DIGGS

Data Interchange for Geotechnical and Geoenvironmental Specialists

Introduction to DIGGS

This document has been prepared by:

Dr Chris Power - Mott MacDonald
Dr Roger Chandler - Keynetix

Revision History

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Executive summary

DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists) is an international standardised format for the electronic transfer of geotechnical and geoenvironmental data that can be used at all stages of a project, and by all parties involved in a project. The DIGGS Format is a software neutral, non-commercial, open standard.

Currently, data can be transferred between the various parties to a project in many different formats, from paper reports to electronic documents, spreadsheets etc. This data transfer works, and projects do get completed, but the use of DIGGS will offer significant improvements in the project workflow, which it has been demonstrated will result in improved efficiency, improved data quality, and hence cost savings for all parties. The particular advantages of DIGGS are:

> **Electronic data is more efficient than paper-based reports. The turn around time from receipt of data to required output can be considerably reduced**

> **Data transfer is faster and more efficient, and can be undertaken in close to real-time in some situations (e.g. for automatically collected monitoring or pile installation results)**

> **Data validation is carried out using a set of rules that is the same for all parties in the data exchange. There can be no interpretation of the rules; therefore mistakes are much reduced**

> **Electronic data has only to be entered once, and can then be used many times. For a project with many diverse parties involved, this allows a 'single version of the truth' to exist, reducing confusion and potential mistakes or conflicts**

> **The DIGGS methodology for handling the referencing of samples taken for laboratory testing reflects the diverse working practices of the parties involved in a project. This flexibility is essential for the complete and accurate handling of test results**

> **Revision handling is much improved and provides an auditable quality assurance record**

> **Data archiving on completion of a project is more efficient**

> **Electronic data, particularly DIGGS Format data, which is geographically located, lends itself well to direct use in CAD and GIS packages**

The initial version of DIGGS covers all of the data needed to reproduce a factual geotechnical ground investigation report such as the borehole logs, the insitu testing results, the geotechnical laboratory test data and some types of insitu geophysical tests. It also includes monitoring data from insitu geotechnical instruments and other types of field measuring devices, and design, construction and test data for piled foundations. The DIGGS Format is fully extensible and future versions will cover other areas of geotechnical and geoenvironmental data, for example geoenvironmental chemical test reporting is currently in development.

This document provides a user's introduction to DIGGS. It describes the data that DIGGS transfers, and some of the concepts that the users will need to be aware of when issuing or receiving data in DIGGS Format. The details of the format and how it is structured are contained in a separate Technical Guide to DIGGS, but most users will not need to know about these technical details as their application software will provide DIGGS import and export functions.

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Introduction

Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) is a standardised, international format for the electronic exchange of geotechnical and geoenvironmental data. DIGGS can be used for exchange of data between all parties involved in a project, and at any stage of a project. DIGGS is a data transfer format, it is not software and it is not a database structure. It is therefore software neutral and is entirely non-proprietary. There are several key reasons why the use of DIGGS can bring both cost and time efficiencies to a project:

> **DIGGS is an electronic data transfer format (utilising XML: Extensible Mark-up Language), giving considerable advantages over paper-based information transfer,**

> **Being an electronic method of data transfer, it is fast and efficient, allowing movement of information from one party to another in close to real time in some situations,**

> **DIGGS data only needs to be entered once, and can then be used many times. Once information is converted into DIGGS, it acts as a 'single version of the truth' with in-built version handling, reducing potential confusion which may come about from different versions of a data source being in existence,**

> **DIGGS data is validated using a set of rules that is not open to any interpretation, and is the same for all parties, therefore mistakes in the data format are avoided,**

> **Project specific extensions to DIGGS are handled in a rigorous and controlled manner, ensuring that confusion over such extensions within a project team are avoided.**

This introductory document sets out to explain DIGGS in non-technical terminology, and provides guidance in the use of DIGGS through consideration of real-world examples. A glossary of technical terms is given in section 10. Those wishing to develop DIGGS compatible software can find full technical details in the Technical Guide to DIGGS. A full description of each data object discussed in this document can be found in the DIGGS Data Dictionary document and Data Dictionary spreadsheet.

This document illustrates the relationships between the data objects using simplified diagrams that are easy for an end user to understand. Anyone wishing to implement DIGGS in an application is advised to use the schema files and data dictionary to fully understand the correct nesting before proceeding.

This document has been compiled for the first public review release of DIGGS and will be updated and expanded with each release. To be kept up to date with the latest version please register for a free account at www.diggsml.com and you will receive email announcements as the review period progresses.

1 The DIGGS project

1.1 Scope of DIGGS

DIGGS encompasses the transfer of electronic data relating broadly to the fields of geotechnical and geoenvironmental engineering. The scope of DIGGS is likely to expand in the future, but for this release the primary areas of coverage include:

Geotechnical engineering, incorporating both soil and rock mechanics,

Engineering geology,

Geoenvironmental engineering,

Geotechnical and geoenvironmental monitoring,

Piling,

Borehole geophysics

Importantly, it should be understood that DIGGS is a format for the transfer of **results**, it is not intended to facilitate the transfer of what could be termed as **raw data**. By way of example, for a moisture content test on a soil sample, DIGGS facilitates the transfer of information such as the calculated moisture content value, it does not allow for the transfer of the information required to derive the value (e.g. the weight of the sample, weight of sample tins etc).

It should also be noted that DIGGS is not a software product. It is a data transfer format that will be able to be used by various software products, which is likely to include stand-alone desktop applications and also web-based applications.

It should also be noted that DIGGS is not a database standard or structure. Whilst DIGGS does contain some structure in terms of the relationships between data held within a particular file, it cannot be used as a database in its own right. Users of DIGGS will be able to design databases to utilise the data transfer format with functionality specific to their particular requirements.

1.2 Project team

DIGGS is being developed through the Transportation Pooled Fund Study (TPF 5(111)) coordinated by the Ohio Department of Transportation (ODOT). The focus of the TPF project is to compile the standards development work of the AGS, COSMOS, the University of Florida, and others to create a new international data exchange format. The project, "Development of Standards for Geotechnical Management Systems, Project TPF-5(111)," was approved and funded in the Summer of 2005 at a funding level of approximately $700k over three years to develop the first release of DIGGS. The study will also fund extensions to this effort in order to include additional types of data.

The pooled fund study is managed through a three tiered committee structure.

The Geotechnical Management System Group (GMS Group) composed of representatives from 12 US State Departments of Transportation (DOT), FHWA-Federal Lands, UK Highways Agency, USEPA, USACOE and the USGS has been formed to govern the initial development of the standards for geotechnical data and to coordinate all final decisions.

Oversight of development is provided by the Geotechnical Data Coalition (GDC) with representation from UF, AGS, COSMOS, CIRIA, FHWA and ODOT. The GDC acts as an executive committee for the development.

The detailed development effort of this first phase is a collaborative effort of the geotechnical Special Interest Group (SIG) consisting of the University of Florida, AGS, COSMOS, USGS and CIRIA, with input from other specialists.

Additional SIGs will be created in order to develop the extensions to DIGGS covering other types of geotechnical and geoenvironmental data. A geoenvironmental SIG has been formed, and others are in the early stages of planning.

A full list of contributors to the DIGGS project can be found in Appendix A

1.3   Promoters and supporters

DIGGS is promoted by:

The United States Federal Highways Administration

The United Kingdom Highways Agency

Twelve US Departments of Transport

The United States Geological Survey

The United States Army Corps of Engineers

The United States Environmental Protection Agency

CIRIA (the UK Construction Industry Research and Information Association)

AGS (the UK Association of Geotechnical and Geoenvironmental Specialists)

COSMOS (Consortium of Organizations for Strong-Motion Observation Systems)

The University of Florida

In addition, DIGGS is supported by:

The International Society for Rock Mechanics

The International Association for Engineering Geology and the Environment

The International Society for Soil Mechanics and Foundation Engineering

The TransXML project sponsored by the US National Cooperative Highway Research Program (NCHRP) and supported by the American Association of State and Highway Transportation Officials (AASHTO)

1.4 Local Implementation Groups (LIGs)

DIGGS has been set up so that it can be customised to include unique local requirements or remove parts of the schema for use within a country. When DIGGS is implemented within a country there may also be a need to define new code lists and rules on how the data is to be contractual transferred among other things. These issues are the responsibility of local representatives and DIGGS encourages the setting up of Local Implementation Groups (LIG) such as the AGS in the UK to specify and define the methods of use of DIGGS.

Local Implementation Groups do not have to be for an entire county and may only focus on a small group of users, e.g. the USA EPA regions may decide to form a SIG to control the specification and use of the format on superfund sites.

If you are interested in setting up a LIG please contact DIGGS via the website at www.diggsml.org and you will be sent more information on how to proceed.

1.5 Special Interest Groups

After reviewing DIGGS you may find that its framework can be easily adopted to work with data from a specialist area that is not already included. For example maybe you need to transfer information on Earthwork condition and can see that by adding a few additional objects in the DIGGS library you could accomplish your goal without having to redo all the work the DIGGS team have already completed.

DIGGS encourages organisations to use the framework to include their own data and will assist you in this process by helping you set up a Special Interest Group (SIG). This will not only give you access to support from the core group but will give you an opportunity to steer future versions of DIGGS and hopefully have your work included in the next official release.

If you are interested in setting up a SIG please contact DIGGS via the website at www.diggsml.org and you will be sent more information on how to proceed.

2   Usage of DIGGS

2.1   DIGGS in the project supply chain

Within any project comprising a series of project phases, data is transferred between a series of different parties. Figure 2-1 outlines a typical supply chain layout for a geotechnical project.
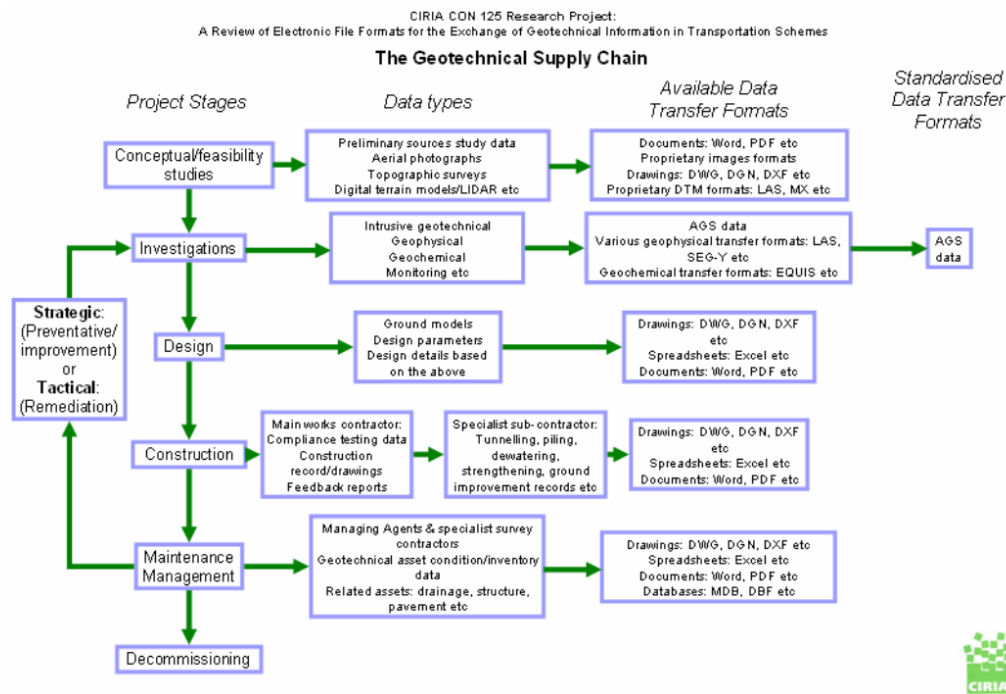
Figure 2-1 Typical geotechnical supply chain (CIRIA, 2006)

Where current formats exist, they tend to concentrate on the transfer of information from the ground investigation phase to the design phase. This first issue of DIGGS also concentrates on this phase, it also incorporates some facilities for later project phases, namely for construction (through the facilities for piling data) and monitoring.

In this release, DIGGS is aimed at the following practitioners:

> **those carrying out or using geotechnical ground investigation data**
>
> **those using geoenvironmental data**
>
> **those commissioning, designing or carrying out piling works**
>
> **those using dynamic soil parameters derived from geophysical investigations**

Future developments of DIGGS will be aimed at a wider range of practitioners, to enable it's use throughout the project supply chain:

> **those involved with geotechnical asset management**
>
> **those concerned with geological, geotechnical and geoenvironmental hazard assessment and risk management**
>
> **those concerned with any form of soil or rock engineering**

2.2   Obtaining DIGGS data

Data in the DIGGS Format will start to become available to you as tools for it's creation and interpretation become available. The key driver to this development will be forward-thinking procurers of geotechnical and geoenvironmental services specifying and requesting DIGGS Format data from those in their supply chain. By building in the requirements for DIGGS Format data into specifications and requirements for future works, it will become available to you.

2.3   Using DIGGS data

2.3.1   How can DIGGS be used?

There are several ways in which DIGGS may typically be used:

Within geotechnical and geoenvironmental data management software packages, such as gINT, HoleBASE and EQuIS,

As part of an online software system that allows data to be accessed over a network (such as the internet). Such a system is known as a web service, and can be used as a means of allowing interoperability between remote systems.

Such a web service, using DIGGS data, lends itself ideally to internet-based collaboration projects, such as the COSMOS Virtual Data Centre, the Florida DoT piling archive, or commercial internet applications such as geotechnicalpoint.com (an online means of sharing ground investigation data) and monitoringpoint.com (for sharing monitoring data)

2.3.2   What training is required to make use of DIGGS?

DIGGS is a data exchange format, and as such it is not a requirement that the technical details of the format itself are understood by the end users of the data. Production, receipt and interpretation of DIGGS Format data into an easily useable form is the job of DIGGS compatible software. Therefore, if good quality DIGGS compatible software is used, you and your staff will only require the training and experience that is needed for any piece of software that you might use. Once confidence in the use of the available tools is achieved, the use of DIGGS Format data will be an integral part of your day-to-day work. And because the possibility of errors in the data is vastly reduced by the use of an XML format, staff will not require the sort of in-depth training and experience which is sometimes required for currently used data transfer formats.

2.3.3   How does DIGGS fit with existing data transfer formats?

DIGGS Format has full backward compatibility with the UK AGS Data Transfer Format (version 3.1), the COSMOS Geotechnical and Geophysical Data Transfer Format and the Florida DOT Piling Data Transfer Format. Future development of DIGGS will see it integrated with the TransXML Exchange Format for Transportation Data. DIGGS also makes use of the geophysical data format and a comprehensive library of definitions of units from the WITSML format, developed by the Petrotechnical Open Standards Consortium (POSC).

2.3.4   What are the legal implications of using DIGGS in the project environment?

Specifiers of projects which make use of the DIGGS Format should ensure that the legal and contractual status of the data being transferred is clearly defined. It is envisaged that many client bodies will choose to make the electronic DIGGS Format data the definitive deliverable for their projects, and may further choose to make the data one of the key measurement tools for payment.

2.3.5   Can DIGGS be used to design a database?

A key concept is that DIGGS is a transfer standard and not a database standard. The difference is crucial. A working database needs to be designed to best meet the needs of the users. A general purpose interchange standard will rarely, if ever, meet the usage requirements of any specific user group. Databases can contain custom functions and business rules that may be important for the operation of a specific project or organisation, but are not relevant in a transfer standard. Using an interchange structure as a working database can lead to awkward data entry procedures, difficulty in data validation, reduced querying capabilities, and loss of information.

The following are some specific considerations to avoid the use of an interchange structure as a working database.

Database vs. Transfer Standard

Consideration	Example
Databases will generally contain more data than is desired to be transferred to other groups.	Laboratory work requires recording of many measurements and readings which are not included in general data interchange formats.
The interchange format structure can lead to awkward and confusing data entry structures.	DIGGS handles monitoring data such as readings from piezometers, inclinometers, settlement plates in a generic way. The structures are generic enough to handle a very wide range of such data so that if a new type of monitoring is encountered all that is required is the addition of a new type in the code list. No change to the format definition would be required. In a working database, this structure is so generic so as to be confusing to the data entry personnel. A much better approach for a working database is to create separate table groups for the recording of each of the different monitoring tests.

The above is not to say that one can design a working database with no regard to interchange standards. However, compliance with an interchange standard is just one more design consideration for the working database. As long as the data can be mapped to and from the interchange standard, the working database can take on the structure that best meets the needs of its users.

2.3.6   What data does DIGGS transfer?

DIGGS is intended to provide a standard means of transmitting most of the data currently presented in paper reports on forms such as borehole logs, trial pit records, in situ test data and laboratory test summaries, pile load tests and construction details, and summaries of borehole geophysics tests. The intent of DIGGS is to capture the commonly reported information that is most often required in project reporting, it is not intended to transfer all the data that may have been collected.

In the DIGGS view there are 5 types of data associated with field and laboratory tests:
1.   Metadata about the test (includes the testing standard used)
2.   Base testing data and parameters derived from the test
3.   Raw data from the test from which the base data and parameters can be derived
4.   Calibration data needed to derive the base data and parameters from the raw data and instrument readings
5.   Associated data (such as sample photographs or site plans)

The DIGGS format is principally intended to transfer data types 1 and 2 above, however facilities are provided to transfer all of the other data as Associated Files.

The following examples for consolidation, triaxial and in situ vane tests illustrate the difference between raw test data which is not transferred by DIGGS and the resultant base test data which is transferred.
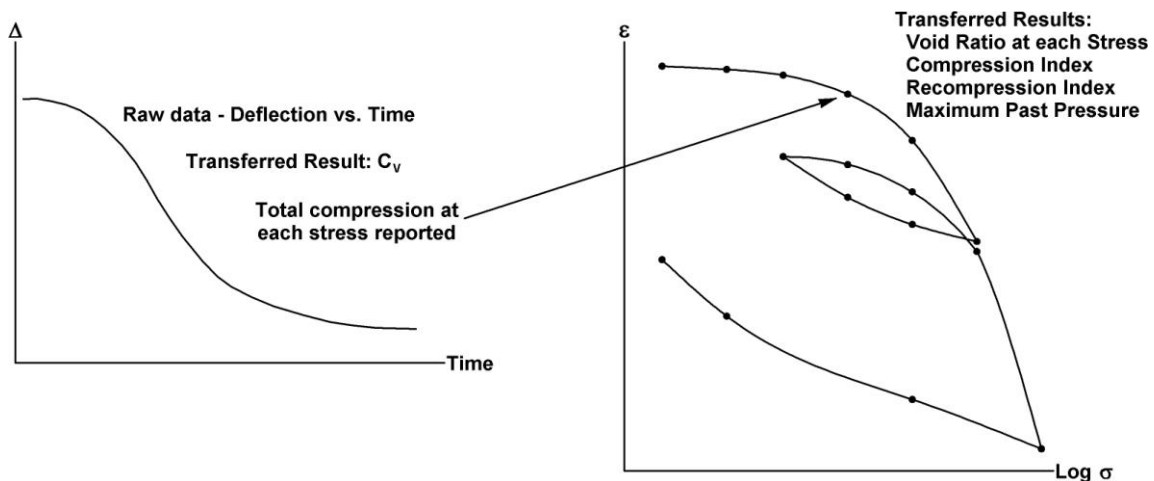
Figure 2-2 Consolidation Test Data Example
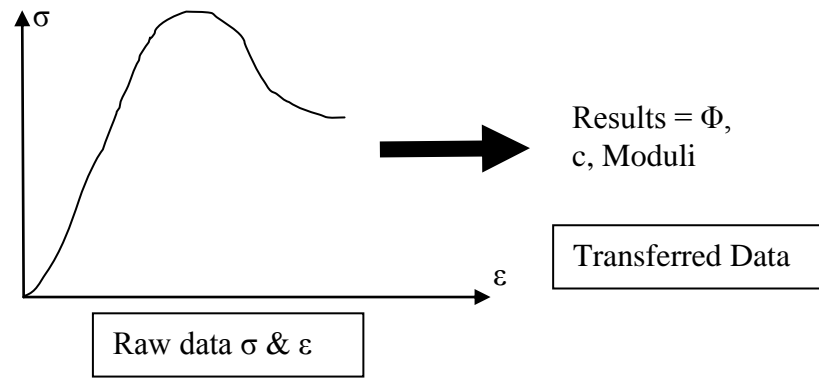
Figure 2-3 Triaxial Test Data Example
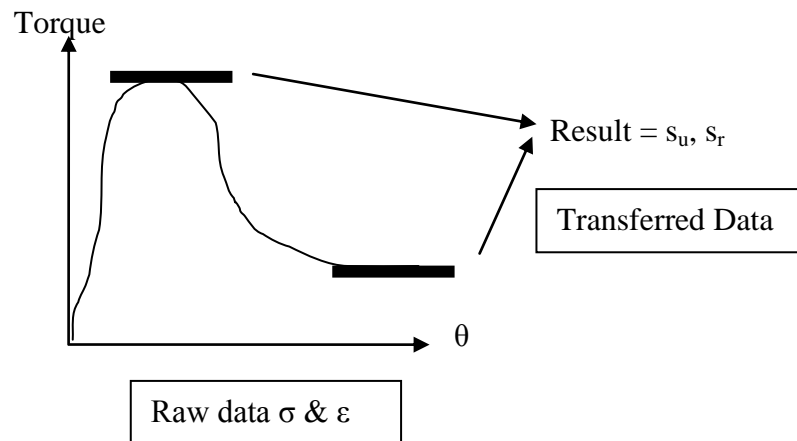
Figure 2-4 Vane Test Data Example

3 The basics of DIGGS

This section sets out to explain the basic components of the DIGGS data transfer format. It deliberately sets out to be non-technical. The in-depth technical aspects of DIGGS can be investigated further in the associated technical guidance documentation.

3.1 Introduction to data structure diagrams and terminology

It is important to understand the terminology and graphical representations used within this document before reading chapters 4 - 7.

All parameters describing a single process or physical item are grouped together into an item called an object. For example, to describe a layer of backfill you need three parameters; these are grouped together into a backfill object within DIGGS-
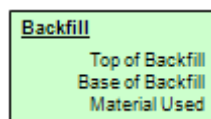
Figure 3-1 Properties of the Backfill object

A Collection Object is used to keep all the objects together within the parent object. Collection objects sit above the single item objects and usually have the plural name of the objects they contains. In our example the collection object would be called backfills. This relationship is shown graphically within this document using the method in Figure 3-2. To enhance the clarity of the diagrams all the parameters shown in Figure 3-1 are not repeated in Figure 3-2.
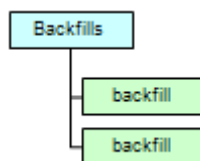
Figure 3-2   Nesting of objects as a collection

3.2 Data structure

3.2.1 Data Hierarchy

DIGGS conforms to a broadly hierarchical structure, part of which is simplified in Figure 3-3.
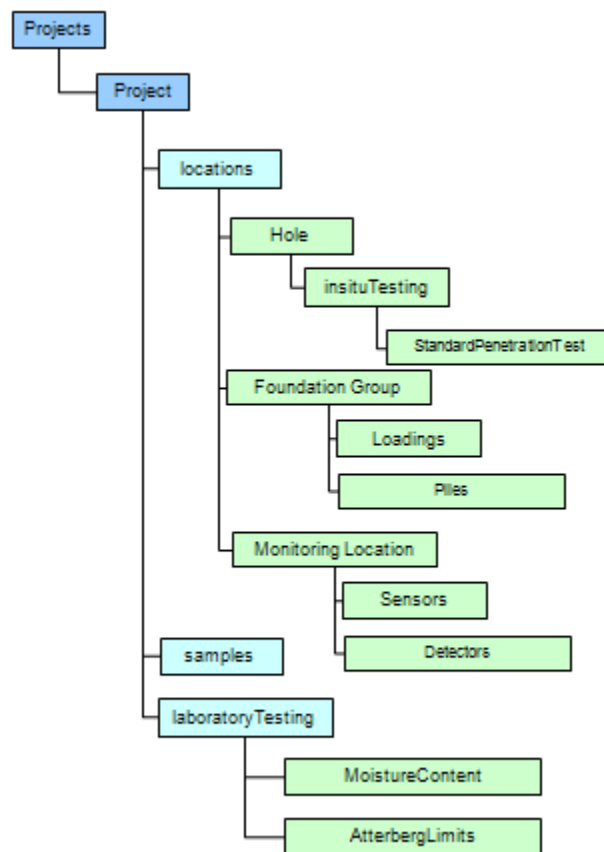
Figure 3-3 Hierarchical structure of DIGGS

Using this hierarchical structure, a Project can contain data belonging to any or all of the disciplines handled by DIGGS. Within the geotechnical sections, a project can contain any number of Holes, from which any number of insitu testes can be taken etc. This hierarchy is based on the real-world structure of the data collected in the field or from laboratory testing. Moreover, the hierarchy is embedded into the format of the data, which greatly improves data accuracy and validity. Further details of the structure of DIGGS are discussed below.

3.2.2   Data Format

DIGGS is an XML (eXtensible Mark-up Language) compatible format. XML is specifically designed to allow the sharing of structured electronic data, and being extensible, it can be adapted to meet the needs of DIGGS. There are several key reasons why XML was chosen for DIGGS:

XML can be validated using a file called an XML Schema. This has considerable benefits for the checking of DIGGS files,

The hierarchical structure of DIGGS, as described above, is embedded within the XML file. This ensures that the relationships between segments of DIGGS data are always maintained (for example, the descriptions of geological layers encountered within a hole will always remain associated with that hole),

The methodology for creating user defined extensions to DIGGS is formalised through the use of XML

XML allows linkage to pre-defined lists of useful information, such as units of measurement, lists of contamination determinants, geological strata codes etc

By using XML for DIGGS, it is capable of plugging into other XML data types

XML can be used to define data which is optional, or mandatory, thereby forcing essential data to be entered correctly

Whilst a detailed explanation of the XML structure of DIGGS is not appropriate for this document, it is worth outlining the broad concept of how geotechnical and geoenvironmental data is described using XML.

Within DIGGS, the tiers of the hierarchy within which the data is held are referred to as **objects** (e.g. Project, Hole and Layers). Objects are broadly comparable with tables within a database. Within each object are the placeholders for the data that describe the objects, which are known as **properties**. Properties are broadly comparable with fields within a database table. For example, a borehole **object** will include **properties**, such as borehole name, ground level etc. There are various ways in which objects and properties can be used to describe data, which are explored in the next section.

Many elements of DIGGS data have a location, e.g. boreholes have coordinates and ground levels, samples are taken from a location in a borehole or trial pit etc. DIGGS makes use of an accepted methodology for the description of locations: Geography Mark-up Language (GML). GML is an XML compatible language that can be used to describe any kind of location within DIGGS, and being an international standard, it will enable DIGGS data to be used with GML compatible applications. Further details of the use of GML in DIGGS are given in the accompanying Technical Guide to DIGGS.

3.2.3   Samples and specimens

Within geotechnical and geoenvironmental engineering, the taking of samples, and their subsequent testing in a laboratory for the determination of a wide range of characteristic properties, is an essential part of most projects. A large part of the data that can be transferred by DIGGS relates to such samples.

Within DIGGS, there is a no distinction between **samples** and **specimens**. Samples can be taken from physical objects such as Hole, Pile, Installation and importantly, another sample (creating a sub sample or specimen depending on your terminology)

Samples can also reference the process that created them, so if a sample is taken from a well installation during a purging process the sample will reference the well installation as its source and the purge event as the process that created it. In the same way, if a sample is created by performing a SPT test then the sample will reference the Hole as its source and the SPT test as the process that created it. One final example of this important method in DIGGS is a sample that is created as the result of a test. If a Sample is created via a compaction test for a CBR subsequent test then that sample will reference the original test sample as its source and the compaction test as the process that created it.

3.2.4   Paired objects

There are several types of geotechnical laboratory testing methods that can be considered to have two levels of data relating to them, and as such within DIGGS utilise a data construct referred to as paired objects. By way of example, consider triaxial testing of a soil sample. Typically, triaxial testing will be undertaken using a series of test stages. The data associated with triaxial testing can therefore be considered to belong to two objects in the DIGGS hierarchy:

A general object that refers to the general details of the triaxial test being undertaken. This object will include data properties such as the type of triaxial test (e.g. drained, undrained with porewater pressure measurement, multi-stage etc.) and shear strength data derived from the entirety of the test stages (e.g. peak cohesion, angle of friction etc.). The general object sits below the sample in the DIGGS hierarchy,

A series of detail objects that refer to the individual stages of the triaxial test carried out. This object will include details such as the cell pressure of the individual test stage, the deviator stress at failure etc. The detail objects sit below the general object in the DIGGS hierarchy, hence the combination are referred to as paired objects.

A **general object** can include any number of paired **detail objects**, from one for a single stage test to as many as are required to describe a multi-stage test. For a three stage drained triaxial test there would be one general object and three detailed objects to fully report the test results.

3.2.5   Generic index testing results

Geotechnical testing often requires measurement of an index property, such as moisture content, as an integral part of the test. Where such index tests occur within DIGGS, the same data construct is used to transfer the test result data. As well as ensuring efficiency and consistency within the DIGGS format, this data construct is also designed to allow the end use applications of DIGGS data to easily extract such data from the DIGGS file, for example, to extract all of the natural moisture content data whether it was measured as part of triaxial, oedometer or shear box tests. This generic approach to index tests is used in DIGGS for moisture content, density and particle size, and there is a facility to indicate whether the moisture content or density are natural or not.

It is important to note that this generic data construct only applies when the test being carried out to determine a material parameter is absolutely the same test. Where different types of test have been carried out to determine the same parameter, different data constructs are utilised in DIGGS. For example, undrained shear strength can be derived from a number of tests (e.g. uniaxial test, shear box test, hand vane etc.) but is not reported within DIGGS using the same construct, as the tests to determine the parameter are very different, and direct comparison of results may not be applicable.

3.3   Links to lists and external data sources

Within geotechnical and geoenvironmental engineering, there are many examples of types of data that can be described by the use of lists of standardised and agreed codes, units, numbers etc. Typical examples would be:

Standard soil classification codes (such as the USCS system)

Codes to describe geological strata (for example the lexicon of the British Geological Survey)

Codes to describe chemical determinants for geoenvironmental testing (for example the CAS registry numbers)

Set lists of standard units of measurement (for example the list provided by the Petroleum Open Standards Consortium, POSC)

Agreed descriptive codes for colours (such as the Munsell codes)

There are many other such examples.

One of the advantages of the use of XML for DIGGS is that it can make reference to such standardised lists (known as codelists), which can be defined by the DIGGS format itself or, if they are already defined elsewhere in an XML format, can be utilised from other sources. Such links within the DIGGS format are enormously powerful for several reasons:

Because the standardised lists can be held centrally, all data making reference to the lists have the same reference, ensuring data accuracy and validity,

Because the lists are often maintained by others, they are periodically updated, which cascades down into DIGGS, which in turn will always be up-to-date

The powerful potential of external codelists can be shown with the following example. An organisation is specifying several different site investigation contracts with different companies for a large job. When the data is submitted by each contractor the client will want to be able to put these datasets together with minimum effort. If the client requires additional codelist items to be used or indeed wants to restrict the codelist options for the contract then they can create a codelist file for the project and host it either on the DIGGS domain (www.diggsml.com/client/job/codelists.xml) or even on their own domain. All contractors are now able to check the data that they supply to the client with reference on the client's Codelist and the client will not get multiple codes for the same property.

3.4   Multiple projects

The DIGGS hierarchical structure (see Figure 3-) is set up so that any one DIGGS file can be used to transfer data relating to one or more projects.

The uppermost tier of the DIGGS hierarchy is used to transfer information on the DIGGS file and to reference external files that are needed by the application software to fully understand the DIGGS file and validate it. At the next level is general information on equipment, specifications and business associates that apply throughout the DIGGS file. Directly below this information in the hierarchy is the project information, within which all the data associated with that project are held. Any number of projects can be transferred within a DIGGS file, which do not necessarily have to be related.

3.5   Location referencing systems

Geographical location is essential to almost all geotechnical and geoenvironmental data, in the form of the location of the exploratory holes, sampling points, pile locations etc. Because of this, DIGGS has been structured to be both rigorous and flexible in the ways by which locations are referenced. As outlined in Section 3.2.2, DIGGS makes use of the recognised GML methodology for the handling of locations in three dimensional space. GML allows for the transfer of both the coordinates of locations, and the coordinate reference system that is being used to define the meaning of the recorded coordinates. The use of GML location referencing has a number of key benefits:

Any coordinate referencing system can be used, meaning that DIGGS data can be used internationally,

GML also allows for more than one coordinate referencing system to be used within a DIGGS file, so one location could be referenced in several different ways. This is of particular use for long running projects that, for example, may operate on latitude and longitude in the early stages of scoping, on regional or national grid during the investigation phase, and on a defined local project grid during construction,

GML is a recognised, standardised methodology for the transfer of location information, with a proven history of successful usage,

Because GML is an international standard utilised in many data transfer formats, it means that DIGGS data can be utilised by existing software, and in conjunction with other GML compatible data sets

Of particular importance for much of the data held in DIGGS is the location of data represented as a point at a particular depth within an exploratory hole, or as a length along a line etc (for example, samples taken from a borehole will be recorded as being from a depth, or depth range within the construction of that borehole, not as a point in three dimensional space). DIGGS handles such data by using GML to first define the 'line' of the borehole or other reference line (such as a surface scanline along a quarry face) and then to relate sample or test locations as depths or lengths along that defined line. By way of example, refer to Figure 3-4.
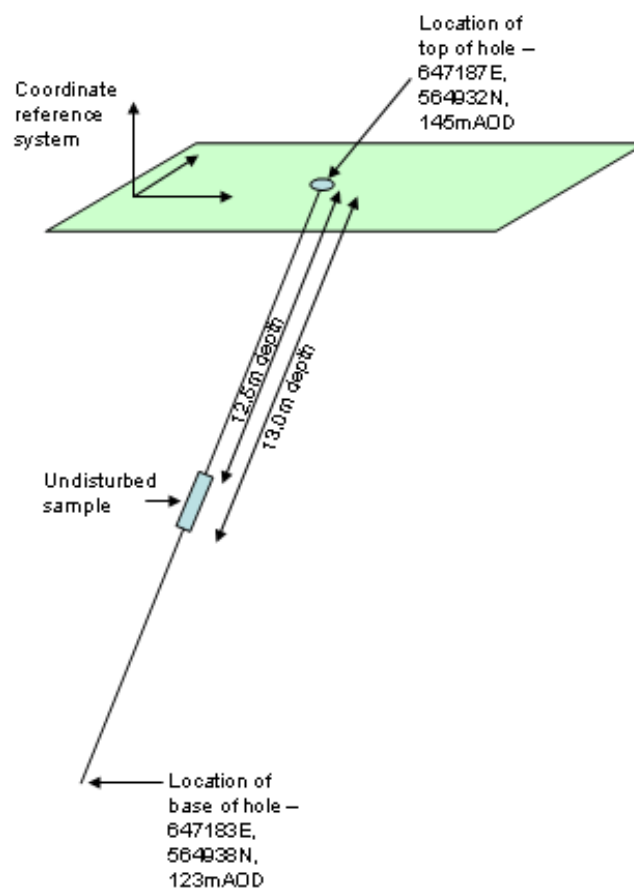
Figure 3-4 Example of sample location referencing within a borehole

In this example, an undisturbed sample has been collected within an inclined borehole. During construction of the hole, and collection of the sample, the only data available would have been the depth down the hole of the top and base of the sample. This is recorded within the DIGGS data. In order to locate the sample in three dimensional space, four further pieces of information are required. The first is the location of the top of the borehole. The second is the path or line of the borehole which, if it is a straight line, may be defined by giving the coordinates of the base of the borehole, but more practically is measured in the field as its angle of dip and azimuth direction. The third is the coordinate reference system that has been used to record the top of the

borehole and the forth is the coordinate reference systems used to record the path of the hole. In Figure 3-4 a single coordinate reference system has been used to define the location of all the boreholes, although several could be used if the project requires it. A borehole that has a curved path can be defined by recording the 3D locations of multiple points along its length. From the information recorded, software applications have all the necessary information transferred within the DIGGS file to be able to calculate the location of the undisturbed sample in three dimensional space, relative to the coordinate reference system.

3.6   Associated data items

There are a number of generic items of data that can be transferred within DIGGS that, whilst often essential, are not part of the core sets of geotechnical and geoenvironmental results data. Such data includes:

Associated files (for example, to allow a scanned site plan to be associated with a project),

Equipment information (for example calibration information, model and serial numbers for equipment used for testing),

Specification information (for example a reference to the ASTM standard that was used for the particular test),

Remarks associated with any of the data in the DIGGS file,

Roles of individuals or companies involved in any part of the derivation of the DIGGS data (for example the name of the driller of a borehole, the logger of a trial pit, or the geoenvironmental testing laboratory etc),

Within DIGGS, data such as these are stored in a generic way, that can be referenced throughout the transferred data as required. For example, the results of a consolidation test may include details of the oedometer used, it's serial number and calibration history, or a borehole can include details of the driller, the logger and an associated digital photograph of the borehole position.

3.6.1   Roles and business associates

Contact details for people and companies (business associates) associated with the data can be transferred in a DIGGS file as reference information. Each object in DIGGS can define roles for the data. A role is information on who carried out which task and it links to the appropriate business associate reference. A few examples of how this could be used are given below:-

- transfer information on who carried out, checked and signed off a laboratory test

- transfer details of the site engineer, client or contractor

- transfer information on the drilling crew.

3.6.2   Attached files

External files can be referenced by any object within DIGGS. The files can either be referenced locally to the XML file or can be referenced to a network or internet location. DIGGS uses an internet standard for referencing the file's location.

3.6.3   Equipment

Equipment details can be transferred in a DIGGS file as reference information.   Data specific to an item of equipment not need to interpret the result should be transferred in the equipment reference rather than the test data.   Calibration dates and information can also be transferred within the Equipment object is required.

3.6.4   Specifications

Details on the specification and standard used to collect data can be transferred in a DIGGS file as reference information. Each object within DIGGS can have references to one or more specifications.

It is anticipated that local implementation groups will be responsible for defining a referencing system for each standard used within the implementation area.

3.6.5   Remarks

Remarks can be added to each object in DIGGS. Each remark has a text remark, an optional date/time, optional role information (i.e. who made the remark) and optional depth.

3.6.6   Groups

Connections between items can be defined using groups in DIGGS. Each group contains information on the type of group and a list of IDs for the items. Below are a few of the possible ways grouping can be used.

- Defining which when a CPT and borehole can be viewed as related to each other (the AGS Hole Cluster field)

- Grouping boreholes in one or more zones on site

- Defining which samples are duplicates

- Defining which samples laboratory control samples refer to

3.7   Extensions to DIGGS

There may be times when you need to add information to a DIGGS file that is not currently defined in the data dictionary. Information on how to extend the format is contained in the Developer's guide to DIGGS and it is likely that your software program will be able to do all the technical parts for you.

DIGGS can be extended in the following ways:-
- Additional properties can be added to existing objects
- Additional objects can be added to existing collections
- Additional collections can be defined
- New picklists can be specified and published.

If DIGGS is being extended to accommodate a new type of data then this should be done through an appropriate SIG.

3.8 Language

Each object in DIGGS has a Lang property that allows the language of that object to be defined. The lang property can be set at the top of the file and will be considered to be the default unless specified within an object. This flexibility allows borehole descriptions in more than one language to be transferred within the same file.

3.9 Units

Each parameter in DIGGS that requires a Unit Of Measure has a uom attribute to it and each uom is assigned a unit group type (i.e. length, volume, force) within the schema. It is therefore possible to specify any units you require in DIGGS and to ensure the units you are specifying are relevant to the data they are defining.

3.10 Object IDs

Many of the objects in DIGGS have unique IDs. These IDs serve two main purposes. Firstly they allow objects to reference each other within a file and secondly they allow an object's uniqueness to be defined and retained. An ID has two parts; firstly it has a company or office reference of up to 8 characters, this is followed by a dash and then a unique string within that company. Company codes can be registered for free during the DIGGS review period at http://www.diggsml.com/ids. It is the responsibility of the company or office to maintain unique ID within their company code.

This use of IDs and source properties links is key to the way in which DIGGS handles samples and laboratory test results. However, in most cases the user need not worry about this at all, as the application software you are using, whether it be a geotechnical database or a laboratory information system (LIMS), will take care of assigning the IDs and generating the correct linkages. The use of IDs and source links is merely a device used in the DIGGS format to transfer the relationships between boreholes, samples, subsamples and laboratory tests in an unambiguous way. You will see later in this Introduction to DIGGS that this construction is a very powerful way of handling the complex relationships that can exist between samples and laboratory and insitu tests, particularly for environmental sampling where there is the additional complication of control samples and batch testing.

It is important to note than any DIGGS data imported into a system should retain its original ID if it is subsequently exported back to a DIGGS file.

3.11 Version control and data status

In many cases, data files are structured in order to allow the presentation of preliminary data as well as its updating during the course of a project, prior to issue of the final data. For example, piles can have many instances of the same physical pile. The design, constructed, tested and maintenance representation of the same pile can all be contained in the transfer file. The transfer standard allows for these multiple instances but the software which will interpret the file needs to be aware of this and display the data accordingly and not interpret them as independent piles.

3.12 Transmission information

Each DIGGS file must contain transmission information within a single transmission object. This information tells receiving software what version of the data is contained in the file and what software produced it.

3.13 Data checking – format, integrity, completeness

Any data is of little use if it is incorrect or incomplete. This is particular true for electronic data transfer formats such as DIGGS. Through the use of XML, DIGGS has significant in-built checking abilities. Data checking can be considered in terms of four main areas:

Data format: does the data meet the format rules?

Data integrity: are the relationships between the data items correct and complete:

Data validity: does each item of data make sense and is it within a credible range?

Data completeness: is all the expected data present?

Each of these forms of checking, and the ways in which DIGGS address them, are discussed below.

3.13.1 Data format checking

For a transferred DIGGS file to be valid, it must conform to the rules of the transfer format, so that sending and receiving parties are all using the same form of data. DIGGS data is checked using the XML schema, which holds the information about the correct data construction for a DIGGS file. The considerable advantage of using XML as the format for DIGGS is that the schema can be held centrally on the DIGGS website and there will therefore be just one reference file for the data being transferred, drastically reducing the possibility for mistakes in the format of the data.

Any transferred DIGGS file must reference the schema against which it has been prepared. This enables the DIGGS format to develop over time (through the release of different versions of the schema), and as a DIGGS schema will never be deleted, it also means that DIGGS files can be archived at any point in time with their schema.

Database application software will be able to hold local copies of the DIGGS schema, to enable data creation and checking when remote from an internet connection.

3.13.2 Data integrity checking

Whilst the DIGGS schema can be used to check the format of a DIGGS file, it does not check that the integrity of the data is correct. For example, it will not check to see that a laboratory test referenced in the file has a source sample.

4 Geotechnical data

This section will describe how the DIGGS format is used for the transfer of geotechnical data. Use is made throughout of realistic examples of geotechnical investigation and testing practices, with related diagrams to explain how DIGGS is used to organise and transfer the information that is generated from these practices.

4.1 Hole construction

Construction of an exploratory hole in a geotechnical ground investigation typically comprises a series of activities, all of which can be recorded and transferred in a DIGGS file. Such activities would include:

Advancement of a borehole by wash boring or rotary coring,

Casing of a borehole,

Chiselling to pass obstructions in a borehole,

Circulation of a flushing medium in a borehole,

Progress of a trial pit by introduction of shoring support,

The recording of the behaviour of groundwater encountered in an exploratory hole,

The backfilling of a hole, and the installation of monitoring equipment such as piezometers.

Information such as this is important for the measurement of investigations for payments purposes, and is also essential in the interpretation of ground investigation data, (e.g. *in situ* tests such as the standard penetration test). In order to record and transfer information such as this, DIGGS uses four data constructs: construction events, backfills, installations and progress records.

4.1.1 Construction events

A construction event is a construction activity recorded during the construction of an exploratory hole. The data construct used within DIGGS to record these activities is directly related to an exploratory hole (i.e. sits beneath the hole in the DIGGS hierarchy). Several categories of construction events are utilised by DIGGS, which cover the transfer of data relating to:

Borehole and Pit construction: information relating to the method of construction of an exploratory hole, whether it is drilling or boring that has a diameter, or whether it is a test pit that length and breadth, rather than a diameter.

Casing: information on casing used while the hole is being constructed,

Flushing: information on the flushing technique used and flush observations,

Chiselling: information on the time and depths of chiselling.

Whilst each of these categories of construction events has specific properties which relate only to that type of event (e.g. pits contain a property for the recording of pit width and length, which are not relevant in borings or probes), each category shares the ability to record:

Date/Time: of both the start of the event and its end

Top depth: the depth to the top of the event being recorded,

Base depth: the depth to the base of the event being recorded,

Remarks: remarks can be added to the event, using the core DIGGS methodology for recording remarks. In the same way, equipment, specifications, business associates etc. can also be assigned to the event.

In order to illustrate the use of construction events for the recording of hole construction in DIGGS, consider the example shown in Figure 4-1.
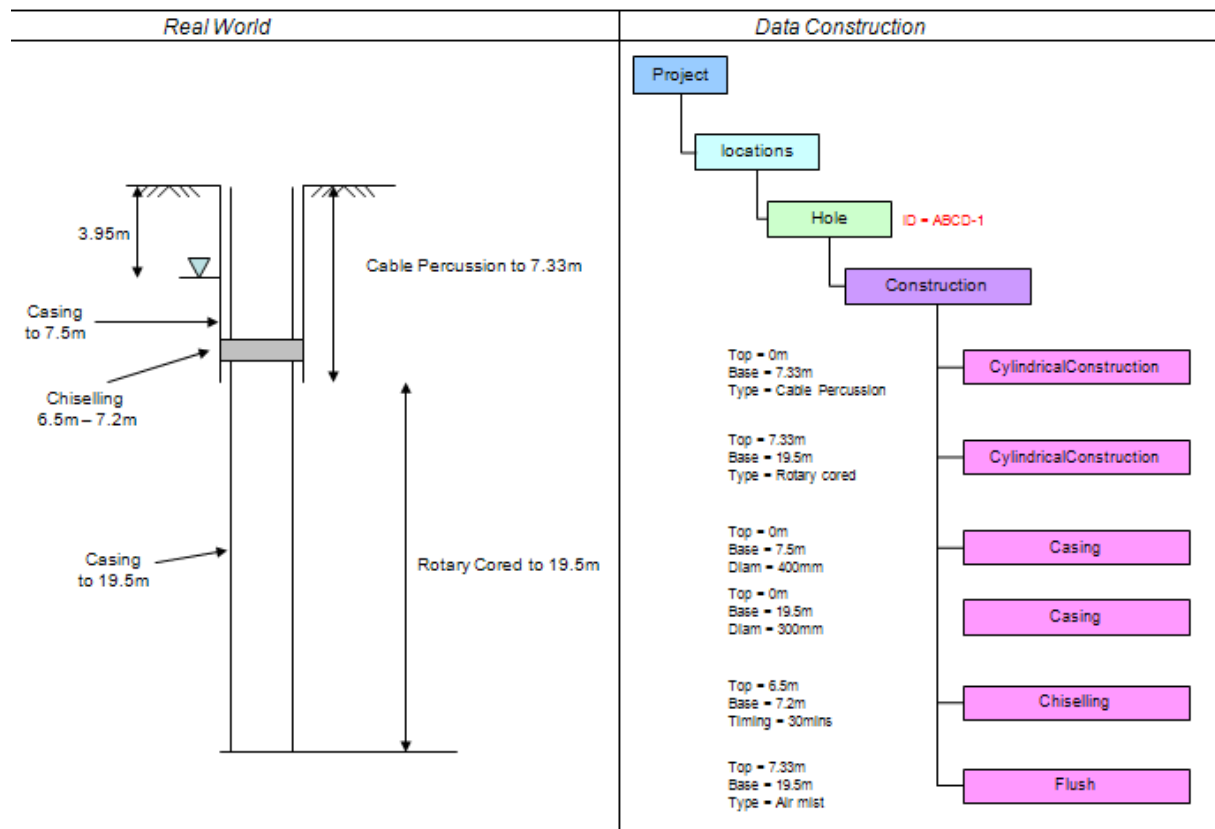
Figure 4-1 Example of construction events for the construction of a borehole

The construction of this borehole has comprised a series of construction events and other events:

Advancement of the borehole by cable percussion methods from 0m to 7.33m,

Continuation of the borehole by rotary coring methods from 7.33m to 19.5m,

A water strike at 3.95m (note: this is not a construction event, see Section 4.1.4),

Chiselling by cable percussion between 6.5m and 7.2m,

Casing installed in the cable percussion borehole between 0m and 7.5m,

Casing installed in the rotary cored boreholes between 0m and 19.5m.

Flushing in the rotary cored borehole between 7.33m and 19.5m.

Of these, the construction events, all use the same data construct (e.g. a date/time for both the start and end of the event, top and base depth), as partially outlined in Figure 4-1. Each construct is used to record relevant information about the event (e.g. time of chiselling, or type of flush etc.). Whilst the water strike noted did occur during the construction of the borehole, it is not considered as a construction event (it 'happened to' the borehole, rather than being the result of a construction activity). The handling of water strikes in DIGGS is considered in Section 4.1.4.

4.1.2   Backfill

The complete construction of an exploratory hole will typically include both creation of the hole, and its backfill. This backfill activity may comprise the simple infilling of the hole with arisings, or other materials, or it may include the installation of some form of instrumentation (see Section 4.1.3). Recording and transfer of backfill data in DIGGS is similar to that for hole construction. Consider the example shown in Figure 4-1:
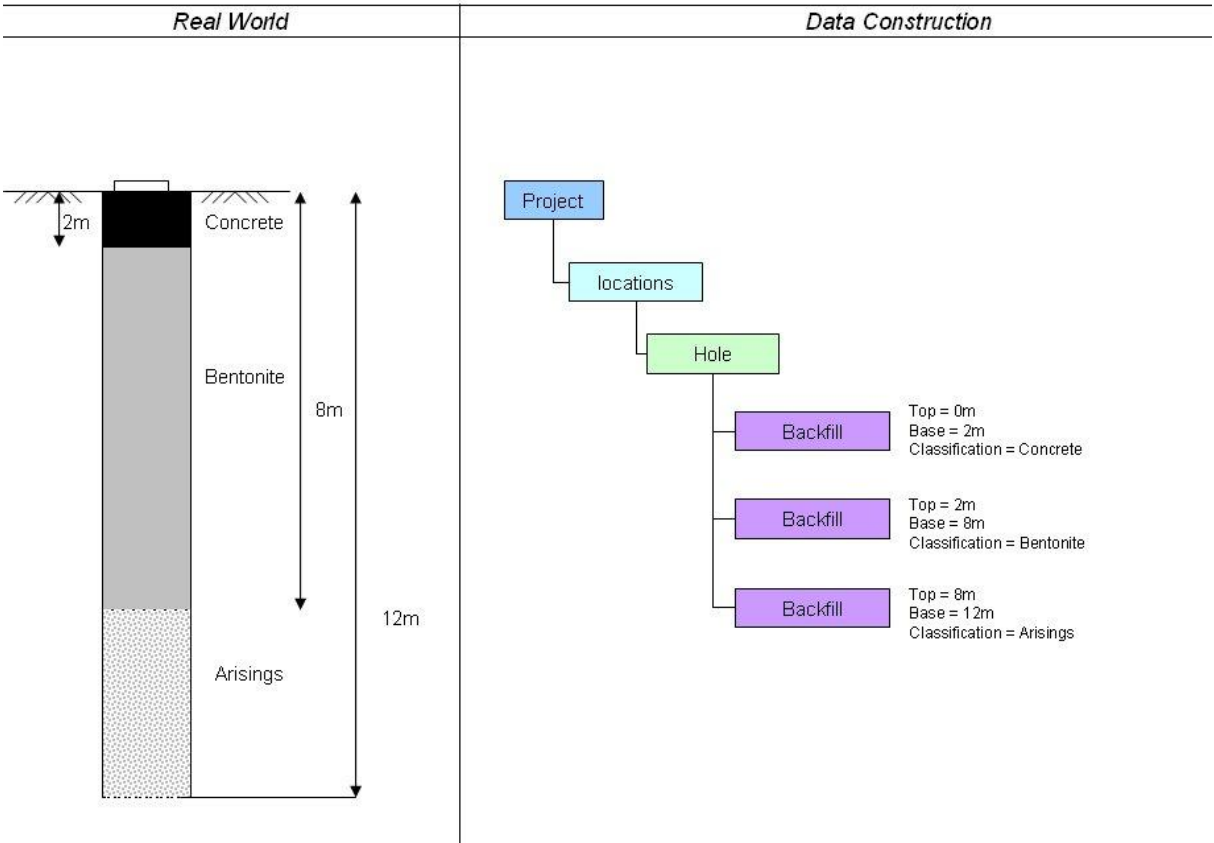
Figure 4-2 Example of backfill events for the backfilling of a borehole

The backfilling of this borehole has comprised a series of backfilling events:

Backfilling of the hole with arisings between 8m and 12m,

Backfilling of the hole with bentonite between 2m and 8m,

Backfilling of the hole with concrete between 0m and 2m.

As with construction events, backfill events can include start and end times and can also contain remarks, equipment used etc. The description of the material used for backfill is described using the same data construction as that for geological layers (see Section 4.2).

4.1.3 Installations

On completion of an exploratory hole, it is common within geotechnical engineering to install a monitoring device of some description. DIGGS can record and transfer details of such installations, and provides a link into the monitoring of the installation, as is discussed in more detail in Section 6. In combination with the recording of the backfill events outlined in Section , the installations data in DIGGS allows a full picture of the monitoring equipment installed in a hole to be transferred by DIGGS.

To understand the use of installations in DIGGS, consider the example shown in Figure 4-3
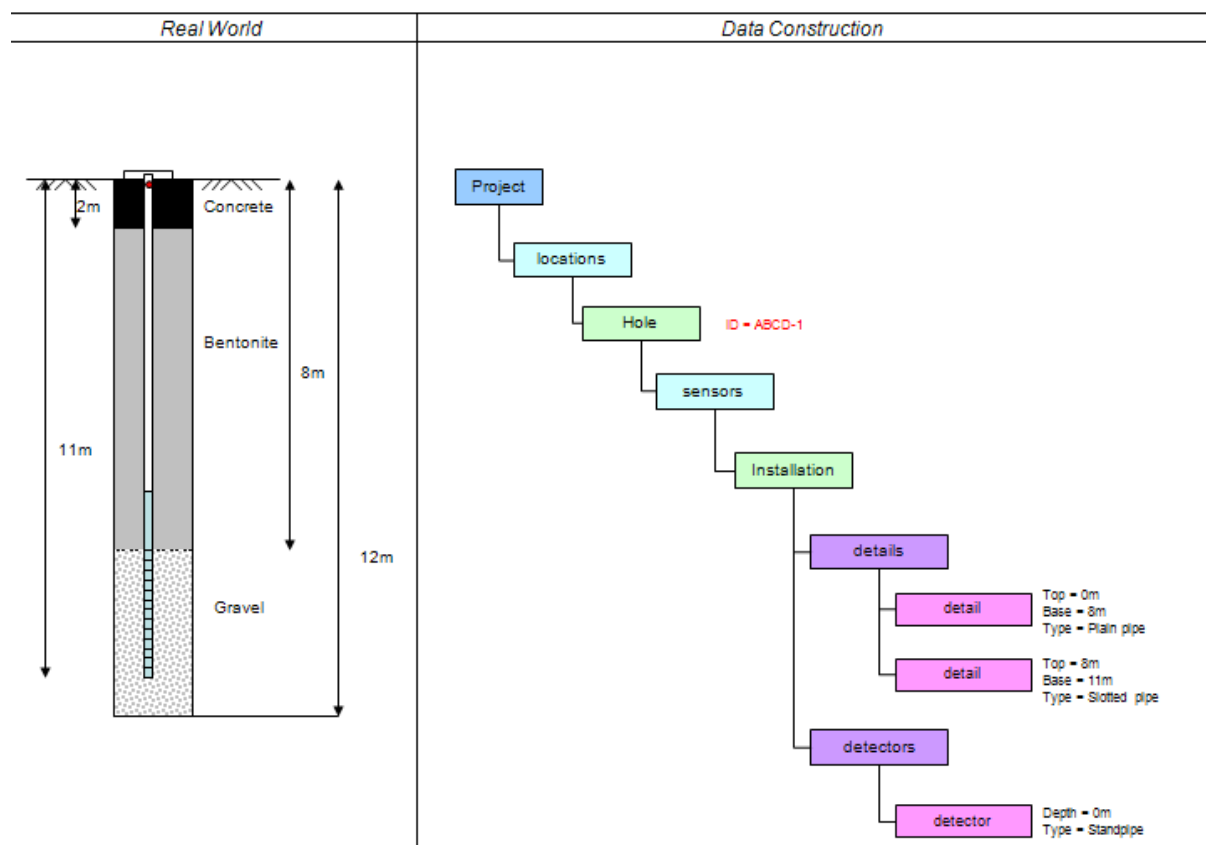
Figure 4-3 Example of a borehole installation

Within this borehole a single standpipe piezometer has been installed to a depth of 11m. The hole has been backfilled with a combination of gravel, bentonite and concrete, the details of which will be recorded using the backfill construct outlined in Section 4.1.2. The details of the piezometer are recorded using the properties:

> **A unique identification number for the piezometer,**
>
> **A code defined in a codelist to describe the type of piezometer installed,**
>
> **A collection of details to describe the piezometer (see below),**
>
> **A list of the detectors in the piezometer, to link to the monitoring of the instrument, as outlined further in Section 6 (a detector is the part of the installation that actually provides the reported reading).**

The piezometer itself is described by a series of details. In the case of the example shown in Figure 4-3, the piezometer will be comprised of a detail between 0m and 8m that describes the plain plastic pipe, and of a detail between 8m and 11m that describes the slotted plastic pipe. Additional information, such as the material used for the piezometer pipe, the size of the perforations in the slotted pipe etc. can also be recorded.

In order to link the piezometer to subsequent water level monitoring carried out in it, it is also necessary to define the detector that is present in the borehole. In the case of the example shown in Figure 4-3 the piezometer will have a single detector point, which may be either the position of the piezometer tip, or the top of the hole if measurements are being taken relative to this point. Further details of the methods for recording monitoring in DIGGS are outlined in Section 6.

4.1.4   Progress records

During a geotechnical ground investigation it is often necessary to record the progress of an exploratory hole, either for the purposes of payment for work carried out, management of the project or for the interpretation of certain *in situ* test results. DIGGS achieves this through the use of progress records. A progress record in DIGGS can record the following information:

The date/time,

The depth of the hole at that date/time,

The depth of any installed casing at that date/time,

The depth to the top of any water in the hole at that date/time,

Any remarks, equipment information etc. using the standardised DIGGS remarks construct.

The progress record construct in DIGGS can be used to record any of the above properties, either together or individually. Therefore, none of the properties in the construct are compulsory.

The progress record construct can be utilised in three ways, as outlined below.

(i)   Hole progress against time

For the measurement of the progress of a project, it is often a requirement to record the progress of an exploratory hole at set points in their construction, typically at the end of each working day. The DIGGS progress record construct allows this. For example, for each exploratory hole which is in progress at the end of a working day, the date/time, hole depth, casing and water depth (if appropriate) can be recorded, and a remark should be entered to denote this progress record as data associated with the end of a working day.

(ii)   Hole progress at the time of an *in situ* test

For certain *in situ* geotechnical tests it is essential to understand the progress of the construction of the hole at the time of the test in order to interpret the test results correctly. The DIGGS progress record construct covers this, by allowing the construct to be used **within** the DIGGS hierarchy alongside the *in situ* test record and results. Consider the *in situ* shear vane test shown in Figure 4-4.
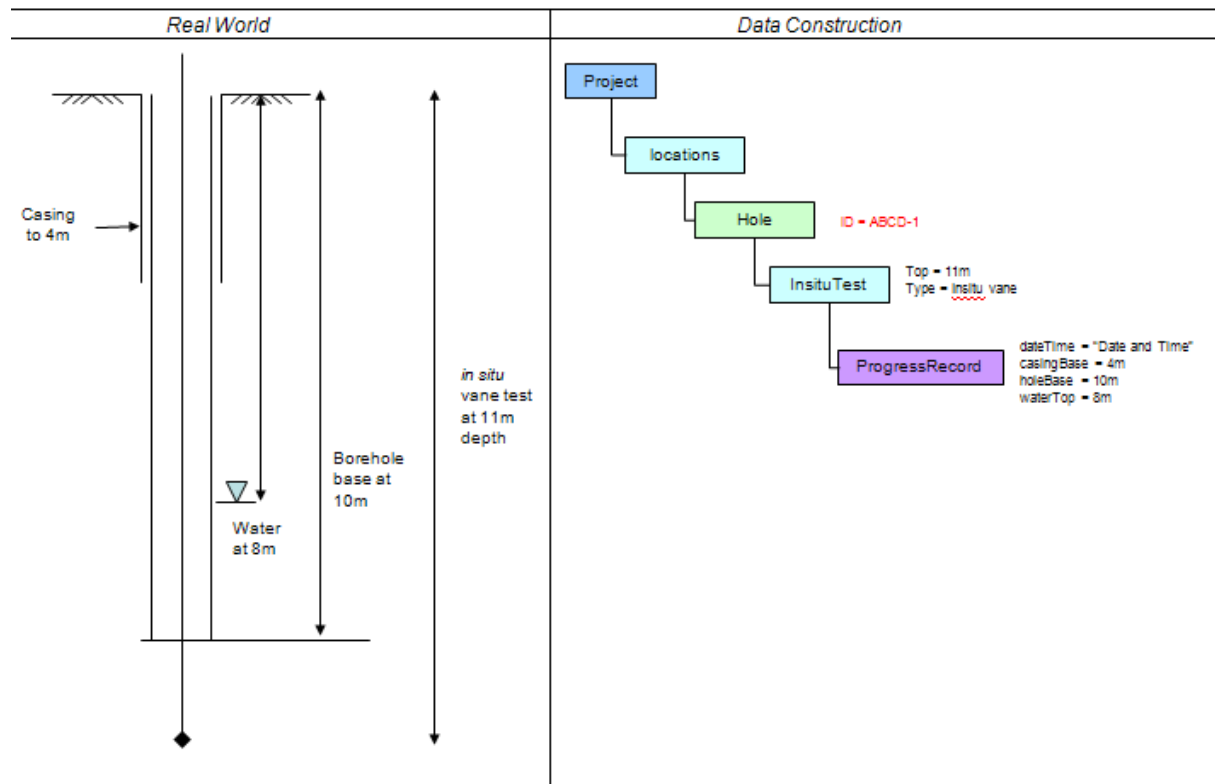
Figure 4-4 Example of an *in situ* test and hole progress record

The vane test itself is carried out at a depth of 11m depth. However, in order to correctly interpret the result from the test, the DIGGS data will also include the following progress record alongside the vane test result:

> **Hole depth: 10m,**
>
> **Casing depth: 4m,**
>
> **Water depth: 8m,**
>
> **Date/time of the test,**
>
> **A remark if required**

(iii)   Waterstrikes

Water strikes within an exploratory hole are recorded through the use of the progress record construct in DIGGS. Consider the example below:

> **Water encountered in a borehole at 8m depth, casing at 4m depth, at 10:15:00 am on 23rd May 2007**
>
> **Drilling stopped, water level recorded at 5 minute intervals until 20 minutes after the initial water strike.**

DIGGS records this information using a series of progress records:

Date/Time	Depth to water	Depth of borehole	Depth of casing
23rd May 2007 10:15:00	8.0m	8.0m	4.0m
23rd May 2007 10:20:00	7.6m	8.0m	4.0m
23rd May 2007 10:25:00	7.4m	8.0m	4.0m
23rd May 2007 10:30:00	7.2m	8.0m	4.0m
23rd May 2007 10:35:00	7.1m	8.0m	4.0m

Through the use of the progress records for water strikes, the slow rise of the water in the hole following the water strike is recorded.

For each water strike recorded in an exploratory hole, DIGGS also contains a property that describes the depth at which the water strike was sealed by the casing (if this situation occurred) which is not time related.

4.2   Geological information

4.2.1   Layers and details

The description of geological layers and depth related details within a geotechnical project is an essential and important part of DIGGS. These layers and details may be geological strata, weathering profiles, geotechnical strength profiles etc. There are a key differences between the use of layers and details:

Layers are sections of the ground, described between a given top and base depth within an exploratory hole, which are *consecutive* and *cannot overlap* for a given layer system within a given hole,

Details are sections of ground, again described between a given top and base depth within an exploratory hole, which *do not* need to be *consecutive* (i.e. there can be gaps between details) and which *can overlap* for a given layer system within a given hole.

The concept of a **layer system** is also of fundamental importance. A layer system is the criteria by which the ground profile is subdivided, described and/or classified. The layer system may be to a defined national standard, or combination of standards, or to a client definition, or to a project specific definition, any criteria can be used as long as it is defined. Examples of a number of layer systems are given in the following table.

Example layer system	Example definition
Engineering geology	Engineering geological description and classification in accordance with USCS for soils and ISRM for rocks
Stratigraphy	Stratigraphic classification in accordance with the British Geological Survey standard stratigraphic lexicon
Weathering	Weathering zonation and description in accordance with the Hong Kong GCO standard specification
Excavatability	Assessed excavation method based on a defined project specific classification

Within a **layer system** both **layers** and **details** can have the following:

- Top and base depth in one dimension (i.e. as a depth down an exploratory hole),

- A description of the layer or detail. This is a free text field, with no constraints or validation. There is the facility to record the description in any language, and in more than one language if required, so that bi-lingual borehole logs can be produced,

- Classifications can be assigned to the **layer** or **detail**, such as a particular legend code, material code etc. Any number of classifications can be applied to a given layer or detail,

- Componentised descriptions can be assigned if required. A componentised description breaks the free form text description down into a series of rigidly defined items, such as strength, colour, principal soil type and secondary soil type. Any number of components can be applied to a given **layer** or **detail**, as required. The benefit of this approach over a free form text description is that the individual components can be validated against a codelist of acceptable terms, and the description becomes machine readable to allow subsequent searching and querying in the software application.

- A unique identifier is assigned to each individual layer and detail. This would normally be assigned automatically by the application software without user intervention

Consider the example shown in Figure 4-5, which is a schematic of a trial pit log in a weathered rock material.
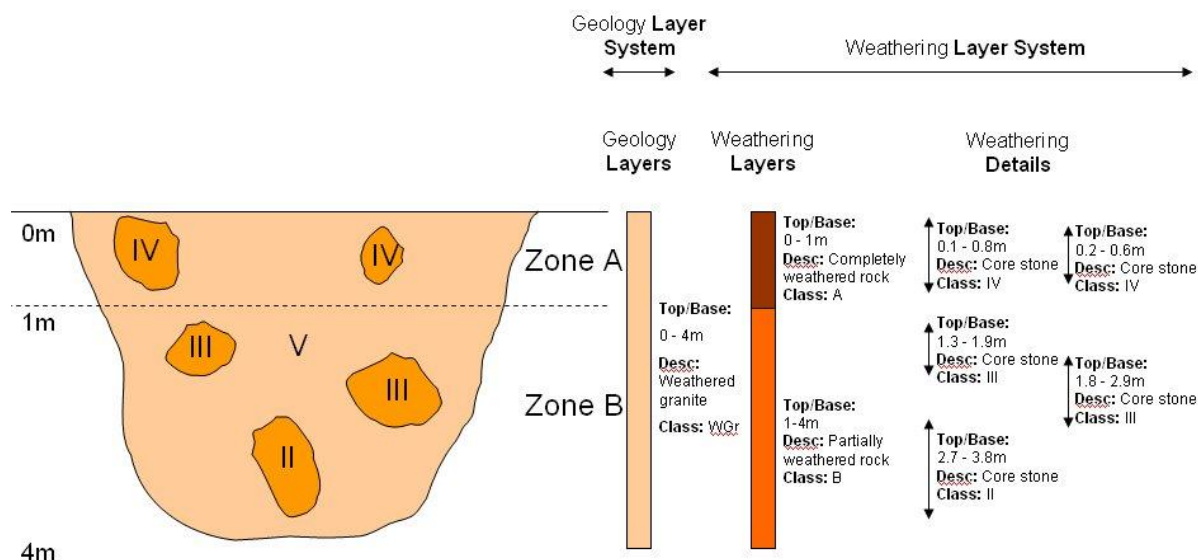
Figure 4-5 Use of layers and details in the description of a trial pit

Two sets of depth related information are conveyed in the DIGGS data in Figure 4-5, through the use of two layer systems, one relating to the geology and the other relating to the weathering. The geological information is recorded as the geology **layers**, because geological strata are non-overlapping and consecutive in one dimension (i.e. depth down the trial pit). Within the geology **layer system** is a single **layer**, from 0 to 4m, described as weathered granite, and classified according to a defined codelist as WGr. The weathering profile is recorded by the use of the weathering **layer system.** Two weathering layers are defined which are consecutive, non-overlapping and are classified into weathering zones A and B according to some specified codelist.. Additionally, the weathering is further described using weathering **details**. These details record information about several core stones observed within the trial pit. These core stones overlap in one dimension, and are also non-consecutive, hence the **details** construct is appropriate. Through the use of these **layers** and **details** within two layer systems the same geological profile can be subdivided, described and classified in different ways. Further layer systems could be defined to describe the profile in other terms such as *Ease of excavation* or *Geophysical shear wave velocity*.

4.2.2   Reporting trial pits

Depth related information collected from boreholes and similar investigation methods is one dimensional, and can easily be described as a series of **layers** and **details** with defined top and base depths. Trial pits are three-dimensional (albeit individual face logs, such as Figure 5-5, are one of a series of two dimensional sketches). DIGGS currently does not allow full description of ground related **layers** and **details** in three dimensions. Therefore, in order to allow individual segments of the ground to be separately described within a DIGGS file, a **stratum reference** code can be applied to any described segment of the ground, most commonly tying into a reference placed on the trial pit (or exposure) sketch, such as demonstrated in Figure 4-6.
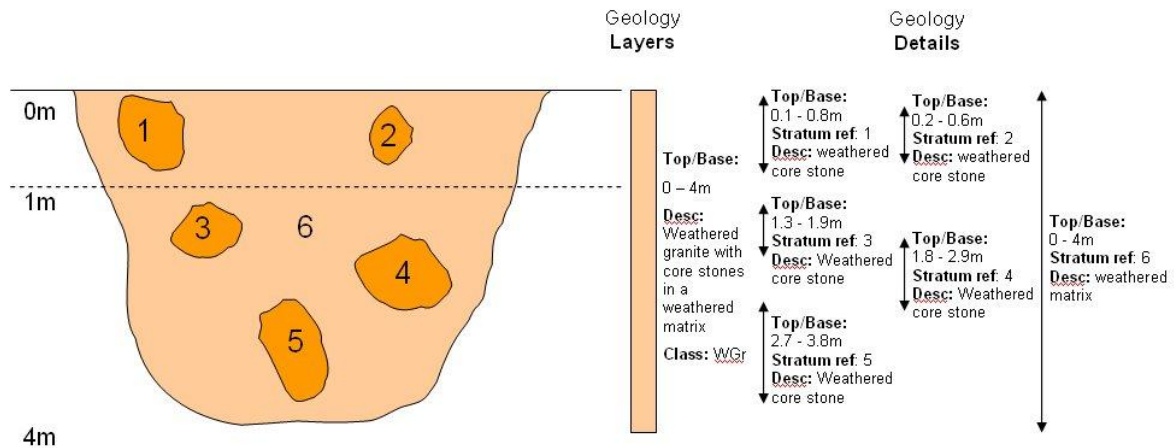
Figure 4-6 Stratum references in the description of a trial pit

In the example given in Figure 4-6, a **stratum reference** has been applied to segments of the ground described as geology **details**, as the individual segments overlap and are non-consecutive.

Whilst the use of a **stratum reference** is essential for the geological description of the ground seen in the trial pit in Figure 4-6, it is further used within DIGGS as a method for linking the segments of the ground encountered to activities carried out within it, such as sampling or in-situ testing. For example, if a bulk sample was taken from the area of **strata reference** 5 in Figure 4-6, and an *in situ* hand vane test were carried out at a depth of 2m in **strata reference** 6, data relating to this sample and *in situ* test would be recorded as follows:

Sample: Top depth 3.5m, base depth 3.7m, sample ID 36252, stratum reference 5

In situ **test: Depth 2m, stratum reference 6, peak shear strength 35kPa etc.**

By use of this data construct in DIGGS, any activity undertaken in the trial pit or exposure can be linked in to the exact area in which it was undertaken.

4.3   Samples and laboratory testing

Perhaps the largest volume of data within a typical DIGGS file for a geotechnical investigation will be related to samples taken in the field, and subsequently tested by one of the many laboratory methods of testing that are available. The structure of DIGGS has been developed to be both rigorous and extremely flexible, to take account of the various methods of sampling and testing that are available. The majority of this section will make use of examples to outline how samples and laboratory tests are described in the DIGGS format. See section 3.2.4 for more information on paired tables.

4.3.1 Samples

Within DIGGS, a sample is defined as a physical portion of the environment (be it solid, fluid, gaseous or a combination of phases) that has been collected or created (in the case of blank and quality assurance test samples, most common in the geoenvironmental sphere). Samples can be directly collected or created, or can be produced from the sub-sampling of a previously existing sample, or the amalgamation of more than one existing sample. Note that the term 'specimen' does not exist in the DIGGS format.

(i) Sample source

A key construct within DIGGS for the handling of samples and laboratory test results is the concept of the source property. This attribute is applied to samples, and to laboratory test results. It describes:

The location from which a sample was originally collected (or created). For example, this may be the ID of the borehole from which a sample was collected,

The parent sample from which a sub-sample was derived

The parent samples from which an amalgamated sample was created

The tested sample from which a laboratory test was derived.

The source property is effectively the ID of the parent of the object being described. It is the fundamental means by which relationships are handled within the DIGGS format. The use of the source property is best understood through consideration of the examples in Section 4.3.3.

(ii) Sampling process

DIGGS uses the concept of a sampling process property to describe the means by which a sample came to exist in a given state, as reported in a DIGGS file. For examples, a sample collected from a borehole will have a process property that described the method of sampling employed (e.g. driven tube sample). A sample that has been sub-sampled from another sample will have a process property that describes the sub-sampling procedure. Again, the process property is best understood by consideration of the examples presented in Section 4.3.3.

4.3.2 Laboratory tests

There are a large number of geotechnical laboratory tests, and it is not possible to describe them all here. However, within DIGGS there are several key data constructs that are seen within the laboratory test objects.

The first construct used is the use of the source property to link the laboratory test to the sample on which the test is conducted. As with the sample source, as described above, the source property is simply the unique ID of the sample on which the test is carried out.

Several geotechnical laboratory tests consist of a series of test stages which are combined to produce an overall test result (e.g. multi-stage triaxial tests, compaction tests etc.). Where this is the case, DIGGS uses the concept of general test information, and detailed test information which is 'nested' within the main test. This allows detailed test (i.e. test stage) information to be related to the main test directly.

The handling of samples and testing data within the DIGGS format for geotechnical data is best described through use of the nine example cases outlined in Section 4.3.3.

4.3.3   Sample and testing examples

The following nine examples are used to explain some concepts of the construction of the DIGGS format, with particular reference to the relationships between samples and laboratory tests.

Each example figure is split into three sections:

Real world – a schematic diagram to explain the context of the example

Data Construction – a diagrammatic representation of the elements of the DIGGS data structure for the example

Linkages – a diagrammatic representation of the sample source linkages for the example.
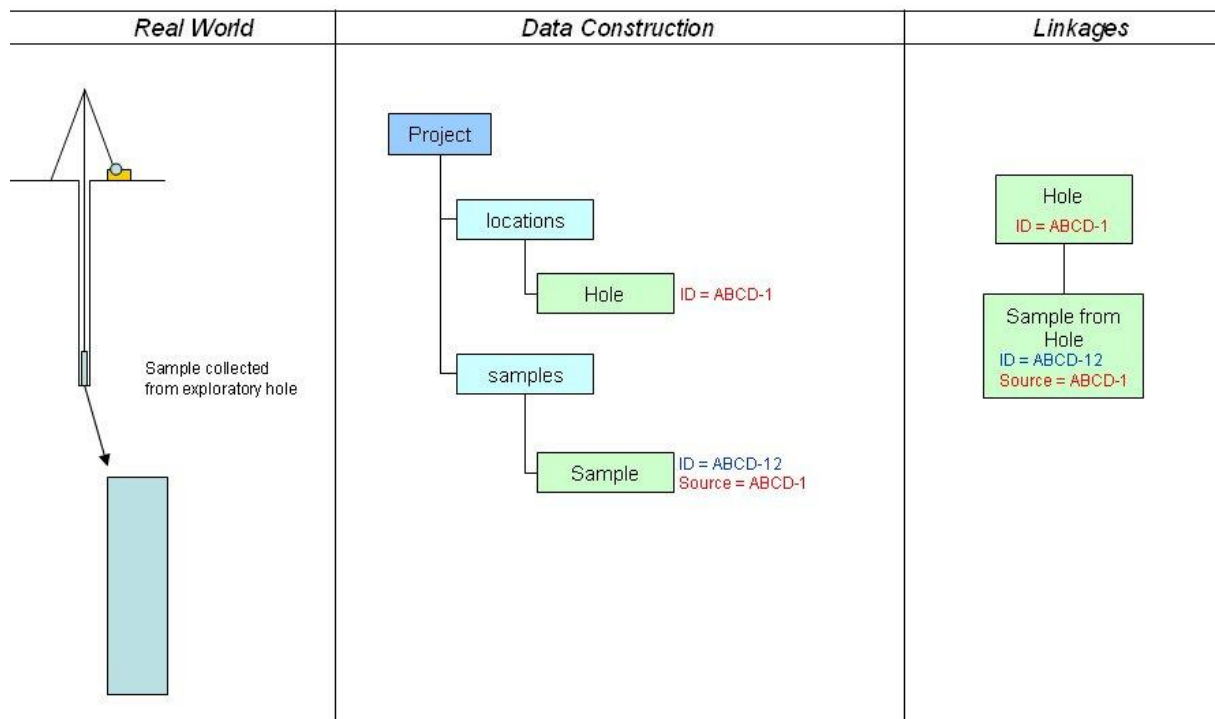

Figure 4-7 Example 1 – Sample taken from an exploratory hole

Example 1 (see Figure 4-7) shows the simple case of a sample taken from an exploratory hole. Note that the ID of the Hole object is referenced as the source of the sample. You should also note that the samples data construction sits directly below the Project (as does the locations construction). This means that a DIGGS file can pass information related to the hole, without the sample data and vice versa. This data construction is key to the way in which DIGGS improves the communication of information in the geotechnical industry between those generating 'field' information, and those generating laboratory information.
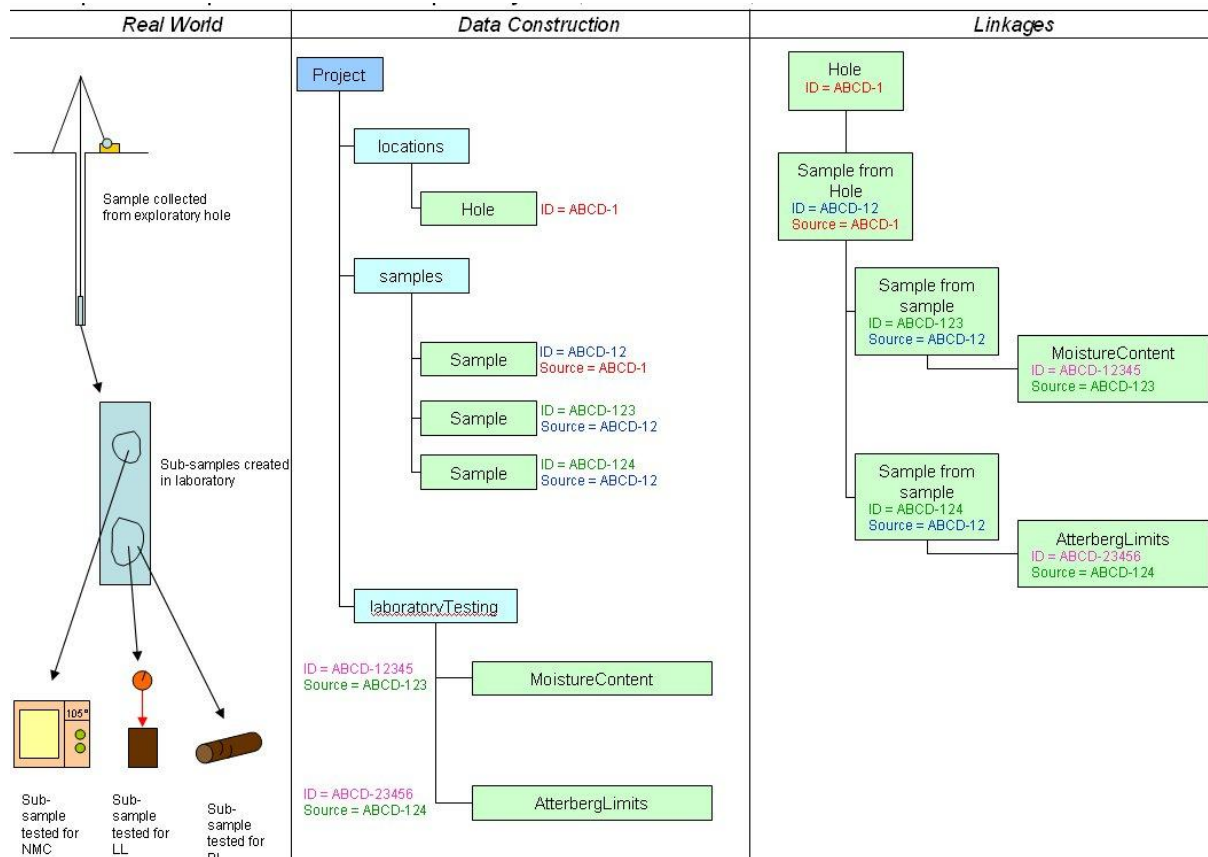
Figure 4-8 Example 2 – Sample taken from an exploratory hole and tested for moisture content and Atterberg limits

Example 2 (see Figure 4-8) shows a simple case of a sample taken from an exploratory hole which is subsequently used for two types of laboratory testing. As for example 1, the sample taken from the hole is related by use of the source property. As more than one type of test has been undertaken on the sample, it must first be sub-sampled. You will note that the two sub-samples created are related to the 'parent' sample by use of the ID of the parent sample as the source of the two new samples. The two laboratory tests that are then carried out on the sub-samples are related by use of the ID of the sub-samples as the source of the laboratory test result. These relationships are shown in the 'linkages' part of Figure 4-8.

This use of IDs and source links is key to the way in which DIGGS handles samples and laboratory test results. However, in most cases the user need not worry about this at all, as the application software you are using, whether it be a geotechnical database or a laboratory information system (LIMS), will take care of assigning the IDs and generating the correct linkages. The use of IDs and source links is merely a device used in the DIGGS format to transfer the relationships between boreholes, samples, subsamples and laboratory tests in an unambiguous way. You will see later in this Introduction to DIGGS that this construction is a very powerful way of handling the complex relationships that can exist between samples and laboratory and insitu tests, particularly for environmental sampling where there is the additional complication of control samples and batch testing.
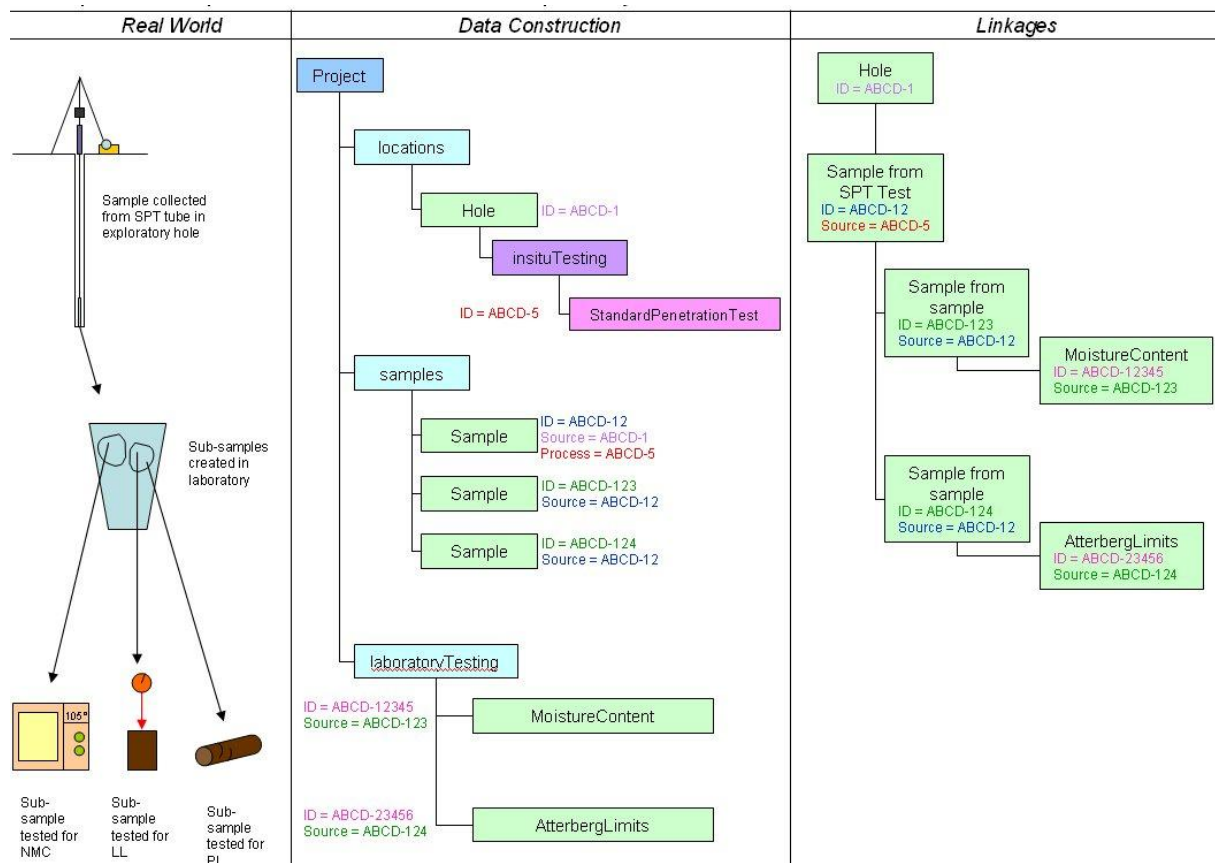
Figure 4-9 Example 3 - Sample taken from a Standard Penetration Test and tested for moisture content and Atterberg limits

Example 3 (see Figure 4-9) shows a very similar situation to that outlined in Example 2. However, in this example the original sample has been extracted from the ground during a standard penetration test, rather than through a direct sampling method. The DIGGS data structure is almost identical to that in Example 2, except that the original sample is linked to the standard penetration test from which it was taken through the use of the process property. The process property of the sample is the ID of the standard penetration test.

This construction within the DIGGS format is key to the way that more complex sampling and testing information is described.
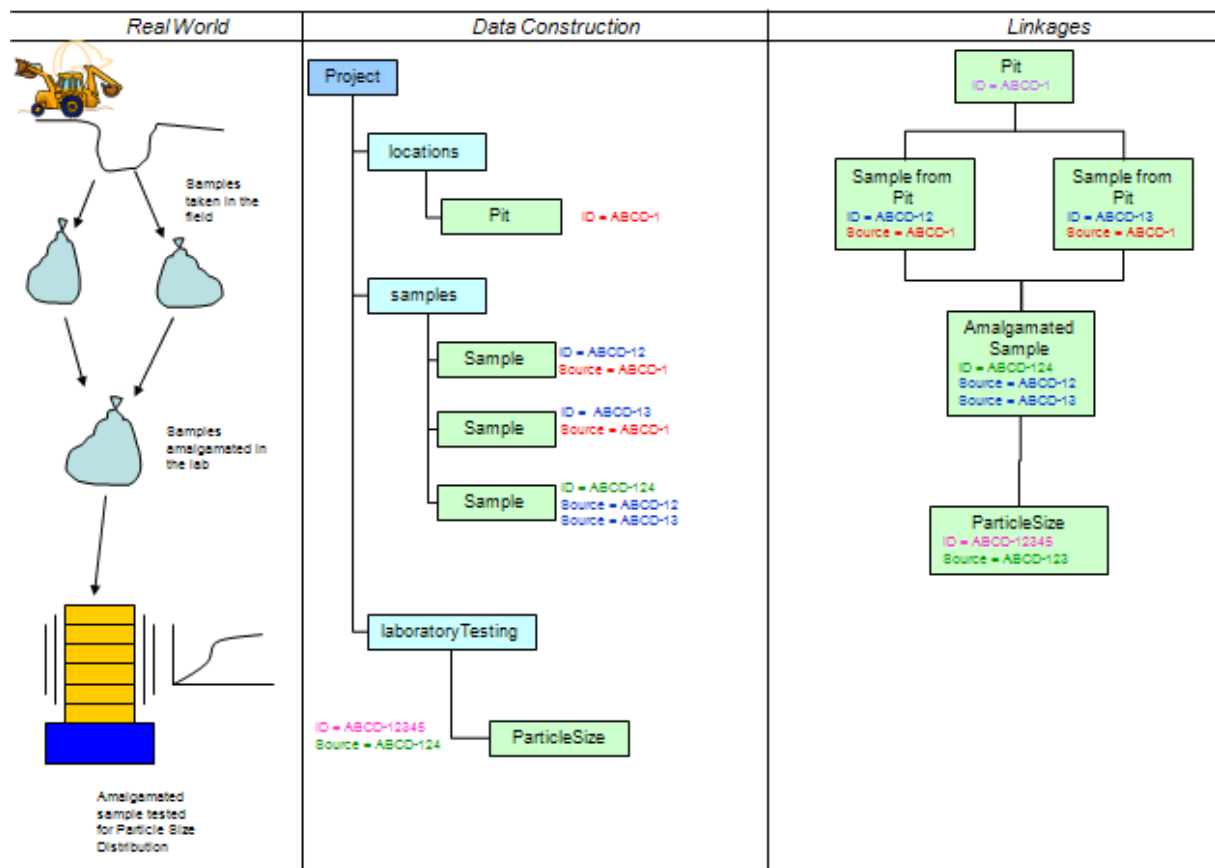
Figure 4-10 Example 4 – Amalgamated samples tested for Particle Size Distribution

Example 4 (see Figure 4-10) shows how the DIGGS format handles amalgamated samples. Two samples are taken from a single trial pit (and hence the source properties of these samples are the ID of the pit). The two samples are then combined (amalgamated) to form a new sample. The source property of this new sample references the ID of both of the samples from which it was created. This amalgamated sample is then tested in the a particle size distribution test, which has its source property as the ID of the amalgamated sample.

DIGGS also allows the proportions of the constituent samples to the combined sample to be reported.
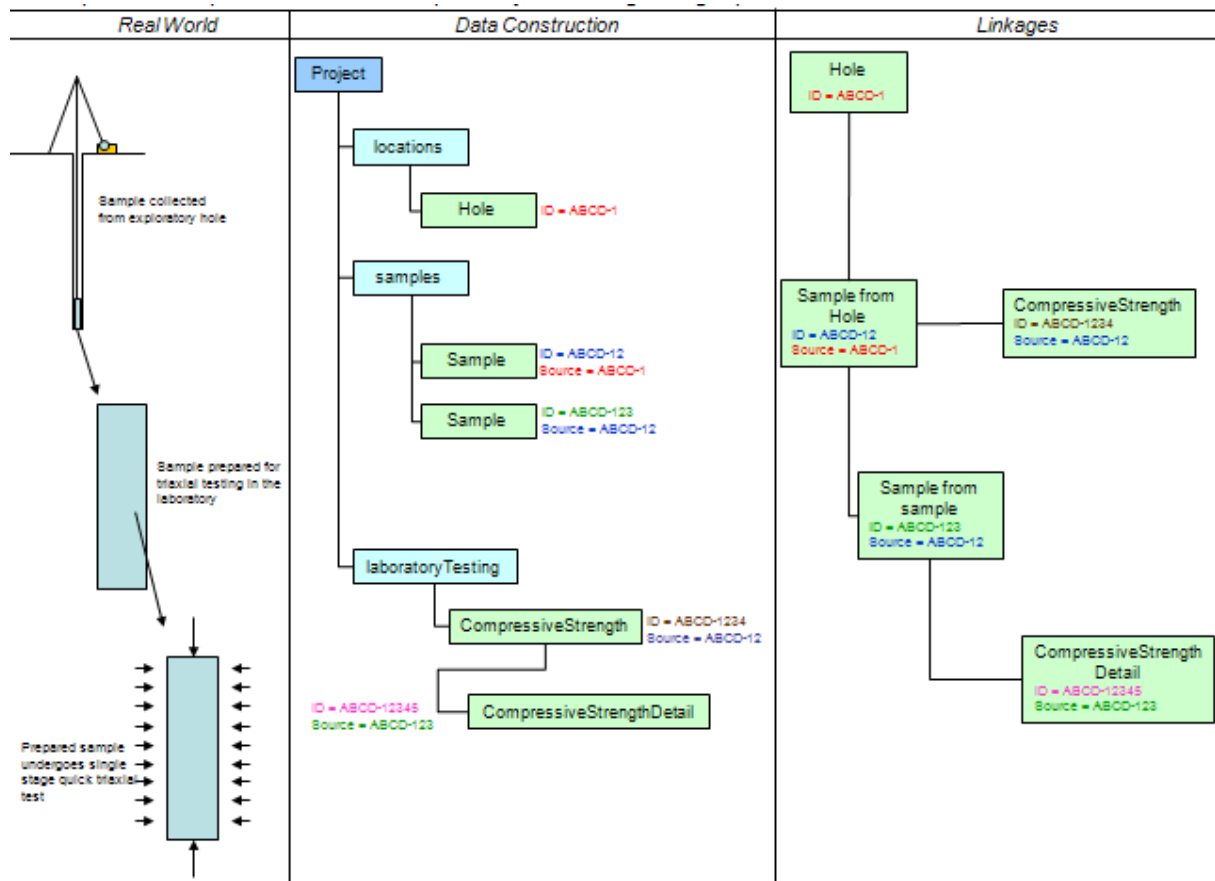
Figure 4-11 Example 5 – Single stage triaxial test on single sample taken from an exploratory hole

Example 5 (see Figure 4-11) is the first of a series of three examples that relate to triaxial testing undertaken on soil samples. This example describes a single stage triaxial test undertaken on a single sample. In this simple example a sample is obtained from an exploratory hole. This sample is then prepared for testing, creating a second sample that has the source property as the ID of the original sample.

The compressive strength general test data (CompressiveStrength object) are linked by the source property to the prepared sample. The details of the triaxial test stage (CompressiveStrengthDetail object) are linked by the source property to the original sample.
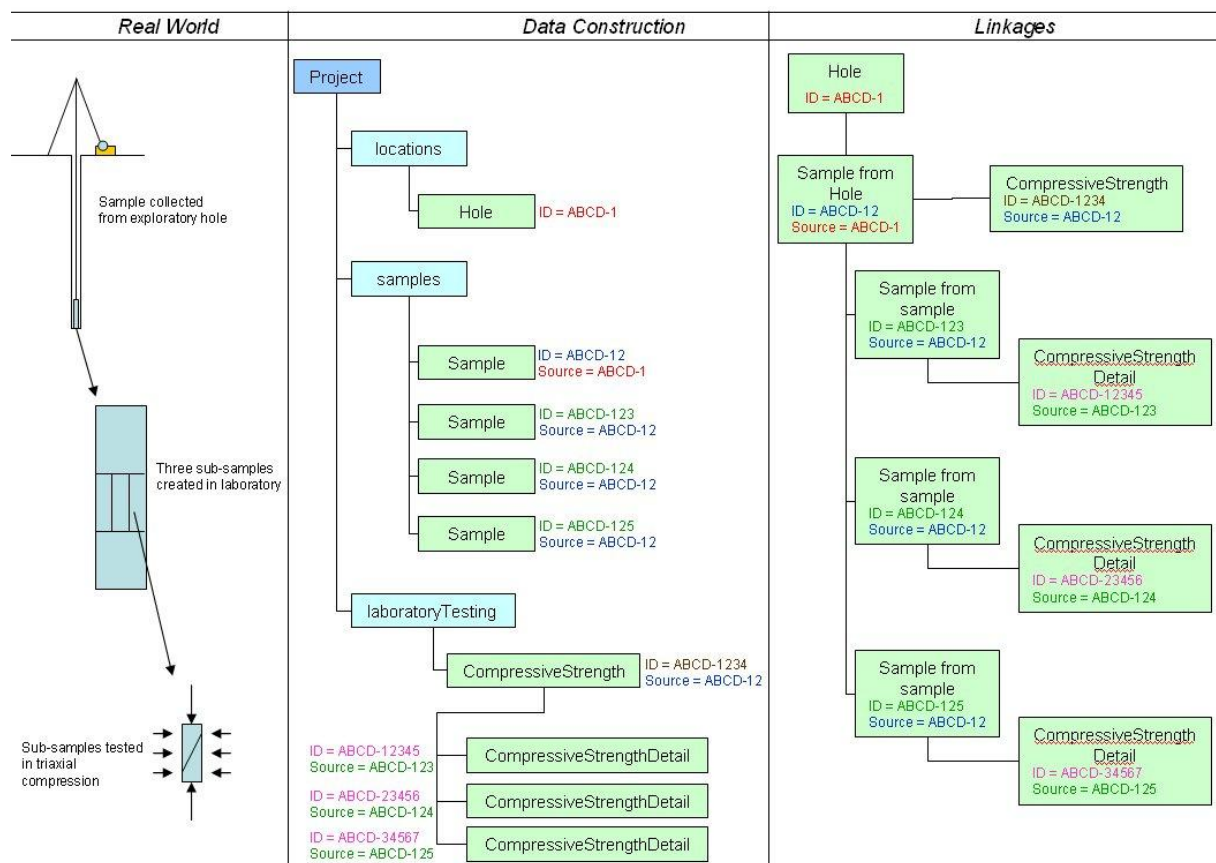
Figure 4-12 Example 6 - Three stage triaxial test on three sub-samples from a sample taken from an exploratory hole

Example 6 (see Figure 4-12) shows a set of three triaxial tests undertaken on three sub-samples prepared from a sample taken from an exploratory hole. The initial sample taken from the hole has a source property relating to the borehole, as in the previous examples. Three sub-samples are then created that each have a source property that relates to the original sample.

The general data of the triaxial test (CompressiveStrength object) are referenced by use of the source property to the original sample from the hole (as the complete test relates to this material). The individual test stages (described by the CompressiveStrengthDetail objects) are then referenced by use of the source property to each of the individual sub-samples created from the original sample.
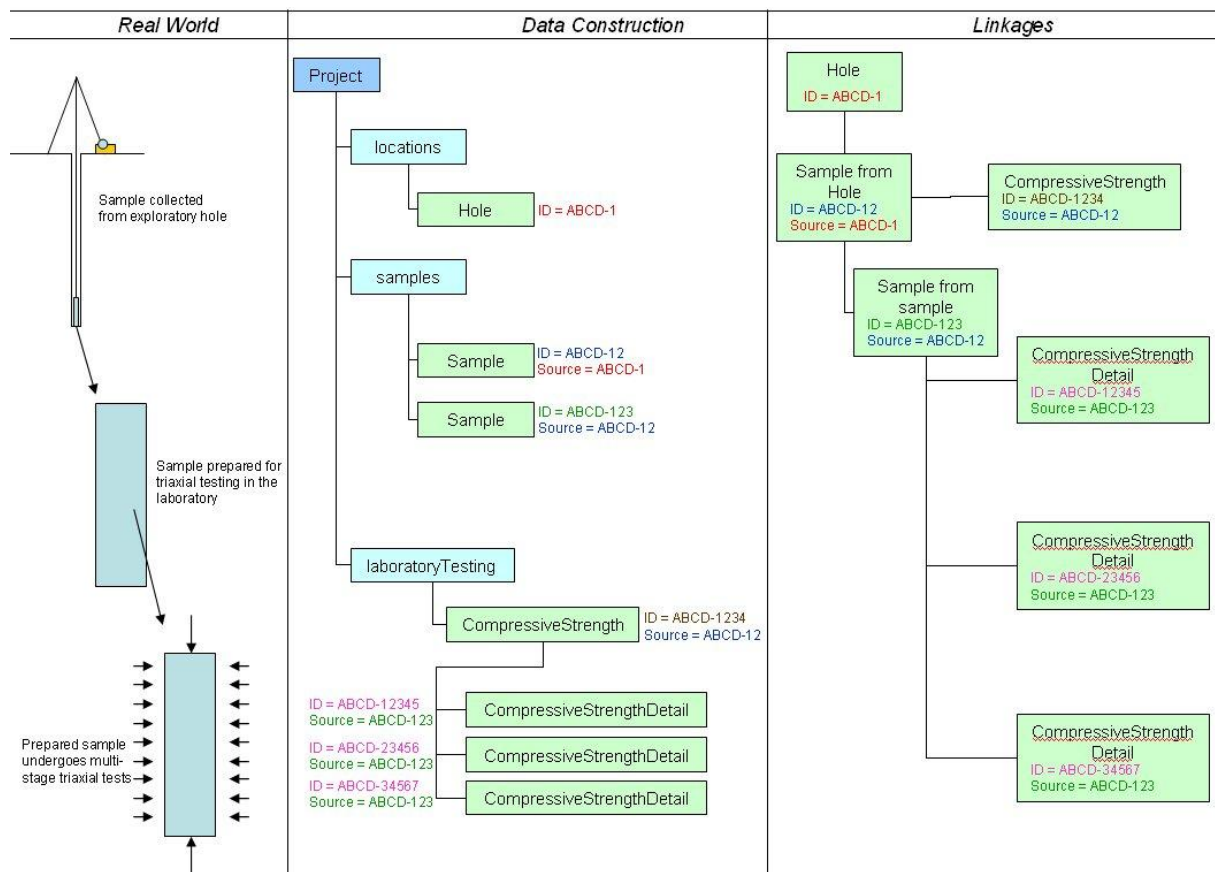
Figure 4-13 Example 7 - Three stage triaxial test on a single sample taken from an exploratory hole

Example 7 (see Figure 4-13) shows a multi-stage triaxial test undertaken on a single sample which has been prepared from a sample taken from an exploratory hole. Again, the initial sample taken from the hole has a source property relating to the borehole. The prepared sample that has been created for testing has a source property that relates it to the original sample.

The general details of the triaxial test (CompressiveStrength object) are referenced by use of the source property to the original sample from the hole (again, as the complete test relates to this material). The individual test stages, on the single sample (described in the CompressiveStrengthDetail objects) are then each referenced by use of the source property to the single prepared sample created from the original sample.
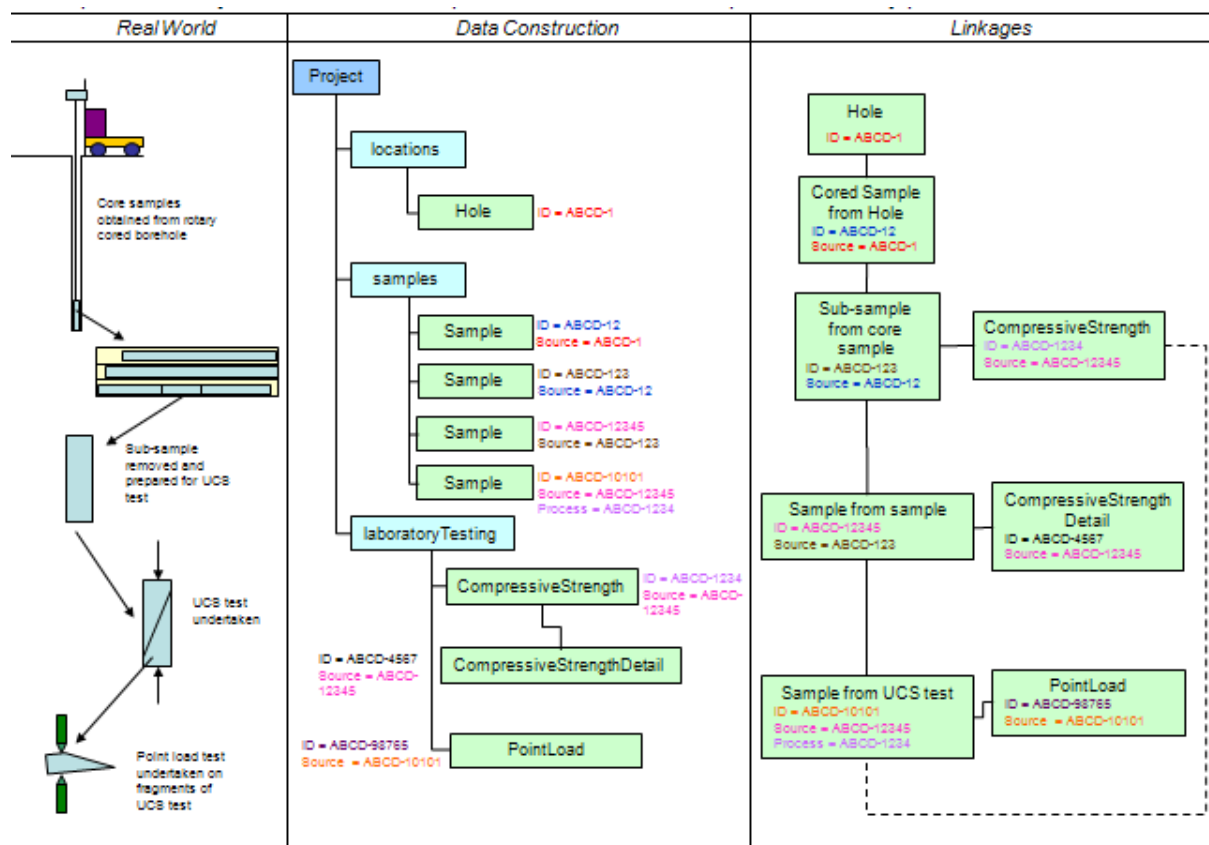
Figure 4-14 Example 8 – Unconfined Compressive Strength test and point load test undertaken on sample from rock core

Example 8 (see Figure 4-14) shows how the DIGGS format handles sample and test result information for the more complex situation of linked rock testing. An initial sample is created from a rotary cored borehole (the sample being the individual core run). This initial sample (core run) is linked to the borehole through use of the source property. A subsequent sub-sample is created by extraction of a section of the core run. This sub-sample is then referenced to the original sample (core run) through the use of the source property.

This sub-sample from the original sample (core run) is then prepared for an unconfined compressive strength test, creating a new sample, linked to the sub-sample through the source property.

Following the unconfined compressive strength test, broken fragments of the sample are tested to determine their point load strength (testing of just one fragment is shown in Figure 4-14). This new sample is linked to the prepared sample for the UCS test through the source property, but importantly the process that created the sample is recorded as the ID of the unconfined compressive strength test conducted.

5 Environmental data

The DIGGS Environmental Extension takes the concepts already described in section 4 and 5 of this document and adds five main components:

- Advanced methods for transferring data on well installations together with the samples and readings associated with these wells.
- A means of recording when a sample is collected from a surface location rather than down a borehole
- Methods for transferring field and laboratory quality control sample information.
- Methods for transferring test analysis and quality assurance data associated with a physical laboratory test.
- Methods for recording batch information for samples.

5.1 Well Construction and Sampling

Section 4.1.3 describes how well installations are constructed within a borehole. The DIGGS Environmental Extension expands on the well information by adding the recording of water level readings and details of purging of the well

5.1.1 Water Level Readings

Water level readings can be taken in a well installation at any time, or specifically during purging of the well. Each time a water level reading is taken the following details can be recorded:

Date/Time: date and time of the reading or the start of the purge event

Is Dry: Was the well dry?

Is reportable: Is this value to be reported?

Method: General method used to measure water levels

ProductType: Type of contaminant product found

Type: Type of reading, such as depth to water level, depth to product or depth to bottom of well

Remarks: remarks can be added to the event, using the core DIGGS methodology for recording remarks. In the same way, equipment, specifications, business associates etc. can also be assigned to the event

For each recorded depth reading, the following information can be recorded:

Depth: Recorded depth to water level

Corrected Depth: Water level depth after any transducer corrections

Product: Type of contaminant product (if present)

CRS: The CRS (co-ordinate reference system) used to record the reading can change during the life of the installation. For example a monitoring well may be extended upwards as a landfill is raised, or may be cut down as the fill settles, in either case the reference point for depth measurements at the top of the well has changed, and needs to be defined as a new CRS.
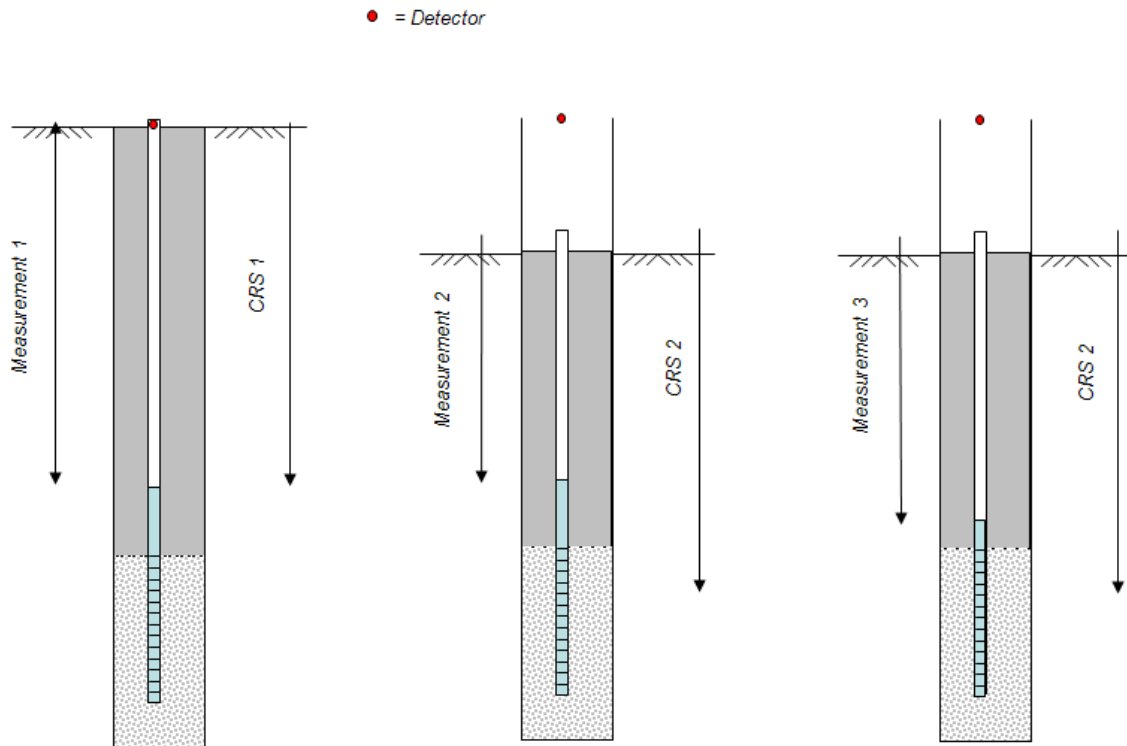
Figure 5.1 – Monitoring water levels with a changing datum

In Figure 5.1 well is constructed and the first measurement is taken using a coordinate reference system defined from the top of the well down. However on the second visit to the site it is noted that the top of well has changed (due to settlement or excavation) and so the datum point for the well needs to be redefined and the measurement taken with respect to this second coordinate reference system. On the third visit the datum was the same and therefore a new CRS is not required.

There are methods available in DIGGS to transfer whether the change in local datum has been gradual since the last visit (i.e. for subsidence) or whether the change has been a sudden change (i.e. due to an accident or excavation).

5.1.2   Purge Data

When a well is purged the following information can be recorded:

> **Date/time for the start of the purge event**
>
> **Type of purge.**
>
> **Volume of casing**
>
> **Total volume of water removed in this purge.**
>
> **Was this well purged to dry?**
>
> **Was the water removed in containers?**
>
> **Was the water treated in containers?**
>
> **Was contaminant product removed in containers?**

Were contaminant product containers labelled?

Remarks

During a well purge the water level readings can be recorded throughout the purging process.

Samples taken during purging will reference the Purge ID in the process source property as shown in Figure 5.2 below.
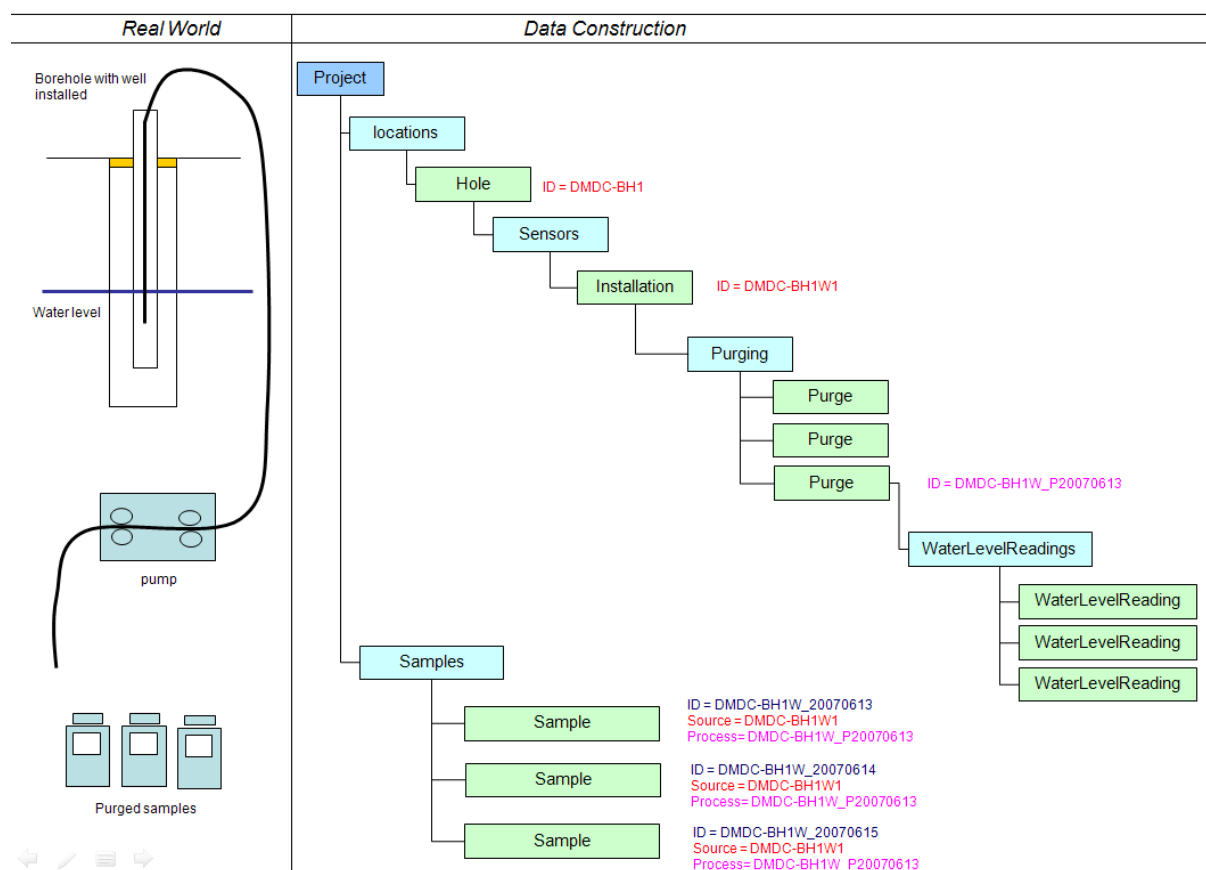
Figure 5.2 – samples taken from Purge events reference the purge ID in their process property

5.1.3 Multiple well installations per borehole

The data construction described above can easily be applied to a situation where you have more than one well installation per borehole. This is illustrated in Figure 5-3 below where a single borehole has three well installations that have been purged to produce one sample from each installation.
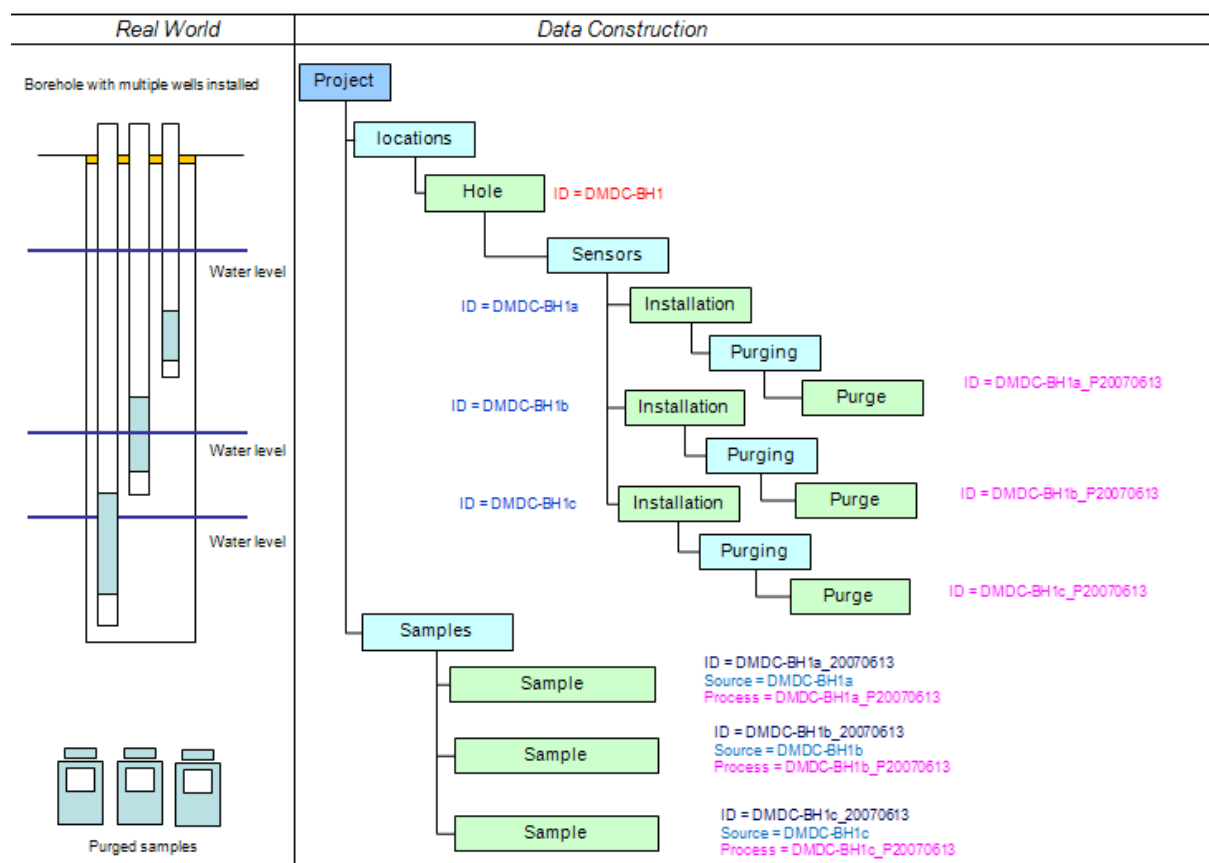
Figure 5.3 – Samples extracted from multiple well installations

5.2   Surface sampling

Where a soil sample is taken from the ground surface, or a water sample is taken from a river, then the use of the borehole or well installation described previously is not appropriate, instead the location of the sampling site is described, as illustrated in Figure 5-4 below.
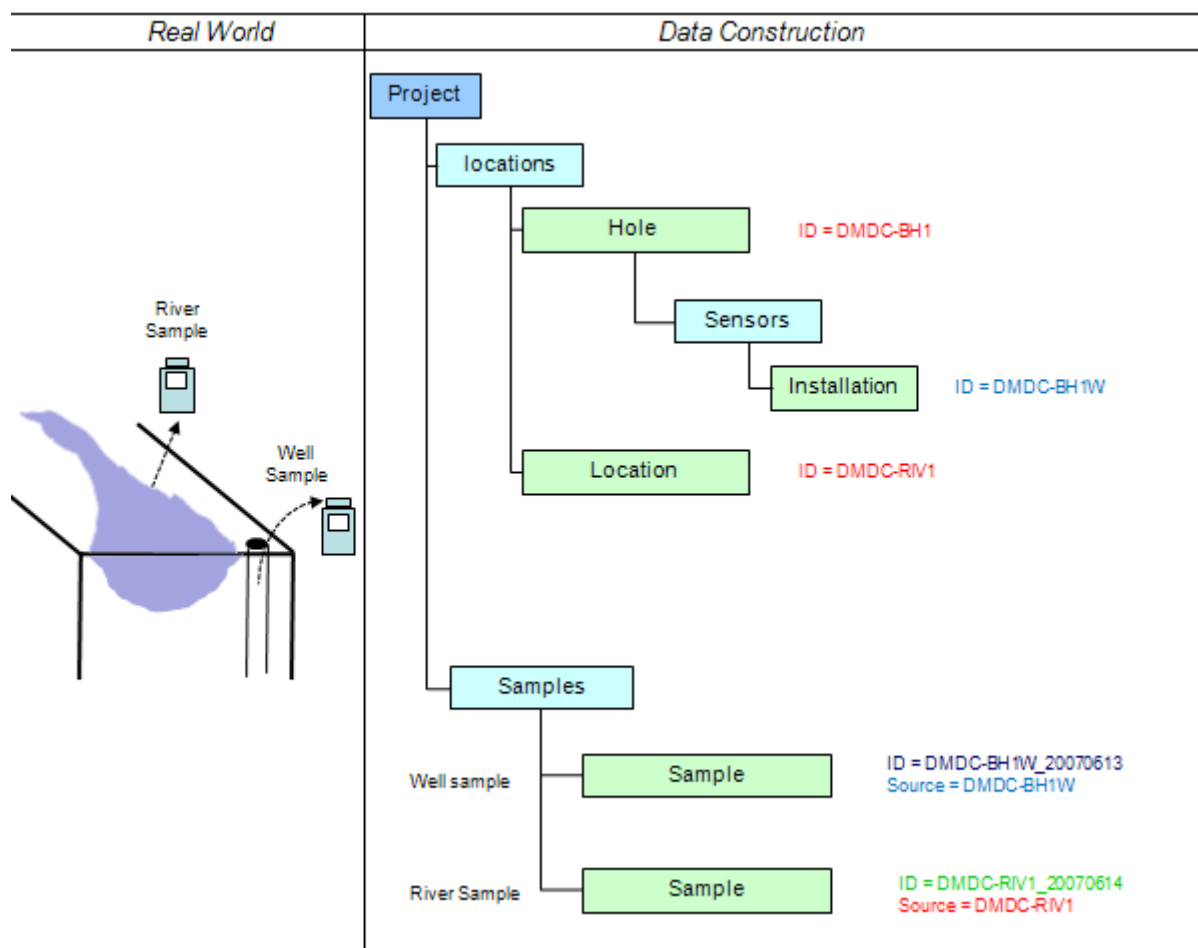
Figure 5.4 – Sample taken above and below ground

5.3 Quality Control Samples

5.3.1 Field Control Samples

Data relating to field quality control samples can be transferred in the same way as data from normal environmental samples but by omitting the source property. When the sample information is transferred to the laboratory the sample IDs need to be transferred but the rest of the sample information is optional. By omitting the source property from the samples the laboratory will not be able to distinguish between true field and control samples.

When a batch of samples is submitted to a laboratory it may consist of true field samples, duplicate field samples for control testing and trip samples also for control testing. All of these samples need to be related together, so that their test results can be compared, and DIGGS provides a way of doing this as illustrated in Figure 5-5
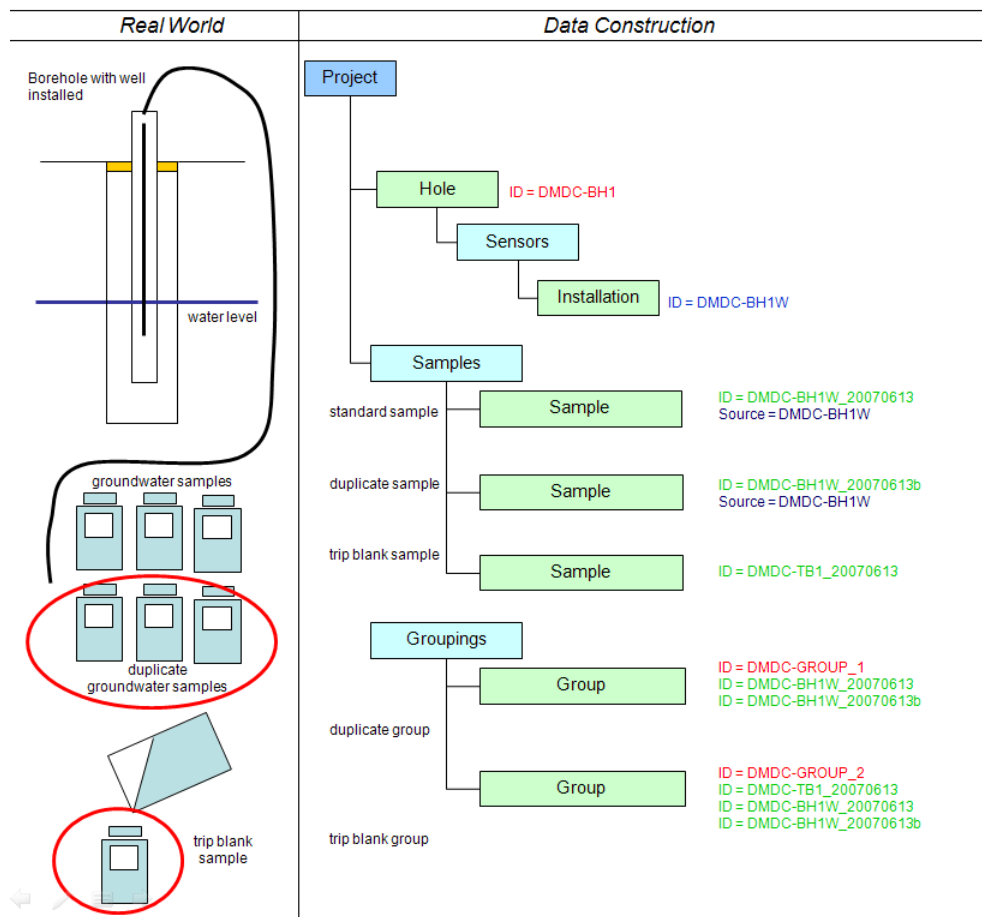
Figure 5.5 – Duplicate and field control samples

5.3.2   Laboratory Control Samples

The transfer of laboratory control sample data is identical to data for field control samples in that the sample source can be omitted. However, the grouping together of the true and the control samples is even more important, and must always be defined as illustrated in Figure 5-6 below.
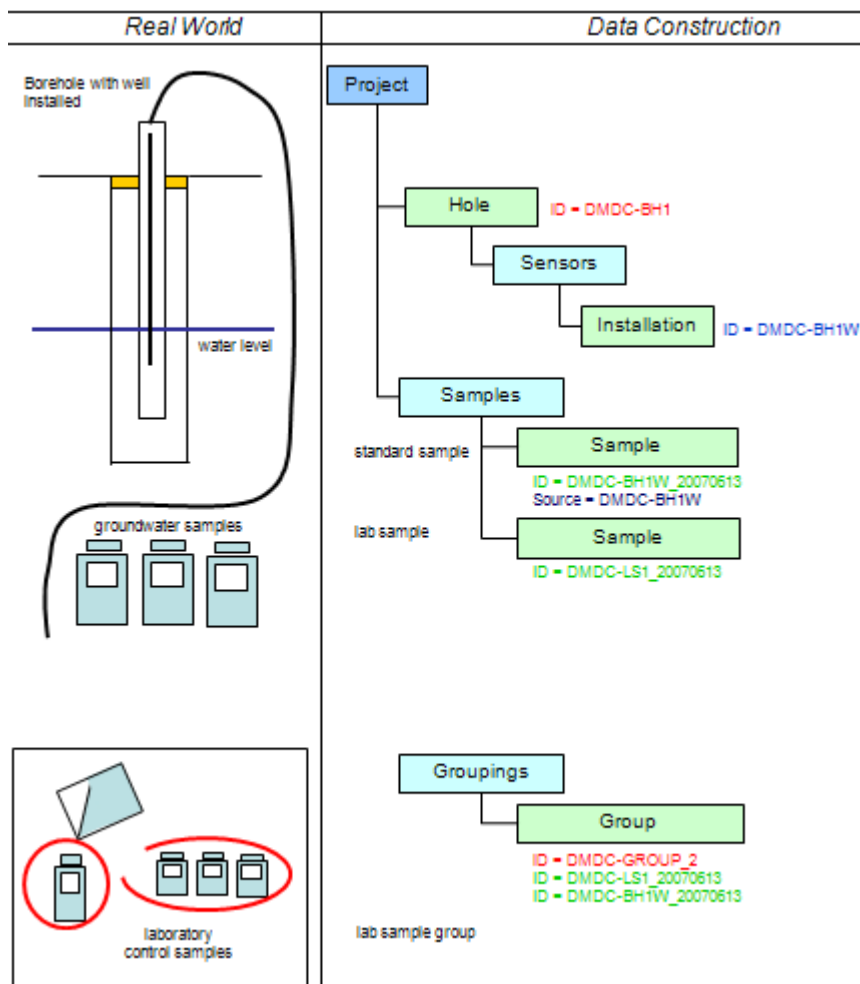
Figure 5.6 – Laboratory control samples

5.4   Environmental Testing

The results from an environmental test can have six components;

Environmental Test: The general test procedure, requirements and methods (e.g. AA, ICP, EPA 8260)

Analysis: Reports the specifics about the analysis method used and includes the time element for the test (e.g. EPA 8260, 6 June 2008). Each environmental test could be carried out by one or more analysis methods.

Result: Transfers information about the chemical concentrations found from the analysis. There may be one or more results for each analysis (e.g. Ca, Mg, Na, etc.).

Detection Limits: Contains information on each detection limit that applies to the data in the results. Each result may have one or more detection limits.

Qualifiers: Contains information on each qualifier (i.e. what the less than symbol means in front of a value) that applies to the data in the results. Each result may have multiple qualifiers (e.g. method, validation, etc).

The hierarchical relationship of these six data components is illustrated in Figure 5.7 below.
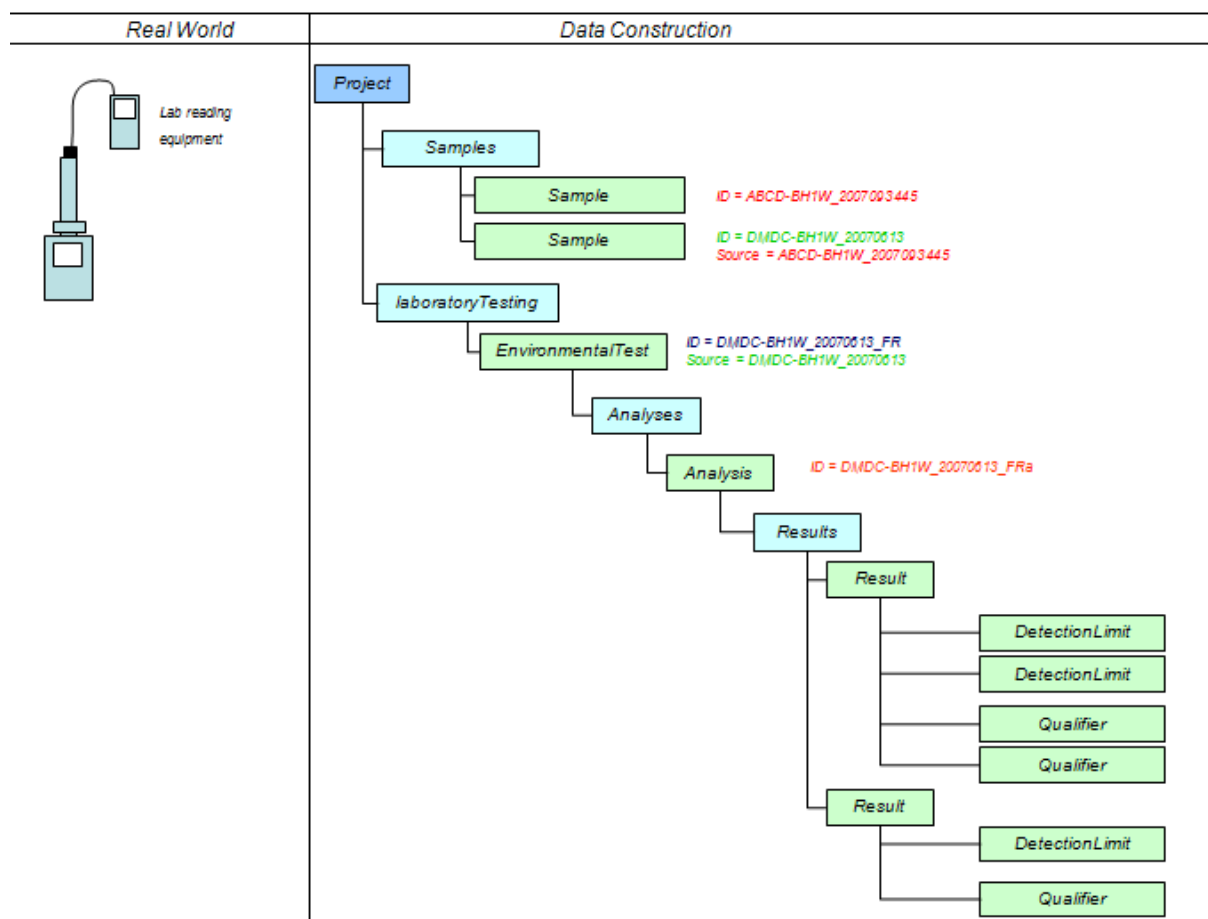
Figure 5.7 – Laboratory testing data structure

5.4.1 Tentatively Identified Compounds (TICs)

The analysis of Tentatively Identified Compounds (TICs) involves the statistical matching of mass spectral analyses against a library of standard results for the commonest, most toxic compounds. In addition to reporting the chemical test results in the same way as standard results two extra fields are required:

Percentage match: to report the statistical percentage match of the TIC to the suggested chemical;

Retention time: specified as a start and end time or a duration time that the component was retained in the mass spectrograph instrument column.

6 Monitoring data

The DIGGS Monitoring Extension takes the concepts already described in sections 4 and 5 of this document and adds two main components to them:

- Location information for sensors and detectors

- Tabulated readings data

6.1 Sensors and Detectors

DIGGS represents each monitoring instrument using a sensor and one or more detectors. This simple system allows all types of instrumentation data to be transferred using the same data structure.

A sensor is a point or a line in 3D space either down a borehole or at a monitoring point on, above or below ground. A sensor is often equivalent to the actual instrument placed on a structure or down a borehole. Simple examples of sensors are: an earth pressure cell, a strain gauge, a tilt meter, a crack meter or a temperature gauge.

Each sensor can record one or more types of measurement using one or more detectors. Each detector can measure omni-directional parameters (e.g. porewater pressure) or uni-directional parameters (e.g. horizontal pressure) . If a detector is measuring a uni-directional parameter then the Coordinate Reference System (CRS) that it measures along must be defined, that is the orientation of the measurement axis in 3D space and the direction or sense of the measurement..

For example a temperature gauge has a single detector measuring temperature which is an omni-directional parameter, a strain gauge also has a single detector that measures strain in a defined direction, and a spade cell has two detectors, one measuring omni-directional pore water pressure and the other measuring horizontal earth pressure in a defined direction.

Detectors are grouped into a single sensor when their results are only meaningful when used together e.g. a strain rosette is a single sensor with three detectors all measuring strain, each measuring along a different axis. When the results from detectors are independent they may optionally be grouped into a sensor, or represented as separate sensors e.g. a weather station recording temperature and pressure as one sensor and rainfall as a separate sensor.

The example below shows how the information for each sensor and detector is structured for a single spade cell instrument measuring pore water pressure and horizontal stress at the base of a borehole. The detector contains all the information on the parameter being measured, including the units of measurement and directional information required for uni-directional parameters.
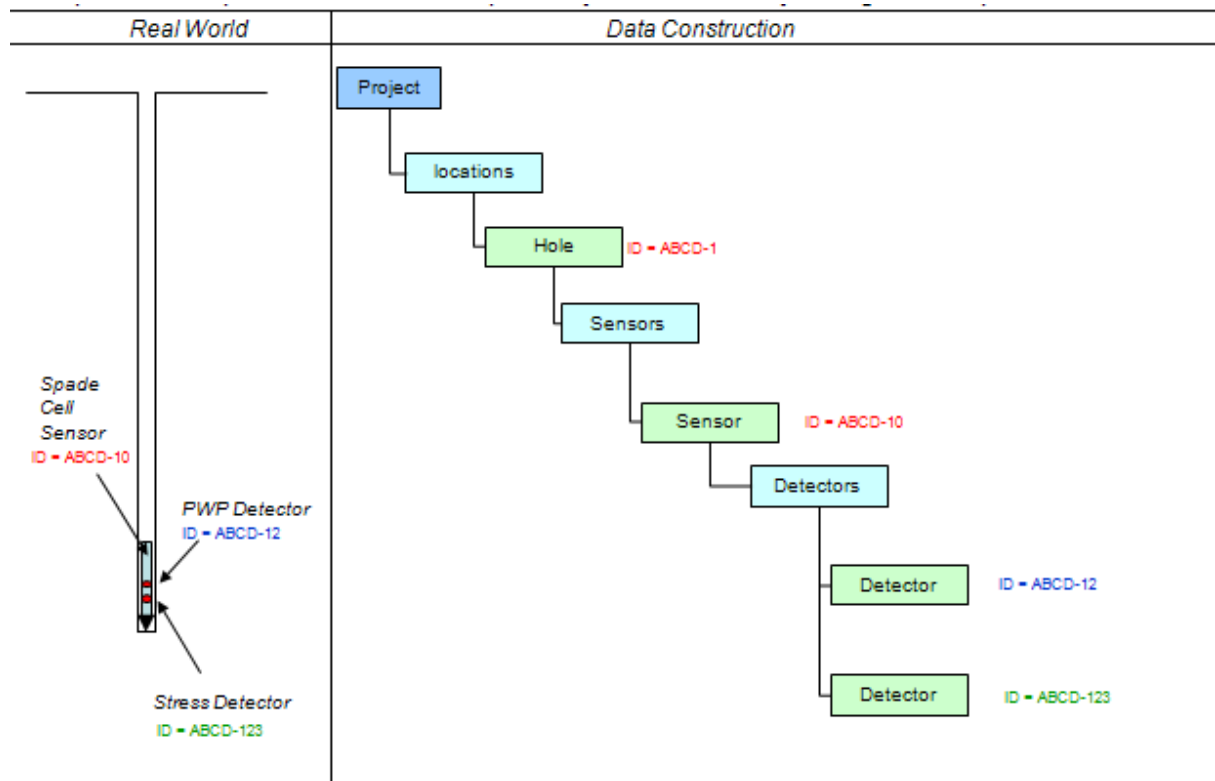
Figure 6.1 – Detector Location within a Spade Cell

Sensors are located within a Hole for down hole monitoring or beneath a MonitoringLocation for instrumentation not located in a borehole. The example below in Figure 6.2 shows a string of electro-levels up the side of a building. The electrolevel string is a single sensor with multiple detectors. As the sensor is not in a borehole it is associated to a MonitoringLocation, defined at the base of the building.
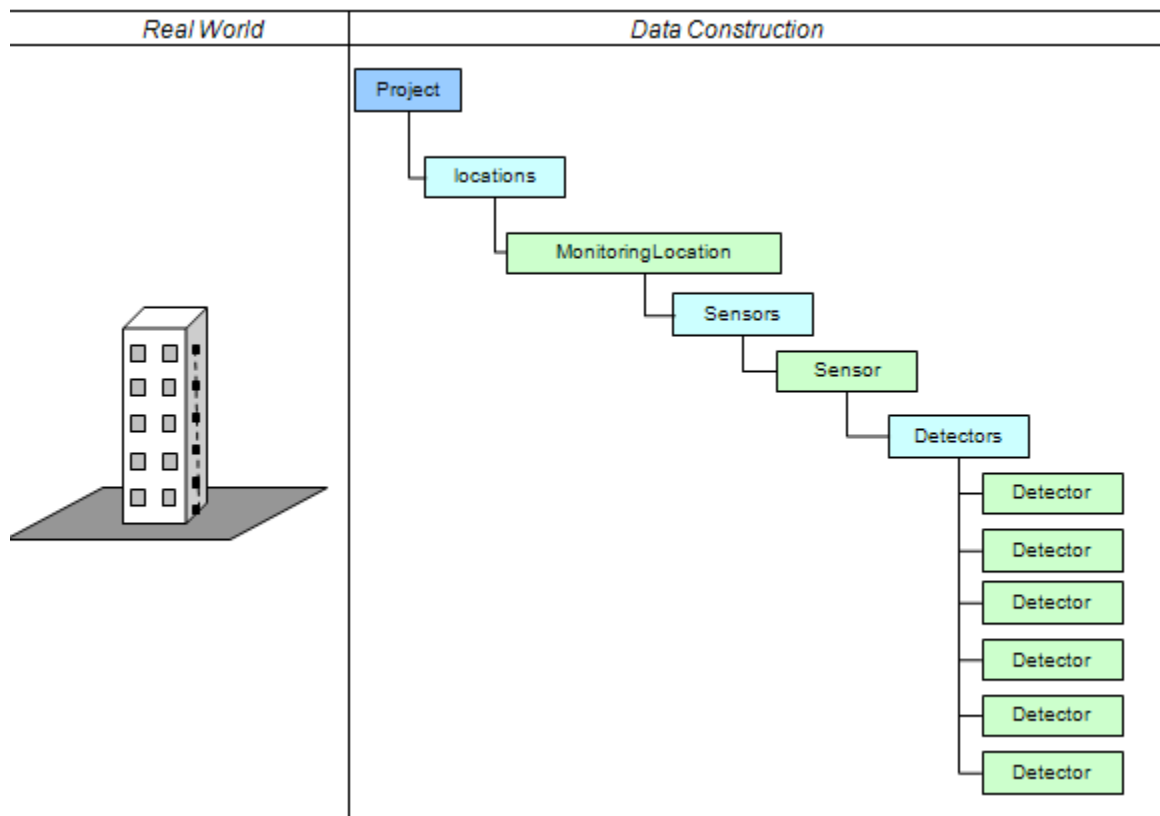
Figure 6.2 – Detector Location within an electro level string

6.2 Readings

Readings from detectors are transferred in DIGGS in a tabular format that has been designed to transfer large amounts of data in a compact file size. Below is a block of tabular data of readings from a piezometer. The first column is the date/time in the standard international format for computer data (year-month-day hours:minutes:seconds), the second column is the reading and the third column is a comment.

2006-02-03T11:45:00,5.62,Initial measurement;
2006-02-04T12:00:00,5.62,;
2006-02-05T11:45:00,5.6,;
2006-02-06T11:30:00,5.57,;
2006-02-07T11:00:00,5.57,;
2006-02-08T12:45:00,5.58,;
2006-02-09T11:45:00,5.56,;

In order for receiving software to be able to translate this data DIGGS also transfers the definition of the data table as well as the data. The structure of the tabular data is shown below. Each of the column definitions identifies the detector that the associated data originates from by including the unique detector ID.

Figure 6.3 – General construction of the Table object

Using the detector link in the column object it is possible to relate columns of data to detectors under both a MonitoringLocation and a Hole in the same table of readings.
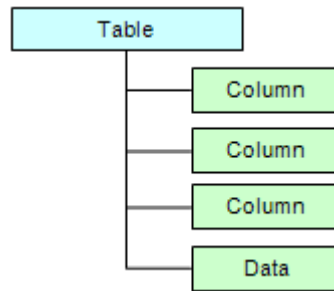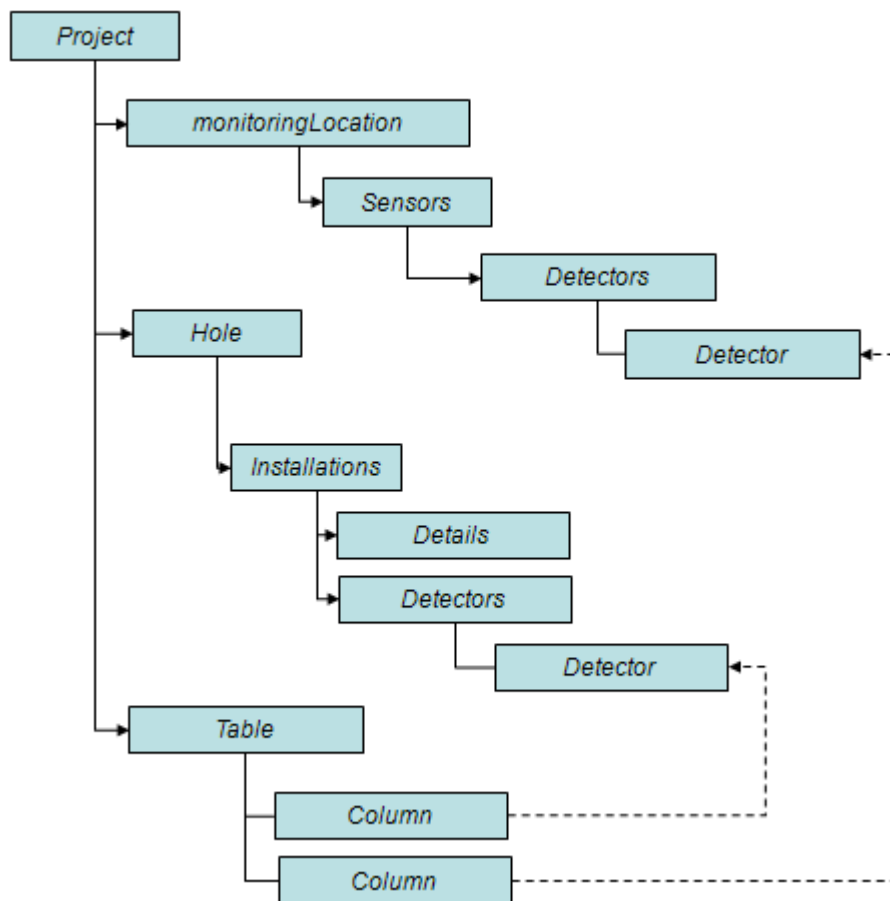

Figure 6.4 – Location of Table object showing links to detectors

7   Piling data

The DIGGS Piling extension allows the transfer of design, as-built, and field testing data for piling. This section covers the basic capabilities of the piling extension. More information will be included in the next release of this document.

7.1   Pile Locations and Schedules

A foundation group is a collection of piles (driven or cast) that work together as a load bearing foundation within a structure. Examples of different bridge foundation groups can be seen in Figure 7-1. Foundation groups sit directly beneath project within the DIGGS structure and form the highest level object in the DIGGS Piling extension.
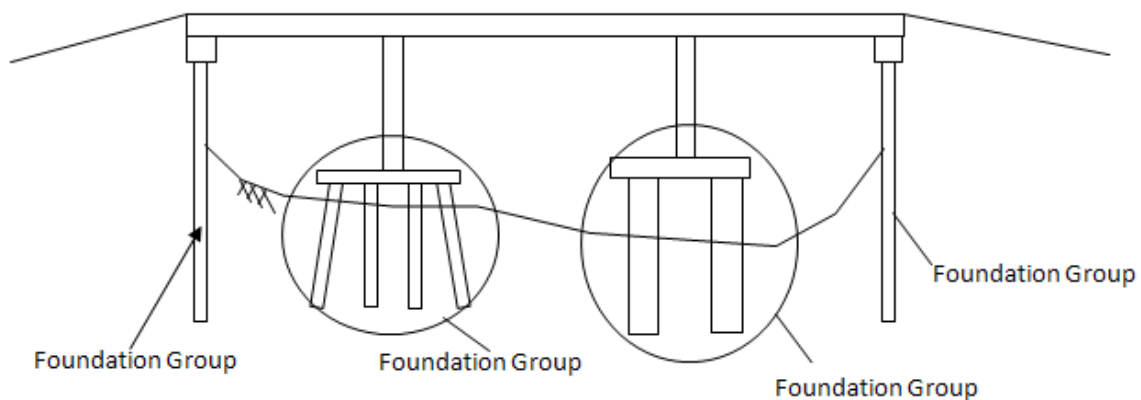

Figure 7.1 Foundation groups beneath a bridge

When specifying piling requirements pile group location and loadings requirements can be transferred via a DIGGS file. Each loading requirement can be transferred for either an entire foundation group or for each pile within a group. Each loading object contains information on the type of load (dead load, live load, wind load etc). There are no limits to the number of loading conditions that can be specified for each pile or group.

The DIGGS piling extension includes a method to transfer versioning information with the piling schedule so that the data receiver can compare pile schedules with previous revisions to identify the client's changes.

7.2   Design and as-built pile composition

The construction composition of each pile can be transferred within a DIGGS file by defining the primary, secondary constitutes and tertiary constitutes for each pile. The example pile shown in Figure 7-2 shows a concrete pile within a steel shell which has a changing diameter and under reaming. Within this example there are four primary constitutes; the steel shell and 3 sections of concrete with different geometry. There are two sections of secondary constitutes; the top section of reinforcement and the base section of reinforcement and these both one tertiary element each (helical reinforcement for the upper section and link reinforcement for the lower section). This example has been devised to show the complexity that DIGGS is able to transfer. Standard piles will usually only have one of each type of constitute.
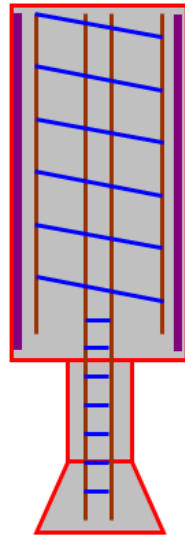
4 Primary Constitutes

   3 Concrete

   1 Steel

2 secondary Constitutes (rebar)

   Each with 1 Tertiary Constitutes
   (Links or Helical reinforcement)

Figure 7-2 – Composition of an example pile

7.3　　Construction Information

7.3.1　　Driven Pile

Piles which are driven, vibrated or jacked into the ground are classified as DrivenPiles in DIGGS. Examples would include:-

- steel sheeting to make a cofferdam
- a driven prestressed concrete pile
- a composite steel/concrete pile with a driven steel shell. flushed (soil removal) and filled with concrete and rebar.

DIGGS can transfer a set of driving log details which record the progress for vibrated, stroked Hammer, Pressure Hammer, Jacked and Impact method of driving associated with each driven pile data.

7.3.2　　Cast Shaft

Piles which are cast in place are classified as Cast Shafts in DIGGS. Examples would include:-

- auger cast piles (ACP, US)
- continuous flight auger (CFA: Europe)
- drilled shafts
- caissons
- micropiles (pressurized)

The specifics of the drilling process to create the hole for the subsequent shaft construction can be transferred within DIGGS using the drilling log. Examples would be the use of temporary/permanent casing for drilling mud, auger diameter, the soil description, and cleanout for a drilled shaft.　For a CFA pile, the auger diameter, torque, & rpm along with penetration rate is required for quality assurance.

Concrete Placement and construction details can be transferring in DIGGS. This includes the pumped concrete volume and pressures (CFA) per depth, losses due to concrete lines, and samples for laboratory testing. The concrete placement is critical or reconstructing the As Built pile dimensions vs. the design values

7.4   Field Testing

Field testing to assess capacity is an essential component of any piling (driven or cast) work. DIGGS allows the transfer of test definition and results for the following pile testing types;

- static top down load testing (referred to as conventional)
- bottom up static load testing (i.e. Osterberg)
- dynamic (PDA or Statnamic) top down testing.

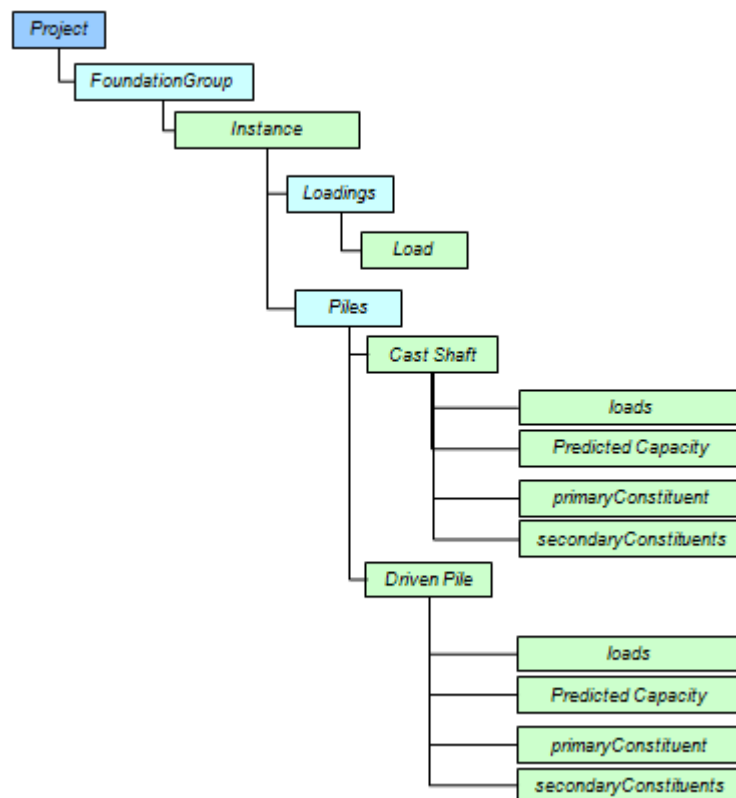## 7.5   Data Structure Overview

Figure 7.3 – Overview Structure of Foundation Groups and Piles

8   Geophysical data

The DIGGS format also allows geophysical data to be transferred by using the WITSML Well Log object. This is defined in DIGGS as an insitu test and can be included wherever insitu tests can be included.

More information will be included in the next release of this document.

9   User support and contact

9.1   DIGGS organization

The DIGGS organization was created through a "pooled fund" project that collected money and in-kind support from a collection of international organizations, industries and individuals. The DIGGS organization provides support for technical and implementation information for the DIGGS schema as well as a governance structure. It also manages any enhancements and updates to the schema. Future enhancements are handled through the creation of Special Interest Groups (SIGs) or Local Implementation Groups (LIGs). SIGs are usually focused on a particular feature or function and are generally international teams that are adapting existing formats and schemas to fit the DIGGS model. This was how the base format and the environmental schema were developed. SIGs can be funded or supported by any group and proposals can be submitted for including those efforts into the DIGGS schema. The current pooled fund study will be funding additional SIGs after version 1.0 is released. LIGs are generally country based groups that represent the requirements of their constituent country. These groups are encouraged to self organize, adopt the DIGGS schema and become members of the DIGGS organization. The DIGGS organization is developing a structure that will allow new LIGs to become members and represent their organization on committees. Information about the organization, how to submit a proposal and how to become an active member is available at the DIGGS website.

9.2   Support and Maintenance

Support for the schema and implementation help are provided by the DIGGS team members through the DIGGS website. The DIGGS Blog offers implementation help, tips, answers to questions and more. The DIGGS Discussion Forum offers a threaded discussion forum where DIGGS team members will respond to questions and discussions on implementation and extension issues. Questions on where to put your data, how to format a file, how to expand a table etc. will all be covered and answered.

New updates to the schema will also be found on the website. As issues get discussed and resolved, new versions will be posted. During the public review period, the schema will be updated every month. If sufficient changes are needed, a new version will be posted before the monthly update.

9.3   The DIGGS web site

The DIGGS standard is making extensive use of its web site not only for downloading of the document, but also for discussion boards so that user's needs can be more readily identified and resolved.

The website is the official repository and namespace for the schema.

Anyone wishing to have access to the DIGGS information and schema must become a website member. Membership provides access to the schema and the discussion forum. It also allows the member to register a unique ID which is needed in order to implement the schema.

The new standard has built-in methods for extension and customization of the transfer format to allow countries, organizations and companies to share information in a standard format that will eventually be considered for inclusion in future releases of the standard.   Examples are included in the Technical Guide to DIGGS on how to develop these extensions.

Members will be allowed to submit their extensions to DIGGS for consideration in the next version of the standards release. A fast review process for any proposed extensions or additions will be used to determine if

the extensions are new or already exist in the standard. All new extensions from active members will be added to a "proposed version" of the schema. Hence, two versions will be available on the website: the official release and the "proposed version". The proposed version will include any country based codelists (pick lists) as well as new elements (properties) and tables (objects). Using this process any proposed amendments or changes can be immediately communicated to all registered users and incorporated into file transfers while the standards process proceeds. The DIGGS web site can be found at http://www.diggsml.org.

9.4 Updating DIGGS

To meet the changing needs of its users the DIGGS Format must continue to develop. DIGGS will therefore be kept under constant review and will be periodically updated. All updates will be published via the DIGGS web site. While placing the standard in open access on the web site permits more frequent updates, all changes are subject to rigorous control and notification procedures. Extensions to the format will continue to be necessary from time to time but any modification cannot be considered to comply with the DIGGS format until it has been approved by the appropriate DIGGS committees. The DIGGS committees will attempt to maintain a balance between keeping the format up to date to meet user needs, whilst avoiding too frequent changes that would make it difficult for software suppliers to maintain compatibility with the format. Any problems in the use of this format that may arise should be brought to the attention of the relevant DIGGS committees via the discussion forum on the DIGGS website. Problems with proprietary software, however, should be directed to the suppliers.

10   Glossary of terms

Term	Explanation
XML	Extensible Mark-up Language
GML	Geographic Mark-up Language
Object	An XML entity grouping a number of properties used to describe a single physical item or process.
Property	An XML entity that contains a single item of data
Element	A common word used instead of the property
Attribute	Attributes provide additional information about properties.
Single object method	A method of transferring similar processes or items within a single object
Separate object method	A method of defining an object for each type of process or item
Paired objects	Method used to transfer data from a test that requires general information and detail information for each stage of the test.
General object	Object used to transfer general information in a paired object set
Detail object	Object used to transfer text information in a paired object set
Codelist	External list of allowable values for a property
Layer	Layers are sections of the ground, described between a given top and base depth within an exploratory hole, which are consecutive and cannot overlap for a given layer system within a given hole,
Layer system	A layer system is the criteria by which the ground profile is subdivided, described and/or classified.
Detail	Details are sections of ground, again described between a given top and base depth within an exploratory hole, which do not need to be consecutive (i.e. there can be gaps between details) and which can overlap for a given layer system within a given hole

11   References

CIRIA (2006) A Review of Electronic File Formats for the Exchange of Geotechnical Information used in Transportation Schemes. CON 125 Phase 1 Report. Author: Mott MacDonald.

Published: Construction Industry Research and Information Association.

12   Data dictionary and Example Files

As part of the DIGGS project a complete data dictionary has been produced with details for every property and object. Below is an example of the data available for the CompactionDetail object. This document, together with a set of example files can be downloaded from the diggsml.org website.

Geotechnical.CompactionDetail

Contents

Derived from Kernel.DiggsBase

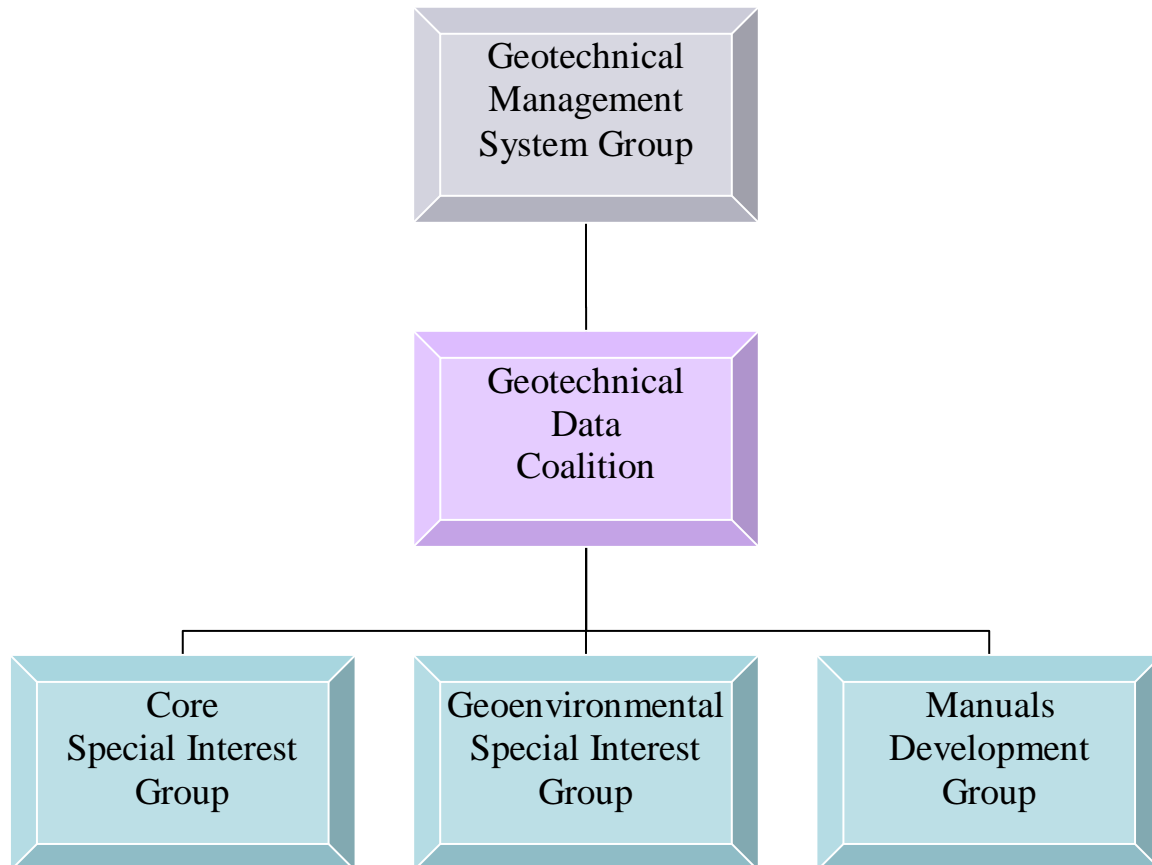| Status	Heading	Unit	Description	Example
	lang		The language that strings in this DIGGSML Object are _predominantly_ written in (this can be redifined on a per-property level). As per RFC3066 at http://www.ietf.org/rfc/rfc3066.txt	
	name			
	description			
	associatedFiles	AssociatedFile	Reference to a set of external files associated with this Object	
	remarks	Remark	Any general remarks about this Object	
	density	DensityMeasurement	Density at CMPT_MC moisture content	1.85
	moistureContent	MoistureContentMeasurement	Moisture content	7.8
	pointNumber	integer	Compaction point number	1

13   Appendix A - Acknowledgements

Acknowledgements

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Bridge Software Institute at the University of Florida
Buro Happold Ltd
California Department of Transportation
Connecticut Department of Transportation
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EarthSoft
Federal Highway Administration (FHWA) – Office of Federal Lands Highway
Federal Highway Administration (FHWA) - Ohio Division Office
Florida Department of Transportation
Georgia Department of Transportation
gINT Software Inc.
Indiana Department of Transportation
Kentucky Department of Transportation
Keynetix Ltd
Minnesota Department of Transportation
Missouri Department of Transportation
Mott MacDonald
North Carolina Department of Transportation
Ohio Department of Transportation
Petrochemical Open Standards Consortium
Stent UK
Tennessee Department of Transportation
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United States Army Corps of Engineers (USACE)
United States Environmental Protection Agency (U.S. EPA)
United States Geological Survey (USGS)

United States Navy
University of New Hampshire

DIGGS Organizational Structure

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                    │  Geotechnical   │
                    │  Management     │
                    │  System Group   │
                    └────────┬────────┘
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                    │  Geotechnical   │
                    │      Data       │
                    │    Coalition    │
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     ┌───────┴──────┐ ┌──────┴───────┐ ┌──────┴───────┐
     │     Core     │ │Geoenvironmental│ │   Manuals    │
     │Special Interest│ │Special Interest│ │ Development  │
     │    Group     │ │    Group     │ │    Group     │
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```

Geotechnical Management System Group

Kirk Beach, Ohio Department of Transportation (Project Lead)
Corey Bobba, Federal Highway Administration – Office of Federal Lands Highway
Derrick Dasenbrock, Minnesota Department of Transportation
Cyprian Fonge, Georgia Department of Transportation
Leo Fontaine, Connecticut Department of Transportation
Mike Fritz, Missouri Department of Transportation
Laurel Gorman, United States Army Corps of Engineers
Will Holmes, Kentucky Department of Transportation
David Horhota, Florida Department of Transportation
Thomas Lefchik, Federal Highway Administration – Ohio Division Office (Technical Lead)
Mohammed Mulla, North Carolina Department of Transportation
Len Oliver, Tennessee Department of Transportation
Jon Paauwe, Indiana Department of Transportation
David Patterson, United Kingdom Highways Agency
Gary Person, Minnesota Department of Transportation

Daniel Ponti, United States Geological Survey
Loren Turner, California Department of Transportation
David Wilson, United States Environmental Protection Agency
Geotechnical Data Coalition

Kirk Beach, Ohio Department of Transportation
Roger Chandler, Association of Geotechnical and Geoenvironmental Specialists
Marc Hoit, Bridge Software Institute at the University of Florida
Thomas Lefchik, Federal Highway Administration – Ohio Division Office (Leader)
Tim Spink, Construction Industry Research and Information Association
Loren Turner, Consortium of Organizations for Strong-Motion Observation Systems

Associate Members:
Jean Benoit, Consortium of Organizations for Strong-Motion Observation Systems
Kirk Hatfield, University of Florida
Mike McVay, Bridge Software Institute at the University of Florida
David Patterson, United Kingdom Highways Agency

Core Special Interest Group

Jean Benoit, University of New Hampshire
John Bobbitt, Petrochemical Open Standards Consortium
Chris Bray, Keynetix Ltd
Salvatore Caronna, gINT Software Inc.
Roger Chandler, Keynetix Ltd
Marc Hoit, Bridge Software Institute at the University of Florida (Group Leader)
Stuart Kenny, Stent UK
Mike McVay, Bridge Software Institute at the University of Florida
Daniel Ponti, United States Geological Survey
Syd Pycroft, Buro Happold
Paul Quinn, Keynetix Ltd
Tim Spink, Mott MacDonald
Mark Styler, University of Florida
Loren Turner, California Department of Transportation

Geoenvironmental Special Interest Group

Roger Chandler, Keynetix Ltd
Kirk Hatfield, University of Florida (Group Leader)
Anand Mudambi, United States Environmental Protection Agency
Joe Solsky, United States Army Corps of Engineers
Kim Stagg, Delta Environmental Consultants, Inc.
David Trevino, United States Navy
Scot Weaver, EarthSoft

Manuals Development

Salvatore Caronna, gINT Software Inc.

Roger Chandler, Keynetix Ltd

Marc Hoit, Bridge Software Institute at the University of Florida

Thomas Lefchik, Federal Highway Administration – Ohio Division Office

Mike McVay, Bridge Software Institute at the University of Florida

David Patterson, United Kingdom Highways Agency

Chris Power, Mott MacDonald

Tim Spink, Mott MacDonald (Group Leader)