

CHAPTER FOUR

Pipe Condition Assessment Model

Manual of Risk Assessment for Contaminant Intrusion into Water Distribution Systems

Chapter-1
IRA-WDS: Overview



Chapter-2
Data Preparation



Chapter-3
Contaminant Ingress Model



Chapter-4
Pipe Condition Assessment Model



Chapter-5
Risk Assessment Model

Chapter 4: Pipe Condition Assessment Model

4.1 Introduction

There are several submenus under the Pipe Condition Assessment menu. This chapter describes the use of these submenus and associated commands for running the Pipe Condition Assessment Model. Figure 4.1 shows the steps involved in executing this component of the software.

The example files given in Table 4.1 are used for illustration purposes to describe the Pipe Condition Assessment Model with the help of IRA-WDS.

Table 4.1. Example input files	
Themes	Filenames
Water distribution	wdstesttheme.shp
	wdstestnode.shp
Groundwater	gwt.shp
Pressure zone	pressure.shp
Soil type	soilbound.shp

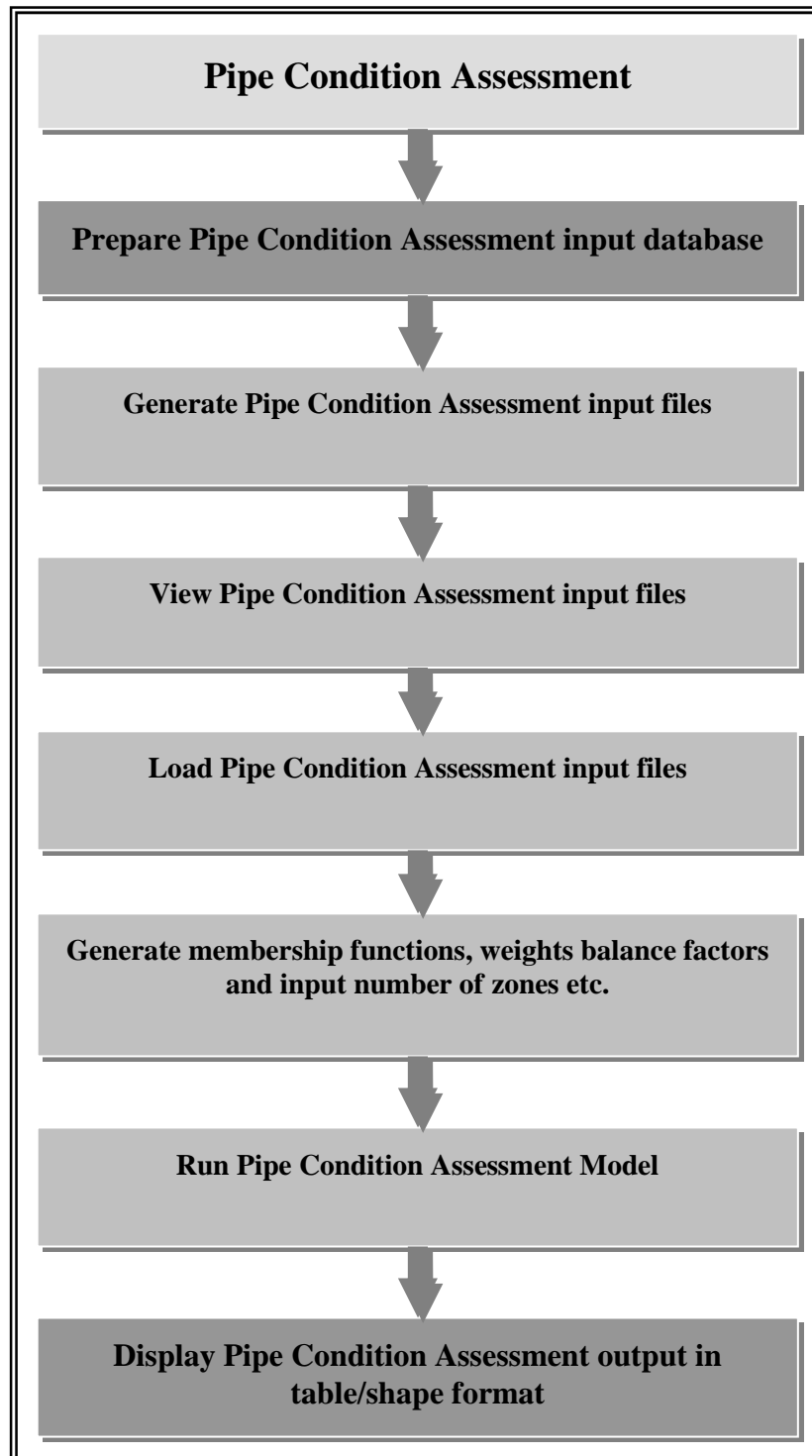


Figure 4.1. Overview of Pipe Condition Assessment Model of IRA-WDS


The following steps need to be performed for running the Pipe Condition Assessment (PCA). These are:

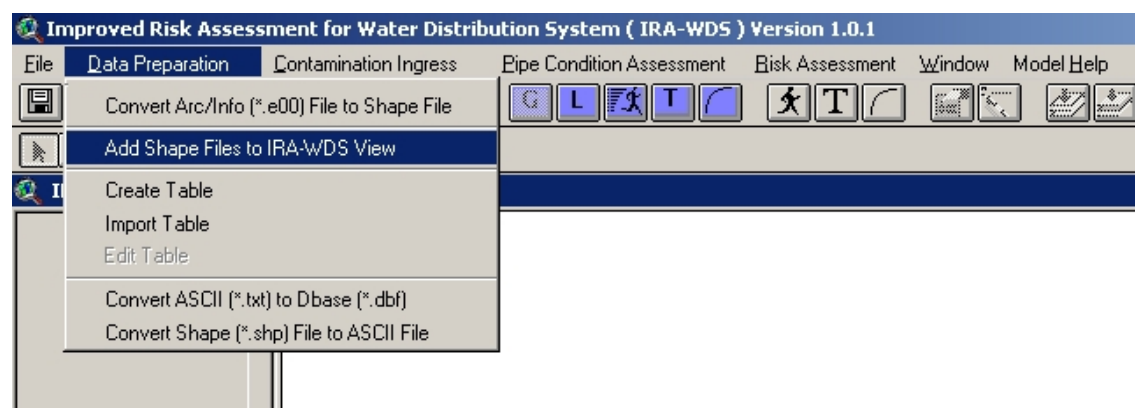
- Adding the data (if not already done so)
- Rearranging the data (optional)
- Generating an input file

- Viewing PCA input file (optional)
- Loading input file
- Running model
- Displaying output (optional)

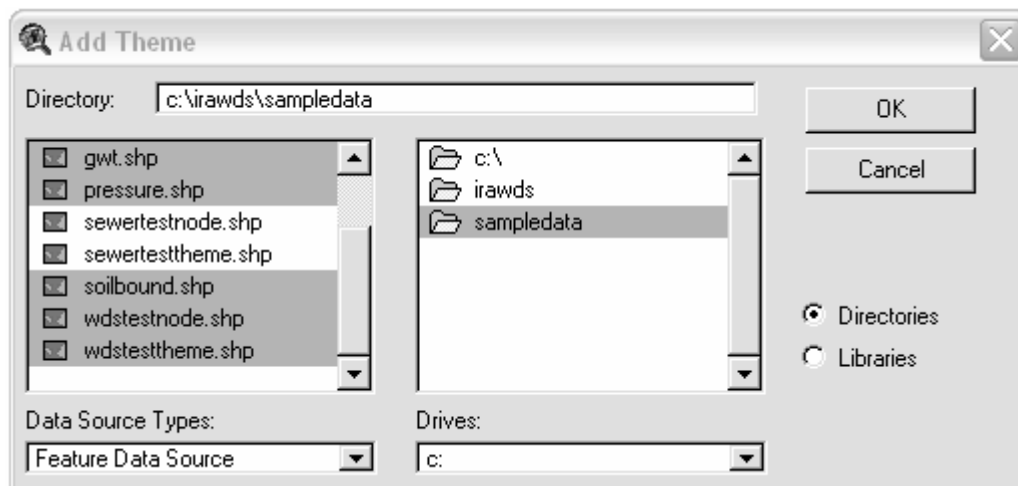
4.2 Shape files

4.2.1 Adding shape files

Adding shape files can be done by clicking on the Tool icon  which is just below the 'Data Preparation' menu or by clicking on the 'Data Preparation' menu and then clicking on the submenu 'Add Shape Files to IRA-WDS View', as shown in the screen below:

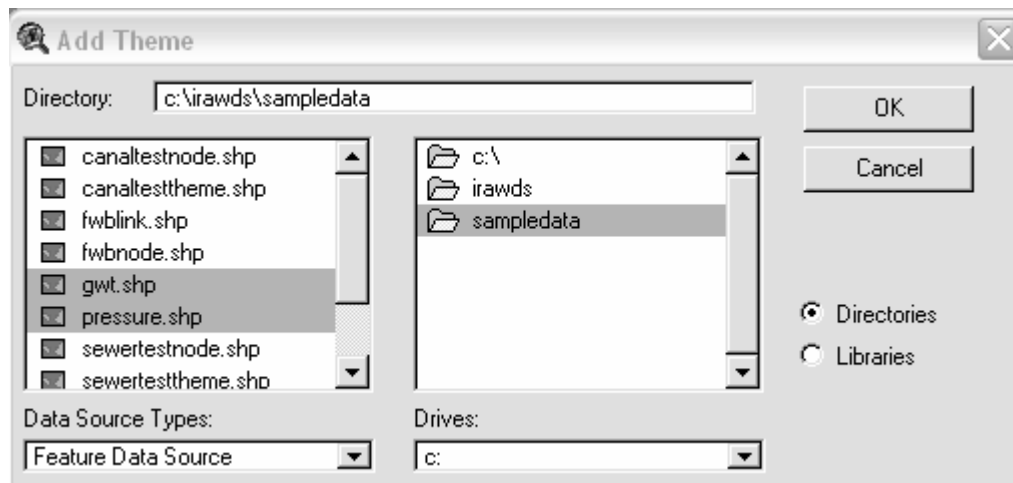


This opens the 'Add Theme' form, as shown below, and the user is then required to select the desired files. At this stage, these files are those relating to: water distribution link and node; soil polygon map; groundwater zone polygon map; and pressure zone polygon map.



If the user is continuing on from the Contaminant Ingress Model, then water distribution link and node data and the soil polygon map will have already been added. (Note that the sewer pipe, canal and foul water bodies link and node data, which are all needed for pipe condition assessment, will also have been added in this

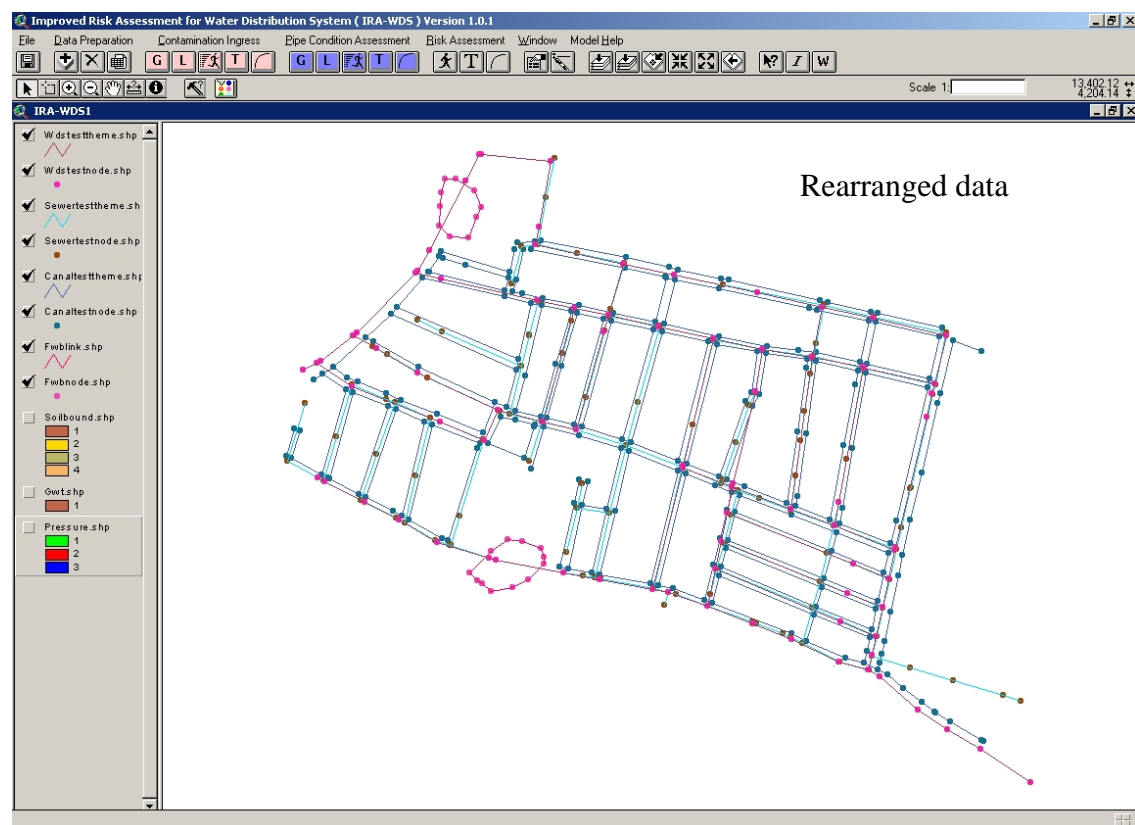
case). Only the groundwater zone polygon map and the pressure zone polygon map need to be added by the user as below.

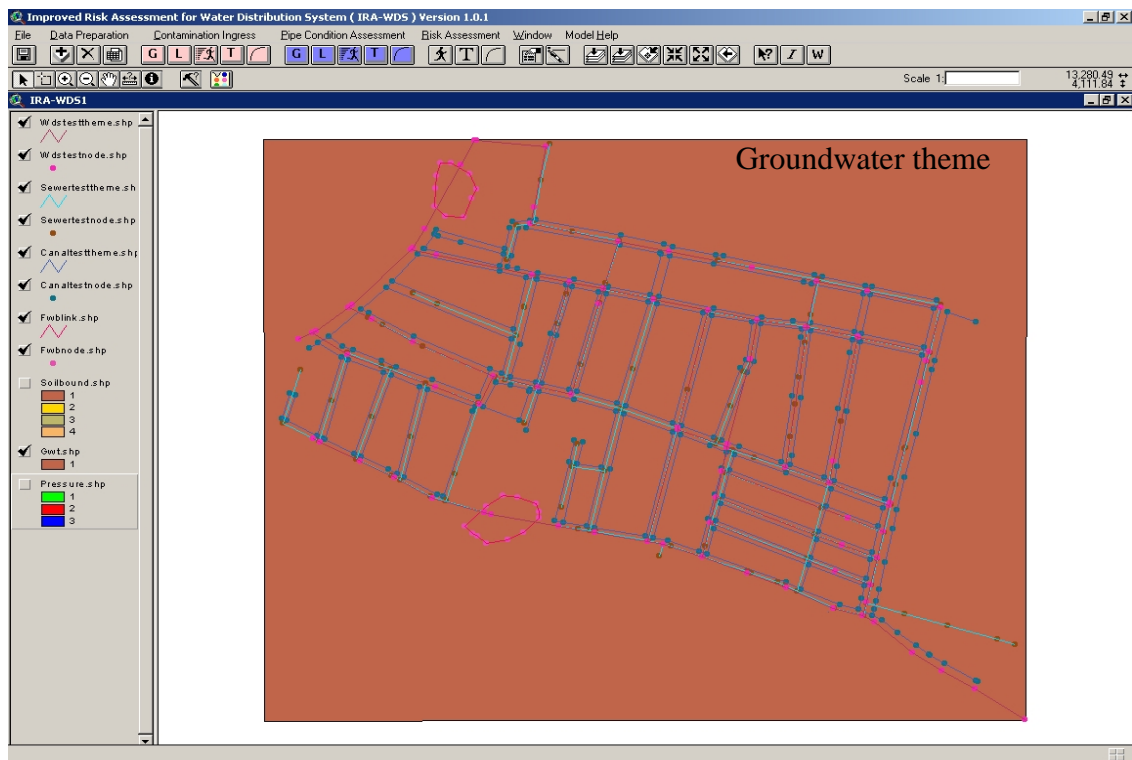
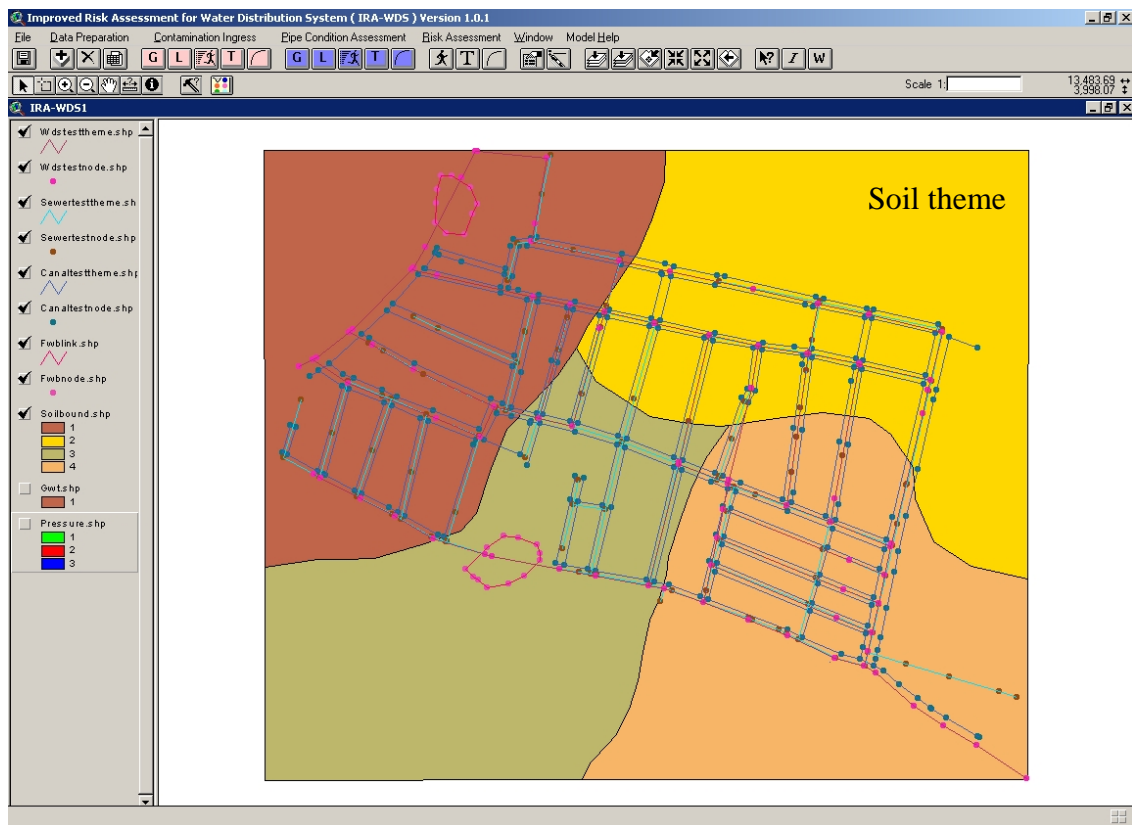


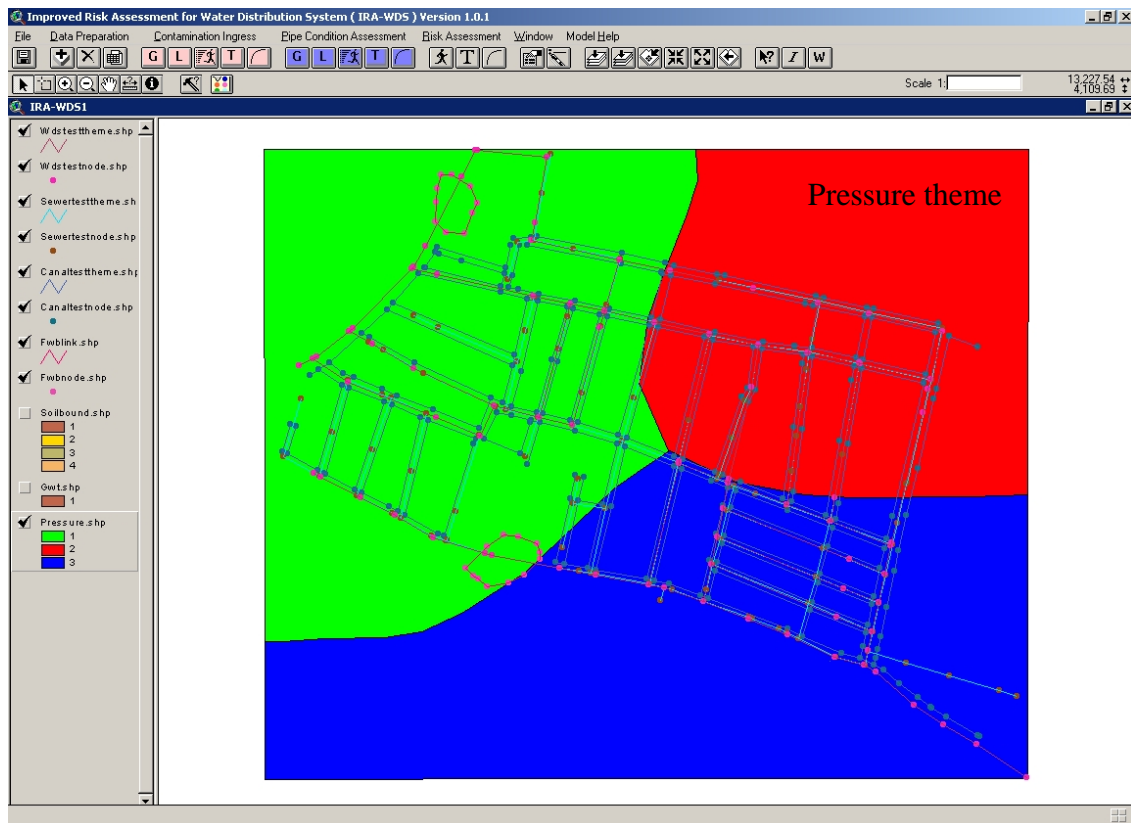
4.2.2 Rearranging shape files

If the user wishes to do so, he or she can rearrange the data to view and query different themes. The following snapshots show:

- Rearranged link and node data
- A soil theme map
- A groundwater theme map
- A pressure theme map




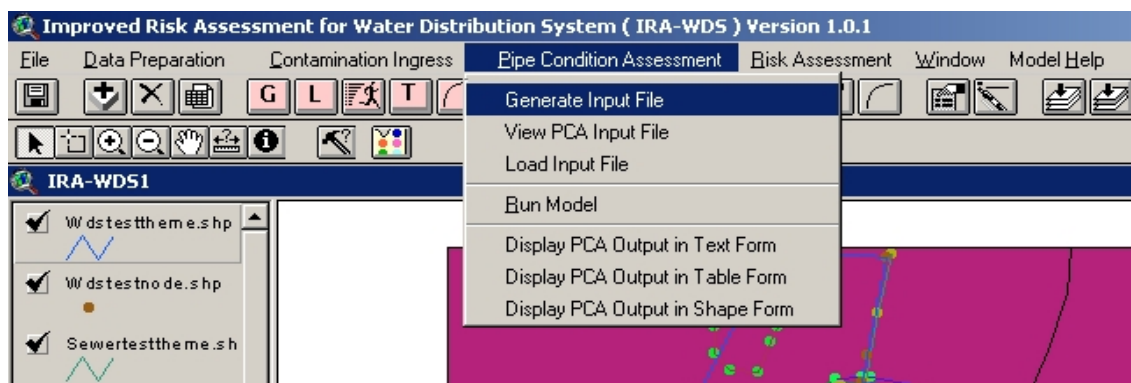





4.3 Generating an input file



4.3.1 Background to Pipe Condition Assessment Model input

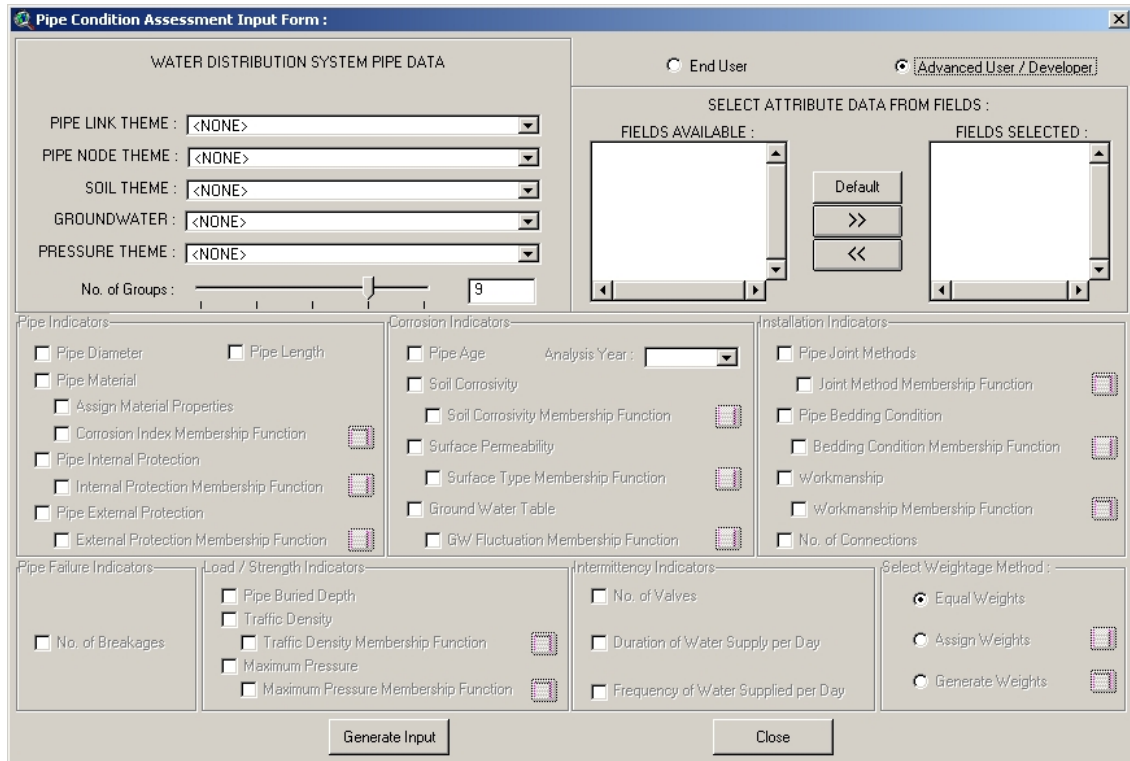
An input file can be generated by clicking on the Tool icon  which is just below the 'Pipe Condition Assessment' menu or by clicking on the 'Pipe Condition Assessment' menu and then clicking on the submenu 'Generate Input File', as shown on the screen below:



The 'Pipe Condition Assessment Input Form' has two radio button options: '**Advanced User**' and '**End User**'.

Advance Users can click on the radio button next to Advance User / Developer, which will allow the user to add or remove fields to or from the 'SELECTED FIELDS' list box. The user can click the  button to select the default field names. Advanced users can add fields to the 'SELECTED FIELDS' list box by selecting

those fields in the 'FIELDS AVAILABLE' list box and then clicking on the  button. To remove fields from the 'SELECTED FIELDS' list box, the user can select those fields in the 'SELECTED FIELDS' list box and remove by clicking on the  button.



Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

FIELDS SELECTED :

End User ☐ **Advanced User / Developer** ☒

Pipe Indicators:

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators:

- ☐ Pipe Age
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators:

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators:

- ☐ No. of Breakages

Load / Strength Indicators:

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators:

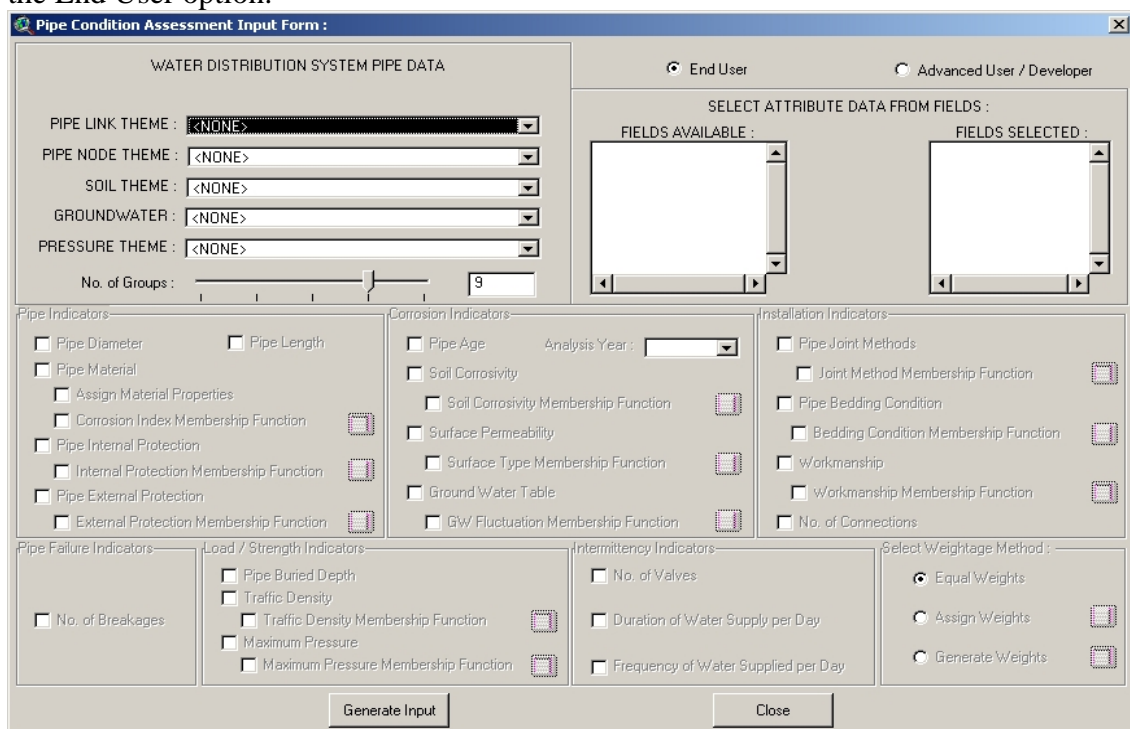
- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input **Close**

End Users are not provided with an option for adding or deleting fields to or from the 'SELECTED FIELDS' list box. In this case, the fields are automatically selected with the End User option.



Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

FIELDS SELECTED :

End User ☒ **Advanced User / Developer** ☐

Pipe Indicators:

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators:

- ☐ Pipe Age
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators:

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators:

- ☐ No. of Breakages

Load / Strength Indicators:

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators:

- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input **Close**

4.3.2 Adding shape files

The user needs to define which theme in the IRA-WDS View represents the water distribution system pipe theme, the node theme, the soil theme, the groundwater theme and the pressure theme. All polyline / line themes added to the IRA-WDS viewer are added to the 'PIPE LINK THEME' combo box. All point / node themes added to the IRA-WDS viewer are added to the 'PIPE NODE THEME' combo box. All polygon themes added to the IRA-WDS viewer are added to the 'SOIL THEME', 'GROUNDWATER THEME' and 'PRESSURE THEME' boxes.

The user is required to select the theme that represents the water distribution pipe theme, the node theme, the soil theme, the groundwater theme and the pressure theme from the combo box. Initially, before selection of the themes, all other menus are disabled. During the selection of themes, the list of fields available and fields that will be selected from that theme are listed in the 'FIELDS AVAILABLE' and 'FIELDS SELECTED' list boxes (just below 'SELECT ATTRUBUTE DATA FROM FIELDS').

4.3.2.1 Pipe (water distribution) link theme

Selecting the water distribution theme in the pipe link theme box lists the fields available and fields selected. It also goes through the first record of the theme and finds which data are available and then enables the further options for data definition accordingly. For example, if the Pipe Diameter has a numeric value in its database, then it enables the Pipe Diameter check box in the Input Form so that the user can choose this for assessing the pipe condition and so on, as shown below:

Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

End User ☒ Advanced User / Developer ☐

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

- Shape
- Pipeid
- Startnode
- Endnode
- Strjoint

FIELDS SELECTED :

- Pipeid
- Startnode
- Endnode
- Strjoint
- Endpoint

Pipe Indicators:

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators:

- ☐ Pipe Age Analysis Year :
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators:

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators:

- ☐ No. of Breakages

Load / Strength Indicators:

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators:

- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input Close

4.3.2.2 Pipe node (water distribution) theme

Selecting the water distribution theme in the pipe node theme box updates the list of fields available and selected.

4.3.2.3 Soil, groundwater and pressure themes

If any of the soil, groundwater or /pressure themes is already selected, then the check box options corresponding to 'Soil Corrosivity', 'Ground Water Table' or 'Maximum Pressure' will be enabled, or else these options will remain disabled, as shown below:

Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

End User ☒ Advanced User / Developer ☐

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

- Shape
- Id
- X_coord
- Y_coord
- Z_coord

FIELDS SELECTED :

- Id
- X_coord
- Y_coord
- Z_coord
- Burydepth

Pipe Indicators:

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators:

- ☐ Pipe Age Analysis Year :
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators:

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators:

- ☐ No. of Breakages

Load / Strength Indicators:

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators:

- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input Close

4.3.2.4 Soil theme

Selecting the soil theme updates the list of available and selected fields. This also enables check box options corresponding to 'Soil Corrosivity' (see screen below). If the water distribution (pipe) node theme is not already selected, then the check box options corresponding to 'Soil Corrosivity' will remain disabled.

The screenshot displays the 'Pipe Condition Assessment Input Form' with the 'Soil' theme selected. The form is divided into several sections:

- WATER DISTRIBUTION SYSTEM PIPE DATA:** Includes dropdowns for PIPE LINK THEME (Wdtesttheme.shp), PIPE NODE THEME (Wdtestnode.shp), SOIL THEME (Soilbound.shp), GROUNDWATER (<NONE>), and PRESSURE THEME (<NONE>). A 'No. of Groups' slider is set to 9.
- SELECT ATTRIBUTE DATA FROM FIELDS:** A list of 'FIELDS AVAILABLE' (Shape, Area, Perimeter, Soilbound_, Soil_id) and a list of 'FIELDS SELECTED' (Soil_id, Corrosivit).
- Pipe Indicators:** Includes checkboxes for Pipe Diameter, Pipe Length, Pipe Material, Assign Material Properties, Corrosion Index Membership Function, Pipe Internal Protection, Internal Protection Membership Function, Pipe External Protection, and External Protection Membership Function.
- Corrosion Indicators:** Includes checkboxes for Pipe Age (with an 'Analysis Year' dropdown), Soil Corrosivity, Soil Corrosivity Membership Function, Surface Permeability, Surface Type Membership Function, Ground Water Table, and GW Fluctuation Membership Function.
- Installation Indicators:** Includes checkboxes for Pipe Joint Methods, Joint Method Membership Function, Pipe Bedding Condition, Bedding Condition Membership Function, Workmanship, Workmanship Membership Function, and No. of Connections.
- Pipe Failure Indicators:** Includes a checkbox for No. of Breakages.
- Load / Strength Indicators:** Includes checkboxes for Pipe Buried Depth, Traffic Density, Traffic Density Membership Function, Maximum Pressure, and Maximum Pressure Membership Function.
- Intermittency Indicators:** Includes checkboxes for No. of Valves, Duration of Water Supply per Day, and Frequency of Water Supplied per Day.
- Select Weightage Method:** Includes radio buttons for Equal Weights, Assign Weights, and Generate Weights.

Buttons for 'Generate Input' and 'Close' are located at the bottom of the form.

4.3.2.5 Groundwater theme

Selecting the groundwater theme updates the list of available and selected fields. This also enables check box options corresponding to 'Ground Water Table' (see screen below). If the water distribution node theme is not already selected, then the check box options corresponding to 'Ground Water Table' will remain disabled.

Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

- Shape
- Area
- Perimeter
- Gwf_id
- Avg_gwtdep

FIELDS SELECTED :

- Gwf_id
- Avg_gwtdep
- Avg_gwtflc

Pipe Indicators

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators

- ☐ Pipe Age
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators

- ☐ No. of Breakages

Load / Strength Indicators

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators

- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input **Close**

4.3.2.6 Pressure theme

Selecting the pressure theme updates the list of available and selected fields. This also enables check box options corresponding to 'Maximum Pressure' (see screen below). If the water distribution node theme is not already selected, then the check box options corresponding to 'Maximum Pressure' will remain disabled.

Pipe Condition Assessment Input Form :

WATER DISTRIBUTION SYSTEM PIPE DATA

PIPE LINK THEME :

PIPE NODE THEME :

SOIL THEME :

GROUNDWATER :

PRESSURE THEME :

No. of Groups :

SELECT ATTRIBUTE DATA FROM FIELDS :

FIELDS AVAILABLE :

- Shape
- Area
- Perimeter
- Pressure_
- Pres_zone

FIELDS SELECTED :

- Pres_zone
- Pressure

Pipe Indicators

- ☐ Pipe Diameter
- ☐ Pipe Length
- ☐ Pipe Material
- ☐ Assign Material Properties
- ☐ Corrosion Index Membership Function
- ☐ Pipe Internal Protection
- ☐ Internal Protection Membership Function
- ☐ Pipe External Protection
- ☐ External Protection Membership Function

Corrosion Indicators

- ☐ Pipe Age
- ☐ Soil Corrosivity
- ☐ Soil Corrosivity Membership Function
- ☐ Surface Permeability
- ☐ Surface Type Membership Function
- ☐ Ground Water Table
- ☐ GW Fluctuation Membership Function

Installation Indicators

- ☐ Pipe Joint Methods
- ☐ Joint Method Membership Function
- ☐ Pipe Bedding Condition
- ☐ Bedding Condition Membership Function
- ☐ Workmanship
- ☐ Workmanship Membership Function
- ☐ No. of Connections

Pipe Failure Indicators

- ☐ No. of Breakages

Load / Strength Indicators

- ☐ Pipe Buried Depth
- ☐ Traffic Density
- ☐ Traffic Density Membership Function
- ☐ Maximum Pressure
- ☐ Maximum Pressure Membership Function

Intermittency Indicators

- ☐ No. of Valves
- ☐ Duration of Water Supply per Day
- ☐ Frequency of Water Supplied per Day

Select Weightage Method :

- ☒ Equal Weights
- ☐ Assign Weights
- ☐ Generate Weights

Generate Input **Close**

4.4 Indicator data

Depending on the data available on various themes, the options for entering data for the following different indicators will be enable or disenabled.

1. Pipe Indicators
2. Corrosion Indicators
3. Installation Indicators
4. Pipe Failure Indicators
5. Load/Strength Indicators
6. Intermittency Indicators

The user needs to select which parameters of these indicators he or she wants to use for pipe condition assessment. The data used for these parameters are not only quantitative (crisp value data) but also qualitative (fuzzy data). In case of fuzzy data, the user needs to define the membership functions for the fuzzy data sets.

Pipe material

Various material properties are considered while deciding the condition of the pipe. These properties are:

1. Resistance to corrosion (a fuzzy parameter)
2. Maximum pressure it can sustain
3. Maximum impact load it can sustain
4. Minimum and maximum diameters in which pipes are made
5. Minimum and maximum lengths in which pipes are made
6. Maximum design life
7. Age-Hazen-William Roughness Coefficient (C) relationship

The input for pipe material properties is made in two different input forms. After opening the form 'Pipe Material', the user checks the "Assign Material Properties" box (see screen below). This form lists the available pipe materials in the water distribution pipe theme. If the default database for the pipe material in the IRA-WDS contains the pipe material listed in water distribution pipe theme, then it populates the respective fields for those pipe material properties for which data are available; otherwise nothing is written. For example, in the screen below the IRA-WDS database has all the necessary data for the pipe material 'AC' listed in the water distribution pipe theme, hence all the pipe material properties' check boxes are filled. However, for the pipe material 'U1', the IRA-WDS database has no pipe material data and hence all the pipe material properties' check boxes are empty. The user needs to fill in all the empty fields in the form appropriately. He or she can also modify the data if they do not agree with the IRA-WDS default database. An input form having some default data from the database and some material to be defined by the user is shown on next page.

Pipe Material Properties Input Form :

Pipe Material	Corrosion Index	Max. Pressure	Max. Load	Design Life	Max. Diameter	Min. Diameter
AC	Very Strong	35.700	23.500	60	2500.000	50.000
RCC	Very Strong	30.000	30.000	60	1200.000	400.000
U1	Very Strong					
PVC	Very Strong	15.300	4.400	60	1200.000	75.000
CI	Very Strong	97.920	150.000	70	2000.000	75.000

☐ Assign 'C' Values OK

The completed data form is shown below:

Pipe Material Properties Input Form :

Pipe Material	Corrosion Index	Max. Pressure	Max. Load	Design Life	Max. Diameter	Min. Diameter
AC	Very Strong	35.700	23.500	60	2500.000	50.000
RCC	Very Strong	30.000	30.000	60	1200.000	400.000
U1	Very Strong	15.000	25.000	50	1000.000	300.000
PVC	Very Strong	15.300	4.400	60	1200.000	75.000
CI	Very Strong	97.920	150.000	70	2000.000	75.000

☐ Assign 'C' Values OK

To define the 'Pipe Material: Age-C' relationship, the user should click on the check box 'Assign 'C' Values' on the 'Pipe Material Properties Input Form'. This opens the 'Pipe Material: Age-'C' Values Relation Input Form'. Again, if the default database for the pipe material in the IRA-WDS program contains the pipe material listed in

water distribution pipe theme, 'C' values appear in the check boxes; otherwise the check boxes remain empty. (Note that values are assigned up to the designed age of the pipe and '0' 'C' values are assigned for any ages greater than the designed age of the pipe). An input form filled in with values from the database is shown below:

Pipe Material : Age - 'C' Values Relation Input Form

Material \ Age	0 - 10 yrs	11 - 20 yrs	21 - 30 yrs	31 - 40 yrs	41 - 50 yrs	51 - 60 yrs	61 - 70 yrs	71 - 80 yrs	81 - 90 yrs	91 - 100 yrs
AC	150	130	130	120	120	120	100	0	0	0
RCC	130	120	110	95	70	70	70	0	0	0
U1										
PVC	150	140	140	140	140	140	130	0	0	0
CI	150	110	100	90	80	70	70	60	0	0

OK

The user needs to complete the form appropriately by entering values in any blank fields. He or she can also modify the data if they do not agree with the default database. The completed data form is shown below:

Pipe Material : Age - 'C' Values Relation Input Form

Material \ Age	0 - 10 yrs	11 - 20 yrs	21 - 30 yrs	31 - 40 yrs	41 - 50 yrs	51 - 60 yrs	61 - 70 yrs	71 - 80 yrs	81 - 90 yrs	91 - 100 yrs
AC	150	130	130	120	120	120	100	0	0	0
RCC	130	120	110	95	70	70	70	0	0	0
U1	120	120	110	110	100	50	0	0	0	0
PVC	150	140	140	140	140	140	130	0	0	0
CI	150	110	100	90	80	70	70	60	0	0

OK

4.5 Other data

The remaining data used is in quantitative (crisp data) and qualitative (fuzzy data) forms, which are described below.

Crisp data

The parameters that are quantitative in nature are: 'Pipe Diameter', 'Pipe Length', 'Pipe Material', 'Pipe Age', 'Number of Connections', 'Number of Breakages', 'Pipe Buried Depth', 'Number of Valves', 'Duration of Water Supply per Day' and 'Frequency of Water Supplied per Day'. Except for the 'Pipe Age', the remainder of the parameters do not require any more information. These parameters need to be selected if required. For 'Pipe Age', further information pertaining to the 'Analysis Year' is required, which can be selected from the combo box, as shown below:

The screenshot displays the 'Pipe Condition Assessment Input Form' with the following sections and controls:

- WATER DISTRIBUTION SYSTEM PIPE DATA:** Includes dropdown menus for 'PIPE LINK THEME' (Wdtesttheme.shp), 'PIPE NODE THEME' (Wdtestnode.shp), 'SOIL THEME' (Soilbound.shp), 'GROUNDWATER' (Gwt.shp), and 'PRESSURE THEME' (Pressure.shp). A 'No. of Groups' slider is set to 9.
- User Selection:** Radio buttons for 'End User' (selected) and 'Advanced User / Developer'.
- SELECT ATTRIBUTE DATA FROM FIELDS:** Two list boxes. 'FIELDS AVAILABLE' contains Shape, Area, Perimeter, Pressure_, and Pres_zone. 'FIELDS SELECTED' contains Pres_zone and Pressure.
- Pipe Indicators:** Checkboxes for 'Pipe Diameter' (checked), 'Pipe Length' (checked), 'Pipe Material', 'Assign Material Properties', 'Corrosion Index Membership Function', 'Pipe Internal Protection', 'Internal Protection Membership Function', 'Pipe External Protection', and 'External Protection Membership Function'.
- Corrosion Indicators:** Checkboxes for 'Pipe Age' (checked), 'Soil Corrosivity', 'Soil Corrosivity Membership Function', 'Surface Permeability', 'Surface Type Membership Function', 'Ground Water Table', and 'GW Fluctuation Membership Function'. An 'Analysis Year' dropdown is set to 2005.
- Installation Indicators:** Checkboxes for 'Pipe Joint Methods', 'Joint Method Membership Function', 'Pipe Bedding Condition', 'Bedding Condition Membership Function', 'Workmanship', 'Workmanship Membership Function', and 'No. of Connections'.
- Pipe Failure Indicators:** Checkboxes for 'No. of Breakages'.
- Load / Strength Indicators:** Checkboxes for 'Pipe Buried Depth', 'Traffic Density', 'Traffic Density Membership Function', 'Maximum Pressure', and 'Maximum Pressure Membership Function'.
- Intermittency Indicators:** Checkboxes for 'No. of Valves', 'Duration of Water Supply per Day', and 'Frequency of Water Supplied per Day'.
- Select Weightage Method:** Radio buttons for 'Equal Weights' (selected), 'Assign Weights', and 'Generate Weights'.
- Buttons:** 'Generate Input' and 'Close' at the bottom.

Fuzzy data

The parameters that are qualitative in nature are: the 'Pipe Material Corrosion Index', 'Pipe Internal and External Protection', 'Soil Corrosivity', 'Surface Type/Permeability', 'Ground Water Table Fluctuation', 'Traffic Density', 'Maximum Pressure', 'Pipe Joint Methods', 'Pipe Bedding Condition' and 'Workmanship'. All of these require further information regarding their membership function.

4.5.1 Membership functions

If any fuzzy parameter is clicked, its membership definition form appears. For example, if Pipe Material and then Corrosion Index Membership Function are clicked, its membership form appears (see screen below). The form is common for all the parameters except the title and group labels, which vary according to the indicator for which membership function is to be defined.

The form consists of five buttons and 20 text boxes for user input. The membership function is defined with the help of these text boxes. A trapezoidal or triangular membership function can be defined with this input form. If the 'Middle Left' and 'Middle Right' values of the membership form are the same, the membership function is triangular. The membership form that appears on the screen contains the default values membership function. However, the user can change the membership function. He or she is advised to refer to the Book-3 (Risk assessment of contaminant intrusion into water distribution systems) of this series for this purpose.

There are five buttons to facilitate defining membership functions. These are:

Default: Clicking this button loads the membership definition text boxes with default values defined for various indicators in the IRA-WDS database.

Clear All: Clicking this button clears all membership definition text boxes.

OK: By clicking this button, the membership definition is completed and the membership definition dialogue box is closed.

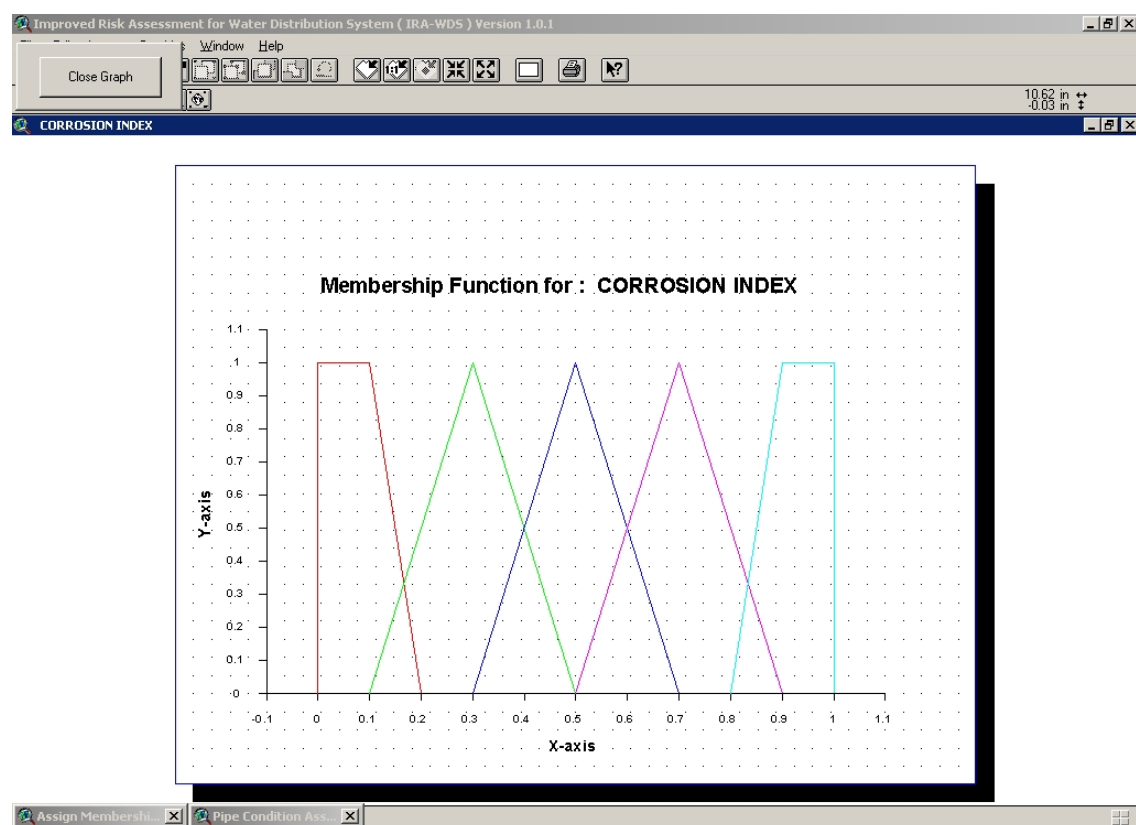
Cancel: By clicking this button the membership definition is cancelled and the dialogue box is closed.

Chart: By clicking this button, the membership definition and the 'Pipe Condition Assessment Input Form' are minimized and the layout dialogue box is opened within which the membership defined is shown graphically.

1. Pipe Material Corrosion Index

	Left	Middle Left	Middle Right	Right
Very Weak	0.0	0.0	0.1	0.2
Weak	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Strong	0.5	0.7	0.7	0.9
Very Strong	0.8	0.9	1.0	1.0

Buttons: Default, Clear All, OK, Cancel, Chart



2. Pipe Internal Protection

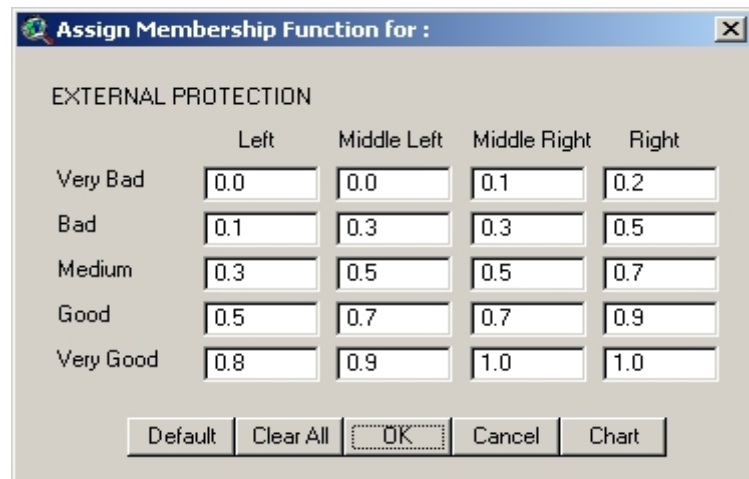
Assign Membership Function for :

INTERNAL PROTECTION

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Good	0.5	0.7	0.7	0.9
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

3. Pipe External Protection



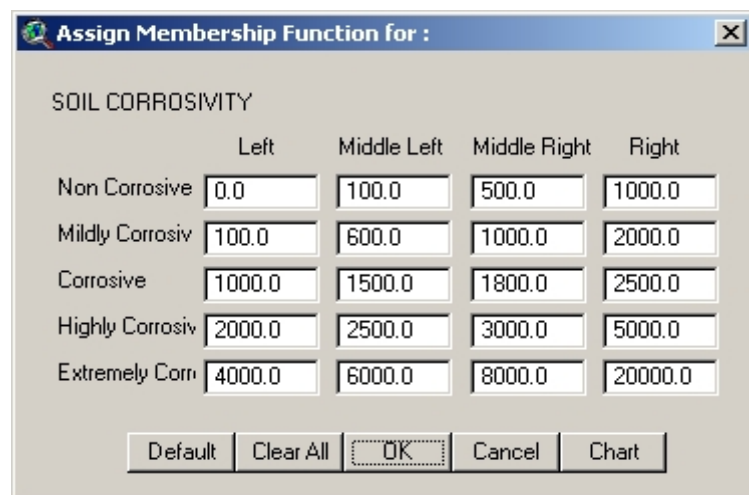
Assign Membership Function for : EXTERNAL PROTECTION

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Good	0.5	0.7	0.7	0.9
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

4. Soil Corrosivity

When defining the soil corrosivity membership function, the 'Soil Corrosivity' property is used.

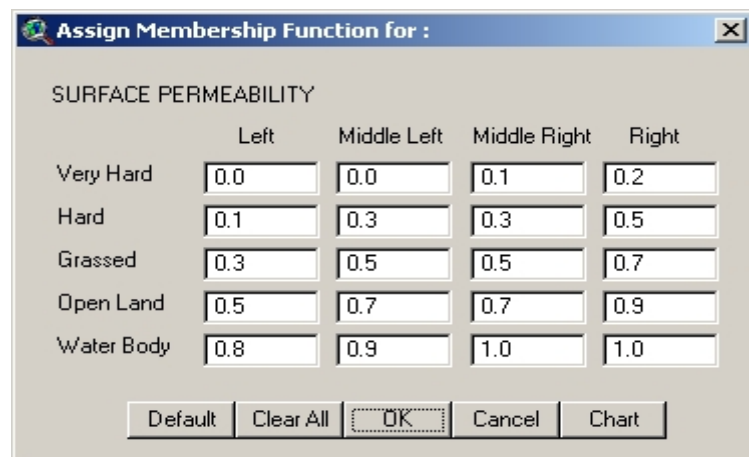


Assign Membership Function for : SOIL CORROSIVITY

	Left	Middle Left	Middle Right	Right
Non Corrosive	0.0	100.0	500.0	1000.0
Mildly Corrosiv	100.0	600.0	1000.0	2000.0
Corrosive	1000.0	1500.0	1800.0	2500.0
Highly Corrosiv	2000.0	2500.0	3000.0	5000.0
Extremely Corn	4000.0	6000.0	8000.0	20000.0

Default Clear All OK Cancel Chart

5. Surface Type/Permeability

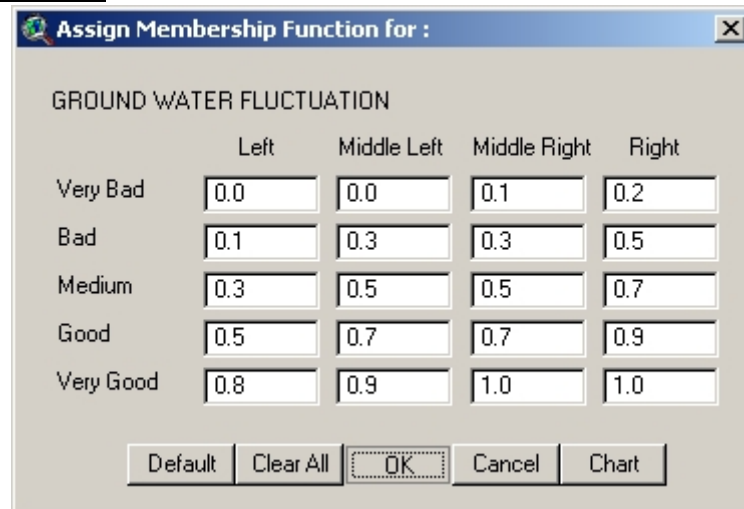


Assign Membership Function for : SURFACE PERMEABILITY

	Left	Middle Left	Middle Right	Right
Very Hard	0.0	0.0	0.1	0.2
Hard	0.1	0.3	0.3	0.5
Grassed	0.3	0.5	0.5	0.7
Open Land	0.5	0.7	0.7	0.9
Water Body	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

6. Ground Water Table Fluctuation



Assign Membership Function for :

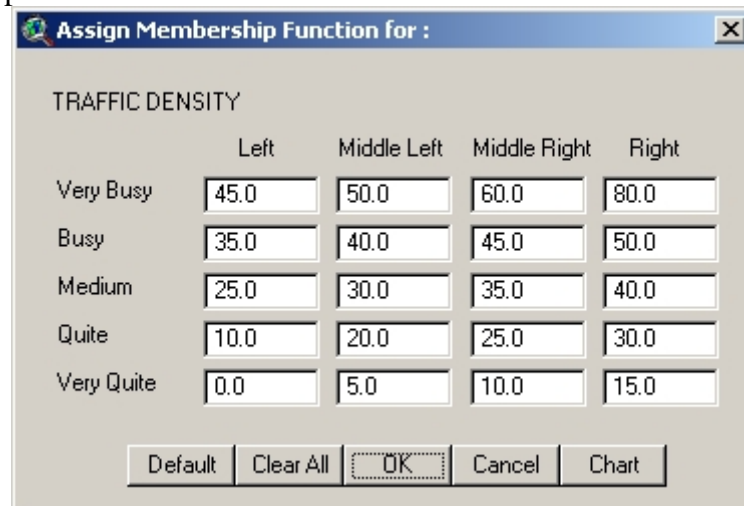
GROUND WATER FLUCTUATION

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Good	0.5	0.7	0.7	0.9
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

7. Traffic Density

When defining the traffic density membership function, the actual observed values of number of vehicles passing per hour should be used.



Assign Membership Function for :

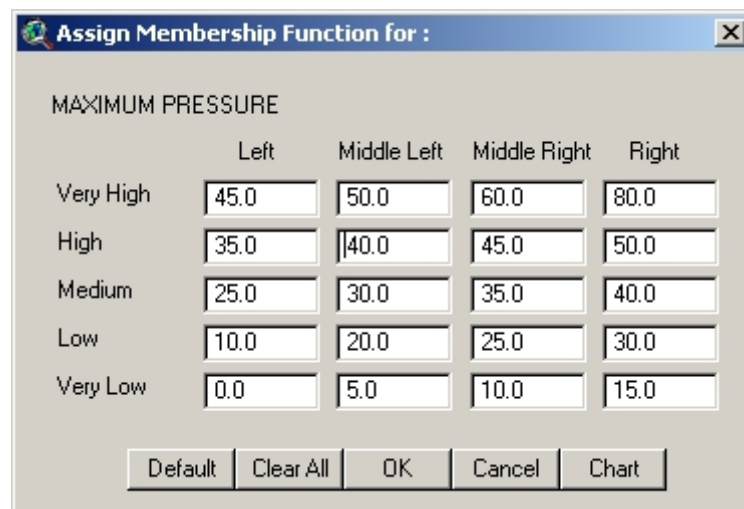
TRAFFIC DENSITY

	Left	Middle Left	Middle Right	Right
Very Busy	45.0	50.0	60.0	80.0
Busy	35.0	40.0	45.0	50.0
Medium	25.0	30.0	35.0	40.0
Quite	10.0	20.0	25.0	30.0
Very Quite	0.0	5.0	10.0	15.0

Default Clear All OK Cancel Chart

8. Maximum Pressure

When defining the maximum pressure membership function, the values of pressure at the outlets should be used.



Assign Membership Function for :

MAXIMUM PRESSURE

	Left	Middle Left	Middle Right	Right
Very High	45.0	50.0	60.0	80.0
High	35.0	40.0	45.0	50.0
Medium	25.0	30.0	35.0	40.0
Low	10.0	20.0	25.0	30.0
Very Low	0.0	5.0	10.0	15.0

Default Clear All OK Cancel Chart

9. Joint Method

Assign Membership Function for :

JOINT METHOD

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.4	0.4	0.7
Medium	0.4	0.65	0.65	0.9
Good	0.6	0.8	1.0	1.0
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

10. Bedding Condition

Assign Membership Function for :

BEDDING CONDITION

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Good	0.5	0.7	0.7	0.9
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

11. Workmanship

Assign Membership Function for :

WORKMANSHIP

	Left	Middle Left	Middle Right	Right
Very Bad	0.0	0.0	0.1	0.2
Bad	0.1	0.3	0.3	0.5
Medium	0.3	0.5	0.5	0.7
Good	0.5	0.7	0.7	0.9
Very Good	0.8	0.9	1.0	1.0

Default Clear All OK Cancel Chart

4.5.2 Weightage methods

The user also needs to assign weights for various indicators and balance factors for various groups. Weight allows importance to be given to different parameters/indicators within a group. Balance factors reflect the importance of the maximal deviations between indicators (criteria) in the same group, where ‘maximal deviation’ means the maximum difference between an indicator value and the best value for that indicator. The larger the balancing factor, the greater the concern with respect to the maximal deviation. Low balancing factors are used for a high level of allowable compromise between indicators of the same group. A balancing factor equal to 1 means that there is a perfect compromise between indicators of the group. If the level of compromise between indicators is moderate, a balancing factor of 2 will be sufficient. A balancing factor of 3 or more reflects a situation of minimal compromise between indicators. In the present (Pipe Condition Assessment) model, three weightage methods are included. These are:

Equal Weights: With this method, equal weights are assigned to all the indicators of particular group. A balancing factor of 1 is assigned to all the groups.

Assign Weights: With this method, weights are assigned directly. The form in which they are assigned is shown below:

Assign Weights for Pipe Condition Assessment

Pipe Condition Assessment

Physical Indicators

Pipe Indicators

Diameter 0.200

Length 0.200

Material 0.200

Int. Protect. 0.200

Ext. Protect. 0.200

Balance Factor

Pipe Weight 0.5

Installation Weight 0.5

Physical Balance Factor

Installation Indicators

Joint Method 0.250

Bed. Condition 0.250

Workmanship 0.250

Connections 0.250

Balance Factor

Environmental Indicators

Corrosion Indicators

Pipe Age 0.250

Soil Corrosivity 0.250

Surface Type 0.250

Groundwater 0.250

Balance Factor

Corrosion Weight 0.5

Strength Weight 0.5

Environmental Balance Factor

Strength Indicators

Buried Depth 0.333

Traffic Density 0.333

Pressure 0.333

Balance Factor

Operational Indicators

Failure Indicators

Breakage 1.000

Balance Factor

Failure Weight 0.5

Intermittency Indicators

Valve Number 0.333

Operation Time 0.333

No. of Operations 0.333

Balance Factor

Intermittency Weight 0.5

Operational Balance Factor

Physical Weight 0.333

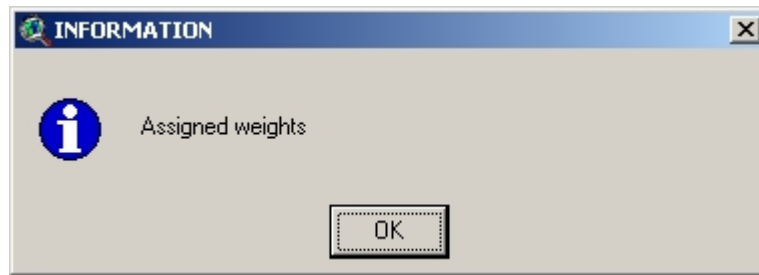
Environmental Weight 0.333

Operational Weight 0.333

Pipe Condition Assessment Balance Factor

Assign Weights Cancel

Depending on the number of indicators selected for the assessment, equal weights are assigned initially to all the indicators. The user can change the weights assigned to each indicator. However, it is necessary that the sum of the weights given in one group should be equal to 1 (see screen above). The user needs to input values for the balance factors of each group. After completing the form, the user can click on the ‘Assign Weights’ button to assign the weights and close the form. The program then displays the following Information message regarding weights assigned. Clicking on ‘OK’ closes this form.



Generated by AHP: Weights can also be generated using the pair-wise comparison, that is, by Analytical Hierarchy Process (AHP). Clicking on 'Generate Weights' causes the following 'Generate Weights using Analytical Hierarchy Process' form to appear.

Generate Weightings using Analytical Hierarchy Process

Pipe Condition Assessment :

Physical Indicators :

Pipe Indicators :

	Dia.	Len.	Mat.	InP.	ExP.	Wts.
Dia.	1.00					
Len.	x	1.00				
Mat.	x	x	1.00			
InP.	x	x	x	1.00		
ExP.	x	x	x	x	1.00	

Balance Factor for Level (I) : 1

Installation Indicators :

	BC	Wms	JM	NoC	Wts.
BC	1.00				
Wms	x	1.00			
JM	x	x	1.00		
NoC	x	x	x	1.00	

Balance Factor for Level (II) : 1

PIPE INSTALL Wts.

	PIPE	INSTALL	Wts.
PIPE	1.00		
INSTALL	x	1.00	

Physical Balance Factor : 1

Environmental Indicators :

Corrosion Indicators :

	Age	SC	SP	GWf	Wts.
Age	1.00				
SC	x	1.00			
SP	x	x	1.00		
GWf	x	x	x	1.00	

Balance Factor for Level (I) : 1

Strength Indicators :

	BD	TD	MP	Wts.
BD	1.00			
TD	x	1.00		
MP	x	x	1.00	

Balance Factor for Level (II) : 1

CORR. LOAD Wts.

	CORR.	LOAD	Wts.
CORR.	1.00		
LOAD	x	1.00	

Environ. Balance Factor : 1

Operational Indicators :

Failure Indicators :

	Brk.	Lek.	Bur.	Wts.
Brk.	1.00	n/a	n/a	
Lek.	n/a	n/a	n/a	
Bur.	n/a	n/a	n/a	

Balance Factor for Level (I) : 1

Intermittency Indicators :

	NoV	Dur.	Fre.	Wts.
NoV	1.00			
Dur.	x	1.00		
Fre.	x	x	1.00	

Balance Factor for Level (II) : 1

FAIL INTER Wts.

	FAIL	INTER	Wts.
FAIL	1.00		
INTER	x	1.00	

Operation Balance Factor : 1

Phy Env Opr Wts

	Phy	Env	Opr	Wts
Phy	1.00			
Env	x	1.00		
Opr	x	x	1.00	

PCA Balance Factor : 1

Select Importance

Less Important

More Important

Generate Weights OK Cancel

The matrix elements are enabled for those indicators that are selected in the 'Pipe Condition Assessment Input Form'. The slider on the right-hand side of the 'Generate Weightings using Analytical Hierarchy Process' form can be used to define the matrix element. The user needs to input values for the balance factors of each group. On completion of the matrix elements and inputting the balance factors, the form appears as shown in the example in next page.

Generate Weightings using Analytical Hierarchy Process

Pipe Condition Assessment :

Physical Indicators :

Pipe Indicators

	Dia.	Len.	Mat.	InP.	ExP.	Wts.
Dia.	1.00	0.25	0.20	0.25	2.00	
Len.	4.00	1.00	0.25	0.25	8.00	
Mat.	5.00	4.00	1.00	0.20	8.00	
InP.	4.00	4.00	5.00	1.00	8.00	
ExP.	0.50	0.13	0.13	0.13	1.00	

Balance Factor for Level (I) : 1

Installation Indicators

	BC	Wms	JM	NoC	Wts.
BC	1.00	5.00	5.00	2.00	
Wms	0.20	1.00	5.00	2.00	
JM	0.20	0.20	1.00	6.00	
NoC	0.50	0.50	0.17	1.00	

Balance Factor for Level (II) : 1

Physical Balance Factor : 1

PIPE INSTALL Wts.

	PIPE	INSTALL	Wts.
PIPE	1.00	0.33	
INSTALL	3.00	1.00	

Environmental Indicators :

Corrosion Indicators

	Age	SC	SP	GWf	Wts.
Age	1.00	0.33	2.00	2.00	
SC	3.00	1.00	0.33	2.00	
SP	0.50	3.00	1.00	5.00	
GWf	0.50	0.50	0.20	1.00	

Balance Factor for Level (I) : 1

Strength Indicators

	BD	TD	MP	Wts.
BD	1.00	5.00	0.33	
TD	0.20	1.00	5.00	
MP	3.00	0.20	1.00	

Balance Factor for Level (II) : 1

Corr. LOAD Wts.

	CORR.	LOAD	Wts.
CORR.	1.00	0.33	
LOAD	3.00	1.00	

Environ. Balance Factor : 1

Operational Indicators :

Failure Indicators

	Brk.	Lek.	Bur.	Wts.
Brk.	1.00	n/a	n/a	
Lek.	n/a	n/a	n/a	
Bur.	n/a	n/a	n/a	

Balance Factor for Level (I) : 1

Intermittency Indicators

	NoV	Dur.	Fre.	Wts.
NoV	1.00	6.00	6.00	
Dur.	0.17	1.00	0.50	
Fre.	0.17	2.00	1.00	

Balance Factor for Level (II) : 1

Operation Balance Factor : 1

FAIL INTER Wts.

	FAIL	INTER	Wts.
FAIL	1.00	6.00	
INTER	0.17	1.00	

Select Importance

Less Important

More Important

Phy Env Opr Wts

	Phy	Env	Opr	Wts
Phy	1.00	0.50	5.00	
Env	2.00	1.00	5.00	
Opr	0.20	0.20	1.00	

PCA Balance Factor : 1

Generate Weights OK Cancel

The user then clicks the 'Generate Weights' button, which opens the 'Save AHP Input File' dialogue box to save the AHP input matrix, as shown below:

Save AHP Input File

File Name:

Directories: c:\avirawds\sampldata

OK Cancel

Drives: C:

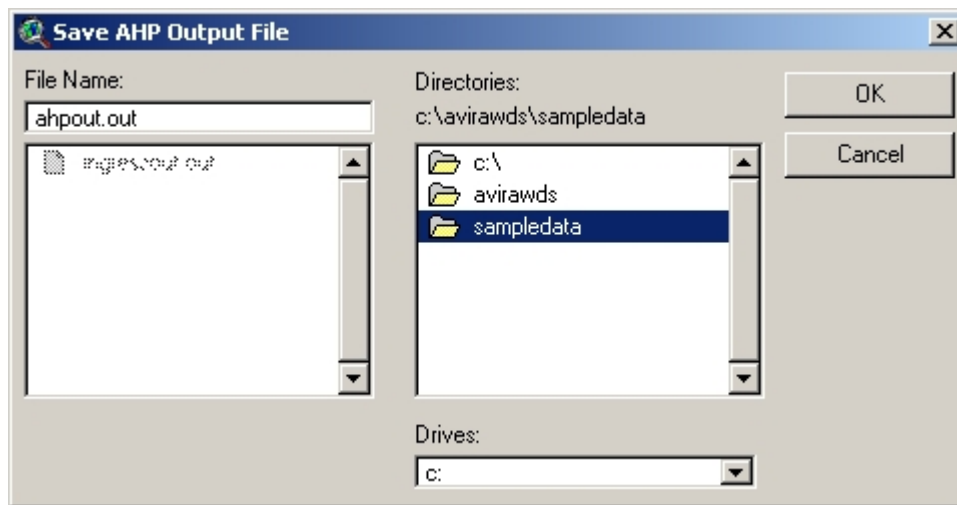
After selecting the input filename to save AHP input, the following dialogue box appears:

Info

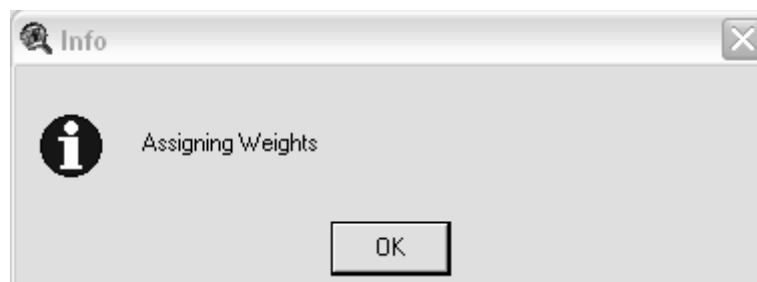
Generated the AHP Input File

OK

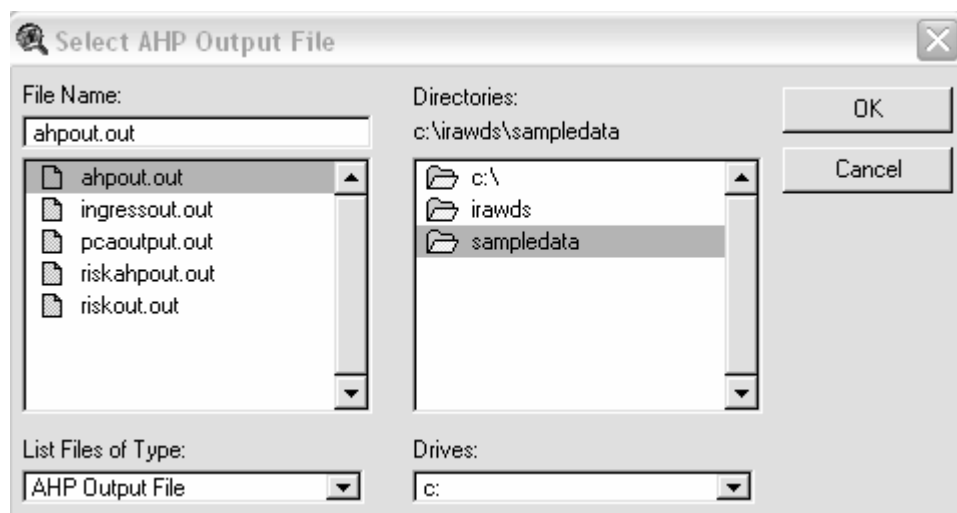
Confirming 'OK' on the 'Generated the AHP Input File' Info message box opens the 'Save AHP Output File' dialogue box and prompts the user about the filename to save the AHP output under, as shown below:



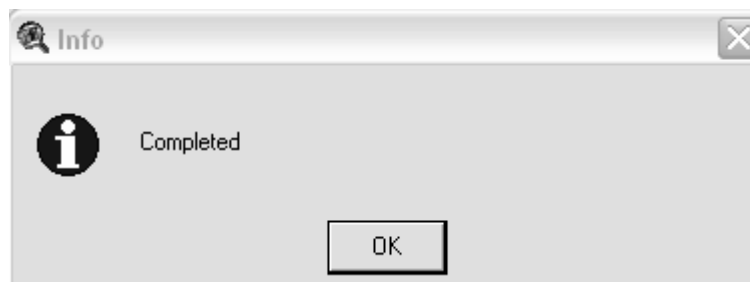
After selecting the output filename to save AHP output under, the following dialogue box appears:



Clicking 'OK' executes the AHP model, which generates the weight for each parameter considered in the 'Pipe Condition Assessment Input Form' and then asks the name of AHP output file for viewing, as shown below:



After the user gives the name of AHP output file, the following message appears:



After the user confirms 'OK', the weights can be seen (see screen below). If the weights generated using AHP are consistent, then those values are presented in the respective text boxes; otherwise '-99' appears in those boxes. If any particular indicator is not considered in the analysis, then '-999' appears in the text box as shown below:

Generate Weightings using Analytical Hierarchy Process

Pipe Condition Assessment :

Physical Indicators :

	Dia.	Len.	Mat.	InP.	ExP.	Wts.
Dia.	1.00	0.25	0.20	0.25	2.00	0.063
Len.	4.00	1.00	0.25	0.25	8.00	0.152
Mat.	5.00	4.00	1.00	0.20	8.00	0.265
InP.	4.00	4.00	5.00	1.00	8.00	0.483
ExP.	0.50	0.13	0.13	0.13	1.00	0.034

Balance Factor for Level (I) : 1

Installation Indicators :

	BC	Wms	JM	NoC	Wts.
BC	1.00	5.00	5.00	2.00	0.531
Wms	0.20	1.00	5.00	2.00	0.237
JM	0.20	0.20	1.00	6.00	0.139
NoC	0.50	0.50	0.17	1.00	0.090

Balance Factor for Level (II) : 1

Physical Balance Factor : 1

PIPE INSTALL Wts.

	PIPE	INSTALL	Wts.
PIPE	1.00	0.33	0.249
INSTALL	3.00	1.00	0.750

Environmental Indicators :

Corrosion Indicators :

	Age	SC	SP	GWf	Wts.
Age	1.00	0.33	2.00	2.00	0.244
SC	3.00	1.00	0.33	2.00	0.270
SP	0.50	3.00	1.00	5.00	0.377
GWf	0.50	0.50	0.20	1.00	0.107

Balance Factor for Level (I) : 1

Strength Indicators :

	BD	TD	MP	Wts.
BD	1.00	5.00	0.33	0.390
TD	0.20	1.00	5.00	0.330
MP	3.00	0.20	1.00	0.278

Balance Factor for Level (II) : 1

Environ. Balance Factor : 1

CORR. LOAD Wts.

	CORR.	LOAD	Wts.
CORR.	1.00	0.33	0.249
LOAD	3.00	1.00	0.750

Operational Indicators :

Failure Indicators :

	Brk.	Lek.	Bur.	Wts.
Brk.	1.00	n/a	n/a	1
Lek.	n/a	n/a	n/a	-999
Bur.	n/a	n/a	n/a	-999

Balance Factor for Level (I) : 1

Intermittency Indicators :

	NoV	Dur.	Fre.	Wts.
NoV	1.00	6.00	6.00	0.743
Dur.	0.17	1.00	0.50	0.099
Fre.	0.17	2.00	1.00	0.157

Balance Factor for Level (II) : 1

Operation Balance Factor : 1

FAIL INTER Wts.

	FAIL	INTER	Wts.
FAIL	1.00	6.00	0.855
INTER	0.17	1.00	0.144

Phy Env Opr Wts

	Phy	Env	Opr	Wts
Phy	1.00	0.50	5.00	0.352
Env	2.00	1.00	5.00	0.559
Opr	0.20	0.20	1.00	0.088

PCA Balance Factor : 1

Generate Weights OK Cancel

Select Importance

Less Important

More Important

- Extremely
- Very Strongly to Extremely
- Very Strongly
- Strongly to Very Strongly
- Strongly
- Moderately to Strongly
- Moderately
- Equally to Moderately
- Equally
- Equally to Moderately
- Moderately
- Moderately to Strongly
- Strongly
- Strongly to Very Strongly
- Very Strongly
- Very Strongly to Extremely
- Extremely

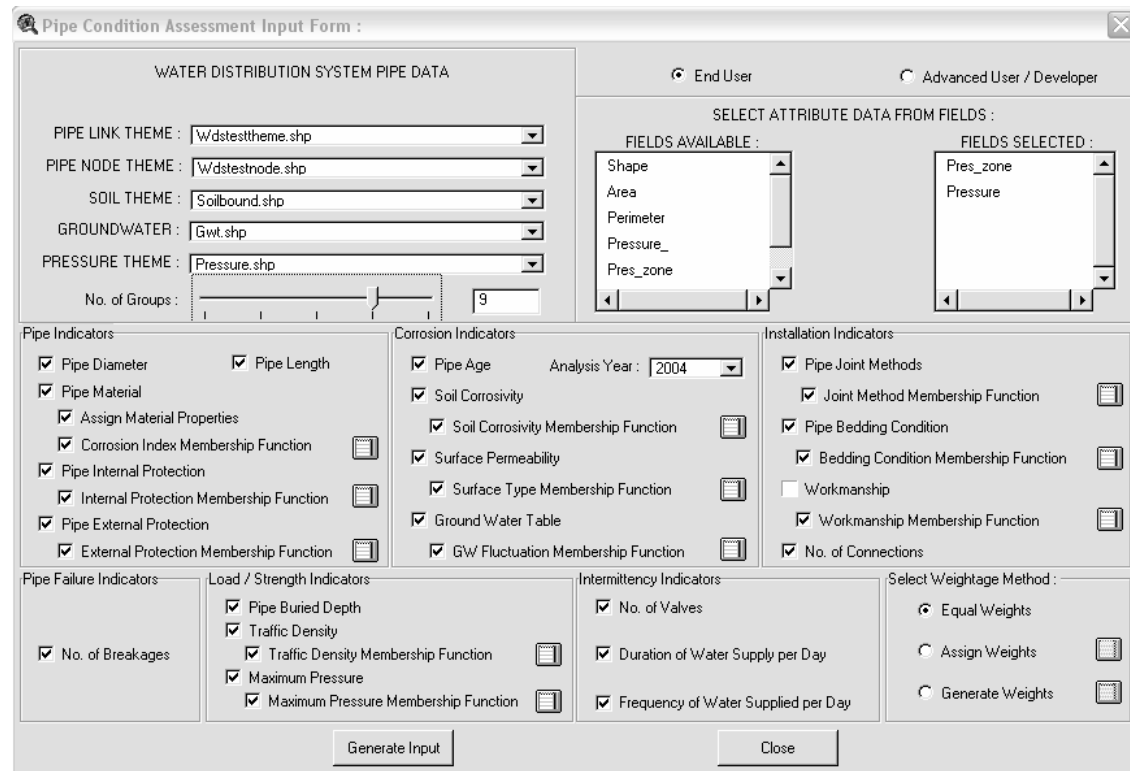
During this step the 'Generate Weights' button is disabled and 'OK' button is enabled. If the user clicks the 'OK' button, then the weights generated by AHP are assigned and a message is displayed as shown below:



If the 'Cancel' button is clicked, then the 'Equal Weights' option will be selected and 'Weights by AHP' will not be selected.

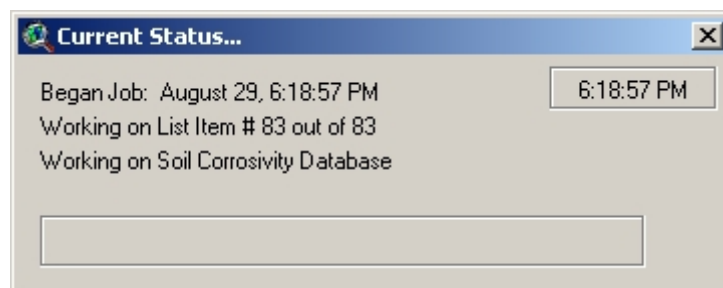
4.6 Number of groups

The output of the PCA model is a ranking of different pipes depending on their respective conditions. These pipes can be placed in different groups on the basis of their conditions. The number of groups can be entered by sliding the bar in front of 'No. of Groups' on the 'PCA Input Form' or by entering a value for the number of groups in the box provided, as shown below:



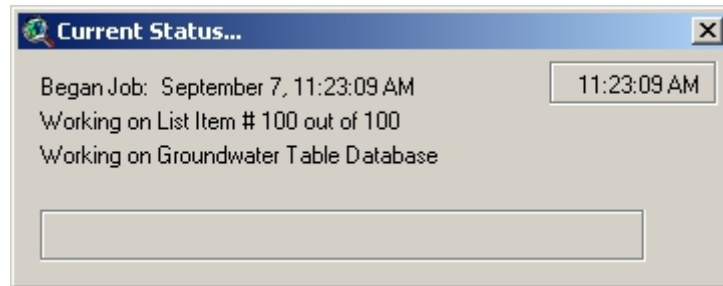
4.7 Generating the input file (PCA)

To generate the pipe condition assessment input file, the user should click on the 'Generate Input' button on the 'Pipe Condition Assessment Input Form'. If 'Soil Corrosivity' is selected, the model finds which pipe falls in which soil type and then appends the water distribution system pipe theme with soil corrosion category data accordingly.

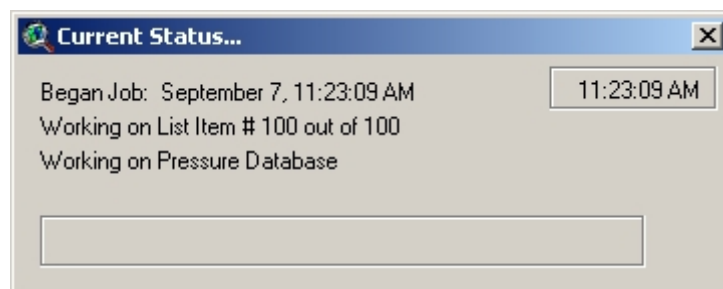


If the 'Ground Water Table' is selected, the interface finds the average groundwater table depth and groundwater fluctuation depth for each pipe. Then using the pipe

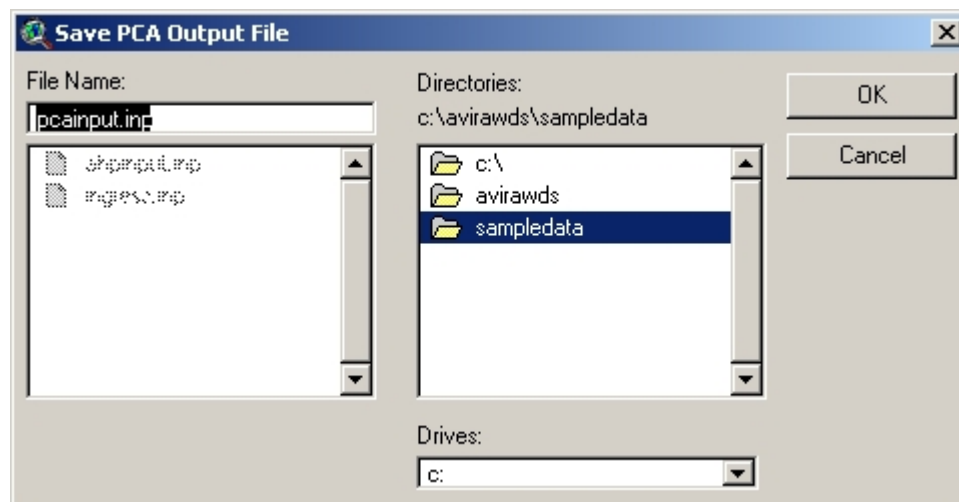
buried depth and the groundwater table data, it computes the groundwater category for each pipe and appends the water distribution pipe theme accordingly.



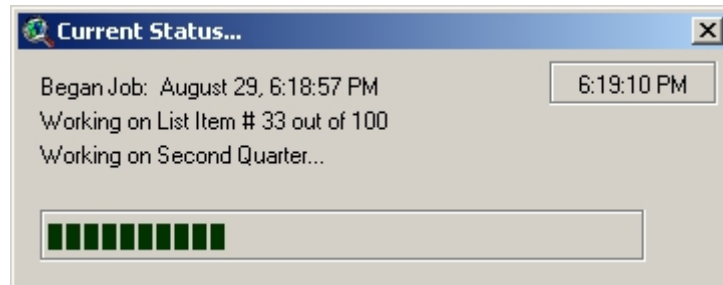
If the 'Maximum Pressure' is selected, the interface finds the pressure for each pipe and then appends the water distribution pipe theme according to the pressure category.



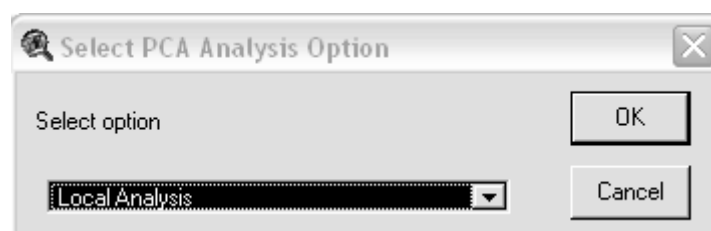
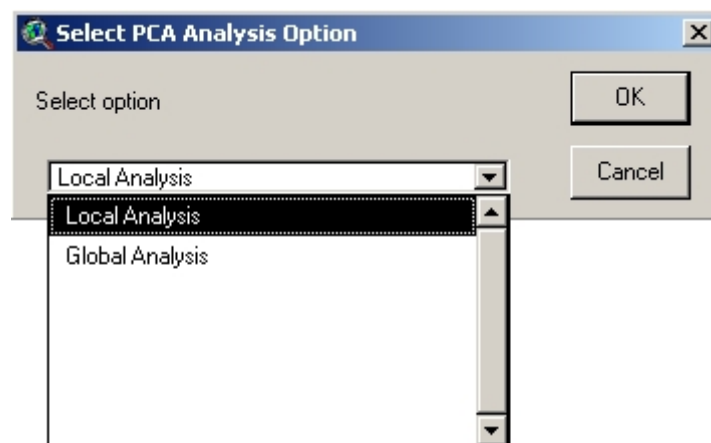
It then opens the 'File Save' dialogue box to save the file with the user-defined name.



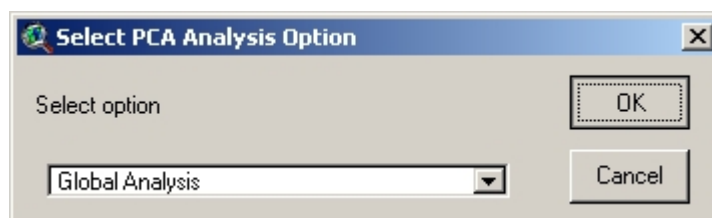
After the user writes/selects the input filename, the interface starts writing the input file. The data generation and writing progress is shown in the ‘Current Status...’ bar, as shown below:



Before completion of data writing, the model prompts an ‘Input Choice’ box asking the user for a ‘Local Analysis’ or ‘Global Analysis’ of pipe condition.

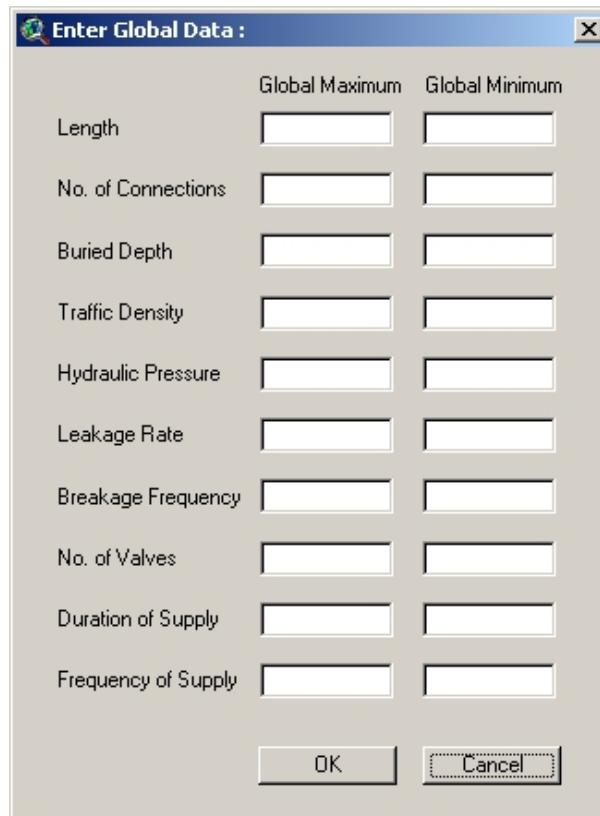


If user selects the ‘Local Analysis’ option, no more data input is required and the interface scans through the data input and finds the local maximum and minimum for the particular parameter required.



If the ‘Global Analysis’ option is selected, then one more input form is opened asking the user to fill in the maximum and minimum for certain parameters; these can then be

used to study and compare different networks in different conditions. The 'Global Data' input form is shown below:

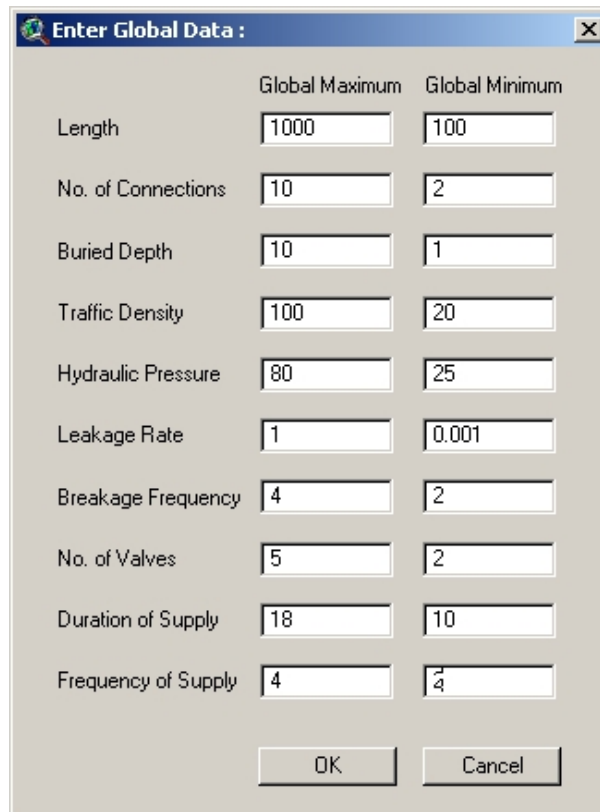


The 'Enter Global Data' dialog box contains the following parameters and their corresponding input fields for Global Maximum and Global Minimum:

Parameter	Global Maximum	Global Minimum
Length	<input type="text"/>	<input type="text"/>
No. of Connections	<input type="text"/>	<input type="text"/>
Buried Depth	<input type="text"/>	<input type="text"/>
Traffic Density	<input type="text"/>	<input type="text"/>
Hydraulic Pressure	<input type="text"/>	<input type="text"/>
Leakage Rate	<input type="text"/>	<input type="text"/>
Breakage Frequency	<input type="text"/>	<input type="text"/>
No. of Valves	<input type="text"/>	<input type="text"/>
Duration of Supply	<input type="text"/>	<input type="text"/>
Frequency of Supply	<input type="text"/>	<input type="text"/>

Buttons: OK, Cancel

After the user has completed the data, the 'Global Data' input form looks as shown below:

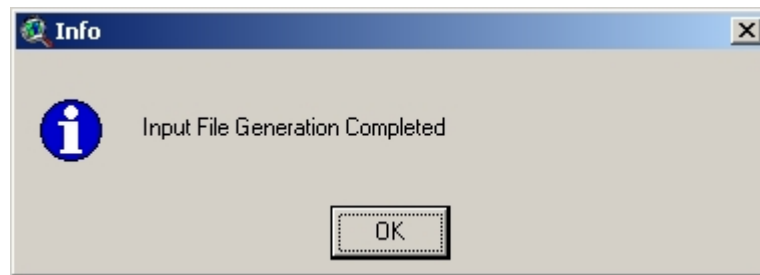


The 'Enter Global Data' dialog box shows the following values entered in the input fields:


Parameter	Global Maximum	Global Minimum
Length	1000	100
No. of Connections	10	2
Buried Depth	10	1
Traffic Density	100	20
Hydraulic Pressure	80	25
Leakage Rate	1	0.001
Breakage Frequency	4	2
No. of Valves	5	2
Duration of Supply	18	10
Frequency of Supply	4	4

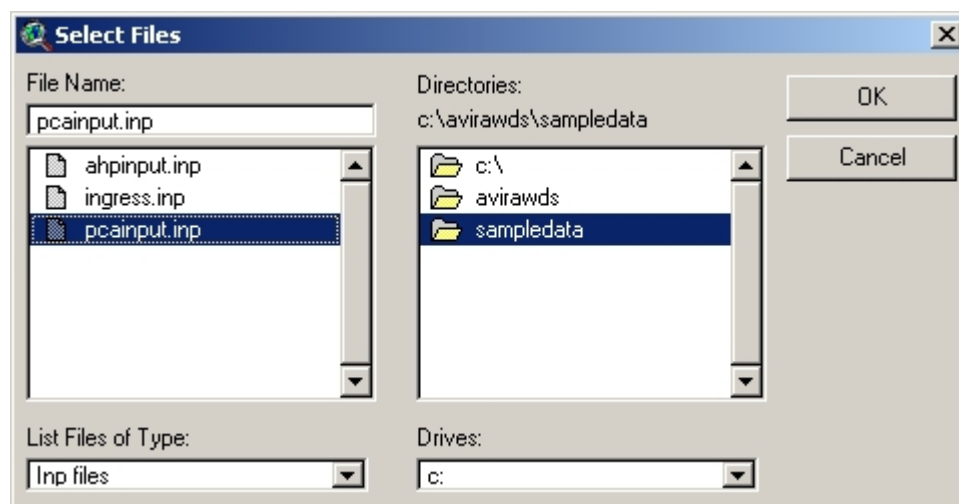
Buttons: OK, Cancel

After completing the data, the user can click on the 'OK' button. After generating the input file successfully, an 'Info' message box indicating 'Input File Generation completion' is displayed as shown below:



4.8 Viewing the PCA input files

The user can view the input file in the notepad by clicking on the  button or alternatively by selecting the 'View PCA Input Files' submenu from the 'Pipe Condition Assessment' menu and browsing the appropriate file to view.



pcainput - Notepad

File Edit Format Help

```

=====
;
; WATER PIPELINE Vulnerability Assessment Input
;
=====

```

[WATER PIPE]

ID	StNode	EndNode	StJoint	EndJoint	Material	Traffic	SurfPerm	InProtect	ExProtect	BedCond	workshop
689	631	632	4	4	0	2	0	2	1	0	1.312
703	632	643	1	1	0	2	2	2	4	4	51.20
722	660	631	1	1	1	2	2	2	4	3	21.79
762	643	696	2	2	0	2	2	2	4	3	48.79
781	696	713	2	2	0	2	2	2	4	3	13.70
786	719	660	2	2	1	2	2	2	4	1	57.72
796	713	728	2	2	0	2	2	2	4	3	65.78
800	732	719	2	2	1	3	2	2	4	1	17.32
803	734	732	2	2	0	2	2	2	4	1	1.848
808	728	739	2	2	0	2	2	2	4	3	37.87
809	740	734	2	2	1	3	2	2	4	1	18.99
818	739	747	2	2	0	2	0	2	1	3	62.12
824	753	740	2	2	1	3	2	2	4	1	72.37
830	747	758	2	2	0	2	0	2	1	3	48.64
831	760	733	2	2	1	3	0	2	1	1	27.62
836	765	728	2	2	0	2	0	2	1	3	38.94
837	765	760	2	2	1	3	0	2	1	1	25.67
842	758	769	2	2	0	2	0	2	1	3	38.08
852	777	765	2	2	1	3	0	2	1	1	12.74
855	780	765	2	2	0	3	0	2	1	1	61.00
856	781	734	2	2	2	4	2	1	4	1	3.559
861	785	781	2	2	2	4	2	1	4	1	0.308
862	786	785	2	2	4	2	1	4	1	2	37.44
865	769	788	1	1	0	3	0	2	1	3	40.72
866	789	777	2	2	1	3	0	2	1	1	19.12
879	800	786	1	1	2	4	2	1	4	1	36.71
880	789	801	2	2	1	3	0	2	1	1	36.38
883	801	806	2	2	1	3	0	2	1	4	35.95
884	807	758	2	2	1	3	0	2	1	4	0.517
885	806	807	2	2	1	3	0	2	1	4	30.13
892	814	785	1	1	2	4	2	1	4	1	3.216
893	815	814	1	1	2	4	2	1	4	1	37.69
898	807	821	2	2	1	3	0	2	1	1	1.133
899	821	822	2	2	1	3	0	2	1	1	11.45
900	823	815	1	1	2	4	2	1	4	1	35.15
905	827	800	1	1	2	4	2	1	4	1	35.88
914	834	788	1	1	0	3	0	2	1	3	52.62
915	822	834	1	1	1	3	0	2	1	4	30.48
917	815	836	1	1	2	4	2	1	4	1	33.21
918	801	837	2	2	0	1	0	2	1	3	7.589
920	839	834	1	1	0	3	0	2	1	4	64.84
936	852	827	1	1	2	1	0	1	1	2	17.21
942	858	839	1	1	0	3	0	2	1	4	85.53
944	760	860	2	2	0	1	0	2	1	1	33.33
945	852	860	2	2	0	1	0	2	1	1	69.51
949	836	863	1	1	2	4	2	1	4	1	74.34
950	865	780	2	2	0	1	0	2	1	1	25.65
951	860	865	2	2	1	1	0	1	1	2	24.21
956	869	852	1	1	2	1	0	1	1	2	35.20
957	863	869	1	1	2	3	0	1	1	2	

pcainput - Notepad

File Edit Format Help

```

=====
;
; WATER PIPELINE Vulnerability Assessment Input
;
=====

```

[PIPE MATERIAL]

```

;0= AC
;1= RCC
;2= UL
;3= PVC
;4= CI

```

ID	Corros	Max P	Max Pres	Max Load	Max Dia	Min Dia	Max Life	Min D
0	4	35.700	23.500	60	150	100	2500.000	50.000
1	4	30.000	30.000	60	130	70	1200.000	400.000
2	4	15.000	25.000	50	120	90	1000.000	300.000
3	4	15.300	4.400	60	150	130	1200.000	75.000
4	4	97.920	150.000	70	150	60	2000.000	75.000

[CORROSION RESISTANCE]

```

;0=very weak
;1=weak
;2=Medium
;3=Strong
;4=very Strong

```

ID	Left	MidLeft	MidRight	Right
0	0.0	0.0	0.1	0.2
1	0.1	0.3	0.3	0.5
2	0.3	0.5	0.5	0.7
3	0.5	0.7	0.7	0.9
4	0.8	0.9	1.0	1.0

[INTER PROTECTION]

```

;0=very Bad
;1=Bad
;2=Medium
;3=Good
;4=very Good

```

ID	Left	MidLeft	MidRight	Right
0	0.0	0.0	0.1	0.2
1	0.1	0.3	0.3	0.5
2	0.3	0.5	0.5	0.7
3	0.5	0.7	0.7	0.9
4	0.8	0.9	1.0	1.0

[EXTER PROTECTION]

```

;0=very Bad
;1=Bad
;2=Medium
;3=Good
;4=very Good

```

ID	Left	MidLeft	MidRight	Right
0	0.0	0.0	0.1	0.2
1	0.1	0.3	0.3	0.5
2	0.3	0.5	0.5	0.7
3	0.5	0.7	0.7	0.9
4	0.8	0.9	1.0	1.0

```

pcainput - Notepad
File Edit Format Help
26 0.352189
27 0.559065
28 0.559065

[BALANCE FACTOR]
;0=Pipe Members Balance Factor;
;1=Installation Members Balance Factor;
;2=Corrosion Members Balance Factor;
;3=Strength Members Balance Factor;
;4=Failure Members Balance Factor;
;5=Intermittency Members Balance Factor;
;6=Physical Members Balance Factor;
;7=Environmental Members Balance Factor;
;8=Operational Members Balance Factor;
;9=PCA Members Balance Factor;
;-----
;ID balance factor
;-----
0 1
1 1
2 1
3 1
4 1
5 1
6 1
7 1
8 1
9 1


[DATA BASE]
;0=Length;
;1=No. of connections;
;2=Buried depth;
;3=Traffic load;
;4=Hydraulic pressure;
;5=Leakage frequency;
;6=Breakage frequency;
;7=Valve operation;
;8=Duration of water supply;
;9=No of water supply operation;
;-----
;ID Max Min
;-----
0 1000 0.308
1 10 2
2 10 1
3 100 0
4 80 0
5 1 0
6 5 0
7 5 0
8 18 2
9 4 2

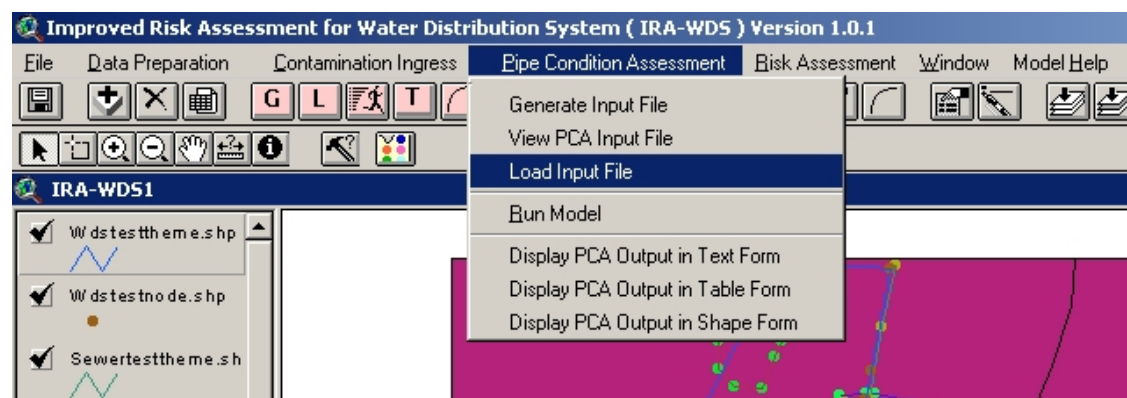
[GROUP]
7

[END]

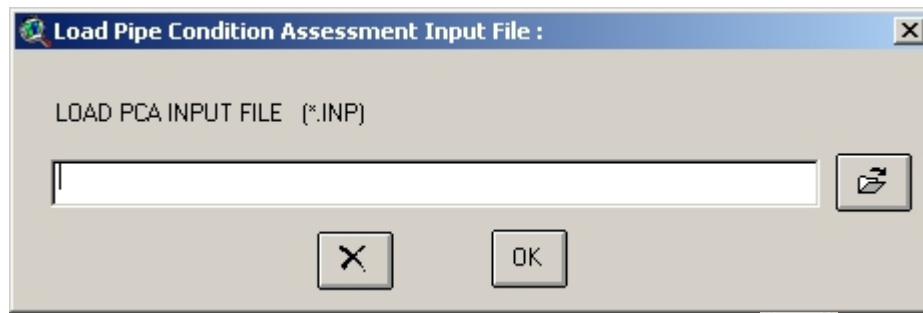
```


4.9 Loading the input file

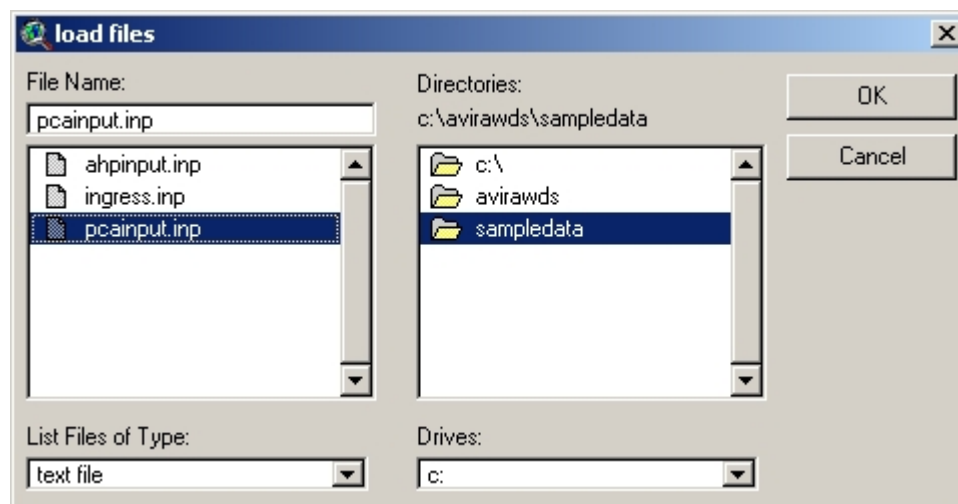
The input file to be used for running the Pipe Condition Assessment Model is loaded using the tool , which is just below the 'Pipe Condition Assessment' menu or by clicking on the 'Pipe Condition Assessment' menu and then clicking on the submenu 'Load Input File', as shown in the screen below:



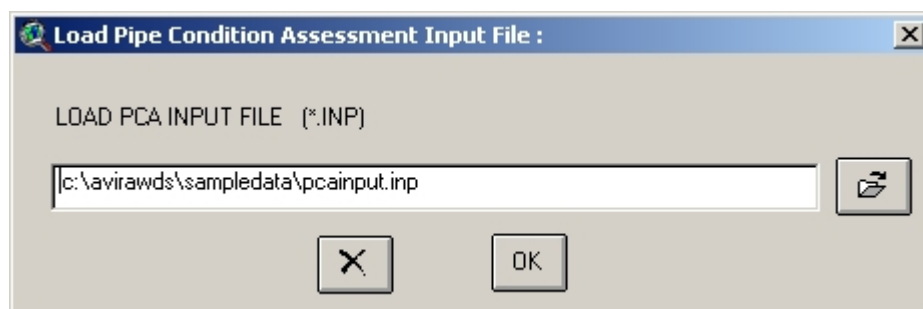
The 'Load Pipe Condition Assessment Input File' is shown below:





The user can browse through the computer by clicking on the  button on the 'Load Pipe Condition Assessment Input File' dialogue box. This opens the 'load files' dialogue box, as shown below:




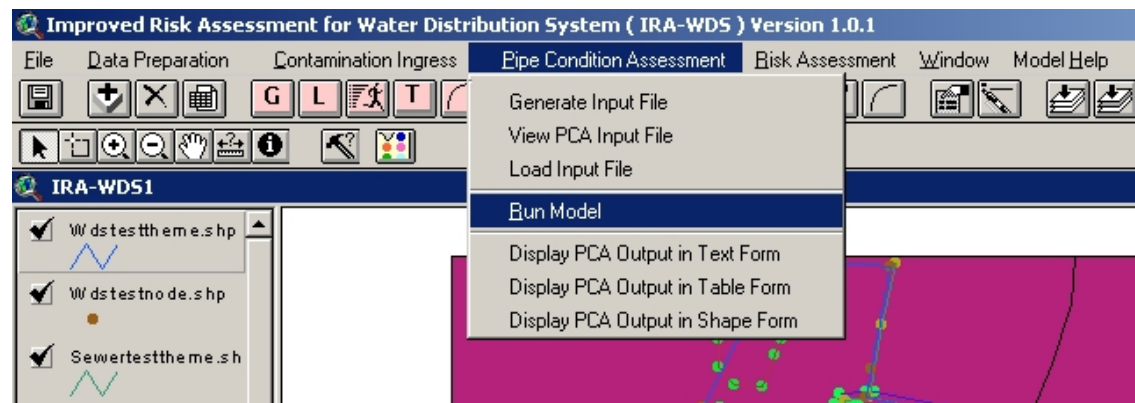
After the appropriate file has been selected and the user has pressed the 'OK' button on the filename, the filename appears in the 'Load Pipe Condition Assessment Input File' dialogue box.



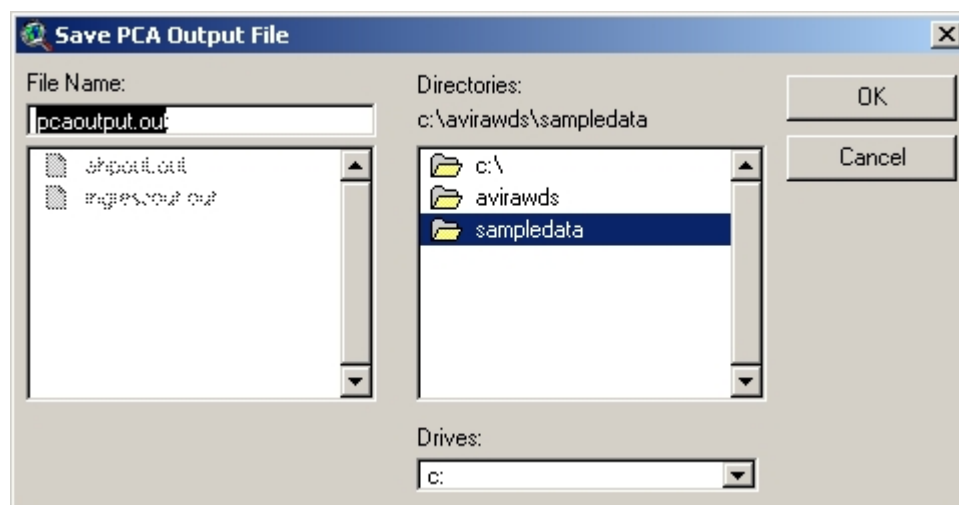
If the user wants to change the filename, he or she can do so by clicking the button , which clears the filename from the 'Load Pipe Condition Assessment Input File' dialogue box. If user is sure of the input file selected, he or she can load it by clicking on the  button. This also closes 'Load Pipe Condition Assessment Input File' dialogue box.

4.10 Running the Model (PCA)

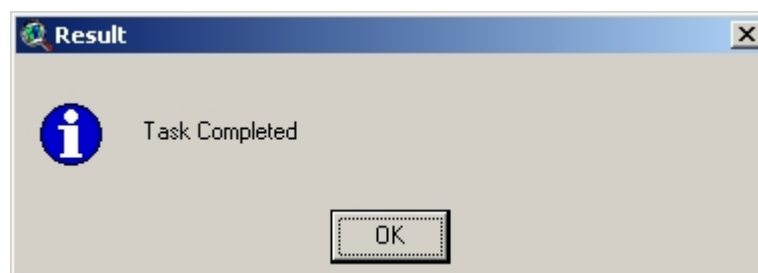
To run the model, the user should click on the  button, which is just below the 'Pipe Condition Assessment' menu or he or she should click on the 'Pipe Condition Assessment' menu and then click on the submenu 'Run Model', as shown on the screen below:



This opens the 'File Save' dialogue box for saving the Pipe Condition Assessment output file as *.out. Once the user has typed the appropriate name and clicked on 'OK', this generates the output selected by the user.



The interface then displays the 'Task Completed' Result message box, as shown below:




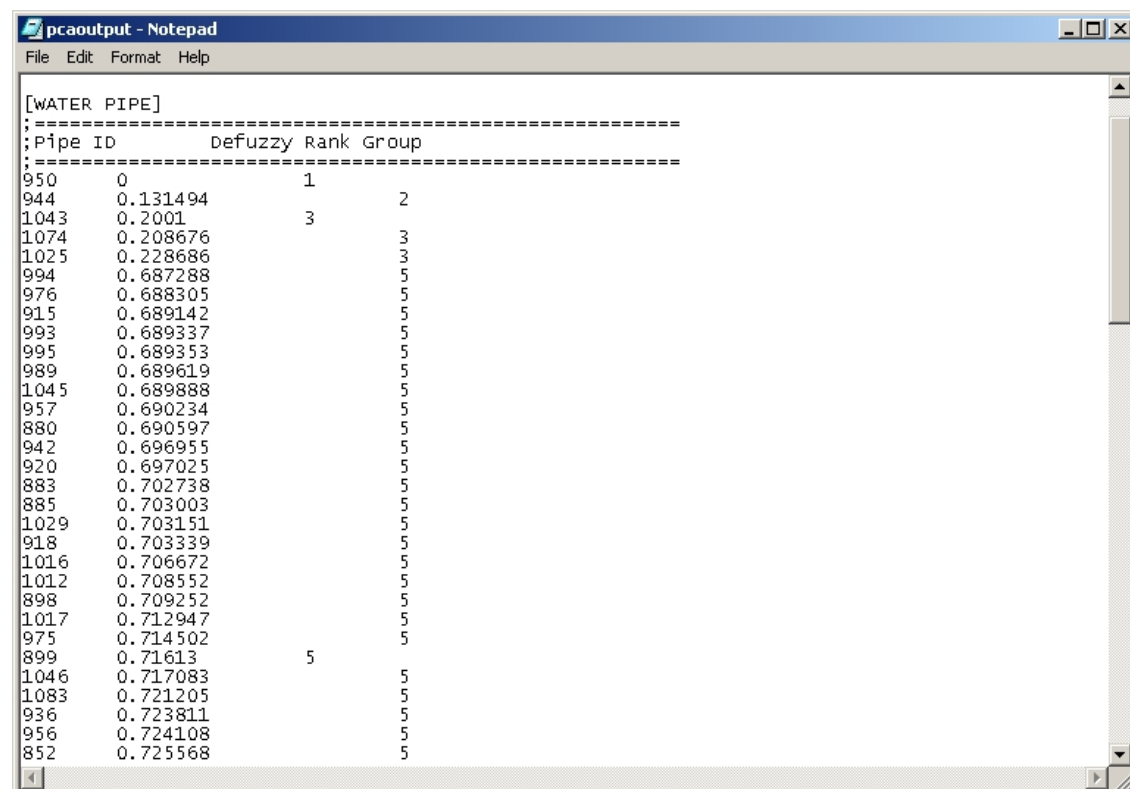
4.11 Displaying the output

Output can be displayed in the following three forms:

1. Display PCA Output in Text form
2. Display PCA Output in Table form
3. Display PCA Output in Shape form

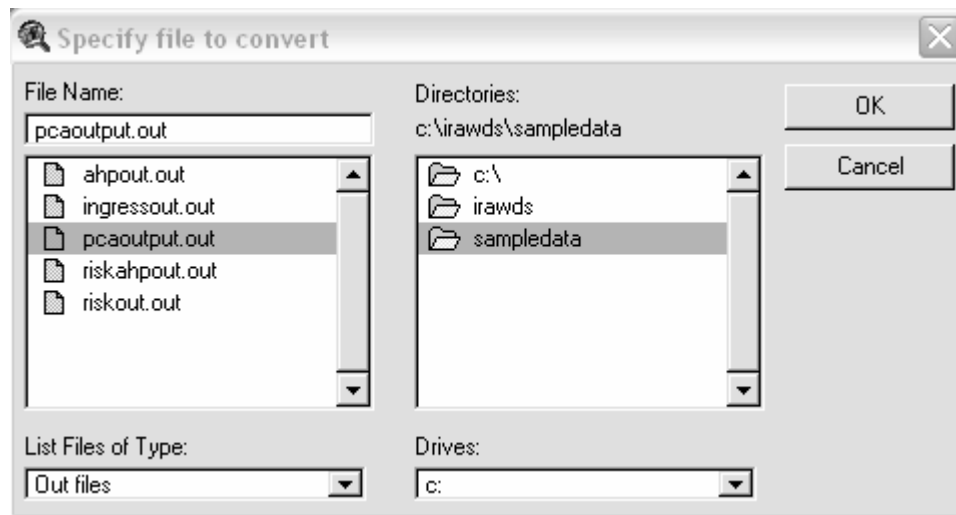
4.11.1 Displaying PCA output in text form

The user can view the output file in the text form in notepad by clicking on the  button or by selecting the 'Display PCA Output in Text Form' submenu from the 'Pipe Condition Assessment' menu and browsing the appropriate output file to view.




4.11.2 Displaying PCA output in table form

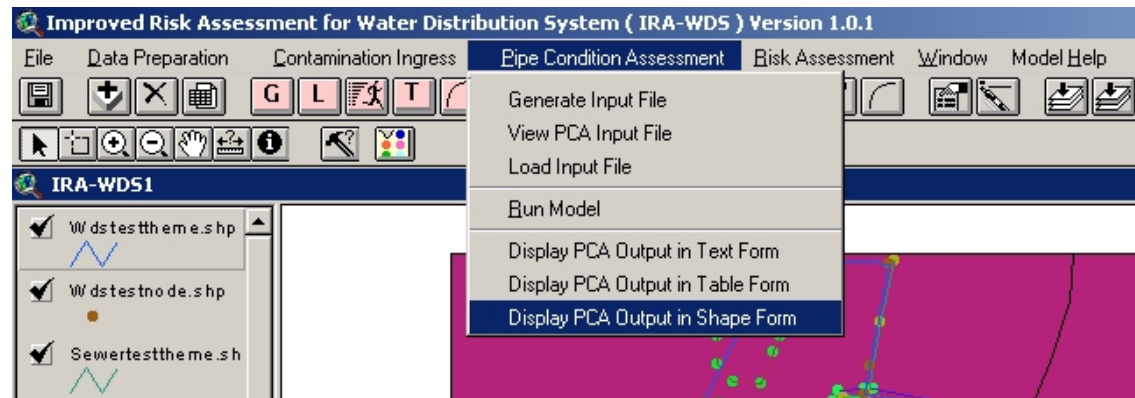
The user can view the output file in table form by selecting the 'Display PCA Output in Table Form' submenu from the 'Pipe Condition Assessment' menu and specifying the appropriate output file to view by browsing, as shown below:



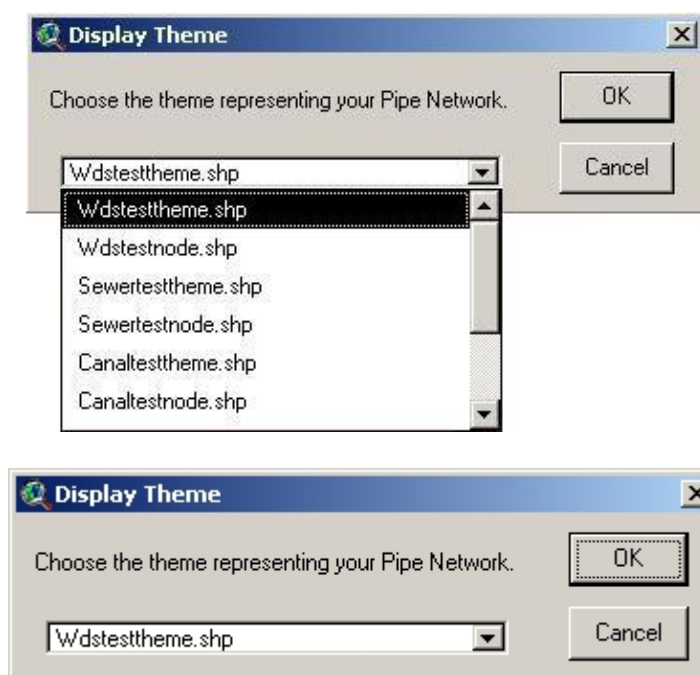
c:\irawds\sampledata\pcaoutput.dbf		
PipeID	DeFuzzy	Rank
950	0.000	1
944	0.283	3
1043	0.430	4
1074	0.448	4
1025	0.491	5
831	0.776	7
975	0.777	7
824	0.778	7
880	0.781	7
852	0.793	7
866	0.797	7
837	0.797	7
951	0.797	7
936	0.799	7
1083	0.799	7
957	0.800	8
809	0.802	8
989	0.804	8
883	0.805	8
994	0.805	8
945	0.806	8
956	0.806	8
915	0.808	8
786	0.809	8
885	0.811	8
1017	0.814	8
949	0.814	8
855	0.815	8
976	0.817	8
856	0.817	8
993	0.817	8

4.11.3 Displaying Pipe Condition Assessment output in shape form

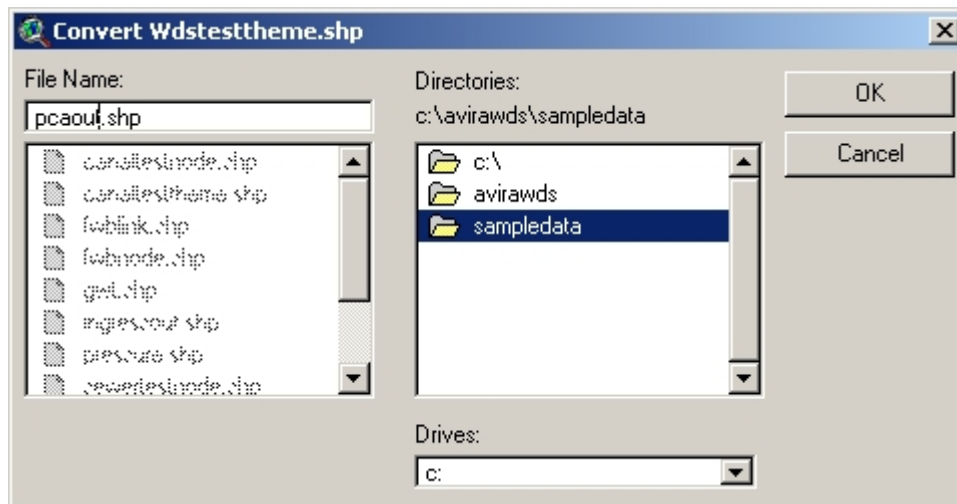
To view the Pipe Condition Assessment output in shape file form, the user should click on the  button, which is just below the 'Pipe Condition Assessment' menu or he or she can click on the 'Pipe Condition Assessment' menu and then click on the submenu 'Display Ingress Output in Shape Form', as shown on the screen below:



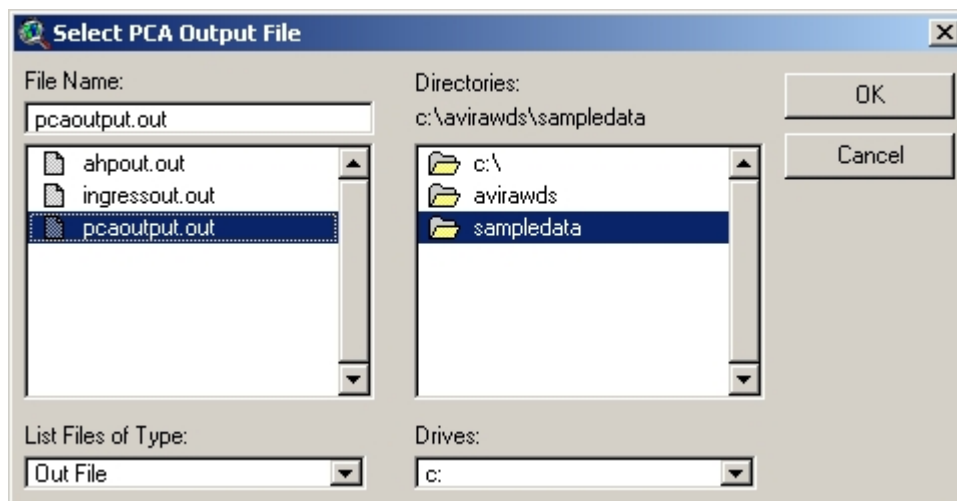
This opens the 'Display Theme' message box asking the user to specify which theme represents the water distribution system pipe theme, as shown below:



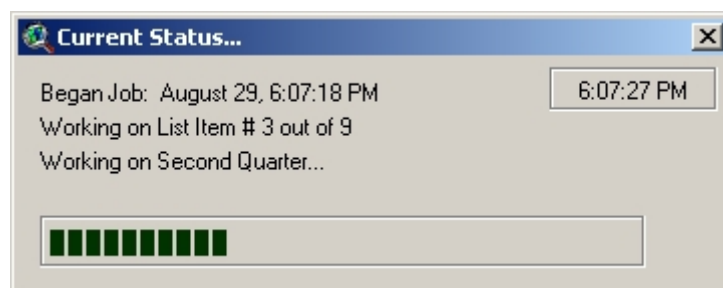
Once the user selects the appropriate theme representing the water distribution system pipe network and clicks on the 'OK' button, the 'Convert Theme' dialogue box appears on the screen and asks the user to give the name with which he or she wants to store/convert the selected theme, as shown on next page.



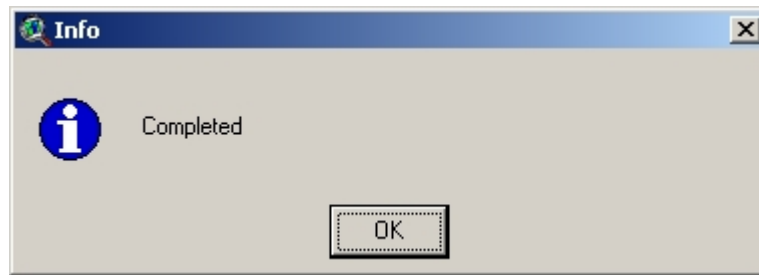
The interface then opens the 'File Select' dialogue box for selecting the Pipe Condition Assessment output file as *.out, from which attributes for pipe condition (PCAValue and PCARank) are to be added to the output theme, as shown below:



Once the user has selected the appropriate filename and clicked 'OK', the program shows the progress meter, as below:



On completion of theme generation and attribute addition, it displays the 'Completed' Info message box, as shown on next page.



After clicking the 'OK' button on this message box, the new shape-file is added to the IRA-WDS data viewer. The 'PCAOut' theme legend needs to be changed by the user and instead of viewing the theme in a single colour, it can be viewed by unique values of 'PCARank', as shown below:

