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**INTEGRATED DECISION SUPPORT  
FOR WELLHEAD PROTECTION**

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Groundwater Research Report

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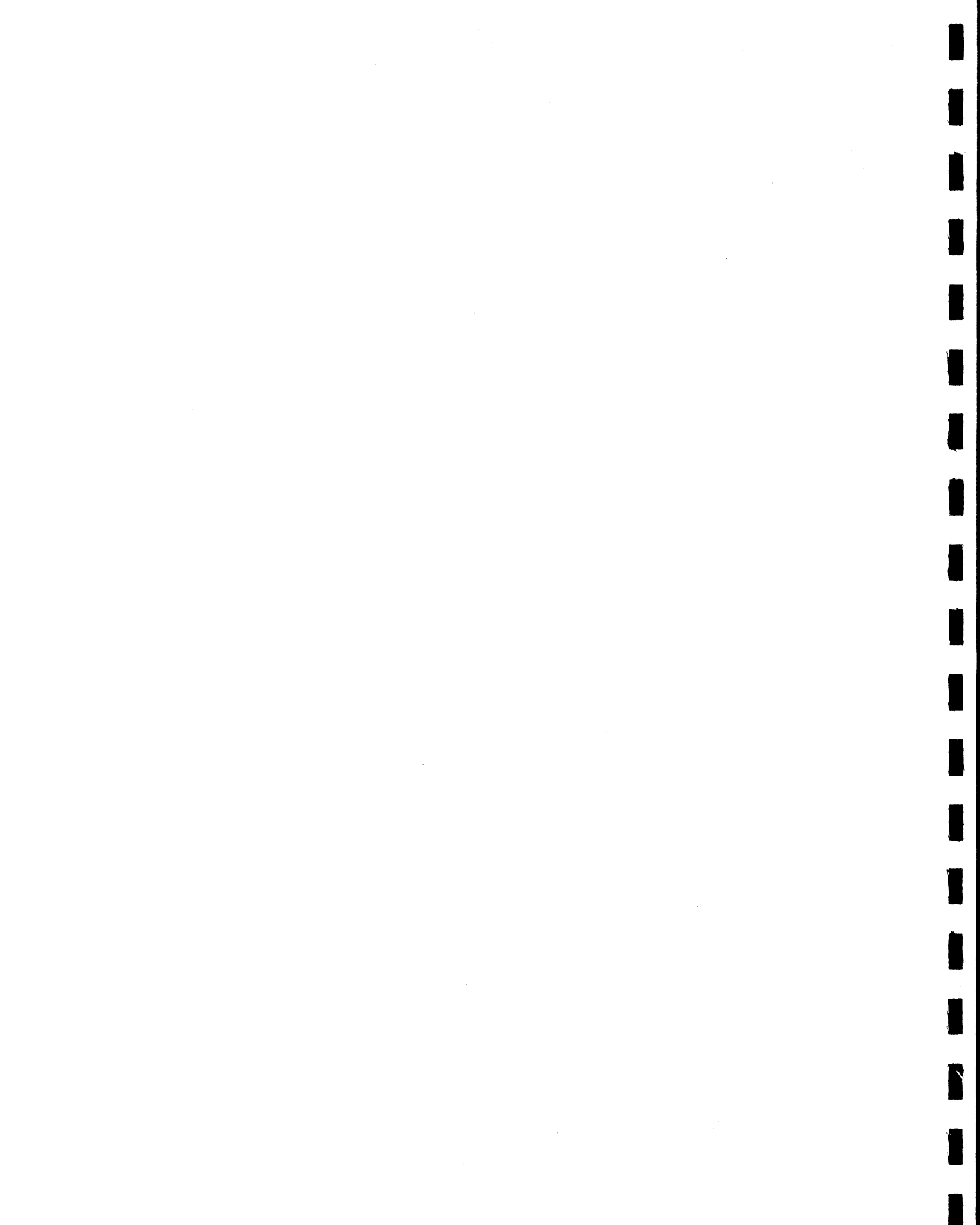
University of Wisconsin System

Groundwater Research Program

Water Resources Center  
University of Wisconsin-Madison  
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Madison, Wisconsin

1994

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## ABSTRACT

A Geographic Information System (GIS) application named WELLHEAD is described. It integrates geographic data on highways, townships, and hydrography on flowing and standing water and wetlands with geographic subsurface information from drilling logs and strata samples. To illustrate the application and utility of WELLHEAD, data from Dane County, Wisconsin has been used to allow hydrogeologists, geologists, geotechnical engineers, and water chemists pursuing pollution control strategies to retrieve and view subsurface data in graphical form. Interactive options allow users to display information in different perspectives.

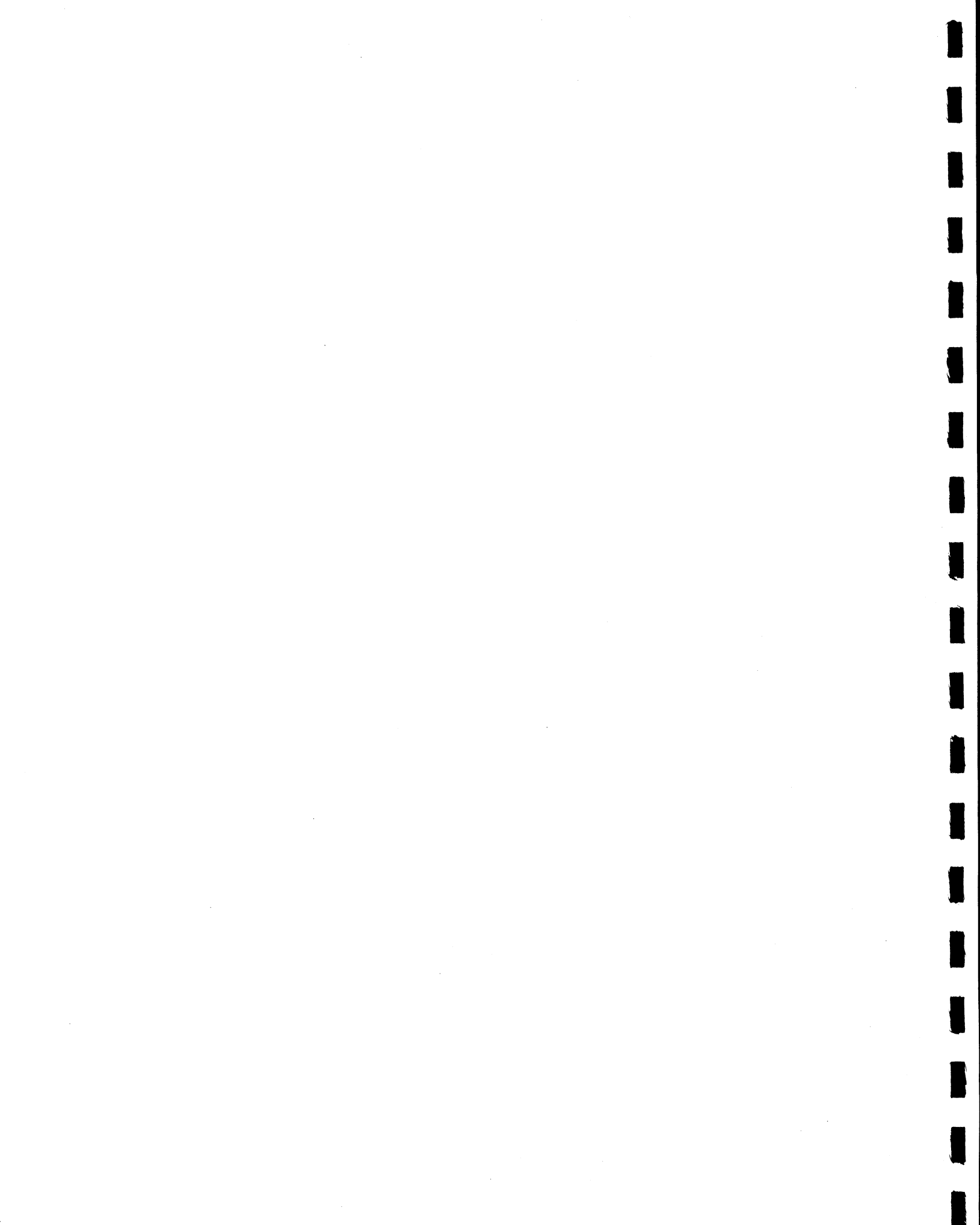
The background describing the need and benefits of WELLHEAD is presented and an overview of its major program components is provided. The WELLHEAD data sets, comprised of highways, township boundaries, hydrography, and lithology, are described. Menu systems, interfaces, database design, and the organization of the subsurface data are detailed. The user is guided through spatial queries to select boring logs. The graphical information system for subsurface characterization, which guides the user to the generation of one, two, and three-dimensional plots of the geographically based subsurface information in the database, are presented and explained.



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## ACRONYMS

AASHTO	-	American Association of State Highway Transportation Officials
DLG	-	Digital Line Graph
GIS	-	Geographic Information System
GWSI	-	Groundwater Site Inventory
LICGF	-	Land Information and Computer Graphics Facility
PLSS	-	Public Land Survey System
SPCS	-	State Plane Coordinate System
SQL	-	Structured Query Language
USC	-	Unified Soil Classification
USEPA	-	United States Environmental Protection Agency
USGS	-	United States Geological Survey
UTM	-	Universal Transverse Mercator
WDNR	-	Wisconsin Department of Natural Resources
WDOT	-	Wisconsin Department of Transportation
WGNHS	-	Wisconsin Geological and Natural History Survey
WTM	-	Wisconsin Transverse Mercator



## BACKGROUND AND OVERVIEW OF WELLHEAD

Critical decisions that involve hazard mitigation or the protection, conservation, and use of natural resources are often based on results of engineering or geological analyses of subsurface hydrogeological and geotechnical data. Raw data comes from a variety of sources, including well cores or boring logs, and are costly to obtain. Boring logs obtained for one investigation can be reused for subsequent unrelated preliminary or final investigations, provided it is readily accessible. GIS technology provides a mechanism for collecting, maintaining, and making subsurface data available on demand for groundwater protection, resource studies, and engineering design.

WELLHEAD -- a GIS application -- that enables hydrogeologists, geologists, geotechnical engineers, and water chemists to view and retrieve subsurface data interactively and graphically, is described. Aside from serving as a composite data source, the system includes a number of utilities such as interactive screen forms for entering log data, analytical tools for data evaluation and display, and data format exchange programs for data conversion and compatibility among users and data sources. The subsurface modeling approach combines surface maps with fence diagrams. Alternative approaches such as geometric solids modeling or topological volume modeling (Youngmann, 1989; Carlson, 1987) will be implemented as the WELLHEAD system evolves. Future efforts will enable users to analyze subsurface conditions interactively for tasks such as groundwater contamination studies and landfill siting.

An overview of the WELLHEAD system is shown in Figure 1. The system comprises map data coverages of Dane County, Wisconsin obtained from three sources. A digital dataset of the state trunk highway system in Dane County was obtained from the Wisconsin Department of Transportation (WDOT). The Public Land Survey System (PLSS) dataset showing townships in Dane County was obtained from the Wisconsin Geological and Natural History Survey (WGNHS). A hydrography dataset consisting of all flowing water, standing water, and wetlands was obtained from the Wisconsin Department of Natural Resources (WDNR). All of the map datasets were made available through the Land Information and Computer Graphics Facility (LICGF) at the University of Wisconsin-Madison.

The WELLHEAD system stores and manages log data collected from multiple sources. The main source of data in the current system is the WGNHS Subsurface Laboratory Data Base which contains a subset of the Groundwater Site Inventory (GWSI) data compiled in the 1970's by the U.S. Geological Survey (USGS) and the WGNHS. The database is statewide and contains logs from drilling and sampling of strata during installation of high capacity water wells. Other potential sources of log data are the WDNR and WDOT; however, data from these sources have not been included in the current system. Because the source agencies have different perspectives in their data collection and interpretation -- regional and local -- the WELLHEAD system demonstrates the usefulness of a subsurface GIS to regional problems, such as groundwater resource management, and to local problems, such as landfill siting.



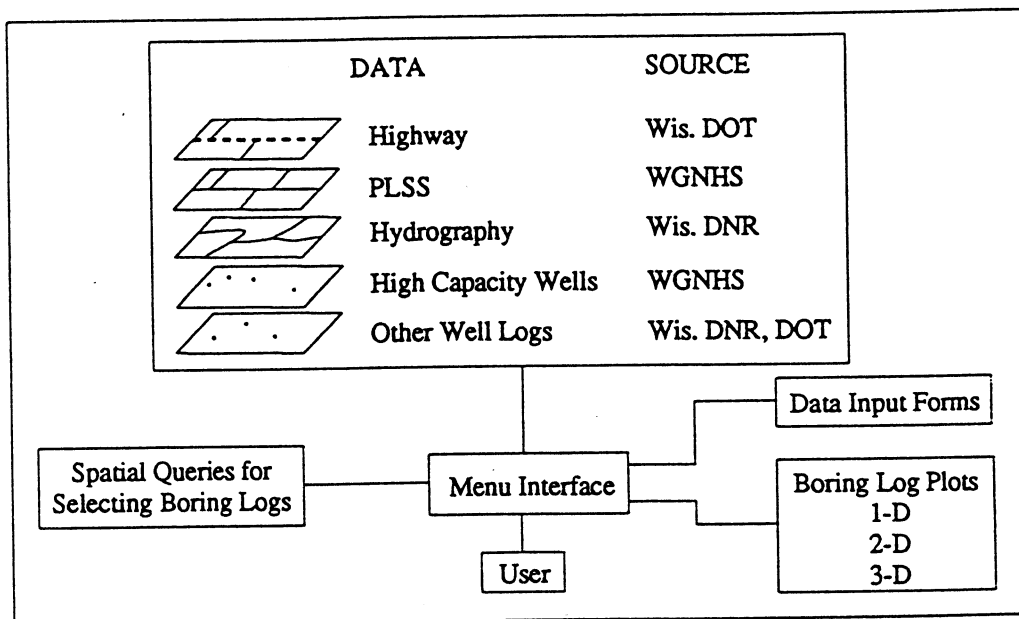


Figure 1. Architecture of the WELLHEAD system.

The current version of WELLHEAD stores and maintains log data and allows users to interactively generate boring logs, profiles, and three-dimensional fence diagrams (see Figure 7) from a set of one or more borings selected from a map. Log data can be further analyzed to determine location of lenses and layers of soil deposited below the surface. Thus, a set of soil segments can be used to approximate the location of soil deposits. Efforts are underway to include capabilities for building topological or solid models of subsurface strata based on output from three-dimensional fence diagrams.

## WELLHEAD DATA SETS

### LINEAGE OF DATA SETS

The application uses four data layers -- highways, township boundaries (PLSS), hydrography, and wells -- in vector format (Table 1). The datasets of highways, township boundaries, and hydrography originated from the USGS in Digital Line Graph (DLG) format and were transformed into ARC/INFO readable format. The digital dataset of the state trunk highway system in Dane County was obtained from the WDOT. The PLSS dataset, showing townships in Dane County, was obtained from WGNHS.

Table 1. Datasets for WELLHEAD.

Type	Source	Format	Scale
Highways	USGS/WDOT	Vector	1:100,000
Township (PLSS)	USGS/WGNHS	Vector	1:24,000
Hydrography	USGS/WDNR	Vector	1:100,000
Core Borings	USGS/WGNHS	Vector	1:24,000

A hydrography dataset consisting of all flowing water, standing water, and wetlands was obtained from WDNR. The original hydrography data layer was a mosaic of the USGS 1:100,000 topographical quadrangle sheets which also contain the quadrangle boundaries. The area covered in the hydrography dataset is larger than Dane County. Because the scope of the WELLHEAD project is Dane County, the dataset was edited to remove the quadrangle boundaries and clip the area outside of Dane County from the coverage.

To plot the features in the WELLHEAD system, the three data layers -- highways, townships, and hydrography -- were converted from ARC/INFO format to ASCII format. The ASCII data file contains line or point ID's and X and Y coordinates. The Dane County Universal Transverse Mercator (UTM) ground coordinate system is used to maintain a common map projection for all data layers. Thus, coordinate transformation from Wisconsin Transverse Mercator (WTM) to Dane County UTM is required for the highways, township boundaries, and hydrography data layers. Specifications of Dane County UTM and the standard UTM differ by X and Y offsets of 200,000 and 4,700,000 meters, respectively (Table 2) (Wisconsin 1990; Synder, 1987). The X and Y shifts allow the entire county to be represented in at most six digits in the Easting and five digits in the Northing at 1 m resolution. Thus, use of the Dane County UTM system reduces coordinate storage without sacrificing accuracy.

Boring log data, the fourth and the major data layer, were collected from the WGNHS Subsurface Laboratory Data Base (WGNHS, 1990). The boring log dataset contains a subset of the GWSI data compiled in the 1970's by the USGS and the WGNHS. The dataset contains

distributions of logs from drilling and sampling of strata during installation of high capacity water wells. The well log dataset contains surface location of each well by several methods, including naming the 7.5 minute topographic map that contains the site of the well, the use of the PLSS, and the USGS identification number based on latitude and longitude that was assigned to each record in GWSI. Among the three, the description in PLSS is the most complete for the whole dataset. Thus, PLSS coordinates were converted into Dane County UTM coordinates for plotting the location of the wells on a map. A PLSS master file containing the coordinates of section corners in Dane County UTM is referenced to compute the location of each well. The master file covers Dane County and was prepared at a scale of 1:24,000. A 'C' language program with embedded SQL queries was prepared for the computation.

Table 2. Specifications of Dane County UTM (Zone 16).

Projection	Transverse Mercator, 6° longitude zones
Spheroid	Clarke 1866 in North America
Longitude of Central Meridian	-87 000 000
Latitude of Origin	0° (the Equator)
Scale Factor at the Central Meridian	0.9996
Unit	Meter
False Northing	0 meters
False Easting	500,000 meters
X shift	-200,000 meters
Y shift	-4,700,000 meters

## DATABASE MANIPULATION AND SCHEMAS

The well log dataset of the WELLHEAD system is referred to as the database *WGNHS*. The *WGNHS* database is organized into four tables: *location*, *litholgy*, *formatns*, and *wellownr*. The schemas and relations of the four tables are described in Table 3. *Wellid* is the key for each table. The *location* section of Table 3 contains the legal location of each well and other general well data such as elevation, depth, sample numbers, and specific capacity. The *litholgy* section of Table 3 has detailed description of rock type, color, grain, and sample depth. The *formatns* section of Table 3 contains the formation code and depth of each formation in a well. The well name, owner and owner address of each well are stored in the *wellownr* section of Table 3.

An additional table named *plss.sql* was created for accessing the *dmaster.ctl*, the UTM Section Corners Control file. The *dmaster.ctl* contains the Dane County UTM X- and Y-coordinates of each section corner. The table is used for converting the PLSS coordinates of each well's location to Dane County UTM coordinates.

Table 3. Schema relations for *Location*, *Lithology*, *Formatns*, and *Wellownr*.

Table name (1)	Attribute (2)	Key (3)	Data type (4)	Description (5)
Location	Wellid	✓	integer	A 7 digit well identification number
Location	co	✓	char(2)	Abbreviated county name
Location	conum	✓	smallint	A well number within a given county
Location	usgsid		char(15)	USGS identification number
Location	permno		integer	Permanent well number given by WDNR
Location	sampno		char(30)	Range or number assigned to geologic sample
Location	ldesc		char(16)	Legal description of the hole's location
Location	sect		smallint	Section number (1-36) within a township in the range
Location	tn		char(2)	Township number in PLSS
Location	m		char(2)	Range number in PLSS
Location	eorw		char(1)	E (east) or W (west) for range value in PLSS
Location	elev		float	Elevation of the ground surface
Location	elevacc		float	Accuracy of the elevation value
Location	ldepth		float	Total depth of the hole
Location	wowner		char(42)	Name of well owner
Location	comments		char(256)	Comments for the geologic record
Location	welluse		char(20)	Intended purpose or use for a well
Location	staticwl		float	Static water level
Location	specap		float	Specific capacity of a well (gal/min/ft)
Location	quad		char(25)	Name of the 7.5 min topographic map containing the geologic record
Lithology	wellid	✓	integer	A 7 digit well identification number
Lithology	indvscamp		char(8)	Individual sample number for a particular depth
Lithology	lithtop		float	Top depth of the sampled interval
Lithology	lithbotm		float	Bottom depth of the sampled interval
Lithology	rocktype		char(15)	Major rock type of the sample
Lithology	color		char(19)	Color of the wet sample
Lithology	mode		char(9)	Average grain size for the rock type
Lithology	range		char(19)	Grain size range for the rock type
Lithology	ldesc2		char(256)	Detailed lithologic description
Lithology	notes		char(256)	In-house note from the studier
Lithology	entrydte		date	The date the lithologic record was added to the computer
Formatns	wellid	✓	integer	A 7 digit well identification number
Formatns	formtop		float	Lower depth for the stratigraphic unit
Formatns	formbotm		float	Upper depth for the stratigraphic unit
Formatns	fmcodes	✓	smallint	Code (500-10000) assigned to a specific stratigraphic unit
Wellownr	wellid	✓	integer	A 7 digit well identification number
Wellownr	wellname		char(42)	Owner of the well
Wellownr	ownrname		char(46)	Full name of a well owner
Wellownr	ownraddr		char(30)	Street address of this owner
Wellownr	ownrcity		char(16)	City of residence of this owner
Wellownr	ownrstate		char(2)	State of residence of this owner
Wellownr	ownrzip		char(10)	Zip code for this owner
Wellownr	status		char(2)	Status of a well owner relative to the well

## CONVERSION FROM PLSS TO DANE COUNTY UTM

The PLSS is used to describe the land in squares by township, range and section (Ziegler, 1981). In Wisconsin, there are 53 bands of townships running east and west in a northward direction from the southern border of the state. The ranges run north and south from the Principal Meridian; that is, a vertical line starts at the junction of Grant and Lafayette Counties and extends north going through Outer Island of the Apostle Islands in Lake Superior. It is numbered to 20 West in the Indianhead country of Polk and Burnett Counties and 30 East on the eastern half of Washington Island in Lake Michigan. For each square, the area is about 15.5 km<sup>2</sup> (6 miles<sup>2</sup>). The area is further subdivided into 36 sections, 260 ha (640 acres) each (in Wisconsin, not all sections equal 640 acres). The section numbering sequence is shown in Figure 2. To identify an area in finer detail, a quarter of a quarter section can be used. For example, as shown in Figure 3, NWNE of Section 11, T7N, R6E means the northwest quarter of the northeast quarter of Section 11 in Township 7, Range number 6 East. By default, all townships in Wisconsin are on the north because the numbering starts from the southern border of the state.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 2. Public Land Survey Section Number Sequence.

Since the PLSS identifies a location in terms of an area, rather than a point in UTM, the conversion from PLSS to UTM requires prior knowledge of the UTM coordinates of the four corners of the PLSS section square. UTM coordinates reference data for each section corner in Dane County are available in the *dmaster.ctl* file. With the four corners measured in meters, the section can be partitioned into four quarter-sections (Figure 3). New four corner coordinates of each quarter-section are then computed. A recursive function is used to compute the quarter of a quarter. The more a quarter is divided, the more accurate is the location of a well. The centroid of the final quarter is then used as the point location of the well. The centroid coordinates are computed from the bivariate mean of n boundary vertices.

$$\bar{X} = \frac{\sum X}{n}$$

$$\bar{Y} = \frac{\sum Y}{n}$$

This algorithm gives approximate locations dependent on available data resolution. The algorithm is used because of its simplicity and availability of the UTM Section Corners Control file. The error introduced by the algorithm may range from 1 to 65 ha (2.5 to 160 acres).

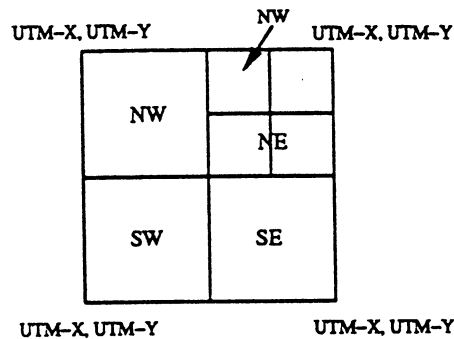


Figure 3. Quarter-sections in PLSS.

The subroutines listed in the appendix show how the corner coordinates of a new quarter and the centroid coordinates of a quarter are computed. The WGNHS encoded the description of quarter-quarter sections in a string combined with two-character identifiers. They include: *NE*, *NW*, *SE*, *SW*, *N2*, *E2*, *S2*, *W2*, and *C*. *NE*, *NW*, *SE*, and *SW* mean northeast, northwest, southeast, and southwest, respectively. *N2*, *E2*, *S2*, and *W2* stand for half on north, east, south and west, respectively. *C* is the center. The WGNHS also described some well locations using 'Just S of Center', 'E of C', 'NW corner', and 'NE corner', etc. To reduce the complexity of the program, without seriously sacrificing accuracy, these descriptions were edited. For example, 'Just S of Center' was edited to *S2* and 'E of C' was changed to *E2*. 'NW corner' and 'NE corner' were edited to *NW* and *NE*, respectively.

## WELLHEAD SYSTEM FILES

The *WGNHS* database is implemented in the Ingres database management system. The SQL command files, *location.sql*, *litholgy.sql*, *formatns.sql*, and *wellownr.sql*, located in the subdirectory */wgnhs*, are used to load the *WGNHS* database. The data files are located in the subdirectory */wgnhs/data*. They are: *location.del* for location; *nosample.del*, *sample1.del* and *sample2.del* for litholgy; *formatns.del* for formatns; and *wellownr.del* for wellownr. An additional SQL file, *plss.sql*, is stored in */wgnhs* which can be used to read and query the Section Corners Control file *dmaster.ctl* in the subdirectory */wgnhs/data*.

## **FUTURE WORK**

Future work for this part of the study should focus on improving the accuracy of the ground coordinates of well locations. There are at least three possibilities to improve the accuracy:

1. To record the well location with a more detailed quarter identifier can help produce a more accurate result.
2. Since UTM coordinates are only available for the section corners, corner coordinates of its quarters are computed from the bivariate mean. This is only an approximation. If there are UTM coordinates surveyed for the quarter or quarter-quarter corners, the accuracy of computing a well location can be improved.
3. A more direct and effective way to improve the accuracy of the well locations is to conduct a land survey and record the location of each well in a more accurate coordinate system, such as the State Plane Coordinate System (SPCS) or the UTM.

# MENU SYSTEMS, INTERFACES, AND DATABASE DESIGN

## WELLHEAD DATABASE

The WELLHEAD database consists of table relations for storing boring log data and soil properties from field and laboratory tests. The normalized database schema is delineated in Table 4. The first and second columns of the tables indicate relation and attribute names. There are sixteen tables in the database and the attributes are designed in such a way that redundancy is reduced. The attribute names are the variable names used to write the queries for different database functions. The third column identifies the key attribute for each table. The tables in the database are interrelated through the key attributes. The tables which store laboratory test data have the jar sample number as the primary key and a unique boring log number as the foreign key (Date, 1990). The fourth column indicates datatype for each attribute. The datatype controls the input given by the user. Datatypes are defined as supported by the INGRES database management system. The fifth column contains a short description of each attribute and the domain of possible values. The attribute names and descriptions in Table 4 describe the information stored in the database. Some attributes require further description.

- For each Boring: A unique boring log number; name and boring log number of the user agency; date of beginning and completion of boring; initials of the personnel who worked at the site; water table level from the surface; water level at 24 hours and at completion of the boring; boring termination depth; elevation and geodetic coordinates of boring log; and, drill rig and method.
- For each Segment: A unique boring log number; a segment number; depth of the segment; and description of the segment.
- For each Sample: Jar sample number; USC and AASHTO (Unified and American Association of State Highway and Transportation Officials) soil classification of the sample; soil sample type according to basic types; sampler type such as SPT (including blow count, penetration depth and recovery); Shelby and other like pistons; and 7.6 cm (3-inch) tube sampler.
- For each AtterbergLimit: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; plastic limits and liquid limits; and soil description (Liu and Evett, 1990).
- For each Gradation: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; percentage of gravel; sand, silt, and clay; coefficient of uniformity and concavity(curvature); and sample description (Liu and Evett, 1990).
- For each Watercontent: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; and water content (Liu and Evett, 1990).



Table 4. Data dictionary for WELLHEAD.

Table name	Attribute	Key	Data type	Description
Boring	boring#	✓	smallint	WELLHEAD boring log number
Boring	agency		char(30)	Name of contributing agency
Boring	agency_boring#		char(10)	Agency's boring log number
Boring	date		date	Date of boring
Boring	date_comp		date	Completion date of boring
Boring	crew		char(30)	Initials of crew members
Boring	temperature		smallint	At time of drilling in degrees Fahrenheit
Boring	precipitation		char(10)	At time of drilling: snow, rain, dry
Boring	casing_type		char(10)	Casing type: steel, pvc
Boring	casing_idiam		float	Casing inside diameter $2 \leq$ and $\leq 36$ -inch
Boring	water_depth		float	Depth from surface to water table (ft)
Boring	water_level_comp		float	Water level at completion (ft)
Boring	water_level_hour		float	Water level at 24 hours (ft)
Boring	term_depth		float	Boring termination depth (ft)
Boring	mud_type		char(10)	Drilling mud type: bentonite
Boring	method		char(20)	Hammer type
Segment	segment#	✓	smallint	Boring log segment number
Segment	boring#		smallint	WELLHEAD boring log number
Segment	description		char(250)	Soil description
Sample	sample#	✓	smallint	Sample jar number
Sample	boring#		smallint	WELLHEAD boring log number
Sample	USC		char(5)	Unified soil classification
Sample	AASHTO		char(5)	AASHTO soil classification
Sample	sample_type		char(10)	Soil sample type: rock, peat, mineral soil
Sample	sampler_type		char(12)	Sampler type: SPT, Shelby, Piston, Auger
BoringLoc	boring#	✓	smallint	WELLHEAD boring log number
BoringLoc	x		float	x geodetic coordinate
BoringLoc	y		float	y geodetic coordinate
BoringLoc	elevation		float	Surface elevation
SegmentLoc	segment#	✓	smallint	Soil segment number
SegmentLoc	boring#		smallint	WELLHEAD boring log number
SegmentLoc	d_bottom		float	Depth from surface to bottom of segment (ft)
SegmentLoc	up_segment#		smallint	Segment number of segment on top
SampleLoc	sample#		smallint	Sample jar number
SampleLoc	boring#		smallint	WELLHEAD boring log number
SampleLoc	depth		float	Depth from surface to sample location (ft)
SPT	sample#	✓	smallint	Sample jar number
SPT	boring#		smallint	WELLHEAD boring log number
SPT	blow_count		smallint	Blows/ft
SPT	penetration		float	Sampler penetration (inches)
SPT	begin_depth		float	Depth at beginning of penetration (ft)
SPT	recovery		float	Sample recovery

Table 4. (Cont.)

Table name	Attribute	Key	Data type	Description
Shelby	sample#	✓	smallint	Sample jar number
Shelby	boring#		smallint	WELLHEAD boring log number
Shelby	penetration		float	Sampler penetration (inches)
Shelby	begin_depth		float	Depth at beginning of penetration (ft)
Shelby	recovery		float	Sample recovery
Other	sample#	✓	smallint	Sample jar number
Other	boring#		smallint	WELLHEAD boring log number
Other	recovery_method		char(50)	Sample recovery
AtterbergLimits	sample#	✓	smallint	Sample jar number
AtterbergLimits	boring#		smallint	WELLHEAD boring log number
AtterbergLimits	lab_tech		char(30)	Laboratory technician (tested by)
AtterbergLimits	test_date		date	Date of test
AtterbergLimits	loc_in_sample		char(15)	Location in sample
AtterbergLimits	PL		float	Plastic limit
AtterbergLimits	LL		float	Liquid limit
AtterbergLimits	PI		float	Plasticity index
AtterbergLimits	soil_desc		char(30)	Soil description
Gradation	sample#	✓	smallint	Sample jar number
Gradation	boring#		smallint	WELLHEAD boring log number
Gradation	lab_tech		char(30)	Laboratory technician
Gradation	test_date		date	Date of test
Gradation	loc_in_sample		char(15)	Location in sample
Gradation	method		char(20)	Method of analysis
Gradation	gravel_percent		float	
Gradation	sand_percent		float	
Gradation	silt_percent		float	
Gradation	clay_percent		float	
Gradation	Cu		float	Coefficient of uniformity
Gradation	Cc		float	Coefficient of concavity
Gradation	sample_desc		char(30)	Sample description
WaterContent	sample#	✓	smallint	Sample jar number
WaterContent	boring#		smallint	WELLHEAD boring log number
WaterContent	lab_tech		char(30)	Laboratory technician
WaterContent	test_date		date	Date of test
WaterContent	loc_in_sample		char(15)	Location in sample
WaterContent	w		float	Water content
Strength	sample#	✓	smallint	Sample jar number
Strength	boring#		smallint	WELLHEAD boring log number
Strength	lab_tech		char(30)	Laboratory technician
Strength	test_date		date	Date of test
Strength	loc_in_sample		char(15)	Location in sample
Strength	spec_sample		char(15)	Shape of specimen

Table 4. (Cont.)

Table name	Attribute	Key	Data type	Description
Strength	test_type		char(10)	Uu, Cu, CD or Ds
Strength	sample_type		char(20)	Undisturbed, remoulded, etc.
Strength	wet_density		float	
Strength	dry_density		float	
Strength	deg_sat		float	Degree of saturation
Strength	str_max		float	Strain at maximum compressive stress
Strength	comp_stress		float	Maximum compressive stress
Strength	pore_press		float	Pore pressure
Strength	phi		float	Angle of internal friction
Strength	c		float	Cohesion
UnitWeight	sample#	✓	smallint	Sample jar number
UnitWeight	boring#		smallint	WELLHEAD boring log number
UnitWeight	lab_tech		char(30)	Laboratory technician
UnitWeight	test_date		date	Date of test
UnitWeight	loc_in_sample		char(15)	Location in sample
UnitWeight	gama		float	Unit weight (lbs/ft <sup>3</sup> )
SpecificGravity	sample#	✓	smallint	Sample jar number
SpecificGravity	boring#		smallint	WELLHEAD boring log number
SpecificGravity	lab_tech		char(30)	Laboratory technician
SpecificGravity	test_date		date	Date of test
SpecificGravity	loc_in_sample		char(15)	Location in sample
SpecificGravity	Gs		float	Specific gravity
Consolidation	sample#	✓	smallint	Sample jar number
Consolidation	boring#		smallint	WELLHEAD boring log number
Consolidation	lab_tech		char(30)	Laboratory technician
Consolidation	test_date		date	Date of test
Consolidation	loc_in_sample		char(15)	Location in sample
Consolidation	sample_type		char(20)	Undisturbed, remoulded, etc.
Consolidation	D		float	Specimen diameter
Consolidation	H		float	Speciment height
Consolidation	w_unit		float	Initial water content
Consolidation	w_final		float	Final water content
Consolidation	in_deg_sat		float	Initial degree of saturation
Consolidation	fn_deg_sat		float	Final degree of saturation
Consolidation	e		float	Initial void ratio
Consolidation	Po		float	Overburden pressure
Consolidation	Pp		float	Preconsolidation pressure
Consolidation	Cv		float	Coefficient of consolidtion

- For each Specific Gravity: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; and specific gravity (Liu and Evett, 1990).
- For each Strength: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; shape of the specimen; sample type (e.g., remoulded, undisturbed, etc.); water content; dry density; specific gravity; degree of saturation; strain at maximum compressive stress; pore pressure; maximum compressive stress; angle of internal friction; and cohesion (Liu and Evett, 1990).
- For each Consolidation: Jar sample number; unique boring log number; name of the laboratory technician; date of the test; sample type; specimen height and diameter; initial water content; final water content; initial degree of saturation; final degree of saturation; initial void ratio; overburden pressure; preconsolidation pressure; and coefficient of consolidation (Liu and Evett, 1990).

## DESCRIPTION OF WELLHEAD DATABASE INTERFACE

A menu interface written in the application development system Windows4GL provides easy access to the WELLHEAD database. Data from different source agencies with different data collection and interpretation methods may be entered using this interface. The interface allows multiple users to store and manage the log data as well as access menus to call programs to generate boring logs and perform spatial queries for selecting boring logs. Windows4GL implements the event-based, object-oriented programming language 4GL. 4GL includes a full range of control flow commands and all INGRES SQL commands, providing easy access to the database (Ingres, 1990). Windows4GL is a window-based application development system which simplifies design, implementation, and testing of an application by supplying a broad range of window-based features, including pull-down menus and mouse-based selection. It provides the information and tools necessary for the end user to examine data from or to perform operations of the database. The application is event driven, allowing the end user to direct the application by entering or changing data, selecting commands from menus, clicking buttons, moving the mouse or pressing the mouse buttons, pressing function keys, and moving from one frame to the next.

Windows4GL uses frames as the building blocks of an application. A frame is a window through which the application displays information and provides control for execution operations. To the end user, a frame is divided into three basic parts.

- *window*: The window provides a boundary around the form and the menubar and contains features which allow the user to control the window, e.g., the window *title bar* contains the application name, the frame name, and provides buttons to resize and close the window.
- *menubar*: The menubar contains all the pull down menus that are available in the current frame.
- *form*: The form is the portion of the frame at which the user can display or modify data, view illustrations, read instructions, and select commands. Forms contain arrangements

of text and images, graphic elements, and active fields. Active fields are the areas on the form where the user can view, modify, or enter data, as well as control the application. Active fields may be single-line entry fields which allow a single line of data to be entered. The data can be edited with the Windows4GL text editor. A *slide bar* on the right allows the user to scroll through the form.

During the creation of an application it is necessary to specify the contents of each frame, the data to be displayed or accepted, command buttons to be provided, and the necessary menu operations. The connections between frames must be defined.

## USER INTERACTION

The WELLHEAD user interface consists of menus, screen-forms, report generator, and programs. The WELLHEAD menus, forms, and report generators are developed using 4GL tools provided with the INGRES database management systems. The forms interface frees the user from applying explicit query language commands for insertion, deletion, and modification of information in the database. The forms are organized in such a way that the data displayed can be perceived by the user, even though it is stored in the database in a different manner.

The WELLHEAD menu system layout is shown in Table 5. The first column in the menu system layout table indicates the internal name for each menu. The selection type indicates the type of component as M for menu, F for form, R for report generator, and P for program. The system call indicates the variable name for that component. The WELLHEAD menu options consists of *get\_in*, *get\_info*, and *lab\_rep* menus, which are used for data input, data information and laboratory report data, respectively.

- *get\_in*: The *get\_in* menu is called from the main menu. The *get\_in* menu contains options for project description, drilling report data input, laboratory report data menu, and close (return to main menu).
- *lab\_rep*: The *lab\_rep* menu contains options for calling forms to input the laboratory test data. The options will be coarse grained, fine grained, highly organic, and close.
- *get\_info*: The user can get the information for different drilling data as well as laboratory test data. For those options, the user must go through these menu options.

The forms are useful components for user interaction with the WELLHEAD database because the database is very enhanced and normalized. Without screen forms the user must be knowledgeable of a query language for data insertion, selection, deletion, and modification. The forms allow any person -- even without the knowledge of a query language -- to use the database. The forms help the user to perceive data in an easier way, regardless of their storage in the database. The forms control the data which is stored in the database and provide a means of ensuring data consistency, integrity, and completeness. The functions of each of the user forms in the WELLHEAD system are briefly described.

- *proj\_des*: Gives the information regarding the project.

Table 5. WELLHEAD menu options.

Menu name	Option no.	Selection text	Type	System call
main	1	Data input	M	get_in
main	2	Spatial queries	F	get_loc
main	3	Data information	M	get_info
main	4	Exit		exit
get_in	1	Project description	F	proj_des
get_in	2	Drilling report data	F	dril_rep
get_in	3	Laboratory report data	M	lab_rep
get_in	4	Close		return
lab_rep	1	Coarse grained soil	F	crs_soil
lab_rep	2	Fine grained soil	F	fin_soil
lab_rep	3	Organic soil	F	org_soil
lab_rep	4	Close		return
get_info	1	Drilling data	F	drill_info
get_info	2	Laboratory data	F	lab_info

- *drill\_rep*: Used for entering data regarding field conditions and other drilling information at the time of sampling, e.g., method used for drilling, type of sampler, water level, and depth of soil segment layers.
- *fin\_soil*: Used for entering laboratory test results for the fine grained soils. Seven database tables are combined in this form for input data from seven laboratory tests. The common data are entered only once by the user. Data are stored separately in the seven database tables according to their attributes. The seven tests are atterberg limits, strength, gradation, water content, specific gravity, unitweight, and consolidation test.
- *crs\_soil*: Used for entering laboratory test results for coarse grained soil. Four laboratory tests are included: Unit weight, strength, gradation, and specific gravity. After entering the data into the form, the user presses the insert button to insert the data into the database. Error and confirmation messages appear on the screen accordingly.
- *org\_soil*: Used for entering data results of six laboratory tests for organic soil. The tests are strength, consolidation, water content, unit weight, specific gravity and atterberg limits.
- *drill\_info*: Used to browse through the data stored in the database for drilling condition. The user can put any value in the appropriate column to query other data related to the given value. Data for all columns from the database are retrieved by clicking the select button, which will invoke the select query. The user can query according to multiple attributes by entering values into different columns. The data can be retrieved from more than one table.
- *lab\_info*: The user can retrieve data regarding the laboratory tests from the database. The form contains button fields for different functions like data deletion, data modification (update), and data selection for interaction with the database.



## SPATIAL QUERIES TO SELECT BORING LOGS

The WELLHEAD graphical user interface for accessing well log data through spatial queries is described. The program was developed to effectively maintain the database of high capacity well logs in Dane County, Wisconsin. The major function of the program is to display well data in Dane County along with geographical features such as highways, streams/lakes, and township boundaries. Data is maintained with the Ingres database management system. The C programming language has been used as a source code on a Sun workstation.

The graphical interface of the WELLHEAD system has been implemented with XVIEW, a built-in graphical utility. XVIEW is a network-based, object-oriented windowing system developed by the Massachusetts Institute of Technology in 1988. All graphical subroutines to display well logs and ground features have been incorporated from the XVIEW graphic library.

### INPUT DATA AND PROGRAM OUTPUT

For geographical display, highway, hydrography, and township boundary data have been converted into the ASCII format using USGS scale DLG files. For easy conversion, PC-ARC/INFO, a GIS software package developed by ESRI (Environmental System Research Institute) has been used. For globally locating the geographical features, UTM (Universal Transverse Mecator; unit: meter) has been used. Individual data file names are:

- *dane\_hwy\_utm*: ASCII format USGS highway data in UTM;
- *dane\_hydro\_utm*: ASCII format USGS hydrography data in UTM;
- *dane\_towns\_utm*: ASCII format USGS township boundaries in UTM;
- *dane\_hwy\_data*: converts *dane\_hwy\_utm* into screen x,y coordinate;
- *dane\_hydro\_data*: converts *dane\_hydro\_utm* into screen x,y coordinate; and
- *dane\_towns\_data*: converts *dane\_towns\_utm* into screen x,y coordinate.

Program output depends on user selection, geographical feature displays and the well log database contents.

- User selection: Users can select a specific well log or a group of well logs using the menu option. The point option can select an individual well log; the line option with buffer length can select a group of well logs along the line within the buffer length; and the area option can select a group of well logs within an area.
- Geographical feature display: Initially, the user can select any geographic features as background to the well log display. This provides more information for easy selection of well logs. The geographic overlays are displayed or deleted using the display menu option.



- Well log database maintenance: According to user selection, the program accesses proper well log records by interfacing with the database software Ingres. It also plots major properties of selected well logs.

## PROGRAM STRUCTURE, PROCESS FLOW, AND EXECUTION

For efficient user input handling, a top-down structure has been used. Figure 4 shows the layout of the subroutines used in this program. A description of each subroutine follows.

- *canvas\_repaint\_proc()* - generates a canvas of a certain size and displays well log data onto canvas;
- *numer\_text()* - reads buffer length for line input selection option;
- *accept\_point()* - opens window for point selection;
- *accept\_point\_coord()* - gets selected point's x,y coord (UTM coordinate);
- *point\_draw()* - fills selected point with red (square shape);
- *accept\_line()* - opens window for line selection;
- *accept\_line\_coord()* - gets the selected line coordinates, (start/end points);
- *store\_line\_coord()* - stores x,y line coordinate for line drawing;
- *line\_draw()* - draws line;
- *accept\_area()* - opens window for area selection;
- *area\_draw()* - draws selected area;
- *display\_hwy()* - displays highways of Dane County;
- *display\_town()* - displays township boundaries in Dane County;
- *display\_hydro()* - displays hydrography of Dane County; and
- *quit()* - quits by calling XVIEW interrupt function.

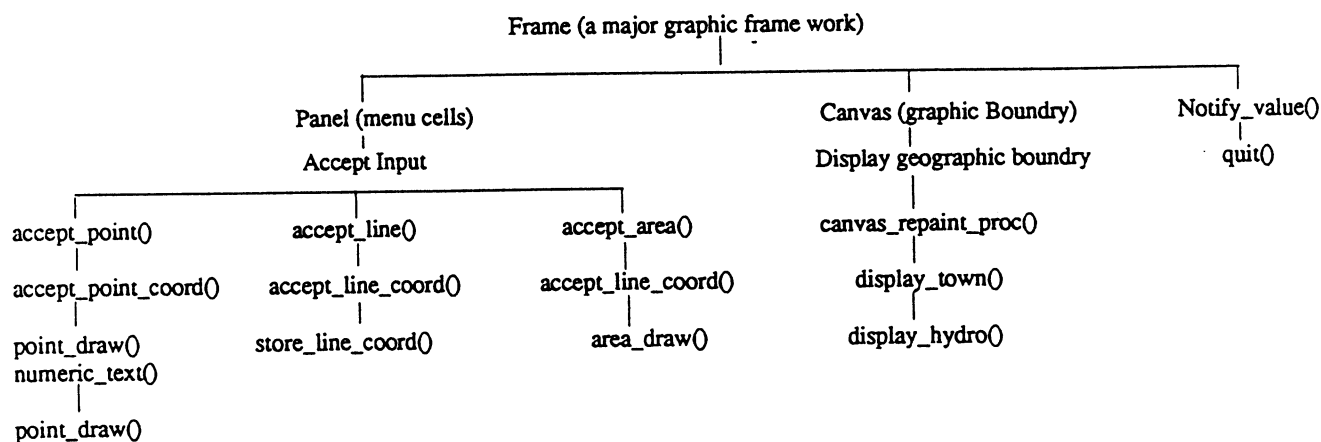


Figure 4. Programming structure.

The following describes the processing flow of the program.

- Define graphic framework and canvas;
- Set up menu for user selection and graphic display;
- Display map legends and message;
- Read coverages and display (user selectable);
- User menu selection: Point, line (and line buffer), and area;
- Interface with Ingres routine so well log (individual or group) can be accessed and displayed/updated; and
- Quit: calling interrupt routine.

The /XVIEW directory has all of the files, including data files and source code (wellhead.c). XVIEWRUN is a shell script that links XVIEW libraries during compilation. To compile the source code, use XVIEWRUN:

XVIEWRUN output wellhead.c

where *output* is the output file name and *wellhead.c* is the source code. To run the program, type output.

## FUTURE WORK

*Interfacing with Ingres Database System.* For effective database maintenance of well logs in Dane county, more should be done to interface the WELLHEAD system with the Ingres database software. Once the linkage has been established, the WELLHEAD system can generate any kind of graphics and reports for the selected well logs. This will mainly depend on the generation of proper subroutines which call relevant Ingres functions based on user queries.

### *Increasing Graphical Functionality.*

- *Window zooming* - by implementing multiple sub-window generation, the capability of zooming to any area of Dane County facilitates user queries, enabling in-depth analysis of the area with detailed geographical features of special interest or high environmental sensitivity.
- *User defined graphical layers* - rather than drawing pre-defined graphical layers, it will be more useful to generate graphical layers based on specific attribute values of the well log database. For example, the user could generate graphical layers which represent the spatial distribution of any well log attribute, such as well capacity or depth, for the county. The linkage between the WELLHEAD system and Ingres, as described, will be the pre-requirement of this functionality.
- *Generation of graphical layers with environmental indexes* - currently, the WELLHEAD system displays only major physical surface features such as highways, townships, and hydrography. It will be essential to have qualitative graphical layers which represent environmental indexes (e.g. VOCs, BOD, pH, etc.). This will facilitate site suitability to locate environmental treatment facilities (e.g., landfill sites, sewage treatment facilities,

etc.). Since many local/governmental agencies (e.g., USEPA, USGS, WDNR) already have these databases, no major problems should be encountered in data procurement. It may, however, require some data conversion.

*Spatial Modeling Capability.* Since the initial version of WELLHEAD has the capability of displaying the selected area of well logs, it will be possible to have area-limited spatial modeling capability. Any kind of spatial modeling technique (e.g., kriging, or moving average approaches, etc.) can be implemented. Although the algorithm and logical complexity will require highly skilled programmers and considerable effort, it will provide baseline information especially useful for environmental impact analysis.

## GENERATION OF ONE-, TWO-, AND THREE-DIMENSIONAL PLOTS

The WELLHEAD system graphics demonstration programs for one-, two-, and three-dimensional subsurface boring log plots are described. With the graphic demonstration programs, users are able to view the subsurface data of a single boring, several borings along a line, or a group of borings within a rectangular area. The boring data graphs may be viewed on the screen and printed. These graphic demonstration programs are written in FORTRAN with embedded GKS subroutines. The programs are compiled with SUN/GKS libraries. Input data for the graphic demonstration programs are obtained from the WELLHEAD database through the spatial query function of the system. The data format required by the boring log plotting programs is described.

### DESCRIPTION OF THE PROGRAMS

There are six FORTRAN programs: *borlog01.f*, *borlogps.f*, *prof2d01.f*, *prof2dps.f*, *fenced01.f*, and *fencedps.f*. They are described as follows.

*Programs for Displaying Single Boring Log Information:* *borlog01.f* is used to graph a single boring log profile including information such as soil description, water content, dry density, liquid limit, water table, and ground elevation. The *borlogps.f* program is used to produce a postscript file of the graph shown by *borlog01.f*. The postscript output can be printed and embedded in report documents. An example of the output from *borlogps* is shown in Figure 5.

*Programs for Plotting Two-dimensional Profiles of Boring Logs along a Specified Cross Section:* The *prof2d01.f* program displays the profile of boring logs along a specified cross section on the screen. The cross section is defined by two points on the map. The profile includes all boring logs within a user defined buffer zone, such as 20 feet from the cross section. The *prof2dps.f* program is used to produce a postscript file of the two-dimensional profile graph shown by *prof2d01.f*. An example of the output from *prof2dps* is shown in Figure 6.

*Programs for Plotting three-dimensional Fence Diagrams of Boring Logs within a Specified Area:* The *fenced01.f* displays the fence diagram of boring logs within a specified rectangular area on the map in a three-dimensional "dynamic" style. The viewing angle of the diagram can be changed by using the mouse device. If we pick up two points on the map, a rectangular area will be defined, then a three-dimensional fence diagram of boring logs within the area will be shown on the monitor with default viewing angles. The user can also change viewing angles by using the mouse device simultaneously. The *fencedps.f* program is used to produce a postscript file of the 3-D fence diagram generated by the *fenced01.f* program. An example of the output from *fencedps* is shown in Figure 7.

PROJECT : IPDS Geotechnical Demo I		BORING: B-3					
LOCATION: UW Madison		DATE : 03/02/88					
CLIENT : Sam		DRILLERS: Richard Bore					
BUILDING: A		WATER TABLE: 10.00					
LOCATION: Civil Engineering Department		GROUND ELEVATION: 202.00					
COORDINATES: E 380,N 180							
SOIL DESCRIPTION	Depth (feet)	N b/11	Water Content %	Dry Density	Liquid Limit %	Plastic Limit %	Fines %
Fine sand, medium dense.	0 - 2		25	110			20
Silty clay, gray to rusty, very moist, stiff.	2 - 5	2	18	118	36	15	68
	5 - 8	8	15	110	40	15	58 67
Clayey sand (SC), fine, light grey firm to stiff with pockets of shell fragments, moderate plasticity, wet to saturated.	8 - 10		23	118			
	10 - 15	15	32	108	34	14	68
Gravelly lean clay (CL), moderate plasticity.	15 - 17		28	118			
	17 - 15	15	32	119	45	17	62
Lean Clay (CL), moderate plasticity.	15 - 20		23	117	43	17	
	20 - 25	17					
Limestone, buff, unweathered, weak, foliated.	25 - 30						
	30 - 40	40					

IPDS - Geotechnical

Figure 5. Postscript output from *borlogps*.

### COMPILING THE PROGRAMS

Two shell scripts were written to simplify the compilation process. For systems using GKS with Sunview libraries, the "g77" script should be used to compile FORTRAN programs. For systems using GKS with XVIEW libraries, the "ng77" script should be used to compile the programs. The ways to compile are:

- For Sunview's SUNGKS
  - g77 <name of source program> <name of executive file>
  - For example: g77 borlog01.f borlog01

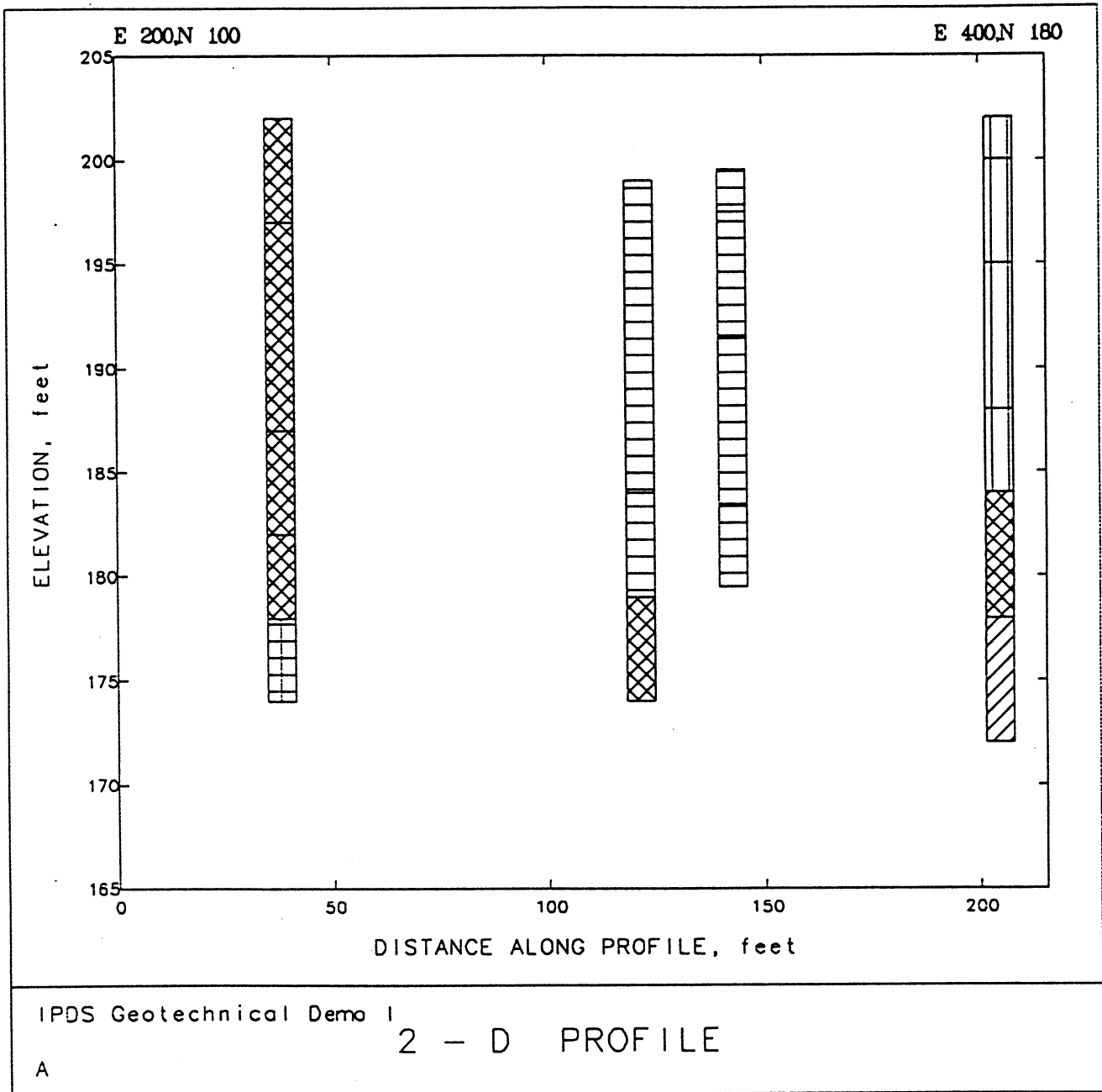


Figure 6. Example output from *prof2dps*.

- For Xview's SUNGKS  
`ng77 <name of source program> <name of executive file>`  
 For example: `ng77 fencedps.f fencedps`

The shell scripts are as follows:

- `g77 :`  
`f77 \ $1 -o \ $2 -lgks77 -lgks -lsuntool -lsunwindow -lpixrect -lm`
- `ng77 :`  
`f77 -I\ $GKSDIR/../../include \`  
`-I\ $OPENWINHOME/include \ $1 -o \ $2 -L\ $OPENWINHOME/lib \`  
`-L\ $GKSDIR/.. -lgks77 -lgks -lxview -lolgx -IX11 -lm`

### 3-D FENCE DIAGRAM

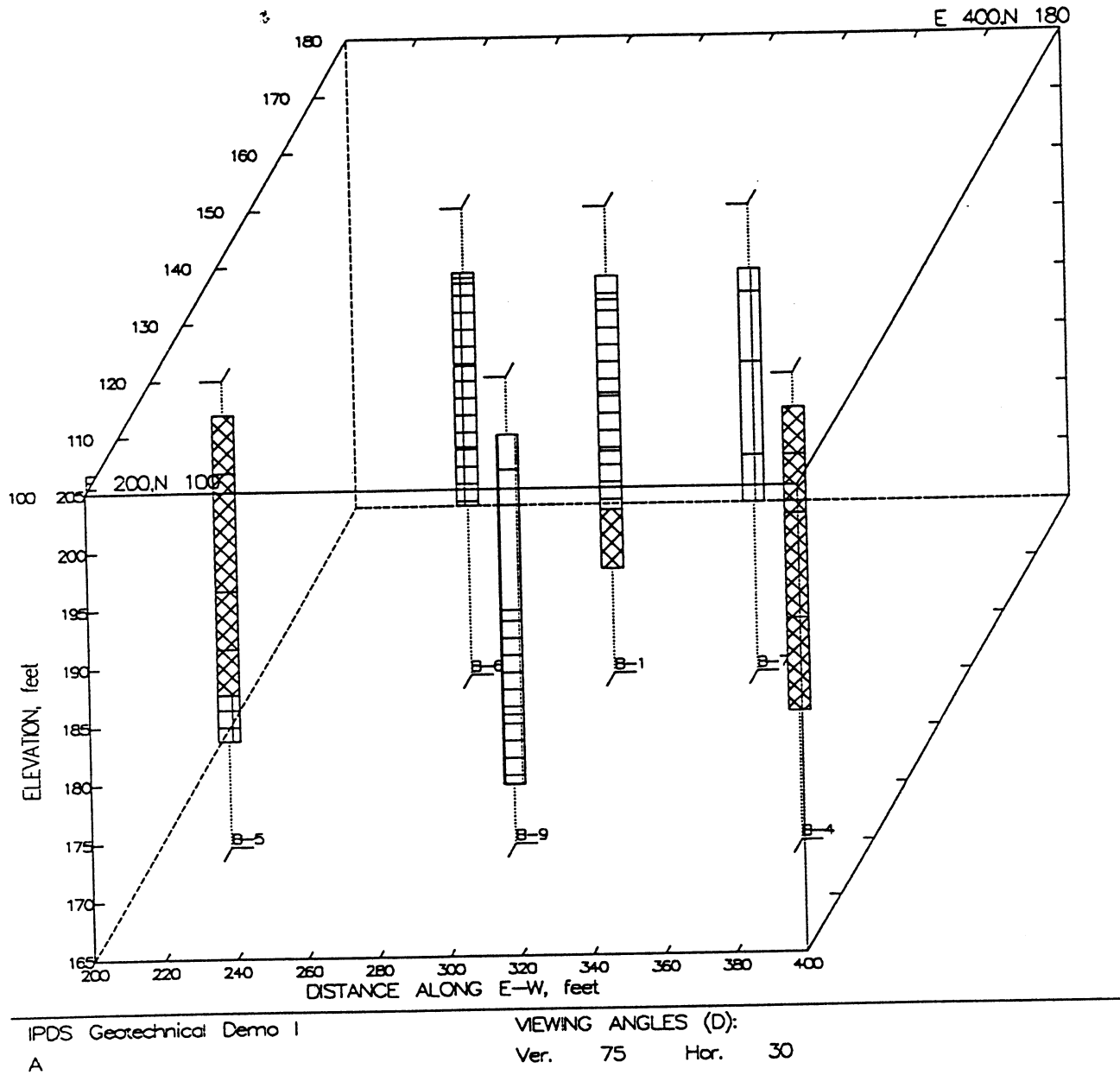


Figure 7. Sample three-dimensional fence diagram output from *fencedps*.

### THE DATA FILES

Execution of the program requires that the data files be produced by the "query" function of the system and be located in the current directory along with the executable programs. The data files required for each program are listed in Table 6.

The data files contain necessary information to graph boring log plots such as shown in Figures 5-7. The content and formats of the data files list (Table 6) are as follows. Many of the data items can be identified from Figures 5-7. Where additional information is needed, comments following the "%" symbol have been added for clarity. The comments should not be included in actual data files.

Table 6. Data files for the plot programs.

borlog01	prof2d01	fenced01
gdbor1.inp	gd2dp.inp	gd2dp.inp
pjinfo.dat	bdata1.dat	bdata1.dat
bdinfo.dat	bdata2.dat	bdata2.dat
brinfo.dat	bdata3.dat	bdata3.dat
ldesc.dat	bdata4.dat	bdata4.dat
dmax.dat		
sample.dat		
dd.dat		
wc.dat		
ll.dat		
pl.dat		
fn.dat		

*gdborl.inp*: graphics descriptors for the boring log chosen (Sengara, 1988).

---

'PAGE'	1.750000E+00	1.250000E+00	1.000000E+00	7.500000E-01	% Margins
	% top	bottom	left	right	(in inches)
'LAYOUT'					
'DESC'	60				Width (%) of Soil Description
'DEPTH'	10				Width (%) of Depth
'SPT'	5				Width (%) of SPT
'WC'	5				Width (%) of Water Content
'DD'	5				Width (%) of Dry Density
'LL'	5				Width (%) of Liquid Limit
'PL'	5				Width (%) of Plastic Limit
'FN'	5				Width (%) of Fines
'HATCH'	3				Width (%) of Soil profile
'SPTH'	1				Width (%) of Sample profile

---

*pjinfo.dat*: project information (Sengara, 1988).

---

'IPDS Geotechnical Demo I', 'UW Madison', 'Sam'

---

*bdinfo.dat*: building & location information (Sengara, 1988).

---

'A', 'Civil Engineering Department'

---



*brinfo.dat*: boring information (Sengara, 1988).

---

'B-3', 'E 380,N 180', ' 202.00', '03/02/88', 'Richard Bore', '10.00'

---

*ldesc.dat*: layer descriptor; the layer descriptor file contains three fields. The first field contains the boring name, the second field contains layer depth, and the third field contains the soil description ~ \cite(Sengara, 1988).

---

'B-3', 2.00, 'Fine sand, medium dense.'  
'B-3', 7.00, 'Silty clay, gray to rusty, very moist, stiff.'  
'B-3', 18.00, 'Gravelly lean clay (CL), moderate plasticity.'  
'B-3', 24.00, 'Lean Clay (CL), moderate plasticity.'  
'B-3', 30.00, 'Limestone, buff, unweathered, weak, foliated.'

---

*dmax.dat*: maximum depth of the boring log (Sengara, 1988).

---

30.00

---

*sample.dat*: samples for experiment; the sample.dat file contains four fields. The first field contains the sampler name, the second field contains the sample depth, the third field contains the blow count, and the fourth field contains the sample recovery (Sengara, 1988).

---

'SPT', 2.00, 2, 1.00  
'Shelby Tube', 4.00, 0, 1.00  
'SPT', 5.50, 8, 1.00  
'Shelby Tube', 7.00, 0, 1.50  
'SPT', 10.50, 15, 1.50  
'Shelby Tube', 15.00, 0, 0.50  
'SPT', 17.50, 15, 1.00  
'Shelby Tube', 20.00, 0, 1.00  
'SPT', 23.00, 17, 1.50

---

*dd.dat*: dry density of the samples; the dd.dat file contains four fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, and the fourth field contains the run or test result (Sengara, 1988).

---

2.00, 'Middle', 1.00, 110  
4.00, 'Top', 1.00, 118  
5.50, 'Top', 1.00, 110  
7.00, 'Middle', 1.50, 118  
10.50, 'Top', 1.50, 108  
15.00, 'Top', 0.50, 118

17.50,'Middle',1.00,119  
20.00,'Top',1.00,117

---

*wc.dat*: water content of the samples; the *wc.dat* file contains four fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, and the fourth field contains the run or test result (Sengara, 1988).

---

2.00,'Middle',1.00,25  
4.00,'Top',1.00,18  
5.50,'Top',1.00,15  
7.00,'Middle',1.50,23  
10.50,'Top',1.50,32  
15.00,'Top',0.50,28  
17.50,'Middle',1.00,32  
20.00,'Top',1.00,23

---

*ll.dat*: liquid limit of the samples; the *ll.dat* file contains four fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, and the fourth field contains the run or test result (Sengara, 1988).

---

4.00,'Middle',1.00,36  
5.50,'Middle',1.00,40  
10.50,'Middle',1.50,34  
17.50,'Middle',1.00,45  
20.00,'Top',1.00,43

---

*pl.dat*: plastic limit of the samples; the *pl.dat* file contains four fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, and the fourth field contains the run or test result (Sengara, 1988).

---

4.00,'Middle',1.00,15  
5.50,'Middle',1.00,15  
10.50,'Middle',1.50,14  
17.50,'Middle',1.00,17  
20.00,'Top',1.00,17

---

*fn.dat*: fines of the samples; the *fn.dat* file contains four fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, and the fourth field contains the run or test result (Sengara, 1988).

---

2.00,'Middle',1.00,20  
4.00,'Bottom',1.00,68  
5.50,'Middle',1.00,58

7.00,'Top',1.50,67  
10.50,'Middle',1.50,68  
17.50,'Middle',1.00,62  
20.00,'Top',1.00,71

---

*gd2dp.inp*: graphics descriptor for the two points chosen (Sengara, 1988).

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'PAGE'  
1.750000E+00 1.250000E+00 1.000000E+00 7.500000E-01 % Margins  
'COORDINATES' % (in inches)  
200 100 'E 200,N 100' % Coordinates of the first picked point  
400 180 'E 400,N 180' % Coordinates of the second picked point

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*bdata1.dat*: descriptor of boring logs included; the *bdata1.dat* file contains three fields. The first field contains the boring name, the second field contains the soil description, and the third field contains the layer depth (Sengara, 1988).

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'B-1', 'Sandy Clay, medium stiff.', 2.00  
'B-1', 'Silty Clay, medium stiff, low plasticity, moist, shrinkage.', 10.00  
'B-1', 'Clay with some gravel (CL), low plasticity.', 20.00  
'B-1', 'Lean Clay (CL), stiff, low plasticity.', 25.00  
'B-3', 'Fine sand, medium dense.', 2.00  
'B-3', 'Silty clay, gray to rusty, very moist, stiff.', 7.00  
'B-3', 'Gravelly lean clay (CL), moderate plasticity.', 18.00  
'B-3', 'Lean Clay (CL), moderate plasticity.', 24.00  
'B-3', 'Limestone, buff, unweathered, weak, foliated.', 30.00  
'B-4', 'Sandy Clay (CH), medium plasticity, fine, dry to moist.', 4.00  
'B-4', 'Silt (ML), stiff, low plasticity, grey, saturated.', 26.00  
'B-5', 'Sandy Clay (CL), very stiff, blue-green.', 5.00  
'B-5', 'Elastic Silt (MH), high plasticity, brown, wet.', 28.00  
'B-6', 'Sandy Clay (CH), high plasticity.', 1.00  
'B-6', 'Silty clay, gray brown, medium plasticity, medium stiff.', 8.00  
'B-6', 'Gravelly lean clay (CL), very stiff, moderate plasticity.', 20.00  
'B-7', 'Sand, fine grained, dry.', 2.00  
'B-7', 'Silty Clay, greyish brown, moist, stiff, shrinkage.', 8.00  
'B-7', 'Gravelly Lean Clay (CL), very stiff, moderate plasticity.', 20.00  
'B-8', 'Siltstone, moderately hard, unweathered.', 25.00  
'B-9', 'Silty Clay, gray brown, medium plasticity, medium stiff.', 6.00  
'B-9', 'Clay with stiff Silt, non plastic, grey, moist.', 30.00

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*bdata2.dat*: surface elevations and depths of boring logs chosen; the *bdata2.dat* file contains three fields. The first field contains the boring name, the second field contains the ground elevation, and the third field contains the maximum depth (Sengara, 1988).

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'B-1',199.00,25.00  
'B-3',202.00,30.00  
'B-4',202.00,26.00  
'B-5',202.00,28.00  
'B-6',199.50,20.00  
'B-7',199.50,20.00  
'B-8',200.00,25.00  
'B-9',200.00,30.00

---

*bdata3.dat*: surface elevations and coordinates of boring logs chosen; the *bdata3.dat* file contains four fields. The first field contains the boring name, the second field contains the ground elevation, the third field contains the x-coordinate of the boring, and the fourth field contains the y-coordinate of the boring (Sengara, 1988).

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'B-1',199.00,300.00,150.00  
'B-3',202.00,380.00,180.00  
'B-4',202.00,380.00,120.00  
'B-5',202.00,220.00,120.00  
'B-6',199.50,260.00,150.00  
'B-7',199.50,340.00,150.00  
'B-8',200.00,300.00,180.00  
'B-9',200.00,300.00,120.00

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*bdata4.dat*: project information; the *bdata4.dat* file contains the project name and building name (Sengara, 1988).

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IPDS Geotechnical Demo I', 'A'

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## RUNNING THE PROGRAMS

The binary programs can be executed to display the graphs required or to create related postscript files for printing the graphs. For running *borlog01* or *prof2d01*, enter the program's name and the graph will be shown on the screen. Pushing the "Return" key again will quit the program immediately. For running *borlogps* or *prof2dps*, enter the program's name. Postscript files *borlog.ps* and *prof2d.ps* will be produced which can then be printed on a postscript printer respectively.

For running *fenced01*, after entering the file name, a three-dimensional fence diagram with viewing angle (45,45) degrees will appear on the screen. There will be a small circle labeled "Rotate" shown on the bottom of the diagram. The arrow cursor can now be moved (by mouse) to "Rotate" and clicking and holding the right hand side button of the mouse will produce the choice menu. Moving the arrow to the chosen menu item, i.e., "v+5", "v-5", "h+5", "h-5" or

"exit", and releasing the button while either turning the fence diagram through an angle of 5 degrees either vertically or horizontally to avoid overlaying of the boring logs to one another, or quitting the program.

For running *fencedps*, after entering the file name, the program will ask the user to input viewing angles, and then it will produce a postscript file called *fenced.ps* with viewing angles as previously input.

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