Using GIS in Preliminary Geotechnical Site Investigations for Transportation Projects

ROCH PLAYER

The purpose of a preliminary geotechnical site investigation is to create a model of the geotechnical conditions and considerations facing a project. The model is then used to analyze the project and to make project decisions. Geographical information systems (GIS) can be used in preliminary geotechnical site investigations to develop and analyze a site model and to plan site activities. In preliminary geotechnical site evaluations, GIS can be used in four ways: 1) data integration, 2) data visualization and analysis, 3) planning and summarizing site activities, and 4) data presentation. GIS allows integration of preexisting data sets with project specific data such as CAD files, survey points, and site reconnaissance photos. The integrated data can be displayed, manipulated, and analyzed using tools built into the GIS program, thus creating the site model. From this site model, decisions can be made for further site activities and the results of the site activities can be integrated into the GIS site model. GIS can also be used to create maps and figures for reports, displays, and field personnel use. GIS was used in the preliminary geotechnical site investigation for the US 63/US 34 Ottumwa Bypass highway. As a result of its use, areas of potential geological hazards that could impact the design and construction of the bypass were identified quickly, and changes were made to the alignment early in the design process before significant design effort had been invested. Key words: geotechnical, geographic, information, systems, GIS.

INTRODUCTION

The purpose of a preliminary geotechnical site investigation is to create a model of the geotechnical conditions and considerations facing a project. The model is then used to analyze the project and to make project decisions. The intent of this effort is to place the project in the context of its surroundings and to identify potential barriers to project completion early in the design process. A successful preliminary investigation may result in significant cost savings in design, construction, and longevity of the project.

Transportation projects particularly need effective preliminary geotechnical site investigations because of the significant investments of private and public funds, their long design lives, and their impacts to the public. This paper focuses on how a geographical information system (GIS) can be used in a preliminary geotechnical site investigation to develop and analyze a site model and to plan site activities. The US 63/US 34 Ottumwa Bypass will be used to illustrate application of the technology and benefits of its use in soils design.

CH2MHILL, 800 Ninth Street, Suite 200, Des Moines, Iowa 50309.

PRELIMINARY GEOTECHNICAL SITE EVALUATIONS

The purpose of a preliminary geotechnical site investigation is to develop a working site model that is used to analyze the site and to plan site activities. This model is continually refined as more information is gathered and integrated into the existing model. The model consists of demographic, hydrologic, geologic, historic, and other types of information that place the project into the context of its surroundings.

The primary benefit of the investigation is the identification of potential barriers to successful project completion early in the design process. Some potential geotechnical barriers that a transportation project could face include:

- Excessively weak soils
- Potentially unstable slopes
- Distance to and type of borrow sources
- Geologic hazards
- Environmental hazards

Early identification of these barriers can avoid costly and time-consuming changes after significant site design has been completed. It also enables the design of facilities that avoid the potential problems or incorporate solutions into the site design.

GIS AND PRELIMINARY GEOTECHNICAL SITE INVESTIGATIONS

The conventional approach to these site investigations can be an arduous task. Existing data sources are found in a variety of hard copy and paper formats such as maps, reports, books, aerial photos, etc. Integrating these data together with photos, notes, borings, and other site specific data can require a significant portion of the effort expended during the preliminary investigation. Less time may be spent on data analysis and acquisition than on data integration. Also, reproducing the work may take as much time as the initial production. Using a geographic information system (GIS) to aid preliminary geotechnical site investigations can greatly improve the efficiency and effectiveness of these investigations.

GIS has been defined as "a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting information that are geographically referenced (*1*)." Most data utilized in geotechnical site investigations have spatial attributes, that is, they can be located at a point in space. The power of GIS is that it can link maps and photos directly to data describing their features and allows data to be searched and analyzed spatially. Layers of data, known as "coverages," can be readily combined to provide a wealth of information about a site and can be added or removed from a base map by turning layers on or off. This results in a flexible site model that can be reused for multiple applications with minimal duplication of effort.

GIS was used during the preliminary geotechnical site investigation for the US 63/US 34 Ottumwa Bypass project, and this project will be used to illustrate its capabilities in this paper. ARCVIEW GIS (ESRI, Redlands, California) was the GIS program used during this effort. In preliminary geotechnical site evaluations, GIS can be used in four ways:

- Data integration
- Data visualization and analysis
- Planning and summarizing site activities
- Data presentation

Data Integration

To develop and refine the working site model, data from various sources need to be integrated. These data may consist of readily available existing information, such as soil surveys and topographic maps, and project specific information, such as proposed centerlines, project extents, survey points, aerial photos, and site investigation results. GIS provides tools for integrating these data. Figure 1 shows a proposed alignment for the Ottumwa Bypass that was generated in a CAD program, imported into ARCVIEW, and combined with preexisting road, drainage, section, and topographic information. To this base map, additional data, such as former coal mine locations, can be added easily as shown in Figure 2. Photos can also be layered with maps to show details.

When integrating data from various sources, two important considerations are data limitations and project coordinate systems. Each data set has inherent limitations. The source of the data must be considered, positional accuracy may vary from tenths to hundreds of meters, and the applicability of the data to their intended use also needs to be considered. The site model is only as accurate as its components. In some cases, the data accuracy may be inadequate for detailed design, however it may be more than adequate for preliminary investigations.

For disparate data sets to be integrated, each must have the same base coordinate system. Readily available data sets may utilize a coordinate system such as the Universal Transverse Mercator (UTM) with varying datums. Project specific data sets may use a standard coordinate system or a project specific system. Most GIS programs contain routines for performing coordinate transformations relatively simply to enable integration of data sets in different coordinate systems.

The Ottumwa Bypass GIS model utilized two coordinate systems. For integrating preexisting data sets such as soil surveys, hydrology, and roads with the road design produced CAD files, the UTM 1927 datum coordinate system was used. When greater positional accuracy was needed for planning site activities and integrating project specific data sets, the project specific coordinate system used by the road designers and survey crews was used.

Data Visualization and Analysis

One of the primary purposes of a preliminary geotechnical site investigation is to identify potential barriers to successful project completion early in the design process. Using GIS to visualize and analyze site data can expedite this process, as shown in the Ottumwa Bypass preliminary investigation.

The proposed Ottumwa Bypass corridor is located in an area of actively eroding slopes and steep drainage ways feeding into the Des Moines River in Southeastern Iowa. This area also was extensively mined for coal from the late 1800s to the middle of the 20th century. As a result, potentially unstable slopes and former coal mines were concerns as the roadway alignment was being refined. A site model was created using GIS to identify areas of concern in relationship to the alignment and their potential impact on the alignment was analyzed. Figure 2 shows the locations of coal mines in the Ottumwa area.

An 800-meter radius buffer was generated around the proposed alignment in Figure 1, and the model was searched for coal mines near the proposed alignment (see Figure 3). It was determined that one mine, the Chet Akers Coal Company Mine No. 2, fell near the proposed location of the Pennsylvania Avenue interchange (see Figure 4).

Also of concern was the occurrence of unstable slopes along the alignment. Through GIS, digitized soil survey information was

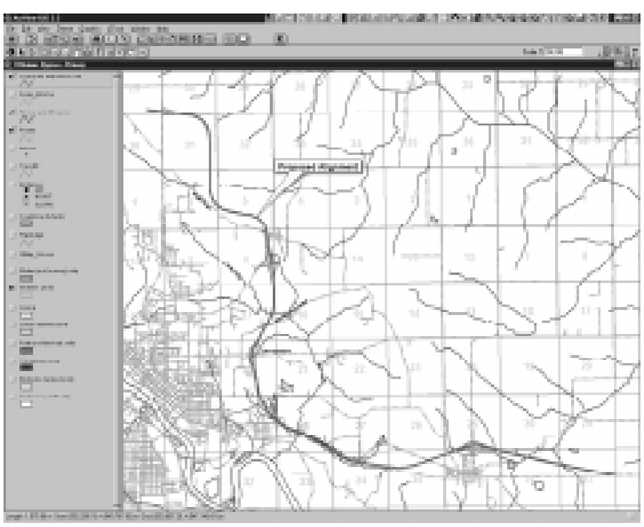

FIGURE 1 Preexisting data sets (roads, drainage, section lines) integrated with project specific data sets (proposed alignment)

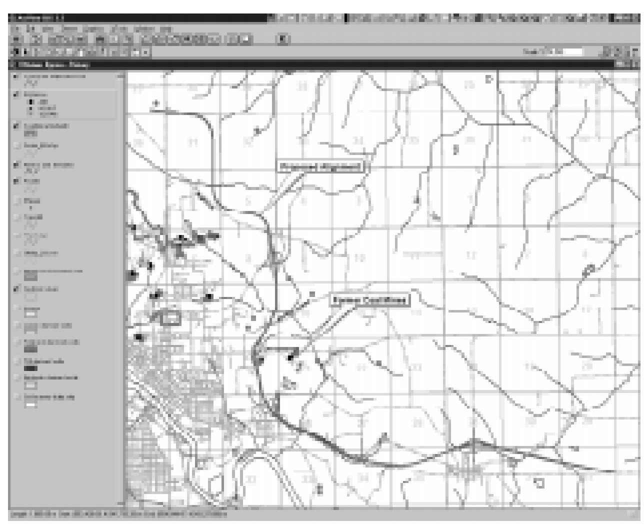

FIGURE 2 Coal mine locations along proposed alignment

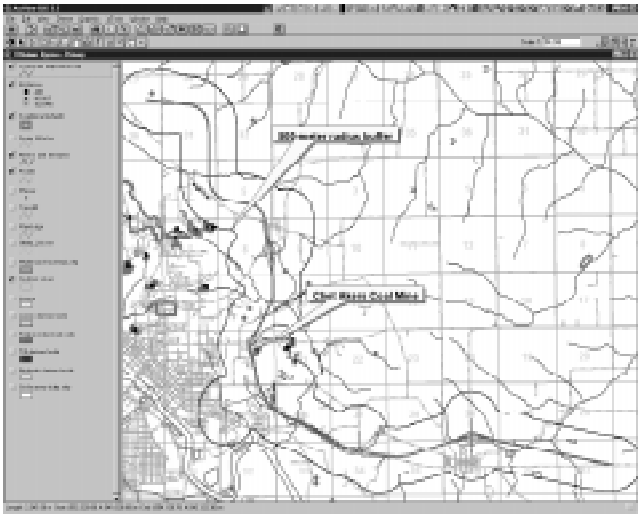

FIGURE 3 GIS used to create 800-meter radius buffer around proposed alignment to identify mines near alignment

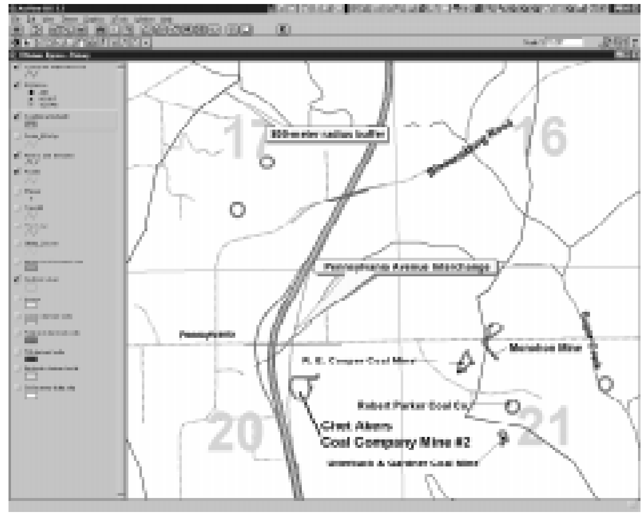

FIGURE 4 Coal mines impacting the Pennsylvania interchange

added to the base map and model was queried for slopes in excess of 20%—the highlighted locations in Figure 5. These slopes were found along the alignment north and south of Bladensburg Road, within the footprint of the proposed road.

Planning and Summarizing Site Activities

After identifying potential problem areas in the office, the next step in the geotechnical site investigation is to field verify assumptions and perform site reconnaissance to collect more information. GIS can be used for both planning site activities and to integrate data collected during these activities into the site model, thus further refining it.

GIS was used for the Ottumwa Bypass investigation to plan the field investigation of both the Chet Akers Coal Mine and the potentially unstable area north of Bladensburg Road. In the case of the mine, a 1930s era mine map was obtained and digitized, using project specific coordinates. Figure 6 shows the mine extent, determined during a literature review superimposed on an aerial photo in GIS. Since this location was approximate, further investigation was needed to identify features associated with coal mining activities. The GIS program was used to plan the locations to be visited during the field investigation. Maps and directions for the field personnel were produced within the GIS program, based on the site model previously created.

Features such as tailing piles, rock outcroppings, sinkholes, and abandoned equipment were noted, and photos and survey shots of these were taken. This information gathered in the field was incorporated into the GIS model in the office, and Figure 6 shows features related to coal mining discovered during the field investigation. The locations of photos taken in the field were stored as a point theme in the GIS model, and each point was linked to an electronically stored copy of the photo. These photos can be retrieved and displayed by clicking points on the screen.

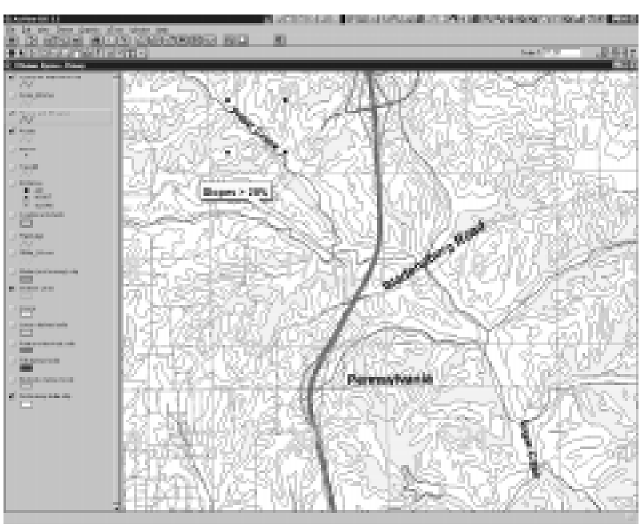

FIGURE 5 Digital soil survey data set queried for slopes in excess of 20% and integrated with proposed alignment

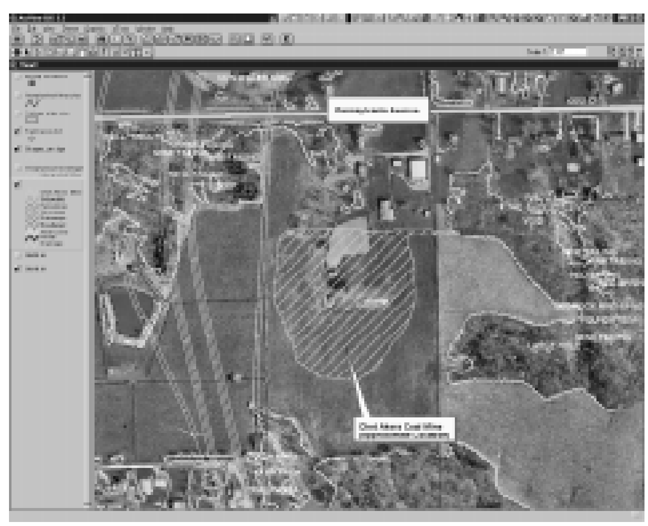

FIGURE 6 Field investigation results showing coal mining features integrated with existing data

Data Presentation

Another benefit of using GIS is data presentation. Layouts can be created for use in reports, papers, posters, and presentations in varying page sizes and formats. Labels, symbols, scale bars, north arrows, and text can be added to maps to provide clarity and improve information transfer. The figures used in this paper were created in the GIS program and exported in a graphic format.

CONCLUSION

GIS is a versatile tool that can be used to aid preliminary geotechnical site evaluations. It was used on the Ottumwa Bypass to identify locations of potential stability problems and possible geologic hazards due to past coal mining. It was used to guide field activities and to merge field data with existing information. This provided an accurate, flexible site model that allowed improved site analysis. As a result, the roadway alignment was shifted away from potential barriers to successful project completion early in the design process, before substantial design effort had been invested.

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