

# GIS APPLICATIONS IN GEOTECHNICAL ENGINEERING

FINAL REPORT  
March 2002

Submitted  
by

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1. Report No. FHWA 2002-06	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle GIS Applications in Geotechnical Engineering		5. Report Date March 2002	6. Performing Organization Code CAIT/Rutgers/URS
		8. Performing Organization Report No. FHWA 2002-06	
7. Author(s) Dr. Trefor Williams, Mr. Patrick Szary, Mr. Thomas Thomann, Mr. Clifford Konnerth and Ms. Emery Nemeth		10. Work Unit No.	
9. Performing Organization Name and Address New Jersey Department of Transportation CN 600 Trenton, NJ 08625		11. Contract or Grant No.	
		13. Type of Report and Period Covered Final Report 6/27/1997 - 3/31/1999	
12. Sponsoring Agency Name and Address Federal Highway Administration U.S. Department of Transportation Washington, D.C.		14. Sponsoring Agency Code	
15. Supplementary Notes			
<p>16. Abstract</p> <p>The NJDOT Bureau of Geotechnical Engineering currently maintains a large database of boring location plans and corresponding test boring logs. These plans and logs are in hard copy format and are stored in boxes, file cabinets, and plan drawers. Locating specific boring location plans and test boring logs can be a very time consuming process that also relies on the memory of the personnel that are responsible for maintaining the database. This report presents the results of a successful pilot study to investigate the development of a Geographic Information System (GIS) to better manage and disseminate soils information, as developed from test boring results.</p> <p>The Rutgers Soil Series is used within and outside the NJDOT to assist in designing roadways and performing preliminary assessments of soil conditions at a bridge or structure. Since the original soil series maps were developed in the 1950's, the base maps used then are not representative of the transportation system as it is today. As such, it is sometimes very difficult to locate a roadway or bridge project using the soil series maps alone. In addition, once the soil type(s) has been identified, the user must go to a soil series book to obtain engineering information regarding the soil type. By placing the scanned soil series maps on the NJDOT base map and digitizing the areas of the soil types, the pilot study presented herein has resulted in an GIS system that makes it easier to obtain information regarding soil types at a specific project location.</p>			
17. Key Words GIS, geotechnical engineering, soil boring, location plans, soil polygons		18. Distribution Statement	
19. Security Classif (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 25	22. Price

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## **ABSTRACT**

The NJDOT Bureau of Geotechnical Engineering currently maintains a large database of boring location plans and corresponding test boring logs. These plans and logs are in hard copy format and are stored in boxes, file cabinets, and plan drawers. Locating specific boring location plans and test boring logs can be a very time consuming process that also relies on the memory of the personnel that are responsible for maintaining the database. This report presents the results of a successful pilot study to investigate the development of a Geographic Information System (GIS) to better manage and disseminate soils information, as developed from test boring results.

The Rutgers Soil Series is used within and outside the NJDOT to assist in designing roadways and performing preliminary assessments of soil conditions at a bridge or structure. Since the original soil series maps were developed in the 1950's, the base maps used then are not representative of the transportation system as it is today. As such, it is sometimes very difficult to locate a roadway or bridge project using the soil series maps alone. In addition, once the soil type(s) has been identified, the user must go to a soil series book to obtain engineering information regarding the soil type. By placing the scanned soil series maps on the NJDOT base map and digitizing the areas of the soil types, the pilot study presented herein has resulted in an GIS system that makes it easier to obtain information regarding soil types at a specific project location.

## **INTRODUCTION**

### **General**

The purpose of this report is to present the results of a pilot study to create a statewide test boring management system and engineering soil series system for the New Jersey Department of Transportation (NJDOT). These systems are referred to as the Geotechnical Geographic Information System (GEOGIS). The purpose of the pilot study is to assess the feasibility and effort that will be necessary for full implementation of the system.

The pilot program for the GEOGIS project has been performed by URS in association with the Center for Advanced Infrastructure Technology (CAIT) of Rutgers University, which is under subcontract to the NJDOT to provide the necessary services.

### **Purpose and Objectives of Project**

The NJDOT maintains a large database of soil boring location maps and individual soil boring logs. This database is currently in hard copy format, stored in boxes, file cabinets, and plan drawers, and is maintained by personnel from the Bureau of Geotechnical Engineering. When soil boring information is requested by NJDOT units or outside agencies and consultants, the personnel search through the hard copy files to locate the appropriate logs and location maps and mail or fax the information to the

requester. This is a very time consuming process that relies on the memory of the personnel (institutional knowledge) to locate the correct information from multiple locations.

In addition, many designers within and outside of the NJDOT use the information contained in the Rutgers soils series. Some of the information included in these series are engineering soil maps and tables of engineering soil properties. The current hard copy maps of the Rutgers soils series do not contain the complete State, Interstate, or county road network which makes finding the needed soils information very time consuming and inefficient.

It is the objective of the NJDOT to transform the information contained in these two sources into a digital format compatible with the existing NJDOT GIS system for use by the Bureau of Geotechnical Engineering and others. Following full implementation of the GEOGIS system, it will satisfy the main need of the Bureau of Geotechnical Engineering, which is to easily locate and retrieve this information.

It is estimated by the Bureau of Geotechnical Engineering that there are approximately 70,000 boring log sheets currently maintained by NJDOT, as well as approximately 4,000 soil boring location plan sheets. The Rutgers soil series consists of almost 100 soil maps and corresponding tables of engineering soil properties. Conversion of all of this information to digital form is a major undertaking. Therefore, the NJDOT has decided to perform this pilot study to investigate the most efficient and cost effective methods for developing the GEOGIS and integrating them into the NJDOT GIS system.

### **Report Organization**

This report is organized in four sections. The summary and introductory section are followed by a section which presents the soil boring management system and includes an overview of the representative boring information that were used in this pilot study. This section also presents an overview of the Rutgers soil series maps and the information that has resulted from this source. Our conclusions are presented in the final section.

## **GEOGIS SYSTEM**

The pilot GEOGIS system basically consist of two modules. One module allows users to obtain electronic boring location plans and boring logs from NJDOT's projects. The other module allows users to obtain electronic information from the engineering soil survey series developed by Rutgers University (hereafter referred to as the Rutgers soils series). The GEOGIS system was developed using the computer software GeoMedia.

The following sections present an overview of the soil boring management system and the Rutgers soil series system

### **Soil Boring Management System**

This section presents an overview of the development of the Soil Boring Management System. Initially, an overview of the boring location plans and logs that were used in the pilot study is discussed. Following this, a description of the methodology used to develop the Soil Boring Management System for the pilot study is presented along with an overview of the implementation of the system.

#### **Overview of Representative Boring Information**

For the purpose of this pilot study, a representative sample of boring information from the NJDOT's library of geotechnical boring information was selected. The NJDOT Bureau of Geotechnical Engineering selected a total of 14 projects located throughout the state. Each project contains a boring location plan(s) and corresponding boring logs. A list of type and number of boring location plans and number of borings and boring sheets for each project is included in table 1. In total, there are 32 boring location plans and 267 test boring logs (382 boring log sheets).

The boring logs are all on similar NJDOT forms, with general project information at the top of each sheet, and sample descriptions with depth on the remainder of the sheet. Most boring logs include location information relative to the project baseline or alignment (stationing and offset) but do not include any project independent coordinates (e.g., latitude and longitude, NJ state plane coordinates, etc). A typical test boring log is shown in figure 1.

The detail on the boring location plans varies significantly from one project to the next. The best location plans provide maps showing where the project is located within the state and more detailed information such as local street names. The worst location plans provide no information where the project is located within the state and only provides very local information (e.g, bridge features such as piers and abutments). In addition, the boring location plans do not contain survey information related to an independent coordinate system (e.g., latitude and longitude, NJ state plane coordinates, etc.)



Table 1: Overview of Documents Used in Pilot Study

Pilot Study Project No.	Project Name	Document type	# of Sheets	Boring Numbers	Number of Borings
1	Route 4 over Kinderkamack & Harkensack	Boring Logs	49	b2, b3-b11, b14-b29	25
		Mylar	4		
2	Vincentown-Retreat Road	Boring Log	6	SB-1 to SB-3	3
		Mylar drawing	1		
3	Route 1 Dinky Railroad Bridge Section 2K	Boring Log	7	515W-99 to 515W-104	6
		Mylar drawing	1		
4	Route 1 & Raritan River Railroad Bridge	Boring Log	14	119W-16 to 119W27	12
		Paper Drawing	1		
5	Washington Street Bridge	Boring Log	6	354W-28 to 354W-32	5
		Paper Drawing	1		
6	Green Bank Road Bridge	Boring Log	9	354W-33 to 354W-41	9
		Paper drawing	2		
7	North Beverwyck Road	Boring Log	5	354W-44,45, 47to 49	5
		Paper drawing	3		
8	Bloomfield Avenue Improvements, Change Bridge Road to Hook Mt. Road	Boring Log	14	354W-51 to 354W-65	15
		Paper drawing	2		
9	Green Pond Road Reconstruction	Boring Log	27	354W-66 to 354W-93	28
		Paper Drawing	8		
10	Abbett Avenue Bridge over Whippany River	Boring Log	6	354W-94 to 354W-97	4
		Paper Drawing	1		
11	North Main Street	Boring Log	5	354W-101 to 354W-104	4
		Paper Drawing	1		
12	Route 55 Freeway Vineland Bypass	Boring Log	6	H1 to H3	3
		Mylar drawings	2		
13	Route 9 Improvements	Boring Log	64	192A-1 to 22, 24, 28, 33, 62 to 192A-66. 192W-1 to 6, 19 to 29, 36, 37, 43 to 192W-46	43
		Paper Drawings	4		
14	Route 1 Orchard Street to Union county line	Boring Log, Plug Sampler logs	164	S39 to 68, S96, W65 to 88, 92 to 97, 101 to 115, 146 to W150. <b>229P-74 to 229P-77</b> . 229W-4, 229W-5. B48 to 61, 63, 95 to B-97.	105
		Paper Drawings	1		
<b>Total Number of Boring log sheets</b>			382	<b>Total Number of Available boring logs</b>	267
<b>Total Number of Boring Location Plans</b>			32		



## **Methodology**

Implementation of the Soil Boring Management System generally consists of:

1. Identifying the boring location plans and boring logs that go with a specific boring contract;
2. Scanning hard copies of the boring location plans and boring logs;
3. Placing the boring location plans at the proper location on the NJDOT base map;
4. Linking the boring logs to their corresponding boring location plans, and;
5. Inputting key attribute data (values placed in the database that are linked to a graphical image) that is included in the boring location plans and boring logs.

After the boring location plan(s) for a specific boring contract are scanned, the boring location plans must be located on a statewide base map. One method for doing this would be to use the New Jersey State Plane Coordinate System. However, this information is not typically available from the soil boring location plans. In addition, the NJDOT base map was compiled at a very small scale with a single line representation of state roadways. The absolute accuracy is estimated by the NJDOT GIS staff to be plus/minus 50 feet. Therefore, even if a boring location plan was tied to the New Jersey State Plane Coordinate System and it was placed on the base map using these coordinates, a 50 foot "error" in its location relative to other features on the base map may occur. Considering these limitations, the boring location plans for a specific boring contract were located on the NJDOT base map by placing a symbol at the approximate location of the boring contract. Once the boring contract location is properly located within the state, the boring logs associated with the boring contract are linked to the symbol.

The attribute data associated with a boring contract, which consists of a set of boring location plans, are as follows:

- Site Identification Number
- Route Number
- County
- Municipality
- Local Project Name

The site identification number is a unique identification number that is sequentially numbered.

The attribute data associated with a test boring location are as follows:

- Local Test Boring Identifier
- Source of Data (In house / Contractor)
- Soil Boring Reference Identifier
- Section
- Station
- Offset
- Reference Line
- Ground Elevation
- Contractor
- Date Started
- Final Depth
- Coordinate Validity
- Northing Coordinate
- Easting Coordinate
- Route
- Local Project Name
- County
- Municipality
- Region
- Agreement Number

The Soil Boring Reference Identifier (SBRI) is a unique number for a given test boring that is sequentially numbered. The coordinate validity will be used to describe the accuracy with which the test boring was located. Not all of the attributes noted above will be available from every boring log; therefore, the table of attributes will not always be complete. Most of the attribute information is provided in the header information of the boring logs.

### **Implementation**

An example of the placement of some of the pilot test boring contracts on the NJDOT base map is shown in figure 2. The test boring contract desired can be selected by either directly clicking on a symbol, or drawing a “fence” around a certain portion of the base map. If a fence is drawn, every test boring contract within the fence will be selected. After performing this, a new screen is displayed, as shown in figure 3. If an area is selected that contains multiple boring contracts, the pull down menu at the top of the screen is used to select the specific boring contract desired, as shown in figure 3.

Once the desired boring contract is selected, the first boring location plan is shown on the screen. If the boring contract consists of multiple boring location plans, each boring location plan can be retrieved by selecting the tabs at the top of the screen, as shown in figure 4. Once the desired boring location plan is retrieved, the buttons at the bottom of the screen can be used to print the plan, zoom in on desired features, annotate on the plan before printing, as well as other options.

The boring logs associated with the boring contract are selected using the tabs located at the bottom of the screen, as shown in figure 5. Once a desired tab is selected, the scanned image of the boring log is retrieved and shown on the screen, as shown in figure 6. The available attribute information associated with the boring is shown on the right side of the screen, as shown in figure 6. As with the boring location plans, the

buttons at the bottom right portion of the screen can be used to print the boring logs, zoom in on desired areas of the log, and annotate on the log as well.

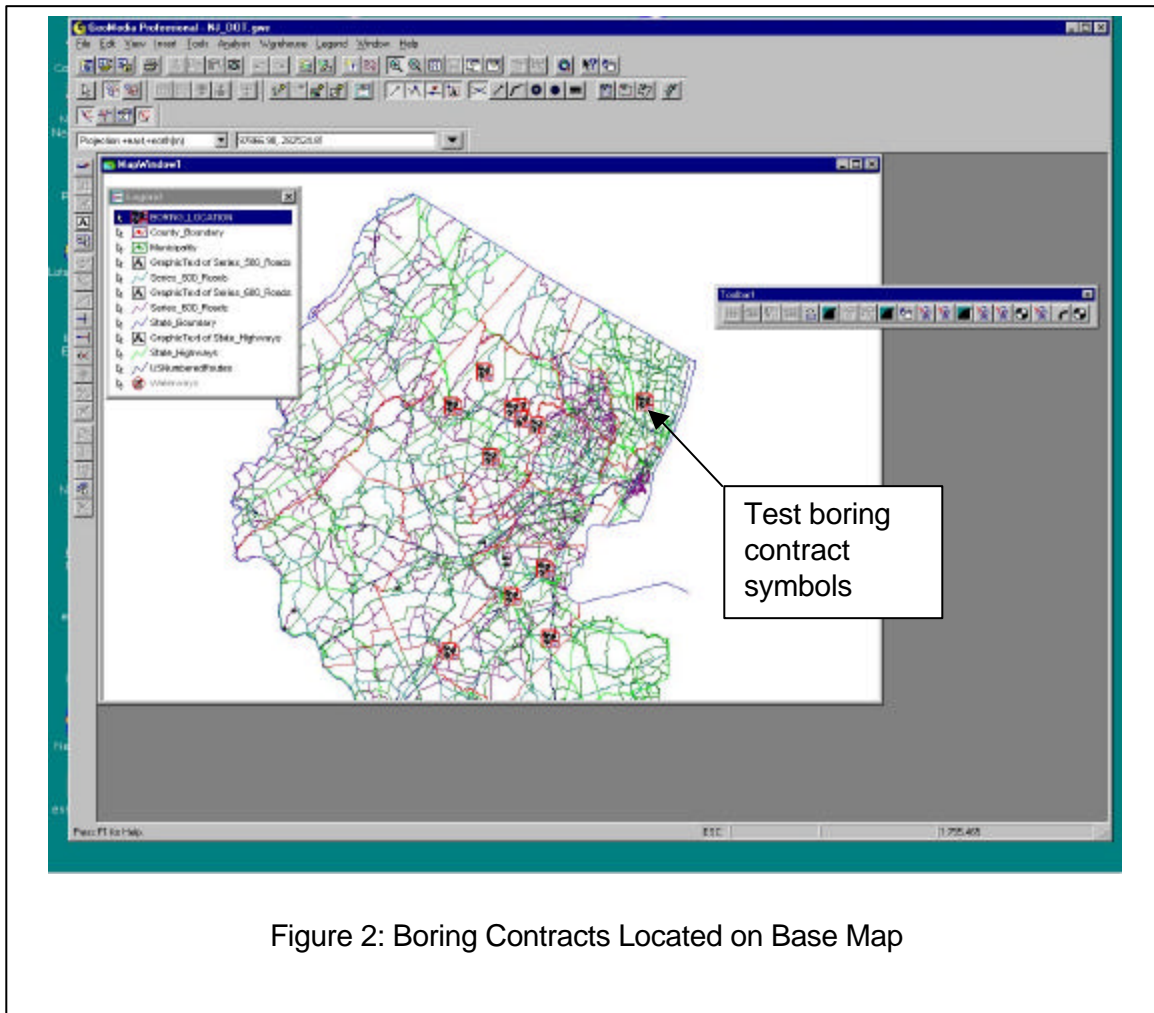


Figure 2: Boring Contracts Located on Base Map

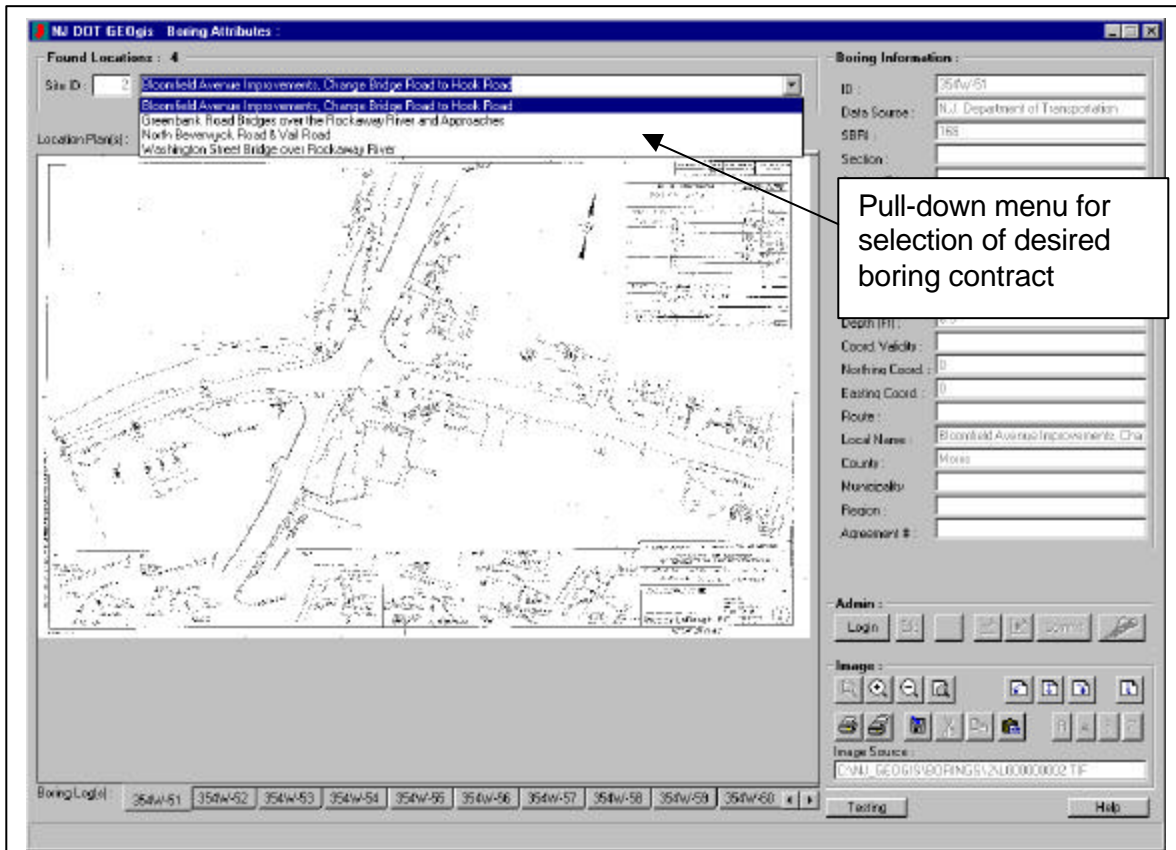


Figure 3: Selection of Desired Boring Contract

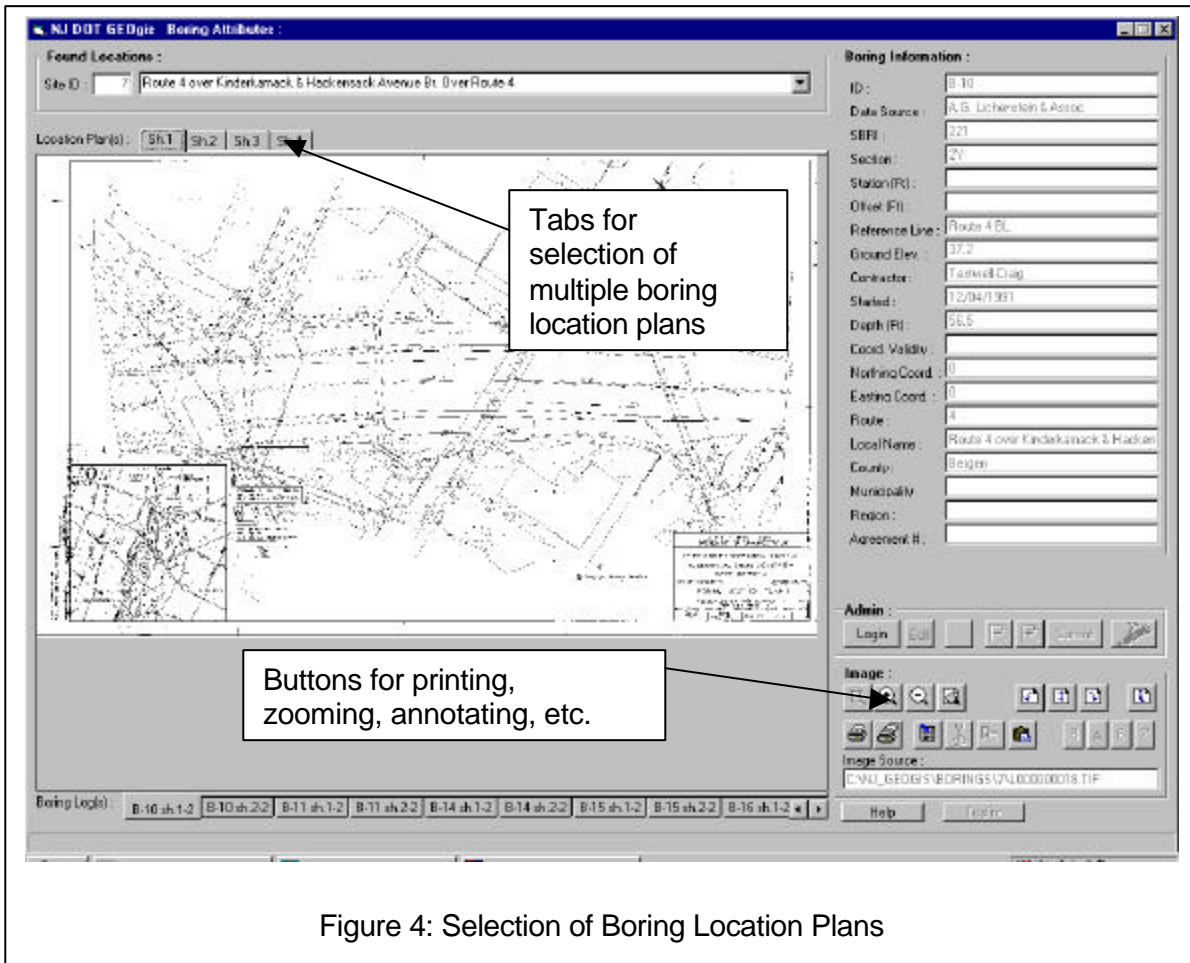


Figure 4: Selection of Boring Location Plans

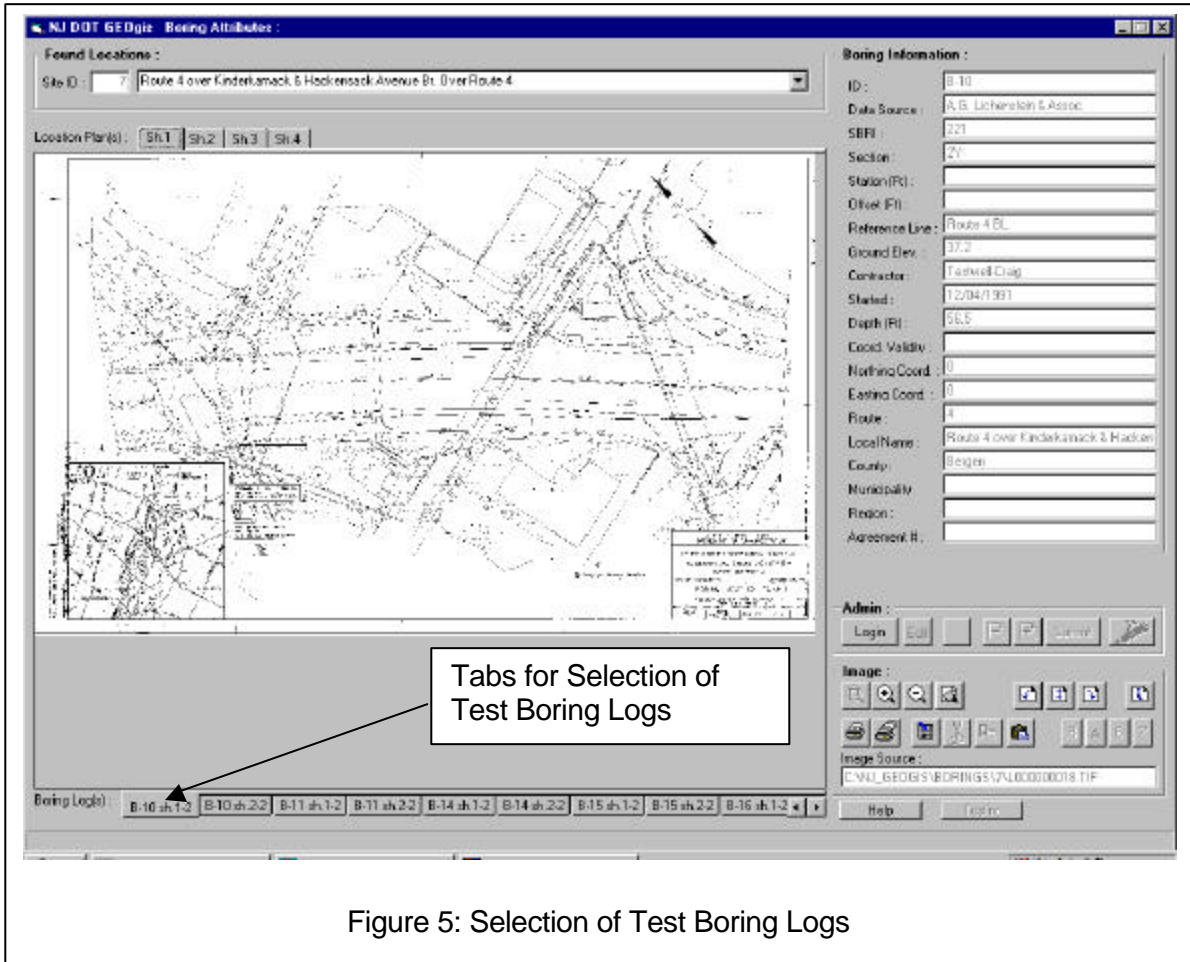


Figure 5: Selection of Test Boring Logs





It is also possible to locate a boring contract by performing a search, or query, on the attribute information. The screen for performing such a query is shown in figure 7. For example, the user could search for all the boring contracts along Route 4 by placing the number “4” in the appropriate field on the screen, as shown in figure 7. Once the query is submitted and completed, the number of boring contracts found is listed at the bottom left side of the screen. The user then selects the “View Plan(s) and Boring Log(s)” button located at the bottom of the screen to launch a screen similar to the one shown in figure 3.

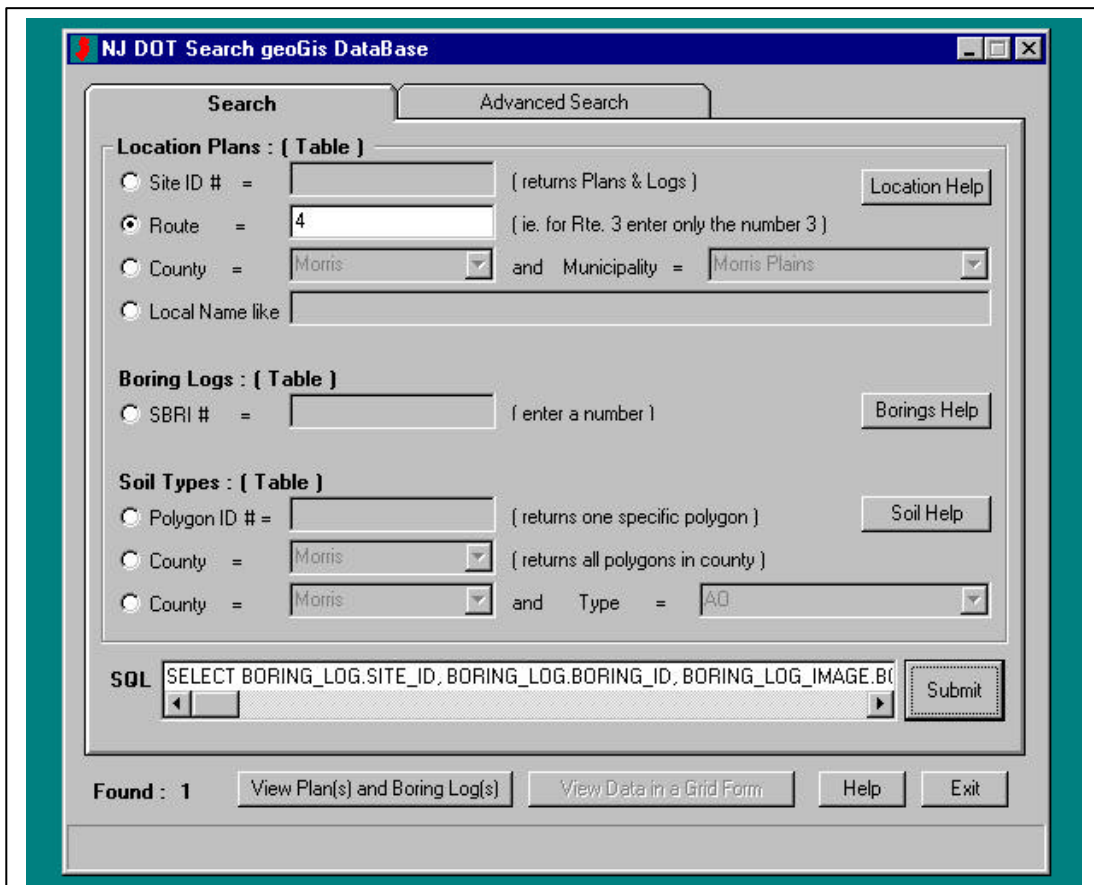


Figure 7: Search Screen

### **Future Test Boring Implementation**

There are several ways that future test boring information can be incorporated into the soil boring management portion of the GEOGIS. The use of a commercial program for logging the borings and transferring the information to a database is not recommended because it would mean that in-house forces, as well as all consultants would need to purchase and use this program. In addition, these programs are typically developed to handle many different boring log formats. Since the NJDOT boring log format is standardized, the use of the multiple formats of a commercial program are not needed

and will make implementation more difficult. As such, during full implementation of the soil boring management system, a computer program will need to be developed specifically for development of boring logs in NJDOT's standardized format. The program will be developed such that the necessary information is entered via specific fields. This information would be stored in a database that is then retrieved to create the boring log in the proper format.

The procedure for incorporating future soil boring information would be similar to that described previously for converting the current paper archives. However, it is envisioned that future soil boring information will be collected by a Web based input and retrieval system. It is also envisioned that New Jersey State Plane coordinates would be required for the boring location plans and the boring logs so that they can be easily located on the base map. The boring location plan(s) would be developed and delivered in a digital format and then located on the base map. The corresponding test boring logs would then be linked to the boring location plans.

### **Rutgers Soil Series Maps**

This section presents an overview of the Rutgers Soils Series Maps, a description of the methodology used to develop this portion of the GEOGIS and a description of the implementation of the system.

#### **Overview of Rutgers Soil Series**

The Rutgers Soil Series, officially called the "Engineering Soil Survey of New Jersey," is a series of maps and 22 Reports (bulletins) which cover the entire State of New Jersey, on a county by county basis. They were developed in the early to mid 1950's by Rutgers University, The State University of New Jersey, and funded by the New Jersey State Highway Department.

The main purpose of the soil maps is to identify the surficial (i.e., shallow) soil type in an area and to show the extent of the soil type in that area. In addition, the maps provide municipal boundaries, and to a limited extent roadways, and man made and natural features (as they were when the maps were created). The identification of a soil type within an area is defined with specific labels. In some instances the label for an area may include a colayer or an underlayer. A colayer indicates that two distinct soils coexist in the same area and are mixed such that it is difficult to delineate where each soil type is concentrated. For example, AR/GL-67pi represents a recent alluvium (AR) mixed with a glacial lake bed deposit (GL) with AASHTO classification ranging from A-6 to A-7 (67) and ground water at 1-3 ft (pi). When an underlayer is indicated, it means that the primary soil is underlain at a relatively shallow depth by the underlayer soil. For example,  $\frac{AM-24}{MV-47}$  indicates that the material denoted by the numerator of the fraction (i.e., AM-24) is present at the ground surface. However, it is underlain at variable depths (but usually shallow) by the material indicated by the denominator of the fraction (i.e., MV-47).

The reports present detailed information concerning the various soil types shown on the soil maps. Each county contains a separate bulletin. The contents of the report include pertinent reference data, an explanation of the labels shown on the maps, and comments on the various soil and non-soil areas shown on the maps. The main chapters of each report include information regarding the soil type such as parent material characteristics, land form characteristics, drainage conditions, and engineering aspects. In addition, for some soil types, tabulated engineering test values are presented.

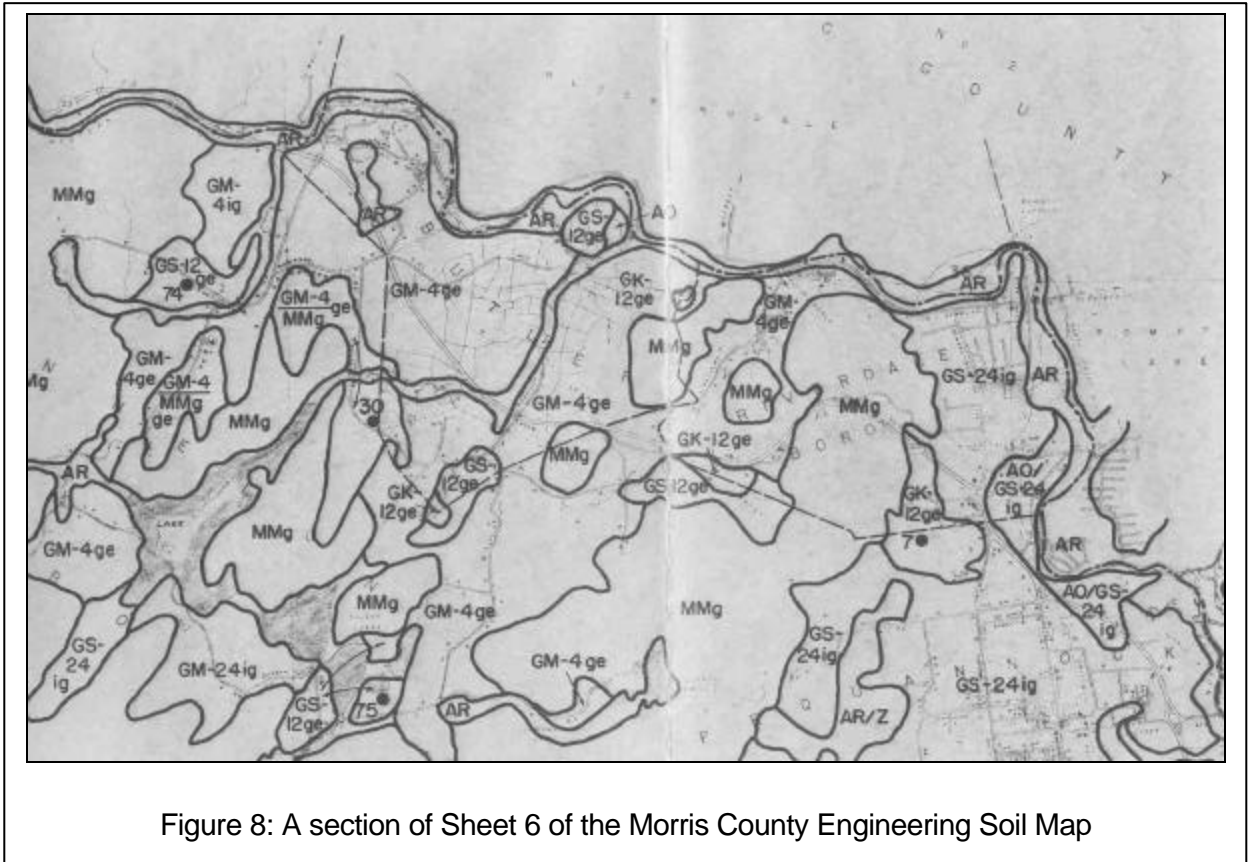


Figure 8: A section of Sheet 6 of the Morris County Engineering Soil Map

This pilot study used the Rutgers Soil Series maps and soil information from Morris County, New Jersey. There are a series of six maps for Morris county available at a 1 in. = 0.5 mile scale. No specific information has been discovered as to the source of the base map for these (Rutgers Soil series) maps. Reports reference interpretation of aerial photography but the level of accuracy, both absolute and relative, cannot be determined. Each map includes a latitude/longitude grid divided into two minute increments. A portion of one of the Morris county soil maps is shown in figure 8.

## **Methodology**

Implementation of the Rutgers Soils Series Map System generally consists of the following:

1. Inputting key attribute data associated with soil type;
2. Scanning the soils series maps;
3. Fitting the soils series maps to the NJDOT base map;
4. Digitizing the various soil types into polygons and linking the polygons to the corresponding attribute data;

After the soil maps are scanned, they are fit to the base map as best as possible. The soil types are then digitized and assigned a polygon identification. The polygon is then linked to the attribute information.

The key attribute data associated with a soil type includes the following:

- Soil Type
- County
- Polygon Identification Number
- Colayer
- Underlayer
- Drainage Descriptor
- Special Designator

In addition, for each soil type that used, the attributes associated with the individual soil types are:

### **Soil Type Attributes:**

- |                        |                        |                        |
|------------------------|------------------------|------------------------|
| • Depth                | • Horizon B            | • Horizon C            |
| • Horizon A            | • Depth                | • Depth                |
| • Depth                | • % Passing #4 Sieve   | • % Passing #4 Sieve   |
| • % Passing #4 Sieve   | • % Passing #200 Sieve | • % Passing #200 Sieve |
| • % Passing #200 Sieve | • % of Silt Particles  | • % of Silt Particles  |
| • % of Silt Particles  | • % of Clay Particles  | • % of Clay Particles  |
| • % of Clay Particles  | • Plasticity Index %   | • Plasticity Index %   |
| • Plasticity Index %   | • Max Density (pcf)    | • Max Density (pcf)    |
| • Max Density (pcf)    | • Optimum Moisture, %  | • Optimum Moisture, %  |
| • Optimum Moisture, %  | • HRB (AASHTO)         | • HRB (AASHTO)         |
| • HRB (AASHTO)         | Classification         | Classification         |
| Classification         | • Group Index          | • Group Index          |
| • Group Index          |                        |                        |

## Implementation

An example of a portion of the Morris County soil map with the digitized soil polygons is shown in figure 9. Also shown on this figure is the scanned image of the soil map which is used to create the digitized polygons. Once a desired soil polygon is selected by clicking, the corresponding attribute information is retrieved, as shown in figure 10. The lower part of the screen shown in figure 10 allows the user to select portions of the soil series books that go along with the maps. If multiple soil polygons are selected, a pull down menu is used to select the desired polygon, as shown in figure 11.

It should be noted that the results from the pilot study indicate that digitizing of the soil polygons will be a very time consuming process, and therefore a relatively costly

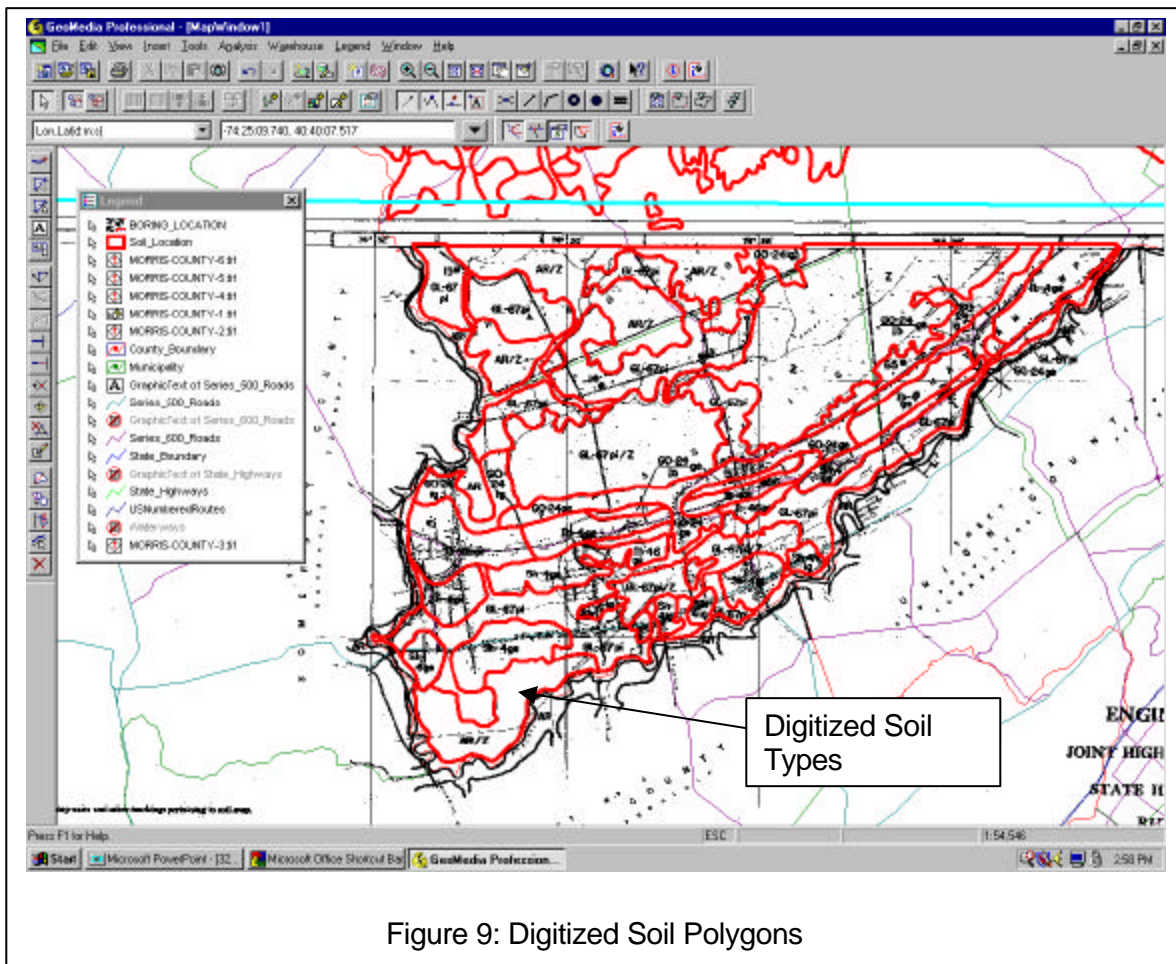


Figure 9: Digitized Soil Polygons

process. The cost of digitizing the soil polygons may also not outweigh the benefits. As such, it is recommended that the NJDOT consider other options whereby the soil maps are scanned and roughly fit over the NJDOT base map. This option will satisfy the NJDOT's most basic desire to have the soils series maps overlying the most recent roadway system.

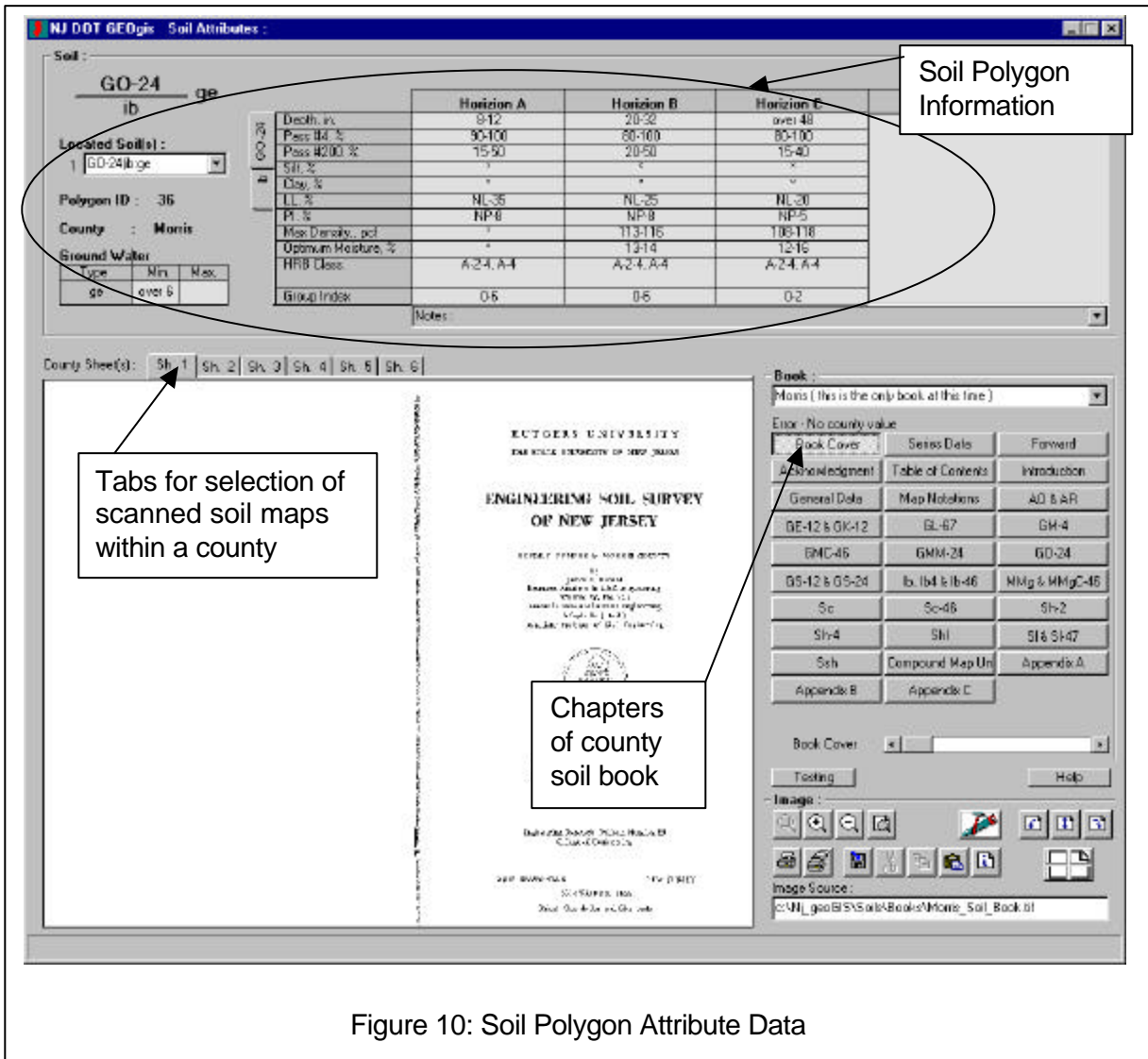


Figure 10: Soil Polygon Attribute Data

NJ DOT GEOgis Soil Attributes : Engineering test values

Soil : **GO-24 ge**

Located Soil(s) :  
 1 GO-24 ge  
 Pol GL-67 pi  
 GL-67 pi  
 Col GO-24 ge

Ground Water  
 Type Min. Max.  
 ge over 6

	Horizon A	Horizon B	Horizon C
Depth in.	8-12	20-32	over 83
Pass #4, %	80-100	80-100	80-100
Pass #200, %	15-50	20-50	15-40
Sh. %	-	-	-
Clay. %	-	-	-
U		NL-25	NL-20
LP		NP-6	NP-5
LO		113-116	109-118
LI		13-14	12-16
LS		A-2-4, A-4	A-2-4, A-4
LP			
LO		0-6	0-2

County Sheet(s): Sh. 1 | Sh. 2 | Sh. 3 | Sh. 4 | Sh. 5 | Sh. 6

Pulldown menu for selection of desired soil polygon

Book :  
 More (this is the only book of this time)

Error - No county value

Book Cover	Series Data	Forward
Acknowledgment	Table of Contents	Introduction
General Data	Map Notations	AO & AR
GE-12 & GK-12	GL-67	GM-4
GMC-45	GMN-24	GO-24
GS-12 & GS-24	lb, lb4 & lb-46	MMg & MMgC-45
Sc	Sc-46	Sh-2
Sh-4	SN	Slz & Slz7
Sh	Compound Map Lin	Appendix A
Appendix B	Appendix C	

Book Cover

Testing Help

Image Source:  
 c:\Nj\_gis\GIS\SOils\Maps\Mons\_Soil\_Maps.tif

THE STATE UNIVERSITY OF NEW JERSEY  
**ENGINEERING SOIL SURVEY  
 OF NEW JERSEY**  
 REPORT NUMBER 100-100-100  
 BY  
 JOHN W. BROWN  
 SENIOR MEMBER OF THE SOCIETY OF PROFESSIONAL ENGINEERS  
 AND ARCHITECTS OF THE STATE OF NEW JERSEY  
 MEMBER OF THE SOCIETY OF PROFESSIONAL ENGINEERS  
 AND ARCHITECTS OF THE STATE OF NEW JERSEY  
 JULY 1960-1962

Figure 11: Selection of Multiple Soil Polygons



## CONCLUSIONS AND RECOMMENDATIONS

The results of this pilot study indicate that development of a GIS system to better manage the NJDOT's soil boring system can be implemented. Once developed, this GIS system will allow for the rapid dissemination of information to NJDOT personnel, as well as outside consultants. In addition, the development of a GIS system will eliminate the need for maintaining the current system of paper originals and copies of the boring location plans and test boring logs, which are susceptible to loss. Development of the GIS system will result in digital images that are less susceptible to loss.

The results of the pilot study also indicate that overlaying the Rutgers Soil Series maps over the NJDOT base map will assist designers in identifying the soil types that may be encountered at a bridge site or along a roadway. The digitizing of the soil types shown on the soil maps into polygons provides the user with a quick method to identify the soil types and retrieve engineering information regarding the selected soil type. The digitizing of the soil types into polygons will provide a user with the ability to query for soil types, or display those intersected by a proposed route as well as retrieve engineering information regarding selected soil type(s). However, digitizing of the soil polygons will be a relatively costly process. Other less costly options whereby the soil polygons are not digitized can also be considered by the NJDOT. The simplest option is to overlay the soil map images over NJDOT's base map to allow for a quick visual evaluation and retrieval of associated information.

The graphical accuracy of any of the above options or steps is directly related to the existing NJDOT base map. The portrayal of graphic locations of location plans and soil polygons should be fit to the most accurate version of the base map available. While it is recommended that future borings be captured with an accurate state plane coordinate, these coordinates will not automatically improve the accuracy of features (roads and bridges) already shown on the base map. These coordinates can be used to improve the accuracy of the base map however, this is not recommended as a cost-effective approach.

Location Plans should be submitted by contractors in a nonproprietary image format such as .DXF. It is envisioned that future soil boring information will be collected by a Web based input and retrieval system. Html programs can be developed to create capture screens for the boring log data that would then be filled in by in-house forces or outside consultants. It is also envisioned that read only access to stored data would be made available over NJDOT's website.

Ongoing maintenance must also be addressed once a GEOGIS is implemented. Specifically hardware and software support and most importantly knowledgeable staff to maintain the proposed GEOGIS database.