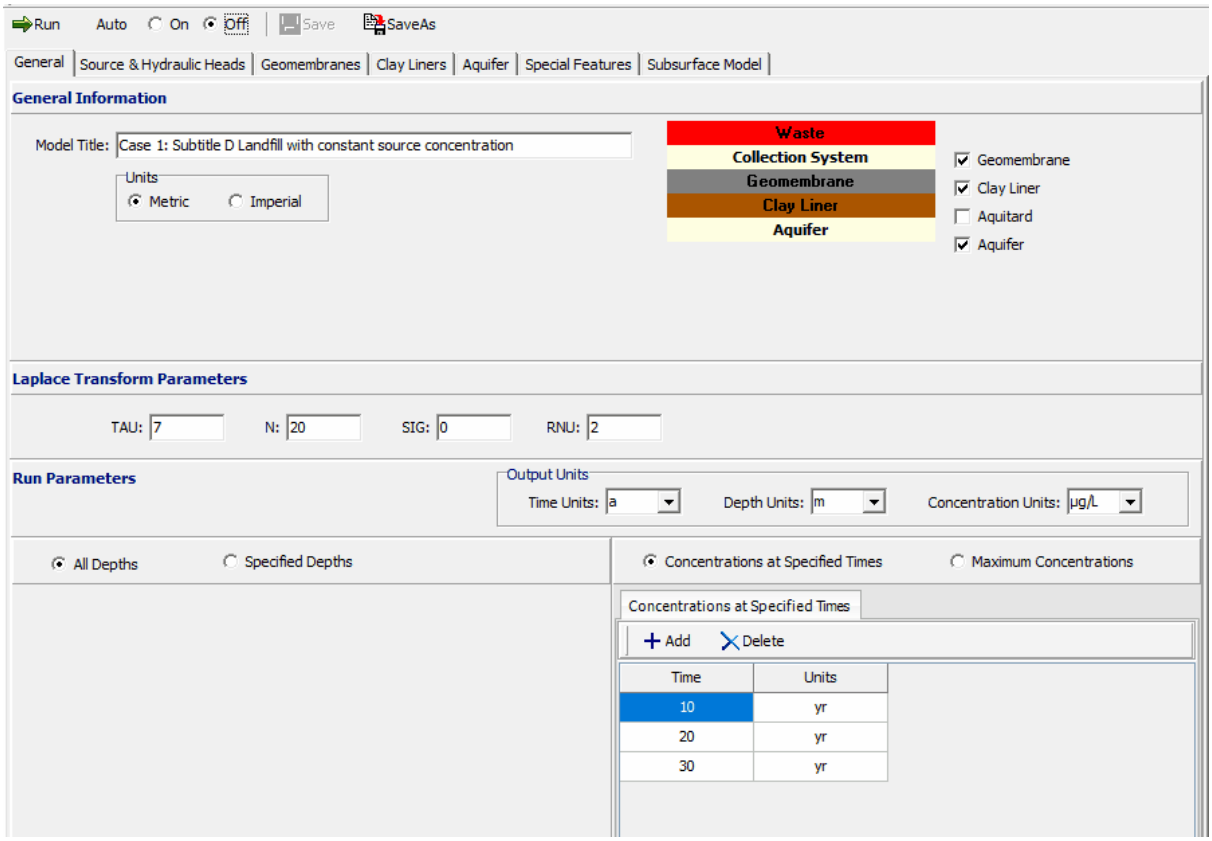
For more information regarding:

- Leakage through composite liners - see Giroud et al (1992).
- Diffusion through geomembranes - see Hughes and Monteleone, (1987); Lord et al (1988).
- Diffusion, sorption, and effective porosity in clays (D, K_d, n) - see Rowe et al (1988)
- Modeling, hydrogeology, and engineering interaction - see Rowe (1992), Rowe et al, 1994.
- Theory used - see Rowe and Booker (1985, 1991), Rowe et al (1994)

Data Entry

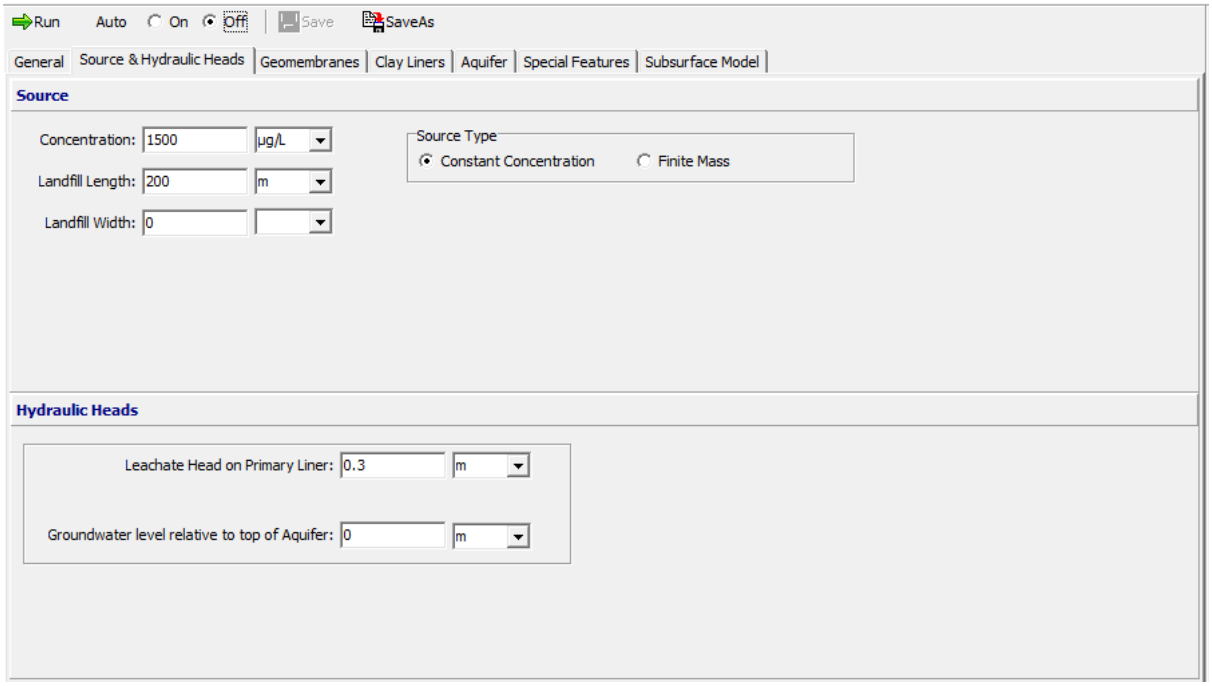
Open the Examples project and open Case 1.

General Tab



On the General tab, the title and layers present in the model are specified as shown above. In this example there is a geomembrane, clay liner and aquifer. At the bottom of the tab the run parameters can be specified. The concentrations can either be calculated at specified times or the time of the maximum concentration can be found.

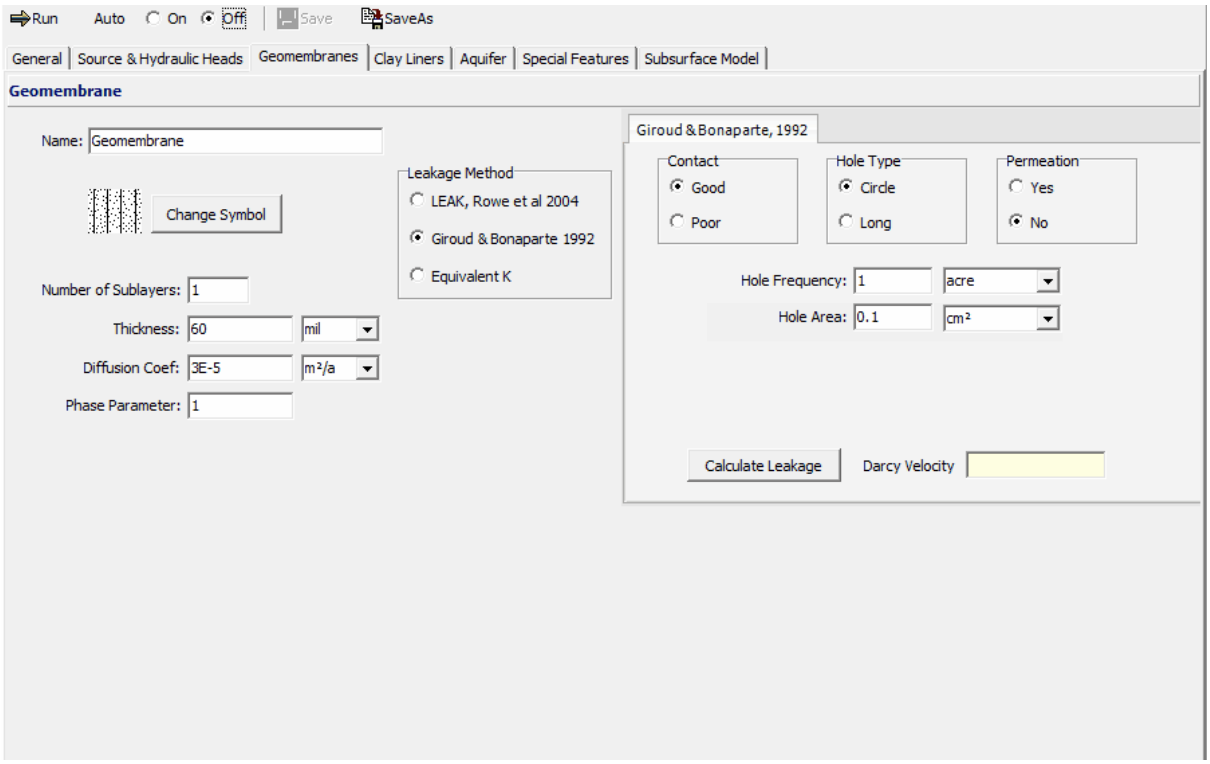
Source & Hydraulic Heads Tab



On this tab the Source Type, Source Concentration and Landfill Length are specified. In this example, the source type is constant concentration. If the source type was finite mass additional information for the source would need to be entered as discussed in Case 4.

The Hydraulic Heads is used to specify the leachate head on the primary liner and the groundwater level relative to the top of the aquifer. These heads are used to calculate the Darcy velocity through the liner.

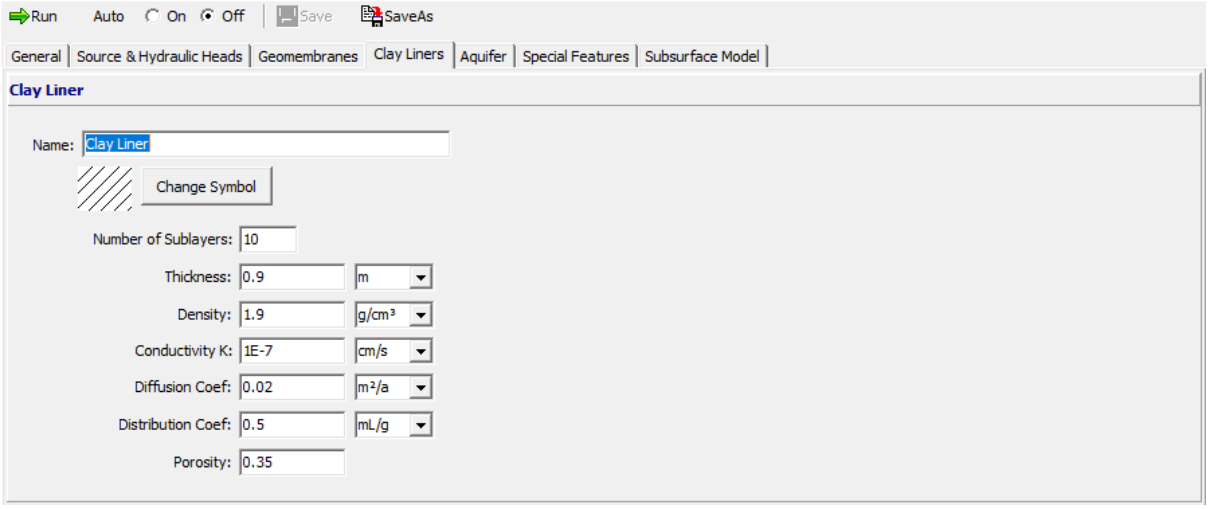
Geomembranes Tab



On this tab the Name, Thickness, Diffusion Coefficient, Phase Parameter, and method to calculate the leakage through the geomembrane is specified. If the method is Rowe et. al. 2004 or Giroud & Bonaparte 1992, an additional tab will be displayed to enter the hole parameters. If the method is equivalent K, then the Hydraulic Conductivity of the geomembrane can be entered on this tab. In this example the leakage method used is Giroud & Bonaparte 1992. Using this method the parameters for the holes in the geomembrane are specified. These parameters include the Type of Contact, Hole Type, Use of Permeation, and Hole Frequency. If the type of holes is Circles then the Hole Area can be specified, if the type is Long then the Hole Length and Width can be specified.

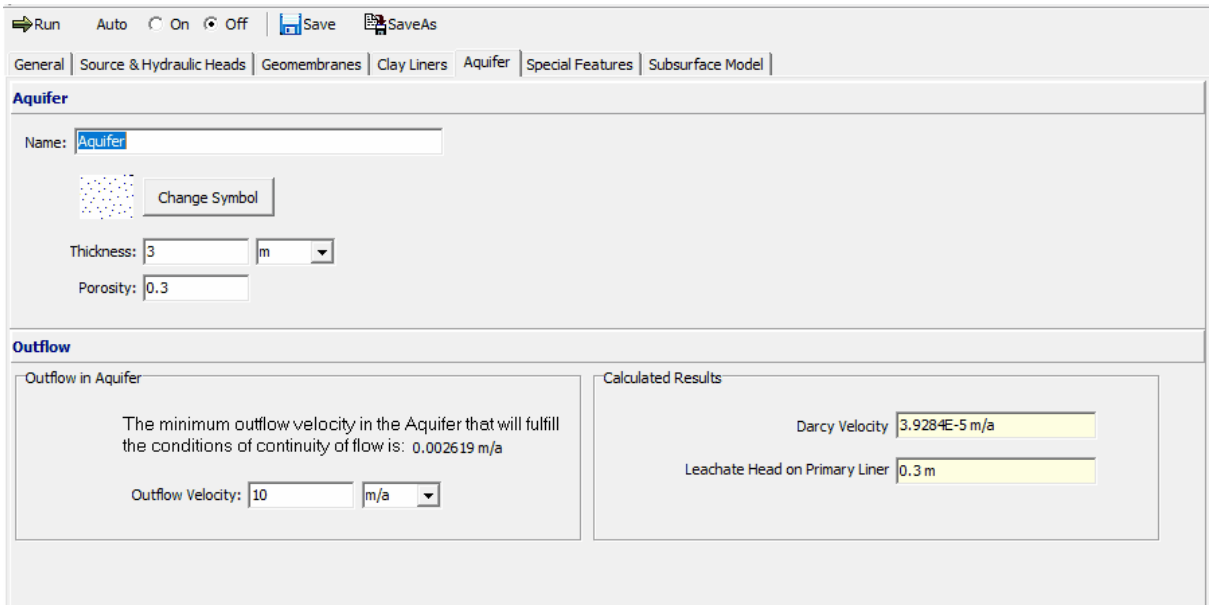
At the bottom of the tab, the Calculate Leakage button can be used to calculate and display the Darcy velocity (leakage) through the primary liner.

Clay Liners Tab



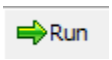
The Clay Liners tab below is used to specify the properties of the clay liner below the geomembrane. These properties include the Name, Symbol, Thickness, Density, Hydraulic Conductivity, Diffusion Coefficient, Distribution Coefficient, and Porosity.

Aquifer Tab



The Aquifer tab is used to specify the Name, Symbol, Thickness and Porosity of the Aquifer. At the bottom of the tab the Outflow Rate in the Aquifer can be specified. This rate should be at greater than or equal to the minimum calculated by the program. In this example, the minimum is 0.002619 m/a.

Model Execution



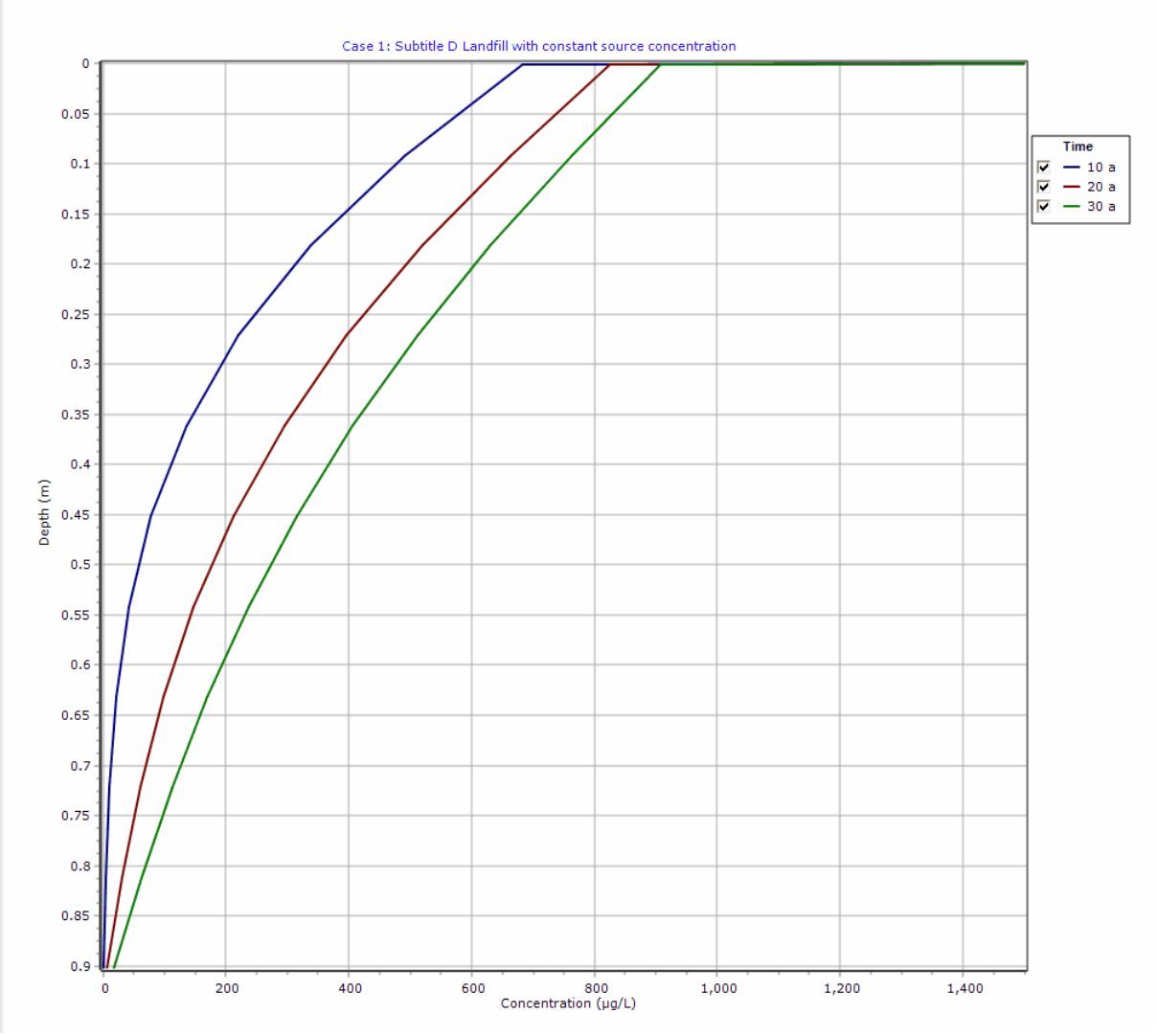
To run the model and calculate the concentrations press the Run button on the toolbar.

Model Output

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

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 1: Subtitle D Landfill with constant source concentration

THE DARCY VELOCITY (Flux) THROUGH THE LAYERS Va = 3.9284E-5 m/a

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Geomembrane	60 mil	1	3E-5 m²/a	1	0 cm³/g	950 kg/m³
Clay Liner	0.9 m	10	0.02 m²/a	0.35	0.5 mL/g	1.9 g/cm³

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

Laplace Transform Parameters

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

Calculated Concentrations at Selected Times and Depths

Time a	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	4.254E+01
	6.315E-01	2.176E+01

	7.215E-01	1.028E+01
	8.115E-01	4.107E+00
	9.015E-01	3.970E-01
20	0.000E+00	1.500E+03
	1.524E-03	8.259E+02
	9.152E-02	6.636E+02
	1.815E-01	5.198E+02
	2.715E-01	3.966E+02
	3.615E-01	2.942E+02
	4.515E-01	2.117E+02
	5.415E-01	1.471E+02
	6.315E-01	9.768E+01
	7.215E-01	6.006E+01
	8.115E-01	3.082E+01
	9.015E-01	6.430E+00
30	0.000E+00	1.500E+03
	1.524E-03	9.082E+02
	9.152E-02	7.636E+02
	1.815E-01	6.309E+02
	2.715E-01	5.115E+02
	3.615E-01	4.062E+02
	4.515E-01	3.148E+02
	5.415E-01	2.365E+02
	6.315E-01	1.698E+02
	7.215E-01	1.126E+02
	8.115E-01	6.246E+01
	9.015E-01	1.675E+01