As Built Survey of road side features for 3D GIS application

by

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Signatures have been redacted for privacy

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1. INTRODUCTION

As Built Survey refers to the process of measuring and mapping the physical features of a site in plan view, profile view and cross-section view. Typically, an As Built survey is performed on completion of a construction project for the purpose of reestablishing the principal horizontal and vertical controlling points and locating the position of all structures and improvements. Prior to As-Built surveying, both horizontal and vertical control must be established to allow features to be tied to some known points or lines. Once control is established, it can be used for the topographic survey, the design, and the construction phase of the project. [40].

An As Built for roadside features typically involves the collection of both road and roadside features and tying the data to a known system. This is primarily done for both inventory control and management. The efficient planning, construction and operation of any project depends on access to the right spatial data, in the right format and at the right time. Methods of collecting spatial data, traditionally done by surveyors, photogrammetrists and remote sensing specialist, have undergone a series of technological changes. There are various techniques for collecting roadside data, ranging from traditional the Total Station [35] survey to the 3D Laser Scanning system [24]. With the rapid growth of technology, data is no longer collected in 2D but in 3D (X, Y, Z) and the attribute data is tied to the spatial information. The spatial and the non-spatial data that are collected are generally stored in a Geographic Information System (GIS) so that spatial analysis can be carried out. The new methods for acquiring, processing and distributing spatial data is affecting the way transportation professionals plan and execute projects [1].

A two dimensional GIS is often referred to as a computer system capable of collecting, storing, manipulating, and displaying geographically referenced information, (i.e. data identified according to their locations). [5]. Basically, GIS depicts spatially distributed data as they would be shown on a map, a two dimensional surface, or viewed from nadir via a high platform, with spatial objects represented by a mosaic of colors and patterns. [46]

GIS integrates spatial and other kinds of information within a single entity thus offering a consistent framework for analyzing data. GIS makes connections between activities based on geographic proximity suggesting or showing new insights and explanations. The linkage between spatial and non-spatial, which often seems so obscure and distant, now makes more sense. This integration between spatial and non-spatial data can be vital for understanding and managing resources.

As with any technology, GIS has not stood the test of time, and strains have begun to show on the "Core GIS". The reason is that users have started bombarding GIS with more complex problems that conventional GIS finds hard to solve let alone interpret. One such example is the way current GIS visualizes terrain upon which most GIS analyses are carried out. The land surface is undulating, objects viewed are three-dimensional and have characteristic structures that appear smaller in the distance, and features are located above, below and around the observer. Unfortunately all GIS simulations are visualized over a 2D representation of the terrain (spatial data). To overcome this problem researchers have tried to represent the analysis in 2.5 D such as D.T.M's. It is called 2.5 D because each x,y point can only store one z value. In a real three dimensional surface, several z values can be stored with each x,y coordinate pair. So, for example, an elevation of the ground above mean sea level, and the height of the tree-cover or a building could all be stored with one x,y pair (Figure 1).

A real 3-D surface can handle different layers of elevations. With the ability to handle different layers of elevation, we can represent the spatial features in true 3D, as they exist in real world. Another advantage of 3D models is that calculation and visualization of volumes is easy. Even though 3D images are intuitive in nature they are harder to create. On the other hand, 2.5 D models are easier to create and are excellent for visualizing data. The general types of 2.5 D surface that can be generated include T.I.N's(Triangulated Irregular Network), Contours, D.E.M (Digital Elevation Models).

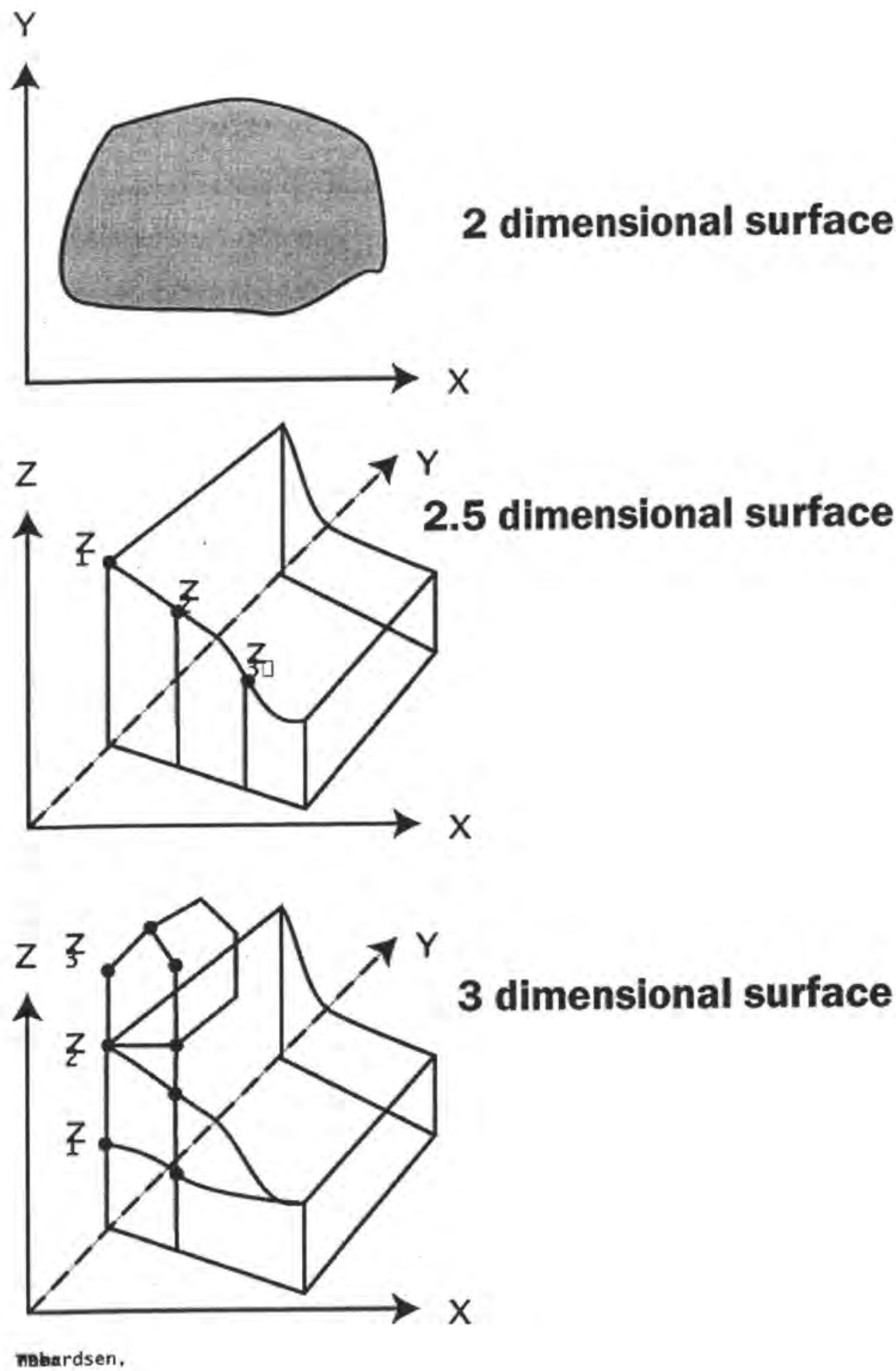

Figure 1. Bernhardsen, T. 1999. Geographic Information Systems: An introduction.

When, the 3D GIS capabilities are added to GIS software it has the ability to visualize the global and spatial data. 3D GIS engages the senses fully and provides full interactivity and, in real time. The concept of merging Geographic Information Systems and 3D graphics into a 3D GIS system is a hot topic of research. Successful attempts have been and are being made to merge GIS and 3D graphics for a more interactive and user-friendly interface. The various research areas where a 3D GIS system is being used are Archeology Urban Planning, Environmental Planning & Impact Assessment, Scientific Visualization, Education (Virtual Field Course) and Military Simulation and Intelligent Application. The following pie chart (Figure 2) shows the amount of work being done in these various fields

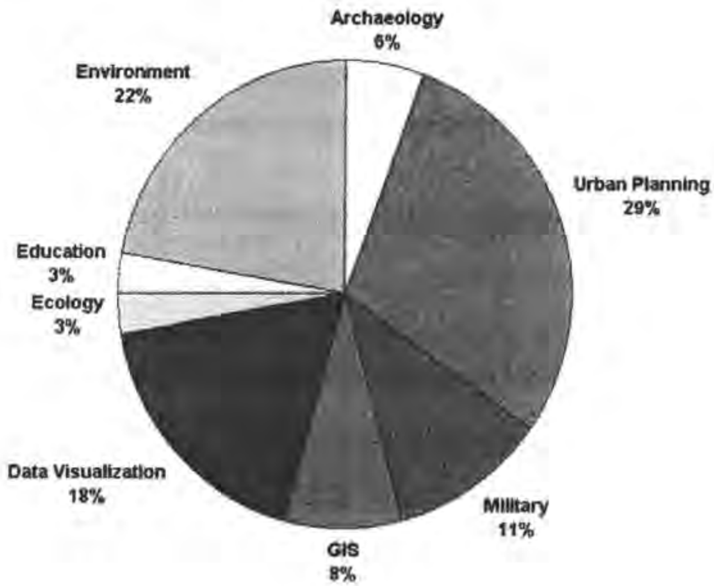

Figure 2 Pie Chart showing the various areas, which uses 3D GIS [20].

The term 3D/Virtual GIS can be defined as a highly integrated and efficient GIS for not only collecting, storing and retrieving spatial data but also visualizing both geographic and non geographic information in a collaborative environment. The term 3D GIS and Virtual GIS have been used synonymously among researchers to denote such an integrated system. However, there is a difference between a 3D GIS and a Virtual GIS. The 3D GIS often corresponds to a non-immersive low-end 3D GIS that relies entirely on low end graphics to achieve the realism. A Virtual GIS often refers to a fully immersive 3D GIS using

Virtual Reality technology as the user interface. This thesis develops a low-end 3D GIS for As Built survey of roadside features.

Most of the research from the industry is in the form of low end so-called Virtual/3D GIS and some of the examples include ESRI's ArcView 3D Analyst [28], which provides the user with a simple 3D vector geometry and a interactive perspective view, and Pawan, a VRML compiler and project management system for MapInfo GIS [34]. It is a software interface, which combines the utilization of virtual reality with spatial display capabilities of GIS. Prototypes of object oriented DBMS are for handling large data sets. Virtual Reality based visualization tools are combined for providing real time navigation of large worlds. [5]. An interesting project is the KarmaVI system, which is an application for modeling, manipulation and analysis of two and three-dimensional spatial (GIS) data within a 3D environment. It is based on existing GIS and 3D graphics technology that uses the three views; plan view, model view and worldview, to support design, development and presentation of large infrastructures plans in the Netherlands [48].

Also, efforts have been made to link the Internet and 3D computer graphics and GIS. These technologies have been around for over three decades, but it is only recently that technology has made possible their mutual interaction. Such technologies include Geo-VRML, JAVA3D and X3D. Another very important tool in developing such a 3D GIS is OpenGL, which helps to run the 3D engine and support real and efficient rendering of high-end graphics. This thesis gives detailed information about the various tools available to develop a 3D GIS.

From this background information it is obvious that 3D GIS coupled with the power of Internet can be effectively used for spatial data visualization. 3D GIS improves the communication of ideas and concepts in a collaborative process. In a GIS, the goal is to support users who are "overwhelmingly map illiterate". Here, 3D GIS acts as a mediator and transmitter of ideas between participants. It is no longer necessary for planners and engineers to look at abstract data and make important decisions.

1.1. Research Objectives

The objectives of this research is to develop and customize a traditional GIS, explore the options available for developing a 3D GIS and develop a web enabled 3D GIS. The research describes and compares the various data collection techniques that can be used to carry out As Built surveys for road and road side features. It also shows how to efficiently develop and customize a GIS. It shows the shortcomings of such a traditional GIS and the need to develop a more robust and powerful 3D GIS, which is not only 3D but also web enabled. The following are the steps adopted to carry out the research

- Site Selection: EDM BASELINE near Ames, Iowa is used as the Study Area
- Data collection using:
    - Total Station Survey
    - RTK GPS Survey
    - Video Logging Van
- Development and Customization of a traditional GIS system
- Exploration of the various ways to develop a 3D GIS system
- Development of a Web Enabled 3D GIS System

The development and customization of a 2D GIS makes use of the data collected using the Total Station, Leveling and RTK GPS done on EDM baseline. The customization of the GIS was based on the scripts written for hot linking of video logging images, use of 2D visualization tools such as Line of Sight and View-shed analysis, and automating the profile and cross-section generation.

Based on the 2D GIS, a 2.5 D GIS in the form of elevation models such as a TIN and 3D GIS were developed. The 3D GIS was developed using Arc View 3D Analyst, in which simple extrusion was used to display the 3D features of objects. Another system that was developed made use of OpenGL. OpenGL was used to implement a 3D GIS, which allowed for more realistic and interactive development. The important features of the system were the fly through, dynamic view port; fog/atmospheric effects and GIS type queries such as feature identification and distance measurement. Another 3D GIS was developed using VRML (Virtual Reality Modeling Language) which incorporated all the features of the OpenGL system but was inherently web enabled allowing the GIS data to be shared in 3D over the internet. Also, routines were developed specific to engineering requirements such as 3D Profiling and Cross Section, Vertical Curve design, Area and Volume computation, and dynamic object positioning and visualization, to emphasis the importance of developing such a 3D GIS system for engineering applications.

This thesis contains six chapters. Chapter 2 discusses the various data collection techniques for carrying out As Built survey for Road Side features. Chapter 3 discusses the principles of a GIS and the various GIS software components available to carry out analyses. Chapter 4 describes the development of a customized GIS for As Built Surveys. Chapter 5 discusses the need to incorporate 3D features into the traditional GIS and it also looks at tools available to develop such a 3D GIS system. Chapter 6 draws conclusion on the work done and states recommendations to further improve the system.

2. AS BUILT SURVEY FOR ROAD SIDE FEATURES

The first stage of the project was site selection, which was a rural road (Zumwalt Road), known popularly as the EDM BASELINE. It is approximately 1.5 miles long. The site consists of five well-established benchmarks, which are used as control points for all subsequent surveys. The following picture is the USGS Quad of the area (Figure 3)

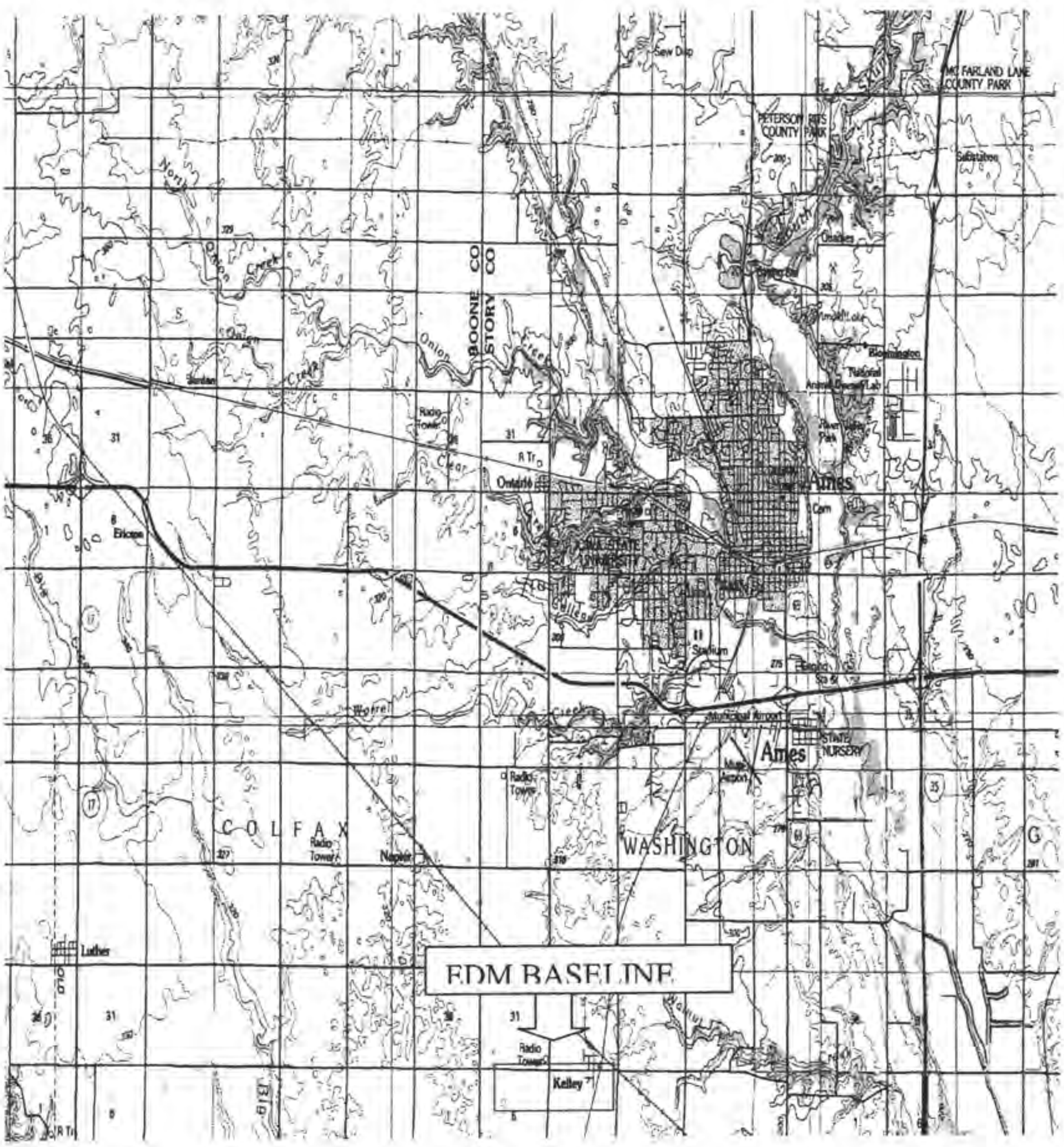

Figure 3. USGS Quad of Ames, EDM Baseline (http://www.gis.iastate.edu)

A reconnaissance survey was carried out of the site to give a better understanding of the various features to be surveyed. Also, it was done to get an estimate of the approximate time frame needed to carry out a traditional total station. The choices of features selected were based on previous work done by Dr. Edward Jaselskis and Dr. Kandiah Jeyapalan [12]. The following is the picture of the reconnaissance survey done (Figure 4).

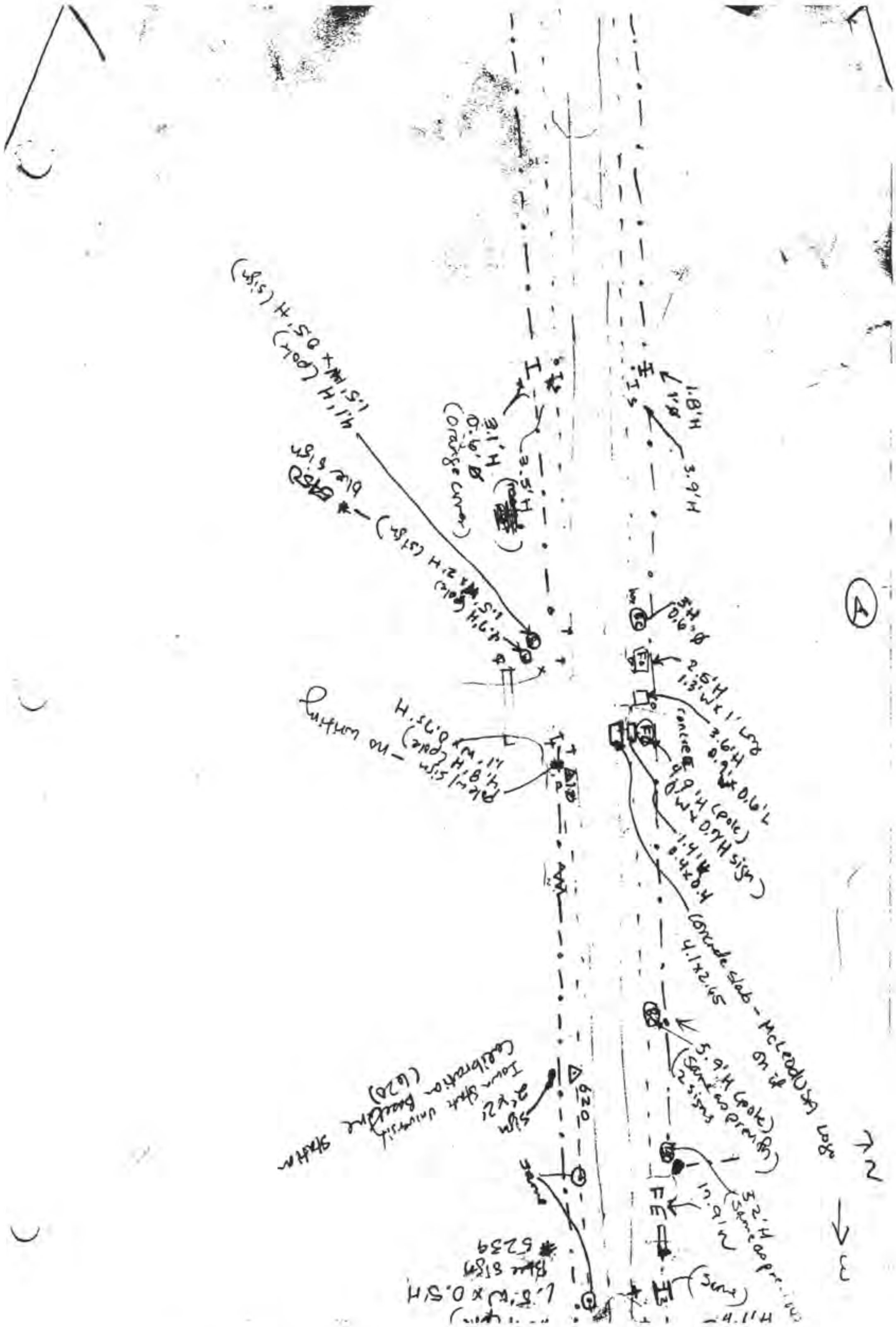

Figure 4. Reconnaissance Survey Rough Drawing

2.1 Data Collection Techniques

2.1.1 Total Station Survey

The Instrument used for Data collection was the Geodimeter 400 System (Figure 5). The Geodimeter System 400 meets all demands for efficient and accurate angle measurement with full compensation for automatic correction for vertical and horizontal angle error and automatic correction for collimation error and Trunnion Axis tilt.

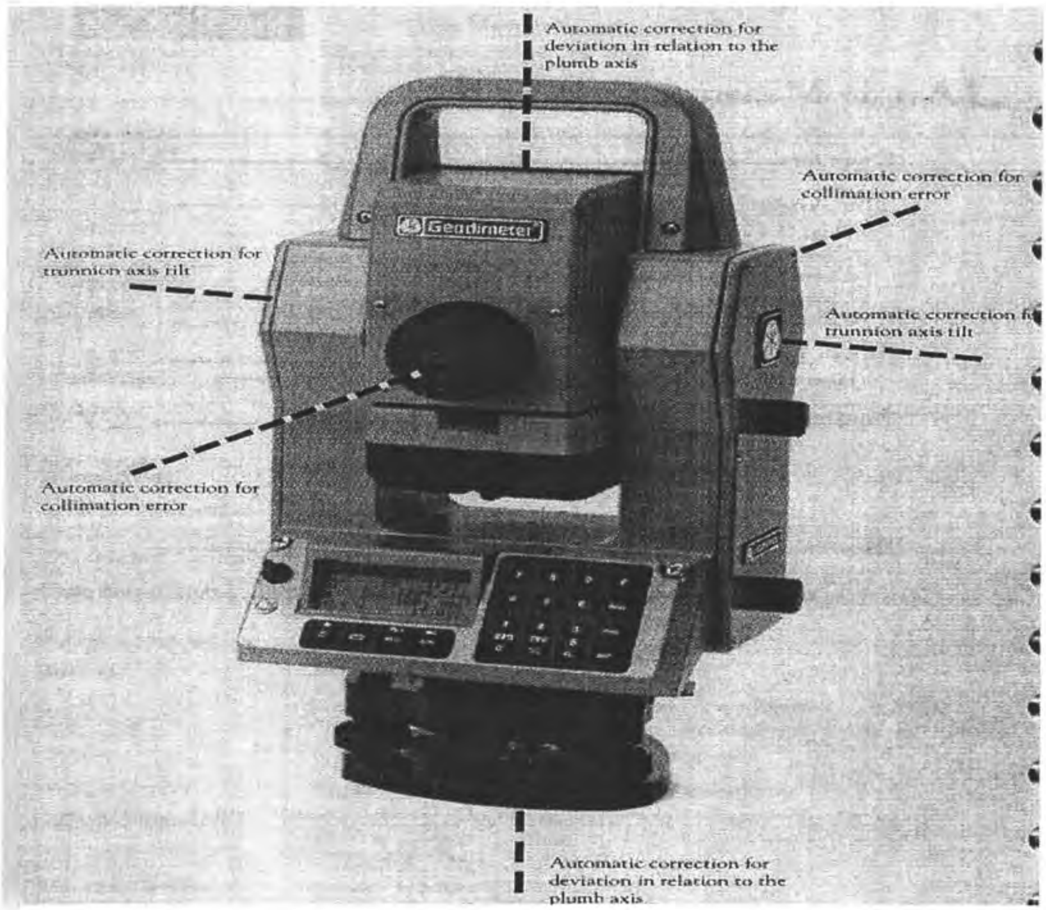

Figure 5. Components of Geodimeter 400 Total Station

2.1.1.1 Angle Measuring Technique

The principle of measurement is based on reading an integrated signal over the whole surface of the horizontal and vertical electronic device producing a mean angular value. In this way, inaccuracies due to eccentricity and graduation are completely eliminated.

2.1.1.2 Dual Axis Compensator

The instrument also is equipped with a dual Axis compensator, which will automatically correct both horizontal and vertical angles for any deviations in the plumb line.

2.1.1.3 Distance Measuring System

The distance module of geodimeter System 400 operates within the infrared area of the electronic spectrum. It transmits an infrared light beam optically towards the target. The reflected light beam is received by the instrument and with help of a comparator, to obtain the phase delay between transmitted and reflected signal [16].

The Following Information was used to tie the measured features to the State Plane Coordinate System.

Table 1. State Plane Coordinates for Known Control Points

Point	Northing	Easting	Elevation	Description
0	1054873.571	1484992.422	282.699	Bench Mark "0"
461	1054872.086	1484531.171	283.865	Bench Mark "461"
621	1054871.488	1484371.937	283.983	Bench Mark "620"
770	1054871.045	1484221.837	284.363	Bench Mark "770"
1370	1054869.090	1483623.062	285.479	Bench Mark "1370"

2.1.1.4 Computation of Coordinates

The computation of coordinates is calculated by using of coordinates of a Back Sight and a known azimuth and the rest of the features for which the coordinates were needed were treated as Foresights. (Refer to figure 6 for the basic setup). The following equations are used to compute the unknown coordinates [40].

$$X_u = X_t + HD * Sin(Azi)$$

$$Y_u = Y_t + HD * Cos(Azi)$$

Where

$(X_u\ Y_u)$: Coordinates for Points of Interest

$(X_u\ Y_u)$: Coordinates of Known Reference Station

Azi: Azimuth

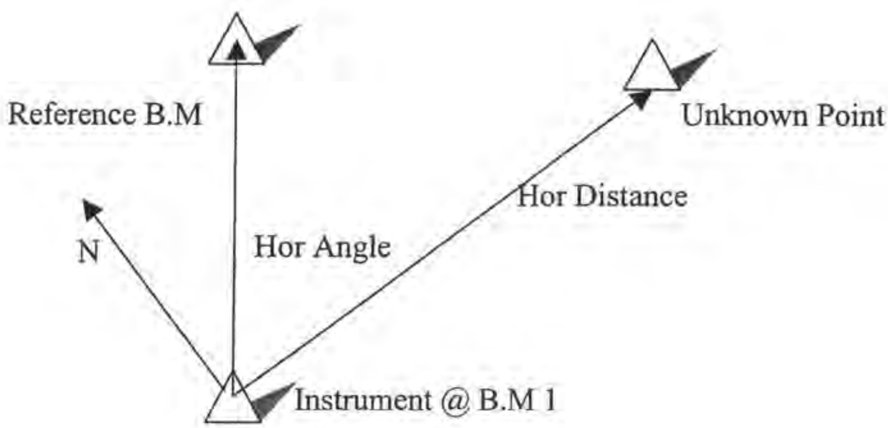

Figure 6. Radial Survey Principle

To get the coordinates of all the points, a different setup was done. For each new setup the instrument was erected at a known station and was Back Sighted to a known station, so that the initial coordinates (in state plane coordinates) and the azimuth were known. Thus, knowing the coordinates and the azimuth the coordinates of unknown station can be directly computed using the measured horizontal angle and the horizontal distance. Once the coordinates have been computed, the data can be bought into a GIS directly. (Refer to Appendix A for list of all computed coordinates). The following are the pictures taken during the actual survey (Figure 7).

Figure 7. Total Station Survey Pictures

2.1.2 Real Time Kinematic GPS Survey

Global Positioning System (GPS) is a satellite based radio navigation system providing precise three-dimensional position, navigation and time information to a suitably equipped user. It is primarily a navigation system but can be used for accurate geodetic positioning purpose. GPS uses the World Geodetic System (WGS84) as a reference system for absolute coordinates and Coordinated Universal Time (UTC) for time reference.

Starting from the known satellite coordinates in the reference frame, the coordinates of user antenna can be determined. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

The GPS satellites are defined by two numbering schemes: one is SVN (Satellite Vehicle Number) according to launch and other by PRN (Pseudo Random Noise) number. The nominal GPS operational constellation consists of 24 satellites that orbit the earth in 12 hours. There are currently, 24 operational satellites with three operating spares to handle satellite failures. The satellite orbits repeat almost the same ground track (as the earth turns beneath them) once each day. [23].

Figure 8. The attributes of GPS Satellite in orbit [23].

One of the most recent innovations in GPS is RTK (Real-Time Kinematic) GPS, a real time technique that provides position accuracy close to that achievable with conventional carrier-phase positioning. In surveying, we are usually interested in determining the position of one or more (relatively) fixed points, which are usually monumented either permanently or temporarily. Often, we are primarily interested in the horizontal coordinates of points, a two-dimensional application, or in heights only, a one-dimensional application, or in all three coordinates, a three-dimensional application.

2.1.2.1 Carrier-Phase Positioning

Recently, scientists and engineers developed a new positioning technique that any application, including surveying and navigation can use for increased accuracy. Real-Time Kinematic GPS employs a method of carrier-phase differential GPS positioning whereby users can obtain centimeter-level position accuracies in real time.

The carrier phase measurements are more precise than the pseudorange. It is the phase of the received carrier with respect to the phase of a carrier generated by an oscillator in the GPS receiver. That carrier has a nominally constant frequency, whereas the received carrier is changing in frequency because of the Doppler shift induced by the relative motion between the satellite and the receiver. Ideally, the carrier-phase observable would be the total number of full carrier cycles and fractional cycles between the antennas of a satellite and a receiver at any instant. Unfortunately, a GPS receiver has no way of distinguishing one cycle of a carrier from another. The best it can do, therefore, is to measure the fractional phase and then keep track of changes to the phase; the initial phase is undetermined, or ambiguous, by an integer number of cycles. To use the carrier phase as an observable for positioning, this unknown number of cycles, or ambiguity, must be estimated along with the other unknowns - the receiver's coordinates. If we convert the measured carrier phase in cycles to equivalent distance units by multiplying by the carrier's wavelength, we can express the carrier-phase observation equation in a form very similar to the observation equation for the pseudorange. The major difference (apart from the sign of the ionospheric propagation delay term) is the presence of the ambiguity term.

The carrier phase's rate-of-change is related to the Doppler shift, which is used to determine velocity. Incidentally, in comparison with the carrier phase, pseudoranges, when measured in code wavelength units (about 300 meters for the C/A-code and 30 meters for the P-code), are sometimes referred to as code-phase measurements. For high-accuracy position determination, carrier-phase measurements made by one receiver are typically combined with those made simultaneously by another receiver to form double differences in which the effects of satellite and receiver clock errors are essentially eliminated. The double differences are then processed using a least-squares filter to estimate the relative coordinates of one receiver with respect to the other. If the coordinate of one of the receivers is well known in some coordinate frame, then the coordinates of the second receiver can be determined in the same frame.

In all of these GPS surveying modes, either the receiver or an external device records the data for postprocessing. The coordinates of the points visited by a roving receiver or the track it followed cannot be determined to the requisite accuracy until its data are combined with those from a reference receiver. Many applications, however, could clearly benefit from obtaining the receiver's coordinates in real time rather than waiting.

Real-time differential GPS (DGPS) has been around since the mid-1980s. However, that technique uses pseudorange data, rather than carrier-phase data, with resulting 2d rms horizontal position accuracies of a meter or so at best. Pseudorange DGPS entails a reference station transmitting pseudorange corrections to nearby user receivers, which combine those data with their own pseudorange measurements to produce corrected pseudoranges. A user receiver then processes these in the usual fashion to determine its coordinates. [2]

2.1.2.2 RTK System Architecture

In an RTK system, both the reference station and roving station consist of a single or dual-frequency GPS receiver, the associated antenna, a data radio (sometimes called a radio modem), and its associated antenna (see Figure 9). Typically, users employ identical GPS receivers and data radios at the base and roving stations, although one must obviously use the reference station data radio for transmitting and the roving station data radio for receiving. Often, the transmitting antenna has higher gain than the receiving antenna, although it is common for both to have omnidirectional whip antennas. Some RTK systems integrate the GPS receiver and data radio into one package, with the GPS and radio link antennas even sometimes sharing a common enclosure. To achieve the best results, the reference station GPS antenna should be mounted in a location free which is free of multipath and, where the radio link antennas can be as high as possible to maximize the link's coverage. [15]

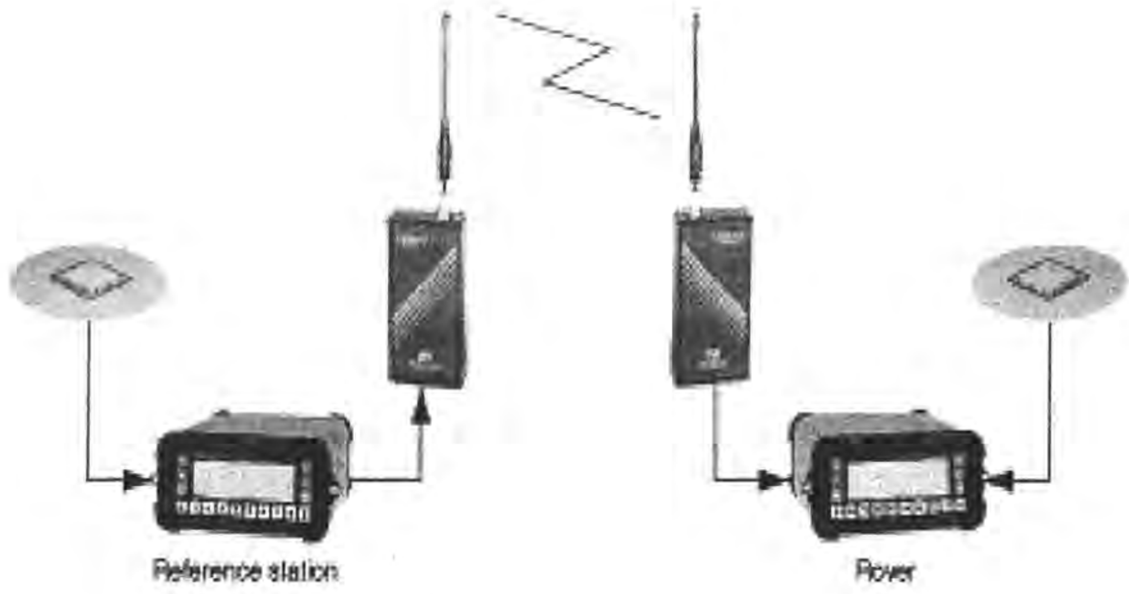

Figure 9. RTK GPS Principle

The key feature enabling the high accuracies afforded by RTK operation is the ability to determine the carrier-phase integer ambiguities while the rover is in motion. If the processing software simply estimates the ambiguities as real values, that is, floating point numbers, the resulting so-called float solutions will have accuracies that can range from the meter level to the decimeter level depending on how long the rover has been tracking the GPS signals. Researchers have devised a number of algorithms for determining or resolving these ambiguities "on the fly (OTF)." Many OTF implementations use the wide-lane combination of L1 and L2 carrier-phase data. Although noisier than L1 data, the wide-lane combination has an ambiguity of 86 centimeters, which is much easier to resolve than the L1 19-centimeter ambiguity. A resulting position from the wide-lane combination can be used to directly compute the L1 ambiguities. The speed with which ambiguities can be fixed depends on several factors, including the number of satellites tracked, satellite-receiver geometry, use of pseudorange data in addition to carrier phase, observation noise, and use of dual-frequency observations. Under good conditions, the fix times can be shorter than one minute and optimally less than 10 seconds [29]. The following are pictures taken during the actual RTK GPS survey performed on the EDM Baseline. (Refer to Appendix B for the list of all computed coordinates).

Figure 10. RTK GPS Survey Photos

2.1.3 Video Logging Van

A Mobile Mapping System (MMS) can be defined as a moving platform, with which the multiple sensor/measurement systems have been integrated, to provide three-dimensional near-continuous positioning on the platform to collect simultaneously the geo-spatial data. The video logging van is one such mobile mapping and data collection system, which can be used to map highway and transportation infrastructure such as signs, bridges etc. The system comprises of a van fitted with a camera and a Differential GPS system that is capable of collecting both visual and spatial information (Camera Location). The following picture shows Iowa Department Of Transportation Video logging van and the camera used to collect pictures. [18]

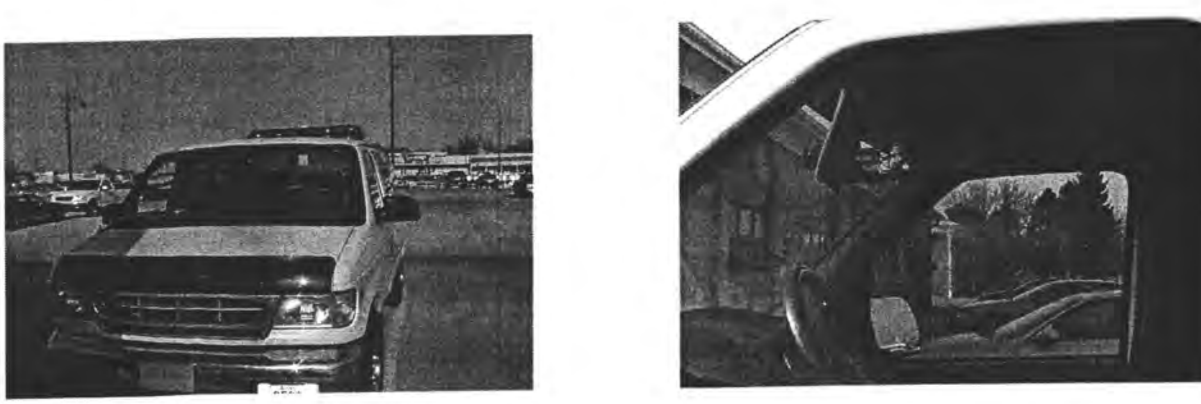

Figure 11. Iowa DOT Video Logging Van

2.1.4 Laser Scanning

The 3D scanning sensor uses laser technology to capture physical objects such as structures or scenes and converts them into digital point cloud data. The software program processes this point cloud data into 3D models. The user can then manipulate the model, extract its geometry and output to various modeling packages. It is ideal for projects that need to capture existing geometry when the use of conventional methods, such as traditional survey or drawings, is inadequate or unavailable. [19] The Cyrax 2500 laser scanning system is a portable system that can capture, model and visualize the site with unprecedented accuracy speed and efficiency. The following is a picture of the Cyrax Laser scanning system. [24]

Figure 12. Laser Scanning Cyrax 2500 system

3. GIS: PRINCIPLES AND PRACTICE

Geographic information systems (GIS) are often referred to as computer systems capable of collecting, storing, manipulating, and displaying geographically referenced information, (i.e. data identified according to their locations). Basically, GIS depicts spatially distributed data as they would be shown on a map, a two dimensional surface, viewed from nadir via a high platform, with spatial objects represented by a mosaic of colors and patterns. The Geographic Information System has the following main components (Figure 13).

- Computer Hardware
- Set of application software modules
- Appropriate organizational context
- Spatial and nonspatial Data

Figure 13. The Different Components of a GIS (http://www.esri.com).

3.1 GIS Software: Arc View GIS, ESRI Inc

Arc View GIS (Figure 14) is a desktop geographic information system (GIS) from ESRI (Environmental System Research Institute), Red Lands, CA. The Arc View interface consists of windows that present information in different ways. In Arc View, features are stored in a database along with information describing them. The descriptive information stored with a feature is called an attribute. Because features and their attributes are linked, we can easily access the attributes for any feature or locate any feature from its attributes. Attributes are displayed in a spreadsheet-like Arc View document called a Table just like a conventional Database Management System. Features and their attributes are linked and managed together in units called themes. A theme consists of a collection of geographic features (such as roads, rivers, parcels, wildlife sightings, schools, or parks) and the attributes of these features.

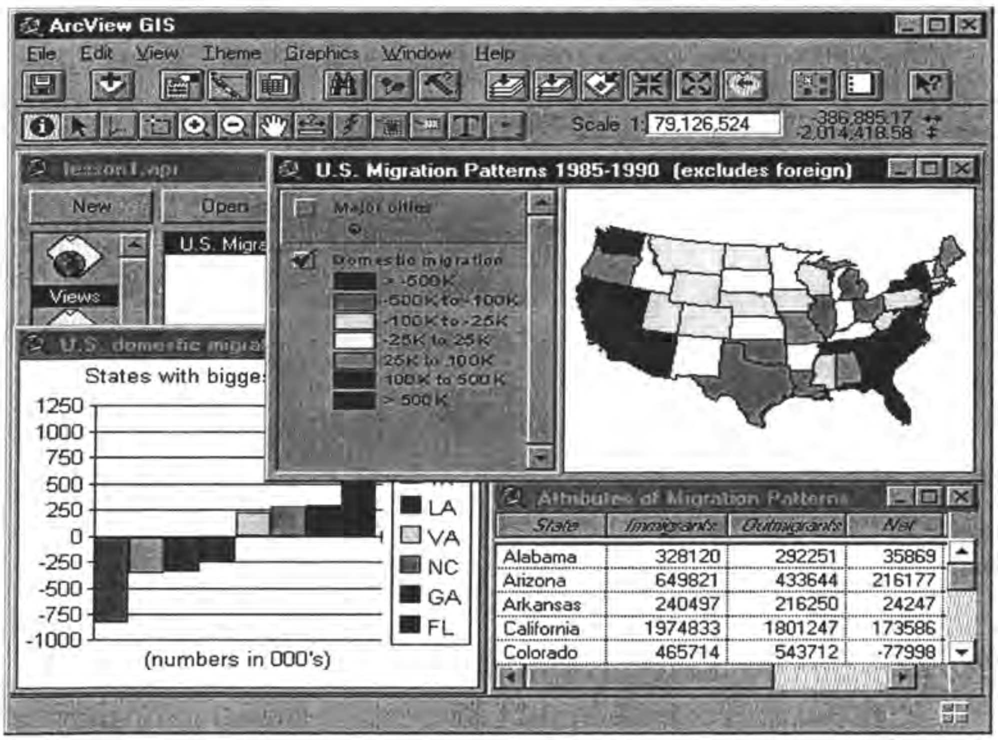

Figure 14. Arc View 3.2 from Environmental Research Institute

Arc View works with project files, which are identified by an ".apr" extension. Projects store and organize information in five types of documents: Views, Tables, Charts, Layouts, and Script Editors. Each document type displays data differently and allows us to interact with the data in different ways. The Arc View graphical user interface (GUI) is located along the top of the active window. The GUI consists of pull down menus, buttons, and tools. The GUI changes according to the active document type. Views display geographic data organized by theme. A view contains a map display area and a table of contents, or legend. Tables display records as rows and fields as columns. Tables linked to a theme are called theme attribute tables, and each record represents a feature and each field represents a single attribute for the feature. Charts display tabular data graphically and are integrated with tables and views. Layouts are documents on which you arrange views, tables, charts, and images. They also can contain north arrows, scale bars, and legends. Layouts are often the main product of a GIS project since they are the maps that present the results of the analysis. Script Editors are used to load and write, edit, compile, and execute Avenue programs (called scripts). Avenue is Arc View's programming language. With Avenue scripts, we can customize almost every aspect of Arc View GIS. [23]

3.1.1 Arc View Extensions

3.1.1.1 Spatial Analyst

Arc View Spatial Analyst helps to: (1) create, query, and analyze cell-based raster maps; (2) derive new information from existing data; (3) query information across multiple data layers; and (4) fully integrate cell-based raster data with traditional vector data sources. The grid theme is the primary data source used by Arc View Spatial Analyst. Grids are especially suited to representing traditional geographic phenomena that vary continuously over space, such as elevation, slope and precipitation. Grids are also the ideal data representation for spatial modeling and analysis of flows and trends over data represented as continuous surfaces (such as hydrologic modeling or the dynamics of population change over time). Arc View Spatial Analyst represents geographic phenomena with cell-based grid themes. Instead of using points, lines, and polygons to model geographic features, grid themes use cells. A variety of analysis tools are available to perform spatial queries, overlay analysis, and surface analysis, including calculation of distance, proximity, density, slope, aspect, hill shade, view shed, and contours. We need to distinguish between vector data model and raster data model.

3.1.1.1.1 Vector data model

In a vector data model, a point, line or polygon objects can be represented on a map as a collection of x and y coordinate pairs stored in a table. The x and y coordinates represent the point's distance from an origin point. Several point objects on a map, such as cities or buildings, can be stored as pairs of x and y coordinates in a vector theme. To represent lines, the x and y coordinates of the beginning point (from node) and the end point (to node) of the line are stored. If the line is not perfectly straight, represent curves or changes in direction as a series of x, y coordinate pairs, known as vertices, at each direction change between the beginning point and end point of the line. Lines have a length. To represent an area (polygon), we simply enclose it with a line, making the beginning and ending points of the line join. Polygons, which share a boundary, are called adjacent. Areas have a perimeter. Two important topological concepts related to the vector data model are:

Connectivity: The topological identification of connected arcs by recording the from- and to-node for each arc. Arcs that share a common node are connected.

Contiguity: The topological identification of adjacent polygons by recording the left and right polygons of each arc.

3.1.1.1.2 Raster Data Model

In the raster data model, location is the main focus of representing geographic features. Using the raster data model, the Earth is treated as one continuous surface. In the raster data model, each location is represented as a cell. Cells are organized into a matrix of rows and columns called a grid. Each row contains a group of cells with values representing a geographic phenomenon. Cell values are numbers, which represent nominal data such as land-use classes or elevation. [27]

3.1.1.2 Arc View 3D Analyst

The Arc View 3D Analyst extension enables users to create, analyze, and display surface data. Unique features of Arc View 3D Analyst include support for triangulated irregular networks (TINs) and simple three-dimensional vector geometry, as well as interactive perspective viewing. In Arc View 3D Analyst, the most commonly used functions are accessible from pull down menus and tool buttons that are added to the Arc View GIS interface when the extension is installed. Arc View 3D Analyst introduces another file format referred to as the 3D shapefile which inherently stores three dimensional data in the form of x, y, z values. The TIN is often considered a 2.5 dimensional (2.5D) GIS capable of displaying elevation data [14].

3.1.1.2.1 TIN (Triangulated Irregular Network)

A TIN is a data structure that defines geographic space as a set of contiguous, non overlapping triangles, which vary in size and angular proportion. Like grids, TINs are used to represent surfaces such as elevation and can be created directly from files of sample points. The TIN data structure is defined by two elements: a set of input points with x, y, and z values, and a series of edges connecting these points to form triangles. Each input point becomes the node of a triangle in the TIN structure, and the output is a continuous faceted surface of triangles.

The triangles are constructed according to a mathematical technique called Delaunay triangulation. The technique guarantees that a circle drawn through the three nodes of any triangle will contain no other input point (Figure 15). The elevation value for any location on a TIN surface can be interpolated using the x, y, and z values of the bounding triangle's nodes. Additional information, like slope, aspect, and surface area, can be calculated for each triangle face.

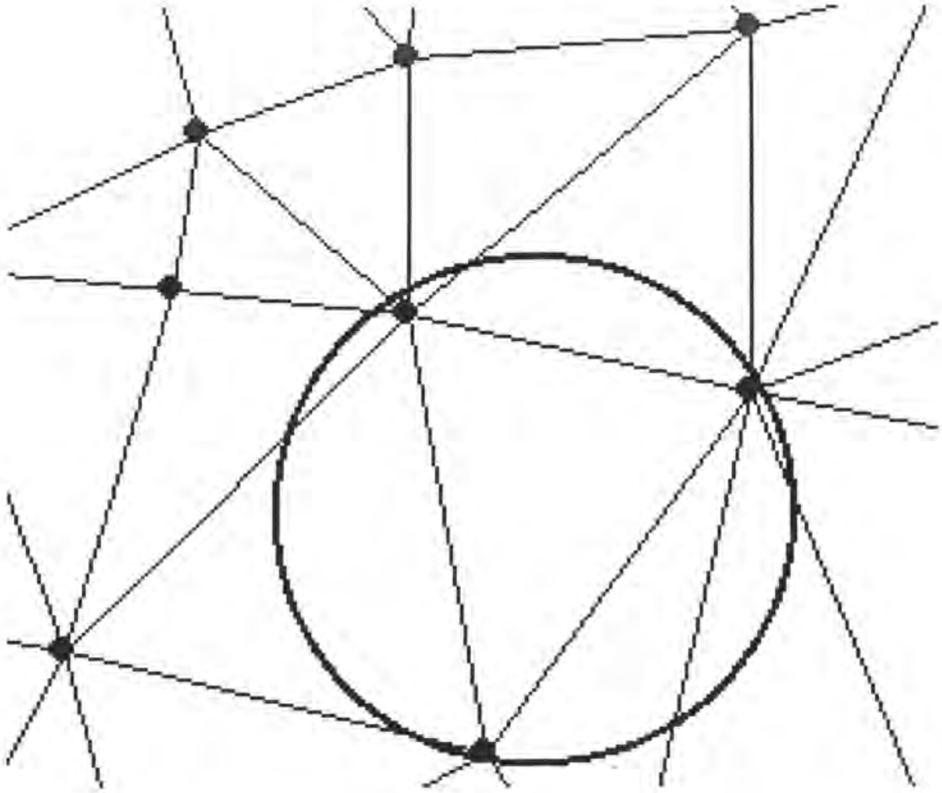

Figure 15. Triangulated Irregular Network

4. GIS FOR AS BUILT SURVEY

4.1 Data Verification

The Following Information was used to tie the measured features to the State Plane Coordinate System (Table 1). To verify the data was compared to the data collected using a RTK GPS system and the results were tabulated (Table 2). The coordinates from both the RTK GPS and the Total Station survey were plotted and compared (Figure 16).

Table 2. State Plane Coordinates of Control Points in EDM Baseline

Point	Northing	Easting	Elevation	Description
0	1054873.571	1484992.422	282.699	Bench Mark "0"
461	1054872.086	1484531.171	283.865	Bench Mark "461"
621	1054871.488	1484371.937	283.983	Bench Mark "620"
770	1054871.045	1484221.837	284.363	Bench Mark "770"
1370	1054869.090	1483623.062	285.479	Bench Mark "1370"

Table 3. Comparison in Coordinates obtained from RTK and Total Station Survey

Point #	Northing(RTK)	Easting(RTK)	Northing(TOT)	Easting(TOT)	Diff in Northing	Diff in Easting
1370	1054866.6612	1483620.1054	1054869.090	1483623.062	-2.4288	-2.9566
620	1054869.1033	1484368.9875	1054871.546	1484371.921	-2.4427	-2.9335
461	1054869.6364	1484528.2037	1054872.086	1484531.171	-2.4496	-2.9673
0	1054871.0933	1484989.3823	1054873.571	1484992.422	-2.4777	-3.0397
				Mean	**-2.4497**	**-2.9743**
				Std Dev	**0.0206**	**0.0458**

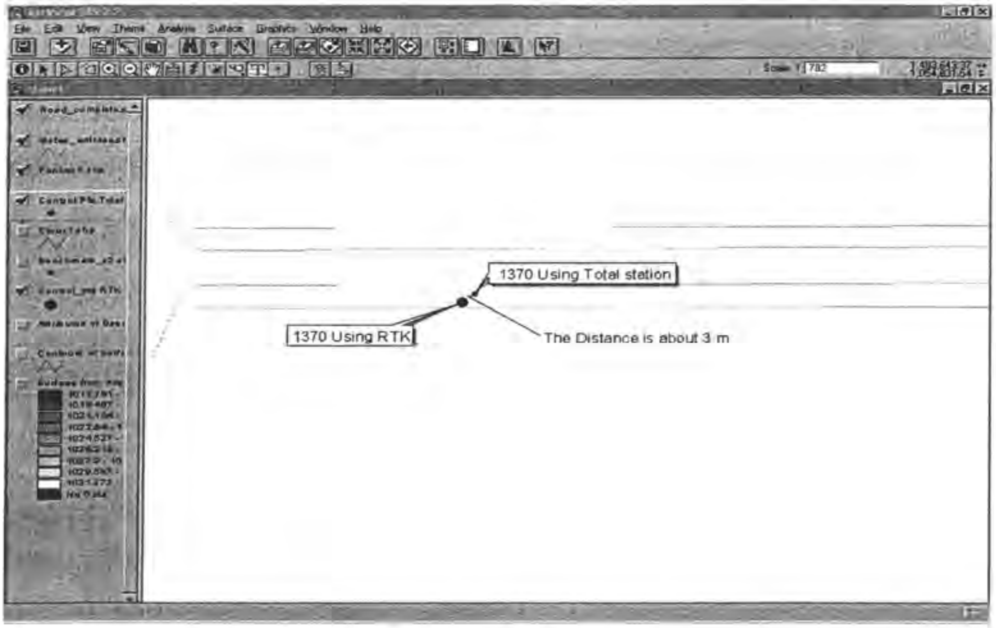

Figure 16. Picture showing the difference and the distance between the RTK GPS survey and the Total Station survey

4.2 GIS File Creation (Arc View GIS)

There are various ways to get spatial data into Arc View. We can create an event theme of point data or create new point, line or polygon shapefiles in Arc View. The procedures for creating and editing features in new shapefiles can also be used to edit existing themes.

4.2.1 Event Themes

An event theme is an Arc View Table containing X and Y coordinate fields that allow the display of records as point features in a View. The coordinates can be lat-long decimal degrees, or coordinates in any projection. If the coordinates are projected, the View should have that projection, as specified in View Properties. Unlike point shapefiles, Event Theme Tables can be created, edited or updated outside of Arc View, using any database or spreadsheet program that handles DBase format data.

To create an Event Theme from scratch, select the Table icon in the Arc View Project window and click on "New" to name and create an empty table, open for editing, then Edit-Add Field to create the appropriate fields, and add as many blank records, type in the data manually with the Table Edit tool. We can also create a field to allow linkage to another table and copy fields from it. To add an event theme to a view, we add the Table with X-Y coordinates to the Project if it is not already included, and use View-Add event theme. In the dialog box, we specify the table name and the fields in the table that contain the X and Y coordinates. Arc View handles event themes just like conventional point themes.

4.3 Importing Data from different source

4.3.1 Different Coordinate System

In Surveying and GIS it is common to see data obtained from disparate sources. The problem with this is that each of the data set might be in different coordinate systems and needs to be bought to a common system to carry out all analysis. The most commonly used coordinate systems include Global, Earth centered, UTM and State plane system.

4.3.1.1 Global System (Latitude-Longitude-Height System)

The most commonly used coordinate system today is the latitude, longitude, and height system (Figure 17). The Prime Meridian and the equator are the reference planes used to define latitude and longitude. The geodetic latitude of a point is the angle from the equatorial plane to the vertical direction of a line normal to the reference ellipsoid. The geodetic longitude of a point is the angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane. The geodetic height at a point is the distance from the reference ellipsoid to the point in a direction normal to the ellipsoid. The Latitude-Longitude-Height system can be directly imported into a GIS system like the Arc View GIS by creating event themes. They are normally input as point themes and can be used for all spatial analysis. They can be set as decimal degrees or degrees minutes and seconds [22].

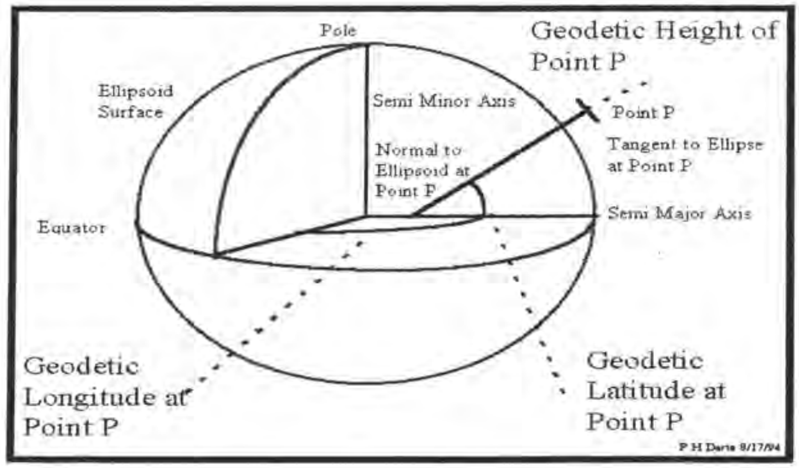

Figure 17. A Pictorial Representation of the Latitude Longitude System [22].

4.3.1.2 Earth Centered X,Y,Z System

Earth centered, earth Fixed Cartesian coordinates are also used to define three-dimensional positions. Earth centered, earth-fixed, X, Y, and Z, Cartesian coordinates (XYZ) define three-dimensional positions with respect to the center of mass of the reference ellipsoid (Figure 18). The Z-axis points toward the North Pole. The X-axis is defined by the intersection of the plane define by the prime meridian and the equatorial plane. The Y-axis completes a right-handed orthogonal system by a plane 90 degree east of the X-axis and its intersection with the equator [22].

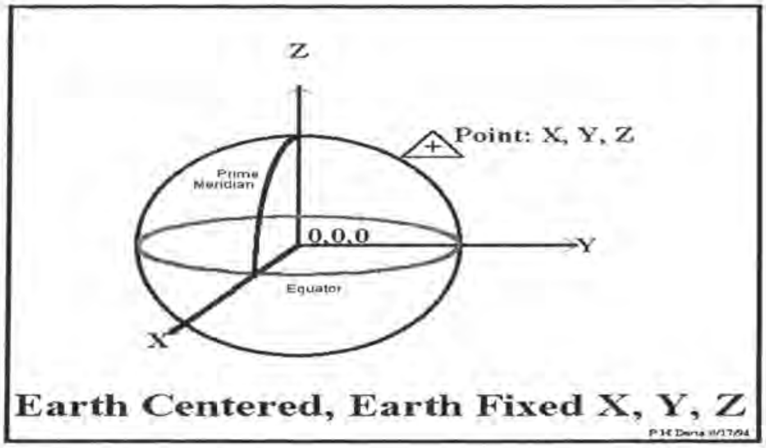

Figure 18. A Pictorial Representation of the Earth Fixed X,Y,Z system [39].

4.3.1.3 Universal Transverse Mercator (UTM)

Universal Transverse Mercator (UTM) coordinates define two dimensional, horizontal, positions. UTM zone numbers designate 6 degree longitudinal strips extending from 80 degrees south latitude to 84 degrees north latitude. UTM zone characters designate 8 degree zones extending north and south from the equator (Figure 19). There are special UTM zones between 0 degrees and 36 degrees longitude above 72 degrees latitude and a special zone 32 between 56 degrees and 64 degrees north latitude. Each zone has a central meridian. Zone 14, for example, has a central meridian of 99 degrees west longitude. The zone extends from 96 to 102 degrees west longitude. Eastings are measured from the central meridian (with a 500km false easting to insure positive coordinates). Northings are measured from the equator (with a 10,000km false northing for positions south of the equator). [22]

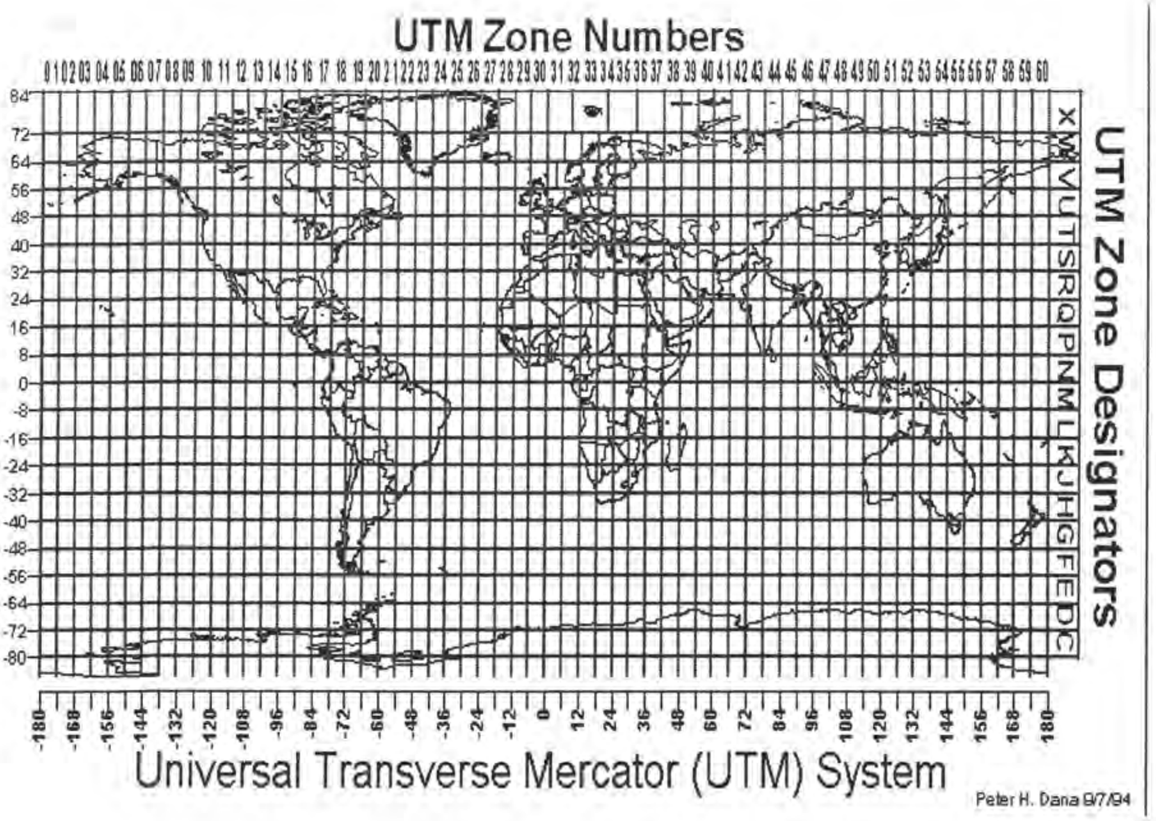

Figure 19. The World UTM Zones [22]

4.3.1.4 State Plane Coordinate System

In the United States, the State Plane System was developed in the 1930s and was based on the North American Datum 1927 (NAD27). NAD 27 coordinates are based on the foot. While the NAD-27 State Plane System has been superseded by the NAD-83 System, maps in NAD-27 coordinates (in feet) are still in use. The State Plane System 1983 is based on the North American Datum 1983 (NAD83). NAD 83 coordinates are based on the meter. State plane systems were developed in order to provide local reference systems that were tied to a national datum. Some smaller states use a single state plane zone. Larger states are divided into several zones. State plane zone boundaries often follow county boundaries. Lambert Conformal Conic projections are used for rectangular zones with a larger east-west than north- south extent. Transverse Mercator projections are used to define zones with a larger north-south extent [22].

4.4 Transformation Methods

4.4.1 Transformation from (ϕ,λ,h) to (U,V,W)

The following is the equation to transform from (ϕ,λ,h) to (U,V,W)

$U = (N+h) \cos\phi \cos\lambda$

$V = (N+h) \cos\phi \cos\lambda$

$W = (N(1-e^2)+h) \sin\phi$

Where

(ϕ,λ, h) = Global Coordinate System

(U,V,W) = Cartesian System

e = Natural Logarithmic Base

4.4.2 Transformation (U,V,W) to (ϕ,λ,h)

The following is the equation to transform from (U,V,W) to (ϕ,λ,h)

$(N+h) \cos\phi = \sqrt{(U^2+V^2)}$

$\tan\phi = w/\sqrt{(U^2+V^2)} * ((N+h)/(N(1-e^2)+h)$

$U/V = \cot\lambda$

Where

(ϕ, λ, h) = Global Coordinate System

(U, V, W) = Cartesian System

e = Natural Logarithmic Base

4.4.3 Transformation to Local System

$X = E = S \operatorname{Sin}Z \operatorname{Sin} Az$

$Y = N = S \operatorname{Sin} Z \operatorname{Cos} Az$

$Z = \text{Elevation} = S \operatorname{Cos} Z$

Where

S = Slope Distance

Z = Zenith Distance

AZ = Azimuth

4.5 Software Used for Transformation

4.5.1 Arc View Projection Utility

The Arc View Projection Utility is a stand-alone wizard-based tool, which allows projection of shapefiles from one coordinate system to another (Figure 20). It also lets us project unprojected shapefiles, and perform datum transformations, including NADCON. The utility provides a way for us to create coordinate system metadata for shapefiles, which do not already have that information. That information is stored in an ASCII projection file, which has the same prefix as the shapefile, and a ".prj" extension. When we project or reproject shapefiles, the original shapefiles are not touched and the utility makes new shapefiles in the coordinate system we specify. The Arc View Projection Utility is built on top of ESRI's projection engine. The Arc View Projection Utility uses ESRI's MapObjects 2.0 for shape input/output and as the hook into the projection engine [27].

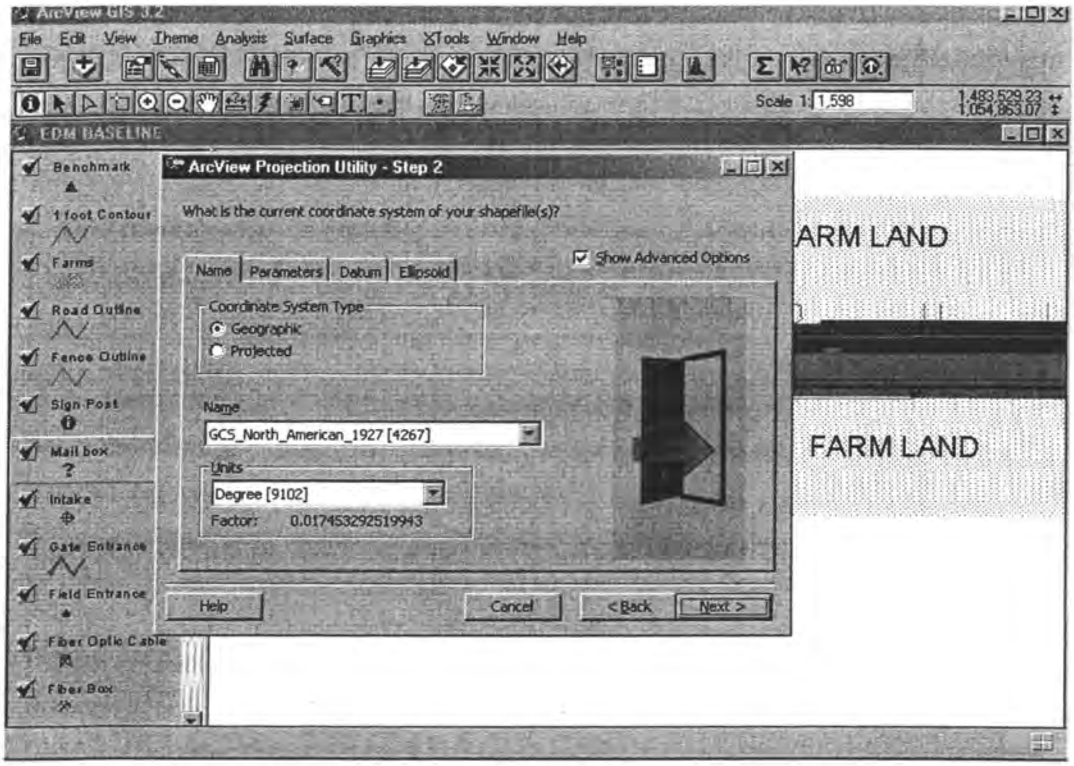

Figure 20. A Snapshot of the Arc View Projection Utility Wizard

4.5.2 Projector

Arc View projector extension allows projecting a theme or coverage into a new projection system (Figure 21). The result is a new shape file in the new projection. To use this extension, we must know what the current projection and map units of the theme. The options available for the conversion are limited but the conversion process is very fast [27].

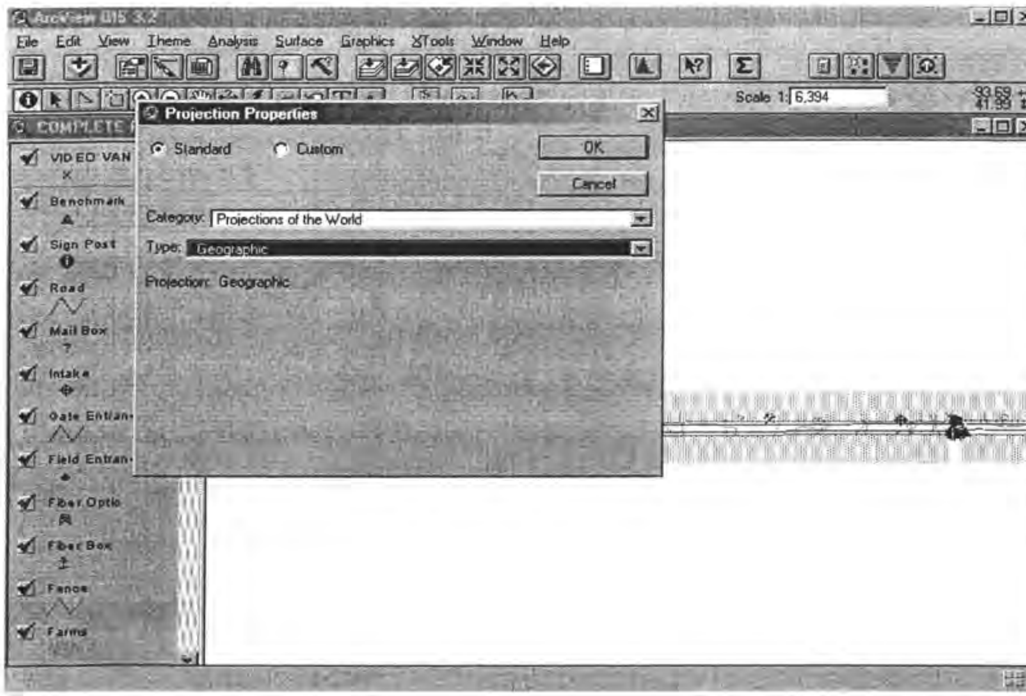

Figure 21. A Snapshot of the Arc View Projector Utility

4.5.3 Arc Info projection

Arc Info Projection utilities are more robust since they can transform any coordinate system to a known system. This can be achieved by making use of control points (at least three) whose coordinates are in a known system. When the coverages are not in the same coordinate system, one or more of the coverages need to be projected using the <PROJECT> command in Arc/Info. If the coordinate system of the coverage is unknown, the <DESCRIBE> command in Arc/Info will give the current projection. Before a coverage or grid can be projected, the current projection needs to be defined. If the current projection is not defined, use the <PROJECTDEFINE> command to define the coverage. When multiple projections need to be made, it is better to create a projection file. A projection file is just a text file that contains all the projection parameters just as they would be entered using the <PROJECT> command. The following figure shows the entire project in SPC system after the transformation was carried out in Arc/Info (Figure 22) [27].

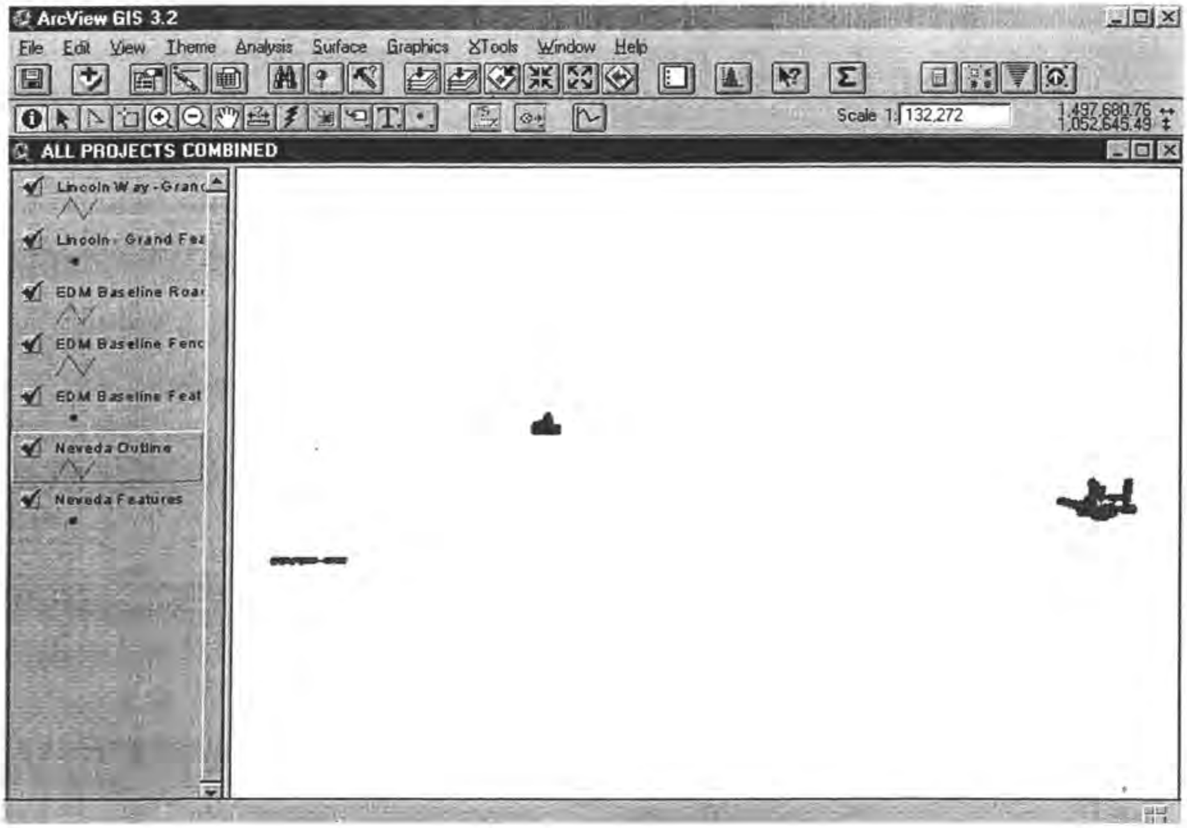

Figure 22. A Snapshot of the Arc View Project all in one common system

4.6 Customization of a GIS: User Defined queries

Avenue is the customization and development environment for Arc View. It allows customizing the way Arc View looks, Modify Arc View's Standard tools, create new tools, integrate Arc View with other applications and develop and distribute custom application on top of Arc View.

Avenue is a pure object oriented language. In Arc View, everything we work with is an object. Objects with similar characteristics are grouped together in a class. A class defines the properties and actions for a specific type of object. All objects in a specific class are defined with the same properties. Objects created from the same class are instances of that class. Classes may be further organized through a class hierarchy that defines the relationship between classes. Class relationships can be described in three ways: inheritance, aggregation and association. In order to illustrate this relationship we use the object model diagram (Figure 23). Object model consists of boxes representing classes and lines connecting them to show the kind of relationship between classes.

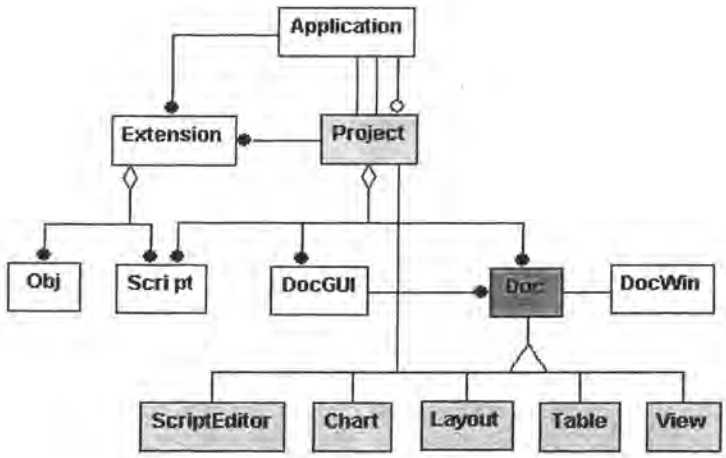

Figure 23. Object Model Diagram of Application Framework [27].

Requests make things happen in Arc View. A request may create a new object, such as a new theme. When a theme is added to a view, it may retrieve information about an object, like the name of the current view, or it may change a property of an object, for instance, changing the name of a theme or making it active. Using Avenue customized queries were developed such as Hot Linking GPS Van Images, Line of Sight, View shed analysis, profile generation and contour generation [27].

4.6.1 Hot Links

Hot links allows access to virtually any data or application directly from a view. For example, clicking on a building to display its floor plan, or clicking on a country to play a video about it. A hot link is followed when you click on a feature in a theme with the Hot Link tool. The action and the field are specified in the panel of the Hot Links of the Theme Properties dialog. Each theme in a view can have its own hot link definition. There is no default hot link definition. Hot links have to be defined before they can be used. If there is an error in linking, then a beep is produced and Arc View cannot find the application or file defined for that feature. The predefined hot link actions helps display text files, images, other components of the project, and even open other projects. The following image formats are supported by Arc View; X-Bitmap, MacPaint, Microsoft DIB, Sun raster files XWD, GIF, TIFF, TIFF/LZW compressed image data. The following is a hot linked image of a electric pole on the EDM baseline (Figure 24).

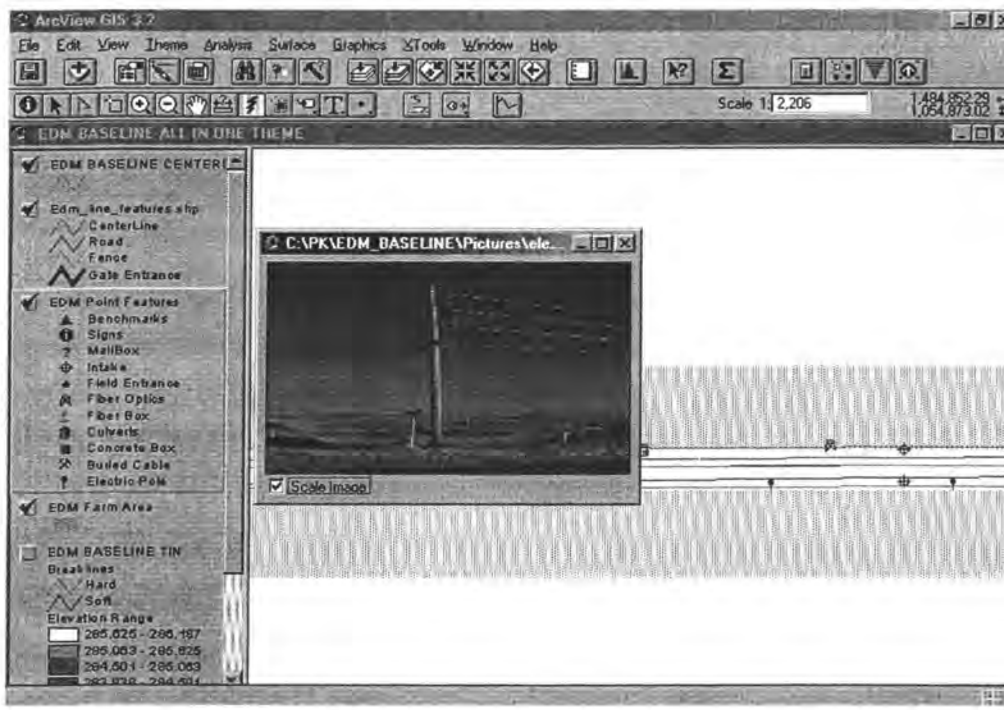

Figure 24. Hot Linked Image for EDM Baseline

4.6.2 Line Of Sight

Line of sight tool tells whether a given target is visible from a particular point of observation. It answers the question, 'Can I see that from here?' Typically, to perform the operation we need to activate a grid or TIN theme in the view that will serve as the surface on which the line of sight will be determined. It will serve as a reference so that we can position the observer and target locations. We select the Line of Sight tool from the tool menu and in dialog, we specify how many units the observer and target positions will be offset above the surface. We then press the left mouse button down at the observation point, move the cursor to the target location, and release the button. The result is a graphic added to the view (Figure 25). The visible portions of the line to the target will be added in green, and the non-visible portion in red. A message in the Arc View status bar at the bottom of the application window will indicate whether the target location is visible. If it is not, the first obstruction point along the line of sight will be added as a blue point graphic and the x-y coordinates of the obstruction will be reported in the status bar.

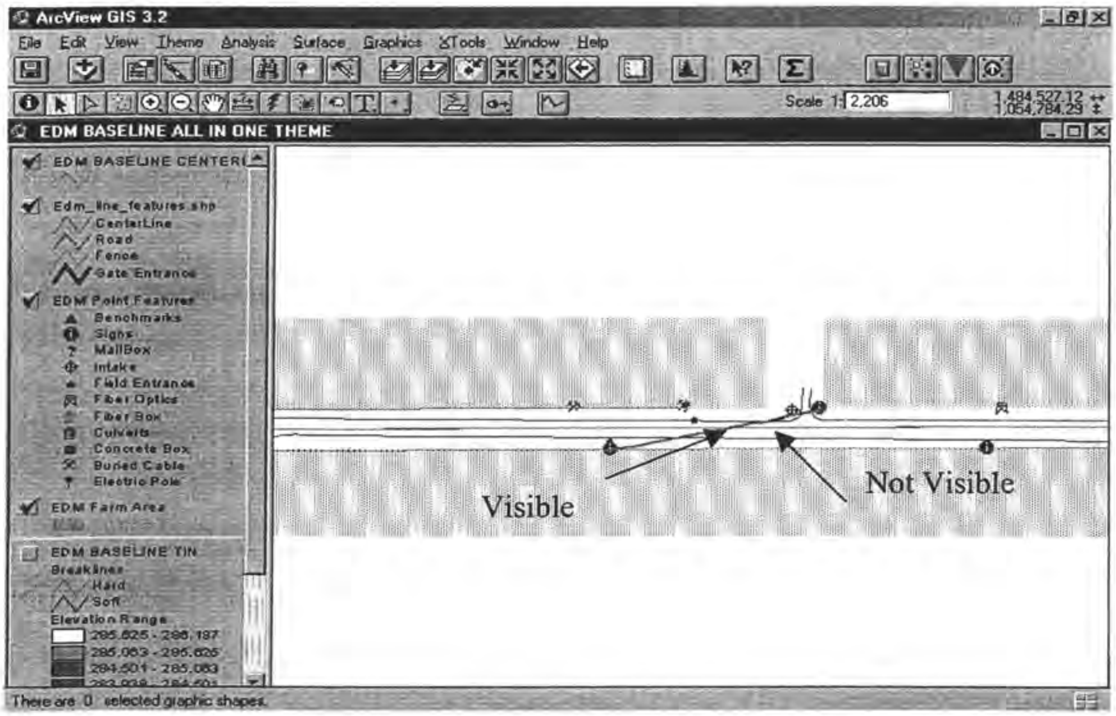

Figure 25. Line of Sight Tool Customized in Arc View

4.6.3 View-Shed Analysis

View shed analysis identifies the areas on a surface that are visible from one or more observation points. It answers the question, 'What can I see from these locations?' In order to perform the operation we need to typically activate a grid or TIN theme that will serve as the elevation surface on which the view shed will be determined in a view or 3D scene. Also, we need to activate a point or line theme, which will be used to supply the observation points. We then choose the Calculate Viewshed option under the Surface menu. We also need to specify the output grid extent on the Output Grid Extent dropdown list, the cell size in the

Output Grid Cell Size input field, and the number of rows and columns in the number of rows and number of columns input fields on the Output Grid Specification dialog. View shed analysis indicates not only what areas of a surface can be seen by one or more observers, but also, for any visible position, how many observers can see the position. The following is a View shed analysis carried out on the EDM baseline (Figure 26).

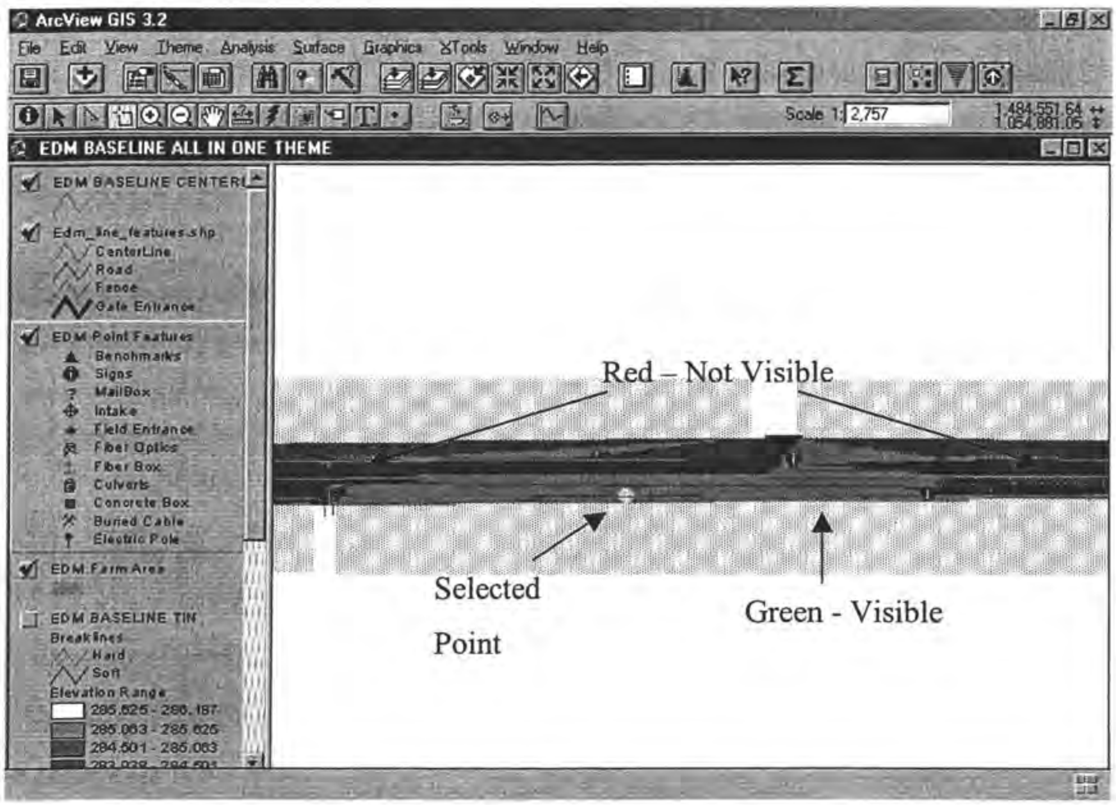

Figure 26. Customized View Shed Analysis in Arc View

4.6.4 Profiling and Cross section

Profiling involves measuring height along a specified line. Typically, the following steps have to be carried out in order to do a profiling or cross section operation. In a view, select the 3D lines you want to place in a graph. The lines can come from either a feature theme or from graphics. If we want the lines to come from a theme, we must first activate its legend by clicking on its Table of Contents. If we want the lines to come from graphics, we must first select the line graphics. In the project, select Layouts from the documents scrolling list. Double click on the Layouts icon or press New to open a new layout, or double click on an already existing layout in the scrolling list to open it. Select the Profile Graph tool. Using the cursor, define the area on the page you want the graph by moving the mouse to the upper left corner of the area, pressing the left mouse button, and, while holding the button down, moving the cursor to the lower right. Then release the mouse button. In the Profile Graph dialog, choose the view containing the selected 3D lines you want to graph. The following is the automatic generation of profile in EDM baseline (Figure 27). The same procedure can be adopted to draw a cross section.

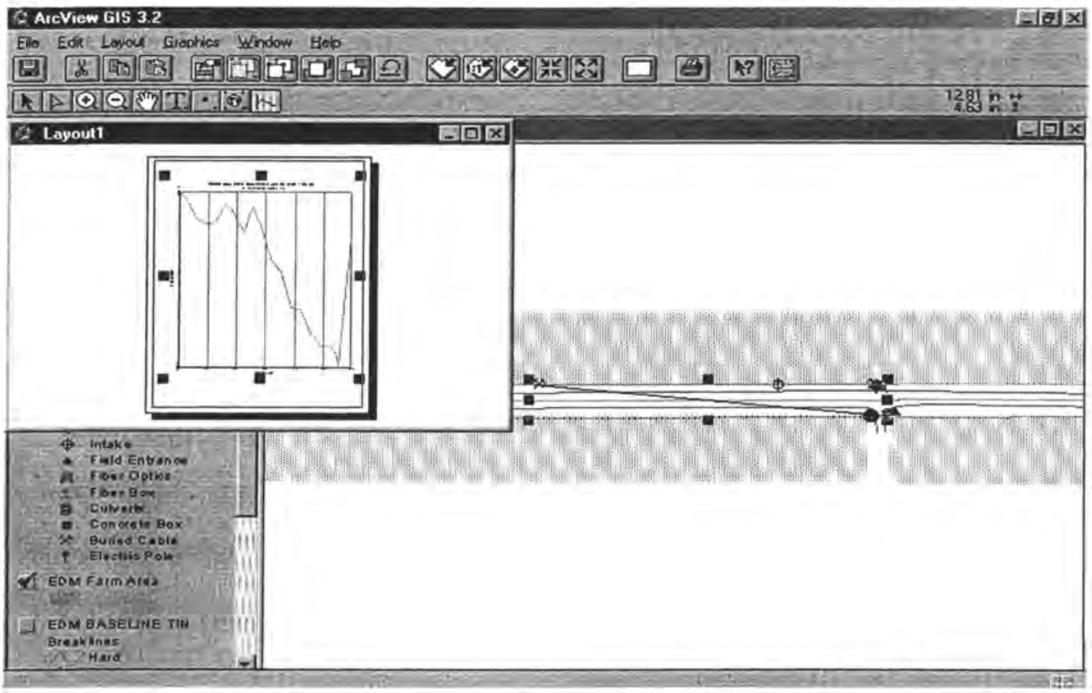

Figure 27. Customized Plotting of Profile in Arc View

4.6.5 Count & Distance

Other simple queries that are possible are determination of distance between features using the distance tool. We can also count the number of features of interest using the count tool which keeps track of the number of features currently selected and the type of feature selected (Figure 28).

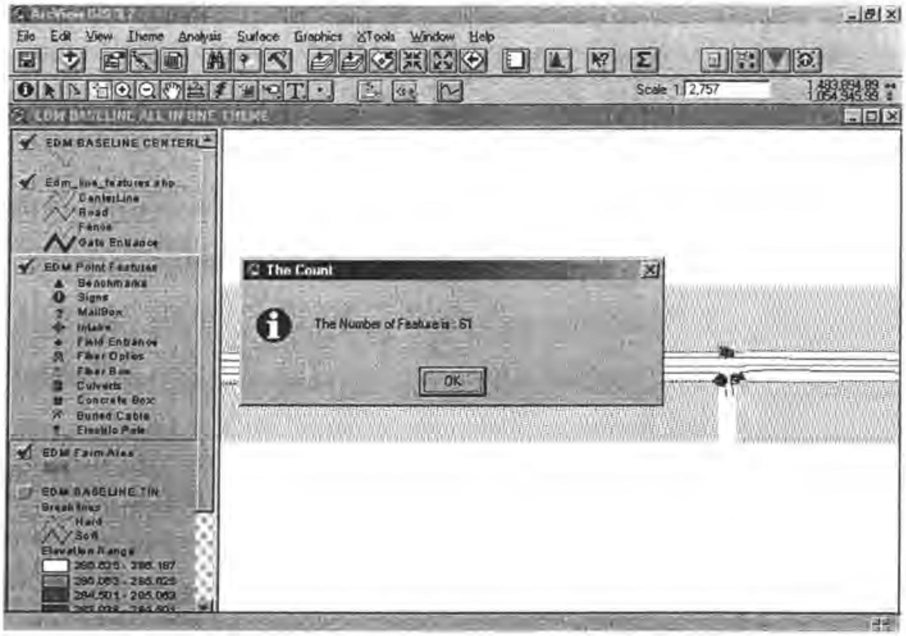

Figure 28. Snapshot of the Count feature in Arc View

4.6.6 Contours

Arc View Spatial Analyst use two methods to draw contours and they are

4.6.6.1 Inverse Distance Weighting (IDW) Method

For the Inverse Distance Weighting Method, a fine mesh grid is laid over the study area and a value is interpolated for each grid cell using the inverse distance squared between the cell location and the measurement location as a weight for each measurement. The interpolator assumes that each point has a local influence that diminishes with distance. It gives more weight to the points closer to the processing cell than to those farther away. We can specify the number of points to interpolate from, or optionally, we can specify all the points within a radius to interpolate from. The power parameter in the IDW interpolation controls the significance of the surrounding points on the interpolated value. Higher powers result in less influence from more distant points. We can also specify barriers beyond which the surface will not interpolate for the input point. In order to draw contours in Arc View we turn on the Spatial Analyst extension from the File menu (Project window active). Open your

View and make the Cross Section Data theme active. Choose Create Contours under Surface Menu. For Output Grid Extent, choose same as Boundary. The Output Grid Cell Size, number of rows, and number of columns will be set according to the Output Grid Extent you choose. However, we can change these values if we want a finer and larger grid cell size. You will now see the Interpolate Surface dialog box. Choose ELEVATION for the Z Value Field and accept the default surface parameters.

4.6.6.2 Spline Method

Another method for interpolating surfaces is the Spline Method. The Spline Method uses a polynomial function to fit a surface which passes through all the data values and which is smoothed so that there are not as many peaks and pits as in the IDW Method. Conceptually, it is like bending a sheet of rubber to pass through the points, while minimizing the total curvature of the surface. This method can overshoot estimated values if there are large changes within a short horizontal distance, but the method is well suited for gently varying surfaces. You can specify two different kinds of surfaces. The regularized method yields a smooth surface while the tension method tunes the stiffness of the surface according to the character of the modeled phenomenon. The weight parameter for the regularized method defines the weight of the third derivative of the surface in the curvature minimization expression, while the weight parameter for the tension method defines the weight of tension. The number of point parameter identifies the number of points per region used for local approximation.

For all analysis the Inverse Distance Weighted method was used to draw contours using the nearest neighborhood (Figure 29).

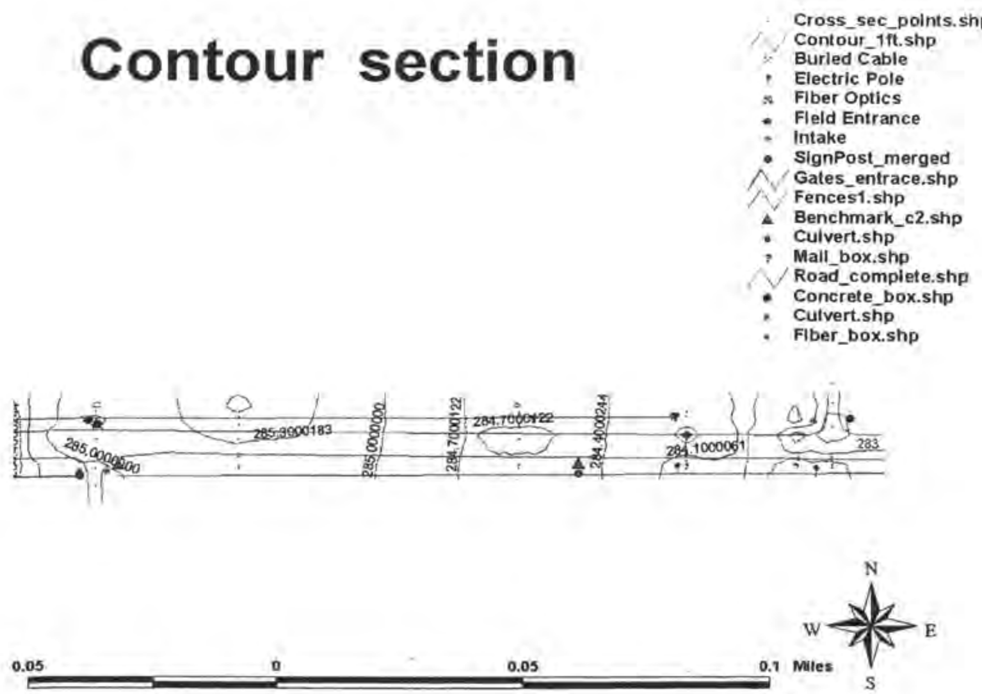

Figure 29. Contour Drawn Using the IDW Method, Arc View

5. 3D GIS FOR AS BUILT SURVEY

5.1 Theory of Computer Graphics

The scenes created in 3D computer graphics can be described by three models. The geometrical model describes the shape of objects in a scene and the vantage point from which they are viewed. The illumination model adds light sources to the scene and material properties to the objects. Finally, the shading model is the algorithm that transforms the scene into a picture on the computer screen, taking into account the properties defined by the other models. The mathematics part of 3D computer graphics is derived mainly from linear algebra. The world is regarded as a set of vertices in R^3. These vertices are represented in the computer as floating point numbers. These vertices are connected by lines to form polygons and the polygons connected to form objects and the objects connected to form more complex objects which make up a 3D scene. These vertices/lines/objects can then be subjected to operations such as translation, rotation and scaling. If each vertex is regarded as a 3x1 matrix then these operations can be expressed as matrix algebra.

All vertices have a color and three light properties; ambient, diffuse and specular. Ambient light represents the "background radiation", light without a source. Diffuse light has a source but no direction and is reflected equally in all directions. Specular light, has both source and direction and hence distributes unevenly, producing the "highlights" seen on blank surfaces. Light sources are represented as points, which emit certain amounts of light of any or all kinds, and, in the case of specular light, in a certain direction. There are more advanced illumination models such as *Radiosity*, which tries to simulate the physics concept of blackbody radiation. This makes for realistic rendering but is very computer intensive.

The process of applying a shading model to a scene is called *rendering*. Rendering transforms the scene into pixels on the screen, a pixel being the smallest addressable unit on the screen. This involves determining which vertices can be seen from the current viewpoint and applying the illumination model to them. To speed up rendering, only vertices that fall inside a *viewing volume* are considered. There are a number of different shading algorithms of varying complexity. The simplest shading model is called constant shading or flat shading. It applies the illumination model once for each polygon and uses the resulting color to shade the whole polygon. This makes edges between polygons of different intensity very visible. The more common shading algorithm (used in OpenGL) is Gouraud shading, also known as intensity interpolation shading. It requires that the normal be known for each vertex making up a polygon and uses this information to produce a smooth shading within and between adjacent polygons in the mesh. A slight improvement on Gouraud shading is Phong shading (also known as normal-vector interpolation shading), in which the normals given are interpolated across the surface of the polygon thus producing more realistic rendering.

A different approach, that can produce more faithful results, is texture mapping. It takes a bitmap, the texture, and pastes it onto the polygon, correcting for perspective. Texture mapping is preferably combined with shading, using the shading algorithm to modulate the intensity of the pixels in the texture bitmap. [11]

5.2 GIS and 3D Computer Graphics

GIS is a tool, which is used for collecting, storing, retrieving at will, manipulating, and displaying non-geographic, geographically referenced information.3D computer graphics is a way for humans to visualize, manipulate and interact with computers and extremely complex data. It can easily be used as a high-end user interface that involves real time simulation and interaction. There is basically two types of computer graphics based on the scale and the complexity: the low end non-immersive computer graphics and the high end completely immersive type. The following figure illustrates the 4 I's of a completely immersive graphics system (Figure 29).

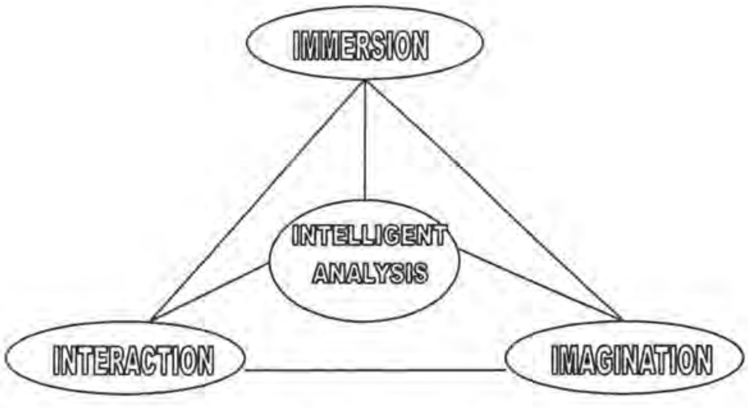

Figure 29. Virtual Reality "Immersion-Interaction-Imagination-Intelligent Analysis".

The concept of merging GIS and 3D Computer Graphics has enjoyed increasing attention in the recent past. In the journey from a 2D map to a more interactive 3D map, GIS is yet to serve the user community well, and there is an increasing demand for better data handling and visualization using the recent developments in computer graphics including Virtual Reality. Such a marriage between these two powerful technologies has its own share of problems even suggesting immediate divorce. The 3D GIS, which has come into play with decidedly more interactive rates for high resolution display than a 2D GIS, has large amounts of data that can be expected to grow by a factor of 100 (3D textures, photo textures, etc.). This makes visualization of data more difficult; hence the rendering algorithms need to be optimized to load only data that is actually visible (such Level of Detail). Due to the performance demands, the increased complexity and hierarchical organization of data, relational databases are no longer suitable to manage a simple GIS database. 3D Computer graphics adds an important freedom for the user to visualize and interpret spatial data more effectively. A real time visual simulation in a 3D GIS supports the accurate depiction of terrain elevation and imagery, in addition to features such as ground cover and trees, buildings, and static objects, roads, and atmospheric effects, thus adding new dimensions to the concept of simulation of real life situations. It adds a new dimension to the visualization of abstract variables (e.g., environmental variables such as pollution level) by reducing the level of abstraction. Thus, the marriage of the two technologies promises the much-needed relief for the demanding user. So researchers around the world, both at academic and industry levels, are feverishly working towards trying to integrate these two technologies together [47].

5.3 Tools For 3D GIS

5.3.1 Off Shelf 3D GIS Packages

5.3.1.1 Arc View 3D Analyst

The Arc View 3D Analyst extension enables users to create, analyze, and display surface data. Unique features of Arc View 3D Analyst include support for triangulated irregular networks (TINs) and simple three-dimensional vector geometry, as well as interactive perspective viewing. In Arc View 3D Analyst, the most commonly used functions are accessible from pull down menus and tool buttons that are added to the Arc View GIS interface when the extension is installed [14].

5.3.1.2 ERDAS Virtual

IMAGINE Virtual GIS provides GIS functions and capabilities within a 3-D environment. Virtual GIS' capabilities include interactive fly-throughs of user-defined flight paths plus the ability to drape and query multiple GIS layers. It also supports ARC/INFO coverage viewing and query, geographic linking of 3-D and 2-D viewers, blending and fading of two images, haze simulation, stereo viewing (full screen or window), contrast enhancement and filtering, and ability to change symbology and colors in the 3-D viewer. It also supports VRML 2.0 file format for exporting and importing and supports anaglyph stereo viewing and export [26].

5.3.2 3D GIS Development Packages

5.3.2.1 Virtual Reality Modeling Language (VRML)

VRML is an acronym for Virtual Reality Modeling Language. In essence VRML is neither virtual reality nor a modeling language, it is just a 3D interchange format used for publishing 3D web pages on the Internet. In other words, VRML is a 3D file format. VRML files are written in plain text and hence, can be created using a simple text editor [6]. The VRML file format was based on the inventor file format from Silicon Graphics. However

Inventor's advanced interaction and animation capabilities were not included in VRML version 1.0. A small extension to VRML 1.0, called VRML 1.1 was tried and it contained facilities to add audio clips to a scene and some primitive animation. The next major step to VRML came when it was decided by the VRML community to upgrade VRML to version 2. The three requirements that was achieved was composability, scalability, and extensibility.

Creating 3D world is much different from creating a 2D because a 3D scene has a camera that is placed by the author to view the desired part of the scene and the computer draws the scene onto a two dimensional computer display. This operation is known as rendering and 3D browsers such as Cosmo player to carry out the rendering. The foundation of all VRML files lie in creating scene graphs. A scene graph in VRML defines the structure of the world being created. VRML file format allows creating scene graph using simple words and punctuations. A typical VRML scene graph consist of different type of objects which range from simple primitives like Box, Sphere, Cone, Cylinder etc. to complex objects like IndexedFaceSet, ElevationGrid etc. The scene graph hierarchy is defined by the relationship between parent and children nodes. A node in VRML implies some functionality and the name of the node indicates its basic function e.g. Cone, Transform and so on. Each node holds a list of fields, which contains values that define parameters for its function. Thus, combining primitive objects complex 3D environments can be created easily [7].

5.3.2.2 OpenGL

OpenGL is a cross platform standard for 3D rendering and 3D acceleration. It is a software interface to the graphics hardware. OpenGL has about 250 commands that can be used to create a 3D scene and render it. In order to support cross platform operations no windowing or input tasks are included in OpenGL. To build a model in OpenGL we need to make use of geometric primitives such as points, lines and polygons. The OpenGL Utility Library (GLU) built on top of OpenGL provides other modeling features, such as quadric surfaces and NURB curves, which make complex modeling a little bit easier. OpenGL is referred to as a state machine. It can be put into various states and it remains in effect till it is changed for subsequent rendering. Rendering in OpenGL is also called as rasterization.

The typical steps that are adopted while creating a 3D scene in OpenGL are constructing objects through geometric primitives, arranging the different objects in the 3D space, calculating the lighting and assigning colors including texture mapping and converting the mathematical description of the objects into pixels on screen. During these operations OpenGL eliminates objects that are hidden by making use of hidden surface removal algorithms. The scenes created using OpenGL goes through a rendering pipeline where the vertex data and the pixel data undergo a series of operation before they are finally written to the framebuffer. OpenGL inherently does not support user input nor does it allow the creation of windowing system. In order to develop powerful application either the GLUT (OpenGL Utility Toolkit) or RapidApp libraries can be made use of to develop interfaces [45]. Most of the current graphic systems are built on top of OpenGL including VRML. The reason for this is that OpenGL has become a well-established standard for computer graphics on all platforms. One more reason for its popularity is that openGL supports server client architecture. The support for OpenGL is evident from the fact that a new standard such as XGL is also based on OpenGL [39].

5.4 3D Models Developed

5.4.3 3D Analyst

Arc View 3D Analyst was used to develop a primitive 2.5D and 3D display of EDM Baseline test site. In order to develop both the 2.5 dimensional display and 3D display a TIN was created to represent the elevation of the terrain. Using the leveling data that was collected, the TIN surface was created. Also, to verify the data collected another TIN surface was created by making use of the data collected using the RTK GPS. The following is the picture of the 3D surface created using Arc View 3D Analyst (Figure 30).

Figure 30. 3D View of EDM Baseline Using Arc View 3D Analyst.

5.4.4 3D Model using OpenGL

OpenGL is a powerful 3D graphics library, which allows the user to develop realistic 3D models of objects. To develop the 3D model the spatial data obtained from the survey was used. Making use of RapidApp tool on the Silicon Graphics platform a user interface was developed. Also, simple GIS functionalities were included such as feature identification and real time distance measurement (Figure 31). Other 3D functionalities of this model included user defined fly through (Figure 32), wire frame/skeleton modeling (Figure 33) and atmospheric effect in the form of fog (Figure 34).

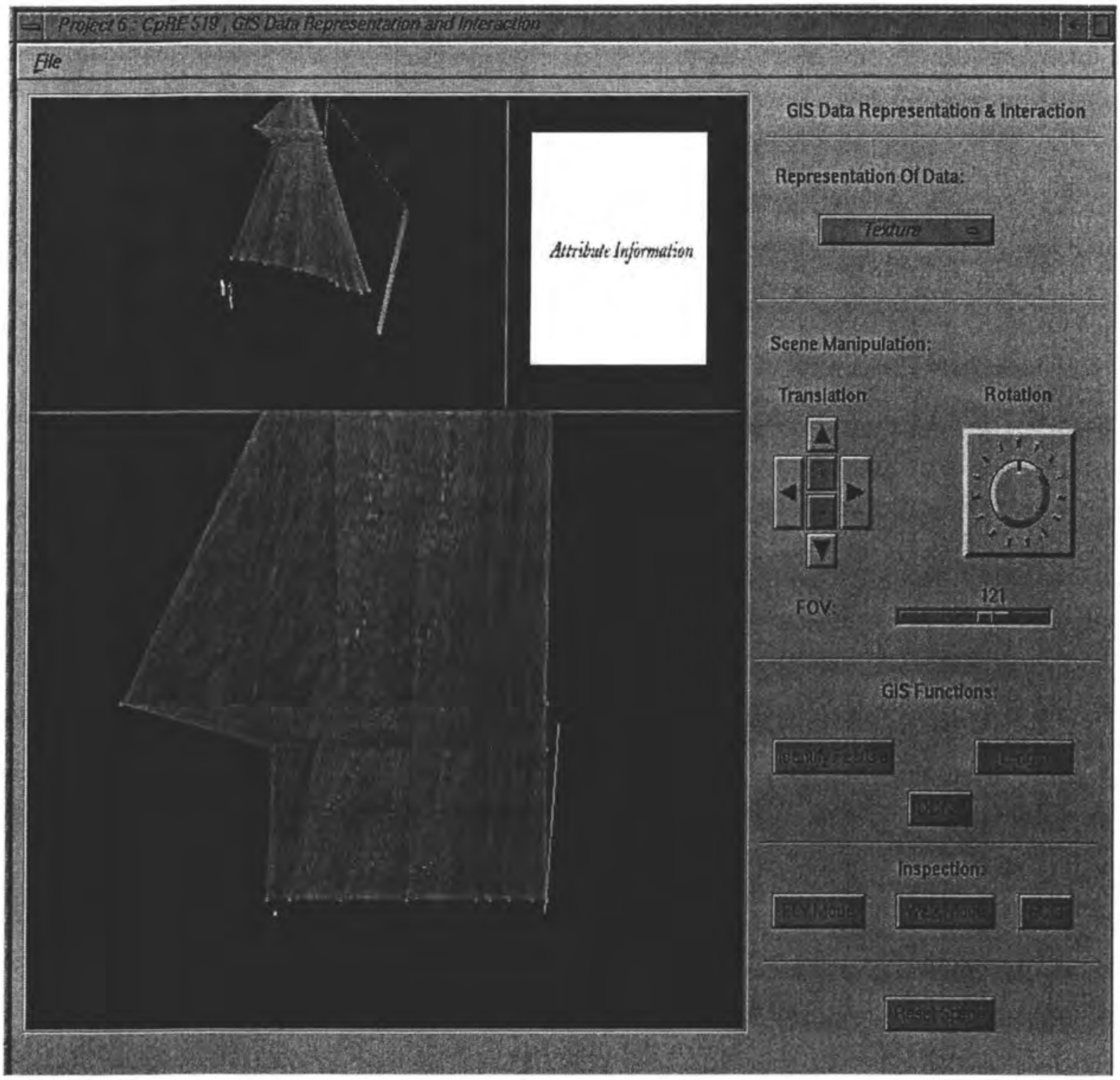

Figure 31. Feature Identification Menu Using OpenGL

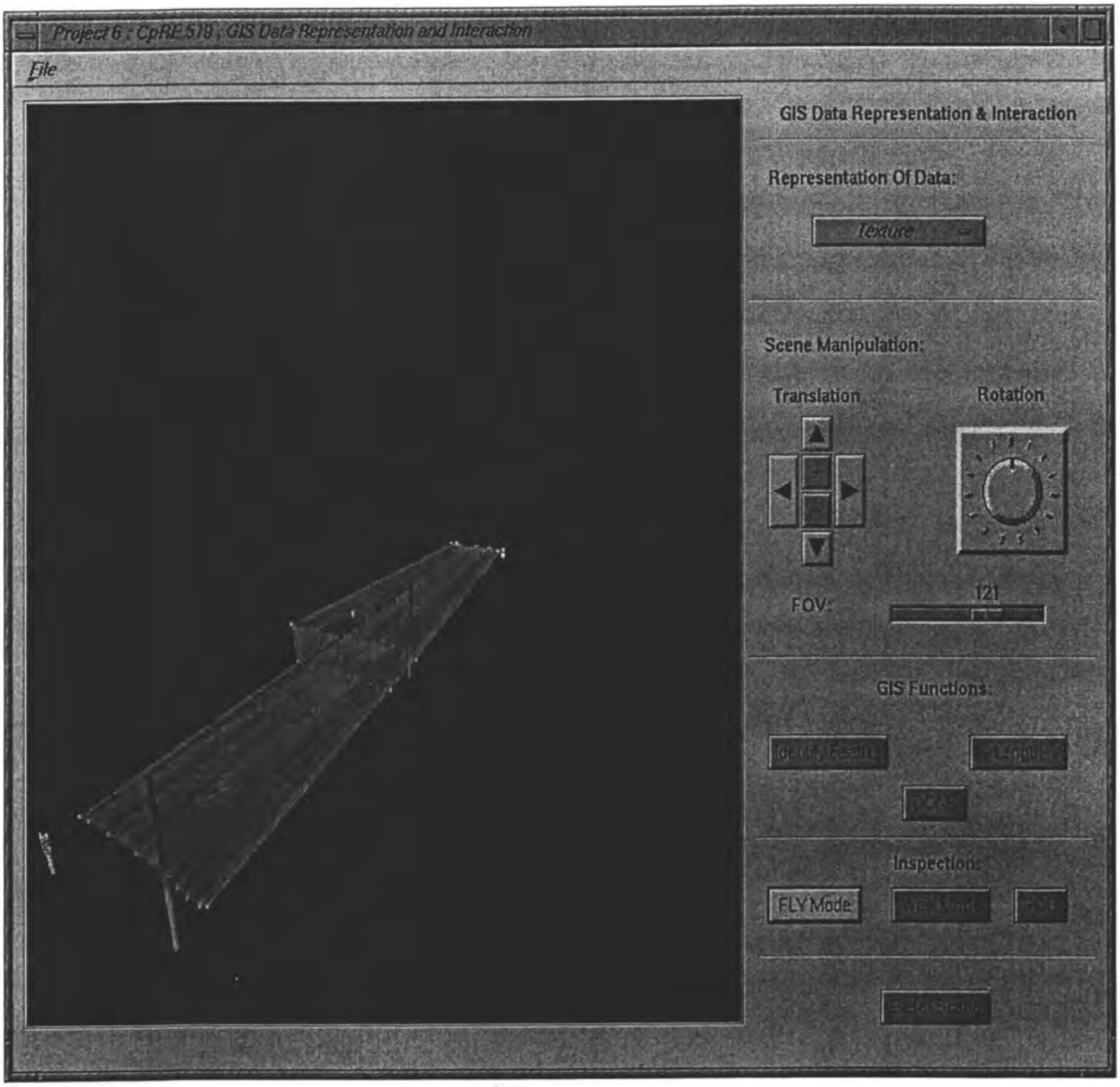

Figure 32. Interactive Fly Through Using OpenGL

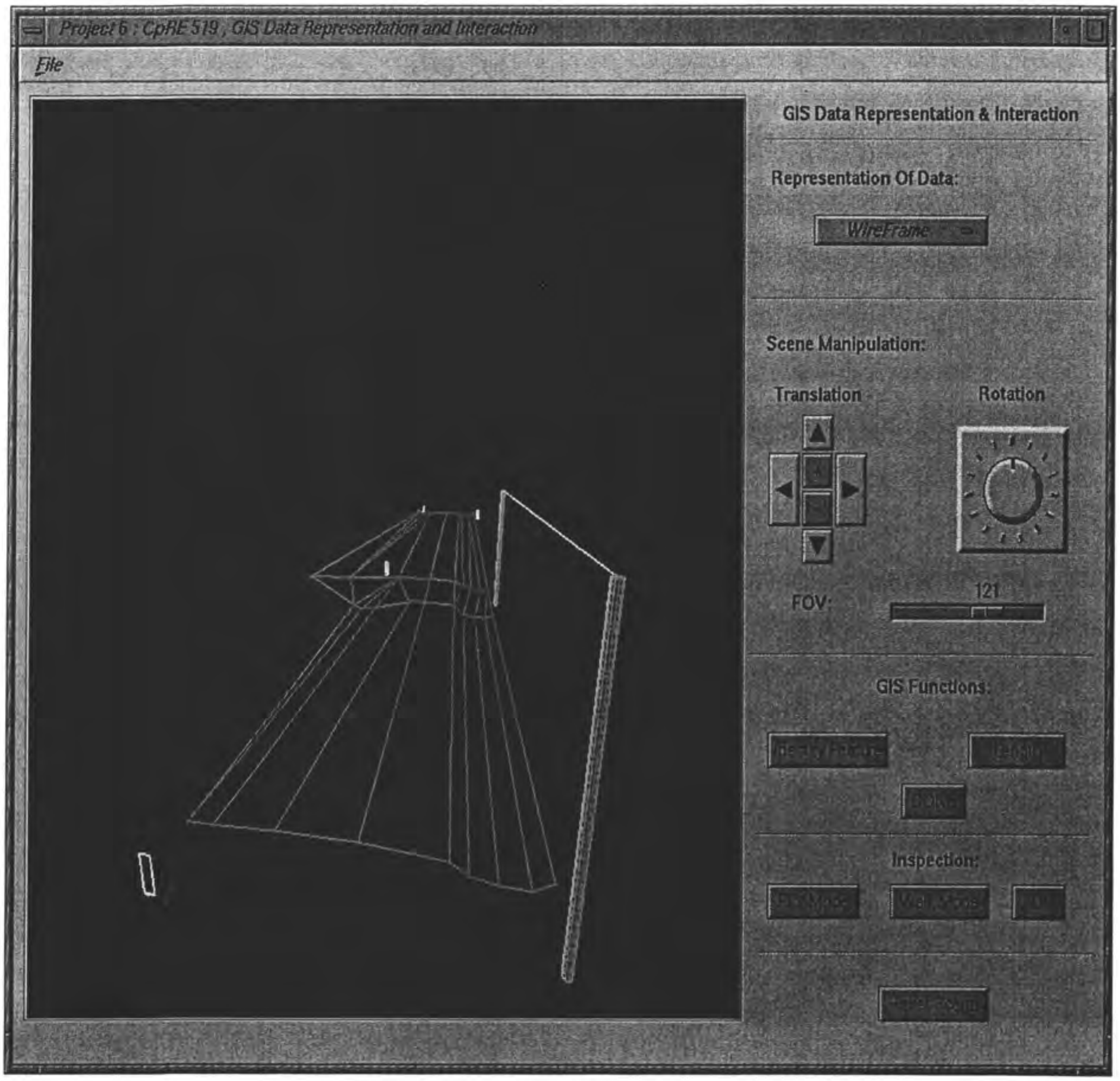

Figure 33. Wireframe/Skeleton Model of EDM Baseline Using OpenGL

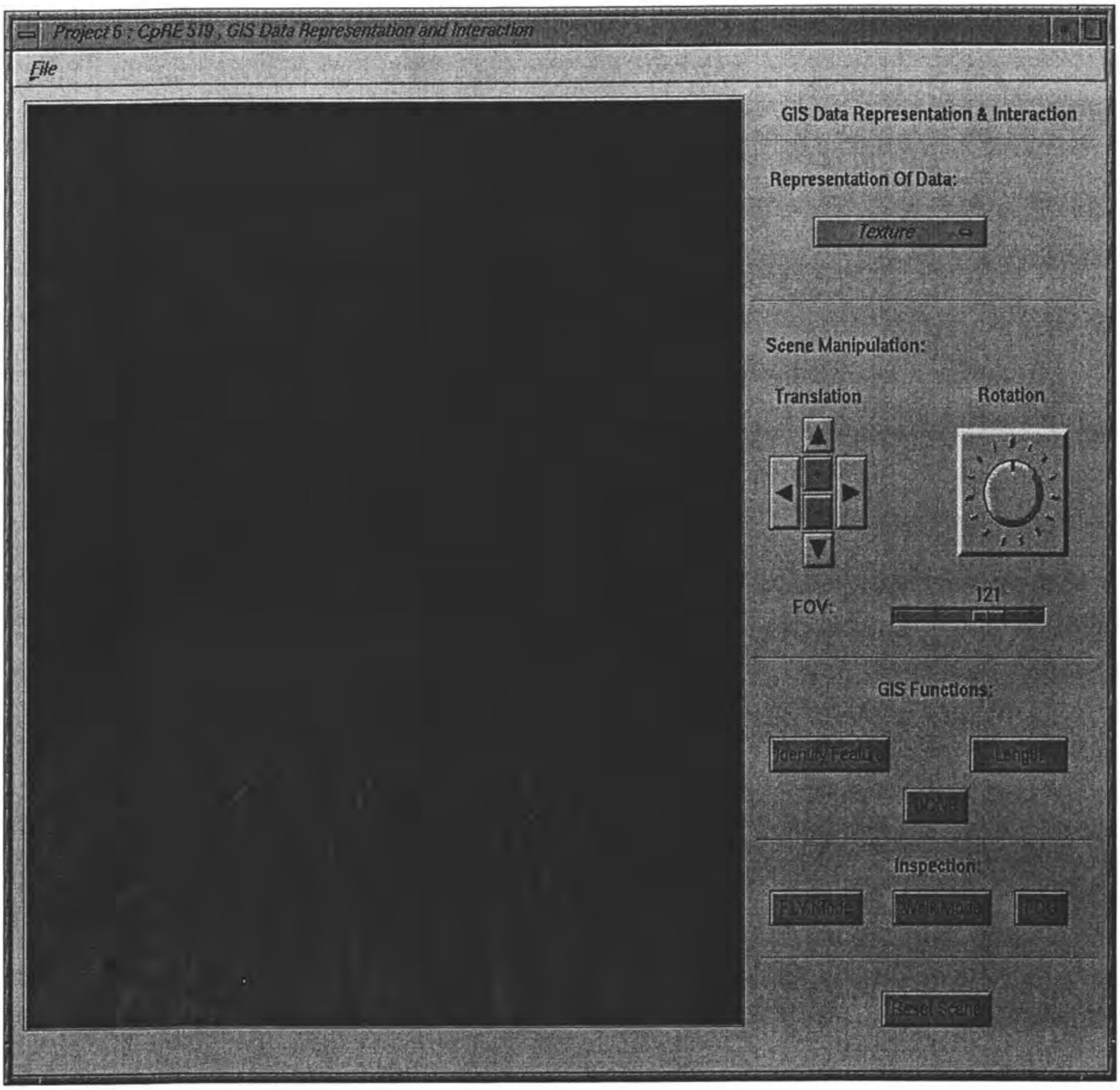

Figure 34. Simulating Atmospheric Effects Through Fog Using OpenGL

5.4.5 3D Model using VRML

3D models were also created using VRML. The advantage of VRML lies in its simplicity. A VRML file essentially contains simple text commands to create a complex 3D object. State Plane coordinates were used to represent the spatial data and simple anchor command was used to tie it to its attributes. Customized fly through (Figure 35), Cross-Section and profile examination (Figure 36), interactive and realistic feature identification (Figure 37), Zoom to Object capability (Figure 38) and dynamic object positioning (Figure 39) were incorporated. Because a VRML file is inherently web enabled (with help of plug-in programs) it was used to develop a web enabled 3D GIS.

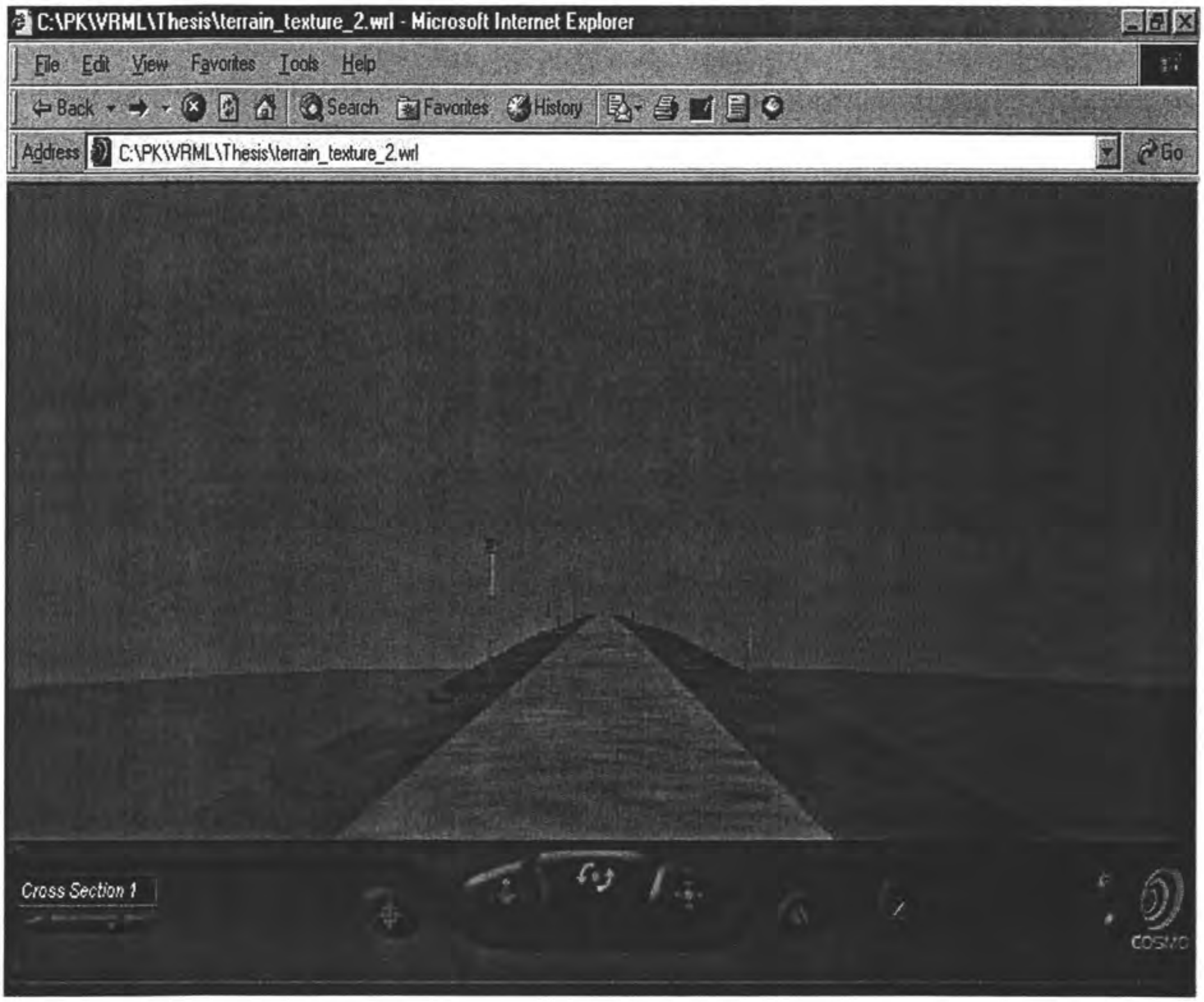

Figure 35. Textured Mapped 3D Objects With Customized Fly Through

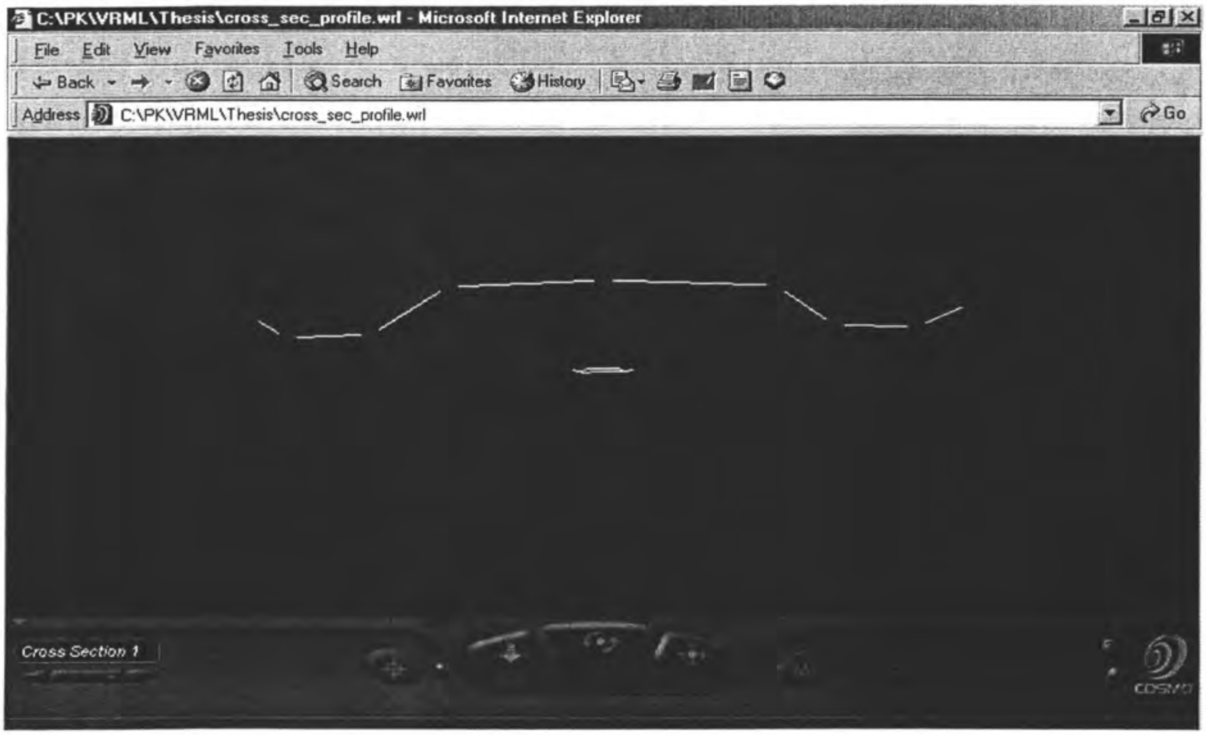

Figure 36. Cross Section and Profile Examination Using VRML Browser

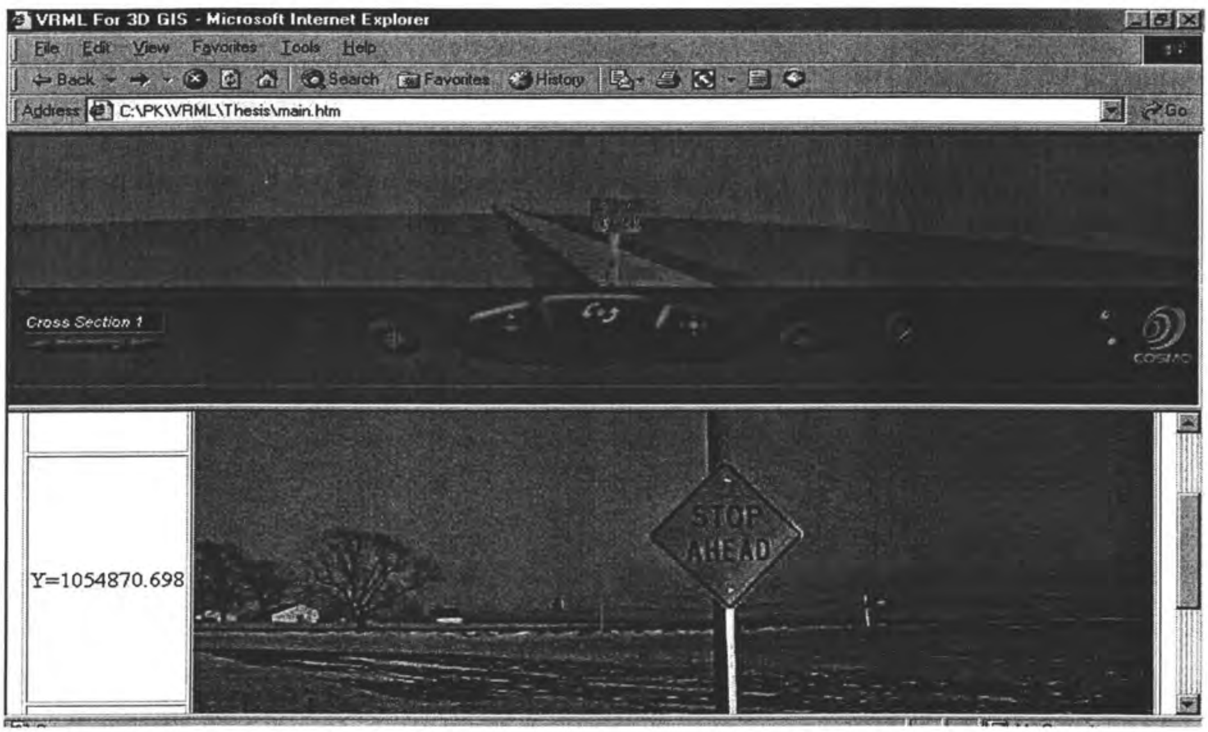

Figure 37. Interactive Feature Identification and Query Capability

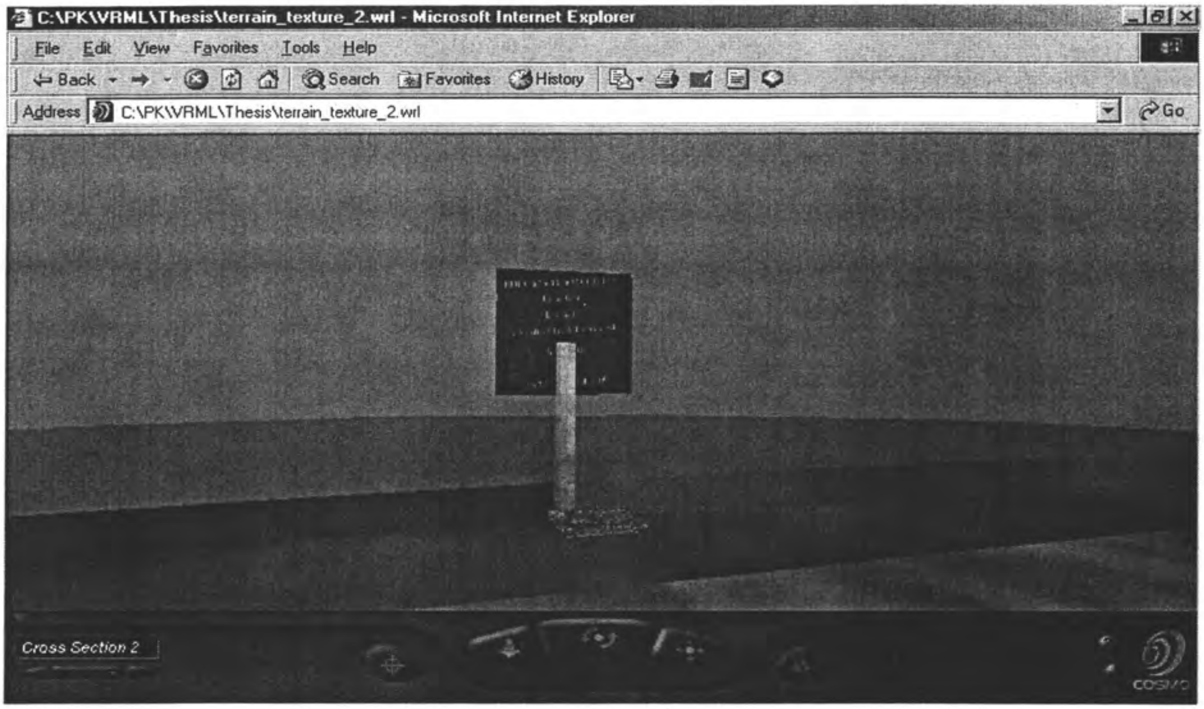

Figure 38. Zoom to Object Feature Using VRML.

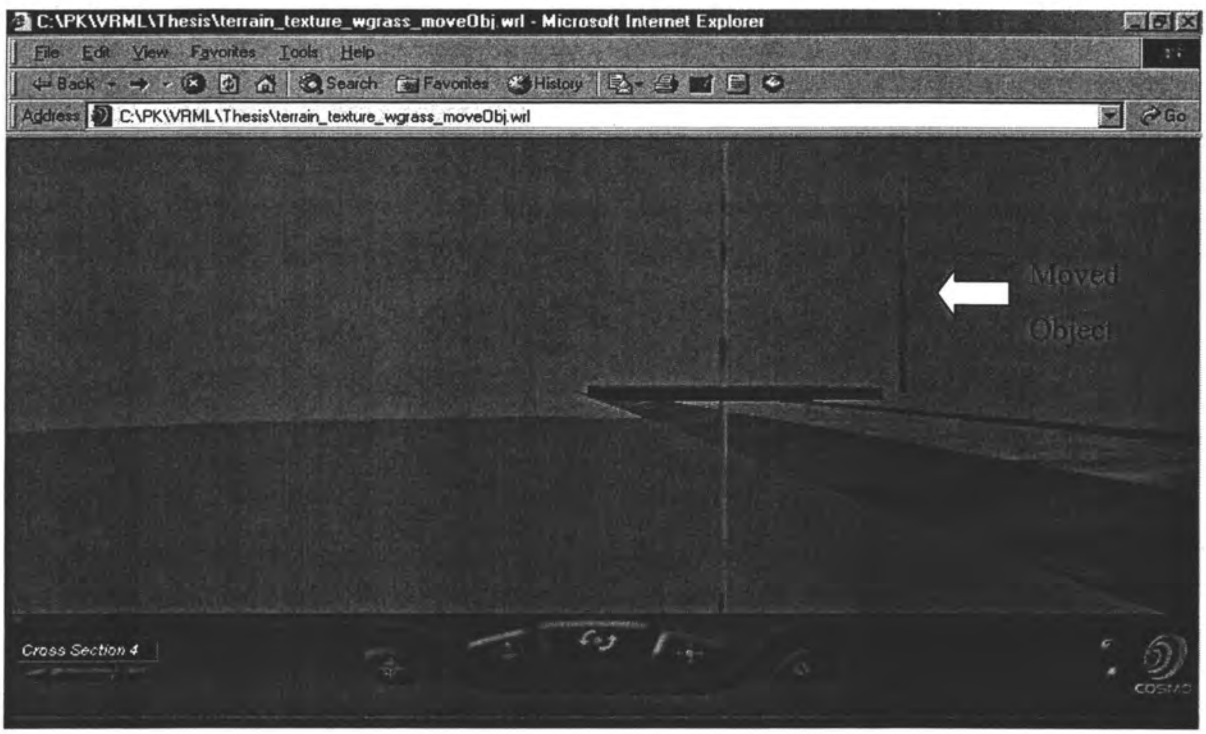

Figure 39. Dynamic Object Positioning of Objects Using VRML Functions.

6. CONCLUSIONS

Through out history, traditional mapping has used a variety of abstract symbols, colors and patterns to characterize the real world. With the advent of computers and analytical/digital mapping, traditional mapping was extended by linking the map features to their attribute data (function of a typical GIS). With powerful analytical capabilities, GIS could examine complex spatial problems and suggest efficient management practices. For the last three decades, GIS started out as a simple 2D system and is now a complex 2D system. Fortunately, technology changes now permit us to transform this complex 2D GIS to a simple 3D GIS, the first step in developing a complex and more robust 3D GIS engine. This thesis looked at the different technologies available in developing such a simple 3D GIS system for As Built survey of roadside features. Despite its limited functionalities, the 3D models work as prototypes for developing better functional 3D GIS. The following conclusion is drawn on the different technologies available to develop a 3D GIS for As-Built surveys.

The Arc View 3D Analyst extension allows visualization of data in three-dimensional space inside Arc View GIS. It also allows interactively fly through, rotation in a 3D view, zoom in, and identify features in three dimensions. Arc View 3D analyst creates the 3D scene from the existing 2D data of surfaces or attributes. Arc View 3D Analyst uses OpenGL for 3D rendering. Arc View 3D analyst is a powerful yet simple tool to achieve moderate visualization results. Unfortunately, the problem with Arc View 3D Analyst is that it adopts data abstraction to represent 3D features and hence the realism achieved is primitive, for example polygons are extruded as cuboids and point features as spheres or cylinders. Thus, Arc View 3D analyst should be avoided if the user is interested in creating realistic 3D scenes. However, Arc View 3D Analyst is best suited for developing simple 3D application.

OpenGL is the most widely adopted graphics standard for developing interactive 2D and 3D graphic application. The real advantage of OpenGL lies in its innovative application development by making use of a broad set of rendering, texture mapping, special effects, and other powerful visualization functions. Developers can leverage the power of OpenGL across all popular desktop and workstation platforms, ensuring wide application deployment. OpenGL assures users and developers high visual quality and performance. The other advantages of OpenGL are stability, reliability, portability and scalability. However, the real disadvantage of OpenGL is the learning and implementation curve, especially in developing 3D GIS applications is a little steep. Also, since OpenGL does not inherently support any windowing or user input functions the developer needs to rely on other programming tools such as RapidApp (for SGI systems) or Visual C++ (for Windows platform) to develop a user interface. Thus OpenGL could be used to develop any high end or low end 3D GIS system with the proper training of the user.

Virtual Reality Modeling Language (VRML) is an open standard for 3D multimedia and shared virtual worlds on the Internet. The user interacts with the VRML world through a special browser (Plugin programs such as Cosmo Player). The advantage of VRML is that it is platform independent. A VRML file essentially contains plain ASCII text and is very space efficient so even a highly interactive VRML world can be downloaded without running into any bandwidth problems. The learning curve for VRML is also comparatively small and complex scenes can be created without much difficulty. Since VRML is inherently web enabled they form the perfect tool for developing a simple web based 3D GIS system.

6.1 Future Work

Development of such a 3D GIS is graphics intensive and hence specialized hardware may be required to deliver near real time interaction. As the power available on consumer-grade desktop increases, more realistic representation becomes possible using lesser hardware. The advancement in hardware and software technology has stemmed out low cost solutions however, these low cost solutions only approximate the realism needed. In order to develop a more realistic and efficient 3D GIS using real time computer graphics for visualization and interaction we need other technologies like Virtual Reality. Virtual Reality promises fully immersive environment, which fully engages all the user's senses and provides full interaction in real time. Virtual Reality can act as a high end user interface that involves real time simulation, interaction and visualization through multiple sensorial channels, thereby providing greater immersion into the world or environment of scientific data, thereby enhancing the researcher's perception of its features and forms [48]. In the journey from a 2D map to a more interactive 3D, GIS has no doubt served the user community well, but there is an increasing demand for better data handling and visualization using the recent developments such as Virtual Reality. There is also a need for a conducive medium in order to make Virtual Reality work with GIS and this medium exist now in the form of the Internet. Internet and 3D computer graphics have been around for over three decades, but it is only recently that technology has made possible their mutual interaction in the form of a collaborative distributed GIS system [10].

GIS has been a very faithful tool for man to carry out many kind of spatial analysis, but the time has come for the much-needed upgrade to all GIS systems. The upgrade to the current GIS system comes in the form of Distributed Virtual Reality where the user no longer uses the system but actually becomes a part of the system. The number of geographical information users has greatly expanded with the Internet explosion and it becomes only obvious that this technology transfer will occur through the Internet. However, like most technologies Virtual Reality, GIS and Internet are continuously evolving and as these technologies evolve with time we will eventually see the seamless integration of these technologies.

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