Prototype Geotechnical Information System

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The concept of a geotechnical information system (GTIS) that integrates the geotechnical data base of a particular area into a geographical information system is discussed in this paper. The geotechnical data base is obtained from earlier soil investigations and is continuously updated by adding the results of new investigations. The GTIS can be used to estimate soil properties at a specified location within a geographical area that may have not yet been explored. A "synthetic" soil boring log and profile can be generated for a particular site within the geographical area using the existing information in the data base of neighboring boring logs in addition to other subjective information about the area such as its deposition history. The feasibility of this concept is demonstrated by a prototype GTIS developed along these lines for part of Jefferson Parish County in New Orleans.

A flow chart for a typical geotechnical investigation is shown in Figure 1. For a given site under consideration for development, the engineer first identifies its location on topographic, geological, and local street maps to assess the general soil conditions. The engineer then refers to the archives of his firm or agency to survey geotechnical investigations performed earlier in the vicinity of the site before designing a final exploration program. The quality and availability of such a geotechnical data base may prove to be a decisive factor in designing an optimal soil exploration program or in winning the contract. The soil exploration program is then designed, which involves drilling and logging of boring holes at the site, obtaining soil samples for laboratory testing, and possibly performing some in situ soil testing. Shallow and deep soil borings are the most important components of any geotechnical investigation; they reveal subsurface conditions and provide disturbed or undisturbed samples for laboratory testing. Results from the laboratory testing programs define characteristics and the mechanical properties of the soil such as grain size composition, strength, permeability, and deformation potential. These parameters form the basis for the selection of the soil as a construction material or its suitability as a foundation material. The results of a geotechnical investigation are usually summarized in a detailed log such as that shown in Figure 2.

The quality of a technical soil report in many cases depends on the experience of the person writing it. For example, a field boring log form completed by a geologist may contain data on color, consistency, presence of organics, as well as a thorough visual classification. By contrast, a form filled out by an inexperienced technician may only provide a simple visual description, such as "sand" or "gravel." Weather conditions, human errors, and insufficient documentation may produce incomplete or erroneous data. Human errors are also possible in the office during reading, interpreting, or rewriting of the field data. The same types of problems may also arise in the laboratory, where some details of test procedures may be omitted. These errors may result in an ill-planned investigation culminating in underestimated or overestimated critical soil properties. The first consequence may prove to be disastrous and the second to be costly.

Based on the results of the exploration program, the designer proceeds to produce a final structural design of the project. In few instances, it may become necessary to acquire additional information about the subsoil properties before commencing the structural design. As outlined in Figure 1, five different tasks are conducted at the office that involve human resources and manipulation of data collected from different sources that may not always be compatible. Although standard techniques to be used in the field and the laboratory are discussed in published guidelines, ample room exists for personal interpretation. These tasks can be automated and standardized by an organization or firm to optimize efficiency and reduce the associated uncertainties.

Discussed in this paper is the concept of a computerized geotechnical information system (GTIS) that integrates tasks 1, 2, 4, and 5 using a geographical information system (GIS), relational data base management, expert system technology, and conventional computer programming. The general strategy of the GTIS will be presented first, followed by an overview of a prototype GTIS developed for part of Jefferson Parish County in the greater New Orleans area.

GENERAL STRATEGY OF GTIS

A GTIS designed to operate on a personal computer or a workstation using commercial or locally developed software could function as (a) a predictor of subsoil conditions at an unknown location, or (b) a repository of information about previous investigations conducted in the area.

In order to assess the prevailing conditions at an unknown location, the user would access first a library of electronic GIS maps on which the site location is identified. An area of influence would be specified, with the unknown site at its center, to identify any previous soil borings and their associated soil investigations, which may help in determining the prevailing conditions at the unknown site. Based on the identification prompted by the GIS, the geotechnical data base would then be accessed, and a summary report of previous investigations would be prepared, along with a probable synthetic stratigraphy for the site. The information contained in

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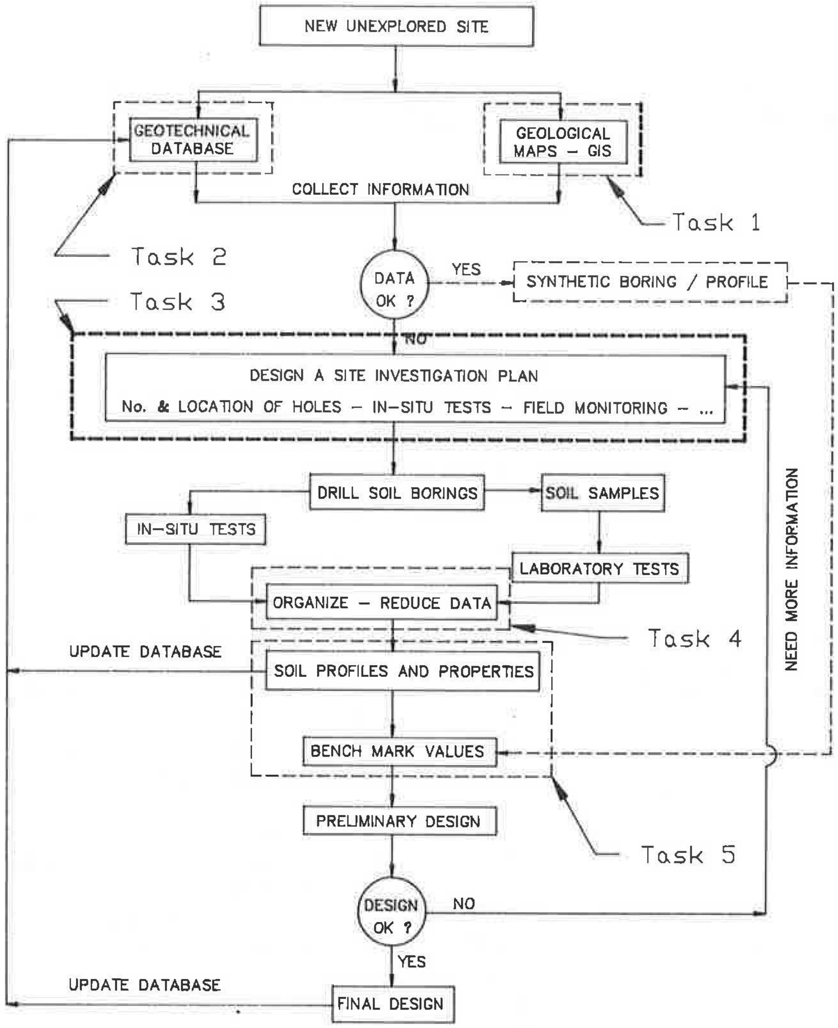


FIGURE 1 Flow chart of a geotechnical investigation.

the data base would be formulated by transferring old archives into computer records or through continuous updates with new data from ongoing exploration programs. The software packages to be used in the GTIS must be compatible to ensure full automation of the process. In addition to offering higher efficiency and better time management, software compatibility would also reduce the possible human errors associated with entering the data more than once.

A GTIS package would consist primarily of four basic modules implemented to perform the tasks of the flow chart indicated in Figure 3. They should be able to run as independent entities or in a fully interactive environment, depending on the application and the preference of the user. The four modules are detailed in the following sections.

Electronic Maps

The electronic computer maps (Module M-1) of the geographical area under consideration are the major feature in a GTIS system. These electronic maps could be purchased from a GIS vendor or digitized or scanned directly by the user from prints using a commercial CAD software or a scanner. Several vendors produce GIS maps for many parts of the United States either for personal computers or workstations. An ideal electronic map library would contain sets, or layers, of geological, topographical, and street maps of the geographical area. In order to expand these GIS maps into a GTIS, the map library would have to be customized further by adding maps, or layers, showing the exact locations of previous soil investigations conducted in the area. These GTIS maps would be updated continuously by appending any new investigations as they become available. Ease of use, price, flexibility, and the offered features should all be considered in the selection of a CAD system for a GTIS. Zooming, panning, layering, and the capability of exchanging data with other software are some of the required features in such a CAD system. The different maps in the GTIS should all share a common reference to allow for exchanging information among the different modules. A standard coordinate system, such as the Coast and Geodetic Survey State Coordinates System (CGSSCS), and unique identification codes should be used on all maps for that purpose. For a given site, the GTIS maps would be searched, and a file containing the identification codes and

Sample No.	SAMPLE Depth—Feet From	SAMPLE Depth—Feet To	STRATUM Depth In Feet	VISUAL CLASSIFICATION	*Blows per Foot	Symbol Log	Scale feet	qu (lbs./sq.ft.)	WATER CONTENT (percent)	UNIT WEIGHT (lbs./cu. ft.) DRY	UNIT WEIGHT (lbs./cu. ft.) WET	ATTERBERG LIMITS L.L.	ATTERBERG LIMITS P.L.	ATTERBERG LIMITS P.I.
			0.0				0							
			0.1	ASPHALT										
			1.5	SHELLS										
1	3.5	4.0		MEDIUM STIFF TO STIFF TAN AND GRAY CLAY W/SILT AND WOOD				2425	33.8	84.7	113.3			
2	6.5	7.0						1150	60.2	64.2	102.9	93		
			8.0											
3	10.0	10.5		SOFT GRAY CLAY W/SPECKS OF WOOD			10	880	66.0	60.9	101.1			
			11.0											
4	14.0	14.5		VERY SOFT GRAY CLAY W/ORGANIC CLAY LAYERS AND WOOD				350	99.5	45.7	91.2			
			15.5											
5	19.0	19.5		MEDIUM STIFF GRAY SILTY CLAY W/CLAY LAYERS			20	1600	28.6	93.8	120.6			
			20.0											
6	21.5	22.0		VERY SOFT GRAY CLAY W/FEW SHELL FRAGMENTS				440	63.3	63.1	103.0			
7	23.0	23.5						490	67.5	60.6	101.5			
			24.0											
8	24.0	25.5		DENSE TO VERY DENSE GRAY FINE SAND	30=0.8'									
9	26.5	28.0			30=0.6'									
10	28.5	30.0			30=0.7'		30							
11	33.5	35.0			30=0.4'									
12	38.5	40.0			30=0.9'		40							
			42.5											
13	43.5	45.0		MEDIUM DENSE GRAY FINE SAND	20									
			47.0											
14	47.5	48.0		SOFT TO MEDIUM STIFF GRAY CLAY W/SAND POCKETS & SHELL FRGMTS.				845	45.6	74.9	109.1	45		
15	49.5	50.0	50.0				50							

CLAY SILT SAND ORGANIC

Predominant type bold. Modifying type light.

* 140 lb. hammer dropped 30in. on 2in. splitspoon sampler after first being seated 6 in.

REMARKS:

FIGURE 2 Typical geotechnical exploration boring log.

coordinates of earlier soils investigations at the vicinity of the site would be prepared for analysis by the other modules of the GTIS.

Geotechnical Data Bases

This module (M-2) would consist of the data bases and tailored programs written in the data base management software environment to manage the data bases and perform the required searches. In order to limit the size of the data base file for a particular geographical area, a series of data base files should be created instead. Each record in the first data base set (DB-1) would correspond to one particular soil boring hole drilled in the geographical area. A typical record in DB-1 would contain a unique identification code of the hole, its location according to the coordinate system used in the electronic map, its maximum depth, whether or not soil samples were recovered, and a list of the in situ tests conducted at the hole, if any. The second data base set (DB-2) would contain the results of the laboratory tests performed on the soil samples recovered from a hole, along with identification codes. Consequently, several records in DB-2 will be associated to one hole and be related to one record in the DB-2 file. A third set of data base files (DB-3) would be required to describe any information about the in situ tests performed at the location of a hole. Records of DB-3 files would contain references to other electronic or printed files depending on the nature of the conducted test. Records in any of the three data base files can be easily related to each other and to the boring through the unique identification code and the coordinates.

The data base module M-2 would be accessed by the other modules in the system to furnish the required information pertaining to the particular holes selected for estimating the synthetic borings and soil properties. When a particular boring hole in DB-1 is included in the estimation analysis, the other data bases (DB-2 and DB-3) are scanned to retrieve the specific information about the soil conditions.

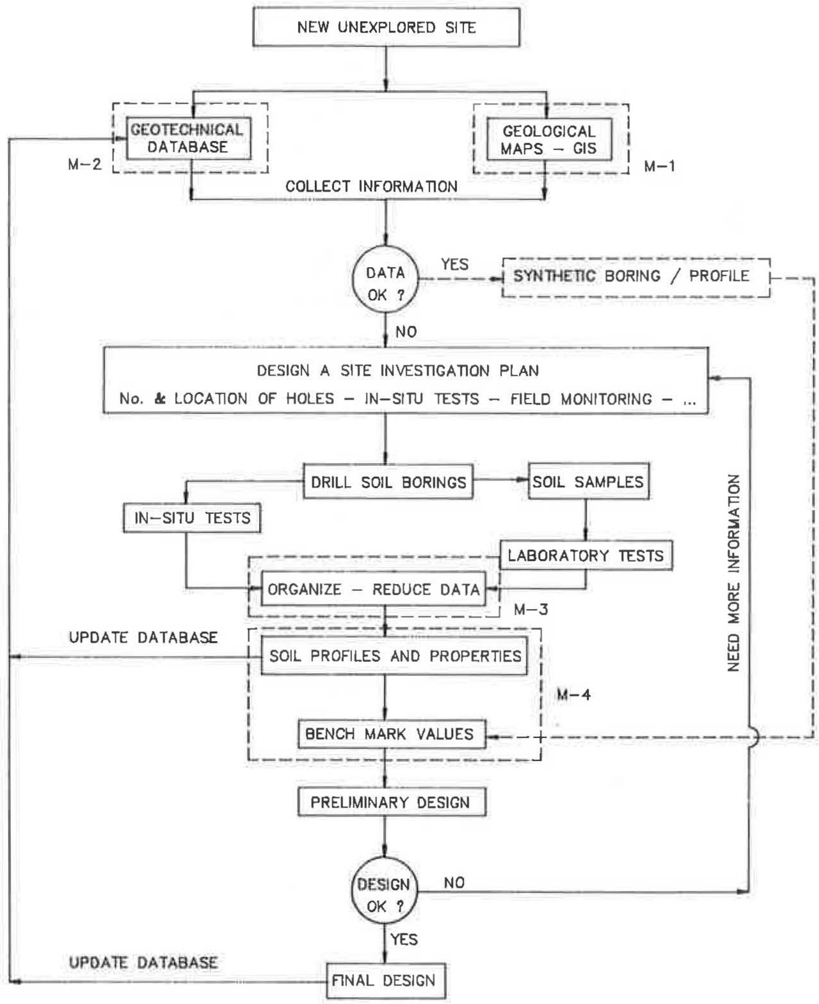


FIGURE 3 Modules of GTIS.

Data Acquisition and Management

Module M-3 consists of a comprehensive package, or a group of programs, that manages both field and laboratory data and upgrades the data bases in M-2 and the electronic maps in M-1. This module has no specific structure; it should be specifically tailored to meet the needs of the agency using it and the sources of information. The software recommended for this module may include commercial packages such as spread sheets or data base management programs, specialized commercial software for soil investigation, or programs developed locally by the agency in a conventional programming language.

Estimator/Predictor

In this module (M-4), soil conditions at an unexplored site are estimated using the data generated by the first three modules. Module M-4 would prepare a summary report listing all the existing boring holes in the vicinity of the site within a specified distance of influence. An expert system program would be required to combine the available objective information, such as distances and data from previous holes, with the subjective information, such as the known geological trends, special soil formations in the area, and local engineering experience. The information provided by the expert system would be used to produce a "most likely" synthetic boring at the location of the unexplored site. This synthetic boring would be used along with data from the other soil investigation to construct soil profiles across that particular site. The provided information could be used by the agency to design an efficient soil exploration program, to perform feasibility studies, or for contract bidding purposes. Following the full soil exploration, the newly acquired data would be appended to the data bases and the electronic maps for future use.

The four modules (M-1, M-2, M-3, and M-4) could be fully interactive or independent of one another. For example, it may not be necessary to identify the information regarding previous investigations from the electronic maps because the user may search the data base directly by specifying a set of limiting coordinates to extrude the existing boring holes within these limits. The modules could be fully developed locally by an agency or a combination of commercial and developed software. To demonstrate the philosophy of a GTIS system, the prototype system TU-DIRT was developed at Tulane University following the above strategy. This prototype is presented in the following sections.

GTIS PROTOTYPE TU-DIRT

The prototype system is targeted toward a specific portion of Jefferson Parish in the New Orleans metropolitan area. Such a small area was selected to control the massive data base size required for a particular geographical area. Although the electronic maps and data bases created for this project are site specific, the other programs that perform computations, searches, and data management are all generic and can be used for other geographical areas with minor modifications. A combination of commercial software packages and programs written in conventional languages developed at the Department of Civil Engineering at Tulane were used to develop the four modules of the GTIS. It should be noted that the commercial packages were selected from the software library available at Tulane, but other computer packages could be used to develop similar GTIS systems.

TU-DIRT Electronic Maps

The geology of the prototype area is dominated by the continuous migration of the Mississippi River over the past 15,000 years (*1*). During this era, fine grained alluvial deposits advanced to the gulf in the form of river deltas created by the many shifts in the river course. Each time the river created a new alluvial fan, it would abandon one course in favor of a shorter and more direct route to the gulf. During the last 5,000 years several major delta complexes have formed, resulting in a complex subsurface geology dominated by the Pleistocene formations and the Holocene deposits. The Pleistocene formations consist of interbedded strata of clays, silts, and sands. High strength deposits are encountered in the overconsolidated crust and are sometimes labeled "local bedrock" (*2*). These deposits form the foundation strata for most heavy structures in the New Orleans area. The soft sediments of the Holocene epoch are typically divided into natural levees, point bars, and backswamp deposits. The natural levees are the slightly elevated ridges that occur on both sides of a water stream. Point bar deposits are the direct result of the lateral migrations of the river when erosion of the banks occurs, and the coarser materials are redeposited immediately downstream at the convex side of the river bank. Backswamp deposits are formed by the deposition of fine sediments in the shallow ponded areas of overbank flows. Backswamp deposits consist primarily of thinly laminated clays and silts, which sometimes exhibit a high organic content. The geological nature of the subsurface desposits governs the selection of foundation systems of a structure. Shallow footings are common on natural levees but are not feasible on backswamp deposits. The depth of the Pleistocene formations is also a strong factor for the selection of a deep foundation type and geometry.

A library of maps was established for the prototype system TU-DIRT showing the main geological features of the subsurface and a schematic of the city streets. Because of the large area covered and the amount of information on city street maps, a series of layers and blocks with varying details was created in the prototype. Figure 4 shows a general view of the region included in the prototype. This particular map was digitized using AutoCAD (*3*) and a digitizing tablet. CGSSCS was used as the standard reference to digitize the details shown on the maps.

TU-DIRT Geotechnical Data Bases

The data base management software dBase III-plus (*4*) was used to organize and manage the prototype data bases. A total of 54 boring holes was coded in the data base, representing more than 650 soil samples tested. The data base information was provided by two local geotechnical engineering firms and the U.S. Army Corps of Engineers, New Orleans District. A typical record in the first data base (JP-LOC.DBF) contains the unique identification of a boring hole, its location, whether soil samples were recovered and tested, and if in situ tests were conducted. The data entry screen of JP-LOC.DBF is shown on Figure 5. Logical variables T or Y for True or Yes, and F or N for False or No are used to indicate the type of tests performed on each hole to provide faster screening of the massive data. The coordinates of each hole are specified in CGSSC to guarantee compatibility with the electronic maps. The second data base (JP-PROP.DBF) contains results of the tests performed on the samples recovered from each hole, as shown on the sample data entry screen on Figure 6. New information and additional holes can be coded into the data base files either directly from the interactive entry screens or by retrieving output files created in the field or the laboratory. Reading data files is more efficient because it eliminates the possible human errors associated with reentering the data, whereas the screen entry is more suited for the gradual transfer of existing data in the archives.

Two programs were written in the dBase III environment to access and mange the data base files. The first program is strictly for data input and editing of the existing data base files. The second program searches the database for previous borings within a specified radius of influence and provides a summary report of the findings. The summary report lists all of the holes within the search area specifying the distance and angle in the X-Y plane from the unknown site as well as the stored values of the requested soil properties. This information is used to produce a synthetic boring for the site.

Field and Laboratory Data Management

Two computer programs, BORLOG and LABLOG, were developed at Tulane for the acquisition and reduction of the field and laboratory data according to standard ASTM formats compatible with the GTIS. The programs were written in BASIC for use on IBM personal computers.

BORLOG

All pertinent information about the site conditions, weather, and working conditions should be recorded by the drilling crew or a supervisor during drilling of a soil boring. Because it is not feasible to obtain samples at every foot along the depth of a boring, the technician at the site is required to monitor the drilling carefully. This information is usually recorded on paper forms and transcribed at the office.

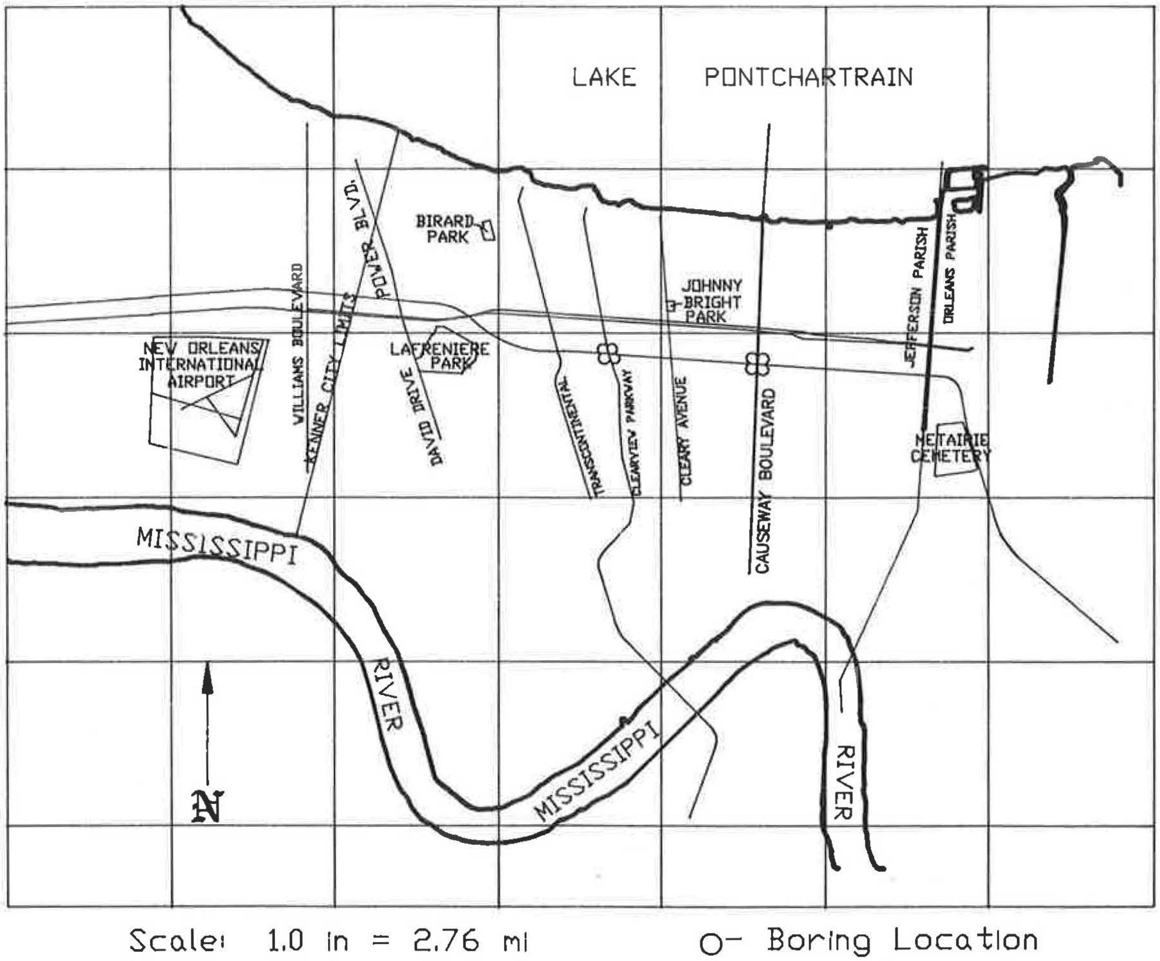


FIGURE 4 General view of Jefferson Parish, Louisiana.

TULANE UNIVERSITY DEPARTMENT OF CIVIL ENGINEERING
GENERAL BOREHOLE DATA SHEET

Date: 08/30/89 Boring Identification: HEBERT-B1
Location: X= -1298452.00000 Y= -3498763.00000
Bottom Depth of Hole: 100.00

Were Samples Recovered ? Y
Were Lab Tests Performed ? Y
SHEAR: UCT Y Triax Test Y Direct Shear N
GENERAL: Consolid Y Permeability Y
Atterberg Y
Were In-Situ Tests Performed ? N
SPT N CPT N PMT N FVT N

FIGURE 5 Data entry screen for JP-LOC.DBF.

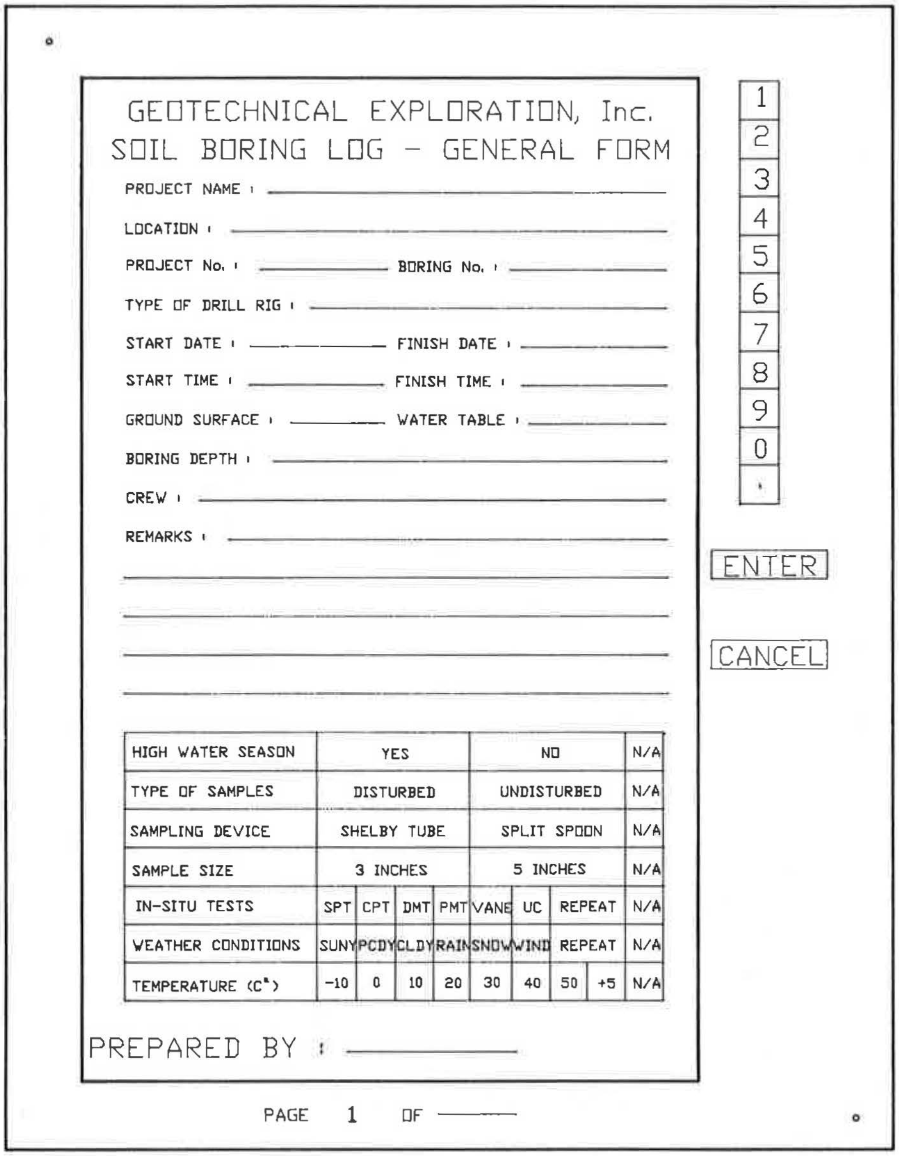
TULANE UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
SOIL SAMPLE INPUT FORM

SAMPLE SOURCE: US-COE LOCATION: JP LEVEE 41-U ZONE: 2-F
NORTH COORD: 1258.33 EAST COORD: -3025.0
DEPTH: 41.9 DATUM: NGVD DEPTH WT: 0.0 GS: 5.7
USCS CLASSF: CH VISUAL CLASSF: PLASTIC CLAY, GRAY, SHELLS
SAMPLE TYPE: UNDIST DRY WT: 58.3 WET WT:98.0
WATER CONT: 72.6 LL: 80 PL: 24 LI: 0 PI: 56
TESTS PERFORMED ON SAMPLE: TRIAX CONFIDENCE: NA
SHEAR TEST: Q-TEST Qu: NA C: 448.0 C': NA
CLAY FRACTION: NA PHI: 0.0 PHI': NA GRAIN SIZE: NA
PERMEAB: NA COMPR INDEX: NA PENETROM: NA
COMMENTS:

FIGURE 6 Data entry screen for JP-PROP.DBF.

The computerized boring log program BORLOG was developed to provide a unified format for recording boring logs according to the ASTM standards (*5*). The program simplifies documenting soil boring logs and provides the data base files required for the GTIS system. BORLOG is interactive and user-friendly software that provides on-line data error checks, instructions, and assistance. The input data for BORLOG can be entered directly at the site via a portable computer, or indirectly by transcribing written data forms at the office. Both methods follow the format shown in Figures 7 and 8 and yield identical output files (*6*).

Direct Entry Mode Direct entry is performed at the site with a DOS-type portable computer installed on the drilling rigs. The information required for the program is based on the visual and field tests specified by ASTM, such as the



GEOTECHNICAL EXPLORATION, Inc.
SOIL BORING LOG – GENERAL FORM

PROJECT NAME :
LOCATION :
PROJECT No. : BORING No. :
TYPE OF DRILL RIG :
START DATE : FINISH DATE :
START TIME : FINISH TIME :
GROUND SURFACE : WATER TABLE :
BORING DEPTH :
CREW :
REMARKS :

HIGH WATER SEASON	YES				NO			N/A
TYPE OF SAMPLES	DISTURBED				UNDISTURBED			N/A
SAMPLING DEVICE	SHELBY TUBE				SPLIT SPOON			N/A
SAMPLE SIZE	3 INCHES				5 INCHES			N/A
IN-SITU TESTS	SPT	CPT	DMT	PMT	VANE	UC	REPEAT	N/A
WEATHER CONDITIONS	SUNY	PCDY	CLDY	RAIN	SNOW	WIND	REPEAT	N/A
TEMPERATURE (C°)	-10	0	10	20	30	40	50 / +5	N/A

PREPARED BY :

1 2 3 4 5 6 7 8 9 0 .

ENTER

CANCEL

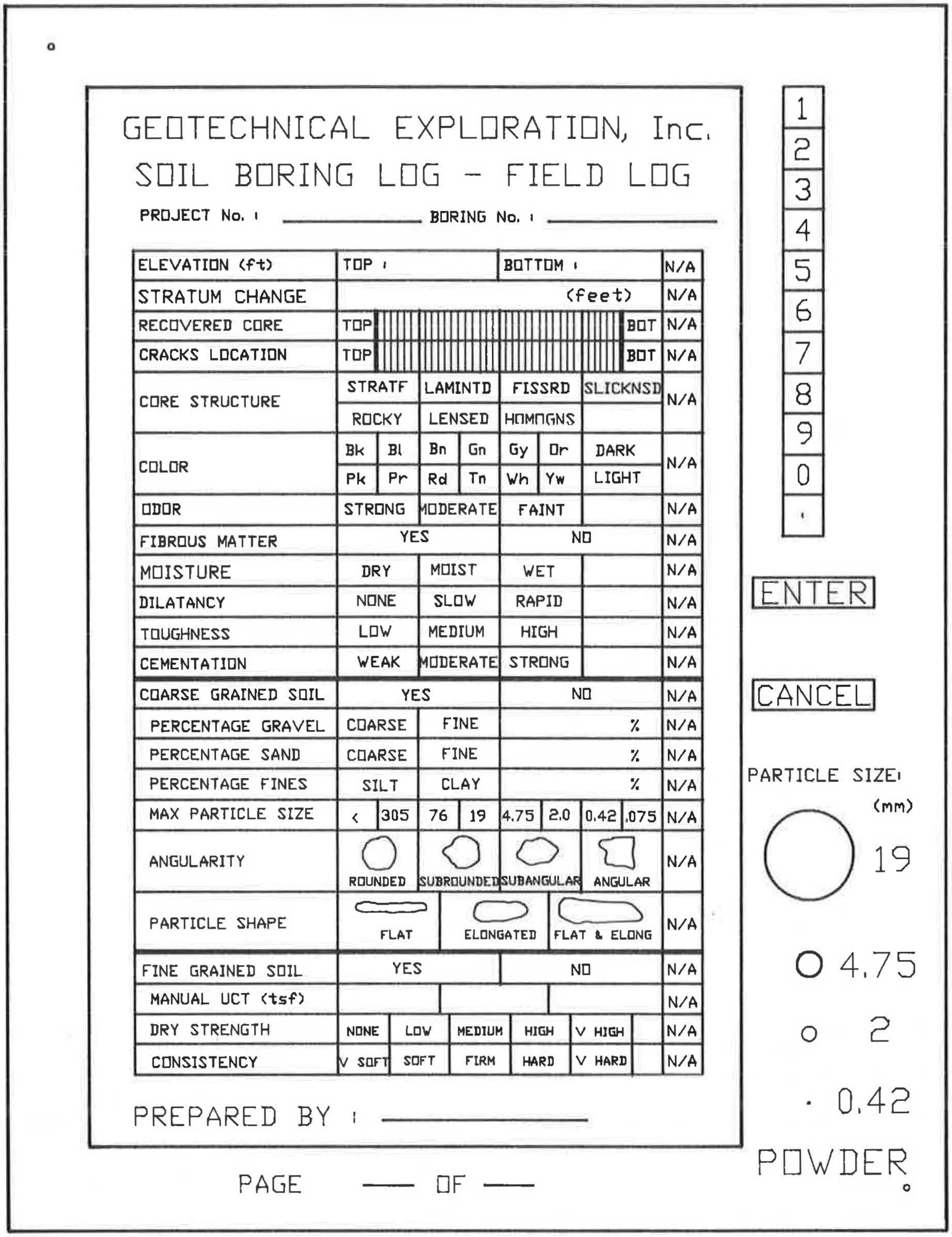
PAGE 1 OF

FIGURE 7 General form for soil boring logs.

approximate grain size distribution. However, this data can be updated later by LABLOG to include the more accurate results from detailed laboratory tests, such as the exact grain size distribution. A series of screens similar in format to Figures 7 and 8 are used in BORLOG to acquire information. Details of these screens are explained later.

Indirect Entry Mode For indirect entry, the drilling crew fills out a general form, Figure 7, per boring per day at the start of drilling. The first nine lines of the general form contain the information necessary to identify the exploration program (project name, location, crew, equipment, weather conditions, time, and date). It is written by the crew on the paper form. The next five lines on the form are for the crew to include their remarks, such as the use of special equipment, site condition, or weather changes. Starting from line 15, the crew enters the responses by checking the appropriate box or boxes on the form. The N/A entry is used when the entry is not applicable or when no data is available.

Figure 8 shows the form accompanying each sample recovered during the investigation. On that form, the crew defines the elevations of the core and indicates if any changes occur in a soil layer. The quality of the core can be described by indicating its length and the location of any observed cracks on the two scales representing a standard 3-ft-long sampling tube. Other information on the recovered core will be described in the subsequent lines, including its color, odor, and moisture content. Some of the information on the form can be obtained in the field by performing in situ tests described by ASTM (D-2488). The remaining information is entered by checking the appropriate box or boxes on the form for indirect entry option. The shapes and sizes of the soil particles are required to classify coarse grained soils and to determine their engineering properties. The crew can use the grain shapes plotted on the form to identify the shape of soil particles. The



GEOTECHNICAL EXPLORATION, Inc.
SOIL BORING LOG - FIELD LOG

PROJECT No. : ______ BORING No. : ______

ELEVATION (ft)	TOP :				BOTTOM :				N/A
STRATUM CHANGE	(feet)								N/A
RECOVERED CORE	TOP							BOT	N/A
CRACKS LOCATION	TOP							BOT	N/A
CORE STRUCTURE	STRATF		LAMINTD		FISSRD		SLICKNSD		N/A
	ROCKY		LENSED		HOMOGNS				
COLOR	Bk	Bl	Bn	Gn	Gy	Or	DARK		N/A
	Pk	Pr	Rd	Tn	Wh	Yw	LIGHT		
ODOR	STRONG		MODERATE		FAINT				N/A
FIBROUS MATTER	YES				NO				N/A
MOISTURE	DRY		MOIST		WET				N/A
DILATANCY	NONE		SLOW		RAPID				N/A
TOUGHNESS	LOW		MEDIUM		HIGH				N/A
CEMENTATION	WEAK		MODERATE		STRONG				N/A
COARSE GRAINED SOIL	YES				NO				N/A
PERCENTAGE GRAVEL	COARSE		FINE				%		N/A
PERCENTAGE SAND	COARSE		FINE				%		N/A
PERCENTAGE FINES	SILT		CLAY				%		N/A
MAX PARTICLE SIZE	<	305	76	19	4.75	2.0	0.42	.075	N/A
ANGULARITY	ROUNDED		SUBROUNDED		SUBANGULAR		ANGULAR		N/A
PARTICLE SHAPE	FLAT		ELONGATED		FLAT & ELONG				N/A
FINE GRAINED SOIL	YES				NO				N/A
MANUAL UCT (tsf)									N/A
DRY STRENGTH	NONE	LOW	MEDIUM		HIGH	V HIGH			N/A
CONSISTENCY	V SOFT	SOFT	FIRM		HARD	V HARD			N/A

PREPARED BY : ______

PAGE ___ OF ___

1 2 3 4 5 6 7 8 9 0 .

ENTER

CANCEL

PARTICLE SIZE: (mm)

19

4.75

2

0.42

POWDER

FIGURE 8 Form for details of boring logs.

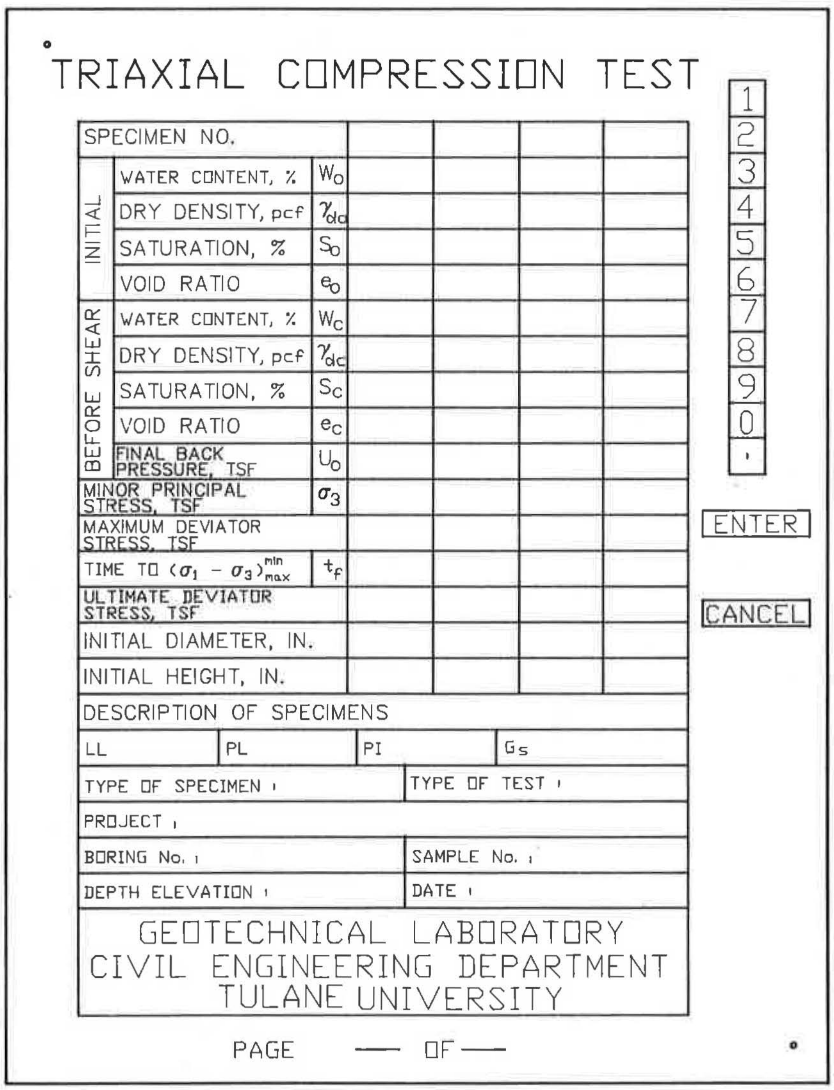
circles on the right side of the form on Figure 8 represent the standard ASTM sizes of soil particles. These circles are plotted to scale on the production version of the form for use in the field for measuring the size of soil particles. In a direct entry in the field, consecutive screens, identical to the paper form on Figure 8, will be displayed on the monitor of the portable computer. Particle shapes and sizes will also be displayed on the computer screen in the direct entry option.

Information Retrieval The data recorded on the special paper forms, or as a file on the computer disk, is transferred

back by BORLOG to a computer at the office. This task does not require engineering background and needs minimal computer skills. For indirect entry, data will be entered via an electronic transducer. The current version of BORLOG uses a Summagraphics MM 1201 digitizing tablet with four cursor buttons to read the forms into a computer. The four buttons on the cursor pad execute the functions pick, enter, cancel, and quit. The information collected on the forms, or by BORLOG, is used for classifying the soils and to expand the geotechnical data base of the GTIS system. The keyboard of the office computer is used to enter the first lines written on the general form. The form can then be affixed to the digitizing tablet, and the tablet is calibrated using the two small circles at the top and lower corners of the paper form. The remaining data on the forms will be read by placing the tablet cursor anywhere within the boundaries of the marked box at the field and pressing the pick button on the pad. Numerical values can be entered using the numerical boxes on the top right corner of the forms or the keyboard. Entries can be canceled by picking the cancel box or pressing the cancel button on the pad. The enter box, or enter button on the pad, is used to enter numeric entries. The quit button is used to abort the session. During the session the computer displays the form on the screen showing the questions, possible answers and the selected responses in three different colors. The user is asked at the end of each screen to check the data before it is written to the data files. BORLOG creates two data files: a standard ASCII file and a GTIS file to be read by dBase III.

LABLOG

A series of forms was developed for most of the standard laboratory tests frequently performed in soils investigations. These laboratory forms are also available in both paper as well as a computer format for direct or indirect entry mode. Figure 9 shows the form pertaining to the triaxial test. The computer version of the forms is the program LABLOG. LABLOG acquires the information and prepares output reports and files for automatic upgrades of the data bases according to a format similar to that used by BORLOG.


TRIAXIAL COMPRESSION TEST

SPECIMEN NO.					
INITIAL — WATER CONTENT, %	W_o				
INITIAL — DRY DENSITY, pcf	γ_{do}				
INITIAL — SATURATION, %	S_o				
INITIAL — VOID RATIO	e_o				
BEFORE SHEAR — WATER CONTENT, %	W_c				
BEFORE SHEAR — DRY DENSITY, pcf	γ_{dc}				
BEFORE SHEAR — SATURATION, %	S_c				
BEFORE SHEAR — VOID RATIO	e_c				
BEFORE SHEAR — FINAL BACK PRESSURE, TSF	U_o				
MINOR PRINCIPAL STRESS, TSF	σ_3				
MAXIMUM DEVIATOR STRESS, TSF					
TIME TO $(\sigma_1 - \sigma_3)^{min}_{max}$	t_f				
ULTIMATE DEVIATOR STRESS, TSF					
INITIAL DIAMETER, IN.					
INITIAL HEIGHT, IN.					

DESCRIPTION OF SPECIMENS

LL | PL | PI | Gs

TYPE OF SPECIMEN : | TYPE OF TEST :

PROJECT :

BORING No. : | SAMPLE No. :

DEPTH ELEVATION : | DATE :

GEOTECHNICAL LABORATORY
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FIGURE 9 LABLOG form for triaxial tests.

Synthetic Soil Estimator

A synthetic boring can be produced by the expert system BORPROF, which combines objective and subjective information in the analysis. The objective information consists of the summary reports extracted from the data bases. Meanwhile, the subjective information consists of descriptive knowledge of the geographical area, including geological trends such as a point bar, special soil conditions such as a hydraulic fill, and information supplied by experts and local engineers. The expert system and the external routines were built using Turgo Pascal version 4.0 and BASIC. The system combines the data obtained from the holes neighboring the proposed site through a weighing algorithm to develop a synthetic boring. The weighing algorithm adopted in the current version of BORPROF is a power formula of the distance (R_i) multiplied by a function of the difference in azimuth $F(\text{ALPHA}_i)$ between the required synthetic boring and each of the actual borings. Each property of the soil obtained from Boring i is assigned a weight in the calculations that expresses its "closeness" to the proposed site. The following formula is currently used to obtain the weight factor W_i multiplier for each hole:

$$W_i = 1/R_i^a * F(\text{ALPHA}_i) \quad (1)$$

The exponent a of the power function and the nature of the function $F(\text{ALPHA}_i)$ are specified by the expert system by combining the distinctive trend in the data along with the subjective information retrieved from the knowledge base. The information from the knowledge base is extracted through a consultation with the expert system. The system first queries the user for the location of the site and the trend observed in the data. It then consults its knowledge base to identify the distinctive features of the area under consideration and proposes weighing factors along with their associated confidence. For the particular application discussed in this paper, some geological features are important. Sand ridges, old tributaries, and backswamp deposits produce a complex variation in stratification with different levels of homogeneity. Sand ridges are typically elongated and curved, resembling a moon crescent. Accordingly, properties of a hole centered in a sand ridge will be approximated better by the average of the holes following the longitudinal axis of the sand ridge than by the average of those following the transversal axis, which may lay beyond the width of the ridge. The knowledge of the extent of the ridge combined with the inclinations of its axes will be used to specify weighing factors for the data obtained from the different holes. This procedure is still under development, and further refinement will be made to the statistical model to improve its predictions.

APPLICATION

General

The GTIS TU-DIRT is used herein to simulate a soil boring in Jefferson Parish, Louisiana. The programs BORLOG and LABLOG were used earlier to prepare the data base files in the GTIS. Locations of the borings are entered on the LOCATION layer of the AutoCAD map of the area. The boring location is indicated by inserting a BLOCK entity with an attribute label. The BLOCK insertion point defines the coordinates of the soil boring, and the attribute tag is an identification name for the boring, which is used to link to the dBase III records containing the soil boring data.

The procedure to generate a synthetic boring is as follows:

1. The desired location of the boring is indicated on the map by a symbol.
2. A radius of influence is selected to draw a circle that surrounds the holes in the data base that will be used. Note that the analysis can be performed more than once. Using the Selection Set capabilities of AutoCAD, the holes within the circle are selected.
3. With the selection set defined, an AutoLISP routine is invoked to execute the ATTEXT (Attribute Extraction) command of AutoCAD to produce a CDF-Format file, which can be transported to dBase III for further processing. This file contains the coordinates and identification code of all borings within the circle of influence.
4. Using the CDF-Format files, the data base files are searched for full information on the holes, and a summary report is prepared.
5. The summary report is sent to the EXPERT system BORPROF, which then produces the synthetic boring.

Example

From Figure 4 a site identified for exploration, which is near Johnny Bright Park, in square 4-E, is shown in Figure 10, with all the layers turned on, showing all the streets. Using the ZOOM command the area was enlarged, as shown on Figure 11. The site, at the intersection of 19th Street and Neyrey Drive, is indicated by a dot. Two analyses were performed, with a radius of influence of 400 yd shown by the inner circle on Figure 11 and a radius of influence of 530 yd shown by the outer circle. Three and five previous holes are covered by the circles. Their characteristics are extracted and sent out to two files and are listed in Tables 1 and 2. This area consists mostly of backswamp deposit, and the Pleitocene formation is found at a depth of a 100 ft. The depth of the boring was set at 75 ft with increments of 5 ft. No particular features exist around the site, and the weighing function was set to $1/R$ with no account for angle effect. Based on the above information BORPROF searched the data bases and produced the synthetic boring presented in Table 3. The table shows a possible stratification along with benchmark values for the soil properties. The synthetic hole obtained using five holes is presented in Table 4. Little difference exists between the two synthetic borings, indicative of the relative homogeneity of the area.

CONCLUSIONS

The concept of a GTIS that combines the geotechnical data base of a geographical area with its GIS maps was introduced. The system could be developed and tailored to meet the needs of a specific agency using either commercial packages or lo-

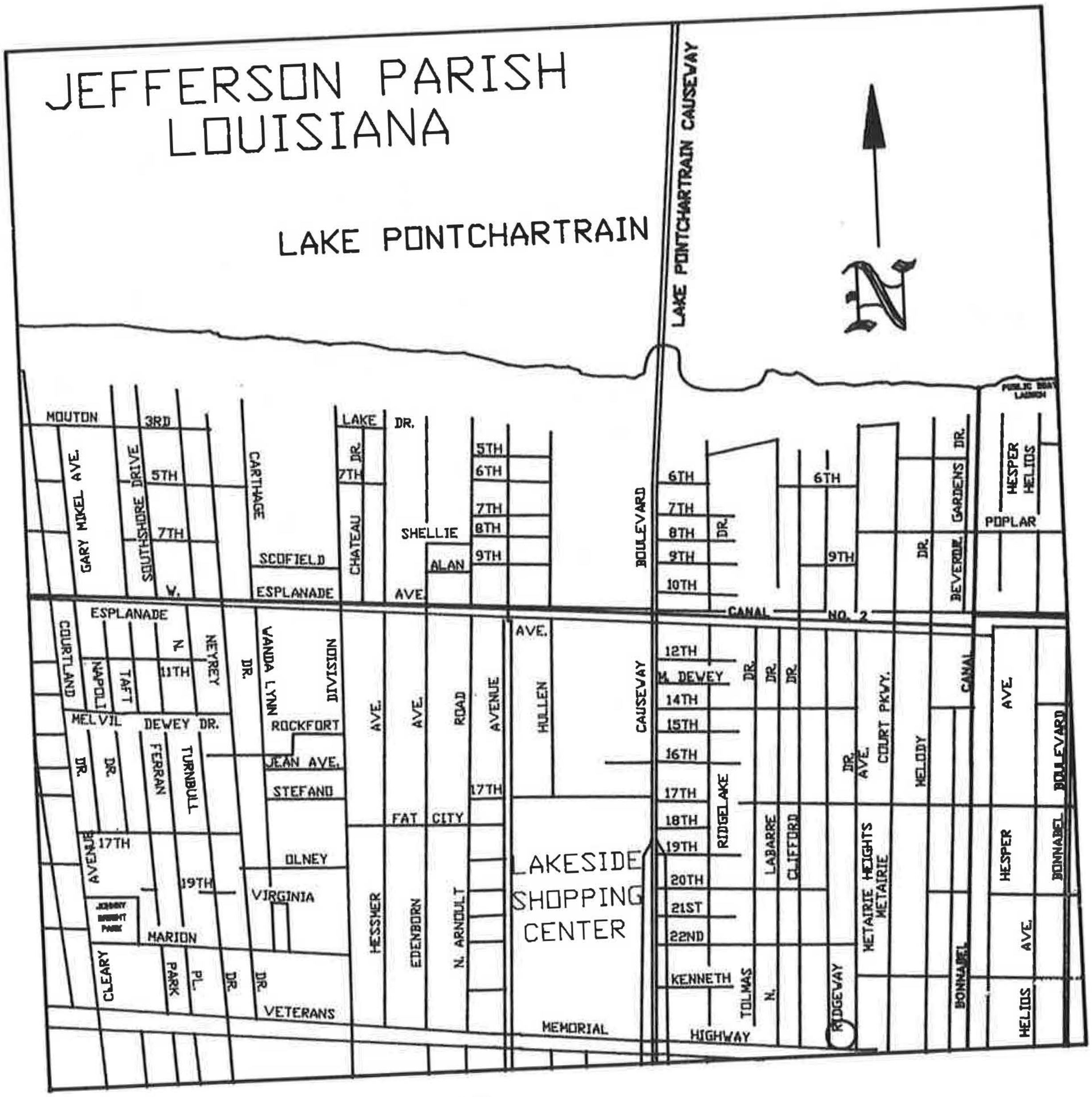

FIGURE 10 Example of application (Square 4-E).

TABLE 1 LIST OF HOLES FOR USE IN GENERATING SYNTHETIC BORING IN BORPROF WITH RADIUS OF 400 yd

Identification	Coordinate East	Coordinate North
JP-8-N68	-2850.00	-1683.30
JP-8-N63	-2716.70	-1791.70
JP-8-N117	-2633.30	-1108.30

TABLE 2 LIST OF HOLES FOR USE IN GENERATING SYNTHETIC BORING IN BORPROF WITH RADIUS OF 530 yd

Identification	Coordinate East	Coordinate North
JP-8-N117	-2633.30	-1108.30
JP-8-N111	-3058.30	-1191.70
JP-8-N94	-3141.70	-1650.00
JP-8-N68	-2850.00	-1683.30
JP-8-N63	-2716.70	-1791.70

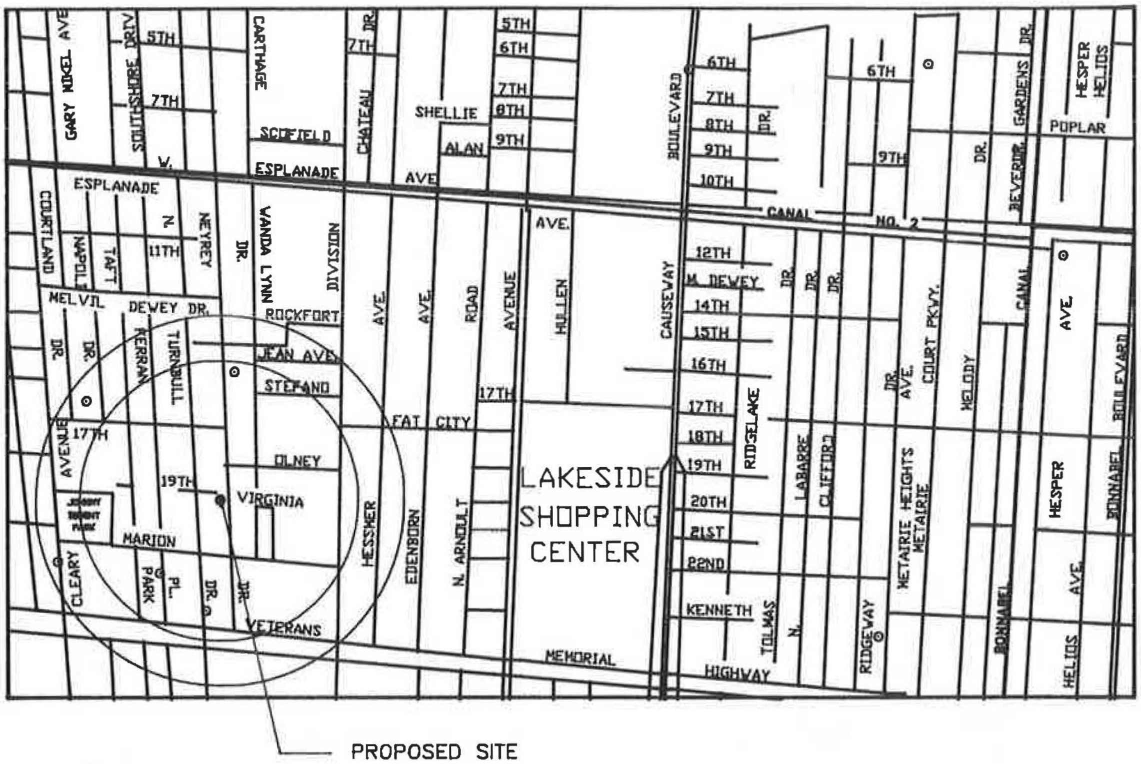

FIGURE 11 Close-up view of site.

TABLE 3 SUMMARY REPORT FOR SYNTHETIC BORING (400-ft RADIUS)

BORING DEPTH (ft)	SOIL TYPE USCS	WEIGHTED AVERAGES Q_u (psf)	LL	PL	PI	SPT
5.00	PT	381.61	0	0	0	0
10.00	CH	235.15	0	0	0	0
15.00	CH	330.00	0	0	0	0
20.00	CH	269.10	0	0	0	0
25.00	SC/CH	170.00	0	0	0	26
30.00	SW	560.00	0	0	0	31
35.00	SW	0.00	0	0	0	17
40.00	CH	550.00	0	0	0	0
45.00	CH	797.31	96	26	70	0
50.00	CH	725.60	0	0	0	0
55.00	CH	1060.00	67	22	45	0
60.00	CH	2690.00	0	0	0	0
65.00	CL	3220.00	34	22	12	0
70.00	CL	2995.00	0	0	0	0
75.00	SC	785.00	24	19	5	30

TABLE 4 SUMMARY REPORT FOR SYNTHETIC BORING (530-ft RADIUS)

BORING DEPTH (ft)	SOIL TYPE USCS	WEIGHTED AVERAGES				
		Q_u (psf)	LL	PL	PI	SPT
5.00	Pt	381.61	0	0	0	0
10.00	CH	278.18	0	0	0	0
15.00	CH	385.27	0	0	0	0
20.00	CH	297.39	0	0	0	0
25.00	CH	312.07	0	0	0	0
30.00	SW	557.82	0	0	0	31
35.00	SW	0.00	0	0	0	17
40.00	CH	550.00	0	0	0	0
45.00	CH	843.31	88	22	66	0
50.00	CH	725.60	0	0	0	0
55.00	CH	1056.17	67	22	45	0
60.00	CH	2690.00	0	0	0	0
65.00	CL	3220.00	34	22	12	0
70.00	CL	2995.00	0	0	0	0
75.00	SC	785.00	24	19	5	30

cally developed software. The geotechnical information to be included in the GTIS is acquired from previous soil investigations and would be updated continuously. The system is capable of estimating soil properties of an unexplored site within the geographical area or to create synthetic soil boring logs and profiles for that site. Data bases from neighboring boring logs and subjective information about the area are used to generate the synthetic data. A prototype GTIS, TU-DIRT, was developed along these lines. The advantages of the computerized format of the GTIS are many and include standardized format for documenting soil investigations, consistency in the information supplied by technicians, reduction in bias, preservation of data, and full interaction with the other components.

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