DIGITAL MAPPING TECHNIQUES 2018

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http://ngmdb.usgs.gov/info/dmt/
3D geological modeling and management system for Singapore

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This presentation describes the procedure for the establishment of a 3D geological modeling and management system for Singapore based on borehole data collected by the Building and Construction Authority (BCA) of Singapore and the 3D geological model and geotechnical models that have been built so far. More than 60,000 borehole data with geotechnical testing data are available to be used for this project. The first step was to screen all the data. This involved in removing errors and duplicates from the database as well as identifying and adjusting missing data in the database using the SubsurfaceViewer software. Geological consistency was also checked by comparing among adjacent boreholes. The second step was to construct fence diagrams zone by zone. Different zones were connected using common boundaries. Finally, 3D geological models were constructed using all the fence diagrams and the digital elevation model. Some sections of the models are shown in the presentation. For critical areas where changes in geological formations are involved, the use of extra data and extra fence diagrams to reduce the uncertainties in the geological model is also illustrated in the presentation. The plan for future online access of the 3D geological model and the services that the model could offer is also outlined in the presentation.
3D geological modeling and management system (GeM2S) for Singapore

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Nanyang Technological University, Singapore

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Building Control Authority, Singapore

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Outline

• Introduction
  – Background of the project
  – Geology of Singapore
• The Geodata Modelling and Management System (GeM2S) – in the making
• Future plan
Objective

- **To establish a geodata modelling and management system (GeM2S)** to transform 60,000 borehole data and geotechnical testing data to 3D geological and geotechnical models for future underground developments in Singapore.
- The **key deliverables** are the 3D geological model, geotechnical models and a web-based design tool for future underground projects.
- The models are to be verified by a tunnelling project by the Land Transport Authority (LTA) and apply it to the master plan by the Urban Utility Board (URA).
- It will be BIM ready and form part of the Digital City program.

2D Geological Map of Singapore
Updating of Bedrock Geology

Some 100 new boreholes (c. 13,400 m of new core), with new 2D seismic data in five study areas; and new outcrop study from some 300 locations (•).
Project Milestones

- Milestone 1: Geotechnical borehole data
- Milestone 2: Establishment of validation methods to select correct and useful geo-data
- Milestone 3: Validation of data
- Milestone 4: Web-GIS geo-data management system
- Milestone 5: Applied to URA master plan and LTA project
- Milestone 6: 3D geo-model interactive visualization tool
- Milestone 7: Web-GIS Geo-model data base
- Milestone 8: Proposed uncertainty analysis method to evaluate the mean value trends of geo-data and identify “abnormal” data point
- Milestone 9: 3D geo-models

M1: Processing of Borehole Data

1) Compiling digital BH data (.ags) into access database

<table>
<thead>
<tr>
<th>Total No of BH</th>
<th>BH data in .ags</th>
<th>BH data in pdf files</th>
</tr>
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<tbody>
<tr>
<td>59,275</td>
<td>48,828</td>
<td>10,447</td>
</tr>
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</table>

BH data from LTA
BH data from HDB
BH data from BCA, MPA, URA and private sectors
BH data from JTC

48,828 digital BH data in .ags (SG) digital data transfer format include:
- Site specific information: geology, core, fracture, ground water condition, etc.
- In-situ testing data: geophysical, permeability, SPT, PMT, etc.
- Lab testing data: physical, chemical, compressibility, consolidation, stiffness, strength, etc.
M2: Validation of Geological and Geotechnical Data

1) Geological data

1st Step: Using SubsurfaceViewer to identify and adjust missing data

HDB-1970-10B_24453

Normal data (GEOL matches with HOLE) • Missing data (GEOL does not match with HOLE)

2nd Step: Translate Geological Code 1&2 to Code 3

Used for building 3D geological models

GEOL 3 (Lithostratigraphical classification)
398,854 Total in GEOL table
321,784 (61%) Unclassified in SI Report
M2: Validation of Geological and Geotechnical Data

1) Geological data

3rd Step: Check inconsistency in geological data

Comparing adjacent boreholes with each other

M3: Establishment of 3D Geo-models

1. Software used:
   - SubsurfaceViewer 6_MX
   - SKUA GoCAD 15.5
   - Leapfrog Geo 4.0.1

Shallow 3D geological modelling

Deep 3D geological modelling

3D geotechnical modelling
M3: Establishment of 3D Geo-models

2 Geological modelling-Nine sub-zones

M3: Establishment of 3D Geo-models

2 Geological modelling-zone 1

Cross-sections (15) -> Fence diagrams -> 3D geological model

Fence diagrams

3D geological model

- BH data from LTA
- BH data from HDB
- BH data from BCA, MPA, URA and private sectors
- BH data from JTC
M3: Establishment of 3D Geo-models

2 Geological modelling - zone 3

Cross-sections (10) - Fence diagrams - 3D geological model

M3: Establishment of 3D Geo-models

2 Geological modelling - quality control method

Fence diagrams quality control (Adding sub-cross-sections)

Cross-sections - Sub-cross-sections
M3: Establishment of 3D Geo-models

2 Geological modelling-quality control methods

3) 3rd method: Layer boundary quality control (Based on boreholes and geological map)
M3: Establishment of 3D Geo-models

SPT Geotechnical modelling - BH selection criteria

- **Geotechnical Data in hand**
  - 43,054 boreholes all over Singapore
  - 416,366 rows of SPT data
  - Other types of geotechnical data are given as attachments

- **Error form**
  - Duplicated Hole ID
  - Conflicted BH information
  - Overlapping segments
  - Conflicted soil data for re-bored BH

- **Selection criteria**
  - If soil data is conflicted in re-bored BH, use the new one
  - Contradicting BH data is filtered by majority of the nearby BH

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M3: Establishment of 3D Geo-models

SPT Geotechnical modelling - BH data processing

- Models with two levels of details are to be produced regarding the SPT N value
  - Coarse model – for the whole Singapore
  - Fine model – take sample boreholes and form smaller models all over Singapore

- Coarse model - five categories
  - N <12,  N 12-25,  N 25-50,  N 50-100,  and  N >100 (very hard layer)

- Fine model - ten categories

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<th>N-value</th>
<th>Consistency</th>
<th>Category (tentatively)</th>
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<td>Very Loose</td>
<td>$1</td>
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<tr>
<td>4-10</td>
<td>Loose</td>
<td>$2</td>
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<tr>
<td>10-30</td>
<td>Medium Loose</td>
<td>$3</td>
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<tr>
<td>30-50</td>
<td>Dense</td>
<td>$4</td>
</tr>
<tr>
<td>&gt;50</td>
<td>Very Dense</td>
<td>$5</td>
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</table>

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<table>
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<tr>
<th>N-value</th>
<th>Consistency</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>&lt;4</td>
<td>Very Soft to Soft</td>
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<tr>
<td>4-8</td>
<td>Firm</td>
<td>C2</td>
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<tr>
<td>8-15</td>
<td>Soft</td>
<td>C3</td>
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<tr>
<td>15-30</td>
<td>Very Soft</td>
<td>C4</td>
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<tr>
<td>&gt;30</td>
<td>Hard</td>
<td>C5</td>
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</tbody>
</table>
M3: Establishment of 3D Geo-models

3 SPT Geotechnical modelling- Coarse Model

Legend
- SPT N < 12
- SPT N 12-25
- SPT N 25-50
- SPT N 50-100
- SPT N >= 100

M3: Establishment of 3D Geo-models

3 SPT Geotechnical modelling- Fine Model
M4: Moving on from GeM2S to online 3D models

Web-based 3D Geo-models

System operation interface

The visible content of 2D and 3D view are synchronized. When visible extent in 2D view is changed, such as zoom in/out and pan, the 3D view will automatically change to same visible extent.
Web-based 3D Geo-models

Address Search widget allows user to search address by inputting road name, land mark name and postal code.

Borehole query widget allows user to search boreholes by inputting BH ID, location and radius, address and radius.

3D model extraction allows user to specify an area to extract and display on 3D view by drawing a geometry on 2D view using rectangle, circle and free polygon.

Query random cross-sections allows user to get the cross section profile by drawing horizontal polyline on the 2D View.
Web-based 3D Geo-models – Access

Different levels of user access privileges

In Conclusion

• In the past 18 months we have established
  • The 3D geological models of 9 sub-zones;
  • The 3D SPT model and other geotechnical models are ongoing;
  • A working procedure for the Web-based GeM2S system

• Coming up:
  1. Complete the 3D geological model;
  2. Complete the 3D geotechnical models;
  3. Setup the online access platform;
  4. Verify the system using a tunnelling project;
  5. Merge it with Digital City Program.