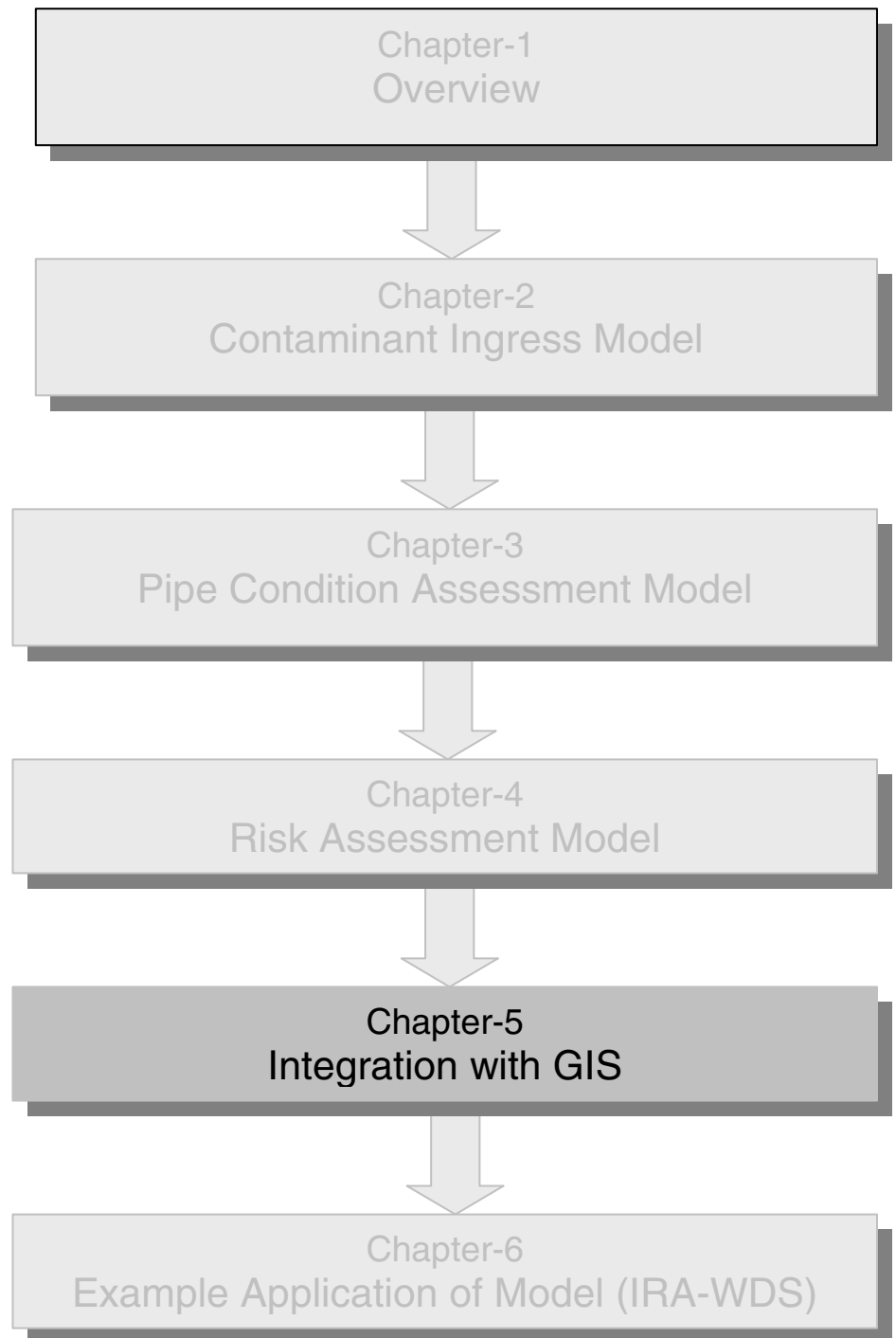


# **CHAPTER FIVE**

## ***Integration with GIS***

# Risk Assessment of Contaminant Intrusion into Water Distribution Systems



## **Chapter 5: Integration of the Model with GIS**

### **5.1 Introduction**

This chapter provides information about how a geographic information system (GIS) can be developed for the area of study. IRA-WDS is GIS-based software and hence, in order to use it, one needs to build a GIS for the area of study. This chapter begins by introducing GIS and its applications in the area of risk assessment. It then outlines the process of data collection and preparation of maps, and provides an introduction to IRA-WDS.

### **5.2 Why GIS?**

Risk is an inherently spatial phenomenon. It is clearly not sufficient to report risk non-spatially. A risk map should be considered as the ultimate product of any risk investigation, and should be the first resource sought for any risk decision or evaluation. As the process of risk assessment requires the assimilation of data that are spatially variable in nature, geographic information systems are an ideal tool for such assessments. GIS techniques can be central to these important and critical processes of risk identification, quantification, and evaluation. It has proved to be a useful tool for risk assessment and management. Coupling of GIS with the contamination, pipe condition assessment and risk assessment models enhances the value of the models and makes the models more user-friendly. In the present study, an attempt has been made to assess and manage risk by integrating the contamination ingress, pipe condition assessment and risk assessment models with GIS. The database required for the models is prepared using GIS, the model is processed through GIS, and the output maps can be used for printing, display and investigation purpose.

### **5.3 Geographic Information Systems and Risk Assessment**

A geographic information system (GIS) is an integrated system of computer hardware and software designed to capture, store, analyse, manipulate and display spatial data. It acts as an integration platform and offers the possibility of a consistent, interactive user-friendly environment. The advantage of GIS lies in its ability to relate data sets through a common denominator, which is a spatial location. GIS also provides the tools for managing the modelling process, organizing model input parameters,

analysing the model results and displaying both model input and output in an user-defined scale.

In order to assess potential pollution risks, the stored data has to be manipulated beyond simple digital mapping of the existing features. A number of tools within a GIS make it possible to analyse, combine, update, interpolate and query the records to create new or redefined information, thus adding value to the original data. Complex geographical analysis, such as map algebra or overlay, essentially combining the attributes of two or more data layers depending on their geographic location, can be used to identify hazard source areas. Selections based on a map layer's attribute information can be used to provide input data for calculations of risk frequency. Logical overlay (using *and*, *or*, *not* terms) can be used to combine data where map attributes are represented on a nominal (e.g. soil type, land cover type) or ordinal (e.g. data ranked from poor to excellent) scale. Arithmetic overlay (addition, subtraction) can be used when the map attributes need to be represented by an interval level of measurement such as rainfall values.

In general, the intrinsic capacity of a GIS to store, analyse, query and display large volumes of data makes it an ideal tool for performing risk assessment.

## **5.4 Tool Used for Integration**

The GIS software tool used for the process of integration in the present study is ArcView GIS 3.2 developed by ESRI. It is one of the most widely used commercial Windows GIS packages. It is primarily designed for the manipulation of spatial vector data, extended with optional modules for the analysis of network data (Network Analyst extension), raster data (Spatial Analyst extension), and other types of data. The object oriented Avenue script language supported by ArcView allows external programs or computer packages to be integrated into the ArcView environment to offer enhanced functionality for spatial analysis, and the customizing facility of ArcView GUI (Menus, Buttons, Tools) provides a user-friendly approach to using the integrated tools. ArcView also has integration capabilities that allow users to access system resources (i.e. clipboard and system variables), issue operating system commands inside ArcView, and support Dynamic Data Exchange (DDE) in the Microsoft Windows environment and Remote Procedure Call (RPC) in UNIX.

In the present study, contaminant ingress, pipe condition assessment and risk assessment models have been integrated with ArcView GIS in such a manner that the model can be used effortlessly.

## **5.5 Strength of GIS in Risk Assessment**

Within the past five years, many conferences/workshops have been organized which primarily discussed research in environmental modelling and engineering practices using GIS. The area of risk assessment/management modelling and integration of GIS with user models have also been studied. The purpose of this section is to explain the strengths of GIS in environmental modelling.

### **5.5.1 State of the art**

Previous research studies on use of GIS were mainly focused on the type of connection established between different water quality related models and GIS software. In addition, the type of GIS software used was a concern. Tim and Jolly (1994) presented a good overview of three types of model interfaces possible with GIS. They described three levels of integration as (1) ad hoc integration, (2) partial integration, and (3) complete integration. In the first level, the GIS data structure and environmental model are developed independently. The data is extracted from GIS, the model is run separately, and the outputs are analysed at the user's discretion. In the second level, i.e. partial integration, GIS supplies the data and then accepts the modelling results for processing and presentation. In this case GIS plays more of an integrated role in modelling. The third level, i.e. complete integration, consists of complete model development within the GIS software. The user has a single operating environment, where the data stored in the GIS is structured to meet the demands of the model and vice versa. It should also be noted that there are numerous types of GIS software with which a model link can be accomplished. The earlier works were reviewed and some important reported works are explained herein to show the utility of GIS for the current study.

### **5.5.2 Integration of environmental modelling and GIS**

For over a decade, the integration of GIS with environmental modelling has been an important research topic. The use of GIS for modelling provides ease and accuracy in the management and spatial representation of data. Recent projects which have conducted environmental modelling directly in the GIS have included studies in simulating hydrologic processes, river basin planning and management, predicting chemical concentrations in rivers, and assessing non-point source loading over a watershed (Maidment 1992).

Akcakaya (1994) developed an integrated model linking GIS and models of ecological risk assessment. In this work, a model that links GIS for viability analysis and risk assessment which was applied to endangered species was explained in detail. The model integrates landscape data on habitat requirements with demographic data to analyse risks of extinction, evaluate management options, and assess human impact on wildlife populations. Other applications of the model involve design of nature reserves, wildlife management, and population viability analysis. The model analyses habitat data exported from a GIS, and identifies the patches of habitat that can support a population. The structure of these patches, including their locations, sizes and distances from each other, define the spatial structure of the meta-population. The spatial structure is combined with demographic data and other information on the ecology of the species to complete a meta-population model, which incorporates age or stage structure and density dependence for each population, spatial correlation and dispersal among populations, environmental and demographic stochasticity and catastrophes. The model performs a risk analysis, and runs multiple simulations, automatically changing parameters to analyse the sensitivity of risks to input data.

Kumar et al. (1997) demonstrated an approach to integrate GIS software and models using their design of the Solar Analyst and TopoView, tools for calculation of incoming solar radiation (insolation) over landscape scales. The calculation engine of these models was implemented in DLL format using C++. The DLLs were then

loaded into ArcView to create the Solar Analyst extension. The ArcView GRIDIO library was used to read a DEM as input and write insolation GRIDs as output. They used techniques such as ArcView GRIDIO usage, procedure communication (system call/DDE/DLL/ActiveX), design of DLLs, and on-line help systems for use with ArcView. Extending these models to large areas in a GIS environment can be accomplished by obtaining data layers of parameters for the areas. System integration can be accomplished by using common files, system calls, DDE/RPC, DLLs, or Active X controls, according to specific user needs. There is growing interest in extending point-specific processes to broader spatial scales, using spatially explicit raster models. ArcView GRIDIO provides an easy way for non-ESRI products to directly access ESRI grid data and this paper explained ways to export C++ functions and workarounds to call C++ member functions when developing DLLs for use with ArcView. As GIS is used in more and more ways to solve more complex problems, the topic of integrating GIS with user models becomes increasingly important.

Yates and Bishop (1997) developed a simple and comprehensive approach for the integration of separately developed software systems. According to them, any information system can be integrated using the methodology without the complexities introduced by providing an interpretation of a universal language. The design of the integration methodology consists of four separate components: the protocol for communication, a message queuing system, wrapping software, and an integration manager. Relevant conceptual models and implementation techniques are discussed in this paper. Some examples of the software that have been successfully integrated were also presented with an example script for managing a simple integration activity.

Fedra (1998) described an overview of integrated risk assessment and management. He explained the role of GIS in risk assessment and management, and concluded that the risk assessment and management strategy is not only a spatially distributed problem, but also a dynamic problem. While geographic information systems provide powerful tools for spatial analysis, their capabilities for complex and dynamic analysis are limited. Traditional simulation models, on the other hand, are powerful tools for complex and dynamic situations, but often lack the intuitive visualization and spatial analysis functions that the GIS offers. Obviously, the integration of GIS and simulation models, together with the necessary databases and expert systems, within a common and interactive graphical user interface should make it more powerful and easy to use. He has demonstrated the integration process with the development of a risk information system for the Netherlands. In this integrated model, GIS is considered as the central tool, and the user-interface, database on hazardous installations and hazardous chemicals are linked in a hypertext structure. They include tools for spatial risk assessment based on externally generated risk contours, and links to models describing accidental and continuous atmospheric releases, spills into surface water systems, and transportation risk analysis.

Hornung et al. (1994) developed models that are fully geo-referenced and integrated with the underlying GIS layers, and include an embedded rule-based expert system to help with model input specifications, and the interpretation of model results. Model results take the form of interactive graphics and animated topographical maps for an intuitive understanding, and a more efficient interactive analysis.

Steele et al. (1999) explained the development of a GIS-based risk assessment methodology that incorporates contaminant source, groundwater vulnerability and abstraction, and catchment elements in order to prioritize areas and boreholes potentially at risk from chlorinated solvent pollution on a regional scale. Factors incorporated in the vulnerability assessment such as the nature of soils, presence or absence of superficial or glacial deposits, fault density and depth to water table were employed with a simple ranking system from which the derived vulnerability assessment index was combined with current chlorinated solvent user-industry data and source protection zone components. Results indicated that the presence of high-risk areas in urban locations where locally dense distributions of chlorinated solvent user industries combine with high vulnerability aquifers within the catchment of supply boreholes. Ranking of catchment-specific risk reveals the abstraction points under greatest stress. The proposed methodology has applications as a regional-scale initial screening tool to guide site selection for regulatory inspections and assist in prioritizing monitoring strategies for existing boreholes. The study was concluded by indicating that future developments will provide guidance for locating new urban boreholes in areas of lowest risk.

How (1998) explained a model that linked the naUTilus model, to GIS technology in order to facilitate prediction of volatile organic compound (VOC) emissions from large industrial sewer networks. The connection of naUTilus with a GIS software package, ArcView®, was achieved through a series of Avenue scripts. The integrated naUTilus/GIS model was used to predict VOC emissions from actual industrial sewer systems under varying environmental, flow, and sewer conditions. Stripping efficiency was predicted to (1) increase with increasing wind speed, (2) increase with increasing temperature (liquid and ambient), (3) decrease with increasing liquid flow rates, and (4) decrease with an increasing number of sealed drains. The integrated model was also used to analyse emission estimates on a spatial level. Ventilation patterns assumed in the naUTilus model were found to have a significant effect on predicted emissions.

Geter et al. (1995) discussed a GIS interface to four Agricultural Research Service (ARS) pollutant loading models: Agricultural Non-Point Source (AGNPS), A Basin Scale Simulation Model for Soil and Water Resources Management (SWRRBWQ), Erosion Productivity Impact Calculator (EPIC), Groundwater Loading Effects of Agricultural Management Systems (GLEAMS). The goal of this research was to develop an interface which resulted in standardized and consistent input data to all the water quality models, while providing a platform for interpreting the model results through tables, graphs, and maps. The user first enters the necessary model data in the form of attributed coverages within the GIS software, Geographic Resource Analysis System (GRASS). The total connection requires five raster-based maps linked to sixteen attribute tables. This base information is then interpreted by the GRASS interface and consistent model input is determined. The link established actually writes the derived input into the formatted file necessary for the models' input, and the connection provided a means for the user to view the model output through charts, tables, and raster maps.

Tim and Jolly (1994) demonstrated the concept of integrating an agricultural non-point source water quality model, AGNPS, with an Arc/Info interface. GIS provided the means to generate and spatially organize the data needed for the non-point source

modelling effort, while AGNPS was used to predict water quality related parameters such as soil erosion and sedimentation. A partial integration link was established, by developing computer programs which provided 'access points' between the GIS database, the AGNPS model, and the user. The link read the model input from raster coverages imported into Arc/Info's subprogram, Grid. Once the grid-based data were converted to a readable format by AGNPS and the model executed, the output was re-imported into Grid and displayed through ArcPlot.

Besides hydrologic processes, GIS has been used to assess pollutant loadings entering a water body and to explain the transport of chemicals in surface water. Various studies have investigated the concept of non-point source (NPS) loadings from watershed areas. Two projects in particular used GIS to develop projected aerial loadings of different chemical constituents (Saunders and Maidment 1996). Mitchell and McDonald (1995) developed a grid-based model which assessed NPS loadings of nitrogen, phosphorus, cadmium, and faecal coli-forms into a small coastal bay in South Texas. The method used a grid of land-use-based estimated mean concentrations (EMCs) multiplied by spatially distributed runoff volumes to obtain an annual aerial loading over the watershed. A similar study also used the concept of EMCs and runoff volumes to develop an assessment of NPS loads into Galveston Bay, Texas (Newell et al. 1992). They used GIS to spatially distribute runoff volumes, land use characteristics, EMCs, and final loading values. A slightly different pollutant study is applying GIS to project chemical concentrations in the Upper Mississippi River Basin (Mizgalewicz 1996). Using data collected in the United States Geological Survey (USGS) toxic chemical program throughout the Midwest, this GIS model is meant to explain the relationship between chemical concentrations in a stream and parameters such as chemical application, runoff, precipitation, season, and watershed characteristics. In addition, this research aims to describe chemical losses due to transport downstream using GIS as the ultimate modelling interface for these processes.

In summary, various concepts have been developed within the GIS framework to assist in traditional environmental modelling by development of an interface between the water quality/quantity models with GIS. Of more concern for this research, though, is the establishment of a connection between developed models relating to contamination ingress, pipe condition assessment and risk assessment and the GIS software. Many earlier research workers have investigated the feasibility of linking various models to GIS to assist in data management, manipulation, and output processing. Of particular interest for this project were those previous studies which concentrated on water quality and quantity model links. These projects have ranged from incorporating an entire model into the GIS software, to concentrating on a subprogram of the model to connect to the interface.

## **5.6 Methodology in Developing IRA-WDS**

The various steps involved in developing IRA-WDS are as follows:

- Data collection
- Preparation of maps
- Development of IRA-WDS



- Integration of models
- Generation of output.

### **5.6.1 Data collection**

First there is collection of field data on the existing water distribution system and sewerage collection system including canals/open drains, surface foul water bodies.

The major steps in the data collection process are as follows.

1. Identify the needed data/information  
The data required includes: thematic maps (base maps, contour maps etc.); network data (water distribution system, sewers etc.).
2. Determine data availability  
Check sources and availability of the data identified in Step 1. Determine which data are currently not available and which are out of date.
3. Physically collect data  
Once the data requirements are identified and the availability ascertained, decide on how to collect the required data (e.g. a relevant department might be a good place to start). A work-plan needs to be prepared, clearly identifying the required data, the methodology to be employed for its collection, and the time period (and money) available to collect it (schedule the data collection process).
4. Verifying the accuracy of the data  
An important aspect of the data collection process is to verify the accuracy of the data. Errors may be clerical, subjective or methodological. It is important to appraise your data to eliminate known and suspected errors.

### ***Sources for obtaining maps***

Maps can be collected/requested from sources such as:

- Local government sources
- Water authorities
- Other state departments such as irrigation, electricity, highway etc.
- GIS / Topographical Department (remote sensing)
- Town Planning Department
- The Ministry of Defence
- Private companies / consultants.

If the maps obtained from the above sources are not up to date, then a survey of the area may be required to reveal elements missing from the map. It is of a great importance that the base map should be very accurate and that it includes areas of settlement (this could be identified by roads and properties) in the study area, as all these play an important role in the design of a water distribution system.

### ***Sources of data for network identification***

Sources of network data include water authorities, municipalities and other local agencies. It is the experience of the authors that the data availability with the local

agencies is generally poor and collection may be required. It is useful to contact local contractors and the operators (lineman), as they often have a better knowledge of the system than the managing authorities. Below, details of how data can be collected are given.

1. Existing data can be obtained from:
  - Water authorities
  - Consultants/organizations
  - Past reports/projects
  - Interviews: engineers from the water authorities, consultants/contractors, linesmen, valve operators.
2. Data can be physically collected in the field by:
  - Identifying the pipes that can be seen on/under culverts/bridges
  - Identifying valves
  - Actual excavations if necessary.

### **5.6.2 Preparation of maps**

The data preparation part includes the preparation of various data/layers required for IRA-WDS, viz.:

- Thematic layers
- Network database
- Derived maps.

Figures 5.1 and 5.2 illustrate the process of converting maps into a GIS format. More details of this process can be found in Chapter 2 of Book 4.

#### ***Thematic layers***

The first step in data preparation is thematic layers preparation. The following thematic layers of the study area need to be prepared by using the collected field data and data from other sources such as remote sensing.

- Base map: infrastructure and contour maps
- Environmental maps: soil, groundwater, and pressure maps.

The various maps are prepared by digitizing, editing and projecting the coordinates to a polyconic projection system using ArcView GIS. The output from this process will be a collection of shape-files containing each theme. See Chapter 2 of Book 4 for details of the data associated with the thematic maps.

#### ***Base map***

Infrastructure This map should be prepared from Survey Toposheets of the available scale (for example 1:50,000 from Survey of India (SOI), Government of India). The entire area needs to be divided into different major classes, viz. settlement, surface foul water bodies, vegetation and roads. The final map consists of details such as roads, water bodies, railways etc.

Contour map The contour map needs to be prepared from reduced level data obtained by a levelling survey.

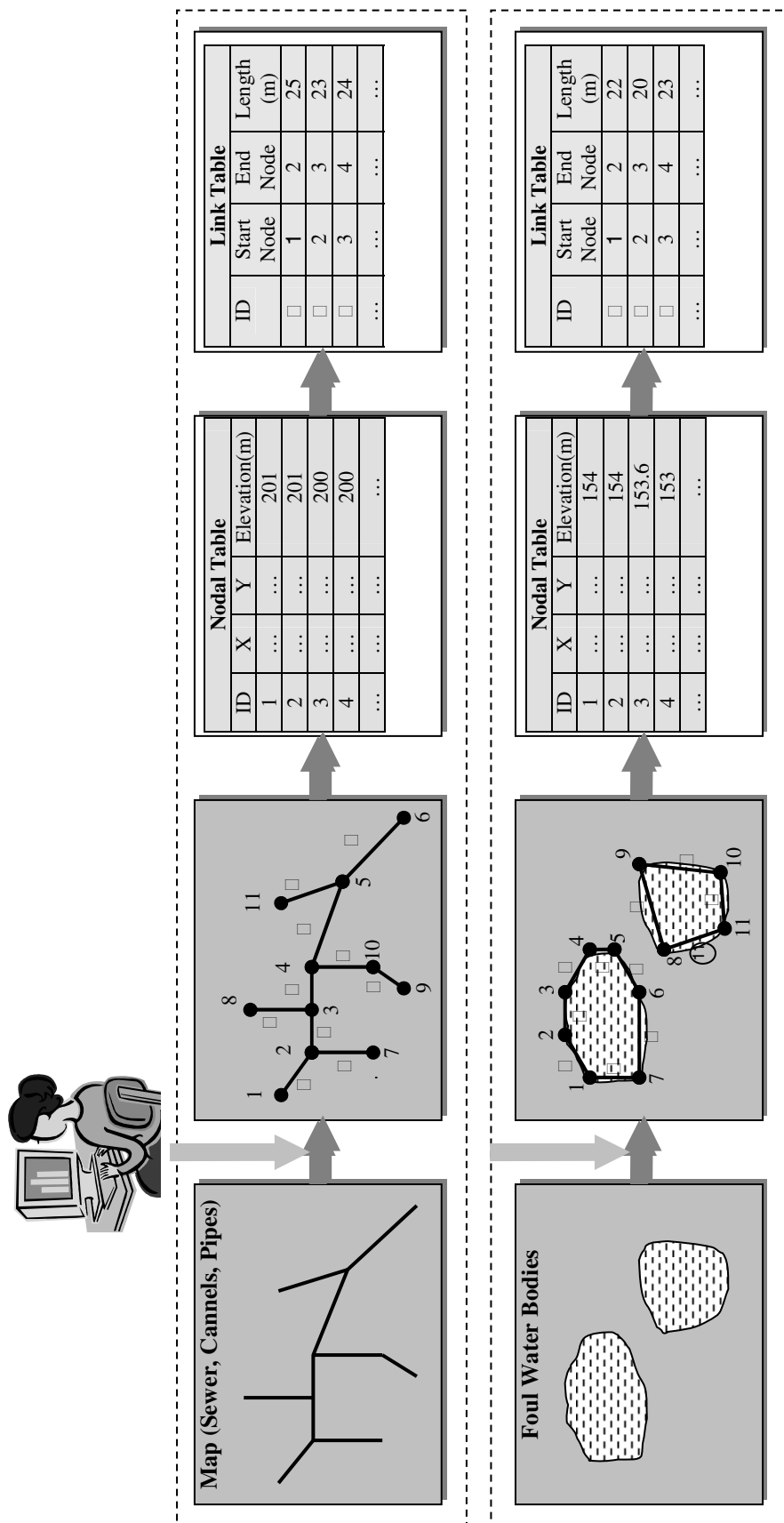


Figure 5.1. Digitization of real-world network

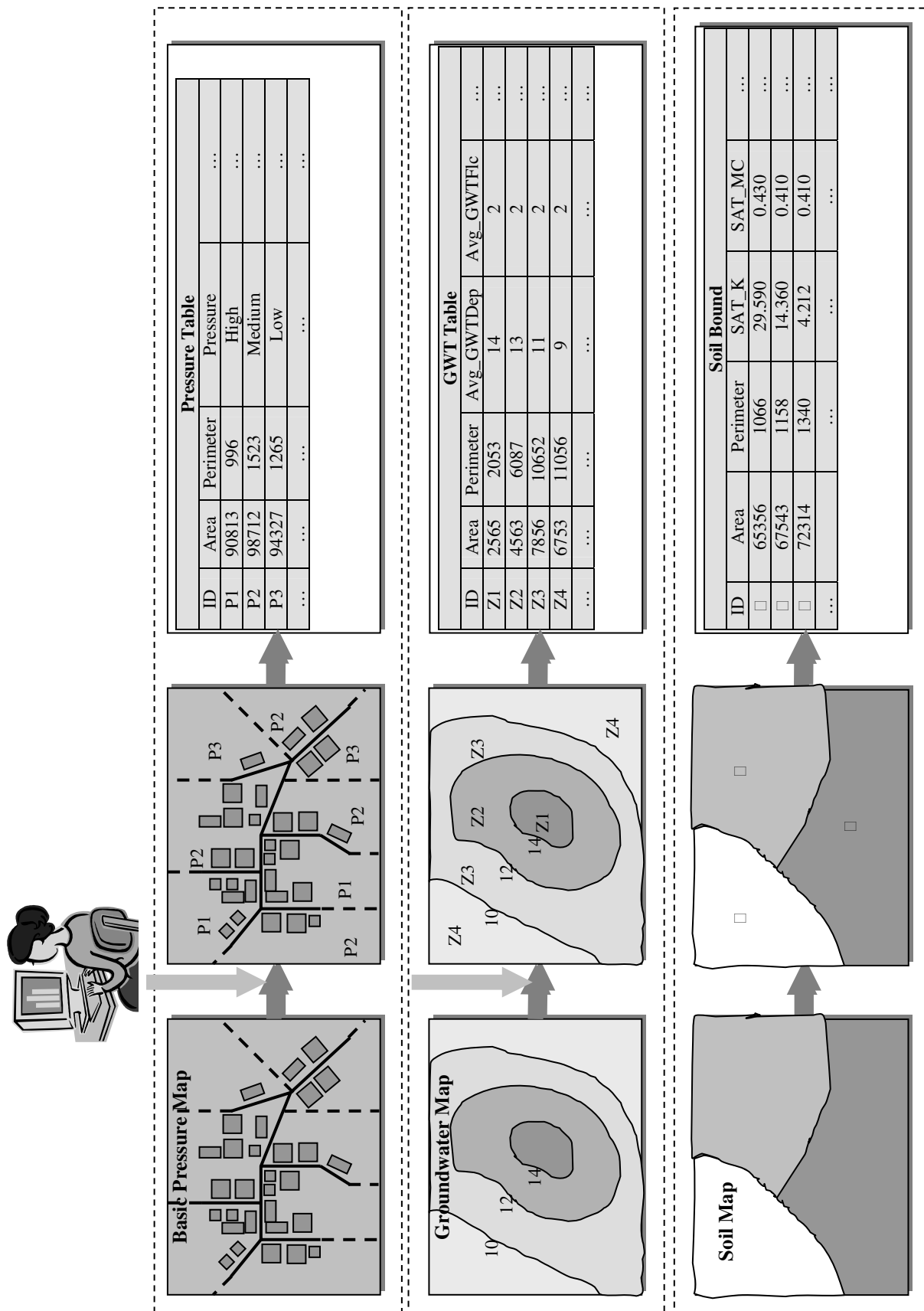


Figure 5.2. Digitization of thematic maps

### ***Environmental maps***

Soil map The soil map can be prepared by conducting a detailed soil survey or by collecting the information from soil survey and soil testing laboratories. The soil maps should contain data pertaining to various soil properties (see Chapter 2 of Book 4).

Groundwater map The groundwater table map can be prepared using the data pertaining to groundwater depth and average fluctuation data.

Pressure zone map The pressure zone map can be prepared by recording actual pressure or from the hydraulic analysis of the network. It should provide information on operating pressure zones.

### ***Network database***

Data preparation includes the construction of network data required for the contamination ingress and pipe condition assessment models.

Network model A network model is a simple representation of complex reality. A network comprises of number of interconnected links/elements and nodes.

- Nodes represent points at which there is an input, output or a junction of two or more links (or pipes). They also include points where there is a change in characteristics or connections to system features.
- Link (or pipe) refers to connection between two nodes.

GIS network maps are required to be developed on the following themes, by incorporating nodes and links data:

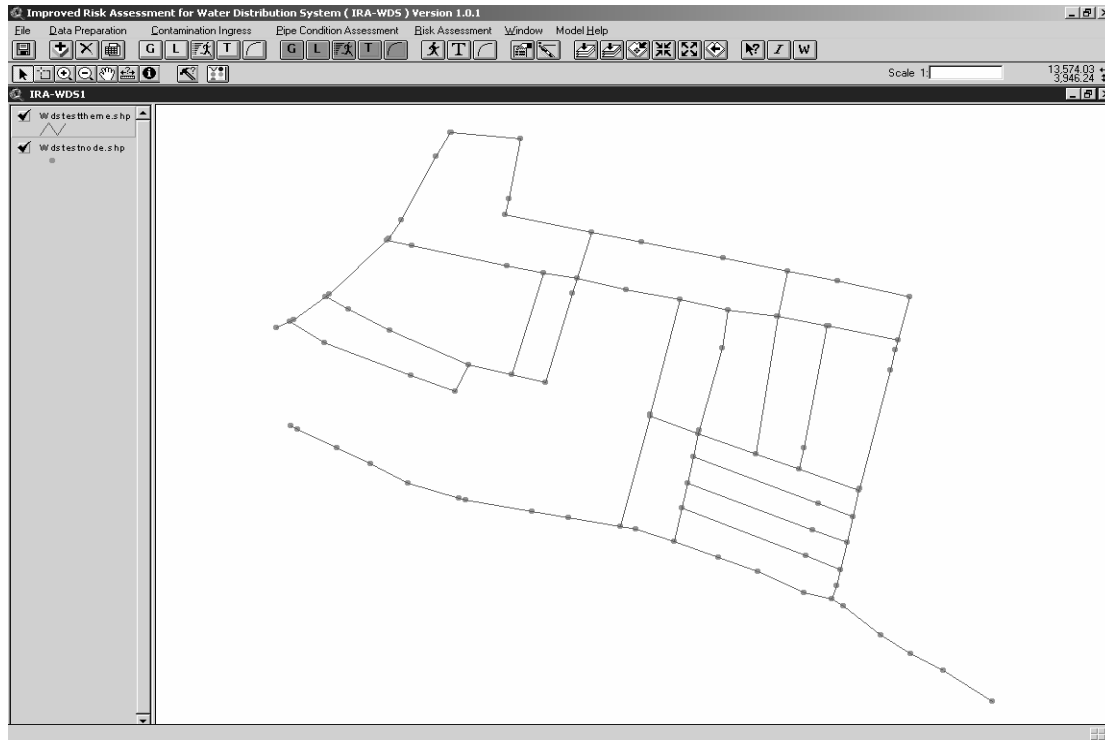
1. Water distribution system network
2. Sewer system
3. Canals/open drainage network
4. Surface foul water bodies.

Each of the network maps will need to be digitized and unique identification (ID) assigned to all elements/links/pipes and nodes. The network maps will then be stored as shape-files and all other attribute data added (e.g. diameter, age and material of links etc.).

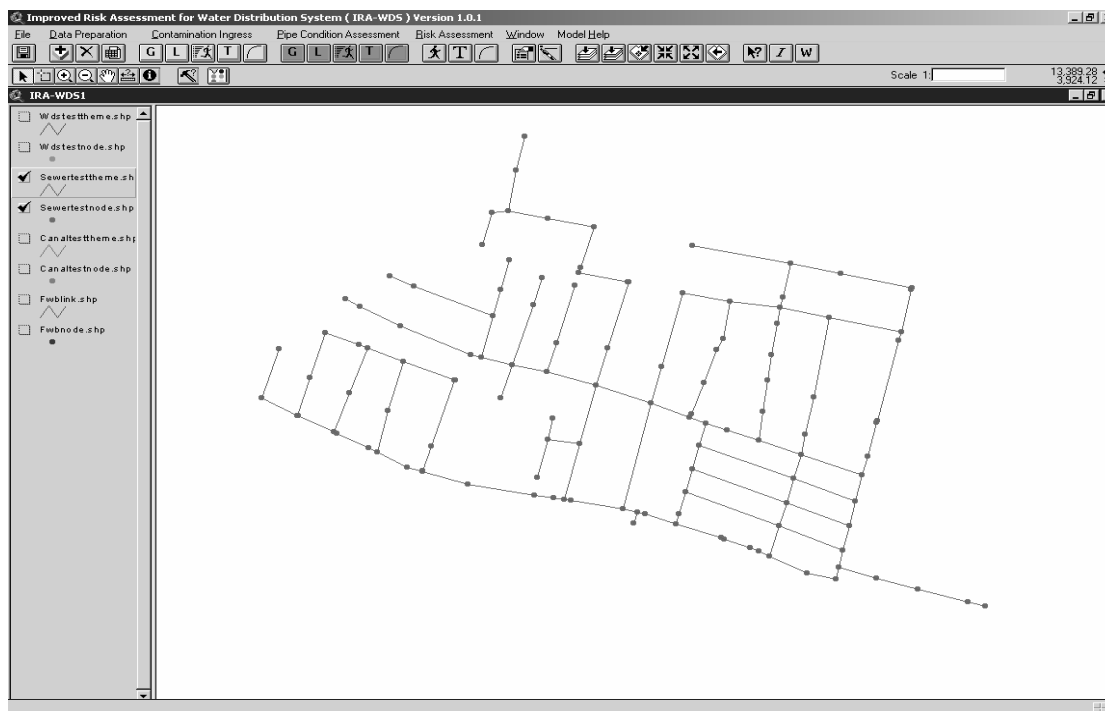
***Water distribution network theme:*** The water supply system consists of tanks, reservoirs, junctions which are represented as nodes, and pipelines that are represented as links (see Figure 5.3 for example). The water supply link comprises data attributes such as pipe length, diameter, age, material, leakage frequency etc. The node consists of attributes like x, y, z coordinates and bury depth.

***Sewer distribution network theme:*** Sewer pipes are represented as elements and junctions, manholes are represented as nodes (see Figure 5.4 for example). Details of sewer pipes such as pipe diameter, pipe length, pipe material, direction of flow, joint type, location of manholes, depth of manholes, age of pipe, bury depth etc. need to be included in the sewer network theme.

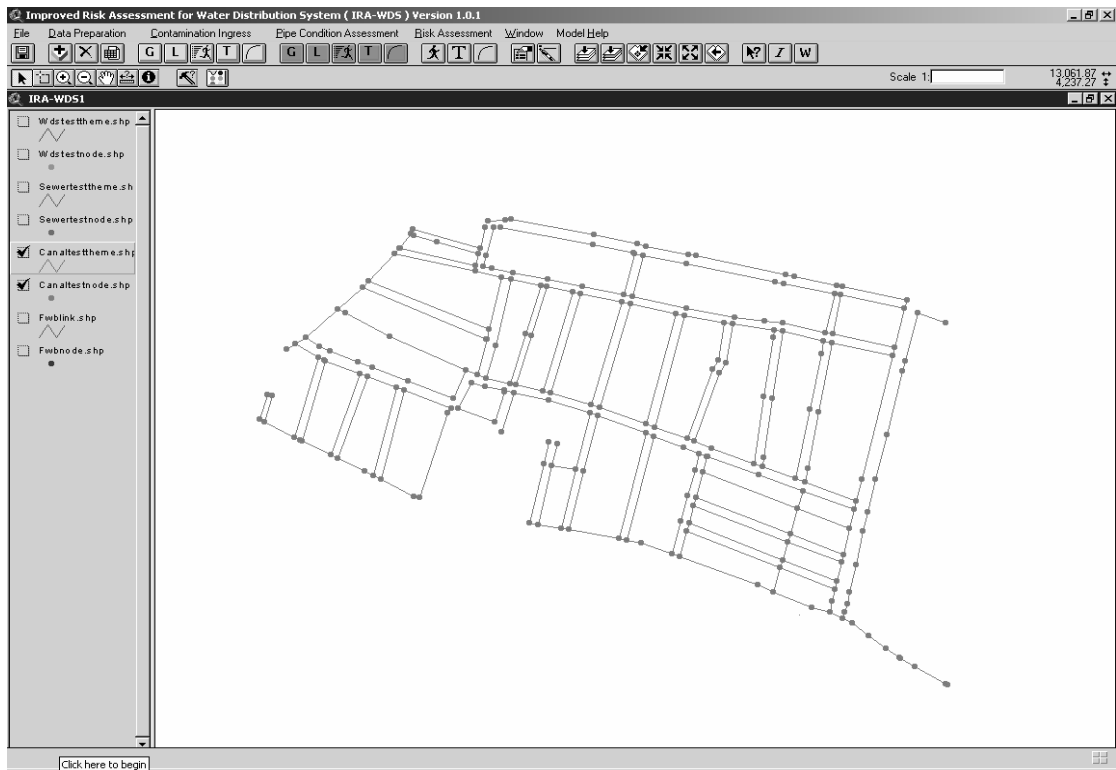
**Canal network theme:** Open drainage canals are represented as elements/links. Junctions and points where there is a change in direction are represented as nodes (see Figure 5.5 for example). The open drainage network theme database includes data on the type of drainage, geometry of the canal, slope. Canal node consist of attributes like x, y, z coordinates.



**Figure 5.3. Water distribution network**

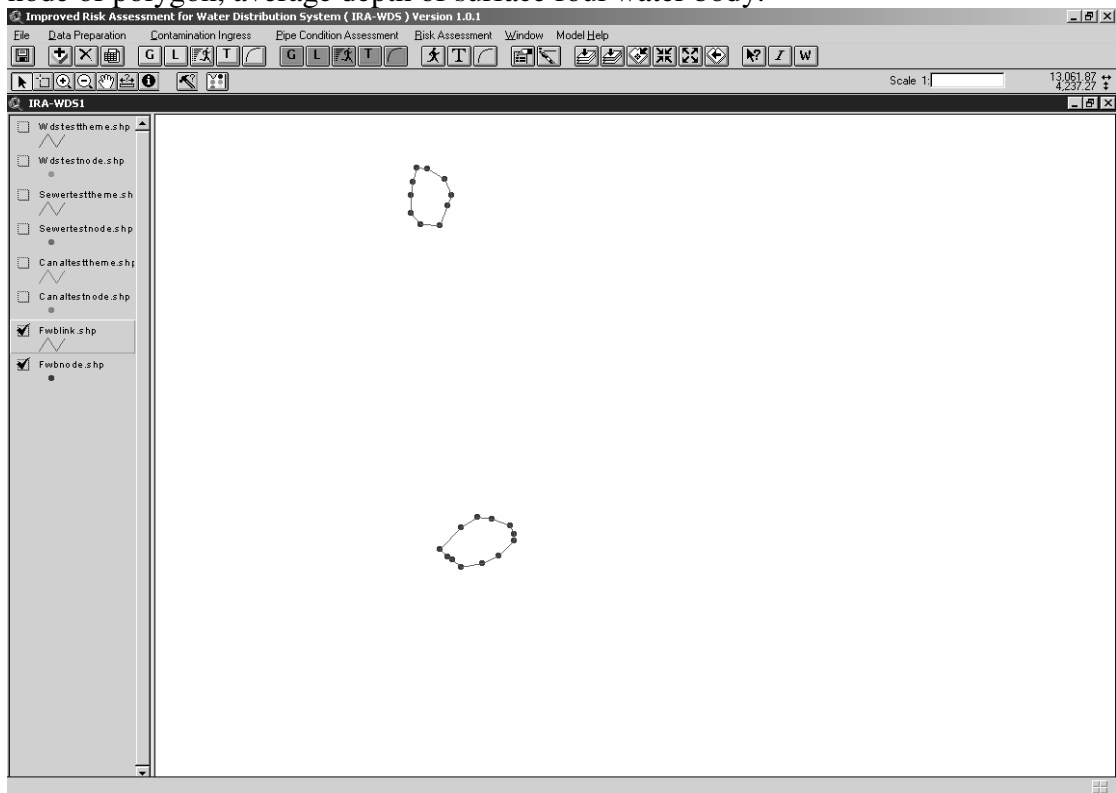


**Figure 5.4. Sewer distribution network**



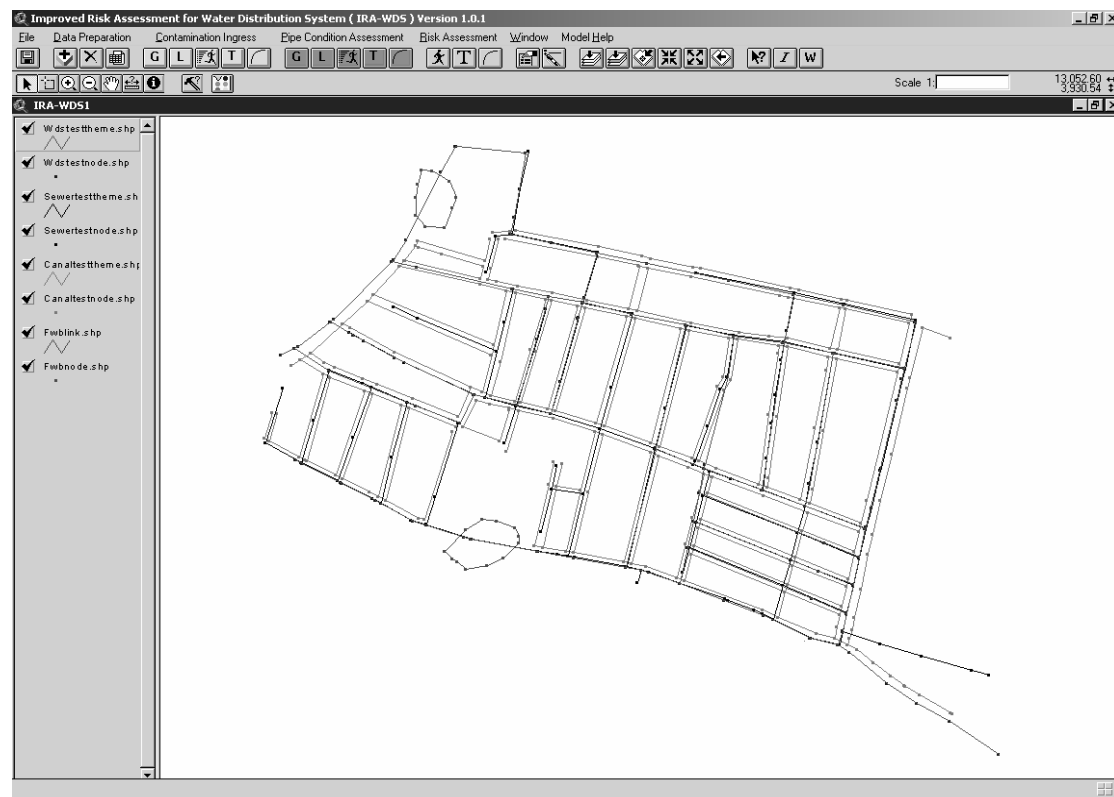
**Figure 5.5. Canal distribution network**

**Surface foul water bodies:** The foul water bodies are represented as polygon features in the network. The boundary of the polygon is represented as the link and points where the direction of the boundary changes are represented as nodes (see Figure 5.6 for example). The database includes the link, start and end node of link, coordinates of node of polygon, average depth of surface foul water body.



**Figure 5.6. Surface foul water body theme**

**Overlay of above themes:** Figure 5.7 shows all the above network themes overlaid into a single derived map.



**Figure 5.7. Representation of the scenario (by overlaying themes)**

### ***Derived maps***

The secondary maps are derived from the thematic maps and the attribute data collected from the Municipal Corporation. A Triangular Irregular Network (TIN) and/or Digital Elevation Model (DEM) can be derived from the elevation contour map. The TIN represents the surface of the area and DEM represents the elevation of each grid cell in the study area.

### **5.6.3 Development of model**

The three models presented in Chapters 2, 3 and 4 are developed in the C++ programming language and then converted to a dynamic link library (DLL). These DLLs are then installed in the ArcView GIS installation BIN directory. The DLL procedure is called using the Avenue script while running the model. The appropriate input parameters for the DLL procedure are provided by the avenue script (pertaining to input and output files). The DLL then executes the programme and writes the respective output file. The model is integrated within GIS using the partial integration approach.

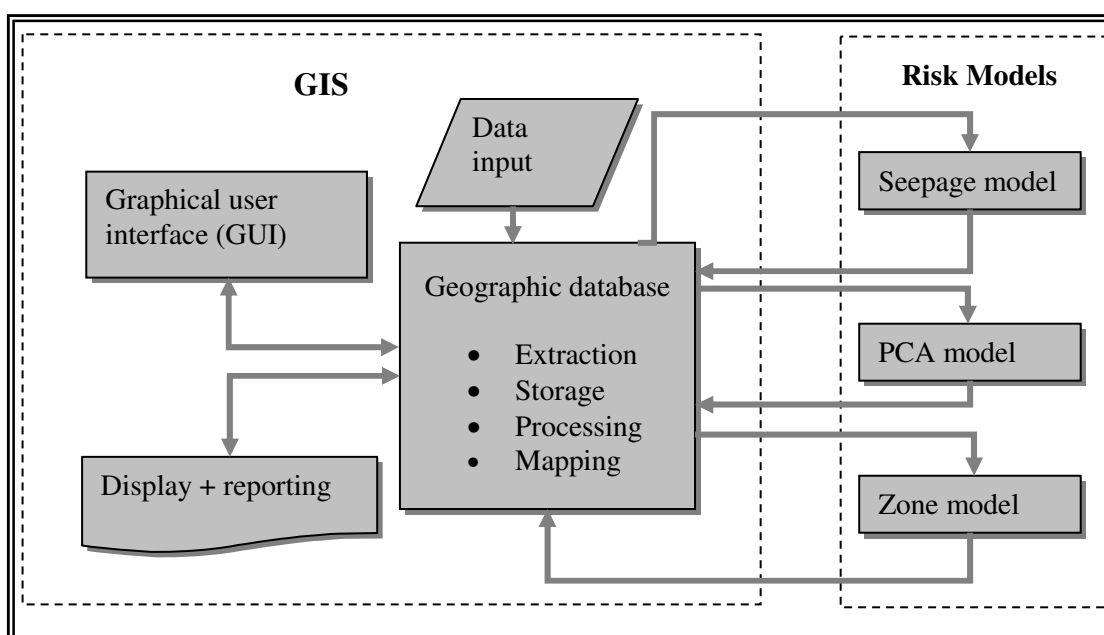
### **5.6.4 Integration with GIS and generation of output**

One of the most important concerns in GIS design is simplifying the user's learning curve. Many current GIS implementations present the user with a bewildering number of functions, which confuses both the novice and expert. The challenge is to propose



an interface which adequately conveys the data model, without posing a complex learning task on the developed model. Data input and retrieval data to and from the model must be performed in a user-friendly manner. Keeping the above criteria in mind, an interface has been developed in order to input and retrieve the data to and from the contamination models. The network data, viz. Pipe link data, Pipe node data, Pipe soil data, Sewer link data, Sewer node data, Sewer soil data, Canal (open drain) link, Canal node data, Canal soil data, and Surface foul water body link data, Surface foul water body node data and Surface foul water body soil data are the input data required for the model.

The different developed models were integrated with GIS to form the 'IRA-WDS' software (see Figure 5.9). The next section deals with different components of the interface and describes various controls and tools used for the interface development (Figure 5.8).



**Figure 5.8. Integration of different developed models with GIS**

## 5.7 IRA-WDS User Interface

A document graphical user interface (DocGUI) based IRA-WDS (Figure 5.9) has been created by using the ArcView GIS tool in the form of ArcView Project. IRA-WDS includes the collection of controls such as menus, buttons and tools that are used to interact with documents like IRA-WDS view, table and chart.

The IRA-WDS view is an interactive document graphical user interface that lets the user display, explore, query and analyse geographic data in ArcView. Similar to 'View' document, any number of IRA-WDS documents can be opened and same data can be saved in more than one IRA-WDS documents viz. IRA-WDS 1, IRA-WDS 2, IRA-WDS 3, etc.

### 5.7.1 Components of interface

The major components of the GIS-based IRA-WDS interface (Figure 5.9) are:

1. File
2. Data preparation
3. Contamination ingress
4. Pipe condition assessment
5. Risk assessment
6. Window
7. Model help

File helps with all file operations such as opening, closing, saving etc.

Data preparation aids the user in converting a file from one mode to another, adding shape files, creating and importing tables etc.

Contamination ingress (see Figure 5.10) helps the user in generating an input file, loading the file, generating output from the contaminant ingress model (running) and viewing input and output. The output of the model identifies the contaminated segments of water supply distribution pipes due to the potential effects of the sewer system, canal system and surface foul water bodies in the area.

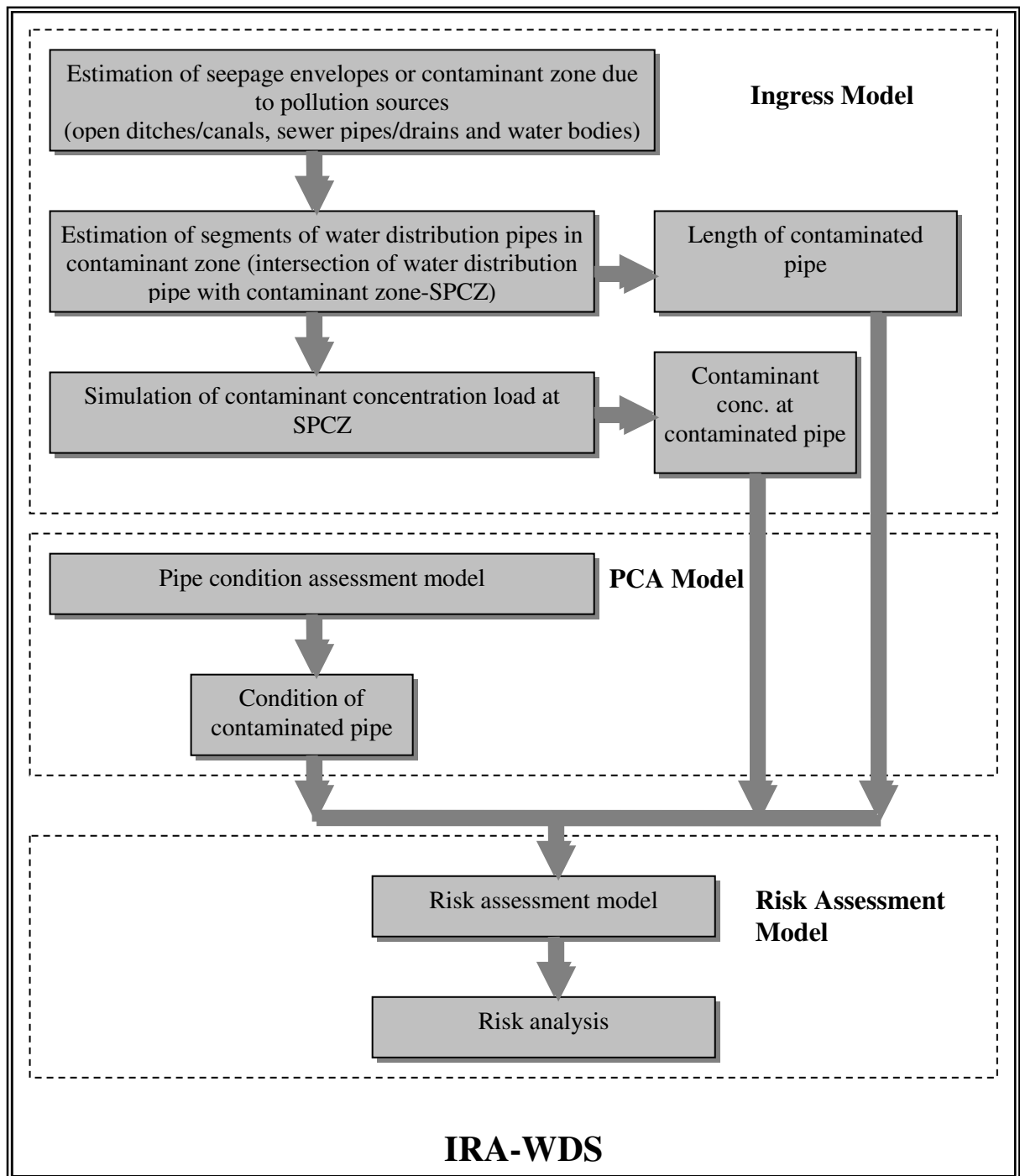
Pipe condition assessment (see Figure 5.11) helps the user in generating an input file, loading the file, generating output from the pipe condition assessment model (running) and viewing input and output. It also aids the user to generate membership functions, weights, balance factors etc. required for obtaining the output. The output of the model ranks the water distribution pipes into different groups based on the vulnerability of the pipes (Figure 5.11).

Risk assessment (see Figure 5.12) helps in loading the outputs of the contaminant ingress and pipe condition assessment models as input, running the model and viewing the input and output. It also aids the user to generate the weights required for obtaining the output. The output of the model enables the user to delineate critical zones of water supply network combining the contaminant ingress potential and the pipe vulnerability (Figure 5.12).

Window performs standard ArcView windows menu operations such as arranging and showing documents.

Model help aids the user in assessing the help file created for the various components of the IRA-WDS Interface.

The interface is designed in such a manner that data input and retrieval data to/from the model can be performed in a user-friendly way.



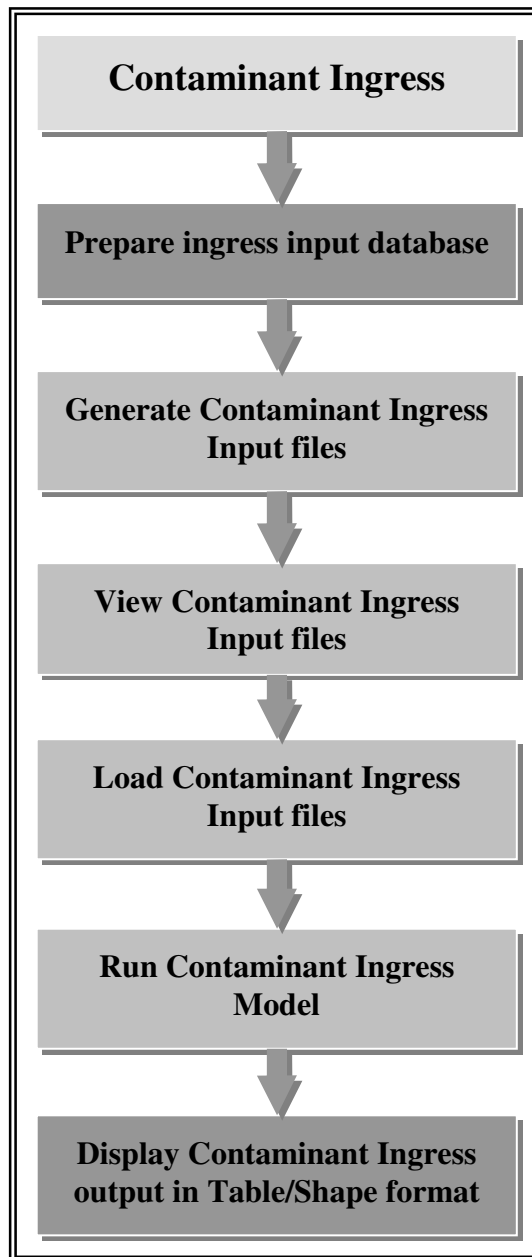
**Figure 5.9. Overview of IRA-WDS**

## 5.8 IRA-WDS Extension

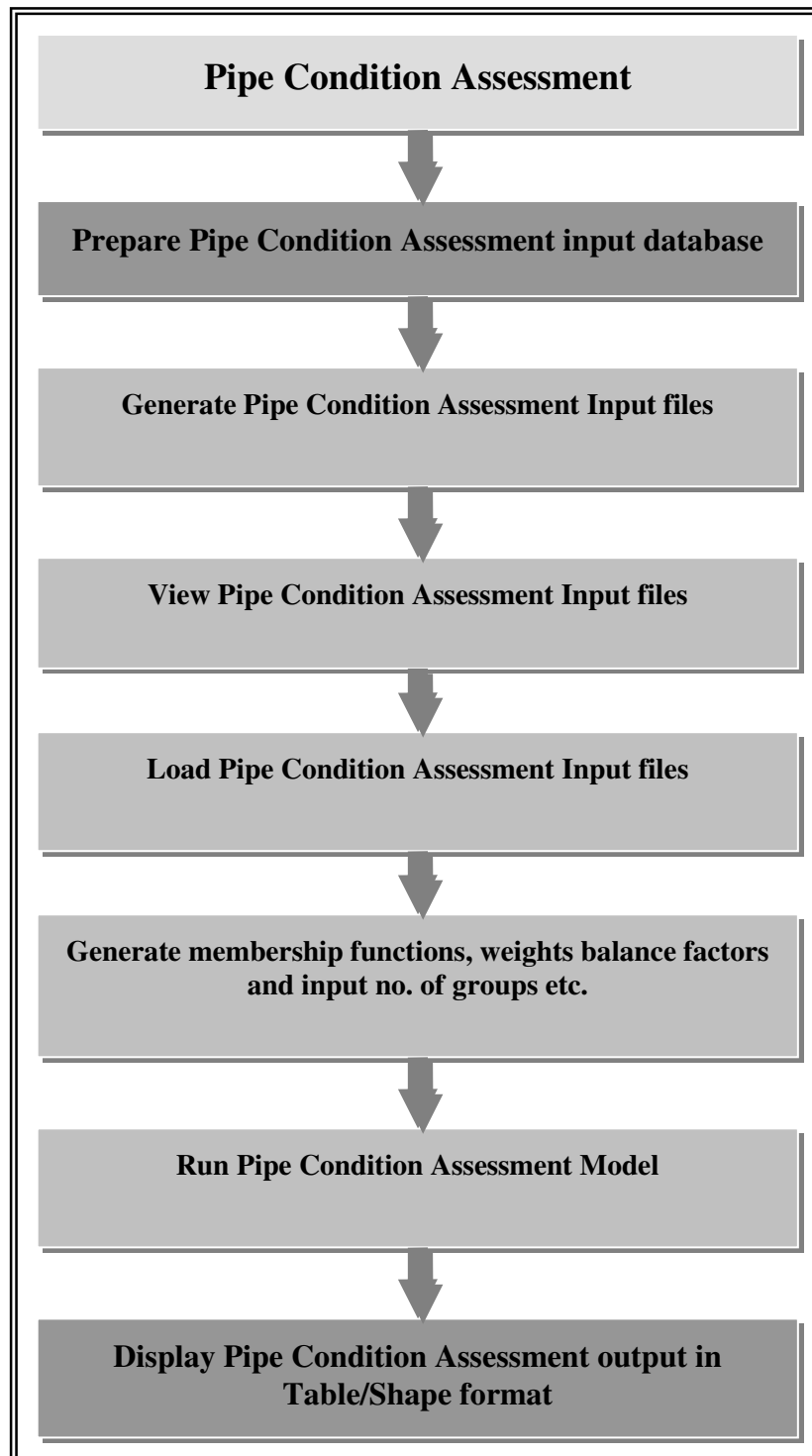
An extension is a kind of object database that can be used to provide new functionality to ArcView without altering existing projects and to permit multiple individuals to contribute without conflict to a single ArcView-based development effort. IRA-WDS has been developed as an extension. Once the extension is loaded, all the controls, viz. menus, tools, buttons, dialog, are automatically loaded into the ArcView's project document. The user can also choose to make the extension default, i.e. whenever the user opens any ArcView project, IRA-WDS interface will be loaded.

The IRA-WDS extension can be loaded automatically by running the shortcut installed by the IRA-WDS setup or through the Program menu. If the user has already opened ArcView and wants to run IRA-WDS he/she should carry out the following steps:

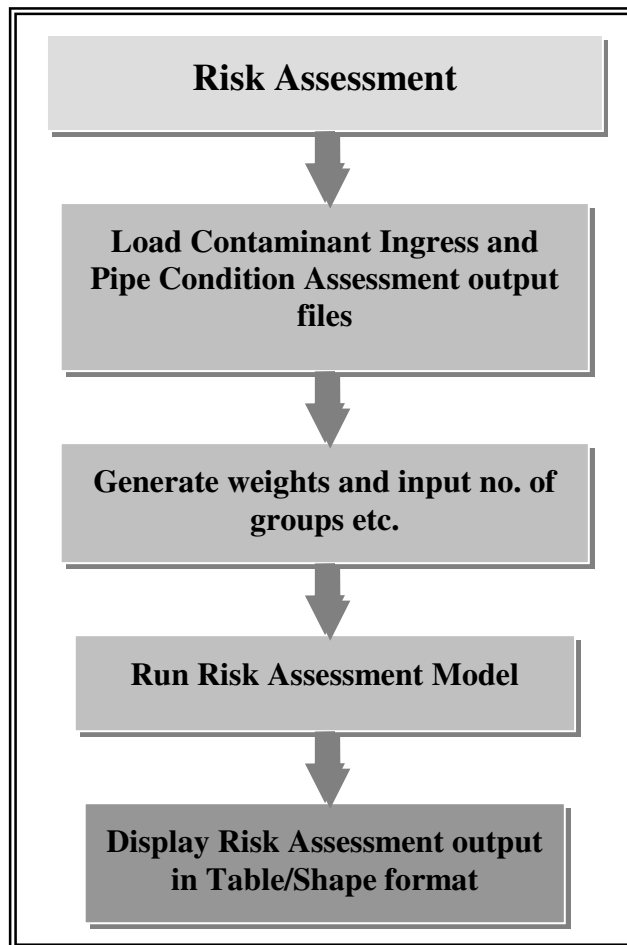
- Activate the ArcView Project window.
- From the File menu, choose Extensions. This will bring up the Extensions dialog.
- Check the box adjacent to IRA-WDS in the Extensions dialog. If user wishes the IRA-WDS extension to load automatically every time user starts ArcView, press the Make Default button after ticking the IRA-WDS. The next time user starts ArcView, the IRA-WDS will automatically be loaded.
- Press OK in the Extensions dialog box.
- The IRA-WDS welcome screen will be opened and the user can opt to cancel/quit ArcView or continue with IRA-WDS loading.



**Figure 5.10. Overview of Contaminant Ingress Model of IRA-WDS**



**Figure 5.11. Overview of Pipe Condition Assessment Model of IRA-WDS**



**Figure 5.12. Overview of Risk Assessment Model of IRA-WDS**

