THE THIRD ANNUAL GEOTECHNICAL, GEOPHYSICAL,
AND GEOENVIRONMENTAL TECHNOLOGY TRANSFER
CONFERENCE AND EXPO
April 20-21, 2006

IMPLEMENTATION OF NC DOT REQUIREMENTS IN gINT

S. Caronna
gINT Software, Windsor, CA, USA

ABSTRACT: Most consultants to the DOT have been using gINT for the storage and presentation of NC DOT site investigation data for many years. Recently gINT Software has been working with the DOT to significantly redesign their database and reports. This paper presents these changes and the added benefits that can be realized beyond log production.

1. INTRODUCTION

Since the early '90s, gINT Software has provided log forms in the format required by the North Carolina Department of Transportation. The specifications for these formats have changed over the years. gINT Software originally obtained the log form specifications from gINT clients, not directly from the DOT, and so much of the structure of the database and reports was left up to our interpretation. Since March of 2006 gINT Software has been working directly with the DOT to make sure the gINT database and reports meet the DOT requirements.

The main considerations in the design of the gINT files are the generation of:

- Log Reports
- Log Sections
- Log Plan Views

As of this date, this work is not completed but enough is done to report the differences with the existing formats and the special features new to the revised format.

With the data in a well-designed database, much more can be accomplished with the data to turn it into useful information.

2. LOG REPORTS

The look of the two log reports (Borehole and Core) has changed little except for some cosmetic alternations and formatting. Following are samples of the current state of the two log forms. These are samples of the single-log-page-per-sheet formats. In addition, two other formats showing two log pages per sheet will also be provided.

NCDOT GEOTECHNICAL UNIT
BORELOG REPORT

PROJECT NO. 8.1500301	**ID.** I-304ER	**COUNTY** NEW ORANGE		**GEOLOGIST** A. BORE
SITE DESCRIPTION Structure No. AB-34. Four hundred meters west of the flag pole, due east of the fire station.				**GROUND WTR (ft)**
BORING NO. BL-1	**STATION** 207+52.6	**OFFSET** 59ft RT	**ALIGNMENT** RP 'CD'	**0 HR.** 24.9
COLLAR ELEV. 2,372.8 ft	**TOTAL DEPTH** 59.4 ft	**NORTHING** 1,007	**EASTING** 725	**24 HR.** 47.2
DRILL MACHINE CME-750	**DRILL METHOD** ROTARY WASH		**HAMMER TYPE** MANUAL	
START DATE 04/05/06	**COMP. DATE** 04/06/06	**SURFACE WATER DEPTH** N/A	**DEPTH TO ROCK** N/A	

ELEV. (ft)	ELEV. DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft) / DEPTH (ft)
2380									
					Ground Surface				2,376.4 / 0.0
2375	2,374.9								**RESIDUAL**
	1.5 / 2,373.1	4	2	2	4	SS-1			Earth Fill: Reddish-brown silty CLAY. (A-7-5)
	3.3	2	2	4	6	SS-2			
2370	2,367.4								2,367.4 / 9.0
	9.0	2	3	3	6	SS-3			**ARTIFICIAL FILL**
2365	2,363.3								2,364.9 / Earth Fill: Tan and gray silty CLAY to SAND with rock fragments at 4.2m. (A-7-5) / 11.5
	13.1	7	6	4	10	SS-4	23		**RESIDUAL** Tan and brown fine gravelly clayey SILT with very fine silica. (A-5)
2360	2,358.3								
	18.0	2	3	2	5	SS-5			
2355	2,353.4								
	23.0	3	2	3	5	SS-6	▽		
2350	2,348.5								
	27.9	1	2	2	4	SS-7			
2345	2,342.7								
	33.6	2	3	3	6	SS-8			2,341.6 / 34.8
2340	2,337.8								**RESIDUAL** Brown and tan and gray clayey SILT. (A-5)
	38.5	6	8	14	22	SS-9	30		
2335									2,333.4 / 43.0
						SS-10	▼		**RESIDUAL** Tan and gray fine sandy SILT. (A-4)
2330	2,328.0								
	48.4	9	9	15	24	SS-11	►		
2325	2,323.1								2,323.9 / 52.5
	53.3	25	43	50/9	93/24	SS-12			**WEATHERED ROCK** SOFT WEATHERED ROCK: Sampled as brown, tan and gray sandy SILT.
2320	2,317.3								
	59.1	50/12			50/12	SS-13	3 gal / min loss		2,316.9 / 59.4
2315									Boring Terminated with Standard Penetration Test Refusal at Elevation 2,316.9 ft in Soft Weathered Rock. Hole backfilled with cuttings 48 hours after completion.
2310									
2305									

NCDOT BORE SINGLE NC_DOT.GPJ NC_DOT.GDT 4/18/06

NCDOT GEOTECHNICAL UNIT
CORE BORING REPORT

PROJECT NO. 8.1500301	**ID.** I-304ER	**COUNTY** NEW ORANGE	**GEOLOGIST** A. BORE	
SITE DESCRIPTION Bridge abutment on US 17 over New River				**GROUND WTR (ft)**
BORING NO. CL-1	**STATION** 203+88.1	**OFFSET** 32ft LT	**ALIGNMENT** RP 'CD'	**0 HR.** 24.9
COLLAR ELEV. 407.8 ft	**TOTAL DEPTH** 32.2 ft	**NORTHING** 1,529	**EASTING** 1,096	**24 HR.** 23.0
DRILL MACHINE CME-750	**DRILL METHOD** MUD ROTARY		**HAMMER TYPE** MANUAL	
START DATE 04/05/06	**COMP. DATE** 04/06/06	**SURFACE WATER DEPTH** N/A	**DEPTH TO ROCK** 27.9	
CORE SIZE NQ Wireline	**TOTAL RUN** 13.8 ft	**DRILLER** I. CORE		

ELEV. (ft)	ELEV. DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
2365										Road Surface
										Wash Drilled to 18.4ft
										Set 3in casing at 18.4ft
	2,347.0									2,347.0 ELEV. (ft) — DEPTH (ft) 18.4
	18.4	3.3	2:34 2:48 3:21	(2.1) 63%		RS-1				**RESIDUAL** Tan-gray mottled fine sandy silty CLAY soft A-4/A-6
	2,343.8									
	21.7	4.6	0:57/0.3 3:28 3:15	(1.8) 40%		RS-2				Brown-gray mottled fine sandy silty CLAY, soft A-4/A-6
	2,339.2									
	26.2	5.9	2:12 3:48 1:57/0.7 4:48 3:24 3:45 5:03 4:51 5:16	(2.2) 37%	(1.5) 25%	RS-3				Brown-grey mottled fine sandy silty CLAY soft to very soft A-4/A-6
										2,337.5 — 27.9
							(2.0) 46%	(1.3) 31%		**COASTAL PLAIN SEDIMENTARY ROCK** Tan LIMESTONE highly weathered and fractured, weak 2 jts at 5°, ADS=0.31 m, ADT=0.00m 3 jts at 5-10°, ADS=0.10 m, ADT=0.00m 5 jts at 5-10°, ADS=0.05 m, ADT=0.00m
										2,333.3 — 32.2
										Boring Terminated at Elevation 2,333.3 ft Hole backfilled with cuttings 48 hours after completion.

2360 2355 2350 2345 2340 2335 2330 2325 2320 2315 2310 2305 2300 2295 2290

NCDOT CORE SINGLE NC_DOT.GPJ NC_DOT.GDT 4/18/06

The most obvious changes are the new header and the centering of the descriptions. Centering the description is the default. Fields have been added in the database to force left justification, where required.

Depth (ft or m)	Bottom (ft or m)	Pattern	Fill	Origin	Description	Line Type	Step N Value 1st	Step N Value 2nd	Recovery Length (ft or m)	RQD Length (ft or m)	Override Layer Thickness (ft or m)	Left Justify Origin	Normal Font Origin	Left Justify Desc	Bold Font Desc
0	2.75	A7	RE	roadway embankment	Earth Fill: Reddish-brown silty CLAY. (A-7-5)							☐	☐	☐	☐
2.75	3.5	A7	AF	artificial fill	Earth Fill: Tan and gray silty CLAY to SAND with rock fragments at 4.2m. (A-7-5)	Dash						☐	☐	☐	☐
3.5	10.6	A5		residual	Tan and brown fine gravelly clayey SILT with very fine silica. (A-5)							☐	☐	☐	☐
10.6	13.1	A5		residual	Brown and tan and gray clayey SILT. (A-5)			25				☐	☐	☐	☐
13.1	16	A4		residual	Tan and gray fine sandy SILT. (A-4)		40	80				☐	☐	☐	☐
16	19.5	WR		weathered rock	SOFT WEATHERED ROCK: Sampled as brown, tan and gray sandy SILT.				0.8	N/A	1.23	☐	☐	☐	☐
19.5	22	CP		coastal plain sedimentary rock	Tan LIMESTONE highly weathered and fractured, weak				2	0.7		☐	☐	☐	☐
												☐	☐	☐	☐

Another obvious change is in the first two body columns on both forms. Previously the first column was the sample elevation and the second the depth. Now the first column is an elevation scale and the second column contains both the sample elevation and depth.

A more subtle change is the algorithm for calculating the depths of the N Value plot points. Previously it was the sample top depth plus the sample length or 1 foot (0.3 meters), whichever was less. Now, if the test runs to full penetration, the point is plotted 1 foot below the top of the sample, otherwise it is plotted at the sample length.

Also in the N Value plot, the grid marks are now aligned to the elevation scale, not the depth.

Many other not-so-obvious changes were made to support the restructured database. That is where the most significant modifications were made.

3. DATABASE STRUCTURE

3.1. Normalization

Normalization of data is the process of analyzing a relational schema, based on its functional dependencies and primary keys, to minimize redundancy. In common terms, normalization is the arrangement of the data, the tables, and their relationships. Following the normalization rules helps avoid problems such as duplicate data entry and makes querying (searching) and reporting of the data easier.

Following are the changes that were made:

- Numerous fields that should contain numeric data were allowed to have text data. For example, ground water depths could have notes like “Dry.” These were all changed so that data that are inherently numeric are now numeric and, where necessary, additional, associated text fields were created for notes.

- An Origin field, associated with a lookup, has been added to the LITHOLOGY table. Previously, this was typed in with the rest of the description and was bolded manually. Now, the report formats it appropriately.

- The Total Run field in the CORE table has been eliminated and the report calculates the total run as the sum of the lengths of all rock core samples.

- The Moisture field in the SAMPLE table previously could take either a moisture content percentage or a descriptive condition (dry, moist, wet, saturated). Two fields are now used: one for moisture content and one for condition.

- The Number field in the SAMPLE table previously contained the full sample number which included the sample type. There is now a Type field tied to a lookup list with all allowable types. The Number field now just contains the number. The reports build the displayed number from these two fields.

- The CORE RUN table has been eliminated and its fields moved to the SAMPLE table.

- The Water Loss fields were removed from the SAMPLE table and moved to their own table.

Depth (ft or m)	Length (ft or m)	Type	Number	Blows 1st	Blows 2nd	Blows 3rd	Blow Count Note	Moisture (%)	Moisture Desc	Implied Blows	Core Recovery Length (ft or m)	Core RQD Length (ft or m)	Core Description
0.45	0.45	SS	1	4	2	2				☐			
1	0.45	SS	2	2	2	4				☐			
2.75	0.45	SS	3	2	3	3				☐			
4	0.45	SS	4	7	6	4		23		☐			
5.5	0.45	SS	5	2	3	2				☐			
7	0.45	SS	6	3	2	3				☐			
8.5	0.45	SS	7	1	2	2				☐			
10.25	0.45	SS	8	2	3	3				☐			
11.75	0.45	SS	9	6	8	14		30		☐			
13.25	0.45	SS	10	13	14	23				☐			
14.75	0.45	SS	11	9	9	15				☐			
16.25	0.45	SS	12	25	43	57/9	97/24			☐			
18	0.12	SS	13	57/12			57/12			☐			
18.12	0.73	RS	1							☐	0.42	0.11	
18.85	0.15	SS	14	59/15			59/15			☐			
19	1.5	RS	2							☐	1.2	0.4	
20.5	1.5	RS	3							☐	1.3	0.5	2 jts at 5°, ADS=0.31 m, ADT=0.00m 3 jts at 5-10°, ADS=0.10 m, ADT=0.00m

These changes help make data entry easier, provide additional data validation, make database searches easier, and, through the use of lookup lists, help ensure consistency.

3.2. Added Functionality

Four new fields were added to the LITHOLOGY table to allow not bolding and left justifying the Origin data and bolding and left justifying the main description.

The total number of log sheets and the sheet number for a log are now user-definable in new fields in the PROJECT and BOREHOLE tables, respectively. Further, the print order of the logs can now be controlled by a new Log Print Order field in the BOREHOLE table.

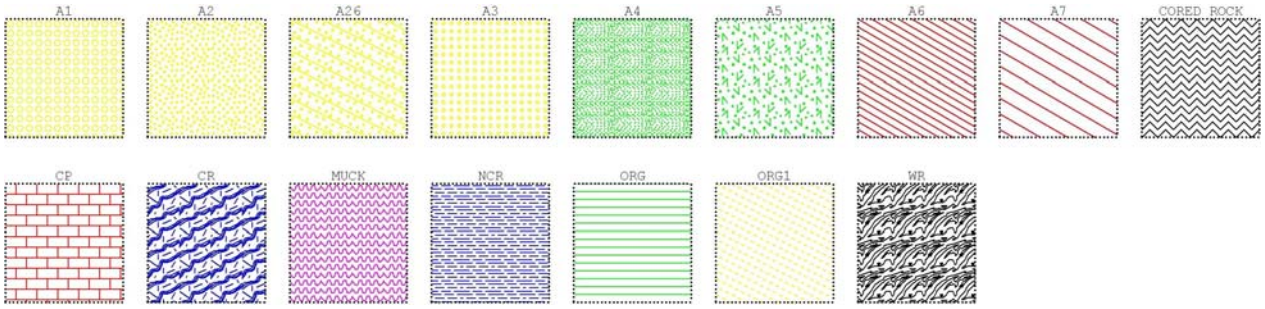
3.3. Altered Functionality

Previously the N Value plot line would plot vertically down to a layer boundary and then horizontal to the value of the first N Value in the next layer and then vertically to that plot point. A field in the LITHOLOGY table allowed suppression of this step. In the new database structure, the Suppress Graph Step field has been eliminated and two new fields added. These allow the specification of the N Values that are used at the layer boundary. If both fields are blank, no step is made at the layer boundary. Note that this is officially a gINT version 8 capability but is included in version 7.1.040 and later. This will not work in earlier versions of gINT.

The SAMPLE table has been changed to allow data at the same depths within a borehole. This allows for bulk samples taken from the same depths as driven samples.

4. PATTERNS

Previously the patterns shipped with the gINT NC DOT files were created from legend sheets. They have now been generated from the official Microstation legend, matching not only the graphics but also the desired colors:



5. GEOPAK® SUPPORT

GEOPAK will be used to generate the log sections and plan view reports. Instead of re-entering data in GEOPAK, the data will be exported from gINT via the GEOPAK export facility in Input. A gINT correspondence file has been written that maps between the DOT database structure and the structure required by GEOPAK. To properly perform the export, GEOPAK Chain Name and GEOPAK Hole Type fields have been added to the BOREHOLE table.

6. WORK STILL IN PROGRESS

The NC DOT is presently testing all functionality of the logs and the GEOPAK export. Furthermore, they are creating lookup lists in all fields that would benefit from a list of choices. When all testing is completed and changes made, gINT Software will repost the new files with the appropriate documentation. These will be available at no charge to all gINT clients licensed for version 7 and later.

7. SUGGESTED WAYS FORWARD

7.1. Introduction

When completed, the above modifications will help streamline the data management processes within the DOT and help in the transfer of data to and from consultants and contractors. However, this foundation can be built upon to produce better quality data, store and report many other types of data, and make querying and reporting the data more flexible and powerful.

7.2. Electronic Field Logging

Many systems, both commercial and privately created, exist for logging boreholes electronically. Electronic field logging eliminates one of the main bottlenecks to the data management process: transcription of data from field notes to the database. Data transcription from field notes is also the main source of errors in the process. If properly designed, an electronic field logging system also acts as a mechanism for data validation and consistency.

Once the database is finalized, Dataforensics of Atlanta, a development partner of gINT Software, has offered to make available at no charge, a correspondence file that will allow the transfer of data from their PLog® system to the gINT NC DOT database structure. However, before this can happen, the DOT will need to come up with a standard description format.

7.3. Component Descriptions

The Origin field is the first step toward a full component model for descriptions. The Description field can be further broken down into many separate fields, most with associated lookup lists, to create a final description.

Following are some typical samples of soil descriptions:

Top (m)	Base (m)	Description
0	0.9	Loose dark brown sandy fine to medium SAND with some roolets (TOPSOIL)
0.9	3.5	Stiff brown with blue veining silty to sandy CLAY with some fine to medium sub-rounded gravel of mixed lithology
3.5	5.5	Stiff brown silty CLAY with some fine to medium sub-rounded gravel and coal fragments, locally a firm, grey silty clay and brown silty fine sand at 4.50-5.00m (GLACIAL DEPOSITS)

This will be designated as the "blob model" of descriptions, a coarse-grained approach. Following are the same descriptions in a "component model," which comprises a fine-grained approach:

Depth (m)	Base (m)	Strength	Colour	Minor Constituent 1st	Minor Constituents Conjunction	Minor Constituent 2nd	Particle Size 1	Particle Size Conjunction	Particle Size 2	Principle Type	Additional Description	Formation
0	0.9	loose	dark brown	sandy			fine	to	medium	sand	with some roolets	topsoil
0.9	3.5	stiff	brown with blue veining	silty	to	sandy				clay	with some fine to medium sub-rounded gravel of mixed	
3.5	5.5	stiff	brown	silty						clay	with some fine to medium sub-rounded gravel and coal	glacial deposits

There are many strong advantages to using the component model for data entry:

- **Consistency** - Consistently structured descriptions are always produced.

- **Enforced Attribute Selection** - Most of the components would have valid data lists associated with them, from which the user chooses. Such data lists aid in data accuracy and consistency. All of the above components, except for "Colour" (this is a British database example) and "Additional Description" are such lookup lists.

- **No Formatting** - Formatting is removed from the data. The burden of the formatting is taken from the user and imposed on the software. Further, the formatting can then be altered as needed without changing the data. Note that in the component model sample above all the components are lower-cased but the final descriptions are mixed-case. Punctuation is also inserted by user-defined rules. In the above example, all components are separated by spaces (except for the formation, which is placed on its own line). However, variable punctuation is possible with commas, periods, colons, etc. placed after any component. Note also the brackets around the formation name. Other component formatting, such as bold, italic, underline, color, etc., are also possible. Finally, the order of the components can be changed at will. User-definable software rules determine the final look of the description.

- **Selective Reporting** - Not all components may be desirable under some situations. On a log form the full description is usually shown. On a fence diagram showing a number of borehole sticks there is less room, so perhaps only the "Principal Type" and the "Strength" would be shown.

- **Enhanced Query Capabilities** - Queries can be run on any combination of components. For example, one could ask for N Value results within layers whose "Principal Type" is "sand."

- **Validation** - Data validation becomes possible. A simple rule could catch "hard sand" or "loose clay."

7.4. Automated Data Validation

Through its relational design, appropriate data type assignments, and lookup lists, the database structure provides a basic level of data validation. However, because databases can be arbitrarily designed gINT does not have intelligence concerning any user-defined structures. For example, gINT does not know anything about recovery or RQD since the user could set up these fields as length or percentage and can name them in any manner they wish. Therefore, there is no inherent validation of these quantities. There is nothing to stop someone from entering an RQD value greater than the recovery or a recovery twice the length of the sample penetration. Other possibilities:

- Drilling start dates after the completion dates.
- Ground water depths supplied when drilling underwater.
- Description like “loose CLAY” or “very stiff SAND.”
- Origins that don’t match description.
- Descriptions that don’t match classifications.
- Patterns that don’t match Origins or descriptions.
- Number of blow count increments that don’t match the length of the sample.

gINT has facilities to check these conditions and many more possibilities. Code would need to be written similar to writing Excel® macros. However, the effort would be well worth it for the added level of data quality.

7.5. Lab Testing

It is strongly recommended that laboratory test data be included in the database. Either gINT could be configured to be the data entry and calculation software for the lab tests or the final test results can be imported into gINT. This would put all the data in one place and allow reporting and analysis with the field data. Further, lab results can be reported with gINT in many different manners.

7.6. Other Field Testing

Many other types of data are collected in roadway and bridge site investigations. To name a few:

- Water level monitoring
- CPT testing
- Slope inclinometer
- Pile load testing

There is no reason not to include these data in the same database with the borehole data.

7.7. Photos

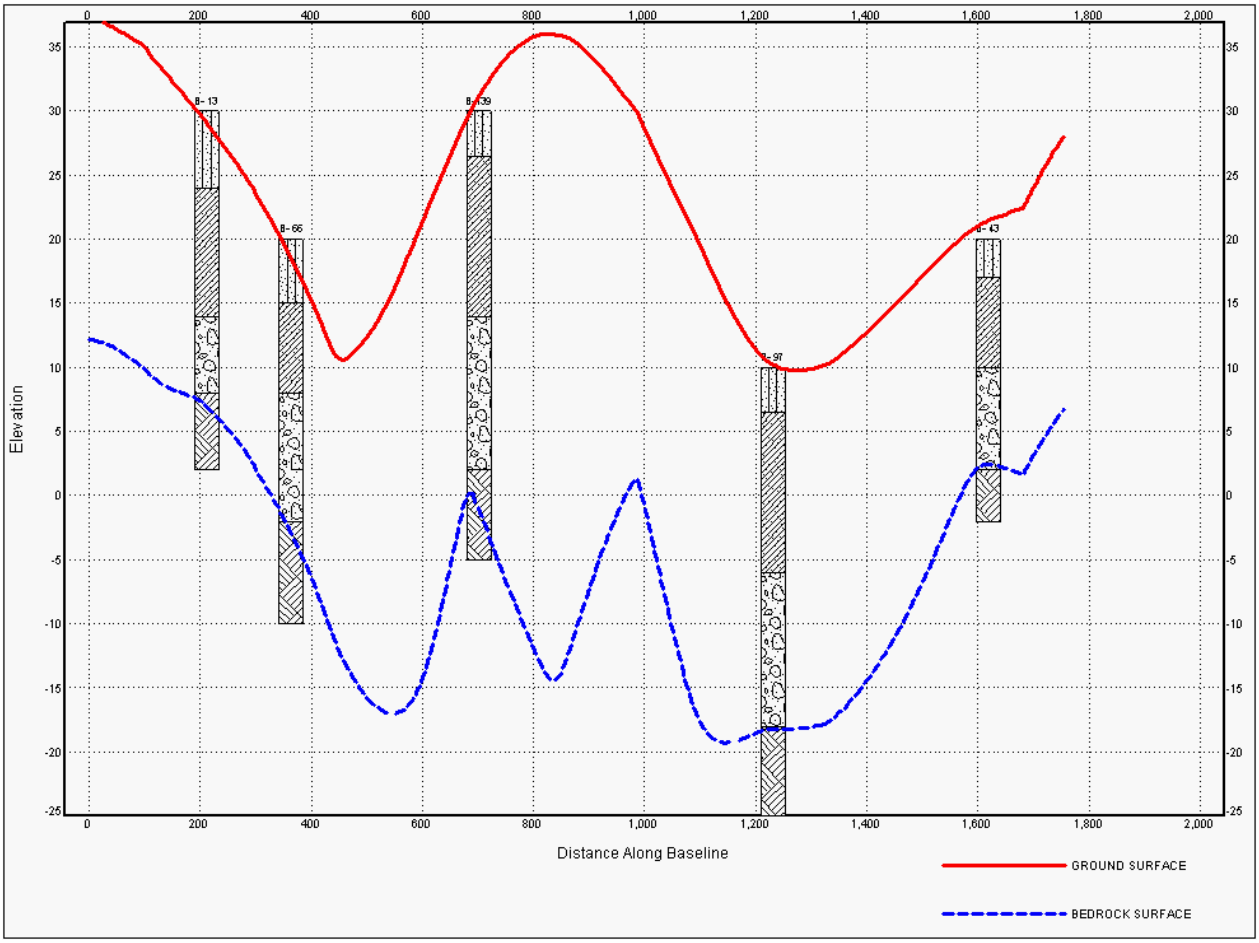
gINT has a facility for referencing photos and other graphic files within the database. The image files remain outside of gINT, but they can be output on any of the nine report styles supported by the program.

7.8. Surfaces

A number of surfaces can be identified in any site and most (if not all) of the data defining these surfaces can be extracted from the database to a form that can be read and contoured by numerous programs (RockWorks, Surfer, etc.). Some possibilities:

- Bottom of fill.
- Top of Aquifer.
- Bottom of Aquifer.
- Top of Bedrock.

The XYZ data defining these surfaces can be extracted from gINT, gridded in other programs, and then imported back into the database. They can then be displayed on gINT fence reports:



7.9. Task Automation

gINT has a facility for writing user-defined code that is executed by a user-defined command that appears in the gINT menu in Input. These "add-ins" can automate tasks that would otherwise require training in performing a multiple step process. For example:

- Import CPT data.
- Import Slope Inclinometer data.
- Generate a summary of all field and laboratory tests run on a project.
- Calculate the average N Values for specific layers.

This facility speeds execution of work and helps retain corporate memory. Specialized knowledge can be encapsulated in such add-ins, instead of residing in the minds of a few people.

7.10. Link to GIS

gINT's database is Microsoft ACCESS® and therefore all the data can be linked into GIS. Further, gINT maintains an ActiveX interface so that programs can be written with the GIS software that can have gINT perform tasks such as outputting reports and running queries based on the user specifications. This is a way to quickly and relatively easily link the subsurface information directly to the site.

7.11. Translation of Legacy Data

There are gINT databases that have been generated for NC DOT projects for about the last 14 years by numerous consultants. They will be in different structures and would require significant effort to translate them to the final DOT structure. However, considering the cost of drilling one borehole and performing the associated field and laboratory testing, converting the legacy databases would be a low cost way of accumulating valuable information.

7.12. An Enterprise Database

Ultimately, it would be most advantageous to port all the individual gINT project files to one Enterprise database system such as SQL Server, Oracle, Sybase, DB2, etc. This would all information for the state in one place and make searches, queries, and analysis much faster and easier.

7.13. DIGGS

The Federal Highway Administration, in partnership with numerous state DOTs (including North Carolina), the Army Corps of Engineers, US EPA, USGS, and the AGS (UK), is managing the development of an interchange format for geotechnical and geoenvironmental data, called DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists). This will allow data sharing in a consistent manner. It is anticipated that the DIGGS standard will be completed by the last quarter of this year. NC DOT has already committed to supporting DIGGS. Additional work will then be required to map to and from the DIGGS format and may involve modifications of the database structure to make better use of the format.

8. REFERENCES

Caronna, S. (2005). "Data Granularity in the storage and reporting of Soil Exploration Information", *The Second Annual Geotechnical, Geophysical, and Geoenvironmental Technology Transfer Conference and Expo*, Charlotte, North Carolina, 14-15 April 2005.

Caronna, S. (2005). "Geotechnical Data Management Issues for Transportation Authorities", *6th Transportation Specialty Conference*, Toronto, Ontario, 2-4 June 2005.

Deaton, S.L. (2003). "Considerations for Digital Field Data Collection", *www.dataforensics.net*, Atlanta, Georgia.