BIM Workflow for Using Geotechnical Data in Civil Engineering

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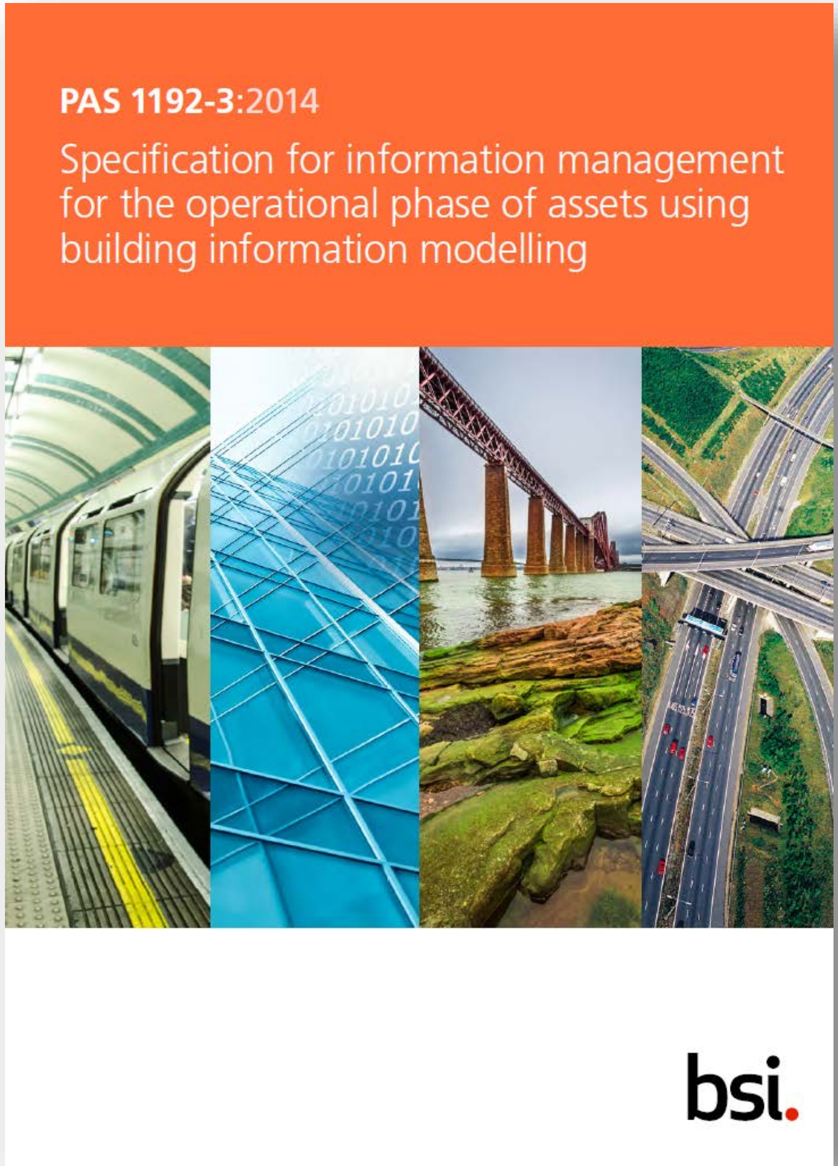
Advancing Infrastructure

"BIM-enabled" *Operations and Maintenance*



Relationship with other publications

This PAS builds on the existing code of practice for the collaborative production of architectural, engineering and construction information, defined within BS 1192:2007.

"LEVEL 1" *DESIGN*

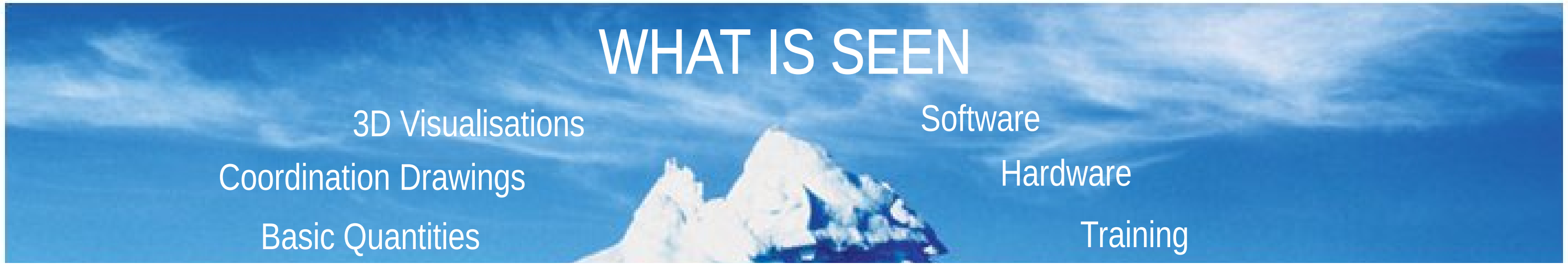
It is a companion document of, and refers heavily to PAS 1192-2:2013, *Specification for information management for the capital/delivery phase of construction projects using building information modelling*.

"LEVEL 2" *CONSTRUCTION*

It also refers heavily to the BS ISO 55000 series, *Asset management*, PAS 55:2008, *Asset management*, and to existing facilities management standards BS 8210:2012 and BS 8587:2012. BS 8536:2010 and BS 8572:2011 have also been useful source documents in relation to facilities management.

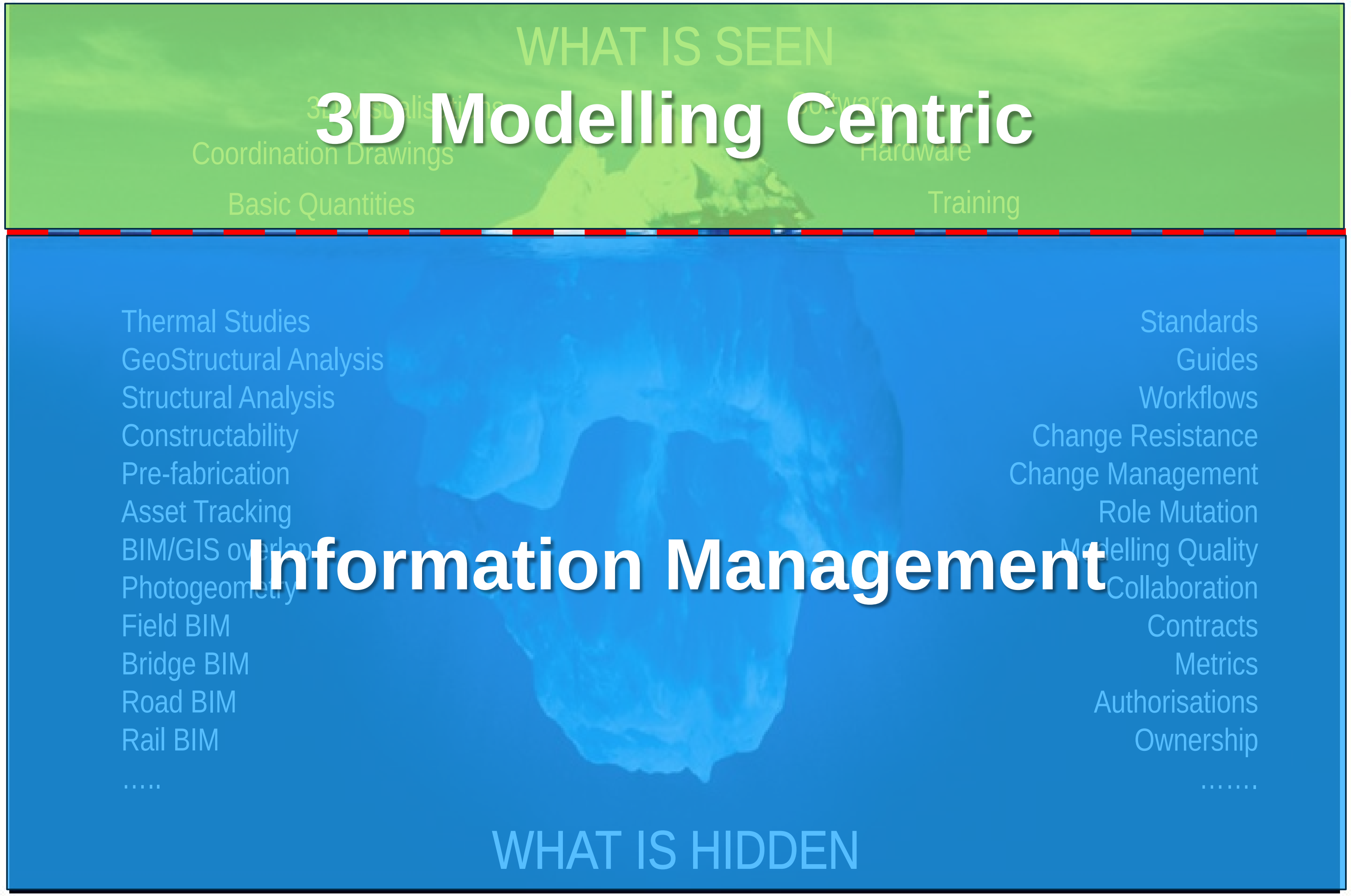
"LEVEL 3" *OPERATIONS*

BIM has started to evolve to where the REAL issues are



BIM Thinkspace

Coordinating teams across all disciplines and geographies

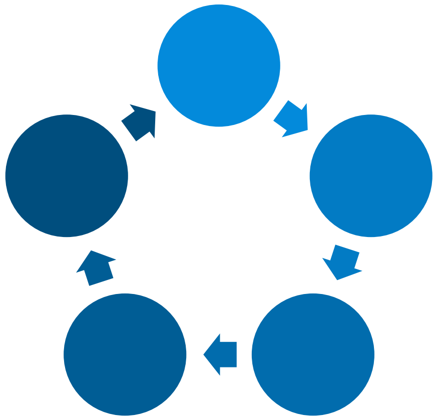


Intro: Geotechnical Data Management and BIM

BIM, “Building **Information Modeling** “

Building Information Modeling insures **sharing** data, it involves a framework that provides **collaboration**, **context** and continuity to the project.

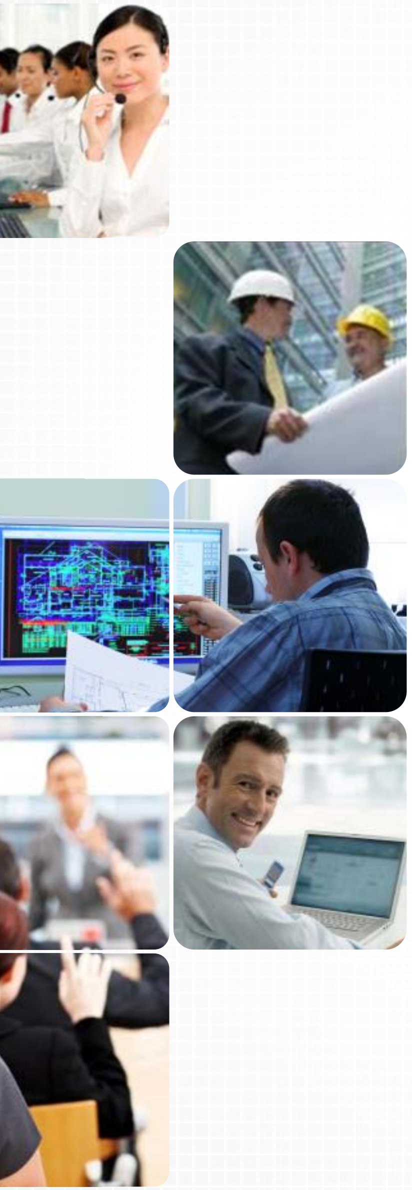
Many organizations that rely on **subsurface** information **fail to integrate** this information in to a BIM model for lack of tools to easily transfer and integrate the data to the model.



Agenda

- Introduction
- Traditional Geotechnical State of Practice
- Including Geotech in BIM
- Conclusion

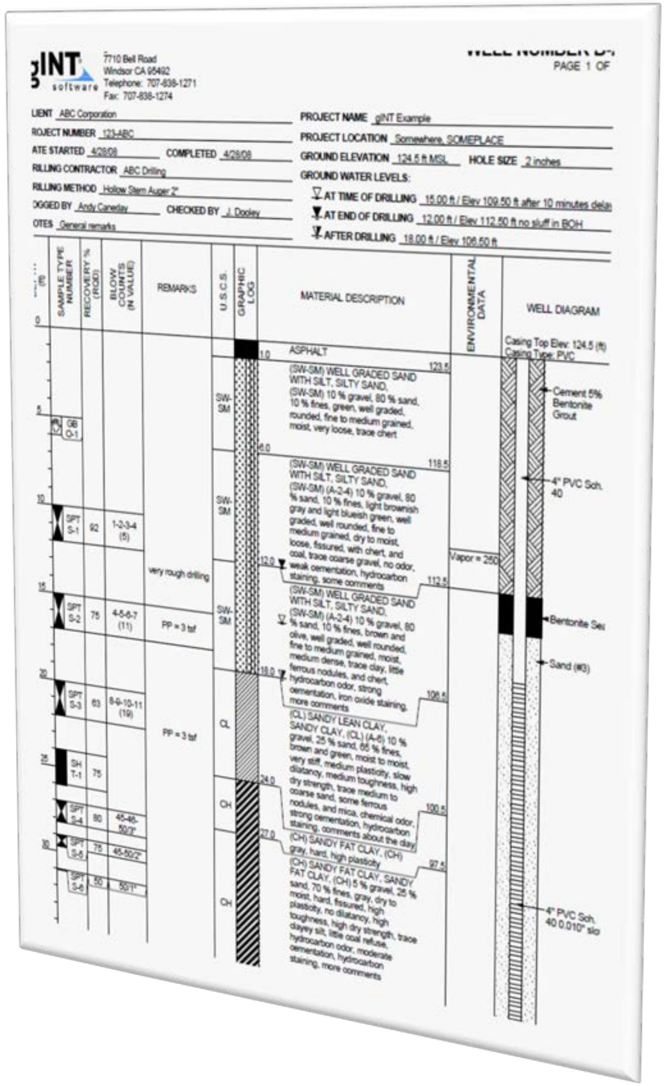
Winter Stratigraphy in Canada



Traditional Geotechnical State of Practice

Traditional Geotechnical State of Practice : Report Driven

- Report Driven
  - Paper based (digital paper, PDF)
  - Lag between drilling and report generation (months)
  - Low reusability/manual data re-entry
  - End game is the report delivery



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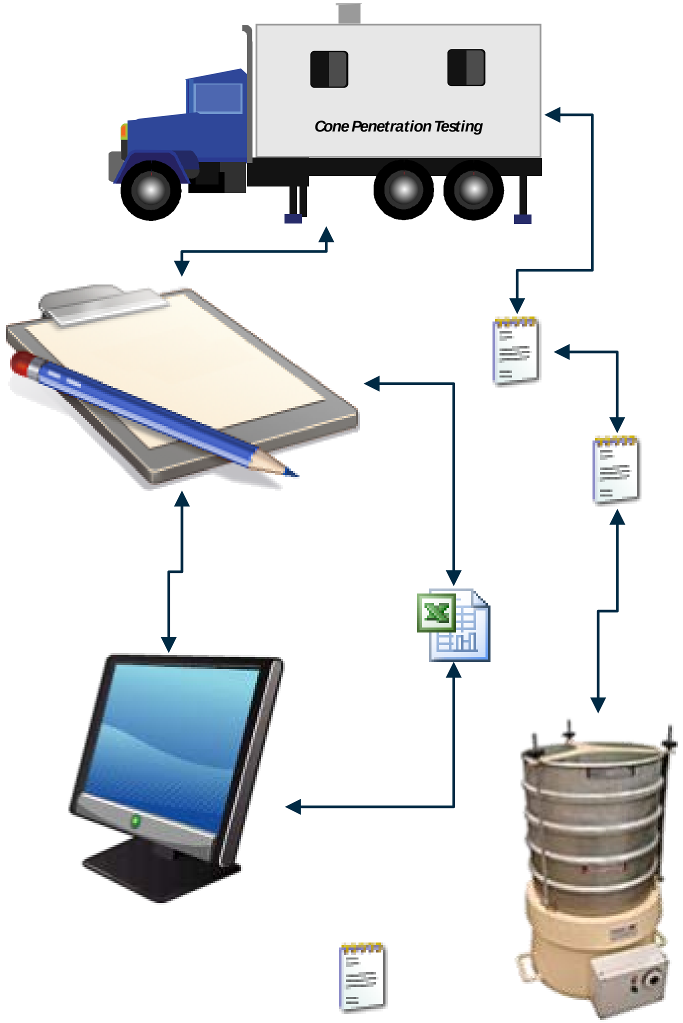
Unmanaged Data Approach

- Data is scattered throughout the organization
- Multiple data sources and multiple formats (paper, excel, etc.)
  - Field monitoring data and collection (handheld devices), lab Information, geophysics, environmental, hydrological, and more
- User must perform extensive manual validation
- Data redundancies
  - Entered three different times for three different reports (borehole, section, lab report)
- Lack of interoperability with other software (GIS, Civil, etc.)
- Scalability issue
- “Manageable” as long as the end game is the report



Unmanaged Data Approach : Comments

- *"Some of my geotechnical data is in an user-defined database and some in Excel files, and some even on paper".*

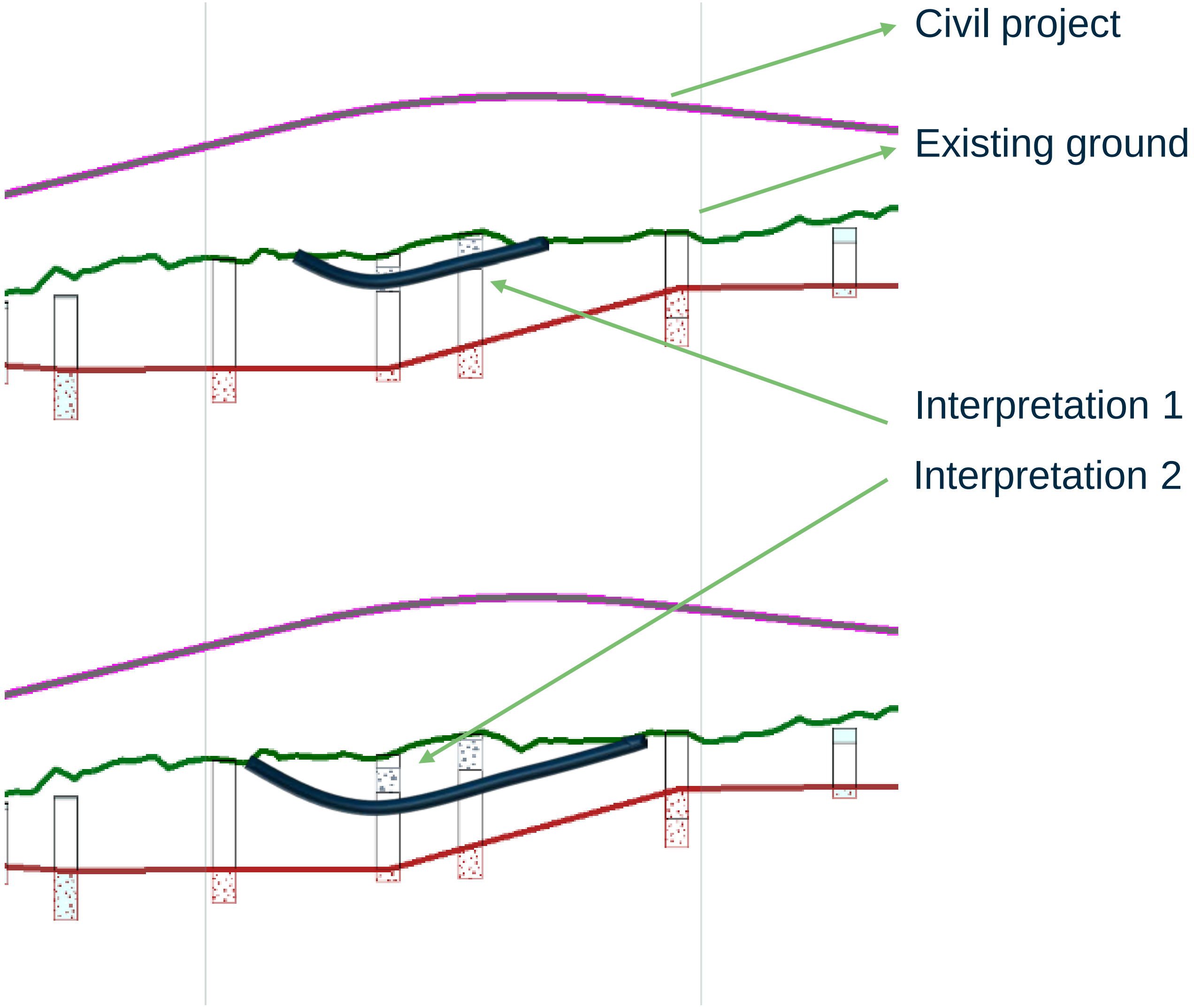
- *"We use different software for collecting data, another for lab testing and another for reporting".*

- *"We require different reports: numerical and graphical, for what sometimes we need to reenter data".*

- ***"It is hard to interact with other disciplines like Roadway, Bridge or GIS".***

Subsurface Interpretation and Liability

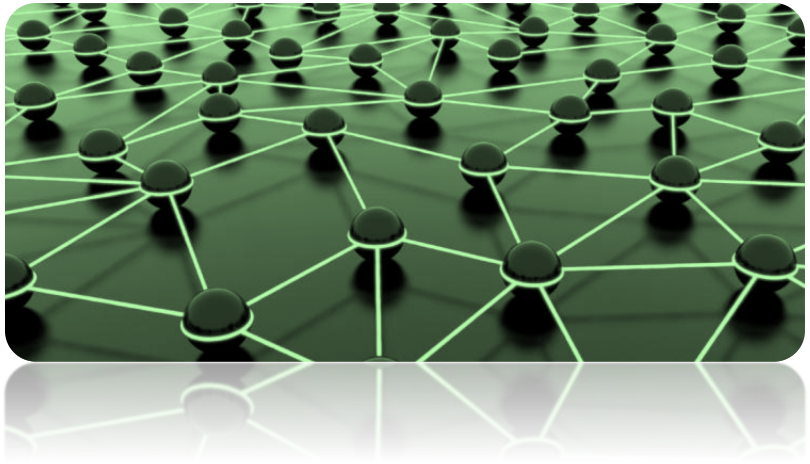
- Geotechnical Models:
- Created from local point data
- For large areas
- High level of unknown
- Interpretation difficulty depending on geology



Traditional Geotechnical State of Practice and BIM

- Geotechnical subsurface interpretation stored in “paper format”
- No single source of truth that can be queried by other systems
- Subsurface interpretation
  - Liability
  - Accuracy

Need for an Information Model



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Including Geotechnical Data in to BIM

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Digital Data : Centralized Database

- For data storage
- For data validation
- For data queries
- For data reporting
- Data sharing with other programs
- Can be supported by Interoperability standards (DIGGS, AGS4)

- Need for a single source of truth : one data store, many uses

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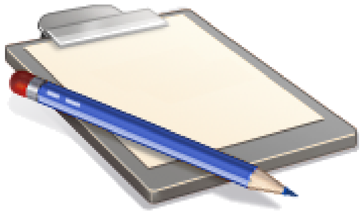
Digital Data: Paper to Database, Database to Models



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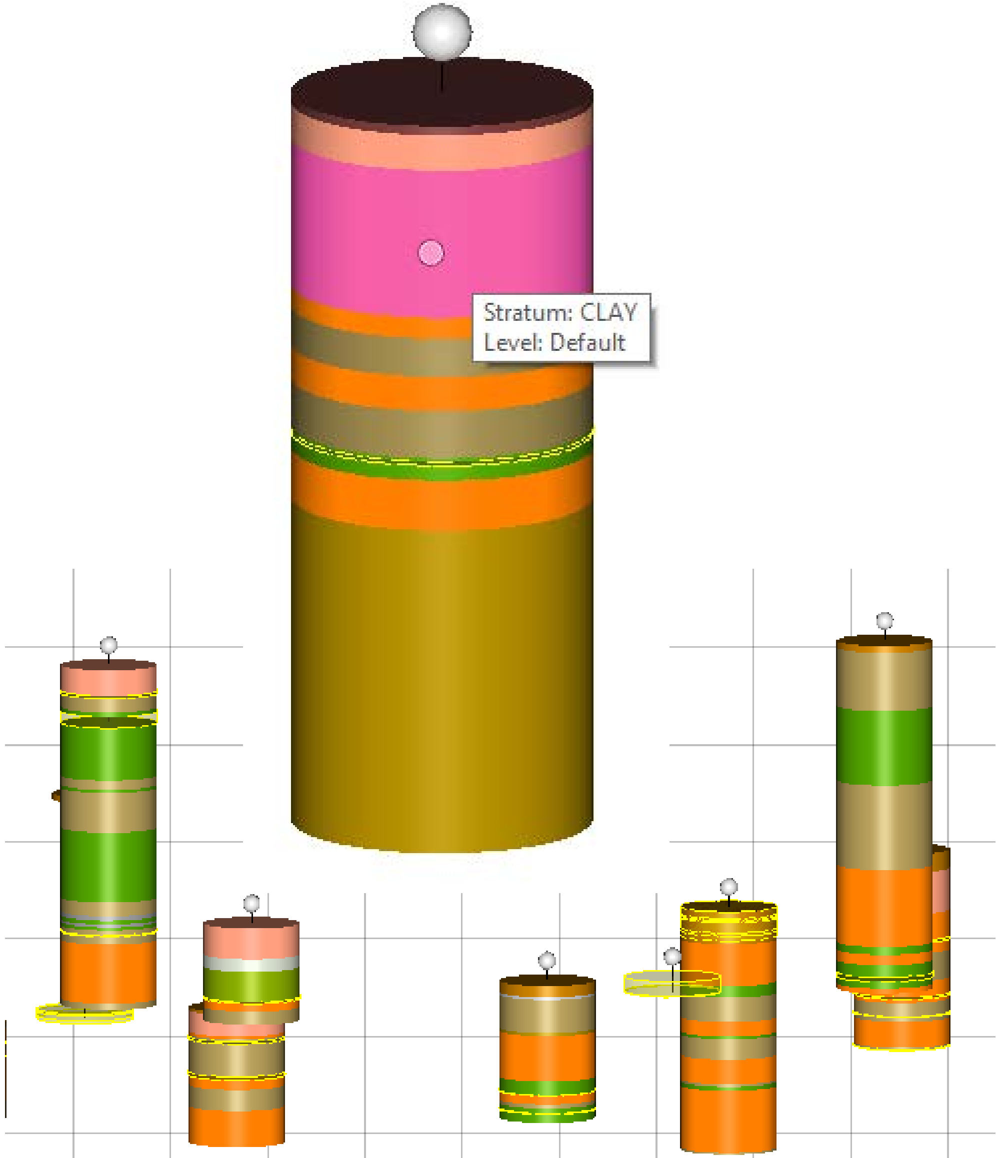
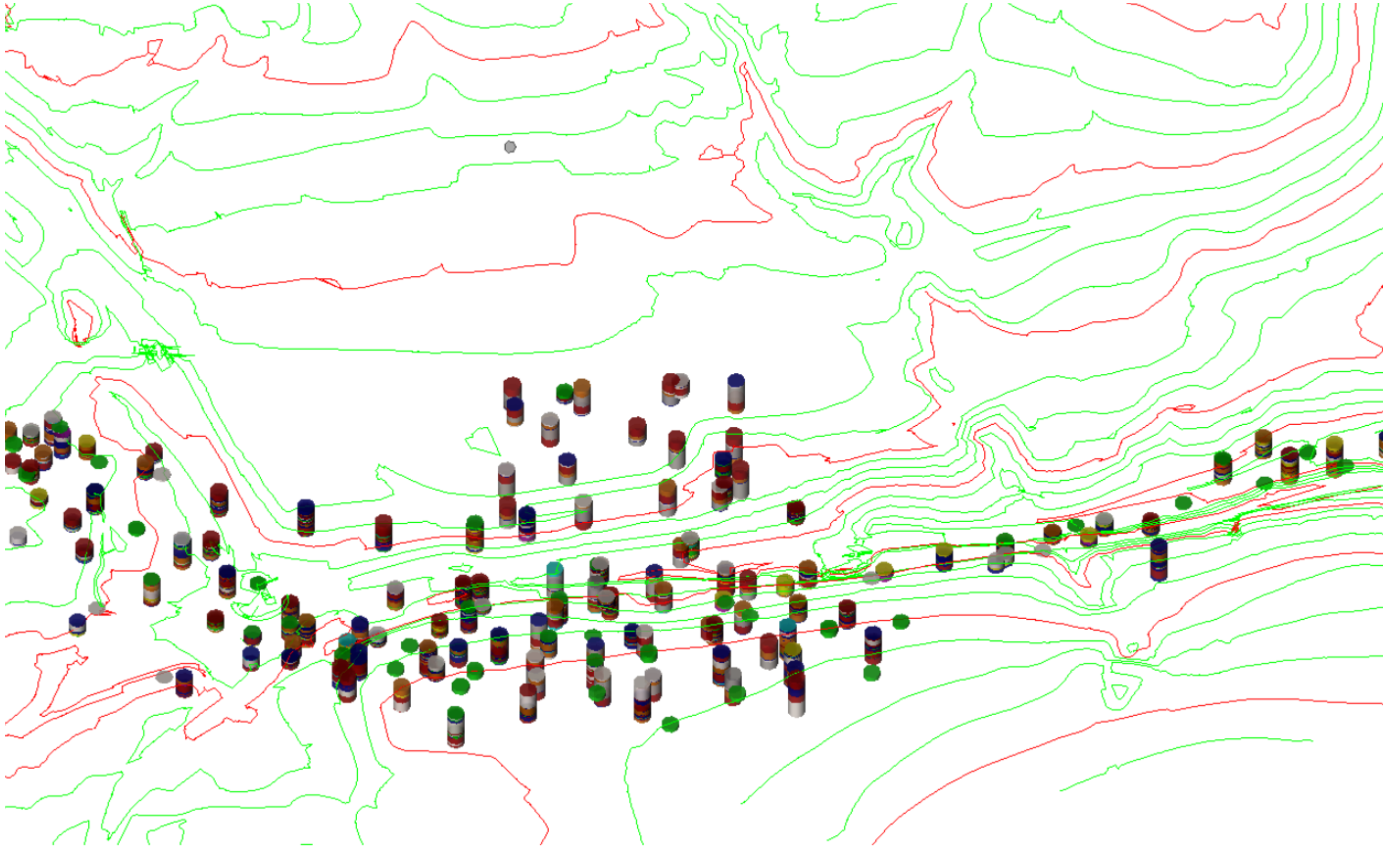
BH38	RC	1/23/1997	1/26/1997	31099.25	12422.11	245.0492368	20.00
BH39	RC	1/27/1997	1/29/1997	31023.99	12422.26	262.1024753	25.00
BH40	CP+RC	11/29/1996	12/4/1996	31010.68	12372.64	272.7349314	15.00
BH41	RC	12/5/1996	12/5/1996	30970.56	12373.69	272.9574418	3.31
BH42	RC	12/5/1996	12/12/1996	30970.56	12373.69	272.9574418	15.00
BH43	RC	9/24/1996	9/30/1996	30891.65	12432.63	269.9964031	25.10
BH44	CP	9/24/1996	9/25/1996	30837.01	12436.47	275.1481336	1.30
BH45	CP	9/25/1996	9/25/1996	30837.01	12436.47	275.1481336	3.38
BH46	RC	10/2/1996	10/3/1996	30837.01	12436.47	275.1481336	9.46
BH47	RC	1/15/1997	1/20/1997	30837.01	12436.47	275.1481336	35.00
BH48	CP+RC	9/23/1996	9/26/1996	30869.96	12367.26	297.8937829	15.10
BH49	RC	10/1/1996	10/2/1996	30809.01	12377.77	292.3013887	10.00
BH50	CP+RC	12/9/1996	1/14/1997	30744.12	12412.70	270.4929268	30.35
BH51	CP+RC	12/10/1996	1/11/1997	30708.37	12395.44	264	30.35
BH52	CP+RC	12/4/1996	1/8/1997	30620.23	12392.58	296.3300577	24.65
BH53	CP+RC	9/20/1996	10/11/1996	30532.20	12350.90	292.7634905	11.00
BH54	RC	10/8/1996	10/16/1996	30532.20	12350.90	292.7634905	30.15
BH55	CP+RC	9/20/1996	10/21/1996	30511.81	12345.30	289.4038521	20.80
BH56	CP+RC	9/22/1996	10/14/1996	30471.00	12334.85	293.3918984	35.00
BH57	CP+RC	9/21/1996	10/20/1996	30436.65	12324.26	292.2586770	30.00
BH58	CP+RC	9/26/1996	10/23/1996	30416.30	12332.16	303.3694834	20.31
BH59	RC	10/29/1996	11/2/1996	30385.25	12311.07	301.4364342	25.14



Displaying Geotechnical Models in Context

- Need for geocoordination tools
  - Local project
  - GPS
  - Station-offsets
  - On the Fly Reprojection



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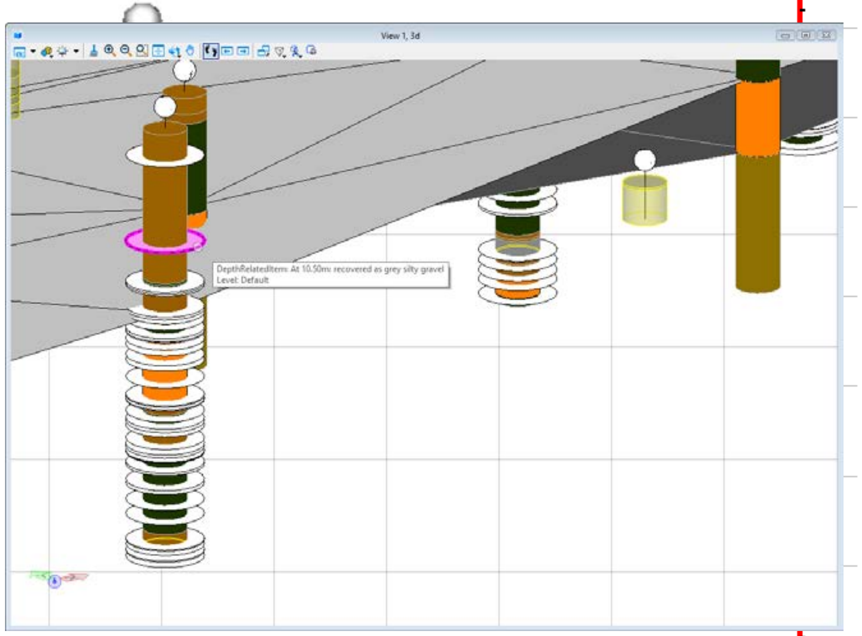
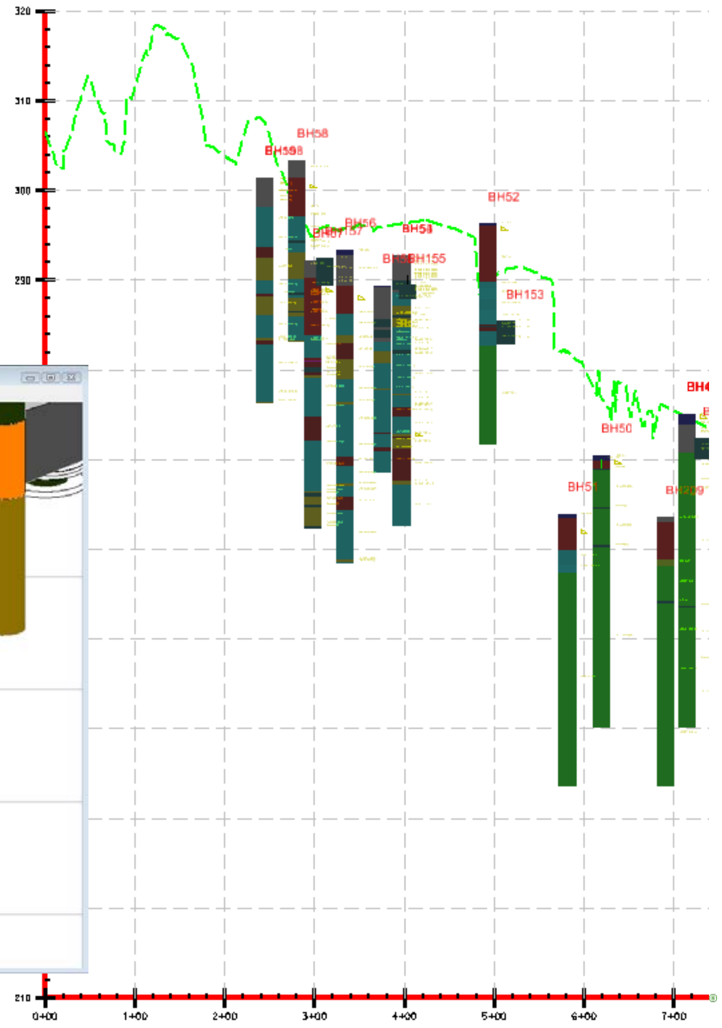
Displaying Geotechnical Models in Context

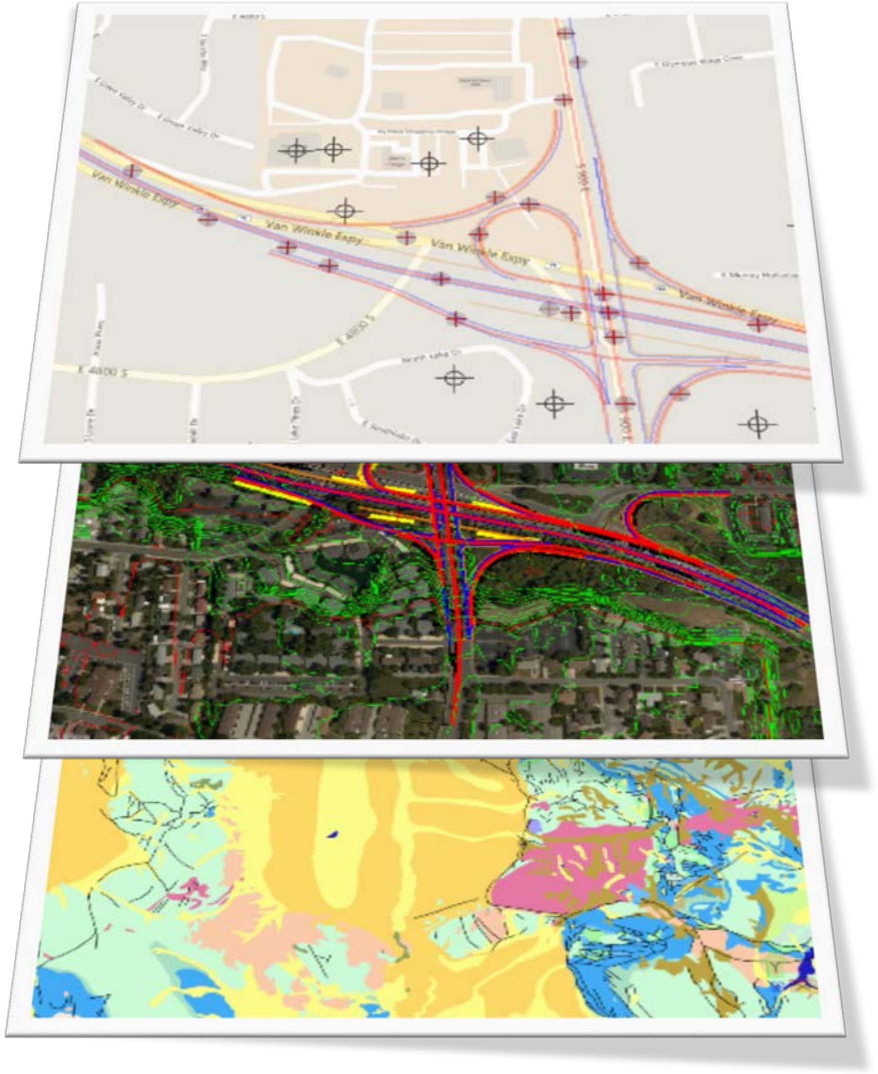
- Geotechnical database output :
  - 2d plans
  - Profiles
  - 3d models
  - Subsurfaces

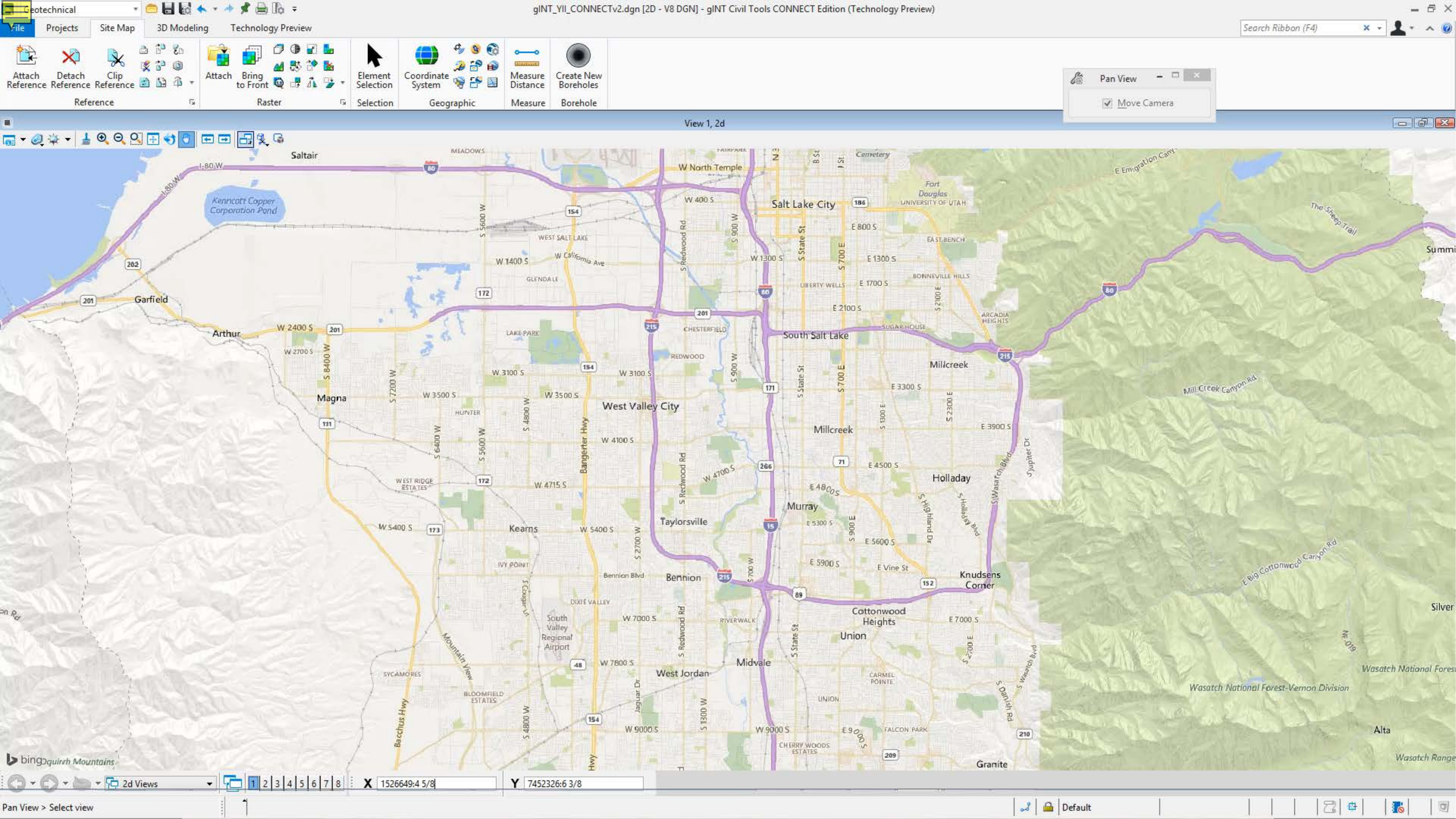




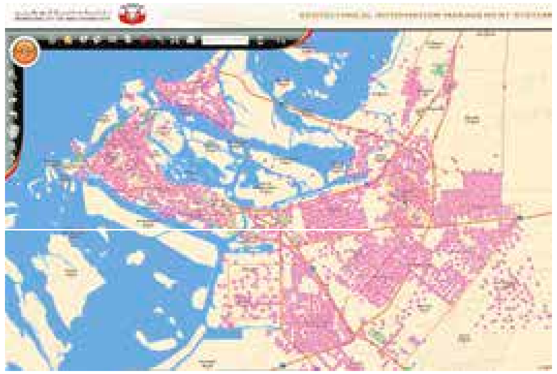
Mapping Workflow

- 2D representation of the boreholes; annotation
- Civil projects: import, reference
- Import / reference CAD and GIS data
- Load raster imagery: from local disk or WMS feed
- Direct Support of BING maps data with Microsoft account
- Projection of the fly: working with multiple coordinate systems and data sources live, no need to import data all in one coordinate system




gINT_YII_CONNECTv2.dgn [2D - V8 DGN] - gINT Civil Tools CONNECT Edition (Technology Preview)
Geotechnical
File
Projects
Site Map
3D Modeling
Technology Preview
Search Ribbon (F4)
Attach Reference
Detach Reference
Clip Reference
Reference
Attach
Bring to Front
Raster
Element Selection
Selection
Coordinate System
Geographic
Measure Distance
Measure
Create New Boreholes
Borehole
Pan View
Move Camera
View 1, 2d
Saltair
Salt Lake City
Kenncott Copper Corporation Pond
Garfield
Arthur
Magna
West Valley City
South Salt Lake
Millcreek
Holladay
Murray
Taylorsville
Kearns
Bennion
Knudsens Corner
Cottonwood Heights
Union
Midvale
West Jordan
Granite
Alta
Silver
Wasatch National Forest-Vernon Division
bing Oquirrh Mountains
2d Views
X 1526649:4 5/8
Y 7452326:6 3/8
Pan View > Select view
Default

2d plans: Case Study (Abu Dhabi)



- Single Source of truth and centralized geotechnical dtaba enable data flow to GIS

- Web Enabled GIS allows engineers to easily access geotechnical information from a portal

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gINT Underpins Comprehensive Geotechnical Information Management System for the Municipality of Abu Dhabi City(Bentley)

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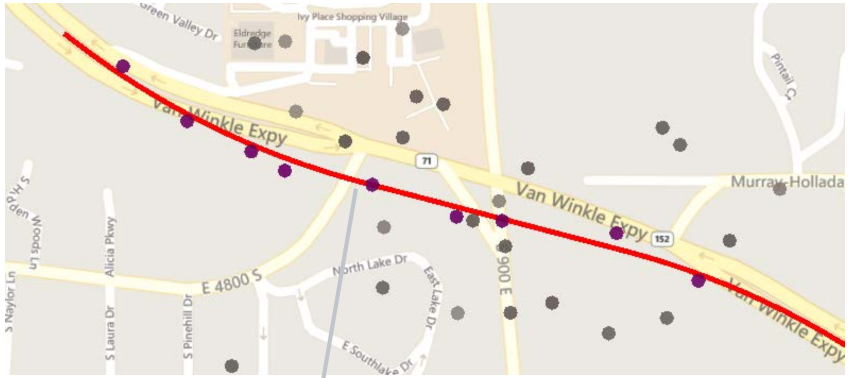
Instant Access to Subsurface Information Increases Productivity Twofold

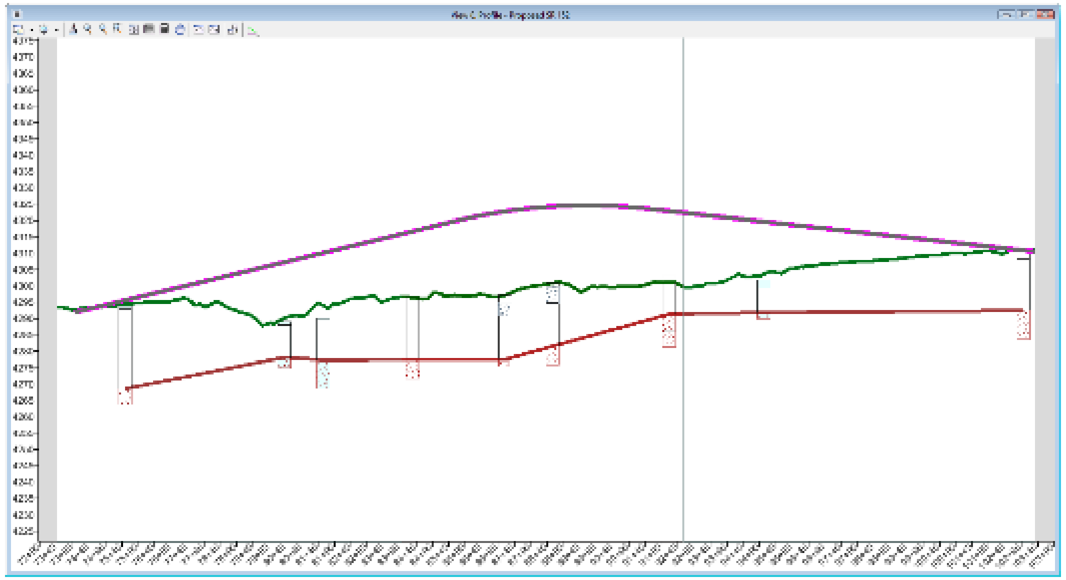
Abu Dhabi Municipality used Bentley's gINT geotechnical software to capture legacy information that included 20,033 hardcopy logs and reports. With software from Bentley, the municipality increased the spatial data division's daily productivity twofold. The Municipality of Abu Dhabi City now has instant access to subsurface investigation data that supports critical engineering decision-making.

Bentley®

Profile Views

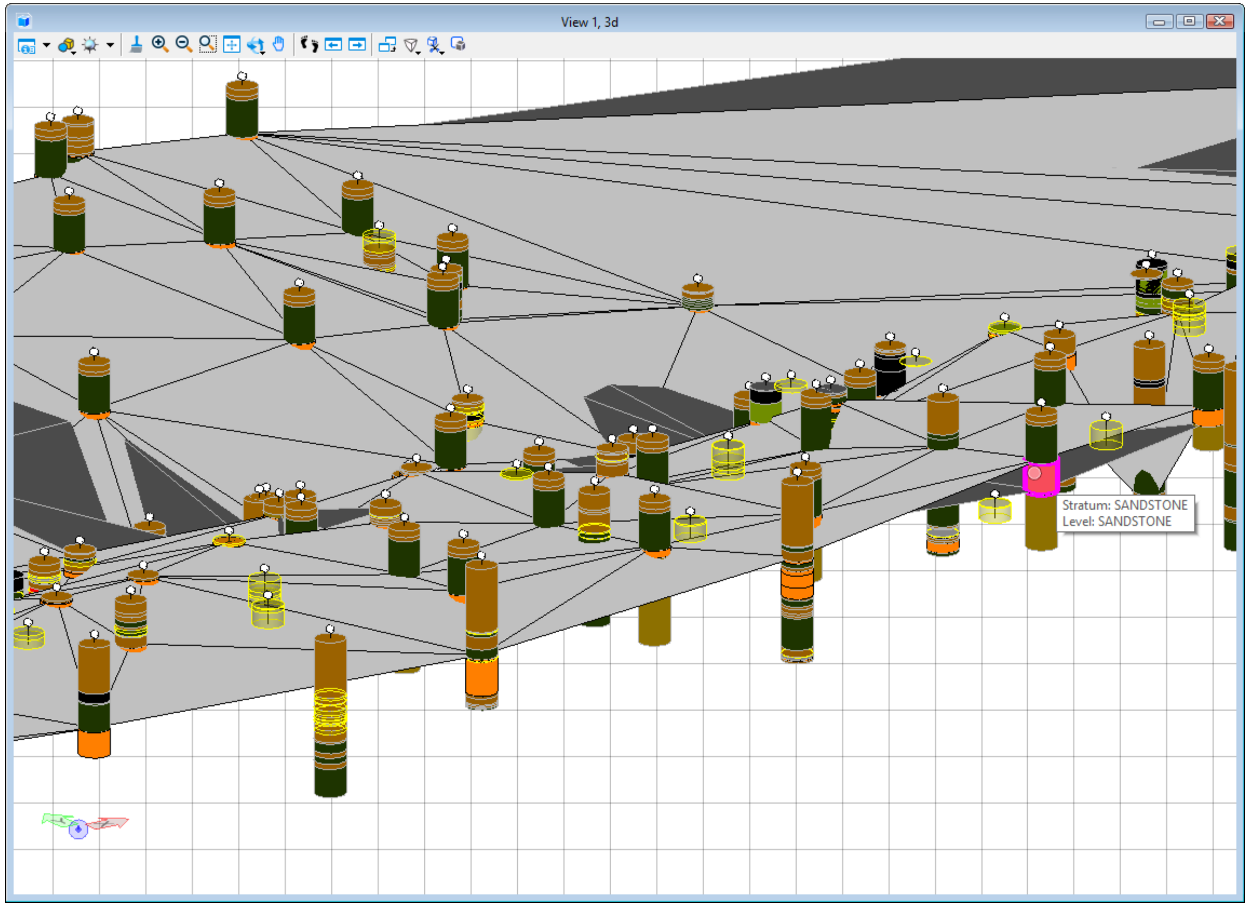
- Dynamic profiles
- Borehole visualization plus surfaces
- Civil projects
- Surface interpretation
- “Browsing” tool for subsurface data



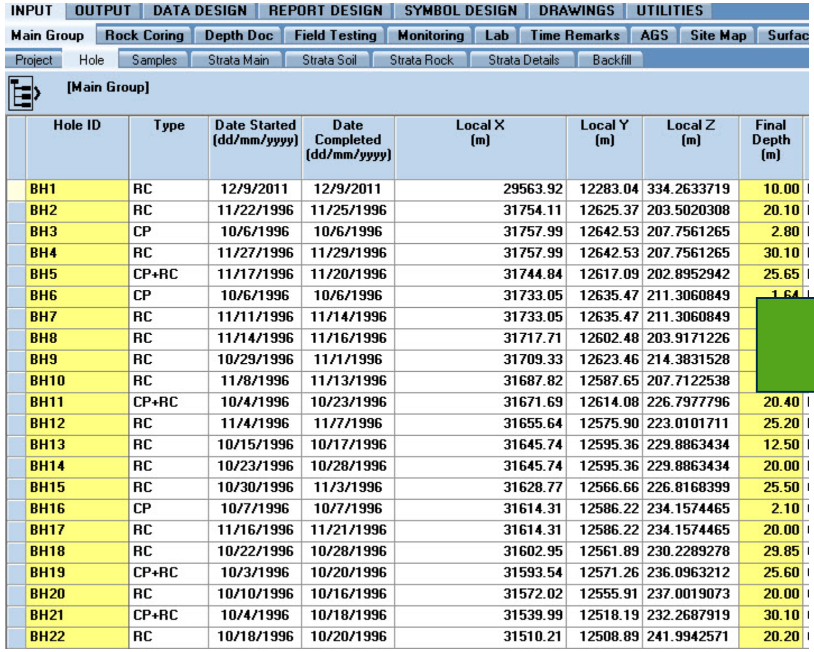


3d Models : Use of Geotechnical Data in infrastructure projects

- Work with terrain and real "DTMs"
- 3D visualization of geotechnical data
- Thematic symbolization
- Overlay site design plans to provide context view
- Data QA/analysis by combining with other data (point clouds, …)



Native Read/Write Projects



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BH7	RC	11/11/1996	11/14/1996	31733.05	12635.47	211.3060849	[illegible]
BH8	RC	11/14/1996	11/16/1996	31717.71	12602.48	203.9171226	[illegible]
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BH10	RC	11/8/1996	11/13/1996	31687.82	12587.65	207.7122538	[illegible]
BH11	CP+RC	10/4/1996	10/23/1996	31671.69	12614.08	226.7977796	20.40
BH12	RC	11/4/1996	11/7/1996	31655.64	12575.90	223.0101711	25.20
BH13	RC	10/15/1996	10/17/1996	31645.74	12595.36	229.8863434	12.50
BH14	RC	10/23/1996	10/28/1996	31645.74	12595.36	229.8863434	20.00
BH15	RC	10/30/1996	11/3/1996	31628.77	12566.66	226.8168399	25.50
BH16	CP	10/7/1996	10/7/1996	31614.31	12586.22	234.1574465	2.10
BH17	RC	11/16/1996	11/21/1996	31614.31	12586.22	234.1574465	20.00
BH18	RC	10/22/1996	10/28/1996	31602.95	12561.89	230.2289278	29.85
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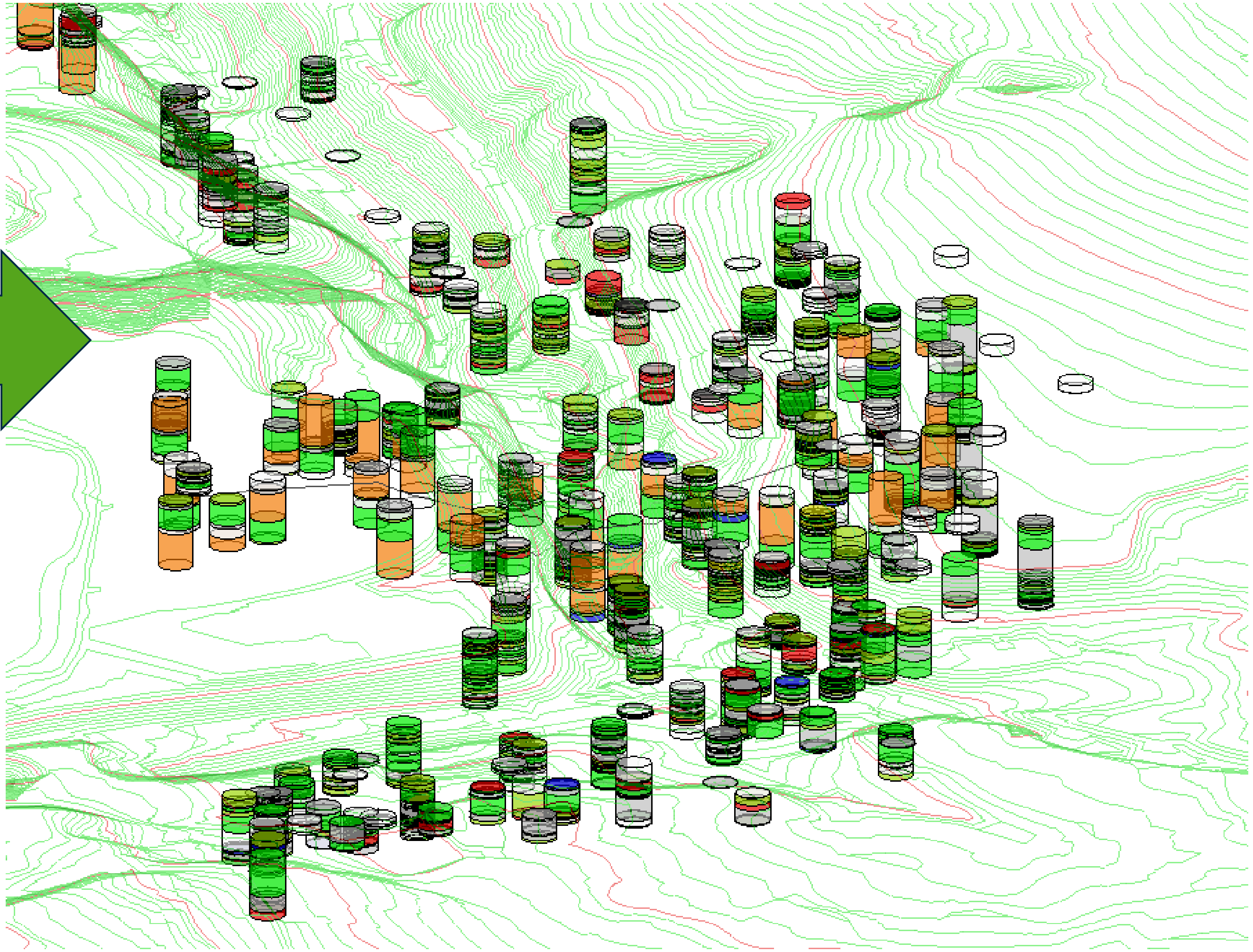

Direct read of Projects minimizes using old data and reduces opportunity for data entry errors

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Subsurface data model : PointID

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BH37	RC	10/1/1996	10/2/1996	31149.12	12398.80	237.3349670	10.25
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BH44	CP	9/24/1996	9/25/1996	30837.01	12436.47	275.1481336	1.30
BH45	CP	9/25/1996	9/25/1996	30837.01	12436.47	275.1481336	3.38
BH46	RC	10/2/1996	10/3/1996	30837.01	12436.47	275.1481336	9.46
BH47	RC	1/15/1997	1/20/1997	30837.01	12436.47	275.1481336	35.00
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BH50	CP+RC	12/9/1996	1/14/1997	30744.12	12412.70	270.4929268	30.35
BH51	CP+RC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BH52	CP+RC	12/4/1996	1/8/1997	30620.23	12392.58	296.3300577	24.65
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BH55	CP+RC	9/20/1996	10/21/1996	30511.81	12345.30	289.4038521	20.80
BH56	CP+RC	9/22/1996	10/14/1996	30471.00	12334.85	293.3918984	35.00
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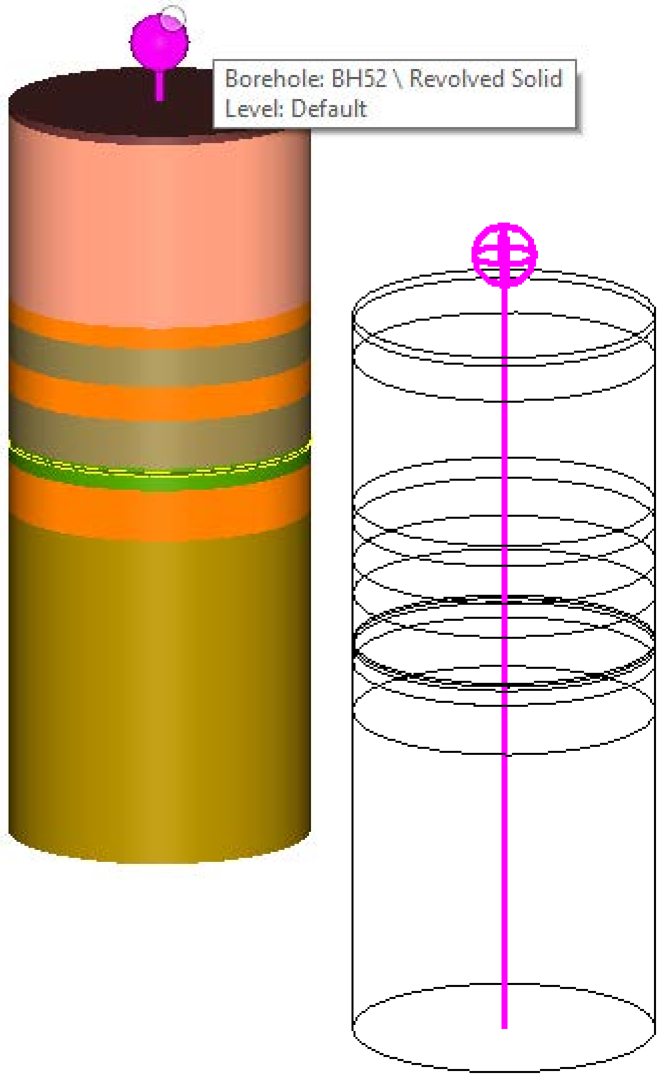
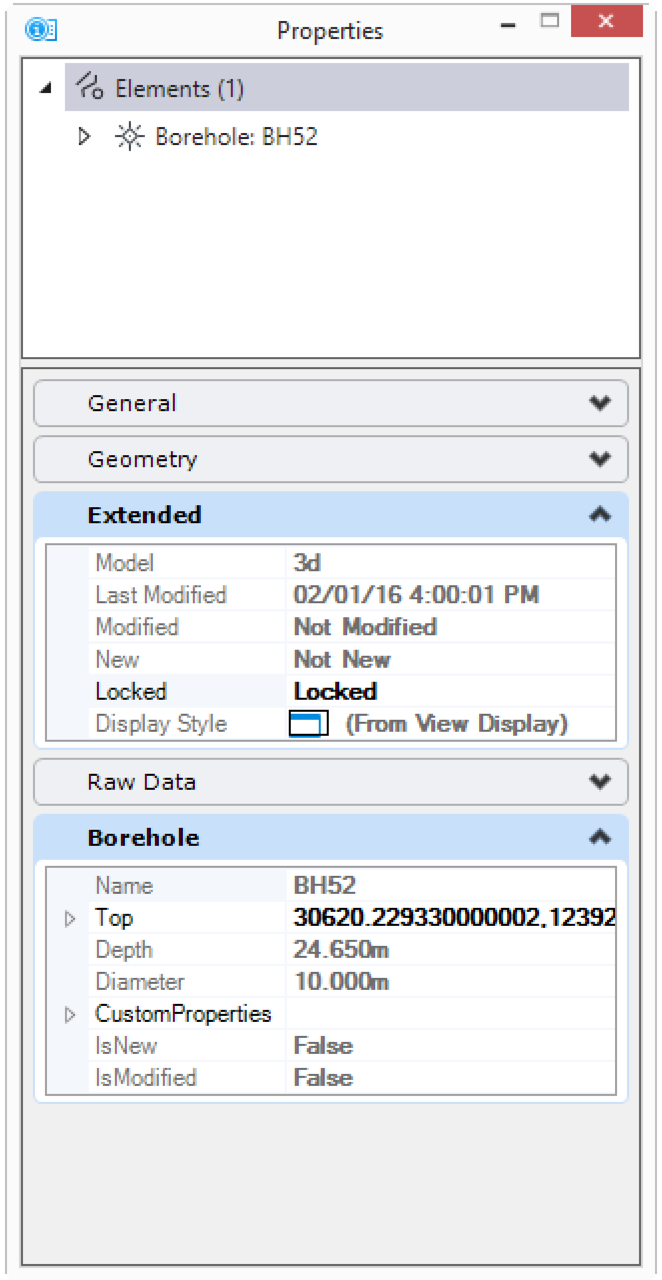
BH58	CP+RC	9/26/1996	10/23/1996	30416.30	12332.16	303.3694834	20.31
BH59	RC	10/29/1996	11/2/1996	30385.25	12311.07	301.4364342	25.14





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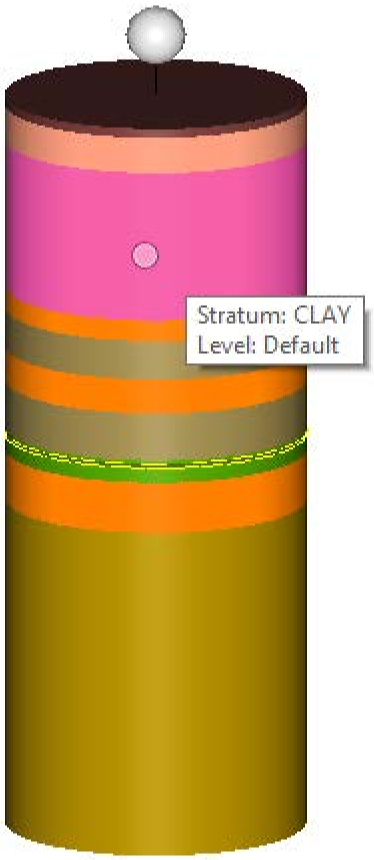
Subsurface data model : Top-Bottom

Top (m)	Base (m)	Description	Legend
0.00	0.30	TOPSOIL **	TOPSOIL
0.30	1.50	Soft to firm yellow and orange brown and grey mottled slightly sandy (fine) silty CLAY with occasional angular fine to medium gravel.	CLAY si sa gr co
1.50	6.50	Very stiff dark brown mottled grey slightly sandy (fine to coarse) silty CLAY with some to much angular to subangular fine to coarse gravel and cobbles of sandstone and quartzite.	CLAY si sa gr co
6.50	7.20	Grey fine and medium grained very thinly to thinly bedded slightly weathered SANDSTONE,strong to very strong. Prominent discontinuities: 1) Bedding fractures: subhorizontal (5? to 15?) planar,rough,clean,orange brown stained. 2) Subvertical (70? to	SANDSTONE
7.20	8.50	Grey thinly to medium bedded slightly weathered CONGLOMERATE,strong to very strong comprising subangular to subrounded up to coarse gravel sized clasts of quartz with a little to some matrix of fine to coarse grained sandstone. Prominent discontinuities: 1) Bedding	CONGLOMERATE
8.50	9.65	Grey brown fine to medium grained medium bedded slightly weathered SANDSTONE,strong and very strong. Prominent discontinuities: 1) Bedding fractures: 15? to 20?,planar,rough,clean,slightly orange brown stained. 2) Very closely to closely	SANDSTONE
9.65	11.25	Grey thinly to medium bedded slightly weathered CONGLOMERATE,strong to very strong comprising subangular to subrounded up to coarse gravel sized clasts of predominantly quartz with a little to some matrix of fine to coarse grained sandstone. Prominent	CONGLOMERATE
11.25	11.35	Grey slightly weathered SILTSTONE,weak to predominantly moderately weak with very closely to closely spaced randomly orientated and subhorizontal (0? to 20?) planar and irregular,smooth,clean discontinuities.	SILTSTONE
11.35	11.50	AZCL	Unknown
11.50	12.00		SILTSTONE
12.00	13.70	Grey fine to medium grained thinly to thickly bedded slightly weathered SANDSTONE,strong to extremely strong. Prominent discontinuities: 1) Bedding fractures: subhorizontal (5? to 20?) planar and irregular,rough,clean. 2) Subvertical (70? to 80?) irregular,rough,locally	SANDSTONE
13.70	24.65	Grey fine to medium grained thinly to thickly bedded slightly to moderately weathered crystalline LIMESTONE,strong to very strong with occasional sand to coarse gravel sized voids (occasionally infilled with quartz and calcite mineralisation). Locally discoloured brown	LIMESTONE



Properties

- Elements (1)
  - Stratum: CLAY
    - Items

General

Geometry

Material

Extended

Model	3d
Last Modified	02/01/16 4:00:01 PM
Modified	Not Modified
New	Not New
Locked	Locked
Display Style	(From View Display)

Stratum

Borehole	BH52
Material	CLAY
Top	30620.229330000002,12
Depth	5.000m
Diameter	10.000m
Bearing	0.0°
Plunge	-90.0°

Raw Data

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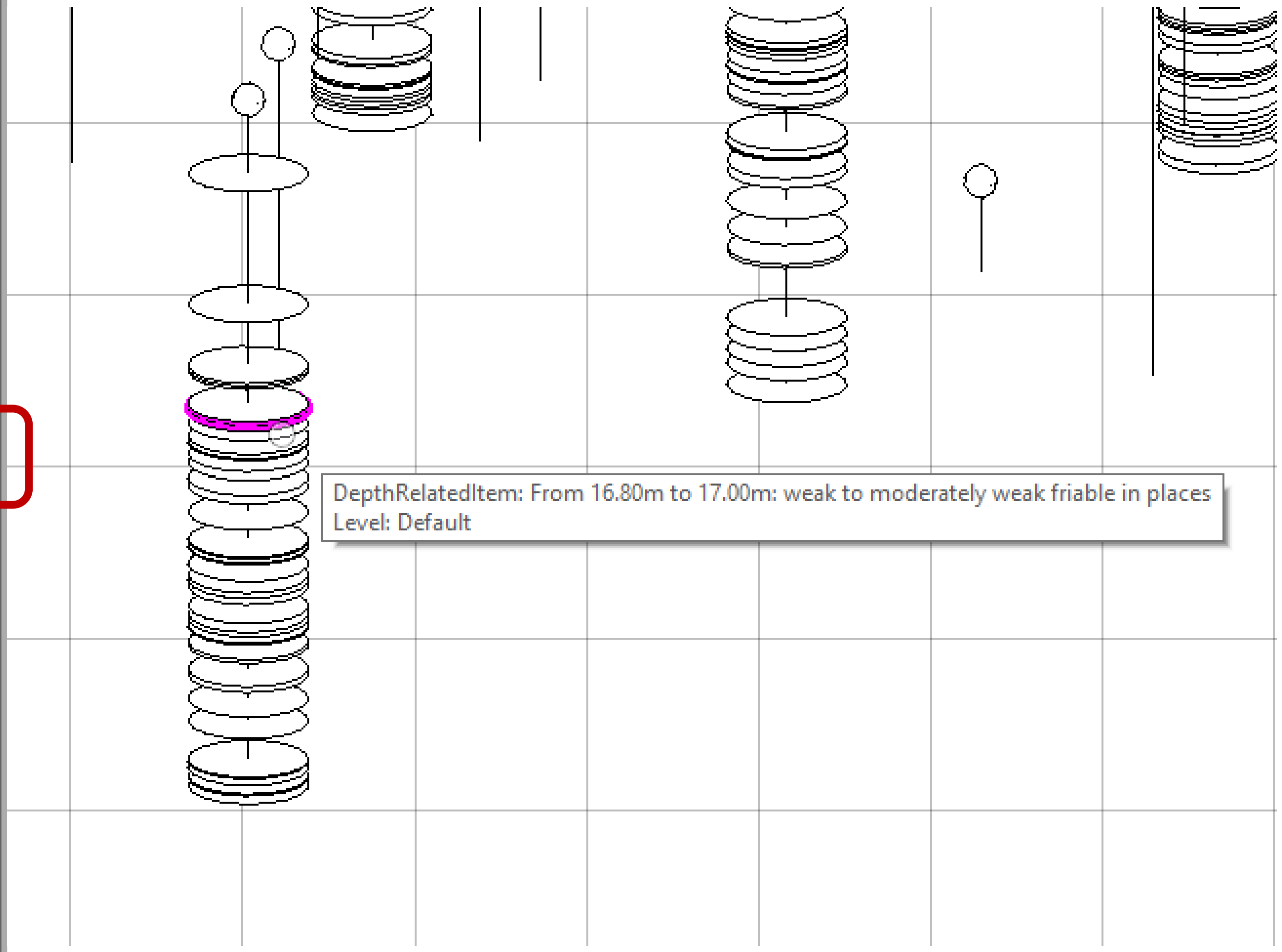
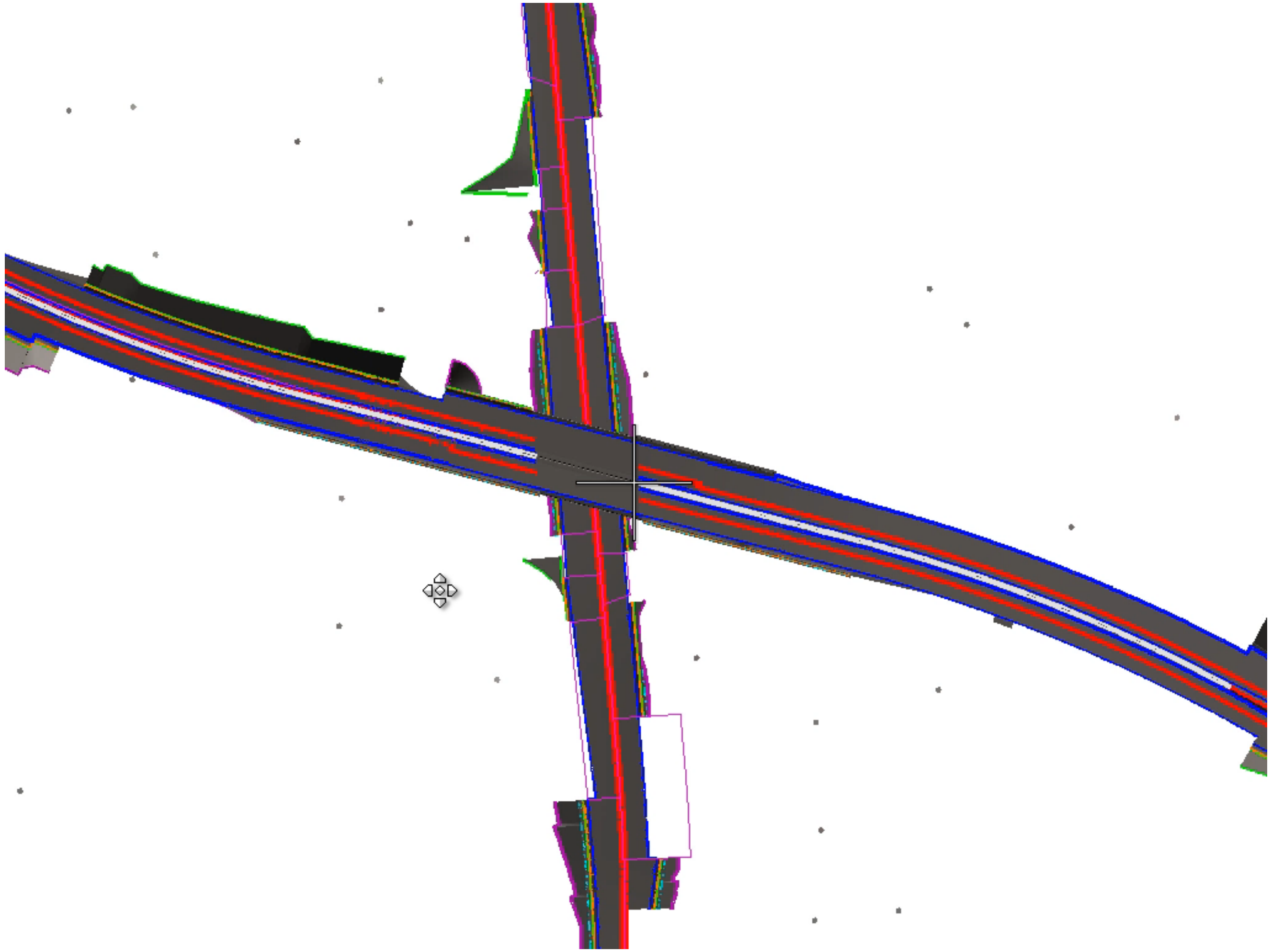
Subsurface data model : Depth Only

Depth (m)	Base (m)	Remark
2.5		From 2.5m: Samples recovered as angular fine to coarse gravel and cobbles of siltstone and fine grained sandstone with some grey brown mottled silty
10.5		At 10.50m: recovered as grey silty gravel
14.22		From 14.22m to 14.52m: 80? to 90? planar,irregular,rough,closed,iron stained joint perpendicular to main joint set
14.4		From 14.40m to 14.57m: fine to medium grained sandstone with occasional interlaminations of sandy siltstone
14.57		From 14.57m to 15.00m: with occasional thin sandy laminae
16.55		From 16.55m to 16.60m: ironstone nodule
16.8		From 16.80m to 17.00m: weak to moderately weak friable in places
17.16		From 17.16m to 17.25m: ironstone nodule
17.75		From 17.75m to 18.00m: slightly weathered,clay smearing along bedding fractures
18.55		From 18.55m to 18.65m: with some coarse gravel size ironstone nodules
18.82		From 18.82m to 18.85m: with some medium gravel size ironstone nodules
18.93		From 18.93m to 19.98m: 75? planar,smooth,closed joint
19.6		From 19.60m to 19.70m: with coarse gravel size ironstone nodules
20.15		From 20.15m to 20.28m: 45?,planar,rough,closed to slightly open (<1mm) joint with a slight clay smearing in places and slight iron staining



Subsurface : Layer Creation for BIM

- Subsurfaces needed for civil projects
- Gradual process
- Liability issues
- “Imperfect interpretation” or “paper logs”



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A Quick Example

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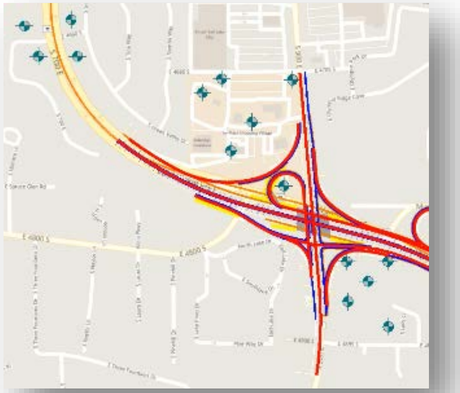
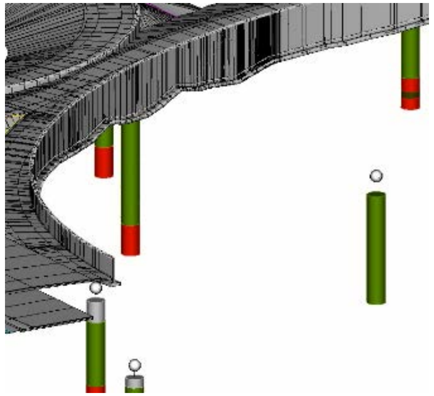
Mapping / GIS



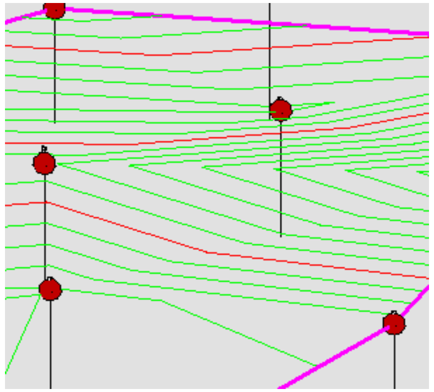
- 2D representation of the boreholes; annotation
- Civil projects: import, reference in, ProjectWise integration
- Import / reference CAD and GIS data
- Load raster imagery: from local disk or WMS feed
- Direct Support of BING maps data with Microsoft account
- Projection of the fly: working with multiple coordinate systems

3d Civil



- 3D representation of the boreholes; annotation
- 3d civil projects: import, reference in, ProjectWise integration
- Import / reference CAD and GIS data
- Load geological layers
- Create surfaces from geology and existing ground
- Intersect geology with civil design

3d Environment



- 3D representation of the boreholes; annotation
- Water levels
- Create water level surfaces and hydraulic flow indicators
- Plot environmental readings in 3D
- Create “heat maps” for environmental readings
- Visualize contamination zones in material types

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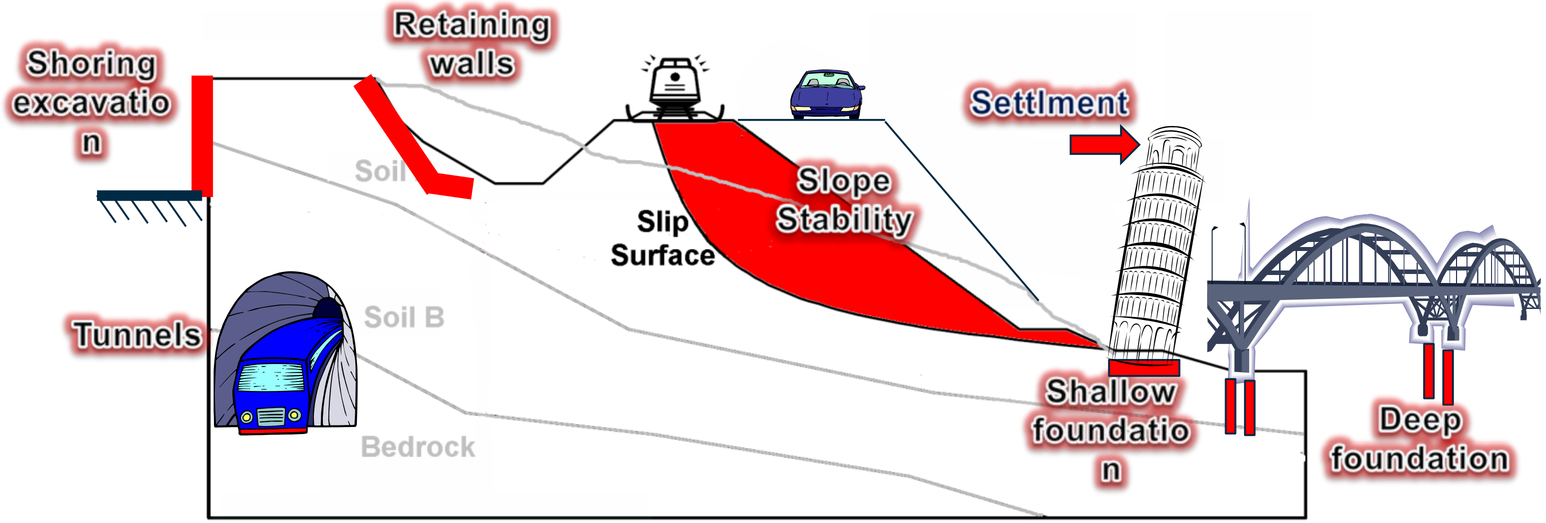
GeoStructural Analysis (GSA)

GeoStructural Analysis (GSA) address all common geotechnical problems in civil engineering such as shoring excavation, retaining wall design, slope stability, foundation design, settlement analysis, tunnels.

GSA: GeoStructural Analysis



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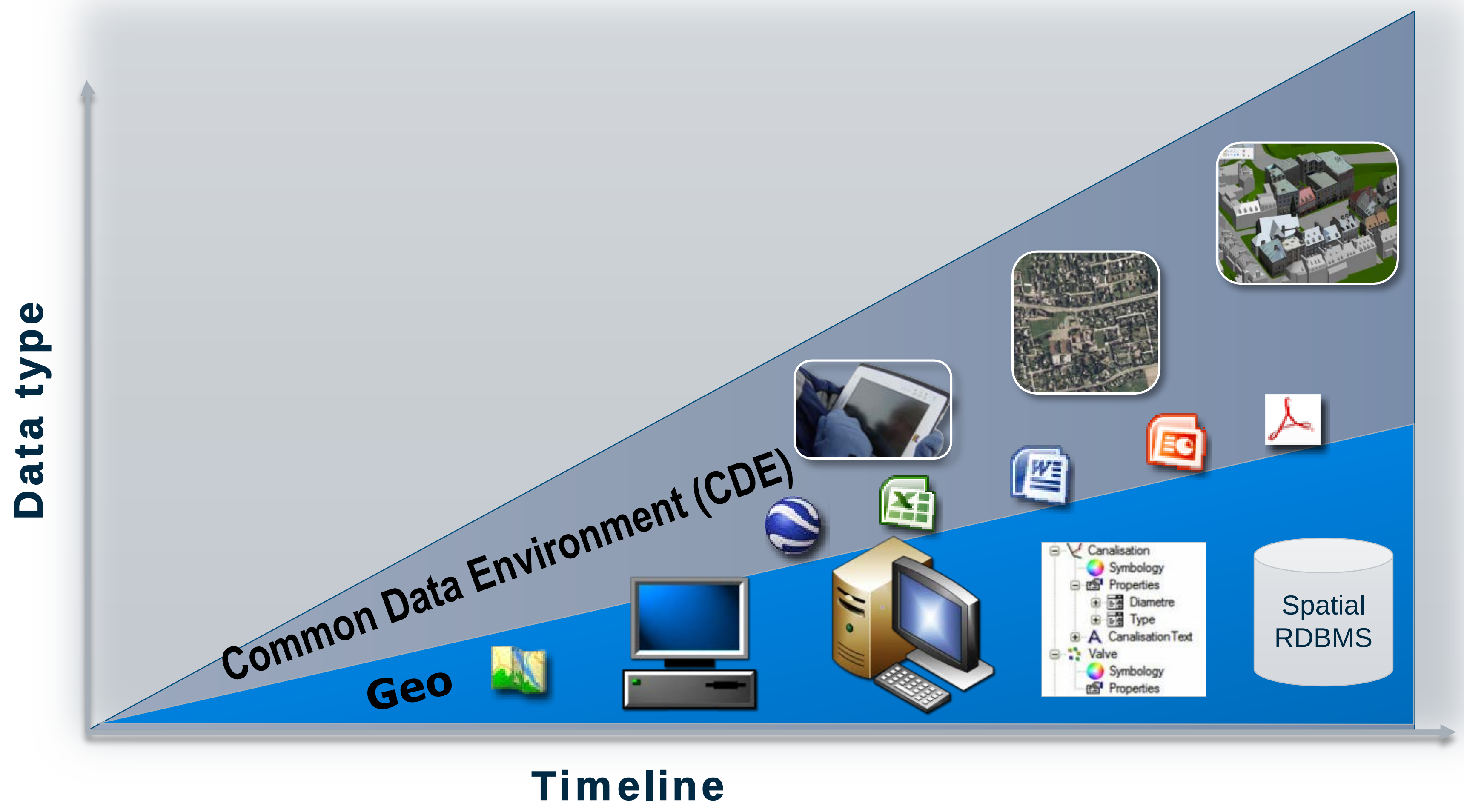
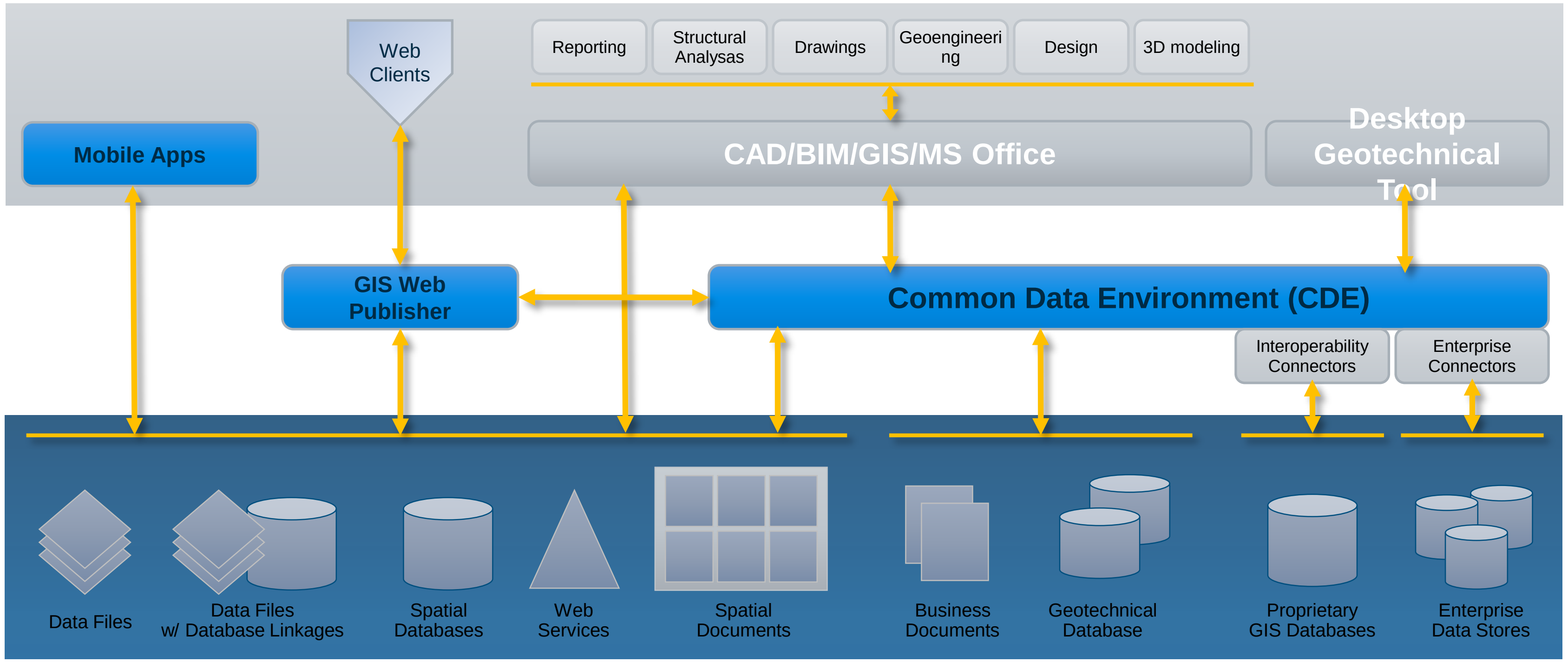
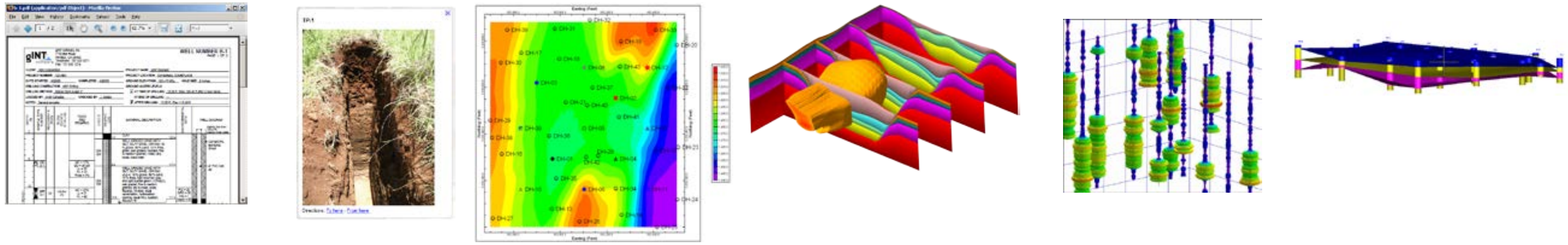
Managing various data types and Geotechnical data

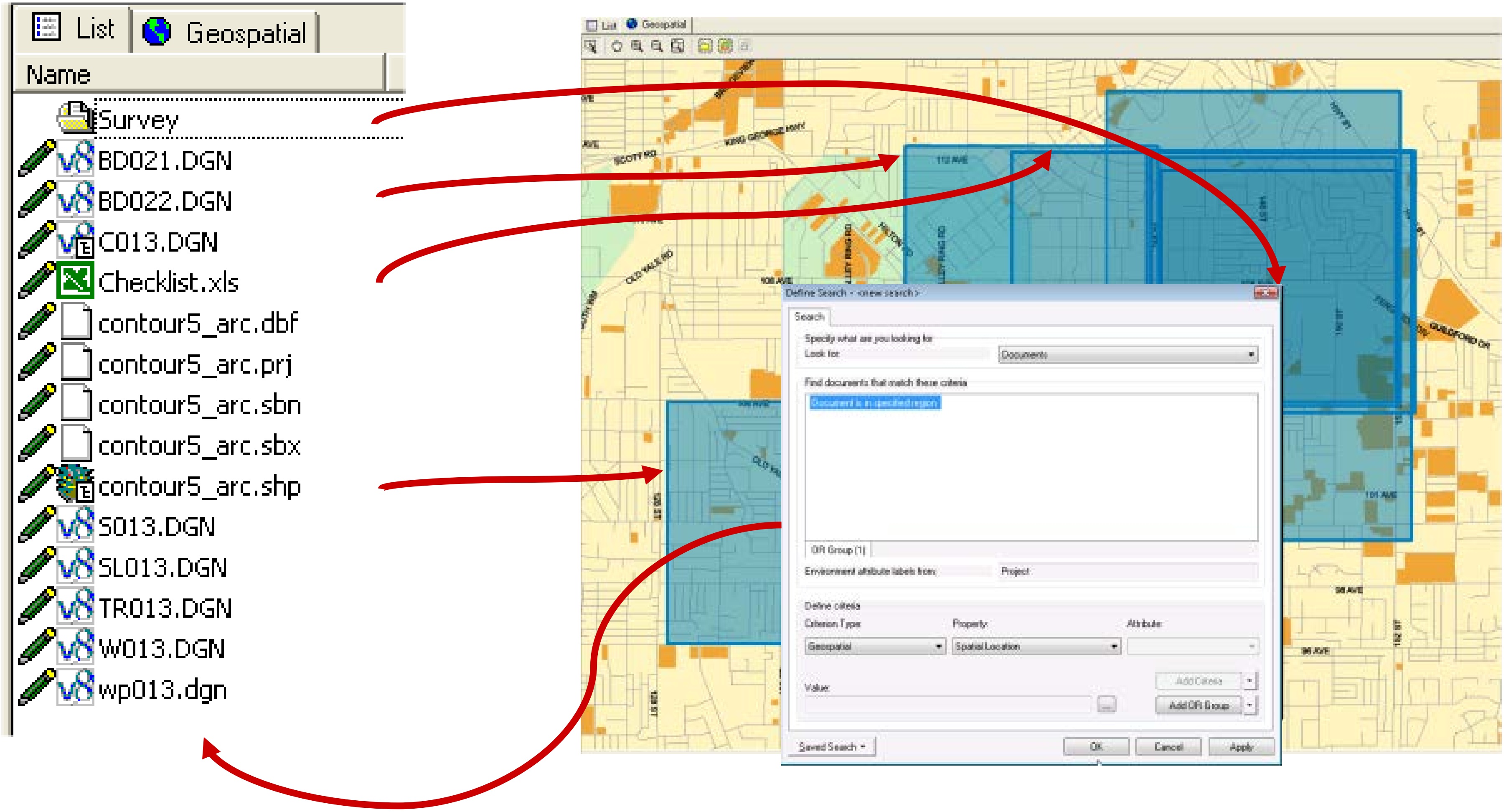


Architecture of Geotechnical Solution





Document/Project Spatial Indexing



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Common Data Environment (CDE) allows you to

- Manage heterogeneous data (geotechnical database, geotechnical data document, images, projections, …).
- Have teams using different CAD/BIM and Geotechnical tools working from a single source of truth (data repository).
- Easily find the data you own about a given location on earth.
- Know if the data you are about to work with is the latest and greatest or not.
- Make sure that colleagues have access to the data they need to perform their tasks, no less, no more.
- Edit spatial databases.

经济效益证明

坝基深槽处理专项技术提出了一种全新的坝基深槽处理方法——钢筋混凝土承载板洞挖全置换方案，在国内外同类工程尚属首创。该方案承载板上下同时施工的特点极大的缩短了深槽处理所占的直线工期，较常规处理方式节省工期约 10 个月，经济效益非常可观。

（1）常规开挖方案工程投资为 15111.37 万元，本项目采用的承载板洞挖置换方案工程投资为 21005.95 万元，较常规开挖方案增加投资约 5894.58 万元

（2）承载板洞挖置换方案可使发电工期提前 10 个月。龙开口水电站多年平均发电量 73.96 亿 kW・h，10 个月的发电量约为 61.6 亿 kW・h，若平均出厂电价按 0.3 元/kW・h 计算，发电效益增加约 18.49 亿元。

综上所述，经济效益增加约 17.9 亿元。

华能澜沧江水电有限公司财务专用章

证明单位（公章）

2014 年 3 月 10 日

成果应用证明

水利水电工程建设中混凝土大坝建基面的选择，是勘测设计的一项重要工作，其选择合理与否不仅关系到工程质量和安全，同时还直接影响施工工期和工程造价。

龙开口水电站拦河坝为碾压混凝土重力坝，坝顶高程 1303m，坝长 768m，最大坝高 116m。在大坝坝基开挖过程中，华东勘测设计院有限公司摸索出一套行之有效方法，对大坝建基面进行了优化。设计通过地质跟踪、坝基超前声波测试和建基面预评价工作，及时收集坝基岩体质量信息，与前期勘察设计资料对比，进行建基面岩体质量预测、预报和复核。并采用现场大剪试验及变形模量试验，对大坝建基面岩体进行了即时评价，使整个设计和施工均处于动态过程控制中。最终提出的建基面优化方案，在保证岩体质量满足要求的同时，节省工程投资约 19397 万元，并缩短了工期，加快了工程进度，取得了显著的综合经济效益。

龙开口工程已于 2012 年 11 月下闸蓄水，目前，所有机组均已发电。大坝运行状态良好。本项技术成果为其它水电工程建基面优化提供了很好的借鉴，对于促进工程建设有重要的社会效益，具有很好的推广应用价值。

应用单位：华能龙开口水电有限公司

龙开口水电工程建设管理局

2014 年 [illegible] 月 [illegible] 日

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Conclusion

- Geotechnical data should be stored in systems that are open for multiple uses rather than "just" the generation of a paper based reports.
- Using a single source of truth will address 2 of the 3 issues identified in the traditional geotechnical state of practice : **unmanaged data** and **report driven**.
- The liability aspect* of the subsurface generation/interpretation remains, it is a major point to be addressed in order to fully deploy BIM workflows.

- ❑ Database
- ❑ Digital models
- ❑ Geocoordination
- ❑ Contracts

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Thank You

Questions ?