Standardized Geotechnical Data Formats: Applications and Examples using the Argus Geotechnical Database

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Standardized Data Exchange Format

- Objective of presentation is to provide an update and specific examples regarding "standardized data exchange formats" and discuss how these can be incorporated into a project (or agency) database
- Show how to introduce new data, how to convert previous entered data, and how the use of a robust database that incorporates at least the basic elements of a standard data exchange formats can be used on geotechnical projects
- Provide examples of instrumentation and construction data visualization, recognizing that other datasets of interest to this audience may include geotechnical boring logs, laboratory testing results, and overall underground geotechnical information management

Standardized Geotechnical Data Formats: Applications and Examples using the Argus Geotechnical Database

- What is a Standardized Geotechnical Data Format?
- Why use a Standardized Geotechnical Data Format?
- OK, I am Sold…What Do I Need To Do?
- Why Do I Have to Wait?
- What is the Argus Geotechnical Database?
- Examples and Applications

What is a Standardized Geotechnical Data Format?

Established set of rules to describe geotechnical data

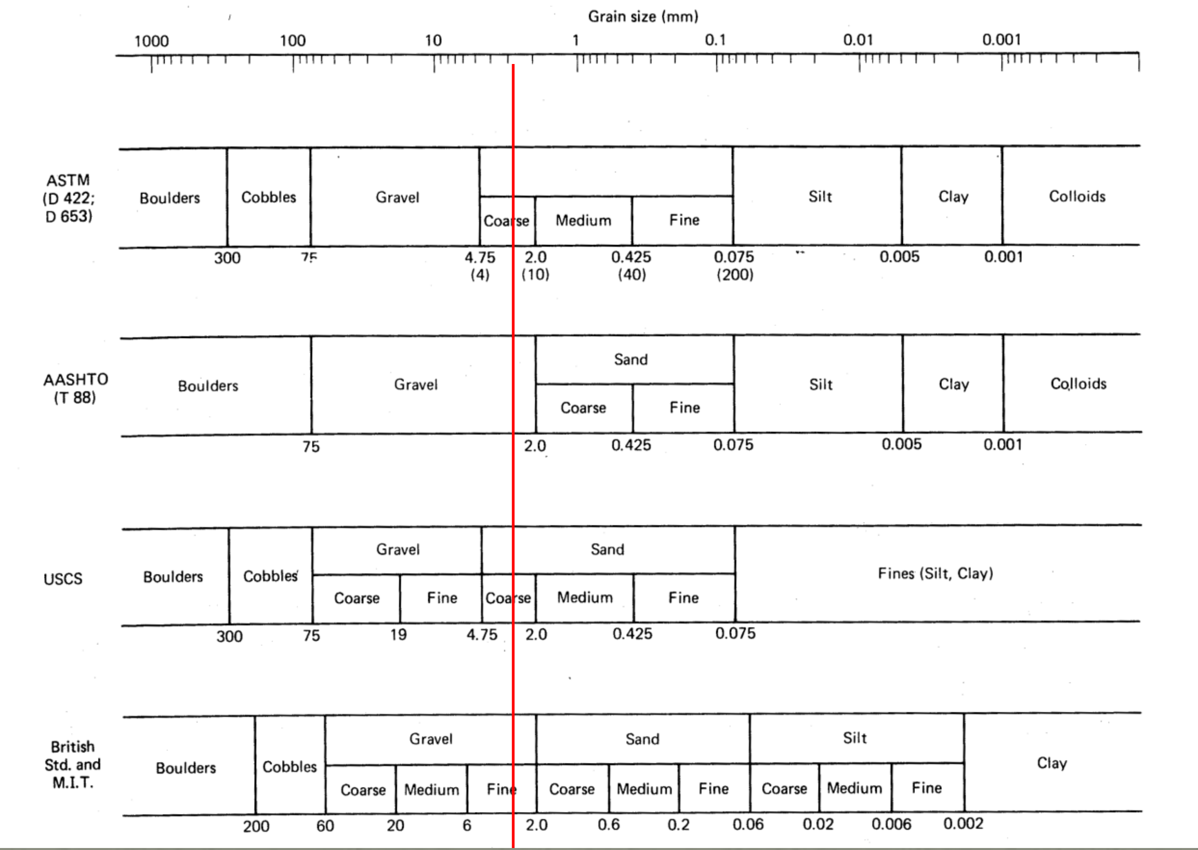
- Requirements of data (i.e., compulsory information, including “required fields”, and “primary keys”)
- Type of data (e.g., text string, date, number)
- Format of the data (e.g., integer vs. decimal, date style, field length)

What is a Standardized Geotechnical Data Format?

Established set of rules to describe geotechnical data

- Relationship between tables (e.g., project data, boring location data, test result data)
  - Boring locations stored in one table, boring log data stored in *related* table
  - Boring and sounding data reflects different information at specific depths
    - blow count, sample description
    - tip resistance, sleeve friction, pore pressure
    -
  - Laboratory data reflects information at specific depth
    - moisture content includes single specimen
    - triaxial test results may include three related tests

Why Standardize Geotechnical Data?



Holtz & Kovacs, 1981

- A 3.0 mm grain of soil can be “Coarse Sand”, “Gravel”, or “Fine Gravel” – depending on what classification is being used.

Why use a Standardized Geotechnical Data Format?

- Why do we use the English language at this conference?
  - It facilitates communication
  - "It easier makes life if rules common we follow"
- Why do we have dictionaries?
  - We have unique meanings for our words
  - It provides (but limits) options
- What does this have to do with a Standardized Geotechnical Data Format?
  - In a word.....everything!

Why use a Standardized Geotechnical Data Format?

"Everything", you say??

- You had previously adopted LogPlot to prepare boring logs but your new boss decides to switch to gINT
- Your consultants use LogPlot, gINT, MicroStation, AutoCAD, and a custom database to prepare logs and you now have a really big project and you would like to use all of your consultants, but would prefer a way to prepare common logs
- You do not know which program you will use and do not know which vendor to believe is "the best"

Why use a Standardized Geotechnical Data Format?

Everything, you say??

- Allows you to apply good database practices by storing, documenting, and sharing data effectively
- Gives you an opportunity to select any software package you desire
- Allows you to interchange and exchange data into your custom application
- Vendors and developers would be able to innovate and improve products because they do not have to "translate" every client's data
- You can hopefully learn from others and not be worried about "reinventing the wheel"

Why use a Standardized Geotechnical Data Format?

Others are doing it

- Environmental analytical data:
  - USEPA Electronic Data Deliverables (EDDs)
- Computational instrumentation data:
  - Standard Data Format (SDF) for Analyzers (Hewlett-Packard)
- Weather data:
  - ESWD (European Storm Agencies) – used to standardize severe weather report data

Why use a Standardized Geotechnical Data Format?

Best of Both Worlds

- Tasks and software that are designed to accept the standard format can use it directly
- Tasks and software that are not compatible with the format can be used via a “data translator” that converts between the standardized and proprietary formats
  - Once translated INTO the standardized format, data are de facto quality-controlled and documented…no need to document any additional “schemas”

OK, I am Sold…What Do I Need To Do?

- Follow instructions, follow the rules, learn the language (or learn where the language is described) and reference the dictionary
- Geotechnical engineers have recently recognized the benefits of incorporating "standardized" data management concepts
- Efforts focused on development of a standardized "data exchange format"
  - Association of Geotechnical and Geoenvironmental Specialists (AGS) in the U.K first by an ad hoc group of practitioners
  - Consortium of Strong Motions Observation Stations (COSMOS) by a public/private consortium of organization desiring to share ground motion information
  - Data Integration for Geotechnical and Geoenvironmental Specialists (DIGGS) format in the U.S. under pooled-fund study from FHWA

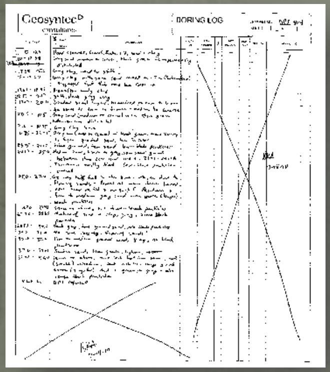
Standardized Data Exchange Format

- One of the obstacles to the widespread implementation of these standardized data formats is that they are (as the name implies) standardized formats for the exchange of geotechnical information
- A data exchange format is not a standardized data format that can be readily implemented into a relational database
- One does not develop a database to mimic an exchange format
- There has been little previous discussion or physical demonstration in the U.S. regarding how to include the standard data exchange format into a new or existing relational database…. until now

Example Using LogPlot

Old School

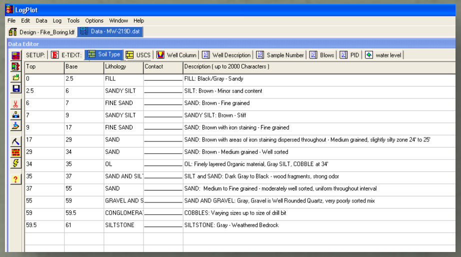
Raw Data



Project Specific Spreadsheet or Database

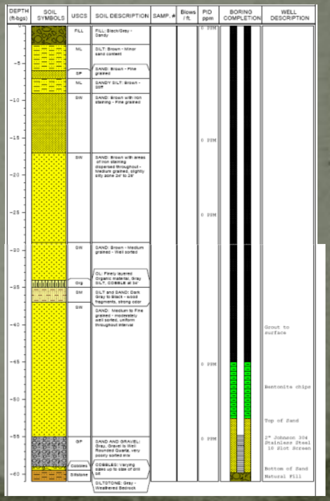
	A	B	F	G
1	DPT-414			
2				
3				
4	Depth (ft bgs)			
5	Top	Bottom	Description	
6	0	10	Fill, gravel/rocks, clay, sand	
7	10	12.58333	sand	
8	12.58333	15	clay	
9	15	17.66667	clay	
10	17.66667	18.33333	clay	
11	18.33333	19.16667	clay	
12	19.16667	20	sand	
13	20	21.5	sand	
14	21.5	21.75	clay	
15	21.75	23.75	sand	
16	23.75	24.16667	sand	
17	24.16667	25	sand	
19	25	27	sand	
20	27	27.91667	sand	
21	27.91667	28.83333	sand with clay	
22	28.83333	30	sand	
24	30	35	no recovery	
25	35	37	sand	
26	37	39.41667	sand	
27	39.41667	42	sand+gravel	

LogPlot Input Interface



LogPlot Input File

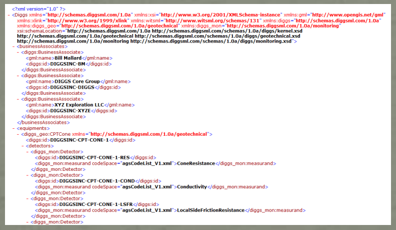
Plot



or

New School

Standardized Data File



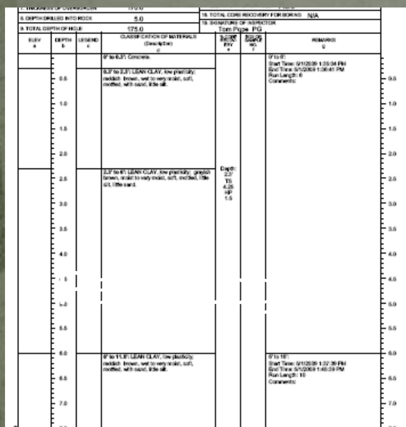
AGS/DIGGS Translator

AGS Association of Geotechnical & Geoenvironmental Specialists

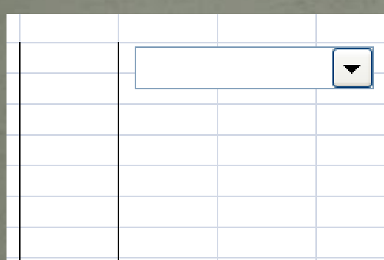
DIGGS DATA INTERCHANGE FOR GEOTECHNICAL AND GEOENVIRONMENTAL SPECIALISTS

Standardized Data Format for Core Logging

Capture Data



Electronic Form



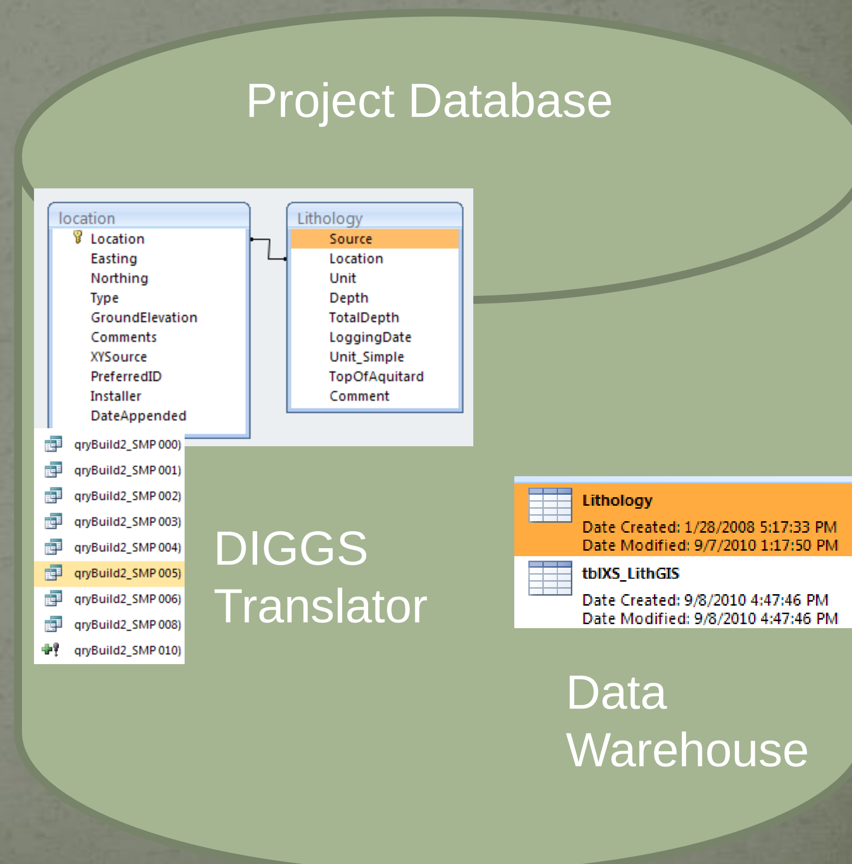
User-Specified Format

BORING	START	STOP	CLASS
GP-1-10	0.0	9.0	FILL
	9.0	11.0	SP
	11.0	18.0	ML
	18.0	19.0	OL
	19.0	25.0	ML
	[illegible]	[illegible]	SP
	25.5	29.0	ML
	29.0	30.0	GW
	30.0	35.0	ML
	35.0	38.0	SP

Location	Depth	Unit
B1	10.5	FILL
B1	13.5	CL
B1	18	ML-OL
B1	[illegible]	CL
B1	40	CL
B-1_1986	14	FILL
B-1_1986	15.5	ML
B-1_1986	18	SM
B-1_1986	24	ML
B-1_1986	25.5	SM

Standardization

Standardized Data



Standardized Data Format Workflow for Core Logging

1. Geologist logs core directly into a tablet PC with an electronic field form (enter borehole ID start depth, end depth, lithology, observations for each segment)

2. Field form transmits data to a translator which reformats the logged data into the DIGGS geology table format, and appends data to master database (which has coordinate information for each borehole)

3. Master database is used as source for computer model, GIS, CAD, etc.

4. Later on, database manager exports all project core data in DIGGS format (export file)

5. Export file is used as input to other software packages that use DIGGS format…

The DIGGS Format

DIGGS
DATA INTERCHANGE FOR GEOTECHNICAL AND GEOENVIRONMENTAL SPECIALISTS

- Developed through the Transportation Pooled Fund Study (TPF 5(111)) and coordinated by the Ohio Department of Transportation.
- Designed to help State DOTs efficiently capture, store, retrieve, and share geotechnical data and information internally and externally.
- Data structure that defines the form and content of the data
- Learn more at www.DIGGSML.com

Contributors:

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Earthsoft
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Federal Highway Administration (FHWA) - Ohio Division Office
Florida Department of Transportation
Georgia Department of Transportation
gINT Software Inc.
Indiana Department of Transportation
Kentucky Department of Transportation
Keynetix Ltd
Minnesota Department of Transportation
Missouri Department of Transportation
Mott MacDonald
North Carolina Department of Transportation
Ohio Department of Transportation
Petrochemical Open Standards Consortium
Tennessee Department of Transportation
United Kingdom Highways Agency (UKHA)
United States Army Corps of Engineers (USACE)
United States Environmental Protection Agency (U.S. EPA)
United States Geological Survey (USGS)
United States Navy
University of New Hampshire

DIGGS Data Dictionary

Example Table Description http://www.diggsml.com/

Geotechnical.MoistureContent

Contents

Derived from Kernel.LaboratoryTest

Related table

Status	Heading	Unit	Description	Example
	[illegible]		The language that strings in this DIGGSML Object are _predominantly_ written in (this can be redifined on a per-property level). As per RFC3066 at http://www.ietf.org/rfc/rfc3066.txt	
	associatedFiles	AssociatedFile	Reference to a set of external files associated with this Object	
	remarks	Remark	Any general remarks about this Object	
	equipment	Reference	Equipment relevant to this Object	
	roles	Role	Business Associates (companies or individuals) who have a role in the activity described in this item	
	specificationReferences	Reference	A link to the Specification that provides definitions of the procedure(s) used for this Object	BS5930
	status	gml:CodeType	The status of this item	Preliminary, Draft, Archive
Mandatory	id	Identifier	The unique identifier of this Object	DIGGSINC-BH127
	ources	Reference	The sources that this test applies to.	
	[illegible]	ArbitaryTimeSpan	Date and Time this test was conducted (start and optional duration / end)	

Field name

Required field

Related field

Documentation already provided

Reality of the DIGGS Format


```
<?xml version="1.0" ?>
- <Diggs xmlns="http://schemas.diggsml.com/1.0a" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:gml="http://www.opengis.net/gml"
    xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:witsml="http://www.witsml.org/schemas/131" xmlns:diggs="http://schemas.diggsml.com/1.0a"
    xmlns:diggs_geo="http://schemas.diggsml.com/1.0a/geotechnical" xmlns:diggs_mon="http://schemas.diggsml.com/1.0a/monitoring"
    xsi:schemaLocation="http://schemas.diggsml.com/1.0a http://schemas.diggsml.com/schemas/1.0a/diggs/kernel.xsd
    http://schemas.diggsml.com/1.0a/geotechnical http://schemas.diggsml.com/schemas/1.0a/diggs/geotechnical.xsd
    http://schemas.diggsml.com/1.0a/monitoring http://schemas.diggsml.com/schemas/1.0a/diggs/monitoring.xsd">
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        <gml:name>Bill Mallard</gml:name>
        <diggs:id>DIGGSINC-BM</diggs:id>
      </diggs:BusinessAssociate>
    - <diggs:BusinessAssociate>
        <gml:name>DIGGS Core Group</gml:name>
        <diggs:id>DIGGSINC-DIGGS</diggs:id>
      </diggs:BusinessAssociate>
    - <diggs:BusinessAssociate>
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        <diggs:id>DIGGSINC-XYZE</diggs:id>
      </diggs:BusinessAssociate>
    </businessAssociates>
  - <equipments>
    - <diggs_geo:CPTCone xmlns="http://schemas.diggsml.com/1.0a/geotechnical">
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            <diggs:id>DIGGSINC-CPT-CONE-1-RES</diggs:id>
            <diggs_mon:measurand codeSpace="agsCodeList_V1.xml">ConeResistance</diggs_mon:measurand>
          </diggs_mon:Detector>
        - <diggs_mon:Detector>
            <diggs:id>DIGGSINC-CPT-CONE-1-COND</diggs:id>
            <diggs_mon:measurand codeSpace="agsCodeList_V1.xml">Conductivity</diggs_mon:measurand>
          </diggs_mon:Detector>
        - <diggs_mon:Detector>
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            <diggs_mon:measurand codeSpace="agsCodeList_V1.xml">LocalSideFrictionResistance</diggs_mon:measurand>
          </diggs_mon:Detector>
        - <diggs_mon:Detector>
```

DIGGS – A Closer Look

DIGGS looks great on paper, but real-world implementation appears to be very difficult. The devil is in the details:

- DIGGS is admittedly still in its infancy – significant challenges lay ahead in terms of implementation
- DIGGS is in a “Beta Version” and is still undergoing changes
- Commercial Software Vendors are struggling to incorporate DIGGS
- Instrumentation Manufacturers have not adopted the format
- In tough economic times, state and federal agencies have little incentive (and stomach) to fund and implement research initiatives

DIGGS – Hope for the Future

Conclusions/Predictions:

- DIGGS has emerged in the US to meet the growing need for a standardized geotechnical data exchange format
- In the short term, DIGGS will continue to evolve and grow to become more useful to the Geotechnical Community
- It will be some time before the use of DIGGS results in cost savings on a broad range of projects
- In the foreseeable future, a standardized geotechnical data exchange format such as DIGGS will become the de facto standard of practice

A Look Across the Pond: The AGS Format

AGS Association of Geotechnical & Geoenvironmental Specialists

- Association of Geotechnical and Geoenvironmental Specialists (AGS) is a UK-based trade organization – look at www.ags.com

- Members include:
  - GI contractors
  - Consulting Engineers
  - Software Developers
  - Laboratory Testing facilities

- Developed a data transfer format (AGS v1) in 1992

- Currently developing AGS Version 4

AGS Usage

According to the AGS:

- Most UK contractors can produce the data
- Most UK major clients ask for the data in their contracts
- Most major consultants ask for and receive the data
- Users are requested to register with the AGS – currently 108 registered users
- A number of high profile projects have used AGS data transfer
- Used successfully for monitoring data

However:

- Most contractors use proprietary software to produce the data and others use in house Excel scripts to produce the transfer file
- A significant part of the UK geotechnical work load is for small projects and electronic data is not typically used.

Source: Walthall, 2009

Why Do I Have To Wait?

- With a defined structure and data dictionary, geotechnical engineers can start to benefit and software vendors can more easily produce solutions
- Unfortunately, both DIGGS and AGS will take time to be fully implemented into U.S. geotechnical practice, but it is inevitable
- However, please do NOT let this eventuality stop you from starting now, because there are benefits in adopting Standard Data Formats.....
- Case Study: Geotechnical Monitoring Instrumentation Data Management using Argus

What is Argus?

- For this discussion, the Argus database will be introduced and specific techniques will be demonstrated regarding the incorporation or introduction of the standardized data fields
- Argus is a *proprietary* database that can read a *standard* data file format
- Extensively used for instrumentation data currently

Instrumentation, Testing & Monitoring Ltd

Argus – Project Database

- ITM has been developing and implementing IMS for Geotechnical and Structural Instrumentation since early 1990's (pre MS Windows)
- ITM currently owns a working and proven suite of IMS including the open source (Linux/Apache/MySQL/PHP) web based "Argus"
- Argus stores data into a relational enterprise database (MySQL), which:
  - performs the required calculations on the data
  - presents the results in graphical and numerical format (creating automated PDF reports and more)
  - generates alarm messages

Argus – Project Database

- Argus interacts with users via web-browser without the need to install any software on the work stations (Software-as-a-Service model) and provides a level of visualization
- Argus is platform-independent and can be accomplished from the local network or, when connected to the Internet, from any location in the world
- Argus (and predecessor I-Site) has been in use in many active projects in the UK and all over the world including USA, Germany, Asia, Australia and Russia
- Example projects include:
  - Landslide Monitoring (Ireland)
  - Ground Improvement (Scotland)
  - Railway Emergency Notification (London)

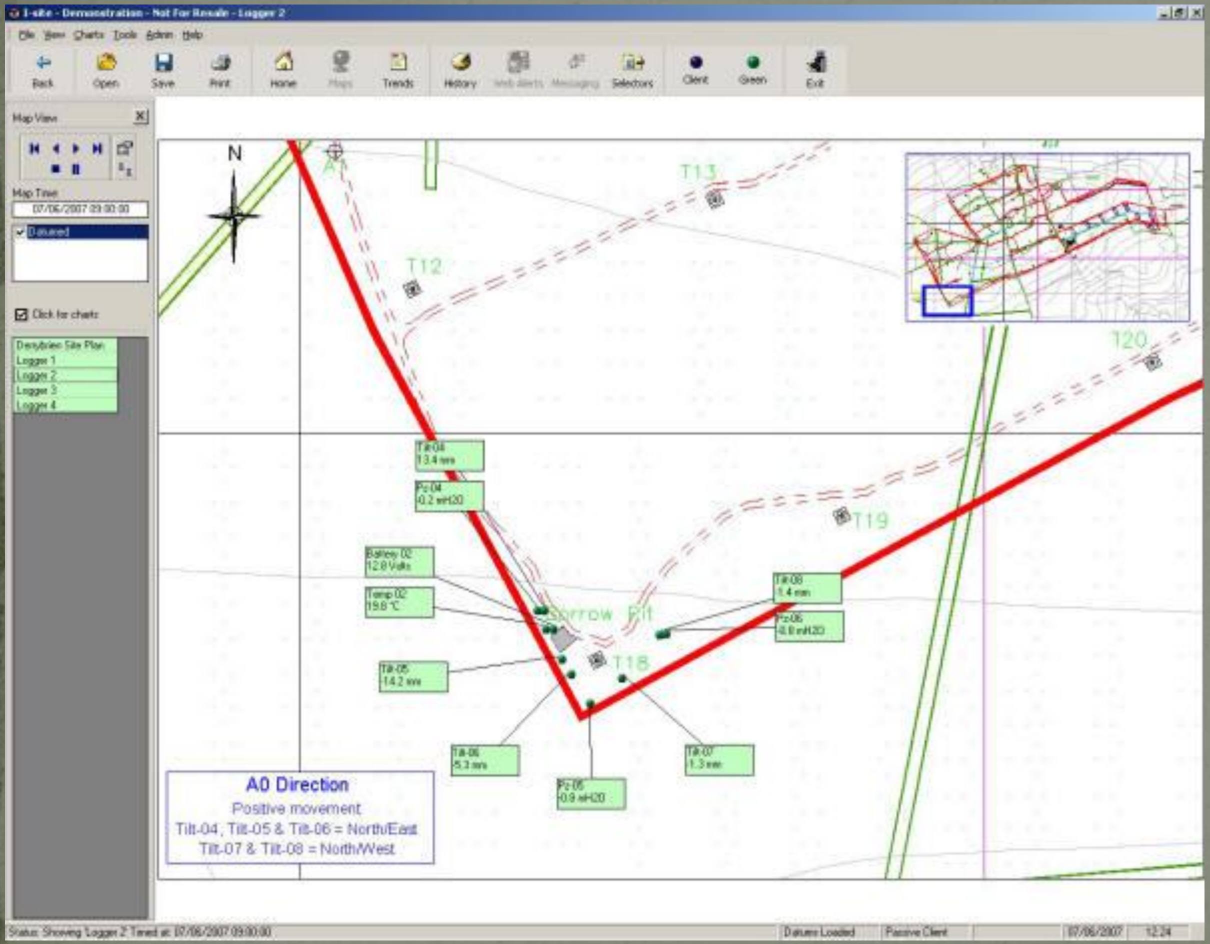
Landslide Monitoring

- **<u>Location</u>**: Wind Farm in Ireland

- **<u>Scope of Work</u>**:
  - Use In Place Inclinometers (IPIs) and piezometers to monitor performance of active landslide
  - Use radio transmission to post data
  - Double-click on data box to see time series

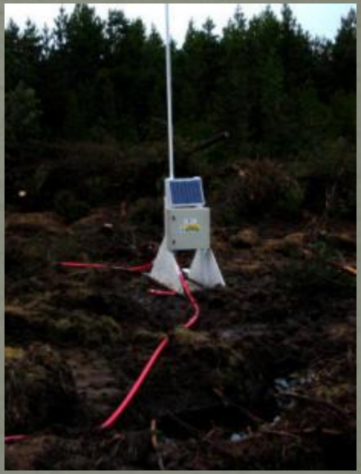
- **<u>Alert Notification</u>**: If rate of movements are exceeded, alarm notification is provided

Landslide Monitoring - Ireland



Plan Map of Site and Instrument Locations/Readings

Site underlain by Peat



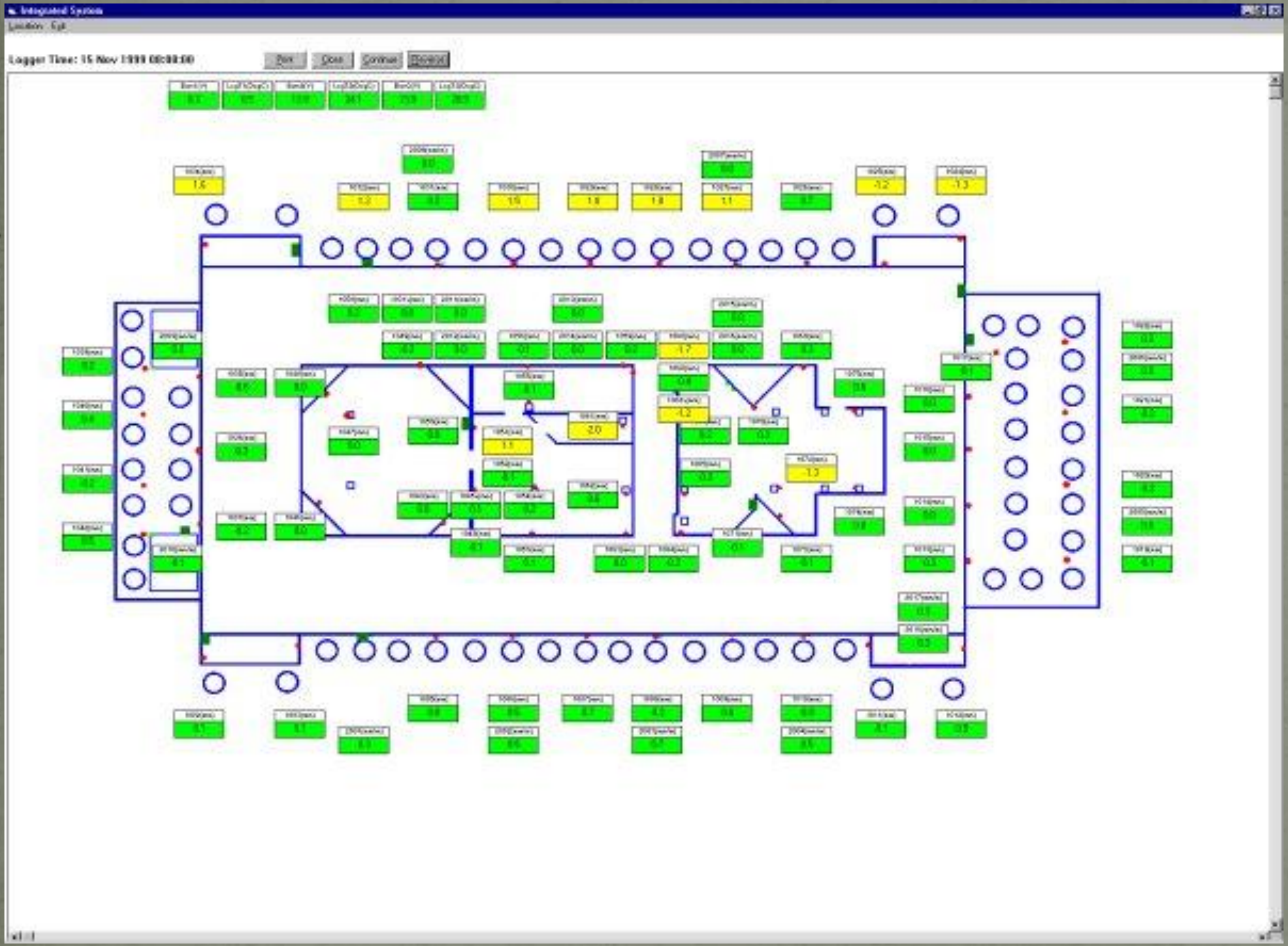
Radio Transmission

Ground Improvement - Scotland

- **Location**: Royal Scottish Academy – Edinburgh, Scotland
- **Scope of Work**:
  - Structural monitoring during compensation grouting
  - Use liquid level sensors and radio transmission
- **Alert Notification**: Automated alarm system if differential settlement is detected

Ground Improvement - Scotland

Liquid Level Sensor



Plan View of Site and Sensor Location

Work at Site

Hooley Cut Project - London

- **Location**: Just north of the M25 on the London to Brighton line just outside Coulsdon.

- **Scope of Work**:
  - Monitor rock fall netting on the cutting by measuring the bulging in the netting through draw wire mounted on the king pile wall
  - Sensors are read 4 times a second and stored each hour the unless there is an alarm where the data is stored instantly
  - Data logger is backed up with two cameras one wide angle and one telephoto these all make use of a 3G router track side.

- **Alert Notification**: Network rail view the data in Argus and receive text and email alerts. Should an alert is received they use the cameras to assess if the trains need to be slowed or even stopped.

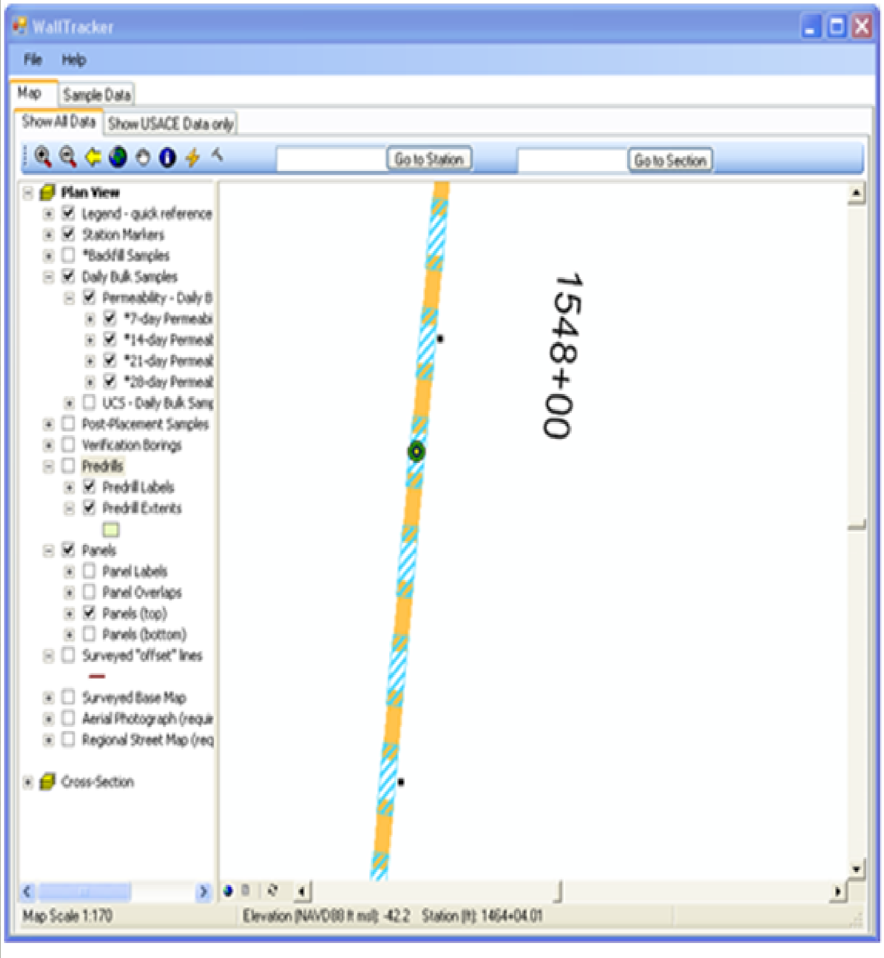
Hooley Cut Project - London

- **<u>Reasons for Monitoring</u>**:
  - Monitor any rock falls or embankment movement that has the potential to block the track and derail the trains
  - Lost train minutes cost tens of thousands of pounds a minute

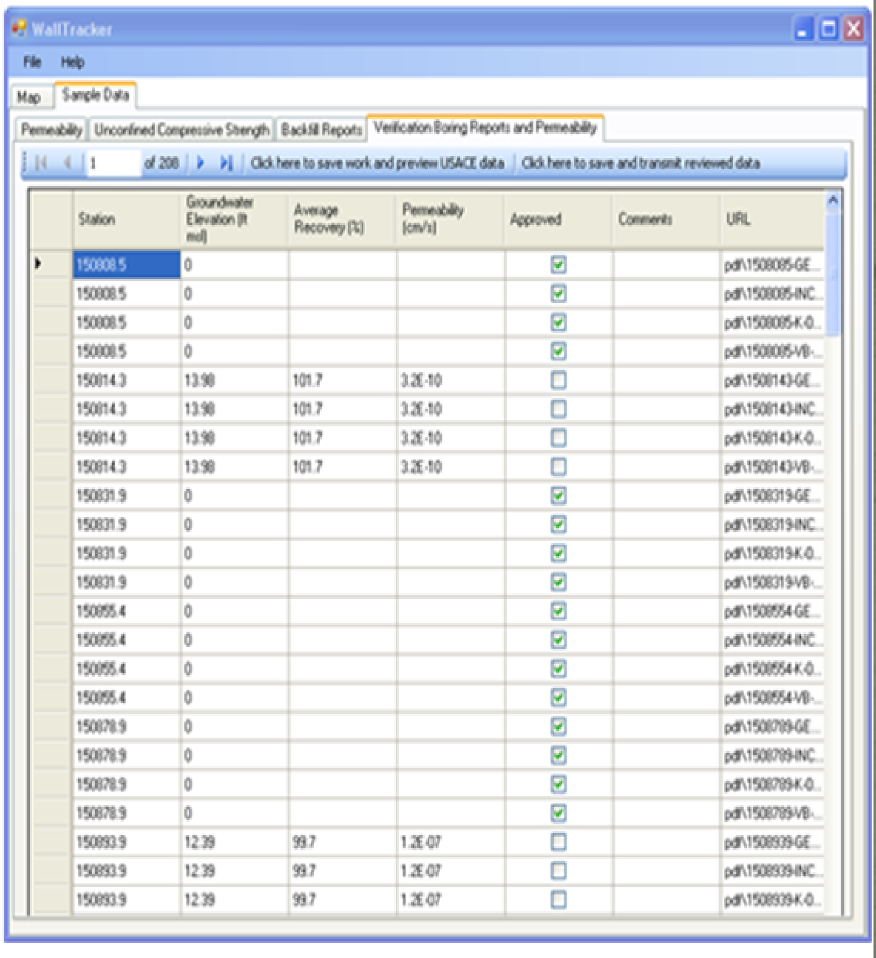
Next Generation of Argus

- Fully compatible with AGS data format
- Potentially compatible with DIGGS (???)
- GIS interface developed using both ESRI and Open Source applications
  - Construction monitoring of staged construction using geotubes in New York
  - Underground Construction Information Management System (UCIMS) for Crossrail beneath London
  - Construction monitoring for installation of hydraulic barrier for Herbert Hoover Dike, Lake Okeechobee , FL

Geographic Information System

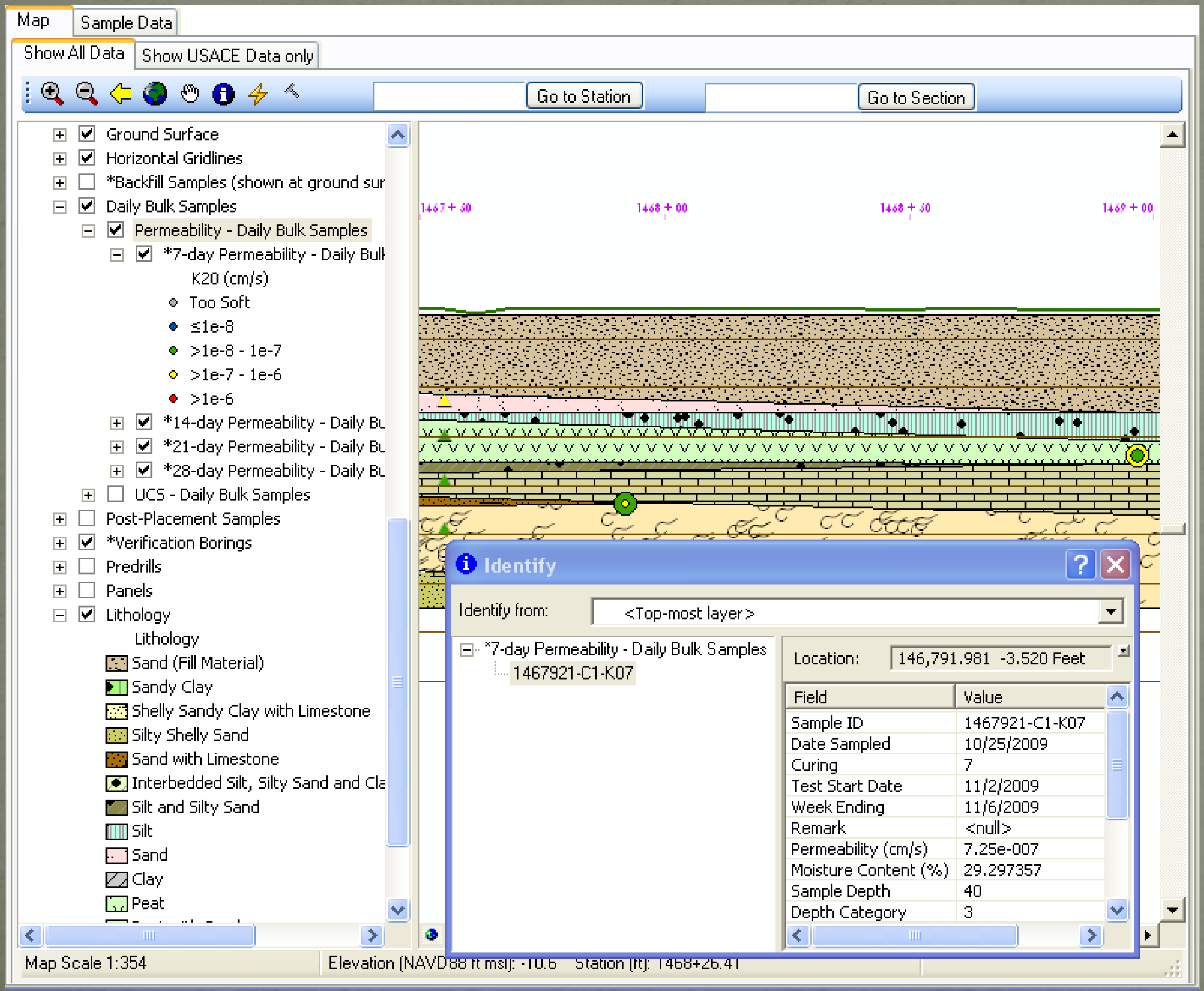


Plan View



Tabulated Data

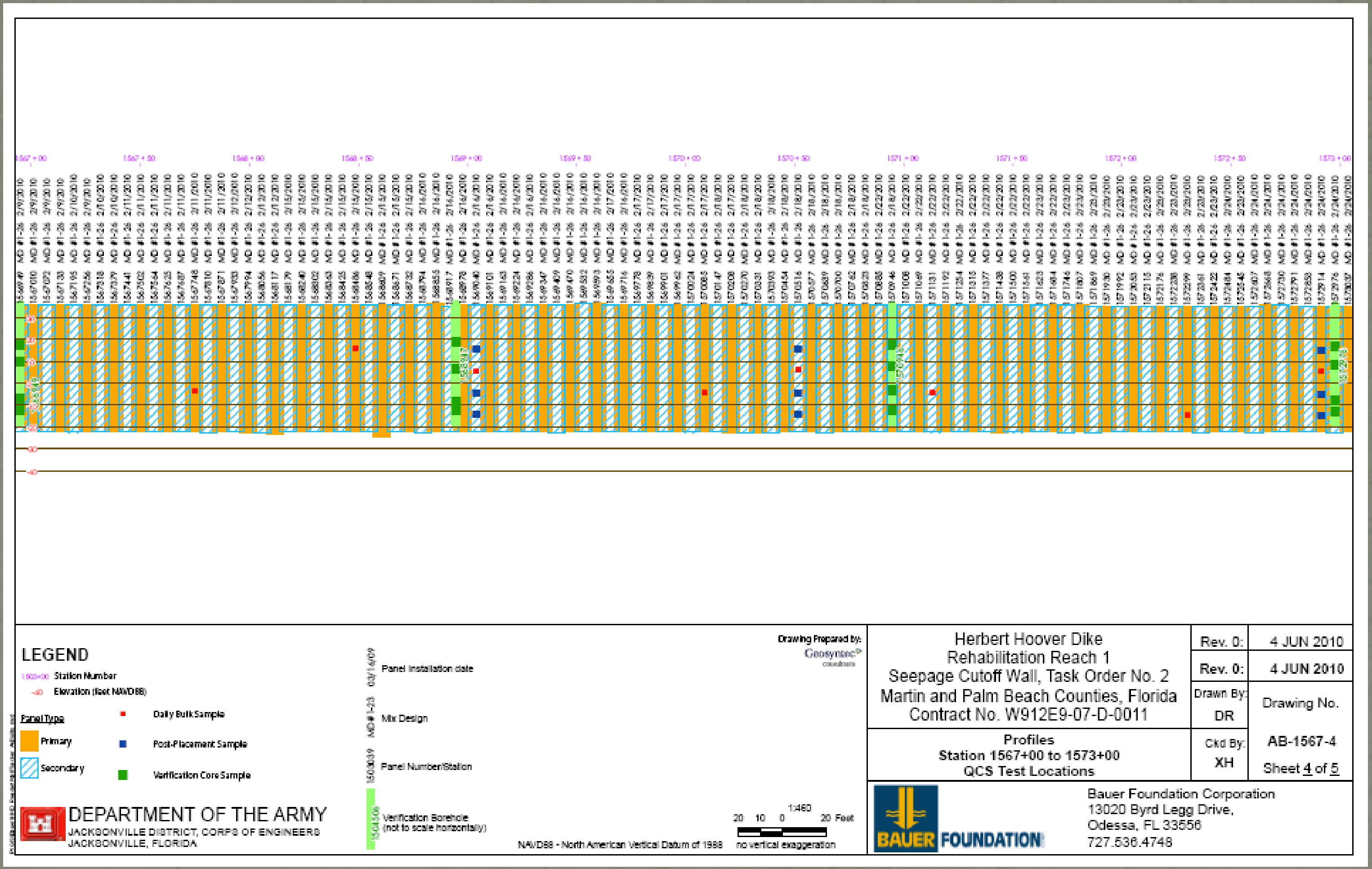
Geographic Information System



Cross-section Representation

Identify or Hyperlink

Geographic Information System

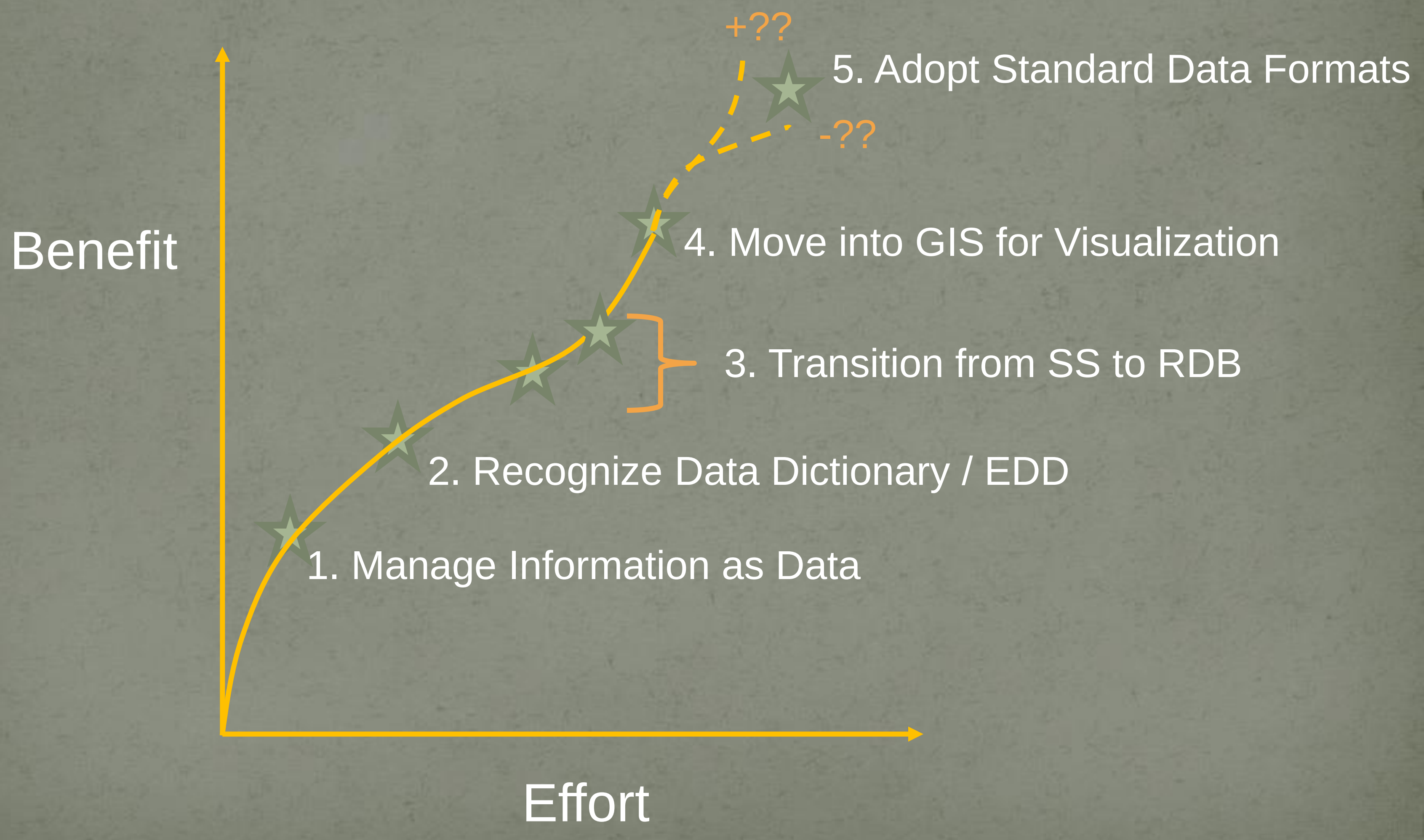


As-built Drawings Generated Automatically

So….What is Next???
The Five-step Program

- Step 1: Manage your geotechnical information as Data
  - For lab testing, use a LIMS system or spreadsheet (min)
  - For field investigation/testing, use plotting software
  - Force consultants to do the same and provide to you
- Step 2: Become familiar with a Data Dictionary (DD) and develop Electronic Data Deliverable (EDD) formats
- Step 3: Start to transition from the spreadsheet (SS) to the relational database (RDB)
- Step 4: Move into the Geographical Information System (GIS) world of data visualization
- Step 5: Adopt the Standardized Data Exchange Format of AGS and/or DIGGS

The Five-step Program



Summary and Conclusion

- Standardized data management concepts are not quite where we want them, but we are getting close and agencies should now be adopting electronic data management
- In the absence of a fully functioning standard data exchange format, recognize benefits of the five-step program
- Argus allows web-based deployment and is compatible with standard data formats

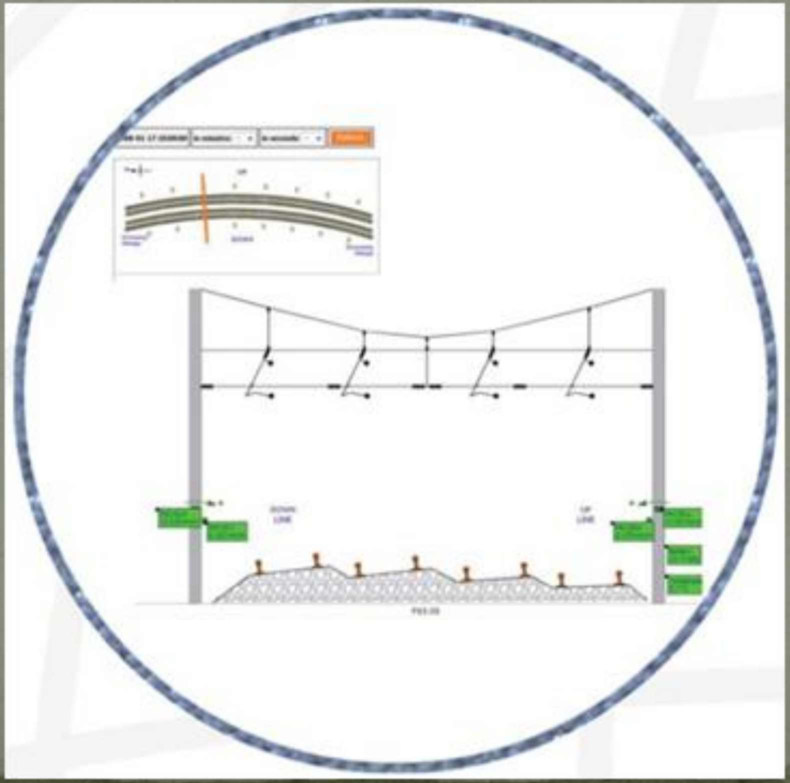
Don't Give Up…… because
I'll be Back!

Croft Spa Project

- **Location**: Near Darlington on the East Coast main line railway in the UK
- **Scope of Work**:
  - Use radio tiltmeters to monitor the overhead catenaries
  - Readings taken hourly; data downloaded twice a day
- **Alert Notification**: Automated alarm system is not implemented.

Croft Spa Project

- **Reason for Monitoring**:
  - Monitoring due to the movement in the embankment which is making the catenaries masts unstable.



Old Street Project

- **Location**: East London EC2
- **Scope of Work**:
  - Monitoring the network rail tunnel just south of Old Street station for movement using an RTS and 5 point prism arrays over a distance of 100m
  - RTS is controlled by a battery powered and rugged data logger
  - Battery is charged by low voltage AC down the tunnel
  - Communication via short haul modems back to the communication room where we share a BT line
  - Data logger dials ITM head office in Uckfield after a measurement cycle is completed
  - Data are recorded and collected hourly
- **Alert Notification**:
  - Client uses Argus to track the tunnel deformation and receives text and email alerts when preset threshold is exceeded.

Old Street Project

- **<u>Reason for Monitoring</u>**:
  - Monitor pitch and roll of the tunnel during adjacent piling and excavation