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CON125 - Phase 1 Report

A Review of Electronic File Formats for the Exchange of

Geotechnical Information used in Transportation Schemes

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Summary

Good data management is increasingly being seen as of key importance to transportation infrastructure owners. In geotechnics, the large amount of data required for successful development of infrastructure projects, from conception, through investigation, design, construction and asset management has led to recognition of the importance of geotechnical data management systems (GDMS) for the efficient utilisation of both current and historical data sets. In order to make full advantage of such a system data users need to be able to import and export data from a database which functions as a storage vehicle, whilst allowing active querying, usually with a GIS interface. In order to drive a GDMS standard data transfer formats are required. Whilst in the UK there is a well developed industry standard data transfer format for ground investigation data, there are still problems with its implementation. In addition, this represents only a small part of the project supply chain.

Consequently, this project, CIRIA CON125 has been set up to review the existence and use of data transfer formats for geotechnical applications. The project aims to build a cross industry forum to lead to improvements in the quality of current practice, improvements in our knowledge in this field and improvements in the scope of future achievements. This document is the report for the Phase 1 of the CON125 project and covers reviews of current practice, international initiatives, standards and guidance, as well as making recommendations for Phase 2 of the project, which will achieve the aims described above.

A review of existing data transfer formats relevant to geotechnics in transportation schemes was carried out. Although many data transfer formats were found to exist, not all were in active use or supported by software applications. There is a trend to the development of open source XML data transfer formats, but as yet these are not widely supported by software developers, who prefer to use proprietary binary or ASCII file types. The most widely used data transfer formats relate to general data types such as mapping and GIS information, images and databases. Most of the specialist geo-data transfer formats relate to ground investigation information, with little development of data transfer formats in other parts of the supply chain.

Despite data transfer formats being essential to a successful GDMS application, there is little guidance on the transfer formats themselves. This demonstrates that although data transfer formats are important, there are other elements that are also key for GDMS implementation. These include a relevant policy framework with leadership support, training and education of Clients and Users, software development and adoption and far sighted financial investment.

Storage and transfer of data, particularly by government bodies may also be subject to certain statutory requirements or government policy. Whilst the legal framework for data is driven by public access to public and personal information, data managers need to be aware of initiatives that may effect access to, or transfer of, their data. Currently there are no requirements specifically aimed at geotechnical data management, although some aspects of this information, if owned by government bodies and also classified as environmental information, may be subject to public access requirements. In the future however, there are likely to be drivers for greater European integration of spatial data and possible harmonisation of its storage and transfer. This would require pan-European data transfer formats.

The review of data transfer formats, standards and guidance demonstrated the significant gaps in data transfer formats for the majority of the supply chain. Whilst in the field of ground investigation concerns were expressed that the existing industry standard data transfer format was not always used correctly or even implemented at all. Consequently recommendations are made with respect to both improving current practices and working towards filling the gaps in the data transfer formats for other parts of the supply chain. These Phase 2 recommendations include:-

- Development of industry best practice guidelines including documents targeted at Clients or Sponsors of transportation projects, as well as at Users of geotechnical data.
- Inclusion of data transfer format requirements in published specifications for ground investigations.
- Training of future data managers at university level through increased university links and use of teaching packs.
- Education of Clients or Sponsors in good data management through a CIRIA led forum.
- Training of data users in current best practice as well as providing information on changes to practice that will occur in the future.
- General support for the development of "Data Interchange for Geotechnical and Geoenvironmental Specialists" (DIGGS), including its development and promotion.
- Specific technical support for the development of a geo-asset data transfer format. This will involve bringing together industrial partners to support and lead initiatives in this area.
- Specific support for current initiatives for the development of construction data transfer formats, starting with piling and moving into other areas.
- Commission a broad review of data transfer formats applicable to conceptual and feasibility study data. This will have an emphasis on spatial data and should therefore aim to build links across other disciplines.

A revised steering group with small working groups will be required to take these recommendations forward. This steering group should work with CIRIA and the existing PIMA project and utilise this opportunity for building a broader forum on data management.

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1 Introduction

1.1 Brief Description of the Project

Large quantities of geotechnical data are generated by transportation schemes, from desk study, ground investigation, main works design and construction, through to maintenance and renewals works. With technological advances this data is increasingly transferred electronically. Data may be transferred following ground investigations, during tendering processes, throughout detailed design and at subsequent project handovers, including to maintainers (see Figure 1 Simplified Geotechnical Supply Chain). Although various data transfer formats exist, many of these relate to proprietary software and there are fewer open source standards for exchanging data.

Consequently this project aims to provide guidance on best practice for the transfer of geotechnical data in the broadest sense. Ultimately this may include published principles of best practice on:

- The data file formats available for the exchange of geotechnical data.
- The recommended electronic data transfer format for different types of information exchange.
- The recommended issue media (including labelling and document control).
- Associated metadata.

This Phase 1 report presents a review of existing electronic geotechnical data transfer formats used throughout the lifecycle of infrastructure projects. This encompasses both the data transfer formats themselves, the data and data management needs of users, the current software and its compatibility, any statutory requirements and the associated training needs.

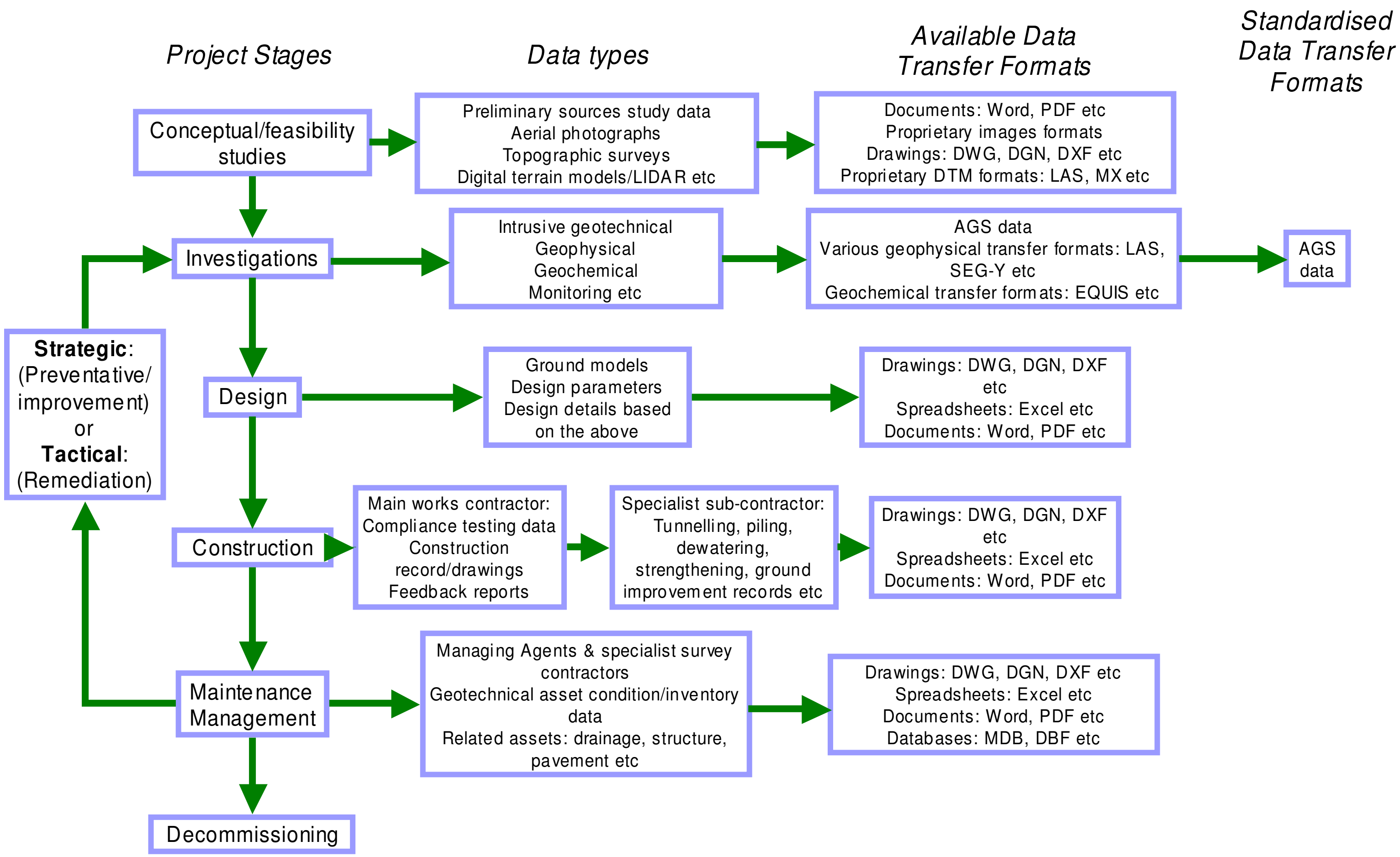
In Phase 2 of the project it is intended to implement the recommendations of Phase 1 in order to develop and publish guidance on best practice for the transfer of geotechnical information in transportation schemes. Recommendations for Phase 2 are given in Section 7 of this report.

1.2 Terms of Reference

The Project Working Group (PWG), see Appendix A , are contracted by CIRIA in accordance with the CON125 Research Project Specification (included in Appendix B). The PWG are required to report on the review of existing electronic data transfer formats leading to recommendations for Phase 2 of the project. This includes scope, programme and methodology for the production of a best practice guide for publication.

Reporting for the project will be initially via this Phase 1 Report, issued in Adobe Acrobat pdf format to all members of the Project Steering Group (PSG), see Appendix A , and also by presentation to the PSG. Subsequent reporting for Phase 2 will be in accordance with the recommendations of this document (see Section 7) and in a manner for it to be transferred to CIRIA for publication.

Figure 1 Simplified Geotechnical Supply Chain



Concept of simplified supply chain shown for clarity. In reality, many more complex arrangement exist, which only serves to reinforce the importance of standardised data transfer.

1.3 Aims and Objectives

The overarching aim of the project is to create a forum for establishment of the current state of knowledge in geotechnical data transfer formats as well as promoting the furtherance of best practice in this area. In doing so this will allow:

- Identification of broad needs relating to data transfer across the geotechnical community in transportation.
- Provision of support to national and international initiatives for development of geotechnical data transfer formats.
- Promotion of best practice in geotechnical data transfer.

In achieving its aims the project will:

- Improve the quality of current practice.
- Improve knowledge of current best practice.
- Improve the scope of what can be achieved in the future.

1.4 Scope

The scope of the project is limited to data transfer formats and their associated metadata. The content of these data files and detailed data dictionaries are not considered.

1.5 Basic Definitions

The data transfer process, from one user with particular software, formatting and application requirements to another user with different requirements is shown in Figure 2. This includes a number of terms regarding the data transfer and the format in which it occurs. The terms are defined for the context of this report in the text which follows.

Data – the information that is being transferred, stored in a formal manner to allow efficient processing or use by software.

Data transfer format – used to indicate a standard means of transferring data that includes specification for data, schema and reference data.

Format type – used in reference to the nature of the content being transferred (eg geotechnical format type, geological format type).

Format file type – in this report this term is used to distinguish the file type. There are three main file types, binary, ASCII and XML. This distinction has been made based on the trends in available data transfer formats as discussed further in Section 2.3.

File format extension – several letters at the end of a file name used to indicate the type of information stored in the file, eg '.ags', .'pdf'.

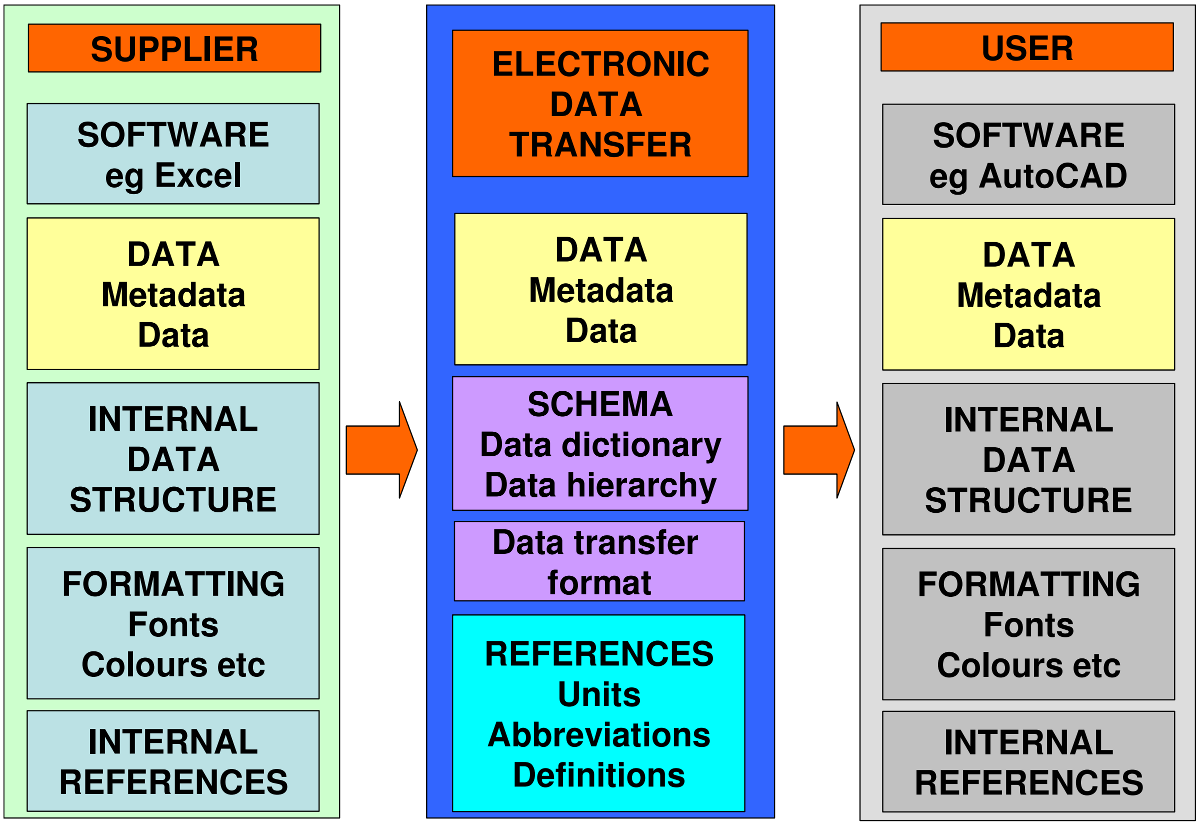


Figure 2: Data Transfer Summary

Meta data – the summary information or characteristics of a set of data or 'data about data'. This normally includes information on what the data is about, who created it, where it was created and when it was created.

Data schema – collective term to encompass the data dictionary, the data hierarchy and the data transfer format that define the standard structure of the data being transferred.

Data dictionary – the standard terms used to identify or 'tag' the data being transferred. This will likely result in the data being structured into a number of groups or tables according to its content. Each group or table will contain fields for individual data items.

Data hierarchy – the relationship between the groups or tables and their fields of data as arranged by the data dictionary. For example the name or location reference of a data collection point will be at a higher level to all the data collected at that point.

Reference data – Information pertaining to any standard abbreviations or units used in the data and also definitions relevant to the data.

Open Source – Data transfer formats referred to as open source are those developed by independent organisations and are hence not related to specific software applications. They are free to use.

Proprietary – Data transfer formats referred to as proprietary are those owned and controlled by software developers. The format specifications may or may not be publicly available.

Geotechnical Data Management System – GDMS is a commonly used term to encompass a system for efficient management of geotechnical data usually through electronic means, including both electronic storage and electronic transfer. A common arrangement of a GDMS involves some form of database for storage of geotechnical data with a web based GIS portal to allow interrogation of the database, uploading data and extracting data. Use of GDMS is considered further in Section 3.

1.6 Glossary of Terms

AGI	Association for Geographic Information
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Exchange
AGS	Association of Geotechnical and Geoenvironmental Specialists
CON125	CIRIA Contract 125
COSMOS	Consortium of Strong Motion Observation Systems
DIGGS	Data Interchange for Geotechnical and Geoenvironmental Specialists
DLIS	Digital Log Interchange Standard
DOT	(USA State) Department of Transport
DTD	Document type definition
eEarth	Electronic Access to the Earth through Boreholes
e-GMS	e-Government Metadata Standard
EIR	Environmental Information Regulations
FHWA	(USA) Federal Highways Administration
FoI	Freedom of Information Act
FPS	Federation of Piling Specialists
GADML	Geotechnical Asset Data Mark-up Language
GDMS	Geotechnical Data Management System
GEF	Geotechnical Exchange Format
geo/engineering	Used in this report to mean geotechnical/geological/geophysical/geoenvironmental
GEMINI	Geo-spatial metadata interoperability initiative
GENIE	Geographic Information Network in Europe
GGSD	Geotechnical and Geoenvironmental Software Directory
GI	Geographical Infromation
GIS	Geographical Information System
GML	Geography Markup Langauge
NGDF	National Geospatial Data Framework
IGGI	Intra-Governmental Group on Geographic Information
INSPIRE	Infrastructure for Spatial Information in Europe
LAS	Log ASCII Standard
LIDAR	Light Detecting and Ranging
LIS	Log Information Standard
PEER-LL	Pacific Earthquake Engineering Research Lifelines
POSC	Petrochemical Open Standards Consortium
PSG	Project Steering Group
PSI	(re-use of) Public Sector Information
PWG	Project Working Group
SDSFIE	Spatial data standard for facilities, infrastructure and environment
SDTS	Spatial Data Transfer Standard
SGML	Standard general markup language
SISG	Site Investigation Steering Group
USACE	United States Army Corp of Engineers
USGS	United States Geological Survey
XML	Extensible Markup language
XMML	Exploration and Mining Mark-up Language

2 Existing Electronic Geotechnical Data Transfer Formats and Supporting Software

The review of existing electronic geotechnical data transfer formats and the identification of software that supports these formats forms a key component of the Phase 1 study and will provide answers to the questions:

- What geotechnical data transfer formats are available?
- Which of these data transfer formats are supported and maintained by a sponsoring organisation?
- Which of these data transfer formats are supported by existing geotechnical software?
- And hence, which data transfer formats are in use and actively supported?
- And also which data transfer formats are in development and have the potential to be useful in the future?

Hence, this section presents a review of the existing data transfer formats and provides an overview of the key current open source data transfer formats in active use or development. This then allows identification of gaps in the available data transfer formats to be identified in Section 5, leading to recommendations in Section 7.

2.1 Methodology

2.1.1 Data Transfer Formats Review

A detailed review of existing data transfer formats has been conducted. This has been made from public domain information utilising the following sources:

- Information provided by PWG or PSG members.
- Information provided by known practitioners in the field of geotechnical data interchange.
- Information from the internet, particularly the Geotechnical & Geoenvironmental Software Directory (GGSD) published at www.ggsd.com.

Information relating to these existing data transfer formats has been collected together in a database, the output of which is included in Appendix C . The format type, reflecting the nature of their contents (eg geotechnical, geophysical), details of their supporting organisation and specifications have been collated and the trends identifiable are discussed further in Section 2.2 below.

Many existing data transfer formats are related to proprietary software products and as such are unlikely to form the basis of future broader interchange standards. Whilst proprietary data transfer formats have been included in the database for completeness, the information collection exercise has attempted to focus on file formats supported by independent best practice or collaborative organisations that are not related to specific software products.

2.1.2 Supporting Software

The GGSD has been used to compile information on which software programs support which data transfer formats. The GGSD currently catalogues 1644 programs in the fields of Geotechnical Engineering, Soil Mechanics, Rock Mechanics, Engineering Geology, Foundation Engineering, Hydrogeology, Geoenvironmental Engineering, Environmental Engineering, Data Analysis and Data Visualisation. It only lists programs that are readily available including commercial software, shareware, freeware and public domain software; it does not list research software, proprietary or bespoke software that is not generally available.

The listed program descriptions have been searched for reference to the identified 113 data transfer formats. The 806 worldwide suppliers and publishers of these programs currently listed in the GGSD have been emailed to confirm whether this information is up to date.

The resultant cross referenced database of which programs support which data transfer formats has been published on the GGSD at www.ggsd.com, and the proprietor has undertaken to maintain this information after the completion of the CON125 project.

2.2 Data Transfer Format Types and Applications

The data transfer format review has compiled information on 113 data transfer formats, full details of which are contained in Appendix C . The study has focussed on identifying geo/engineering (see bullet points below) data transfer formats, and in this area the listing of 71 data transfer formats given in Appendix C is believed to be fairly comprehensive, but not exhaustive. The remainder of the list are 42 general data transfer formats and this is known to be far from comprehensive as it has been compiled from those general data transfer formats supported by the reviewed geo/engineering software programs.

On this basis, the identified data transfer formats can be split into a number of distinct format types according to the types of data which they transfer:-

- Geo/engineering transfer format types:
  - Asset data transfer formats.
  - Geoenvironmental data transfer formats.
  - Geological data transfer formats.
  - Geophysical data transfer formats.
  - Geotechnical data transfer formats.
  - Petroleum geoscience related transfer formats.
- General data transfer formats:
  - Database and spreadsheet transfer formats.
  - Document transfer formats.
  - Image data transfer formats.
  - Mapping and GIS transfer formats.

The grouping of the 113 data transfer formats by the above format types is summarised in Figure 3 and shows the dominance of mapping/GIS, geotechnical, geological or geophysical format types. Of the geophysical formats, most have arisen from the Oil Industry, rather than the Geotechnical Industry. Figure 4 illustrates the distribution of format types as classified by the number of supporting software applications that can import or export data in each of the data transfer formats. Figure 4 demonstrates that even for the specialist geo/engineering software investigated, the general data transfer formats are more widely supported than the specialist geo/engineering formats.

Of the data transfer formats developed specifically for the geo/engineering community, most relate to ground investigation data. As shown in Figure 5, few data transfer formats have been identified for other parts of the geotechnical supply chain.

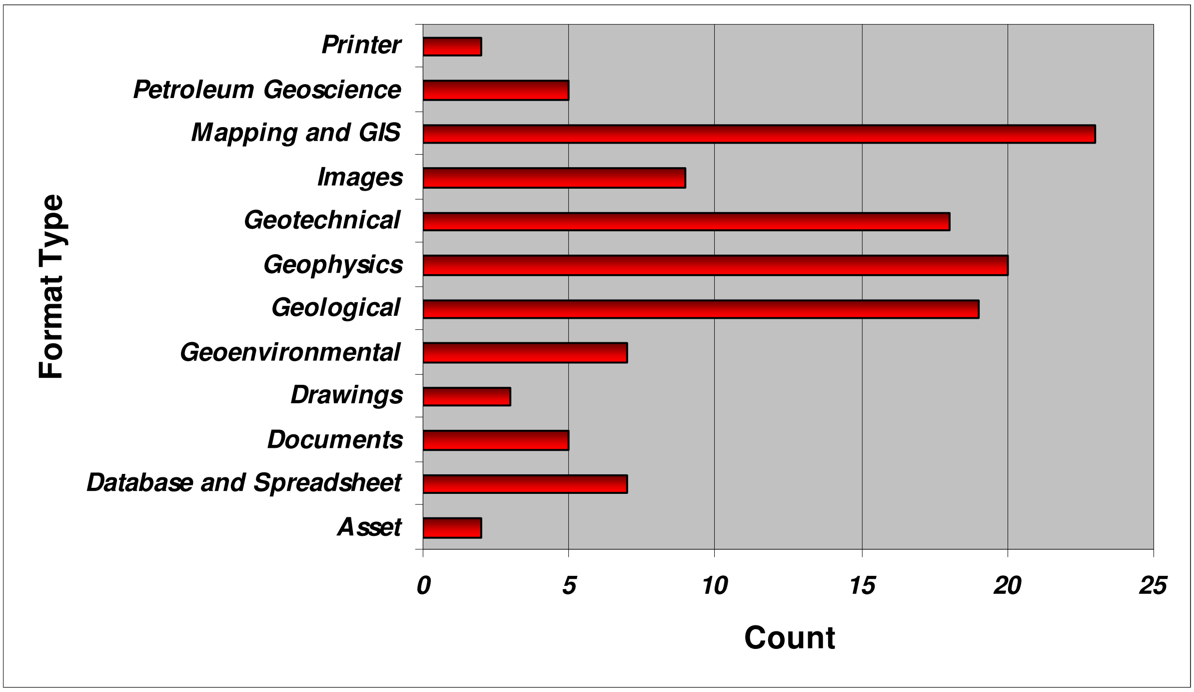


Figure 3 Distribution of Data Transfer Format Types

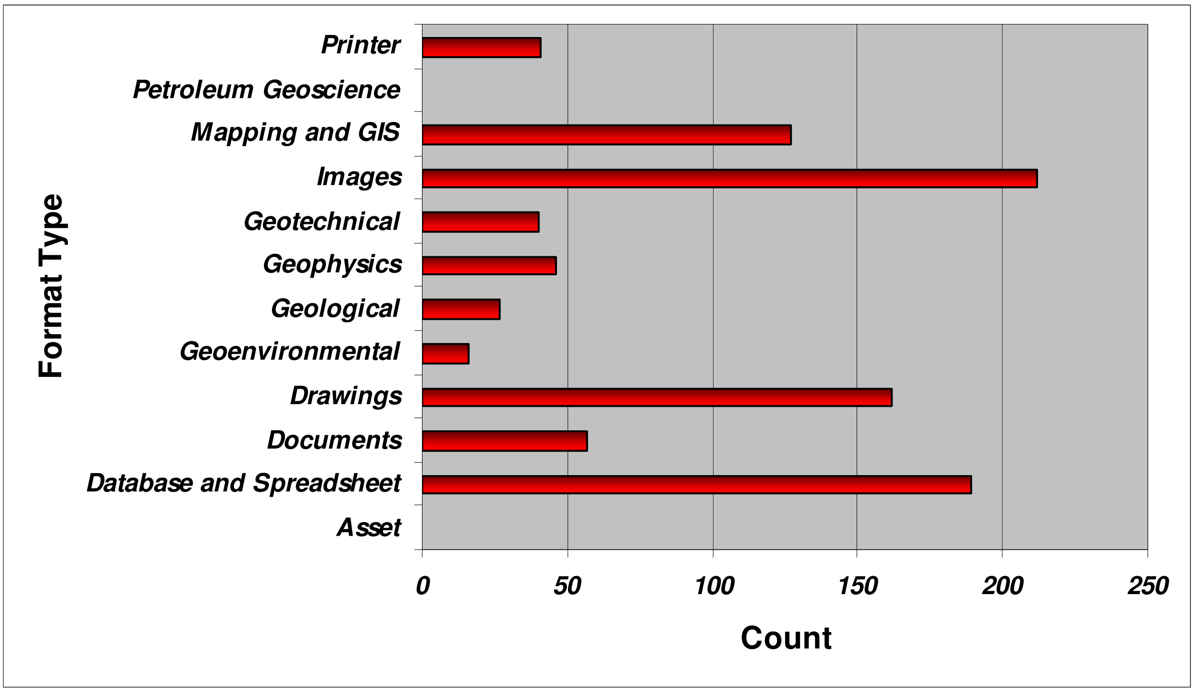


Figure 4 Distribution of Data Transfer Format Types by Supporting Software

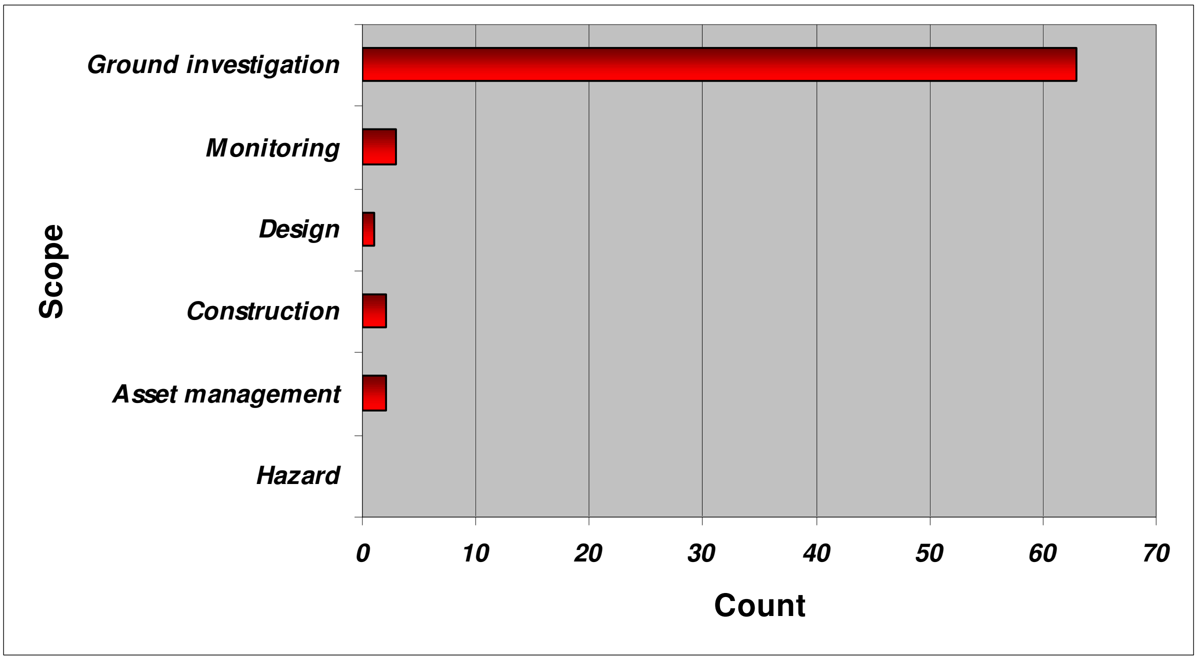


Figure 5 Scope of Geo/engineering Specific Data Transfer Formats

More data transfer formats were found to have been developed as open source formats than as proprietary (see Figure 6). However, this was not reflected in the supporting software (see Figure 7) with three times as many software packages supporting various proprietary rather than open source data transfer formats.

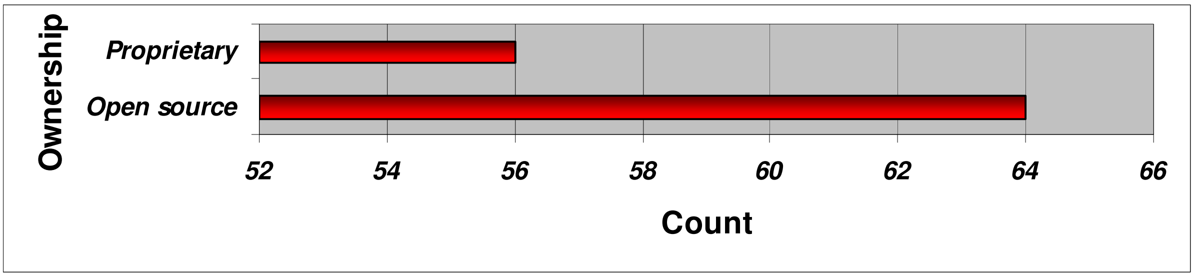


Figure 6 Data Transfer Format Ownership

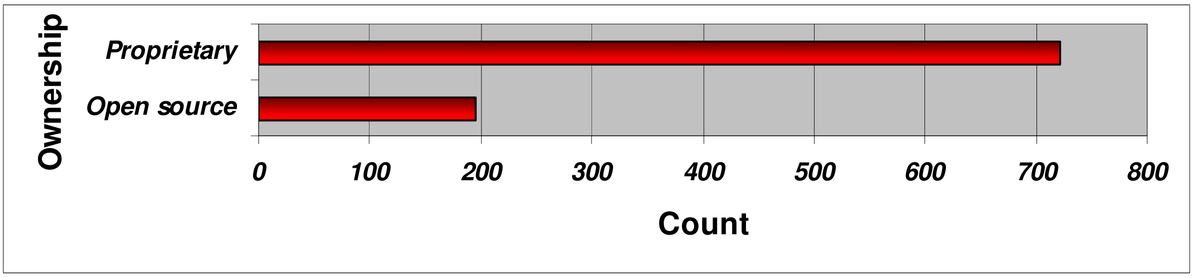


Figure 7 Data Transfer Format Ownership by Supporting Software

Data transfer formats have also been classified by their assessed status, with the distinction being made between 'active' data transfer formats, being actively supported by their originating organisations, and ‘in use’ data transfer formats, which although widely used are no longer receiving active organisational support. Data transfer formats categorised as 'development' are not yet in use beyond their research environment. 'Inactive' data transfer formats do not appear to be supported or in general use. 'Obsolete' data transfer formats have been superseded and are no longer supported by their originating organisation, although they may still be in use.

Figure 8 demonstrates that most data transfer formats are categorised as ‘in use’ but with a significant number of 'active' and 'development' formats. When considering supporting software, unsurprisingly, most data transfer formats are either 'active' or 'in use' (Figure 9).

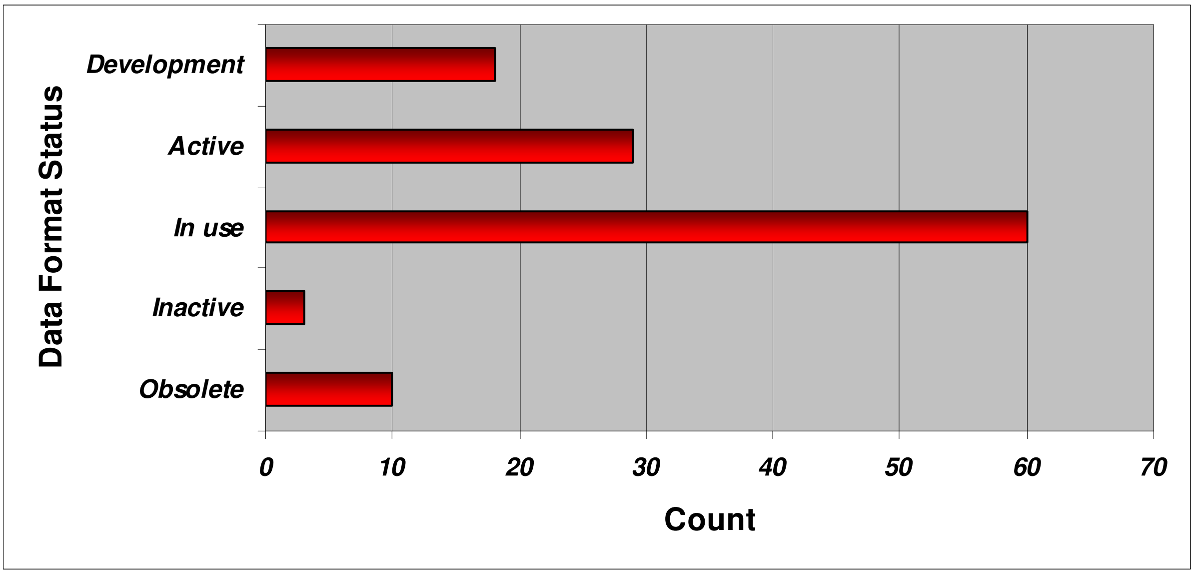


Figure 8 Data Transfer Format Status

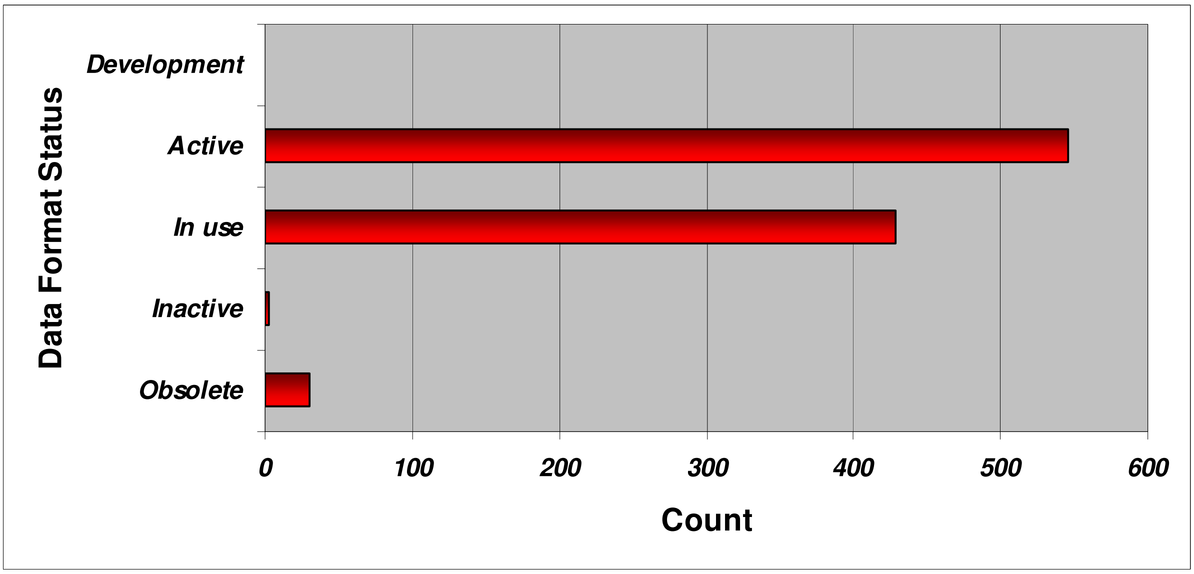


Figure 9 Data Transfer Format Status by Supporting Software

2.3 Format File Type

Three main types of format file type were identified for the transfer of geo/engineering data: ASCII, XML and binary. The distribution of these format file types is shown in Figure 10.

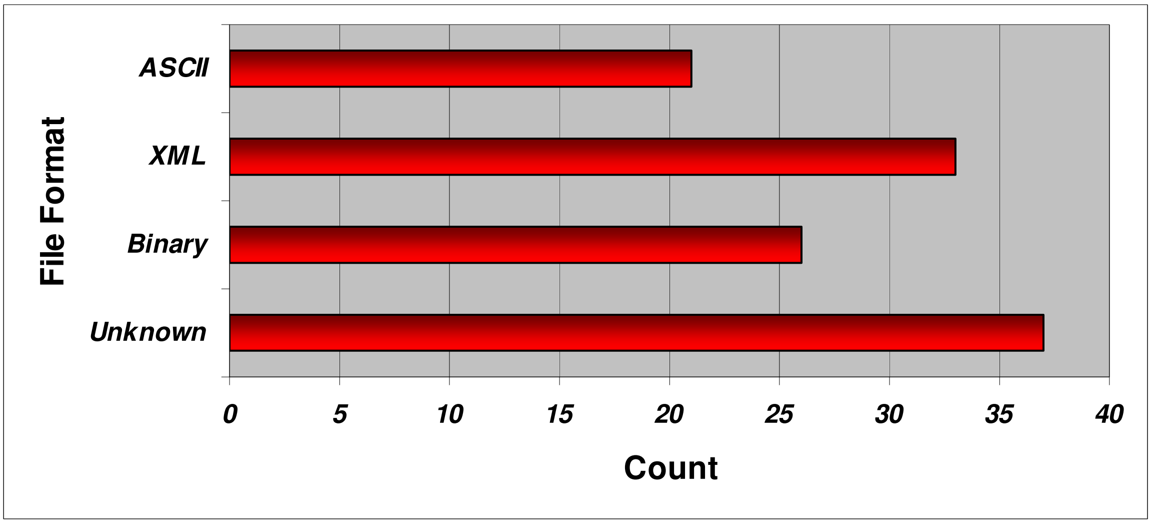


Figure 10 Format File Types

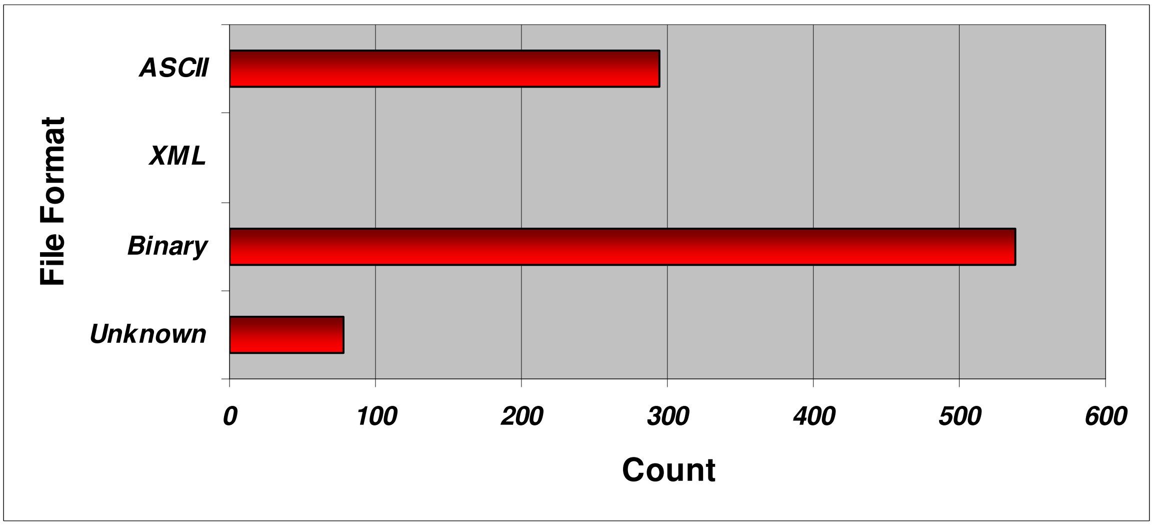


Figure 11 Format File Types by Supporting Software

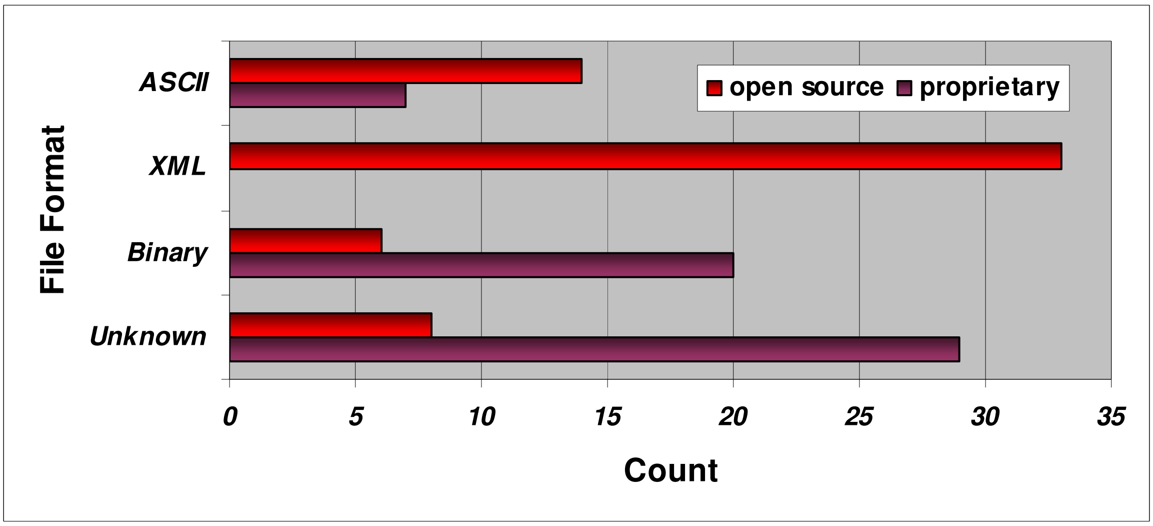


Figure 12 Format File Types by Ownership

ASCII (American Standard Code for Information Exchange) or plain text files are commonly used by open source developers (Figure 12) as well as being well supported by current software (Figure 11). An example of geotechnical data transfer using an ASCII format is given in Figure 13.

Increasingly, however, Extensible Markup Language (XML)[1] is being used by open source developers (Figure 12). XML was introduced for exchange of information over the internet in 1997 and is highly flexible within the rules of the language. Data is contained in text files within 'tags' that are developed for specific types of information transfer. Therefore standards for specific XML applications are required in order to define the Data, Schema and References in a standard manner. An example of geotechnical data transfer using an XML format is given in Figure 14. However, as Figure 11 demonstrates, there are few software applications ready to use the new generation of XML based data transfer formats. This may be due to a combination of:

- the time lag between the release of a new standard and its adoption by the software industry
- a number of the XML data transfer formats identified appear to be academic research exercises that have not been promoted outside of their limited arena and are unlikely to be adopted by commercial software vendors

Binary format files use non-ASCII formatting characters and are preferred by proprietary software developers (see Figure 11 and Figure 12) as the file sizes are smaller for a given data load, and if the developer chooses not to publish the format, it can be difficult for competitors to fully and accurately duplicate its functionality.

[1] http://www.w3.org/XML/

```
"**PROJ"                                              << Project TABLE
"*PROJ_ID","*PROJ_NAME"                               << HEADER
"6554","Croydon Arena"                                << DATA

"**HOLE"                                              << Hole TABLE
"*HOLE_ID","*HOLE_TYPE"                               << HEADER
"501","TP"                                            << DATA

"**GEOL"                                              << Geology TABLE
"*HOLE_ID","*GEOL_TOP","*GEOL_BASE","*GEOL_GEOL"      << HEADER
"501","0.0","0.5","Topsoil"                           << DATA
"501","0.5","3.4","Weathered London Clay"             << DATA
```

Figure 13 AGS data transfer using the ASCII format file type

```
<PROJ>                                                << Project TABLE
  <PROJ_ID>6554</PROJ_ID>                             << TAG + DATA
  <PROJ_NAME>Croydon Arena</PROJ_NAME>                << TAG + DATA

    <HOLE>                                            << Hole TABLE
      <HOLE_ID>501</HOLE_ID>
      <HOLE_TYPE>TP</HOLE_TYPE>

         <GEOL>                                       << Geology TABLE
           <GEOL_TOP>0.0</GEOL_TOP>
           <GEOL_BASE>0.5</GEOL_BASE>
           <GEOL_GEOL>Topsoil</GEOL_GEOL>
           <GEOL_TOP>0.5</GEOL_TOP>
           <GEOL_BASE>3.4</GEOL_BASE>
           <GEOL_GEOL>Weathered London Clay</GEOL_GEOL>
         </GEOL>
    </HOLE>
</PROJ>
```

Figure 14 AGS data transfer using the XML format file type

2.4 Use of Data Transfer Formats in Supporting Software

The Top 20 supported data transfer formats identified from this review are given in Figure 15. This shows the greatest number of software products supporting general data transfer formats for drawings, images and database information. Only two geo/engineering data transfer formats appear in the Top 20 formats given in Figure 15. These are the AGS data transfer format for factual geotechnical and geoenvironmental data and LAS, for geophysical well logging data.

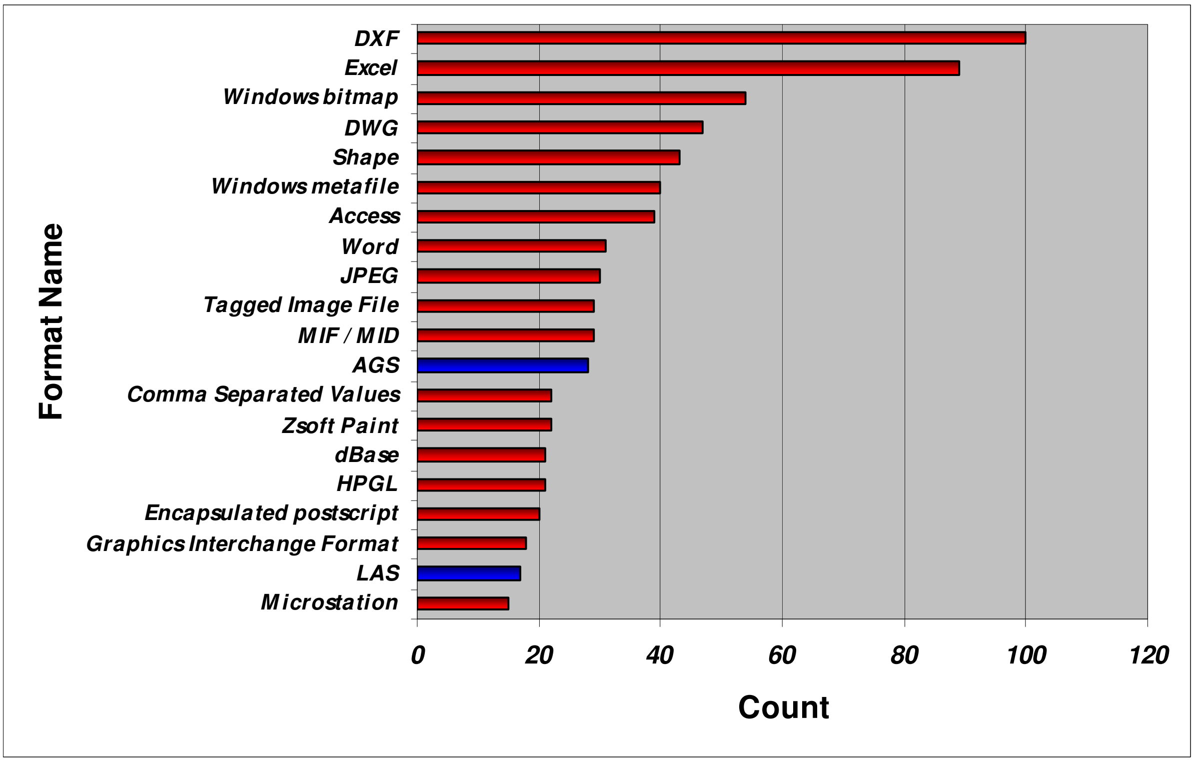


Figure 15 Top 20 Supported Transfer Formats

2.5 Significant Open Source Data Transfer Formats

The following section provides a brief overview of the key open source data transfer formats identified in this study. These were selected according to relevance to geotechnics in transportation by a number of criteria including the format type and application and its common usage or active support.

2.5.1 Geotechnical Data Transfer Formats

The vast majority of the available geo/engineering data transfer formats relate to ground investigation information. Whilst some data transfer formats pertain to borehole data only (see also Section 2.5.2 below), more comprehensive data transfer formats, such as the UK AGS format, include the full spectrum of ground investigation data. Specific data transfer formats for the transfer of CPT data are also available, commonly having their origin in The Netherlands.

(i) AGS

The AGS data transfer format (currently version 3.1) is the most widely used and supported geotechnical data transfer format, being the industry standard for the transfer of ground investigation information including field and laboratory data in the UK, Hong Kong and other former British territories. It now includes monitoring data via the incorporation of the AGS-M format. The format file type is currently ASCII, but an XML based version is under development (AGSML), which is being incorporated into DIGGS (see (vii) below).

(ii) COSMOS

The Consortium of Organizations for Strong Motion Observation Systems (COSMOS) and the Pacific Earthquake Engineering Research Centre (PEER) Lifelines Program are developing a Virtual Data Centre (VDC) for sharing of seismic geo-engineering data in California. As part of the process of developing the data centre a Geotechnical Data XML Schema has been developed. The schema uses a data dictionary based on that developed for the National Geotechnical Experimentation Sites (NGES) program by Benoit et al[2], which itself draws heavily on the UK AGS data transfer format. Whilst the AGS data transfer format was developed largely for use by geotechnical practitioners, the NGES and hence the COSMOS formats reflect more the needs of the research community. The COSMOS data transfer format is currently only used by the VDC project, but is being incorporated within DIGGS (see (vii) below).

(iii) GEF

GEF is a geotechnical data transfer format for CPT data developed by CUR (Civieltechnisch Centrum Uitvoering Research en Regelgeving) in the Netherlands. The format file type is ASCII and is based on the best features of the data transfer formats developed by GeoDelft (Standard File Format) and A P van den Berg (Gorilla!). It is the accepted standard for the transfer of CPT data in the Netherlands. CUR have also recently extended the GEF format to include for standard borehole data.

CUR is in discussion with the AGS with a view to enhancing the CPT aspects of the AGS data transfer format, such that the modified format can be adopted in the Netherlands. This development is also likely to feed into DIGGS in due course (see (vii)).

(iv) GeotechML

GeotechML originated from the World Wide Web of Geotechnical Engineers[3] in 1988 and aspired to be an all embracing geotechnical version of XML extending beyond ground investigation information to include foundations and other geotechnical structures. Although a number of application examples have been produced, most notably by Durham University, the project has not been widely adopted. The data transfer format is not supported by any available software.

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[2] Benoit J, Sawyer S M, Adams M and de Alba P A (1994), National Geotechnical Experimentation Sites : Central Data Repository – User Manual" US Department of Transportation, Federal Highways Administration, Publication No. FHWA-RD-94-071.

[3] http://www.ejge.com/GML/

(v) SlopesML

SlopesML is a slope stability markup language aimed at transferring information pertaining to slope stability case histories. It has been developed in Istanbul Technical University and is compatible with GeotechML. As with GeotechML the data transfer format is not in active use, but has been included here because it is the only format specifically applied to the transfer of geotechnical models and case histories. It is not supported by any available software.

(vi) CivilXML

CivilXML is an XML data transfer format developed in Florida to transfer data in and out of an internet based piled foundations database for the state. It has been developed by Florida University for the state DOT. CivilXML is a component of DIGGS (see below).

(vii) DIGGS

The Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) is a joint UK/USA initiative to develop an international standard for a geotechnical data transfer format. It will be a GML compliant (see Section 2.5.3 (i)) XML format file type. The initial version is due to be published in 2006 and will cover geotechnical and geoenvironmental ground investigation data (based on the AGS data transfer format), piling construction and testing data (based on CivilXML) and geophysical data (based on COSMOS). It is envisaged that subsequent versions will broaden the coverage to include, for example, geohazards, and geotechnical assets.

The project is currently supported by the following organisations:

- In the UK:
  - AGS.
  - CIRIA (through this CON 125 project).
  - Highways Agency.
- In the USA:
  - Federal Highways Administration.
  - University of Florida.
  - COSMOS.
  - FHWA Federal Lands.
  - 12 No state Departments of Transportation.
  - US Army Corps of Engineers.
  - US Environmental Protection Agency.
  - US Geological Survey.

The following bodies have verbally indicated that they will consider adopting DIGGS:

- TransXML (see Section 2.5.6 (ii)).

- The Joint Technical Committee 2 (JTC2) of the International Association of Engineering Geology (IAEG), the International Society of Rock Mechanics (ISRM) and the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE), which has been established to promote an international geotechnical data interchange format.

(viii) Proposed International Standards

There are currently two draft international standards (see also Section 4.5.2) for the Exchange of data of Identification and Description of Soil and of Rock. These documents present an xml schema for exchange of geotechnical data based on the European standards for identification and description of soil and rock.

The two proposed schemas are more detailed than currently in generally use with respect to description information, however, they contain alternative hierarchy arrangements with respect to identification information such as soil strength and plasticity. As such the likely implementation of the standards is not yet known.

2.5.2 Geological Data Transfer Formats

The following European data transfer formats are actively in use or development for the transfer of borehole data.

(i) SEP

This data transfer format is used by the German national geological survey, having been developed by the NLFB, the Geological Survey of Lower Saxony. It was originally developed to store geological information about Lower Saxony, but later extended across the whole of Germany. The data transfer format covers borehole and sample data and is hence far less extensive in range that the UK AGS data transfer format. Its use is limited to Germany.

(ii) SBB

SBB is a shallow borehole data transfer format used for the sale of data by The Netherlands National Geological Survey (The Netherlands Institute of Applied Geoscience TNO). The data is available via the TNO website in either MS excel, ASCII or XML format file types. Its use is limited to the Netherlands.

(iii) eEarth

The eEARTH project (electronic access to the earth through boreholes) aims to increase availability, use and distribution of European digital sub-surface data. To this end a number of European geological surveys and similar organisations are working together to develop an XML data transfer format for storing and exchanging borehole data. This project draws on the experiences of the AGS, SEP and SBB data transfer formats as well as the extensive work carried out by POSC (Petrochemical Open Standards Consortium – see Section 2.5.4). The proposed data transfer format can be used to distribute borehole metadata, or full borehole logs. Proof of concept applications are under development to distribute borehole data over the internet, including to handheld devices.

The UK representative is the British Geological Survey (BGS), who have indicated that it is not clear how this project will be taken forward after the current funding comes to an end in 2006. No publicly available software programs have been identified that support this data transfer format.

(iv) epiSEM

The EpiSEM Action Project is a European research project that intents to develop a Software Framework that can be used to build systems that support the collaborative development and use of geological computer models. It follows from the development of the EpiSEM IS (Epicentre Shared Earth Modelling Information Services) specification by POSC, as an open platform for earth modelling applications allowing consistent earth model metadata management. The EpiSEM Action Project aims to move this work forward and to *"place it in a much broader context, providing services supporting inter-application communication, and coordination between activities of teams of geographically distributed modelling specialists"*.

It is not clear what the concrete results of this project will be, or whether it will have any application outside of the oil industry. No publicly available software programs have been identified that support this data transfer format.

(v) RESCUE

RESCUE (Reservoir Characterization Using Epicentre) is anther POSC initiative for the transfer of data from oil industry geological models. It is based on a binary format file type with accompanying software for reading and writing files. It is expected that much of the work being carried out in the development of RESCUE will feed in to the epiSEM project for shared earth models. No publicly available software programs have been identified that support this data transfer format.

(vi) XMML

The eXploration and Mining Markup Language (XMML) has originated out of the mining industry in Australia. It is GML compatible XML format file type for geoscience and exploration information. It is supported by CSIRO, the Commonwealth Scientific and Industrial Research Organisation, and is intended to support exchange of exploration information in a wide variety of contexts. This includes exchange between software packages as well as between users and organisations.

XMML covers:

- Borehole logs.
- Geochemistry result (assay data and statutory reporting data).
- Geological timescale.
- Geometry features based on points, curves, surfaces and solids for describing 2D geological maps and 3D geological models.
- Geological boundaries of various types.
- Mineral occurrence.
- Gravity measurements.

It is understood that there are publicly available software programs that support this data transfer format, although none have been identified to date.

2.5.3 Data Transfer Formats for Mapping and GIS data

The wider applicability of Geographical Information Systems (GIS) results in numerous existing data transfer formats for spatial data, many of which are proprietary data transfer formats for which the listing in Appendix C is not comprehensive. The UK, EU and USA all have open standards for spatial data at the broadest level, several of which are discussed in more detail in Section 4. This section considers only the main open GIS data transfer formats.

(i) GML

Geography Markup Language (GML) is an XML-based language for describing geographic objects. It was developed by the Open Geospatial Consortium[4], and defines both the geometry and properties of objects that comprise geographic information. GML comprises 28 core schemas, which are extensive and complex. Simpler application schemas, such as LandGML (see (ii)), may be developed from the core schemas, using just those elements that are required.

GML is currently at the draft stage for development as an international standard (see Section 4.5.5). GML is becoming widely adopted by the most recent, or forthcoming, versions of the major CAD and GIS software programs.

(ii) LandXML and LandGML

LandXML is an XML data transfer format for land development professionals, including surveyors, civil engineers and land developers. It is an open source data transfer format that describes industry-specific data such as points, parcels, and alignments. LandXML is widely supported by the most recent, or forthcoming, versions of the major CAD and surveying programs.

LandGML is a project to develop a GML compliant version of LandXML, ie a GML application schema. This initiative has been a partial success with further development required to both LandXML and LandGML to take the projects forward.

2.5.4 Data Transfer Formats for Geophysics

Most significant data transfer formats for geophysics arise from the petroleum industry, in particular oilfield exploration and production. The Petrochemical Open Standards Consortium (POSC)[5] takes a lead role in this respect, being an international not for profit organisation for the development of XML standards. Relevant data transfer formats are summarised in the text below.

[4] http://www.opengeospatial.org/
[5] http://www.posc.org/

(i) LAS

The Log ASCII Standard (LAS) was developed by the Canadian Well Logging Society to transfer geophysical wireline survey data. LAS became accepted as an industry standard and continues to be actively used.

(ii) LIS, DLIS and RP66

The Log Information Standard (LIS) was a binary data transfer format developed by Schlumberger that was an industry standard data transfer format for wireline logging until superseded by DLIS. DLIS, the Digital Log Interchange Standard went on to be adopted under Recommended Practice 66 by the American Petroleum Institute, leading to the RP66 standard. RP66 has subsequently come under the umbrella of POSC who are developing an XML version.

(iii) SEG

The Society of Exploration Geophysicists (SEG) have developed a number of data transfer formats for geophysical data. In particular SEG-Y provides an extensively used format for interchange of seismic field data sets based on a binary format file type.

(iv) POSC XML Data Transfer Formats

There are a number of active POSC initiatives to develop and promote XML data transfer formats for geophysical and other petroleum industry data. A full schedule of these is included in Appendix C with a number of key initiatives mentioned below.

WellLogML is a data transfer format for the interchange of well log data that would supersede the LAS and the DLIS/RP66 formats. LogGraphicsML is a data transfer format for the interchange of log graphics and a sister format to WellLogML. WITSML is for the transfer of information about the well site itself.

Other data transfer formats are under development relating to the transfer of graphic data, fluid systems, well header information, geophysical processing information and production reporting information.

2.5.5 Data Transfer Formats for Environmental Information

(i) The Australian National Groundwater Data Transfer Standard

The objective of this project has been to design a set of consistent data standards and conventions to facilitate the transfer of groundwater data across Australia. Work has concentrated on developing data structures to accommodate the types of groundwater data that are commonly collected in the field, such as water levels, pumping rates, geological and geophysical logging, water chemistry and construction details. However, despite a carefully worked out accessible standard, this data transfer format has not be widely implemented.

(ii) EDF

The American Electronic Delivery Format (EDF) is used for the submittal of environmental data to the US Environment Protection Agency and many state organisations. It is an ASCII format file type in several parts that covers laboratory and field data.

(iii) NEDTS

The Navy Environmental Data Transfer Standard (NEDTS) is an ASCII format file type used for submitting environmental data to the US Navy and other American state or federal organisations.

(iv) AGS

As well as handling geotechnical data, the AGS data transfer format is also used for transfer of geo-environmental data such as testing and monitoring for contaminated land. Separate guidance for its use in environmental applications is expected by the end of 2006.

(v) ASTM Standard Guide for Selection of Data Elements for Ground-Water Investigations

This ASTM standard, number D5474-93(2000), covers data requirements for documentation of groundwater sites. There are four referenced standards which sit under this, as follows:

- D5254 Practice for the Minimum Set of Data Elements to Identify a Ground-Water Site
- D5408 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part 1-Additional Identification Descriptors
- D5409 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part 2-Physical Descriptors
- D5410 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part 3-Usage Descriptors

(vi) US EPA Minimum Set of Data Elements For Ground Water Quality

The United States Environmental Protection Agency provides data requirements for groundwater quality data. The requirements take the form of a Policy statement (EPA Order 7500.1A), which has the aim of more efficient management and sharing of data within the ground water community, including States, local governments, the regulated community, EPA, and other Federal agencies.

The policy does not include a data transfer format in itself, but does prescribe specific formats for some data elements according to the following:

- EPA Locational Data Policy
- Facility Identification Data Standards

2.5.6 Data Transfer Formats for Asset Information

(i) GADML

A GML compatible XML data transfer format for the UK Highways Agency (HA) earthwork data has been developed, known as Geotechnical Asset Data Markup Language (GADML). The data transfer format relates to data on inspections, earthworks and observations. An observation being any distinct feature within an earthwork, such as a defect, area of vegetation, drainage, an intermediate cross-section, or a zone at risk of future failure. The data transfer format is used to transfer data in and out of the HA's Geotechnical Data Management System (HA GDMS) and Pocket PC data capture software developed for the HA.

(ii) TransXML

The USA National Cooperative Highway Research Program (NCHRP) Project 20-64, *XML Schemas for Exchange of Transportation Data*, will develop a set of XML schema for transportation applications in a framework to be called TransXML. The objectives of this project are to develop broadly accepted public domain XML schemas for exchange of transportation data, and a framework for development, validation, dissemination, and extension of current and future schemas. The project will initially focus on four areas:

- Survey/Roadway Design.
- Transportation Construction/Materials.
- Highway Bridge Structures.
- Transportation Safety.

Ultimately TransXML aims to encompass a broader set of schemas. The TransXML development manager has stated that they will adopt DIGGS (see Section 2.5.1 (vii)) for geotechnical data and the geotechnical asset.

2.6 Conclusion of Data Transfer Formats and Software Review

The key points arising from the review of data transfer formats are as follows:-

- Many data transfer formats exist, but not all are in active use or being actively supported by organisations.
- Binary, ASCII and XML are the main format file types in use.
- There is a trend to the development of XML format file types, but these new developments are not currently widely supported by software applications due to the time lag that always exists between the publication of a standard and its adoption, and also because a number of the formats are of academic interest only.
- There is active open source development of data transfer formats in a number of areas, but existing software applications make most use of proprietary data transfer formats.
- The data transfer formats most widely adopted by the available specialist geo/engineering software programs are general data transfer formats for mapping/GIS, image and database information transfer. The specialist geo/engineering data transfer formats are not so widely supported.

- The majority of the geo/engineering data transfer formats are mainly related to ground investigation data, and of these, the AGS format is the most widely supported.
- There is very limited development of design, construction and asset related data transfer formats, and those that have been identified are mainly academic research exercises, or designed for use with proprietary or bespoke systems.
- Important current initiatives include:-
  - DIGGS for a broad range of geotechnical data (and incorporating the AGS, COSMOS and CivilML formats).
  - The proposed Euorpean Standards relating to Exchange of data of Identification and Description of Soil and of Rock.
  - TransXML for transportation data in general.
  - eEarth for geological borehole logs.
  - XMML for mining data and geological models.

3 Supplier and User Requirements

3.1 Methodology

Within the constraints of this project it has not been possible to conduct an extensive supplier and user requirements survey. Therefore the review of data requirements has been based on existing studies carried out for a number of transport infrastructure providers in the UK and the USA and consultation within the PSG.

The documents consulted are given in Table 1 below and their content is summarised in the following sections. Typically the reports commissioned are related to the development of geotechnical data management systems (GDMS) by the commissioning organisation and include information on how users produce, transfer and store geotechnical data. However, they do not specifically relate to user needs for data transfer formats, although such formats are essential to support an efficient GDMS.

Table 1 Data Requirements Review Reports

Section	Title	Reference	Originating Organisation	Supporting Organisation	Country of Origin
3.2	Geotechnical Data Management System. Phase 1 Study Report	45888/GE/REP/01/ B, 1998	Mott MacDonald	UK Highways Agency	UK
3.3	Retaining Walls, Earthworks and Off-track Drainage Database Strategy (REODS). Report on Phase 1 Scoping Study.	115242, Draft Issue, March 2004	Arup-DAL (Arup Geotechnics - Donaldson Associates Ltd)	Network Rail	UK
3.4	Baseline Practices and User Needs for Web Dissemination of Geotechnical Data	ASCE Geo-Trans 2004 conference	COSMOS / PEER-LL	COSMOS	USA
3.5	District Geotechnical Data Requirement Summary	2003-2004	Earthsoft	US Army Corps of Engineers	USA
3.6	Geotechnical Data Management System Assessment Report	February 4, 2004	Geo-Decisions	Ohio DOT	USA
3.7	Geotechnical Data Management System Detailed Assessment	03 February 2005	Earthsoft	Ohio DOT	USA

Section	Title	Reference	Originating Organisation	Supporting Organisation	Country of Origin
3.8	Geotechnical Management System Information Synthesis	June 2005	GeoSyntec	Ohio DOT and FHWA	USA
3.9	Environmental Spatial Information for Transportation. A Peer Exchange on Partnerships.	Workshop, June 23-24, 2003. Conference Proceedings at www.TRB.org	Transport Research Board	Transport Research Board	USA

3.2 HAGDMS Phase 1 Report

This report was commissioned by the UK Highways Agency at the start of its Geotechnical Data Management System (GDMS) development. In terms of 'user requirements' the report considers a review of the data types, sources, quality and quantity that would be managed by the GDMS and also the relevant available software and hardware at that time (1998). Comment is also made of the approaches applied by other organisations at that time.

3.2.1 Types of Data

The main geotechnical data types held by the HA were:-

- Paper desk study reports.
- Paper factual reports.
- Paper interpretative reports.
- Digitally stored reports.
- AGS data.
- Maintenance records (HA48 Forms A and B, reports on earthworks failures).

Many of these data sources contain within them many further point data types, eg borehole information. Additional data sources were also available outside of the HA, for example with County Councils, Designers, TRL and the BGS.

3.2.2 Data Users

The following main data users were identified:-

- HA Geotechnical and Bridge Engineers.
- HA Project Managers.
- Maintenance Agents.
- Design Agents.
- BGS.
- General Public.

3.2.3 Data Management Approaches

The report concluded, from a wide ranging study of UK and International transportation organisations, that geotechnical data management systems are a major tool for infrastructure maintenance. The structure of these systems is typically a GIS system supported by a database and document management software.

3.2.4 Highway Agency Data Management Needs

The report identified a number of key areas or needs to be addressed by the GDMS. These were:-

- Continuity and transfer of information between successive management agents.
- The need for a strategic overview of trends across the entire network.
- The need for cross area communication and transfer of information.
- Use of geotechnical information across disciplines.
- The advantages of the use of a tool that is suitable for viewing and use by a wider audience.
- Security of the system, whilst allowing data access to approved users.
- Compliance with Construction Design and Management (CDM) regulations.

The recommendations of the report formed the foundations for the current HAGDMS. No specific recommendations were made about data transfer formats, other than support for the existing AGS data transfer format.

3.3 REODS Phase 1 Scoping Study

The Retaining Walls, Earthworks and Off-track Drainage Database Strategy (REODS) Phase 1 Scoping Study was carried out by Arup-DAL for Network Rail. The study was part of a larger initiative moving towards a geotechnical asset management database, that would include earthworks, tunnels, retaining walls and off-track drainage. The Phase 1 Study considered only examination and assessment asset management information, although it was envisaged that asset inventory, works prioritisation, incident management, external enquiries and decision support tools would be ultimately included in the system. The Phase 1 Study methodology focused on determining current procedures from the Territory Earthworks and Drainage Engineers (TEDE) for comparison against practices in other parts of Network Rail and other infrastructure maintainers.

3.3.1 Geotechnical GIS Requirements

As a result of the consultations with the TEDEs certain features required from the future geotechnical database and GIS system were identified. The key data types to be managed are:-

- Network Rail Hazard Directory.
- Geological, Ordnance Survey and historical maps.
- Maintenance records, including geotechnical and track. Interface would be required with the Mimicom Information Management System (MIMS), which is Network Rail's track signal and electrical maintenance database.
- Assessment results.
- Photographs.
- Information from the MARLIN GIS system. This contains land and property information pertaining to Network Rail's estate and provides read only information on a variety of spatial data including mapping and environmental constraints.
- Remote sensing data.
- Data concerning slope incidents.
- AGS data encompassing the full range of site investigation and monitoring information.
- Geotechnical interpretative reports.

Links with historical data and data held in other systems was seen as of importance. This particularly applies to historical plans, track data, hazard maps, investigation and remedial works information and other data regarding past earthworks failures.

3.3.2 Particular Requirements for Examination and Assessment

Particular features for management of the examination and assessment data were highlighted for inclusion in the database. These were:-

- The increasing use of remote sensing assessment data. Although currently limited to oblique aerial photography this is likely to include LIDAR in the future.

- The increasing use of GISmo in the gathering of examination data. This is handheld GIS technology that equips the examiner with mapping and earthwork information and a specific format for recording of the examination data. However, most Territories still use a paper based system.
- The use of sketch plans and sections during examination was flagged up as a potential problems as these cannot be stored on the GISmo or shown spatially on GIS.
- Special examinations after incidents are required as well as routine (strategic) examinations.
- Retaining walls are examined and assessed by an entirely different process (to earthworks) as driven by the structural standards.
- Data transfer formats were not specifically addressed.

3.4 COSMOS Baseline Practices and User Needs Report

The USA Consortium of Strong Motion Observations Systems (COSMOS) in partnership with the Pacific Earthquake Engineering Research Lifelines (PEER-LL) Project have been working on a project to demonstrate improved methods of geotechnical data dissemination. This has included identification of user scenarios, creation of a data dictionary for data transfer and development of a web based data centre. As part of this process a potential user survey was conducted to identify baseline current practices and user needs. The results of this survey are summarised below.

3.4.1 User Survey Context

The user survey was designed to obtain information of how geotechnical engineers, both in practice and research, currently generate, store and transfer geotechnical information. The aim of the survey was to consider both current practices and future requirements of a GDMS.

The survey was distributed throughout all the State DoTs and State Geological Surveys, the Federal Highways Administration, the United States Universities Council on Geotechnical Engineering Research and the GeoCouncil (of the American Society of Civil Engineers). The survey was completed by 217 professionals, of which approximately two thirds were working in government agencies and approximately one quarter were consultants. The main fields of practice were geotechnical design, engineering geology and regional geology. Almost one third of respondents were California based practitioners, where COSMOS is based.

3.4.2 Baseline Practices – General

The most commonly used data sets comprised borehole data, laboratory testing data and in situ testing data. The main application of this data is geotechnical design. These results are unsurprising given the demographic of the survey respondents. Other data sets and applications also included geophysics and seismic data, regional geological studies and geo-hazard mapping.

The data utilized is equally likely to be generated in house and by others. The geotechnical data is commonly used spatially, ie in the production of maps, plans and drawings, and therefore GIS software and drafting software is important in the use of geotechnical data. The spatial referencing of the data is mainly by either a geodetic system or a coordinate system in keeping with the GIS application.

3.4.3 Baseline Practices – Data Types

The types of geotechnical data being used in terms of borehole, laboratory and in situ data, are generally comparable to the UK practice and will not be expanded upon here. However, it is worth commenting on a number of key issues and difference in practices:

- Whilst UK geotechnical data should include descriptions in accordance with BS5930, the COSMOS survey highlighted the use of ASTM standards D2488 and D2487 for 'visual-manual' and 'laboratory based' classification.
- Age of deposits by radiocarbon, pediologic or palaeontological methods was also important to some users.
- Groundwater modelling data was indicated as an important data set by one third of respondents.
- Dynamic testing data was important for approximately one third of respondents, due to the need for earthquake hazard studies, particularly in California.
- The need for interpretative data in addition to raw factual data was highlighted in a number of particular circumstances, especially more complex laboratory procedures, use with CPTs and geophysical surveys.

3.4.4 Baseline Practices – Data Management

The survey indicated that both paper and electronic data transfer formats were being used to store geotechnical data with no standard methodology. Where electronic storage was used this was by a variety of data transfer formats, but typically spreadsheets and rich text files.

Whilst there appears to be no consistent approach, most respondents indicated that electronic data collection was important to their work, even though this commonly involves manual entry. Only two out of five specific organisations questioned had systems in place for access to that organisation's geotechnical information in electronic format.

3.4.5 User Needs

The user needs resulting from the COSMOS survey can be summarised as follows:-

- It will be absolutely necessary in the future to have geotechnical data stored electronically.
- Future geotechnical data collection will be electronic, using both automated and manual input. Therefore interface will be required with both PCs and PDAs.
- There was significant interest in the advantages of electronic data management systems both at organisation and multi-organisation level.
- The freely available nature of the data in the management system was considered important (a reflection of the demographic of the respondents, being mostly from government agencies), although this may come with an operation and management expense.
- An internet based system was concluded as the most suitable portal for data access.
- Searching for data would be required, based on a number of key data parameters, particularly data type and location. Sorting of search data would also be required.
- Different arrangements for presentation of the data following search results would be required, eg tables and descriptions.

- Users wanted to receive data in a transfer format consistent with their current practice, suggesting the use of spreadsheets, image files, database files and text files.

3.5 USACE Geotechnical Data Requirements Summary

Geotechnical data management by the US Army Corps of Engineers has been the focus of review by EarthSoft Inc, who were contracted to develop a geotechnical database schema. This work is part of a broader objective to create a software program to allow efficient management of geotechnical data, and would include a relational database with storage, retrieval and editing facilities and be equipped to produce borehole logs and interface with GIS applications. As such, the Data Requirements Summary Report considers only the identification of data requirements leading to the schema development. The software development forms part of future work tasks.

3.5.1 Survey of Corps Districts

Seventeen Corps Districts were contacted by Earthsoft regarding their existing protocols and software usage for geotechnical data management. Their responses went on to form the basis of the schema described below, such that the needs of all the Corps Districts would be met by the schema. A summary of these responses is given below.

- Existing practice is very varied, from Districts which have been using entirely paper based approaches to those which have been utilising database approaches for over 30 years.
- Approximately one third of the Districts currently use gINT to assist their data management.
- Approximately one quarter of the Districts had already developed their own database structures using other software, eg in Microsoft Access.
- Approximately one third of the Districts used no database to assist management of their geotechnical data.
- Historically data storage tended to be by paper copy or by pdf scanned from paper copy.
- One District was using microstation for log and plan drafting and then using an ASCII data transfer format to allow interface with GIS applications or for long term storage. However, no database was held and historical records were maintained only as pdf copies.
- Some Districts embraced the proposed harmonised database approach, whilst others were concerned about the cost of implementation of the new system, particularly for small and non complex geotechnical projects.

3.5.2 Database Schema

The developed schema comes with descriptions of how existing District practices are mapped to the new tables in the schema. The schema is compliant with the spatial data standard SDSFIE (refer to Section 4.5.4 for further details) used in the US Department of Defence. The schema is currently presented in the form of an excel spreadsheet and includes 55 tables split into geotechnical, geological and non-geotechnical tables.

The geotechnical tables mostly contain information concerning geotechnical laboratory testing, but also in-situ testing (restricted to point information). The geological tables contain information concerning the geological classifications for stratigraphy or lithology, sample information and drilling information. The non-geotechnical tables contain information about the project and its locations, about groundwater and also reference information for other tables.

3.6 Ohio DOT GDMS Assessment Report

The Ohio Department of Transport (ODOT) Office of Geotechnical Engineering (OGE) is in the process of developing a Geotechnical Data Management System (GDMS) to include:-

- Construction data.
- Operations and maintenance data.
- Instrumentation and monitoring information.
- Geological site management programme.
- Planning and research information.
- “Operations” information including drilling, geophysical and laboratory testing data.
- Production information.
- Relevant structures information.
- Relevant pavement information.
- Material management.

As part of the work towards the GDMS the Assessment Report includes a study of the existing conditions of data management within ODOT, development of the business case for its implementation and outlines of the conceptual model for the GDMS. To this end information has been gathered from the potential users of the GDMS.

3.6.1 Current Conditions

There are five key user groups for the ODOT GDMS. The OGE is the primary geotechnical resource for the state, acting both on individual projects and on policy issues. Other bodies within ODOT are the Design Resource Section, which oversee geotechnical works carried out by others (Districts and external consultants) as well as carrying out some design themselves, the ODOT Districts, which carry out geotechnical work on projects, and the Geotechnical Operations Section, which provides in-house services for intrusive investigation, laboratory testing and drafting. Lastly geotechnical services on projects are provided by external consultants.

There are three main geotechnical data streams used within ODOT. These are intrusive information, geohazard information and archive data. Data types include new and historical borehole information and soil surveys, water well records, oil and gas well records, Environmental Protection Records, mine maps, wetland maps, landslide maps and construction as-built information.

Intrusive data is collected both in-house and by consultants for particular projects. Therefore data can originate from the Districts, the Geotechnical Operations Section or a number of external parties. Samples from intrusive investigations are typically recorded manually and later transferred to a database. However, the contents of this database are limited to samples and some test results. The majority of intrusive information is hard copy stored and card indexed.

Geohazard information is collected at three main times, at initial site walkovers (ahead of intrusive investigation), during construction and then any subsequent maintenance activities. However, all these data are typically hard copy only and not correlated.

Historical data is available to 1920, but only in hard copy and with no backup. This valuable archive can only be searched in person at the archive through a card filing system. However, changes to referencing systems over the years make this process inefficient. Work is ongoing for a database for this information and to scan the data sources themselves.

3.6.2 Proposed GDMS

The key data types to be supported by the GDMS are given above. These will be supported by a geotechnical information database which will be the engine of the GDMS. The database would include a spatial component to facilitate GIS interaction.

The database would be accessed by a web portal, with options for selecting, searching and viewing data within a GIS interface. The web portal would also act as a data entry portal for users involved in data generation.

3.6.3 Implementation Requirements

In order to successfully implement the GDMS, changes to current procedures would be required including:-

- Standardisation of procedures including methodology and terminology in data collection, transfer and use.
- Improvements to data quality and processes in collection, including locating data points and electronic collection of data. This would be applicable to all data collection, ie construction and maintenance information, not just initial intrusive data.
- Design of a data referencing system and appropriate database model.
- Appropriate computing infrastructure would be required to be in place.

3.7 Ohio DOT GDMS Detailed Assessment

A presentation was made to the Ohio DOT in February 2005 by Earthsoft regarding their detailed assessment that will be carried out for the proposed GDMS. This work followed on from the assessment by Earthsoft carried out for the USACE (refer to 3.5 above).

The presentation tackled the main findings of the Geo-Decisions report (summarised in Section 3.6 above), namely:-

- Volume of data.

- Difficulty in accessing that data.
- Incompatibility of the existing systems.
- Resulting impact on geotechnical design.

Following from the above issues that will be addressed by the GDMS, the presentation outlined the approached adopted by the USACE:-

- The setting up of a geotechnical database schema with a relational structure including:-
  - 55 no. geotechnical (eg compaction, permeability), geological (eg stratigraphy, drilling parameters) and non-geotechnical tables (eg location, project and company details).
  - 600 fields.
- Development of software and GIS interface for the database schema.

The detailed assessment by Earthsoft indicated how the key issues for Ohio DOT could be addressed:-

- Identification of the requirements of a complete GDMS.
- Identification of the document workflow processes that need to be supported by the GDMS.
- Assessment of documents and consequential development of scanning and referencing specifications.
- Identification of all data sources and whether they originate from the DOT or from external suppliers. This would also highlight interoperability issues between the DOT and their suppliers.
- Identification of data transfer formats and standards to allow interoperability.
- Identification of the GIS functionality required for the GDMS interface.
- Review of existing DOT business processes and what changes will be required to support the GDMS.
- Definition of GDMS modules, import and export needs and searching requirements.

3.8 Ohio DOT Information Synthesis Report

This report prepared by GeoSyntec for Ohio DOT and the FHWA covers a summary of current geotechnical data management techniques used by all of the US State DOTs. At the date of this CON125 report, the GeoSyntec report was not at final issue, however the breadth of the study makes it an important assessment to be considered.

The report emphasises the benefits of good data management, whilst observing that there are no standardised guidelines available for collecting, storing or managing geotechnical data. The report therefore aims to gather existing information on current practices in order to assist the FHWA with providing future guidance for both Ohio DOT and other states looking to improve their geotechnical data management.

3.8.1 Data Collection

Data collection was via interviews with key geotechnical personnel in the state DOTs. The data was recorded in a database, set up to allow for comparison of responses in a consistent manner. Information gathered included:

- Information pertaining to the GDMS including history and development, type of information used, development and maintenance costs, procedures and policy relating to the GDMS.
- Future development requirements for the GDMS. This included short and long term visions.
- Information on the format of data and its exchange capability.
- Self assessment of the strengths and weakness of the adopted system.

In addition to the state DOT interviews, additional general or specific best practice information was provided by:

- The UK AGS.
- The USACE.
- COSMOS.
- The FHWA Turner-Fairbanks Research Station.

3.8.2 Assessment of Results

(i) Overview

Response of the state DOTs to the synthesis survey was generally positive, with acceptance of the benefits of implementation of a GDMS. Although few states had implemented an electronic GDMS with GIS interface, most states had in place a system for management of geotechnical data, although this commonly comprised a catalogue system for paper reports. Many states also had systems for tracking geological hazards, possibly due to existing FHWA guidance in this area.

When considering the possible development of a standardised approach to GDMS development and implementation many states expressed a number of concerns. These were related to either financial issues, such as funding for development and training, the scale of changes to current practice likely to be required and also the potential flexibility of the proposed new GDMS to accommodate requirements from all the DOTs.

(ii) GDMS General Information

Although electronic GDMS implementation was rare, most states were able to trace geotechnical information from previous projects, usually via a project number or a road or route number. Use of coordinate systems to trace projects was rare, with GIS technology only incorporated by only a few states. For the majority of states, tracing of information occurred through paper documents, although software such as spreadsheets had often been used to originally record the information. Some states were using databases to record information, usually Access, SQL or Oracle.

The types of information most commonly tracked by the states included geohazards, borehole data, laboratory data and also pile records. It was generally indicated that bridge records were tracked, but by the structures departments of the DOTs. Where states produced borehole logs then gINT was the most commonly used application.

The development costs of the systems used by the DOTs was generally difficult to define and tracing of documents was commonly considered part of normal operations. Where more sophisticated systems were being implemented the work associated with this varied from in house development of simple structures to more detailed collaboration with universities. It was commonly recognised that one or two people were required to maintain data management systems.

(iii) GDMS Development Visions

Common future needs included:

- Better location of data using coordinate systems and GIS interfaces.
- The ability to scan documents to develop an electronic library. However, this was contradicted by a perception that the effort of scanning a large back catalogue outweighed the likely benefits.
- Although there was a growing desire to use technology to improve efficiency, there was little recognition that geotechnical information is data and that such technologies are tools of data management. This raises the risk that development of new systems will not explicitly recognise the types of data being managed.

The need for a data management champion to drive development of a GDMS was recognised as an important factor in assisting future change.

(iv) Format of Data and Data Transfer

Only two states formally identified extensive exchange of data with other bodies, such as geological surveys, although many states acknowledged general exchange of information.

Data transfer standards were recognised as an ‘easy way’ to establish consistent practice, eg for data transfer between the DOTs and their consultants. However, this was not matched by practice and very few such standards have been established.

Only four states currently used web based dissemination for data, despite half of those interviewed indicating that this would be a valuable method of data exchange. This is particularly relevant given the need for a standard data transfer format to facilitate these methods of data dissemination.

(v) Self Assessment of Current Practice

For those states with a largely paper based system the main strength of their current practice was seen as having ‘a system’ which worked. However, key weaknesses cited were:

- Lack of implementation.
- Lack of consistent data.
- Lack of spatial referencing.

- Lack of complete data, including absence of historical archiving from the system.

Where states had a more sophisticated electronic based GDMS, the problems with this approach were generally perceived as problems in gaining funding to fully implement the system.

(vi) Other Agencies

The GeoSyntec synthesis also consulted other agencies, all of which are covered by the other studies reviewed in this CON125 report:

- USACE – refer to Section 3.5.
- COSMOS – refer to Section 3.4.
- AGS Data format – refer to Section 2.5.1.
- UK Highways Agency (via AGS) – refer to Section 3.2.

3.8.3 Synthesis Report Recommendations

Recommendations are made in the three key areas of data management, data conveyance and system development.

- Data management. Identification of data tables for the GDMS database. It is expected that this work would draw on the experiences of the AGS and COSMOS and would help lead to data standardisation.
- Data conveyance. This is likely to include deployment of the data through the web with a GIS interface. Both the software community and those states with functioning electronic GDMS applications would be involved in this process.
- System Development. This is the incorporation of data management and data conveyance into a fully functioning GDMS.

3.9 TRB Peer Exchange on Partnerships

The Transport Research Board (TRB) is a United States organisation for the promotion of innovation in transportation through research. It is a division of the National Research Council, serving the National Academy of Sciences and the National Academy of Engineering. In 2003 the TRB held a workshop entitled "Environmental Spatial Information: A Peer Exchange on Partnerships." This event was aimed at sharing information and lessons learnt from those bodies in the USA that had adopted innovative data-sharing practices. The proceedings from the workshop consider data sharing across organisational boundaries within four states. The following paragraphs consider some common themes across the four states.

3.9.1 Summary and Key Themes

Good data management was concluded to emerge from the confluence of innovation in four separate areas, all of which were required for the success of the data sharing initiatives:-

- Policy innovation. High priority business drivers were necessary within the DOT, leading to a legislative mandate or regulatory requirements. This would likely effect how the DOT planned its projects. For data sharing between organisations a memorandum of understanding or similar was commonly required outlining roles, responsibilities, rights and expectations for those involved in the data exchange.
- Economic innovation. DOTs needed to be willing to underwrite the cost of developing the necessary systems for data collection, storing and sharing. The data sharing needed to be viewed as a public investment.
- Cultural innovation. Strong leadership from the highest management levels was usually required to ensure culture change occurred. Trusted, articulate and highly visible champions were needed to generate and sustain momentum.
- Technical innovation. Access to and experience with relevant technologies was necessary, eg GIS, databases and the internet. This is assisted by well understood metadata management processes and emerging national and state level data standards.

As such generally innovative business processes and approaches to data and partnering were essential for successful data partnerships. Successful practices therefore need to:-

- Take account of different cultures between organisations.
  - Communicate early with all stakeholders and build trust.
  - Understand the needs of the potential data partners.
  - Be proactive, but patient.
  - Publicise successes.
- Start small and build. This will require:-
  - Investment in staff, technology and data.
  - A champion with a supportive group of enthusiastic followers.
- Work towards the ultimate goal that derives from the successful data sharing.
- Remember that the technology in itself is not the solution.
- Beware that increased data access can increase opportunities for its misuse by those who misunderstand it.
- Carefully select and work within relevant data standards, bearing in mind that some standards may be contradictory.

3.10 Project Steering Group Requirements

The PSG for CON125 has been constituted to cover the whole range of the geotechnical supply chain, so that the PSG may be used as a sounding board for the requirements of the geotechnical industry. The PSG includes representatives from:

- Clients - roads, railways, metros, waterways.
- Ground investigation contractors.
- Construction contractors.
- Consultants.
- Government organisations.

- Trade organisations.
- Academia.
- Software suppliers.
- Data providers.
- UK and USA.

The full list of PSG (and PWG) members is given in Appendix A .

At the first PSG meeting in July 2005, the PSG were asked to state their requirements for geotechnical data transfer formats. Whilst the PSG acknowledged that there was a need for the transfer of geotechnical data throughout the whole of the geotechnical supply chain, the responses focussed on the area that was most familiar to the PSG members, that of transferring ground investigation data, and in particular the use of the existing AGS data transfer format.

The data suppliers present were concerned that the AGS data transfer format specification was not sufficiently rigorous, as they were finding that they were increasingly being asked by Clients to customise the AGS data supplied. This was leading to a return of the unsatisfactory situation that existed prior to the AGS data transfer format, of every major client having their own specific data transfer format requirements, which the suppliers had to meet.

The data receivers present were concerned that after 13 years of use of the AGS data transfer format they were still receiving poor quality data. It was acknowledged that many of the detailed errors in implementation of the AGS data transfer format that have been seen in previous years, were now resolved by the major geotechnical investigation companies who were all using specialist geotechnical database software to produce their AGS format data and format checking software. However, errors were continuing to be seen from the smaller geotechnical investigation companies, and the specialist suppliers, such as environmental laboratories and insitu testing subcontractors.

The currently available AGS format checking software only checked for errors in the data transfer format itself, and did not carry out any validation of the data. It was pointed out that it was difficult to automatically validate the data as the AGS data transfer format had no inbuilt specification for data types or data ranges. It was concluded that the AGS's intended move to an XML version of the data transfer format would permit the inclusion of valid data types and data ranges within the schema, and this would permit more rigorous data validation in the future.

3.11 Conclusions of Supplier and User Requirements Review

The recurring themes and key conclusions from the documents reviewed in these sections are:-

- There is a growing consensus that a geotechnical data management system (GDMS) is an essential tool for strategic management and tactical maintenance of infrastructure assets.
- A GDMS usually takes the form of a database with access through a web portal with GIS software.
- Little best practice guidance is available on data transfer formats for GDMS database information.
- User requirements are focussed on the ease of data accessibility rather than the data transfer format used to access the data.

- Users wish to access the full range of geotechnical data, from project inception through design, construction and maintenance. However, this expectation is in contrast to the lack of development of data transfer formats for much of this process.
- Cross organisational data sharing is a developing theme in the USA.
- Successful data sharing and GDMS implementation goes beyond the data and the database/GIS technology. Also required are:-
  - Policy framework with leadership support.
  - Client and user education and training.
  - Software development and adoption.
  - Financial investment.
- The reviewed requirements studies have focused on Geotechnical Data Management Systems, but have generally not considered in any detail how data might be imported in to or exported out of such a system, or the standardised data transfer formats that would be necessary to achieve this.
- The PSG expressed concerns about the existing AGS data transfer format:
  - Data suppliers were concerned that the specification was not sufficiently rigorous
  - Data receivers were concerned about continuing to receive poor quality data, and that the existing transfer format did not specify data type and data range validation

4 Statutory Requirements and Data Standards

For the UK infrastructure market, statutory requirements may relate to UK or European legislation. These are generally at the higher level relating to general spatial data management and accessibility to the general public, rather than geotechnical or infrastructure specific requirements. Other best practice standards and initiatives are also relevant to data transfer, particularly in the area of metadata, and these are also considered below.

4.1 Methodology

A number of international, European and UK national standards may be applicable to various forms of data transfer, particularly for any data transfer relating to UK government bodies. This section of the project review is concerned with the consideration of which, if any, of these standards, and in what circumstances, will apply to geotechnical data transfer for transport schemes. To this end the following relevant standards have been reviewed.

- UK government legislation and initiatives:-
  - The Freedom of Information Act 2000.
  - The Environmental Information Regulations.
  - The Human Rights Act 1988.
  - The Data Protection Act 1998.
  - The Public Records Act 1958.
  - BS7666 Spatial data-sets for geographical referencing
- European Legislation and Initiatives:-
  - INSPIRE (Infrastructure for Spatial Information in Europe)
  - Directive on Re-use of Public Sector Information (PSI)
  - European Environmental Information Initiative
  - Electronic Access to the Earth through Boreholes (eEarth)
- Metadata Standards:-
  - ISO 15836:2003 (Information and Documentation – The Dublin Core Metadata element set)
  - e-Government Metadata Standard (eGMS)
  - National Geographic Data Framework (NGDF) Discovery Metadata Guidelines (now gigateway)
  - ISO 19115:2003 (Geographic Information – Metadata)
  - UK GEMINI (Geo-spatial metadata interoperability initiative)
- Data Transfer Format Standards:-
  - ISO standards 10303 and 13584 for data models and data dictionaries:-
    - ISO 10303 Industrial automation systems and integration -- Product data representation and exchange.

  - ISO 13584 Industrial automation systems and integration -- Parts library -- Part 1: Overview and fundamental principles.
- (USA) Spatial Data Transfer Standard (SDTS).
- (USA) Spatial data standard for facilities, infrastructure and environment (SDSFIE).
- ISO 19136 and the Geography Mark-up Language

4.2 UK Requirements

The UK Intra-governmental Group on Geographic Information (IGGI) promotes the effective use of government geographic information. As such it acts as a forum for issues related to geographic information, the use of standards, legal requirements and general best practice. Whilst UK infrastructure providers are not directly responsible to IGGI, the organisation is a good source of information in this area.

4.2.1 Legal Requirements

UK legislation for public information commenced with the Public Record Office Act of 1838, however this only concerned the Exchequer and by the 1950's there was concern about the state of government records. This led to the Public Records Act of 1958, the major significance of which was the first enshrined right of public access to governmental information (after a 50 year closure period). The legislation remained largely unchanged, with the exception of the reduction of the closure period to 30 years in 1967, until the introduction of the Freedom of Information Act.

The Freedom of Information Act 2000 came into force in January 2005. It lays down the right of access to information held by public authorities and therefore defines duties and responsibilities for those who hold and manage public sector information.

The right of access to environmental information is covered by a separate statutory regime under the Environmental Information Regulations (EIR). The regulations, which also came into force in January 2005, are the implementation of the European Directive 90/313/EEC on the freedom of access to information on the environment (see also Section 4.3.1).

The Human Rights Act 1988 and the Data Protection Act 1988 both provide for protection of personal information. Although they place specific duties on Data Management concerning security of personal information, they are unlikely to have a significant effect on geotechnical data management and transfer.

None of these legal requirements relate specifically to geotechnical infrastructure data, but do apply to public sector data in general.

4.2.2 Other Requirements and Initiatives

Other UK requirements relate mainly to metadata standards, the most relevant of which is UK GEMINI – The Geo-spatial Metadata Interoperability Initiative – which is discussed in further detail in Section 4.4.

The only British Standard document relating to the format of data is BS7666:2000 Spatial Data Sets for Geographical Referencing. This refers to data requirements for compilation of gazetteers for UK streets and land and property units and is hence not applicable to geotechnical data transfer.

4.3 European Legislation and Initiatives

4.3.1 European Directives

There are two recent pieces of European legislation relating to data use and access. Firstly Directive 2003/98/EC on the re-use of public sector information and secondly the proposed directive on establishing an infrastructure for spatial information in Europe (INSPIRE).

In the UK, the Re-use of Public Sector Information Regulations, which came into force in July 2005, implements Directive 2003/98/EC. The driver for the legislation comes from the recognition that public sector information is a valuable resource. By removing barriers to access of such information the idea is to stimulate private sector products and services as well as flow of information to members of the general public. Whilst the Regulations do not apply directly to the Highways Agency, Network Rail or British Waterways, they do apply to local authorities and councils, the Greater London Authority and the Environment Agency.

The text of the proposed INSPIRE directive[6] was only adopted by the European Parliament in June 2005. It will not become a full directive until agreement is reached between the Council, the Parliament and the Commission and hence would not be expected to be implemented in UK law for a number of years. The key objective of the proposed directive is to make more and better spatial data available for EC policy making and implementation, for research and development, for commercial and professional use, as well as by individual citizens of the community. INSPIRE focuses on environmental policy, but is open for use by, and extension to, other sectors including agriculture, transportation and energy. It should be noted that the environment in this context includes soil and water. In fact the recent implementation of the European Soil Portal[7] has already been developed in line with the INSPIRE initiative.

INSPIRE goes beyond making spatial data more accessible, being concerned also with interoperability, ultimately aiming to harmonise spatial data across Europe. Hence in the future INSPIRE may provide requirements about spatial data transfer in order to achieve this interoperability. Such requirements would require pan-European data transfer formats in order to achieve their goals.

[6] http://www.ec-gis.org/inspire/

[7] http://eusoils.jrc.it

4.3.2 The Aarhus Convention

The UK EIR implements the European Directive 90/313/EEC on freedom of access to information on the environment. Currently proposals are being heard for amendments to this Directive based on experience gained in its implementation by the Member States and also the commitment made by the EC by signing up to the Aarhus Convention. The Aarhus Convention (1998)[8] concerns access to information, public participation in decision making and access to justice in environmental matters. It is possible that the UK government will ratify the Convention before the EC. However, it is certain that the principles will become law in the near future.

4.3.3 Electronic Access to the Earth through Boreholes (eEarth)[9]

The development of electronic transfer data transfer format for borehole data for the eEarth Project has already been indicated (Section 2.5.2(iii)). However, the data transfer format is but one element of a much broader and ambitious European Initiative that fits well with the vision of the INSPIRE initiative. Eight EU geological surveys are participating for the establishment of a European data collection which will operate across national boundaries. The final deliverable would be a multilingual portal for digital geo-data through a GIS interface for the whole of Europe.

4.4 Metadata Standards

A number of standards for metadata are available, all aimed at efficient exchange of data and its metadata. Most metadata standards draw on the Dublin Core Metadata Standard[10]. This has become an international standard as ISO 15836:2003 (Information and Documentation – The Dublin Core Metadata element set). The Dublin Core Metadata Standard is intentionally simple in order to apply to a wide range of data types and users. The standard includes only fifteen elements (for example ‘Title’, ‘Description’, ‘Creator’).

In the UK the Office of the e-Envoy has produced policies for interoperability across the public sector under the e-Government Interoperability Framework. Part of this framework is the e-Government Metadata Standard (e-GMS)[11]. Use of e-GMS is mandatory for all public sector bodies. The standard goes beyond the Dublin Core Metadata Standard and comprises twenty-five elements, although only four of these are mandatory.

Whilst the advantage of the Dublin Core Metadata Standard is its simplicity, it provides no where near enough information when dealing with spatial data. As a result further extensions of the standard have been developed by various parties.

In the UK the National Geospatial Data Framework (NGDF) Discovery Metadata Guidelines were developed by the Association for Geographic Information (AGI) in the mid 1990’s. This standard, again an extension of the Dublin Core Metadata Standard, rapidly became the industry standard for users of spatial data. However, the NGDF is now largely superseded by more recent developments, the current international standard ISO 19115:2003 and the UK GEMINI initiative.

[8] http://www.enece.org/env/pp/
[9] http://eearth.nitg.tno.nl/
[10] http://www.dublincore.org/
[11] http://www.govtalk.gov.uk/metadata.asp

ISO 19115:2003 Geographic Information – Metadata provides an international standard which fully supports spatial referencing. It provides information about identification, extent, quality, the spatial and temporal schema and the spatial reference and distribution of digital geographic data. However, no implementation standard has yet been agreed by the ISO. The proposed implementation standard, ISO 19139 Geographic Information – Metadata – XML Schema Implementation, is still only at draft stage and hence has yet to be actually accepted as the international standard.

Whilst public sector bodies should be using the e-GMS standard its limitations with respect to spatial data has lead to the development of the UK Geo-spatial Metadata Interoperability Initiative (GEMINI)[12]. GEMINI contains 32 metadata elements including title, subject, data, originator, bounding coordinates and spatial reference system. GEMINI is compliant with both e-GMS and ISO standards 19115 and 19139.

4.5 Data Transfer Format Standards

4.5.1 ISO 10303 and 13584

The following ISO standards are for the development of information or data models and hence set out requirements for the data, its structure and the associated data dictionary.

- ISO 10303 Industrial automation systems and integration -- Product data representation and exchange.
- ISO 13584 Industrial automation systems and integration -- Parts library -- Part 1: Overview and fundamental principles.

These standards allow definition of the quantity, properties and magnitude of those properties for any materials. The also define any processes applied to these materials. Although the standards are designed for the manufacturing industry and hence are intended to relate to ‘manufacturing product’ properties and processes, they can equally apply to any material (eg soil) properties and geotechnical processes. Therefore any geotechnical data transfer format seeking ISO accreditation is likely to be required to comply with ISO 10303 and ISO13584.

4.5.2 Draft ISO Standards for Exchange of data of Identification and Description of Soil and Rock

Recent introduction of ISO standards relating to description of soils and rocks are expected to be followed by the relevant part standards for exchange of data, currently in draft format.

- ISO 14688-1 2002 Geotechnical investigation and testing -- Identification and classification of soil -- Part 1: Identification and description.
- ISO 14688-2 2004 Geotechnical investigation and testing -- Identification and classification of soil -- Part 2: Principles for a classification.
- ISO 14688-3 (draft - committee stage) Geotechnical investigation and testing -- Identification and classification of soil -- Part 3: Electronic exchange of data of identification and description of soil

[12] http://www.govtalk.gov.uk/schemasstandards/metadata_document.asp?docnum=903

- ISO 14689-1 2003 Geotechnical investigation and testing -- Identification and classification of rock -- Part 1: Identification and description.
- ISO 14689-2 (draft - committee stage) Geotechnical investigation and testing -- Identification and description of rock -- Part 2: Electronic exchange of data on identification and description of rock

The draft standards are being driven by continental European practice and currently at committee stage of the ISO procedures. It is not yet known when they are proposed to be implemented. Further details of the content of the draft standards is given in Section 2.5.1 (viii).

4.5.3 Spatial Data Transfer Standard

The Spatial Data Transfer Standard (SDTS)[13] is a robust way of transferring earth-referenced spatial data between users and applications. It includes spatial data, attributes, geo-referencing, data quality report data dictionary and supporting metadata. The standard was developed by the US Geological Survey for the federal government, being first published as a Federal Information Processing Standard in 1994. The standard was ratified by The American National Standards Institute (ANSI) in 1998 and compliance with the SDTS is now mandatory for all Federal Agencies.

In the UK the office of the e-Envoy sets standards for electronic government in the UK. This includes the metadata standards referred to above and also a range of Government Data Standards. These standards are mainly related to transfer of names, addresses, personal information, company information, financial information and temporal information. The office of the e-Envoy also maintains a catalogue of schemas. For geographical information, GML is recommended. For transport data, schemas are recommended related to the locations and connections of public transport and its interoperability. No construction related schemas are included. e-Government Schema Guidelines for development of XML schemas are also provided.[14]

4.5.4 Spatial Data Standard for Facilities, Infrastructure and Environment

The Spatial Data Standard for Facilities Infrastructure and Environment (SDSFIE)[15] was developed by the USA Department of Defence CAD/GIS Technology Centre. The standard provides a comprehensive framework for the design of geospatial databases, being based around standard entity sets, such as flora, geology or transportation. Hence it is a graphic and non-graphic standard for GIS that is implemented across the Department of Defence. However, it also has much greater usage, having become the de facto standard for GIS implementation in many federal, state, and local agencies; public utilities; and private industry in the USA.

SDSFIE is non-proprietary, providing a data structure and organisation without regard to any specific application. One specific application of relevance to the CON125 Project is the development of a geotechnical database schema by the USACE (US Army Corps of Engineers). This schema has been developed to be SDSFIE compliant, but has found the standard to be limiting with respect to the three-dimensional nature of sub-surface features. As a result of the development of the geotechnical schema some changes will be made to the data structure in the next version of the SDSFIE standard.

[13] http://mcmcweb.er.usgs.gov/sdts
[14] http://www.govtalk.gov.uk/schemasstandards/developerguide_document.asp?docnum=946
[15] http://tsc.wes.army.mil/products/TSSDS-TSFMS/tssds/html/

4.5.5 GML and ISO 19136

The Open Geospatial Consortium[16] Geography Markup Language (GML) Implementation Specification Version 3.1.1 was released in 2005. This version of GML has been edited by both Open Geospatial and the International Standards Organisation. It is the aim that GML Version 3.1.1 will form ISO 19136, currently in draft form under ISO Technical Committee TC211.

4.6 Conclusions of Statutory Requirements and Data Standards Review

The following key points relate to the statutory requirements and standards.

- UK statutory requirements relate mainly to the public rights of access to public sector information, particularly environmental information (including soil and water).
- There are no UK statutory requirements relating directly to geotechnical data.
- Government bodies should work within prescribed metadata standards, particularly UK GEMINI.
- There are developing spatial data standards including the draft ISO standard for GML.
- USA public bodies are subject to mandatory comprehensive spatial data standards. In the UK, government data transfer format standards do exist, but other than the implementation of GML, they are not of relevance to geotechnical data.
- The proposed European INSPIRE Directive may influence future spatial data use and formatting, particularly for government bodies. This initiative aims to harmonise spatial data across Europe.
- There are international ISO standards on data models and data dictionaries that any data transfer format that aspires to ISO recognition should comply with.
- There are two draft ISO standards relating to the Exchange of data of Identification and Description of Soil and of Rock.

[16] http://www.opengeospatial.org/

5 Identification of Geotechnical Data Transfer Gaps

5.1 Existing Data Transfer Formats in the Geotechnical Supply Chain

From the above reviews of existing geo/engineering data transfer formats, standards and initiatives the situation presented in Figure 2 on the use of data transfer formats throughout the geotechnical supply chain is summarised below in Table 2.

Table 2 Geotechnical Supply Chain & the use of Data Transfer Formats

Stage	Data Transfer Formats in Common Use	Specialist Open Source Geo/engineering Data Transfer Formats		
		In Common UK Usage	In Common International Usage	Relevant Current Initiatives
Conceptual/ feasibility studies	Proprietary image, spatial and document formats	None	None	eEarth
Investigations	Numerous proprietary and open source formats	AGS, SEG, LAS	AGS, SEG, LAS, GEF, EDF and others in specific countries	DIGGS, XMML
Design	Proprietary analysis software, spreadsheets	None	None	DIGGS ?, XMML ?, POSC
Construction	Proprietary & open source drawing formats	None	None	DIGGS ? TransXML ?
Maintenance management	Proprietary document, drawing and database formats	None	None	DIGGS ? TransXML ?
Decommissioning	Proprietary drawing formats	None	None	None

Table 2 indicates that there is a clear lack of specialist geo/engineering data transfer formats in use for the majority of the geotechnical supply chain. Ground investigation data transfer is well supported by the AGS and several geophysical data transfer formats, plus a small number of other data transfer formats that are well established in other parts of the world outside of the UK. The vast majority of geo/engineering information is passed through the geotechnical supply chain in non-specialist data transfer formats, most of which are proprietary data transfer formats that have become international standards through the widespread distribution and usage of the software programs from which they are derived.

5.2 Gaps in the Existing Data Transfer Formats

From Table 2 the following gaps in current geotechnical industry practice are identified:

- The lack of a standard specialist geo/engineering data transfer formats for conceptual and feasibility desk study information.
- The lack of a standard specialist geo/engineering data transfer formats for interpretative and design data including:
  - Interpretative ground models.
  - Design/analysis models.
  - Design data (eg interpretative soil parameters).
- The lack of a standard approach and data transfer formats for construction information, including piling records, other as-built records, geotechnical observations and feedback made during construction.
- The lack of a standard approach and data transfer formats for asset, asset management (and potentially decommissioning) information.
- The lack of a standard approach for the transfer of:
  - Drawings.
  - Mapping and other GIS data.
  - Documents.

5.3 Relevant Current Initiatives

Table 2 summarises the current development initiatives that have been identified in this review which may be relevant to future studies that will plug the data transfer format gaps that have been identified.

5.3.1 Conceptual / Feasibility Studies

eEarth is the only current initiative identified in this area. It provides for the transfer of geological borehole information. The project presently has substantial funding, and a high visibility across Europe, although questions have been raised as to how it will be progressed once the current funding comes to an end in 2006.

5.3.2 Design and Interpretative Data

Currently the main methods of transfer of this type of information are through documents and drawings (spatially and non-spatially referenced). However, there is the opportunity to transfer 2D and 3D ground models and analysis models directly between applications for use by multiple users. Current and developing practice from the Oil and Mining industries could act as a starting point in this area. Whilst proprietary geological model packages are available, developments by POSC with epiSEM and RESCUE represent the main open source developments in the oil industry and XMML in the mining industry. DIGGS may venture into this area in due course for geotechnical design and interpretative data, but not in its first release scheduled for 2006.

5.3.3 Construction Information

CivilXML is the only non proprietary data transfer format identified in this field. It covers piling construction and testing data, and will be incorporated within DIGGS.

5.3.4 Asset Data

GADML, or a derivative of it, may become the geotechnical asset data transfer format within DIGGS, and DIGGS is likely to be adopted by the broad transportation data transfer format TransXML, under development in the USA.

5.3.5 General Data Transfer Formats

In 2006 Microsoft will launch XML format file types for all of their Office products (Word, Excel, Powerpoint and Access) that will replace their existing binary file formats. Microsoft are currently stating that these will be open source standards, and if this is the case, then they are likely to become widely adopted for all general data transfer. However, rival XML formats are currently in development by the open source community.

The proprietary Adobe PDF transfer format has become the de-facto standard for archive documents by its widespread usage. Rival data transfer formats have been promoted by other software vendors, but none have yet gained the extensive usage of the PDF format.

GML (and its derivatives) will probably become the open source standard for mapping data, and possibly also for CAD, although the proprietary AutoDesk DXF drawing transfer format is likely to be widely used for some time yet.

5.3.6 Project Information Management and Archiving

In 2005 a CIRIA ‘club’ project was initiated titled Project Information Management and Archiving (PIMA). The PIMA project aims to asses project requirements in this field, including practical needs to retrieve different sorts of project information for different reasons. It is anticipated that it will also look at improvements and disadvantages to moving to electronic systems, including associated risk, and the legal framework. The project will result in the production of best project guidance.

Whilst the scope of the PIMA project is broad and potentially includes data transfer formats, in that they would be used for information management and archiving, it currently is not engaging actively with this topic. Current themes being investigated are:

- Document retention, specifically legal aspects.
- Project document categorisation.
- Use of information electronically and collaboratively.

Hence, the project appears currently to be more focused on document management systems, than data transfer formats. However, it is recommended that this initiative be monitored for its future relevance in this field.

5.4 Conclusions and Recommendations for Data Transfer Format Gaps

Recommendations for Phase 2 of this project are given in Section 7 of this report. In the table overleaf brief consideration is given to those areas of Table 2 which are recommended for further study or actions and why different parts of the geotechnical project lifecycle and supply chain are subject to consideration at different levels.

Table 3 Geotechnical Data Supply Chain – Strategy for Phase 2 Recommendations for Data Transfer Formats

Stage	Level of Future Work	Breadth of Future Work	Comments	Report Section
Conceptual/ feasibility studies	High level	Broad	Data transfer associated with these types of studies are commonly related to spatial data, including many maps and plans. As such this forms a much broader field of study that just geotechnical data transfer formats.	(iii)
Investigations	In depth	Narrow	Ground investigations are the subject of well documented and used data transfer formats as discussed in Section 5.1. Concerns of the industry relate to application of the existing data transfer formats.	7.1
Design	None	None	Although there is a significant gap in the data transfer formats for design and interpretative data this has not been considered further in this report. This is due to the relatively small capital cost of design fees in relation to the lifecycle of a geotechnical asset.	None
Construction	Intermediate	Intermediate	Construction data is considered a significant gap in the current data transfer arena. However, a step-wise approach is currently recommended, starting with piling and gradually increasing in scope.	(ii)
Maintenance management	In depth	Broad	Asset management is a significant area where many UK infrastructure maintainers are currently moving forward. This provides an opportunity to assist with development of a standard data transfer format across the industry.	7.2.1
Decommissioning	Monitor	Overview	A number of independent initiatives are ongoing in this area, particularly with respect to the re-use of foundations[17] and nuclear decommissioning. It is recommended that these initiatives are monitored.	(iv)

[17] eg, REFUS, re-use of foundations on urban sites, http://www.webforum.com/rufus/home/index.asp?sid=319&mid=1

6 Training Needs and Responsibilities

Training with respect to the implementation of geotechnical data management systems and the use of geotechnical data transfer formats falls into two distinct categories.

- Users. Those who actually use and transfer the data on a regular basis, and whom would be directly benefiting from the efficiencies and standardisation. This would include geotechnical practitioners from contractors, consultants, research organisations and clients.
- Sponsors. Those whose policies require implementation of a GDMS and who will finance its development, but do not necessarily directly use the system. Sponsor will also include those who commission and specify any geotechnical works (from investigation, through design and construction to maintenance). Sponsors would typically be clients or infrastructure providers, who would gain the long term financial, safety and efficiency benefits from successful systems for geotechnical data transfer, sharing and storage.

Without suitable training and education of sponsors, development and implementation of improved geotechnical data transfer will not be achievable.

The implementation of Eurocode 7 will also place a new emphasis on transfer of geotechnical information through the supply train. Training with respect to Eurocode 7 will hence overlap with and potentially contribute to improving the data transfer processes.

6.1 Training Needs

To move forward with better use of existing data transfer formats training and education is required. Although the AGS data transfer format is widely used throughout the UK industry there are still many instances of incorrect data formatting and only partial or absent implementation of the format.

- Incorrect data formatting. This will require continued training of Users.
- Partial or absent implementation. This will require education of Sponsors, particularly those who let tenders or initiate projects.

In addition to improve practice in the future education and training will also be required:

- Sponsors. For more far sighted development of geotechnical data management systems and supporting data transfer formats.
- Users. To develop and implement geotechnical data management systems and supporting data transfer formats.

6.2 Implementation

Financial investment will be required to allow implementation of the required training. This investment will ultimately need to be sourced from the Sponsors and Users either through attendance at training sessions or through support of CIRIA's work on this project. Training will need to be carried out under the auspices of an independent body, likely either CIRIA or the AGS.

Key training areas to be addressed are included in the Phase 2 recommendations in Section 7 of this report.

7 Recommendations for Phase 2

The recommendations for Phase 2 of the CON125 project are contained within this section of the report. The recommendations draw on the evidence gathered in the preceding sections. Their implementation is designed to work towards achievement of the project aims (Section 1.3), hence delivering:

- Improved quality of current practice (refer to short term recommendations, Section 7.1).
- Improved knowledge of current best practice (refer to short term recommendations, Section 7.1.2).
- Improved scope of what can be achieved in the future (refer to long term recommendations, Section 7.2).

7.1 Short Term Recommendations

Short term recommendations are considered as those to be carried out within a one year period. They are developed around the theme of improving the quality of current practice and hence are focused on the field of data transfer for ground investigations. For this reason the AGS are to play a prominent role in delivery of these short term measures. The recommendations are given in the following sections.

7.1.1 Industry Best Practice Guidance

Improved industry best practice guidance for geotechnical data transfer needs to target the two key groups of Sponsors and Users discussed in Section 6. Whilst the majority of the guidance would relate to better implementation of the current industry standard, the AGS data transfer format, it should also seek to raise awareness of the forthcoming changes through XML adoption and DIGGS.

- Client/sponsors document. It is recommended that a CIRIA high level guidance document is produced aimed at those who commission projects and produce tender documents. This document would be short, perhaps limited to four pages, and would set out the financial and efficiency benefits of good geotechnical data management. The document would aim to link development of data management policy to implementation in a holistic manner. It would also cover how to specify use of data transfer formats such as AGS and DIGGS within the supply chain. Production of this document would be let under a separate commission for which funding has been secured.
- User guidance document. This recommended best practice document will be in the form of a manual for implementation of the AGS data transfer format. The document will consider all parts of the supply chain, from those carrying out investigations and producing AGS formatted data to those needing to utilise the data in model and design development. Hence it will be suitable for users of all types, from contractors, designers and clients and also specialists in particular fields such as laboratories or geo-environmental specialists. It is understood that the AGS are currently preparing such a document, to coincide with the release of AGS 3.2. It will be produced in three parts:
    - Specification.
    - Geotechnical guidance document.
    - Geo-environmental guidance document.

- Production of validation rules for data content checking. This would allow software validation for data content, not just structure. It is therefore recommended that a set of such rules are developed in order to encourage software development that would promote improved data quality. It is understood that the AGS are actively coordinating the production of such rules and that these will be AGS and DIGGS applicable.
- Timetable for future development. Although current practice needs improvement through the recommendations described above, current practice also needs to move forward to embrace changes that will occur with further development of data transfer formats. In particular the implementation of XML for the AGS data transfer format and subsequent adoption of DIGGS will lead to changes in current practice. Therefore two recommendations are made:
    - Liaison is maintained with the DIGGS development to allow review of drafts and their timescale with respect to the UK application. The PSG Chairman will carry this forward.
    - Publicity for the developments is actively sought in the UK geotechnical and civil engineering media. It is understood that the AGS are taking this forward.
- Contribute to the SISG. In order to promote best practice from the top down it is recommended that specifications for the use of data transfer formats are included in the updated ICE ‘Yellow Book’, as part of the current revisions to the ‘Site Investigation in Construction Series’ published by Thomas Telford. This is understood to be the case.

7.1.2 Training

In addition to the best practice guidelines described above, direct training is also recommended in order to assist in improvement of current practice.

- User training. Under the guise of the AGS it is recommended that training courses are provided in the implementation of the AGS data transfer format and the efficiencies that can be achieved by users through its successful use. It is understood that a suitable partner for these training courses has been identified and that they will be self funding.
- University teaching packs. In order to assist universities by providing teaching examples relevant to current industry practices the development of a teaching pack is recommended. The aim of the teaching pack would be to use a geotechnical data set as an example of good practice in the general field of data management. The packs would include geotechnical data sets in AGS format, software for checking of the data and setting up databases, questions and model answers. It is anticipated that the datasets would be prepared for the training courses described above and used also for the teaching packs. An individual from the PWG has been identified to produce the teaching packs.

7.2 Long Term Recommendations

Long term recommendations are considered as those to be carried out within a two to five year period. They are developed around the themes of improving the quality of knowledge in the broadest sense and also improving the scope of what the geotechnical community can achieve in the field of data transfer.

7.2.1 Infrastructure Client Forum

It is recommended that CIRIA instigate an infrastructure client forum. Such a forum would allow for interaction of key infrastructure providers, sharing lessons learnt from implementation of best practice and promote collaboration on initiatives in the field of data management throughout the supply chain.

7.2.2 Data Specific Recommendations

The following recommended actions are grouped according to their position in the geotechnical supply chain and hence may be cross referenced to the assessments made in Table 2 and Table 3.

(i) Maintenance and Asset Management Data Transfer

It is recommended that CIRIA support the development of a standard geo-asset data transfer format or other guidelines. In doing so this would require the building of a cross industry consensus and would follow on from the recommended Infrastructure Client Forum. It would be essential to bring together the relevant asset owners and maintainers as well as those developing GDMS applications for those owners. It is anticipated that this initiative would feed into the future development of DIGGS.

(ii) Construction Data Transfer

Current initiatives are already in place for the further development of construction data transfer formats. With the development of DIGGS, the AGS are currently assisting with the formulation of a standard data transfer format for piling information. It is recommended that CIRIA support this collaboration, and promote the involvement of relevant industry bodies, for example the FPS, with the aim of the data transfer format becoming the UK industry standard. In addition CIRIA should support expansion of this data transfer format to cover others areas of construction, possibly ground improvement, retaining walls or other foundation elements.

(iii) Conceptual/Feasibility Data Transfer

Conceptual and feasibility studies and typical desk study information are principally spatial in nature, commonly relating to maps, plans and drawings. The use of geological (rather than geotechnical) data at this stage in projects also relates to cross geological survey initiatives such as the eEarth project. In addition, the common use of proprietary data transfer formats, such as pdf and dxf, demonstrate that this area is extremely broad, both in terms of the data being transferred and the cross over applicability with other disciplines.

For these reasons it is recommended that a broad and high level study be carried out in the field of conceptual and feasibility study data transfer. By necessity this will have a large bias towards spatial data and general data transfer formats, but should also encompass the full range of data types relevant to the geotechnical community. This study should also aim to build links with other disciplines, particularly in the aligned field of environmental data, and could include the CIRIA PIMA project.

(iv) Decommissioning Data Transfer

It is recommended that the Steering Group (see Section 7.3 below) for Phase 2 monitor current initiatives in the field of decommissioning and decommissioning data, but that no further action is taken at this stage. It is possible that CIRIA could support such initiatives in the future, particularly in the area of re-use of foundations.

7.3 Implementation of Long Term Recommendations

In order to implement the recommendations made above a number of aspects need to be in place.

- A project steering group. This steering group would not be the same as the current PSG, but would aim to draw on a smaller, but broad, cross section of the industry. It is recommended that the steering group has attached to it a number of small working groups to implement the specific recommendations made above. The chair of each working group would sit on and report to the steering group.
- A programme and work schedule. This would be developed from the recommendations made above.
- Funding. Possible sources of funding for the work include the CIRIA core members and key infrastructure providers and data users.

Appendix A Project Working Group and Project Steering Group Details

A.1 Project Steering Group

David Patterson, Highways Agency (Chair)

Steve Walthall, AGS and Bechtel

Martin Ball, British Waterways Technical Services

Mike Black, Cross London Rail Links Ltd

Brian McGinnity, London Underground Limited

Jason Scott, Stent

Jonathan Harrod-Booth, Highways Agency

Tony Daly, Highways Agency

John Findlay, Stent & RCS

Digby Harman, Norwest Holst Soil Engineering Division

Eifion Evans, Network Rail

Anne Kemp, Atkins

Michael Williams, Landmark Information Group

James Procter, Environment Agency

Andrew McKenzie, British Geological Survey

A.2 Corresponding Members of the PSG

Salvatore Caronna, gINT Software

Thomas Lefchik, US Federal Highways

A.3 CIRIA Representatives

Dr Andrew Pitchford

Chris Chiverrell

A.4 Working Party

Tim Spink, Mott MacDonald (Chair)

Chris Power, Mott MacDonald

Fleur Loveridge, Mott MacDonald

Dr Roger Chandler, Keynetix

Dr David Toll, Durham University

Mark Rudrum, Ove Arup & Parners

Appendix B CON125 Research Project Specification

CON125 - Research Project Specification

A Review of Electronic File Formats for the Exchange of Geotechnical Information used in Transportation Schemes

Document No. SPEC No. 2213

March 2005

Version: 11.00

Prepared by: NBH/TD/DP/TS

Contents

1. OBJECTIVES

This research project will review, then develop and publish guidance on the file formats for the exchange of geotechnical/geoenvironmental information generated during ground investigations and main works for transportation schemes. The research has been prompted by the increasing exchange of information in electronic format during ground investigations and main works, and the use of database management systems and GIS to analyse and store information on a project level and for archive purposes on a national level. The project is to be biased towards the UK, but with consideration of the international perspective

The full specification objectives are to establish and publish principles of good practice on:

- The file formats available for the exchange of geotechnical data
- The recommended electronic file format for different types of information exchange
- The recommended issue media (including labeling and document control issues)
- Associated metadata.

The Project has been divided into two phases: Phase 1 to review existing information exchange and Phase 2 will be to develop and publish standards/best practice.

Phase 1 will provide recommendations for phase 2 (development of standards) in the form of a brief report developed by a Working Party consisting of specialists in this area and drawing upon industry consultation.

Phase 2 will be subject to the agreement of the Steering Group and adequate funding (*Note: Phase 1 will be entirely funded by Highways Agency but it is anticipated that Phase 2 will be financially supported by a range of interested parties).*

1.1. Background

At present, geotechnical/geoenvironmental information is requested and provided in many different file formats. The format in which the data is presented is either dependent on the software used to produce the information or the format specified in a job-specific contract. Not having a common standard presents significant problems to the users of the data, the producers of the information who are required to adapt to bespoke formats and software developers.

Geotechnical/geoenvironmental information may be supplied from, or input into the following program types:

- Word processing
- Spreadsheets
- Databases
- CAD
- Imaging
- GIS
- Numerical modelling/Design

In order to address these concerns, the overall purpose of this project is to provide suppliers, users and Clients/Owners with best practice advice and (where appropriate) Standards in this field and specific to transportation assets but as widely applicable to civil engineering infrastructure as possible.

2. CONTRACT WORK

2.1. Method

The Working Group shall form a working group to undertake the following:

- review existing electronic geotechnical information exchange formats.
- review the requirements of suppliers and users of information.
- review the import/export ability of commonly used software i.e. interoperability.
- scope potential for development of file formats where a gap is currently identified.
- Consider statutory requirements (e.g. Public Records Office, e-Government & International initiatives).
- Consider training and data quality assurance responsibilities of developers, suppliers and users.

The initial reviews need not be limited to the above items and should draw heavily on the actual experience of suppliers, users, other relevant working groups and software providers. Discussion of the findings, following consultation with these bodies, will be required in the Phase 1 report.

The project is concerned only with file formats and associated metadata. The project shall not consider the content of the files e.g. the AGS Data Dictionary, or CAD layer names/pen styles etc.

In addition to the brief summary review outlined above, the Phase 1 report shall set out a detailed brief for the development of guidance information that will be the key outcome for Phase 2 i.e. against key topic heading: working member(s), intended scope/content and programme and then how this will be drawn into a succinct and complete guide for publication.

2.2. Outputs

2.2.1.Presentation

The Working Group shall present the findings to a meeting of the Steering Group (and guests) at the end of the Phase 1 review period.

2.2.2.Report

The findings shall also be presented in an interim report, which shall be in Adobe Acrobat pdf format, distributed on CDROM. This report will not be published at completion of this phase but will provide the basis of the work to be undertaken in Phase 2.

The Working Group shall provide details of the scope, cost and programme to complete Phase 2 in an Appendix to the above report. The exact nature of Phase 2 will be decided by discussion with the Steering Group in Phase 1.

The reported outcomes from Phase 2 will be provided in a manner to be detailed by CIRIA that allows it to be transferred for publication by CIRIA (for distribution to Core Members and to the Public domain) with a minimum of delay.

Appendix C Summary of Existing Data Transfer Formats

FormatID	FormatName	FormatType	FormatDescription	FormatFileExtension	FormatFileType	SupportingOrganisation	WebAddress	Status	Ownership	ContactName	ContactEmail
1	GADML	Asset	Geotechnical asset condition information for UK Highways	.xml	XML	Highways Agency	http://www.hagdms.com/	Active	Open source	Tim Spink	tim.spink@mottmac.com
2	TransXML	Asset	XML Scheme for exchange of transportation data including: Survey/Roadway Design; Transportation Construction/Materials; Highway Bridge Structures; Transportation Safety.	.xml	XML	National Cooperative Highway Research Program (NCHRP) Project 20-64	http://www.transxml.org/	Development	Open source	Frances Harrison	fharrison@camsys.com
3	Access	Database and Spreadsheet	Relational data	.mdb	Binary	Microsoft	http://www.microsoft.com/	Active	Proprietary		
4	Comma Separated Values	Database and Spreadsheet	Tabular data	.csv	ASCII			In use	Open source		
5	dBase	Database and Spreadsheet	Relational data	.dbf	Binary	dBase Intelligence Inc	http://www.dbase.com/	Active	Proprietary		customerservice@databi.com
6	Excel	Database and Spreadsheet	Tabular data	.xls	Binary	Microsoft	http://www.microsoft.com/	Active	Proprietary		
7	Extensible Markup Language	Database and Spreadsheet	Structured data	.xml	XML			Active	Open source		
8	FoxPro	Database and Spreadsheet	Relational data	.dbf	Binary	Microsoft	http://www.microsoft.com/	Active	Proprietary		
9	Paradox	Database and Spreadsheet	Relational data	.db	Binary	Corel	http://www.corel.com/	In use	Proprietary		
10	NCCTP	Documents	Open transfer format of project files for collaborative working	.xml	XML	CIRIA	http://www.ncctp.net/standard.htm	Active	Open source	Bill Healy	ncctp@ciria.org
11	Portable Document Format	Documents	Image of formatted text	.pdf	Binary	Adobe	http://www.adobe.com/	Active	Proprietary		
12	Rich Text Format	Documents	Formatted text	.rtf	ASCII	Microsoft	http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnrtfspec/html/rtfspec.asp	In use	Open source		
13	Text	Documents	Unformatted text	.txt	ASCII			In use	Open source		
14	Word	Documents	Formatted text	.doc	Binary	Microsoft	http://www.microsoft.com/	Active	Proprietary		
15	CDX	Geoenvironmental	Central Data Exchange format for US Environmental Data	.xml	XML	Environmental Protection Agency	http://www.epa.gov/cdx/	In use	Open source		epacdx@csc.com
16	EDF	Geoenvironmental	Electronic Deliverable Format for environmental test results including subformats for laboratory analytical reports (LAB EDF), field sample chain of custody (COC EDF), field sample collection information (FIELD EDF), location information (LOCSETUP EDF) and container and method information	.txt	ASCII	ArsenaultLegg, Inc.	http://www.enabl.com/downloads/e-formats/LAB_EDF_FormatSpecs.pdf	In use	Open source		edfhelpdesk@arsenaultlegg.com
17	EQUIS	Geoenvironmental	Environmental Quality Information System		Unknown	Earthsoft	http://www.earthsoft.com/	Active	Proprietary		info@earthsoft.com
18	EVS	Geoenvironmental	3D environmental data transfer format	.pgf	Unknown	C Tech Development Corporation	http://www.ctech.com/	In use	Proprietary		evs-info@ctech.com
19	NEDTS	Geoenvironmental	Navy Environmental Data Transfer Standards (NEDTS).	.txt	ASCII	US Navy	http://thadium.spawar.navy.mil/nedts/Download.htm	In use	Open source		NEDTS@spawar.navy.mil
20	The Australian National Groundwater Data Transfer Standard	Geoenvironmental	The Australian National Groundwater Data Transfer Standard	.xml	XML	Bureau of Rural Sciences, Groundwater Committee (NGC), National Landcare	http://www.brs.gov.au/land&water/groundwater/	Active	Open source	Lorraine Bates	lorraine.bates@per.clw.csiro.au
21	Datamine	Geological	Drilling information and 3-D geological modelling data.		Binary	Datamine	http://www.datamine.co.uk/	In use	Proprietary		info@datamine.co.uk
22	DGSM	Geological	Digital Geoscience Spatial Model. Geology, structural geology, landforms, stratiraphy		Unknown	BGS	http://www.bgs.ac.uk/science/3Dmodelling/DGSM.html	In use	Proprietary	P G Robson	pgro@bgs.ac.uk
23	Earthvision	Geological	3D modelling format for proprietary software		Unknown	Dynamic Graphics Inc	http://www.dgi.com/earthvision/	In use	Proprietary		dgi@dgi.com
24	eEarth	Geological	International borehole data interchange format	.xml	XML	eContent	http://eearth.nitg.tno.nl/schema/eearth_exchange.html	Active	Open source	Alexei Tchistiakov	a.tchistiakov@nitg.tno.nl
25	epiSEM IS	Geological	EPIcentre Shared Earth Model. Petroleum industry focussed research project for transfering geological models.	.xml	XML	epiSEM Action	http://www.episem-action.org/	Development	Open source	Paul Maton	maton@posc.org
26	ESML	Geological	Earth Science Markup Language to describe the structure, semantics and content of any earth science dataset	.xml	XML	Information Technology and Systems Center University of Alabama	http://esml.itsc.uah.edu/index.jsp	Active	Open source		info@itsc.uah.edu
27	GeoSciML	Geological	Geology, structural geology, landforms and text	.xml	XML	BGS / CGI - Commission for the management and application of Geoscience Information	https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/GeoSciML	Development	Open source	Marcus Sen	mase@bgs.ac.uk
28	Micromine	Geological	Mining data processing software with proprietary data format.		Unknown	Micromine	http://www.micromine.com.au/	In use	Proprietary		mm@micromine.com.au
29	RESCUE	Geological	Petroleum industry transfer of data from geomodels through the use of the Epicenter data model		Binary	POSC (Petrochemical open standards consortium)	http://www.posc.org/rescue/	Active	Open source	Rod Hanks	rhanks@benchbuilt.com
30	SEP	Geological	Borehole information	.mdb	Binary	Geological Survey of Lower Saxony	www.nlfb.de/geologie/downloads/sep3/anleitung_SEP3.pdf	In use	Open source	Michaela Dominik	bohrdaten@nlfb.de
31	Surpac	Geological	Mining industry data transfer format		Unknown	Surpac Minex Group	http://www.surpac.com/index.html	In use	Proprietary		ssiuk@surpac.com
32	Vulcan	Geological	Mining data and 3-D mining modelling		Unknown	Maptek	http://www.maptek.com.au/products/vulcan.htm	In use	Proprietary		tech@maptek.co.uk
33	XMML	Geological	Data transfer format for Mining Industry (eXploations and Mining Markup Language)	.xml	XML	Commonwealth Scientific and Industrial Research Organisation - Exploration and Mining	http://xmml.arrc.csiro.au/	Active	Open source	Simon Cox	simon.cox@csiro.au
34	NADM	Geological	North American geological map Data Model	.xml	XML	USGS, AASG (Association of American State Geologist), GSC (Geological Survey of Canada)	http://www.nadm-geo.org/	Development	Open source	Bruce Johnson	bjohnson@usgs.gov
35	SBB	Geological	Shallow boreholes tranfer format for sales from The Netherlands National Geological Survey	.xml .txt. or .xls	Mixed	The Netherlands Institute of Applied Geoscience TNO - National Geological Survey,	http://dinolks01.nitg.tno.nl/dinoLks/about/dataTypes/bor/deliveryInfo.jsp	Active	Open source		dinoshop@nitg.tno.nl
36	LogPlot	Geological	Borehole information		Unknown	Rockware Inc	http://www.rockware.com/	In use	Proprietary		
37	Rockworks	Geological	Borehole information		Unknown	Rockware Inc	http://www.rockware.com/	In use	Proprietary		
38	WinCORE	Geological	Borehole information		Unknown	Texas DOT	http://www.dot.state.tx.us/isd/software/software.htm	In use	Open source		
39	WinLog	Geological	Borehole information		Unknown	GAEA Technologies Ltd.	http://www.gaea.ca/	In use	Proprietary		winlog.support@gaea.ca
40	Atlas CLS Field Tape	Geophysics	Oil industry well logging format		Unknown	Baker Atlas	http://www.bakerhughes.com/bakeratlas/data/index.htm	Obsolete	Proprietary		
41	BIT	Geophysics	Western Atlas Basic Information Tape data. Tape format for oil industry well logging.	.bit	Unknown	Western Atlas (now part of Baker Hughes)	http://www.bakerhughes.com/	In use	Proprietary		recall.support@bakeratlas.com
42	DLIS	Geophysics	Schlumberger geophysical logging format. Oil industry. Digital Log Interchange Standard		Unknown	Schlumberger	http://www.slb.com/	In use	Proprietary		
43	DT1	Geophysics	Ground Penetrating Radar format. Associated with PulseEKKO GPR equipment	.dt1	Unknown	Sensors and Software	http://www.sensoft.ca/products/	In use	Proprietary		support@sensoft.ca
44	DZT	Geophysics	Ground Penetrating Radar format. Associated with Geophysical Survey Systems equipment	.dzt	Unknown	Geophysical Survey Systems Inc	http://www.geophysical.com/	In use	Proprietary		
45	GeophysicalML	Geophysics	Exchange of information about geophysical acquisition/processing objects (source events, stations, receivers, bin nodes) and of data sets which are related to	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/geophysics/GeophysicalML	Development	Open source	Gary Masters	masters@posc.org
46	Geoshare	Geophysics	Geophysical logging format.		Unknown	POSC (Petrochemical open standards consortium) - originated by Schlumberger	http://w3.posc.org/GeoshareSIG/	In use	Open source	Jim Theriot	Jim.Theriot@POSC.org
47	HeaderDescriptorML	Geophysics	Details which variant of SEGY a tape represents	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/geophysics/HeaderDescriprorML	Development	Open source	Gary Masters	masters@posc.org
48	LAS	Geophysics	Log ASCII Standard files	.las	ASCII	Canadian Well Logging Society	http://www.cwls.org/las_info.php	Active	Open source	Kenneth Heslop	kenneth.heslop@las3.org
49	LIS/LIS-79	Geophysics	Geophysical logging format, now superseded by DLIS	.lis	Binary	Schlumberger	http://www.slb.com/	Obsolete	Proprietary		
50	LOG	Geophysics	Oil industry logging format		Unknown	Century Geophysical Corporation	http://www.century-geo.com/	Obsolete	Proprietary		sales@century-geo.com
51	Log II	Geophysics	Geophysical logging format		Unknown	Kansas Geological Survey	http://www.kgs.ku.edu/kgs.html	Obsolete	Open source		

FormatID	FormatName	FormatType	FormatDescription	FormatFileExtension	FormatFileType	SupportingOrganisation	WebAddress	Status	Ownership	ContactName	ContactEmail
52	LogGraphicsML	Geophysics	XML format for exchanging well log graphics	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/LogGraphicsML/	Development	Open source	Jim Theriot	Jim.Theriot@POSC.org
53	RD3	Geophysics	Ground Penetrating Radar format for RAMAC equipment	.rd3	Unknown	Mala	http://www.malags.com/	In use	Proprietary		
54	RP66	Geophysics	Petroleum industry geophysical well log format including Digital Log Interchange Standard (DLIS)		ASCII	POSC	http://posc.org/technical/data_exchange/	In use	Open source		rp66@posc.org.uk
55	SEG-2/SEG-Y	Geophysics	Seismic data format		Mixed	Society of Exploration Geophysicists	http://www.seg.org/	Active	Open source	Art Schrader	aschrader@seg.org
56	SPWLA	Geophysics	Oil industry logging format		Unknown	The Society of Petrophysicists and Well Log Analysts	http://www.spwla.org/	In use	Open source		info@spwla.org
57	WellLogML	Geophysics	XML format for exchanging well log data (aspires to supercede LAS)	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/WellLogML/	Development	Open source		iposc-WellLog@yahoogroups.com.
58	WellPlot ML	Geophysics	Format for exchanging well log related information (eg graphs)	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/WellPlotML/	Development	Open source		xmlactivity@posc.org
59	WITSML version 1.3	Geophysics	Wellsite information transfer standard markup language	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.witsml.org/	Active	Open source	Alan Doniger	Doniger@posc.org
60	AGS	Geotechnical	Geotechnical field, laboratory and monitoring data transfer format.	.AGS	ASCII	Association of Geotechnical and Geoenvironmental Specialists	http://www.ags.org.uk	Active	Open source		ags@ags.org.uk
61	AGS-M	Geotechnical	Monitoring data transfer format. Now included in AGS 3.1	.AGS	ASCII	Association of Geotechnical and Geoenvironmental Specialists	http://www.ags.org.uk	In use	Open source		ags@ags.org.uk
62	AGSML	Geotechnical	Geotechnical field, laboratory and monitoring transfer format. Incorporated within DIGGS	.xml	XML	Association of Geotechnical and Geoenvironmental Specialists	http://www.ags.org.uk/agsml	Development	Open source		agsxml@ags.org.uk
63	bch	Geotechnical	Inclinometer monitoring data file type.	.bch	Unknown	BC Hydro	http://www.bchydro.com/	Obsolete	Proprietary		
64	CivilXML	Geotechnical	Construction records - principally piling, and associated geotechnical data. Incorporated within DIGGS.	.xml	XML	Florida University / Florida DOT	http://diggsml.org/	Development	Open source		bsi@ce.ufl.edu
65	COSMOS	Geotechnical	California based geotechnical data transfer format for earthquake studies. Incorporated within DIGGS	.xml	XML	COSMOS	https://geodata.cosmos-data.org/	Development	Open source	Carl Stepp	cosmos@eerc.berkeley.edu
66	DIGGS	Geotechnical	Data interchange for geotechnical and geoenvironmental specialists. Based on AGSML, COSMOS and CivilXML	.xml	XML	Geotechnical Management System Group	http://www.diggsml.org/index.asp	Development	Open source	Marc Hoit	contact@diggsml.org
67	GEF	Geotechnical	CPT test results	.gef	ASCII	CUR (Centre for Civil Engineering Research and Codes)	http://www.geonet.nl/index.html?http&&&www.geonet.nl/3.021.html	Active	Open source	Fred Jonker	fred.jonker@cur.nl
68	GeoMil	Geotechnical	CPT test results		Unknown	GeoMil	http://www.geomil.com/	In use	Proprietary	Piet Rabouw	Rabouw@geomil.com
69	Geopoint	Geotechnical	CPT test data format		Unknown	Geopoint Systems BV	http://www.geopoint.nl/en/	In use	Proprietary		info@geopoint.nl
70	GeotechML	Geotechnical	Geotechnical field, laboratory and monitoring transfer format	.xml	XML	Electronic Journal of Geotechnical Engineering	http://www.ejge.com/GML/index.htm	Inactive	Open source	Mete Oner	ejge.editor@gmail.com
71	Gorilla!	Geotechnical	CPT test results		Unknown	A P van den berg	http://www.apvdberg.nl	In use	Proprietary		info@apvdberg.nl
72	IRPIMS/ERPIMS	Geoenvironmental	U.S. Air Force Installation Restoration Program Information Management System (IRPIMS)	.mdb	Binary	USAF	http://www.afcee.brooks.af.mil/ms/msc_irp.asp	In use	Open source		afcee.erpims@brooks.af.mil
73	NENGEO	Geotechnical	Dutch CPT test results format.		Unknown	CUR (Centre for Civil Engineering Research and Codes)	http://www.geonet.nl/index.html?http&&&www.geonet.nl/3.021.html	Obsolete	Open source	Fred Jonker	fred.jonker@cur.nl
74	NGES	Geotechnical	Geotechnical data exchange format for scientific research sites	.xml	XML	National Geotechnical Experimental Sites	http://www.unh.edu/nges/	In use	Open source	Jean Benoit	jbenoit@maple.unh.edu
75	RocProp	Geotechnical	Database of Rock Properties		Unknown	RocScience	http://www.rocscience.com/library/libraryrocprop.asp	In use	Proprietary		rocprop@rocscience.com
76	RPP	Geotechnical	Inclinometer monitoring data	.rpp	Unknown	Durham Geo Slope Indicator	http://www.slopeindicator.com/index.html	In use	Proprietary		solutions@slope.com
77	SGF	Geotechnical	CPT test results		Unknown	Swedish Geotechnical Society	http://www.sgf.net/home/index.asp?sid=876&mid=1	In use	Open source		info@sgf.net
78	SlopesML	Geotechnical	Slope stability case history format	.xml	XML	Bulent Hatipoglu	http://www.ins.itu.edu.tr/bulent/slopesml/index.h	Inactive	Open source	Bulent Hatipoglu	bulent@ins.itu.edu.tr
79	Graphics Interchange Format	Images	Raster graphics format	.gif	Binary	Unisys Corporation	http://www.unisys.com/	In use	Proprietary		
80	HPGL	Printer	Vector graphics format	.hgl	Binary	Hewlett-Packard	http://www.hp.com/	In use	Proprietary		
81	JPEG	Images	Raster graphics format	.jpg	Binary	Joint Photographic Experts Group	http://www.jpeg.org/	In use	Open source		
82	Portable Network Graphics	Images	Raster graphics format	.png	Binary			In use	Open source		png-info@uunet.uu.net
83	Portable Pixel Map	Images	Raster graphics format	.ppm	Binary			In use	Proprietary		
84	Tagged Image File	Images	Raster graphics format	.tif	Binary	Adobe	http://www.adobe.com/	In use	Proprietary		
85	Targa	Images	Raster graphics format	.tga	Binary	Truevision	http://www.truevision.com/	In use	Proprietary		
86	Windows bitmap	Images	Raster graphics format	.bmp	Binary	Microsoft	http://www.microsoft.com/	In use	Proprietary		
87	Windows metafile	Images	Vector graphics format	.wmf	Binary	Microsoft	http://www.microsoft.com/	In use	Proprietary		
88	Zsoft Paint	Images	Raster graphics format	.pcx	Binary			In use	Open source		
89	Atlas GIS	Mapping and GIS	Geographical Information System spatial data format.	.agf	Unknown	ESRI	http://www.esri.com	Obsolete	Proprietary		
90	DEM	Mapping and GIS	Digital Elevation Model.	.dem	ASCII	USGS	http://rockyweb.cr.usgs.gov/nmpstds/demstds.html	In use	Open source		nmpstds@usgs.gov
91	DLG	Mapping and GIS	USGS Digital Line Graphics mapping data	.dlg	ASCII	USGS	http://edc.usgs.gov/products/map/dlg.html	In use	Open source		
92	DXF	Drawings	Autodesk's drawing exchange file format	.dxf	ASCII	Autodesk	http://www.autodesk.co.uk/	Active	Proprietary		
93	E00	Mapping and GIS	Geographical Information System spatial data format. Transfer format for ArcInfo	.e00	ASCII	ESRI	http://www.esri.com/	Obsolete	Proprietary		info@esriuk.com
94	ERDAS	Mapping and GIS	Mapping image format	.lan or .gis or .img	Unknown	Leica Geosystems	http://www.gis.leica-geosystems.com/Products/Imagine/	In use	Proprietary		
95	GenIO	Mapping and GIS	3D engineering modelling software transfer format used by		Unknown	Bentley	http://www.bentley.com/	In use	Proprietary		
96	Geopak	Mapping and GIS	3D engineering modelling software		Unknown	Bentley	http://www.bentley.com/	In use	Proprietary		
97	GEOSPOT	Mapping and GIS	Geographical Information System image data format for satellite imagery		Binary	Spot Image	http://www.spotimage.fr/html/_167_.php	In use	Proprietary		info@spot.com
98	GML	Mapping and GIS	Geography Markup Language	.xml	XML	Open Geospatial Consortium	http://www.opengis.net/gml/	Active	Open source	Carl Reed	creed@opengeospatial.org
99	GRASS	Mapping and GIS	File format for Geographic Resources Analysis Support System open source GIS		Unknown	Baylor University	http://grass.baylor.edu/ http://www.grass.itc.it/	In use	Open source		
100	LandGML	Mapping and GIS	Incorporates spatial data used by designers, contractors and surveyors using GML 3.	.xml	XML	Open Geospatial Consortium	http://www.landxml.org/landxml-gml.htm	Active	Open source		landxml@landxml.org.
101	LandXML	Mapping and GIS	Incorporates spatial data used by designers, contractors and surveyors. Interoperability with MX.	.xml	XML	Open Geospatial Consortium	http://www.landxml.org/	Active	Open source		landxml@landxml.org.
102	LAS	Mapping and GIS	Interchange format for LIDAR data	.las	ASCII	American Society for Photogrammetry and Remote Sensing (ASPRS)	http://www.lasformat.org/	Active	Open source		
103	MIF / MID	Mapping and GIS	MapInfo data transfer files	.mif or .mid	Binary	MapInfo	http://www.mapinfo.com/	In use	Proprietary		
104	MOSS	Mapping and GIS	as MX		Unknown	Bentley	http://www.bentley.com	Obsolete	Proprietary		
105	SDSFIE	Mapping and GIS	Spatial data standard for facilities, infrastructure and environment. US military standard, adopted for USACE		Unknown	US Army Corps of Engineers	http://tsc.wes.army.mil/products/TSSDS-TSFMS/tssds/html/	In use	Open source	Toby Wilson	james.t.wilson@erdc.usace.army.mil
106	SDTS	Mapping and GIS	Spatial data transfer standard. Mandatory compliance for US federal agencies		Mixed	American National Standards Institute (ANSI)	htttp://mcmcweb.er.usgs.gov/sdts/whatsdts.html	In use	Open source	Robert Rinehart	rrinehart@usgs.gov

FormatID	FormatName	FormatType	FormatDescription	FormatFileExtension	FormatFileType	SupportingOrganisation	WebAddress	Status	Ownership	ContactName	ContactEmail
107	TIGER	Mapping and GIS	Topologically Integrated Geographical Encoding and Referencing Files. Line based.		ASCII	US Census Bureau	http://www.census.gov/geo/www/tiger/	In use	Open source		tiger@census.gov.
108	XYZG	Mapping and GIS	Rockworks 3D model transfer format		ASCII	Rockware Inc	http://www.rockware.com/	Inactive	Proprietary		tech@rockware.com
109	eosML 1.0	Petroleum Geoscience	Project to develop and distribute a standardized XML specification for the description of fluid system properties using compositional equation of state (EOS) models	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/eosML/	Development	Open source	Gary Masters	masters@posc.org
110	ProductionML	Petroleum Geoscience	Standardized, XML-based production reporting	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/ProductionML	Development	Open source	John Bobbitt	bobbitt@posc.org
111	WellHeaderML	Petroleum Geoscience	A basic well information data exchange standard with an evolving global base schema and country by country profile	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/	Development	Open source		info@posc.org
112	WellPathML	Petroleum Geoscience	A general-purpose directional survey data transfer specification	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/	Development	Open source		info@posc.org
113	WellSchematicML	Petroleum Geoscience	A standardized XML specification for the description of well schematics, including wellheads, boreholes, tubulars and	.xml	XML	POSC (Petrochemical open standards consortium)	http://www.posc.org/ebiz/WellSchematicML	Development	Open source	John Bobbitt	bobbitt@posc.org
126	DWG	Drawings	AutoDesk's drawing file format	.dwg	ASCII	AutoDesk	http://www.autodesk.co.uk/	Active	Proprietary		
127	Microstation	Drawings	Microstation drawing file format	.dgn	Binary	Bentley	http://www.bentley.com/	Active	Proprietary		
128	Shape	Mapping and GIS	ESRI ArcView GIS file format	.shp	Binary	ESRI	http://www.esri.com/	Active	Proprietary		
129	Encapsulated postscript	Printer	Vector graphics format	.eps	ASCII	Adobe	http://www.adobe.com/	In use	Proprietary		
130	Atlas BNA	Mapping and GIS	Atlas GIS file format	.bna	Unknown	ESRI	http://www.esri.com	Obsolete	Proprietary		
131	Surfer boundary	Mapping and GIS	Surfer vector boundary file format	.bln	ASCII	Golden Software	http://www.goldensoftware.com/	In use	Proprietary		
132	Surfer grid	Mapping and GIS	Surfer gridded data file	.grd	ASCII	Golden Software	http://www.goldensoftware.com/	In use	Proprietary		