

# MANAGEMENT OF GROUND ENGINEERING DATA

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**Abstract**—Until recently, ground engineering data has been managed manually, primarily using paper reports and Microsoft® Excel® spreadsheets. However, these methods are time consuming, and it is difficult to transfer information and methodologies from one project to another without considerable effort. A common database for all ground engineering data permits ease of use and long-term accessibility to data in a common format with adequate tools for collecting, validating, using, publishing, and storing data.

While this seems like a simple and straightforward concept, implementing a common database on a wide range of projects throughout the world is a complicated process. This paper describes how each step has been accomplished, the difficulties and successes in implementing the system, and the possibilities for future development. The lessons learned are applicable across a wide range of disciplines that manage data, want to improve its quality and accessibility, and realize the obvious economic advantages. The paper contains examples from recent Bechtel projects in which an electronic ground engineering database has been successfully implemented.

**Keywords**—data, database, ground engineering, implementation, validation, verification

## INTRODUCTION

Historically, ground engineering project data, including geotechnical, geophysical, environmental, and monitoring data, has been processed on paper and presented in picture, table, or graph formats. The introduction of computers made data processing somewhat simpler, and the use of spreadsheets and graphical routines made implementation easier and the output look more professional. However, the real use of data has not developed at the same rate. [1] While spreadsheet-based processes are useful on a “one-off” basis, they are not efficient for managing data over a project’s lifecycle and have hindered the development of an integrated data management system.

Being able to manage project data from start to finish is much more efficient, leads to considerable cost savings, and allows data to be used across disciplines and projects. [2] This paper describes Bechtel’s experiences with managing geotechnical data and how the lessons learned, the processes developed, and the database structures are applicable across many disciplines.

## DATA

To set up a project-wide data management system, it is necessary to understand the nature of data, the principles of data management, and the software systems available to process it.

For purposes of this paper, and to provide a useful definition to remember, data is the record of an observation that has attributes attached to it that provide a unique identification of the observation along with any useful information about how the data was collected. Typically, these attributes consist of location, date and time, and type of reading, including the units of measurement. Other information provided may include the sample and/or test name and, for environmental samples, data about how the sample was collected, prepared, and stored. The same principles apply to laboratory test results and environmental data. Each data item, together with each of its attributes, needs to be gathered in a storage area, known as a data field. For a typical geotechnical investigation, approximately 200 to 300 data fields are required to store all the data and attributes collected. The actual fields can vary, depending on the nature and type of investigation.

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## ABBREVIATIONS, ACRONYMS, AND TERMS

AGS	Association of Geotechnical and Geoenvironmental Specialists
CAD	computer-aided design
COSMOS	Consortium of Organizations for Strong-Motion Observation Systems
CPT	core penetration testing
DIGGS	Data Interchange for Geotechnical and GeoEnvironmental Specialists
Esri®	Environmental Systems Research Institute
GBU	global business unit (Bechtel)
GIS	geographic information system
ISO	International Organization for Standardization
NDIA	New Doha International Airport
PDA	personal digital assistant
QA	quality assurance
QC	quality control
SI	International System of Units
SOE	sequence of events
UAE	United Arab Emirates
UK	United Kingdom
XML	extensible markup language

*Enter the data once but use it many times, enter the data at the source, and have someone else enter the data.*

“Data = 3.00” is an example of data recorded for the depth to water in a borehole. Its attributes include the location, the date and time, and the units of measurement. Additional information such as the name of the person taking the reading, the weather conditions, and barometric pressure may also be recorded simultaneously in a similar format.

Environmental samples and test results have many more attributes, including the quality assurance/quality control (QA/QC) information needed to validate the data.

Data needs to be uniquely defined, i.e., location numbers have to be unique, not only to the investigation but also to the project, to avoid confusion in situations such as multiphase investigations in which several boreholes are designated as 1. The format should also be consistent, since samples taken from the same borehole but recorded as BH10, BH 10, and BH\_10 will all be read differently by the computer. To ensure uniqueness, the Bechtel Civil Global

Business Unit (GBU) developed a simple yet consistent numbering system:

<PROJECT>\_<LOCATION-TYPE>\_<NUMBER>.

Bechtel executes projects throughout the world, often in accordance with local codes and standards. Therefore, the units of measurement need to be stated carefully, since various countries and even regions within countries use different units and methods of representing the units. Computers, unlike humans, cannot spot obvious errors or variations.

For example, it is preferable to use the international date and time format as described in International Organization for Standardization (ISO) 8601:2004 [3]: yyyy-mm-ddThh:mm:ss.sssZ(+hh:mm), where Z is the time zone offset. This format is flexible and can be used in full or part according to user requirements (yyyy-mm-dd or hh:mm:ss or yyyy). The need to define length units carefully is further underscored by the fact that metric units in the International System of Units (SI) have not been consistently adopted in the United Kingdom (UK), which uses millimeters while continental Europe uses centimeters. Similarly, in imperial units, feet and inches and feet and decimal feet are often used interchangeably.

Information can be defined as a collection of data items that have been presented in a usable format such as a graph or a table or, in the case of geotechnical data, a borehole log, where many different sources are combined to produce a complete record of the investigation that can be easily understood by the reader.

Since data is used throughout a project, it is useful to create a data management program for the whole project using the following helpful guidelines:

- Enter the data only ONCE
- Enter the data at the source
- Have someone else enter the data

From a commercial standpoint, data entry costs can be expensive, but each time the data is used, value is added. It follows that the guidelines may be extended to:

- Enter the data once but use it many times

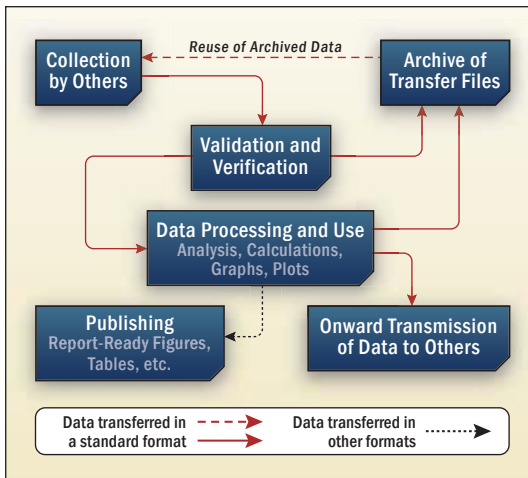
A simple test involves looking at the project lifecycle and asking how many times the data is entered into a system, whether it is via paper, keyboarding, scanning, or some other means. If the answer is more than once, then consideration should be given to reviewing the system.

**DATA MANAGEMENT**

Data management includes a system that consists of the following elements:

- Collection
- Validation and verification
- Manipulation, data processing, and use
- Transfer and onward use
- Publication
- Archiving

The way in which these elements are linked together to allow data to flow through a project is depicted in Figure 1.



**Figure 1. The Flow of Data Through a Project**

**Collection**

Ground engineering data is usually collected by specialist subcontractors specializing in investigations. Typically, these subcontractors include drilling contractors that excavate boreholes, take field samples and conduct tests, and log data on the strata; laboratories and testing houses that conduct laboratory tests; and monitoring contractors that conduct tests and take measurements during the progress of the work. The data to be collected and the format of the data are specified in the subcontract. Bechtel requires data to be in a standardized electronic format.

For the 60-million-cubic-meter land reclamation project at the New Doha International Airport (NDIA), Bechtel specified that all geotechnical data be collected, processed, and stored in a database during construction. Because of this requirement, the contractor implemented a single system that recorded every piece of geotechnical data from the laboratory and field. By comparing this data with the specification, the contractor

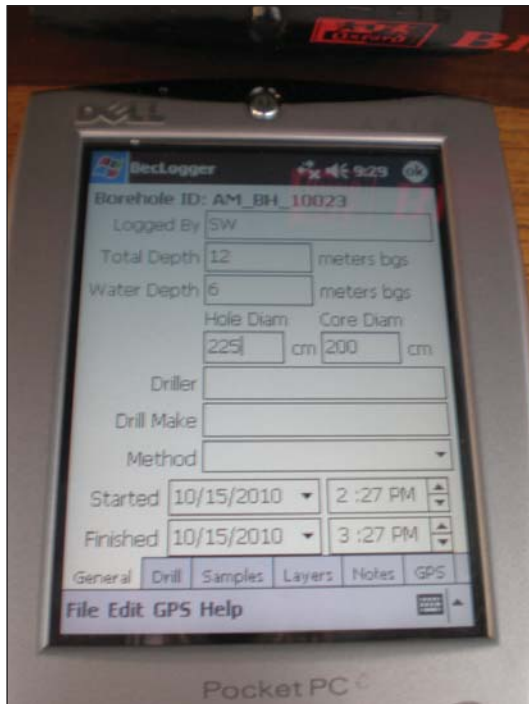
was able to automatically produce the compliance reports for the project, which not only saved time and effort but enabled the completed land reclamation site to be handed over on schedule and with all the necessary documentation.

On projects in which Bechtel has been required to field log investigation holes, BeCLogger, a specialized program developed by Bechtel for use on a personal digital assistant (PDA) (see Figure 2), records data at the source and transfers it directly to the office. Using this program reduces the amount of time required to log data by more than 50%.

Commercial versions of programs similar to BeCLogger are now available outside of Bechtel, and electronic handheld data collection devices are commonly used. The recent introduction of a “big button” device allows drillers in the field to record drilling progress while wearing gloves in the rain.

To monitor projects such as tunneling in sensitive urban areas, the incoming data may be recorded in many different forms—ranging from electronic files [4] from total measurement stations that continuously record data, to copies of water levels and flows recorded in field notebooks. A data management system that handles all of these sources was implemented on the Athens Metro project, and similar systems have been used on other projects.

*Bechtel requires data to be in a standardized electronic format.*



**Figure 2. PDA with BeCLogger Software for Logging Borehole Data in the Field**

The seamless transfer of data among the various parties working on a project is essential if an effective and efficient system is to be created.

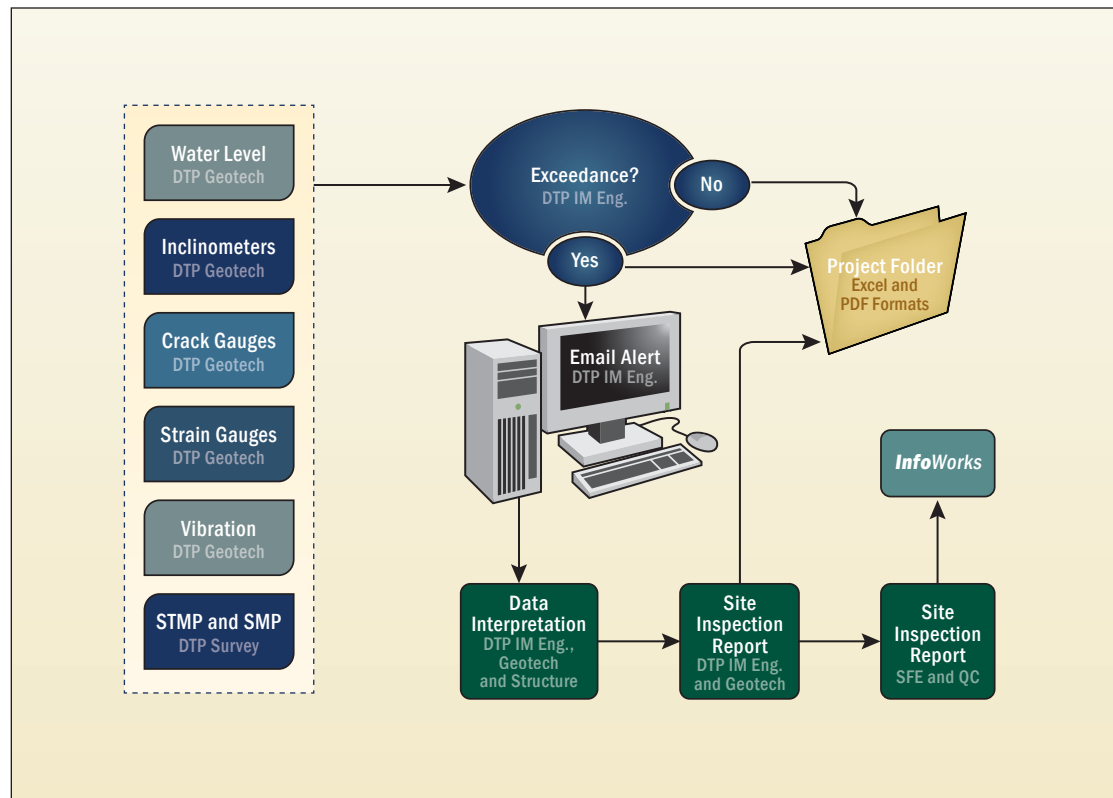


Figure 3. Validation and Verification of Ground Monitoring During Tunnel Construction on the Dulles Metro Project

### Validation and Verification

While data is valuable, for it to be of any use, it must be validated and verified. These terms are often used interchangeably; they both mean that the data must be checked to demonstrate that the reading is correct, e.g., that the water level was taken in the reported borehole and that the reading is the correct depth.

On the Athens Metro project, all monitoring readings were checked against two criteria:

- All the necessary readings had been taken
- The readings did not fall into any “trigger levels”

In the first check, a routine in the database compared the readings taken to the schedule of required readings. Any missing readings were referred back to the surveyors for correction. The second check compared the readings against the trigger levels for absolute, relative, and rate-of-change criteria. If the readings exceeded the preset values, corrective actions were taken based on a procedure used on the Dulles Metro project, as shown in **Figure 3**.

### Manipulation

Data manipulation consists of processing data to ensure that it is useful and can be presented as

information that can be consulted by designers, engineers, and managers. Data is manipulated using a specially structured database that can input, store, process, present, and transfer data. Bechtel uses the Bentley® gINT® program, which can handle all geotechnical data and currently has more than 1,200 data fields available for storing data items. It also is capable of managing environmental and monitoring data together with construction data, if required. A common data structure allows all projects to use the same data structure. It is possible to “hide” those data fields not in use to make the system more user friendly, since a typical project uses less than 200 of the 1,200 data fields available. gINT can produce borehole logs, sections (fence diagrams), graphs, histograms, statistics, tables, and custom reports as required during project lifecycles. Routines are available to produce customized data structures and reports for nontypical projects such as grouting a leaking dam or monitoring settlement of a large oil tank during first filling.

### Transfer

The seamless transfer of data among the various parties working on a project is essential if an effective and efficient system is to be created. Without a common transfer method, formats are

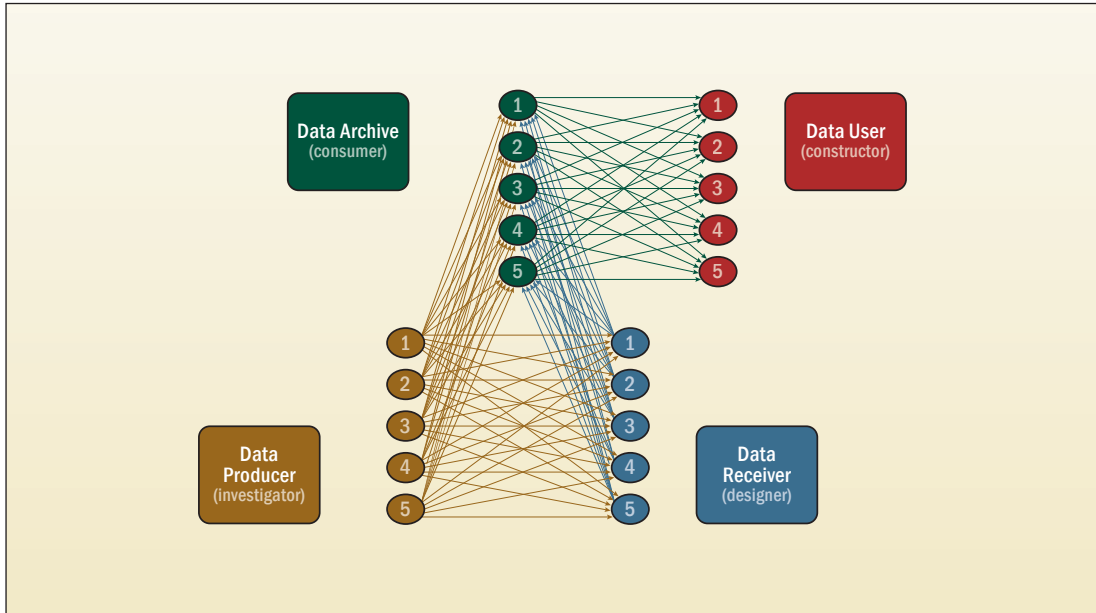
confusing and systems are inefficient, as shown in **Figure 4**.

Bechtel has been involved in both developing and implementing a common standard transfer format [5, 6], which increases ease of use and enables the various software programs to communicate with each other without the need for intervention.

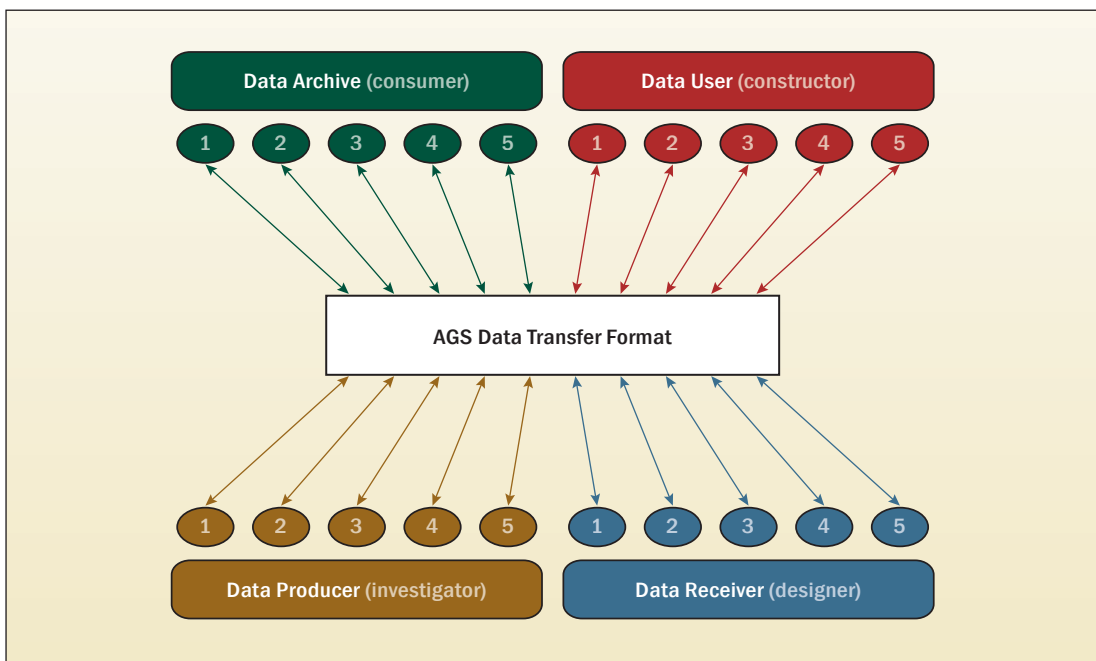
The Association of Geotechnical and Geoenvironmental Specialists (AGS) data format [7], which has been in use for the last 20 years, provides a means of ensuring that project data

has to be entered into the system only once and then transferred (see **Figure 5**). The latest version of the transfer format has over 2,000 data fields. Although it has been designed in accordance with UK practices, it has been structured specifically to be adapted for international use. Of the other existing transfer formats, the Dutch standard for core penetration testing (CPT) [8] is commonly used and Data Interchange for Geotechnical and GeoEnvironmental Specialists (DIGGS) [9], which is being developed in the US, will be available shortly. Bechtel has used the AGS transfer format on many projects and has

*The AGS data format provides a means of ensuring that project data has to be entered into the system only once.*



**Figure 4. Communications Without a Common Transfer Format**



**Figure 5. Data Communications Using the AGS Data Transfer Format**

introduced it to contractors in several countries, including Singapore, China, United Arab Emirates (UAE), Saudi Arabia, Qatar, Greece, and Romania, where it has been implemented rapidly and successfully.

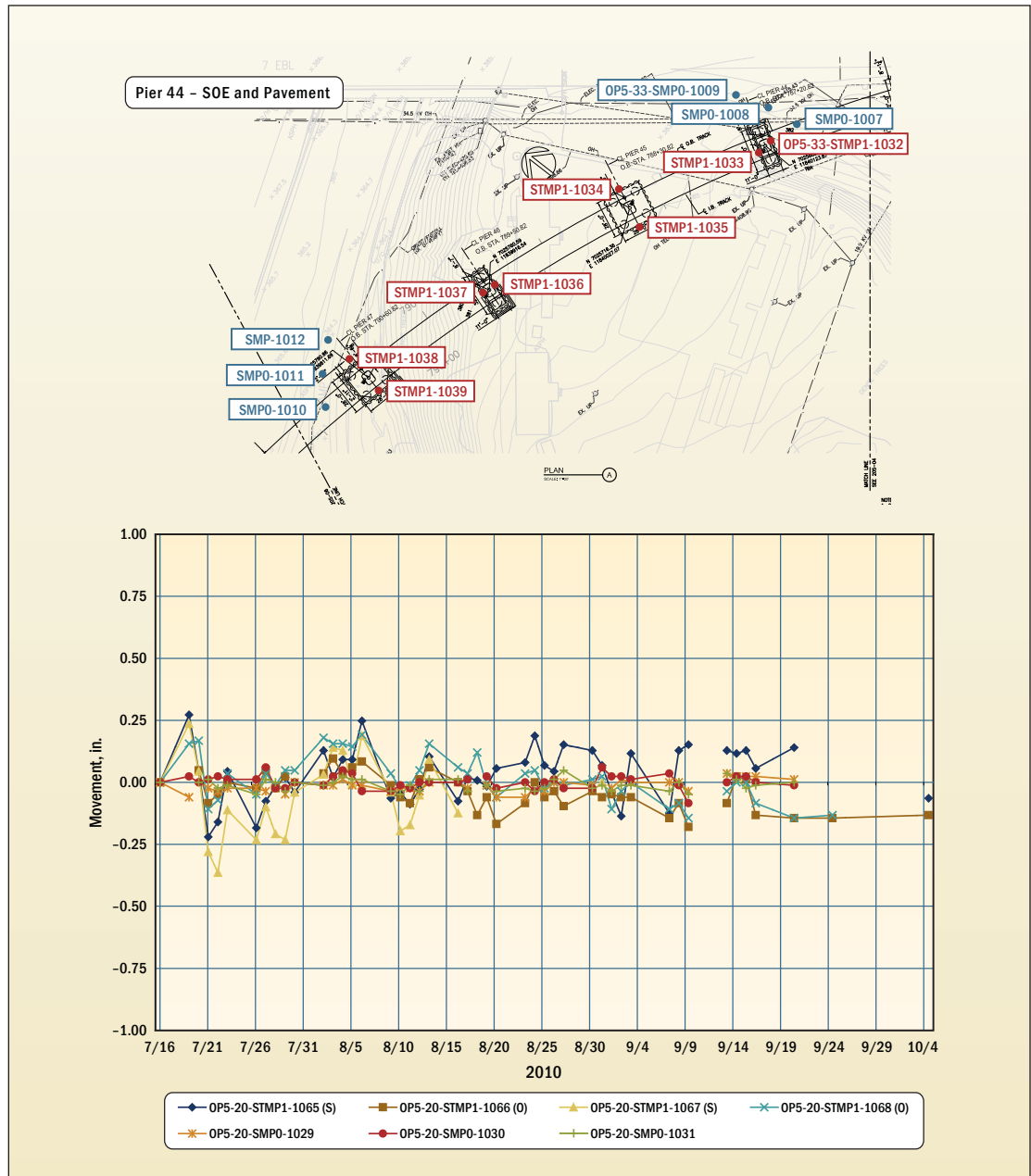
**Publication**

Ground engineering data is usually published as borehole logs, graphs, tables, sections, etc. (see **Figure 6**), to provide engineers and managers with the information as and when they need it and in a format that they are used to seeing. This is particularly important in a project’s monitoring

phase during construction, when a large number of people need to see and understand data quickly to ensure that work progresses safely. In the past, it has been noted [10] that problems have arisen because the data was collected but not examined and the trends and information contained with the readings were not acted upon. These published methods promote the correct and timely use of the data through ease of presentation.

Repeated use of the data throughout a project lifecycle is a major advantage of using a database.

*The repeated use of data throughout a project lifecycle is a major advantage of using a database.*



**Figure 6. Sample Plot Plan Showing Location of Monitoring Instruments and Plot of Typical Readings**

## Archiving

Data is a very valuable asset only when it can be easily retrieved and is in a usable form. By exporting the data from the database in a standard text file that is independent of software and version, it is possible to store the data in standard document management systems such as Bechtel's electronic document management system, *InfoWorks*®. While this system ensures that the data is managed in accordance with project requirements and can be made available across projects if necessary, the data can also be stored confidentially if specified. Since it is stored along with all other project data, no additional system is required.

## FUTURE DEVELOPMENTS

Data management is an ongoing operation that combines new techniques and existing technologies. Software is already available for a number of these new data management techniques that:

- Link geotechnical data to a geographic information system (GIS), including Google™ Earth, Esri® ArcGIS®, etc. (see **Figure 7**)
- Link geotechnical data directly to computer-aided design (CAD) systems to provide online data to others (which allows boreholes to be added directly into CAD drawings from the geotechnical database)
- Implement an "enterprise database" to contain all geotechnical and geoenvironmental data within one system (including client management to ensure that the data is kept confidential if necessary)
- Encourage field capture of data at the rig and in the laboratory
- Integrate "real time" monitoring data, which is already available using proprietary systems, into project procedures
- Apply geotechnical engineering procedures and techniques to other disciplines, including hydrogeological, environmental, and geoenvironmental [11]

A number of these techniques involve the use of third-party software. Bechtel is working to develop a cross-project operation so that they can become available to all.

Future developments being investigated include a new transfer file format using extensible markup language (XML) technology [12] to facilitate the production and publication of data. This format will be published under the auspices of DIGGS, an organization consisting of representatives from

US and UK government agencies, the University of Florida, the Consortium of Organizations for Strong-Motion Observation Systems (COSMOS), and the geotechnical software industry. Originally coordinated by the US Federal Highway Administration, DIGGS is focused on creating and maintaining an international transfer standard for transportation-related data, which will facilitate the use of Web-based systems.

## CONCLUSIONS

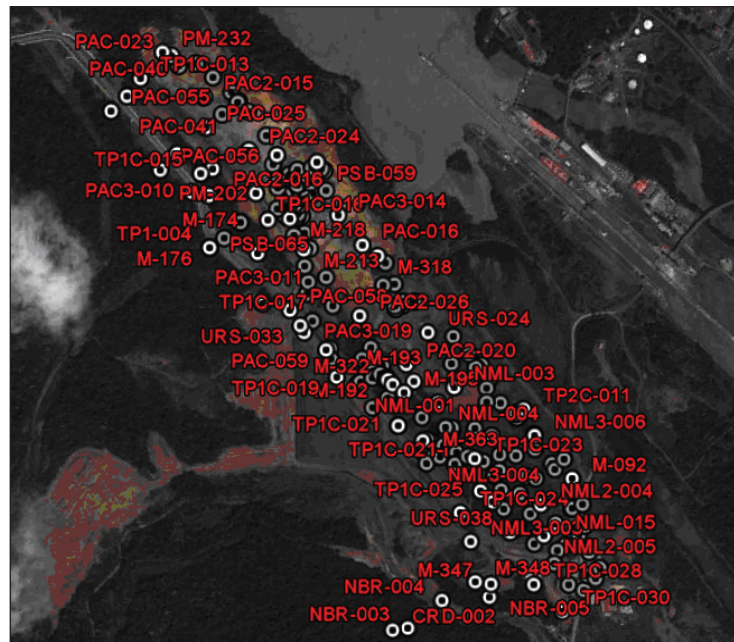
Since the first AGS data transfer format was conceived 20 years ago, the availability of computers has risen dramatically. While the use of ground engineering data has not kept pace with these changes, recent developments have shown that once the fundamentals of data management are grasped by the practitioners in a particular discipline, the rewards are great. The major stumbling block has been the learning curve to understand the fundamental change needed to use data correctly and not to continue to use an uneconomic but comfortable system. ■

## TRADEMARKS

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**Figure 7. Plot of Borehole Locations for New Panama Canal Locks in Google Earth**

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InfoWorks is a registered trademark of Bechtel Corporation.

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## BIOGRAPHY



Stephen Walthall is a technical expert in all aspects of ground engineering. He has 40 years of working experience in the engineering geology, hydrogeology, geotechnics, and construction fields in the UK and internationally.

After starting his career with Ground Investigation Specialists based in the UK (working in the Middle East and Africa), Stephen spent many years with North West Water in the UK as a hydrogeologist before leading its geotechnical section. He developed considerable expertise in construction, particularly in the areas of tunnels and building on poor ground, along with a detailed knowledge of embankment dams.

Since joining Bechtel, Stephen has worked extensively in Eastern Europe and the former Soviet Union (FSU), where he gained expertise in their codes and standards. He has also worked on transportation and oil and gas projects in the Middle East. Stephen was jointly responsible for developing the geotechnical data management systems for the Channel Tunnel Rail Link (CTRL) project, where he was geotechnical lead for the Thames Valley section. On the Athens Metro project, he was an advisor responsible for all geological aspects, including the development and implementation of an electronic monitoring system for controlling tunneling activities through the city.

Stephen is a member of the committee that is preparing British Standard BS 8574, provisionally titled "The Management of Data in Ground Engineering." He has been a member of the AGS working party for the development of the electronic data transfer format from its inception and chaired the committee from 2000 to 2010. He was a former committee member of the Engineering and the Hydrogeological groups of the Geological Society and was an advisor to the DIGGS committee.

Stephen obtained a BSc in Physics and Geology from the University of Manchester and an MSc from the University of Durham. He is a Chartered Geologist, a Chartered Scientist, and a Fellow of the Geological Society of London.