Building 3D models from geotechnical data

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Abstract

Building Information Modelling (BIM) and Virtual Reality (VR) are two of the main directions in the BIM-strategy of the Swedish Transport Administration. Starting from the year 2015 it is a requirement to use BIM even in tenders.

In order to meet these requirements WSP developed their own product Open VR - a data platform for visualization, communication, planning, designing as well as a tool for documentation of new and existing environments.

Geotechnical analysis is an important part in most of the projects and affects the economy, the projects timeframes and further projects design greatly. Availability of good quality basic data is a requirement to succeed in a project. Inaccurate and late delivered rock and soil 3D models cause the problems at the design stage. A completely or partially automated process for creating 3D soil models using geotechnical database and models presentation in Open VR would provide both economic benefits and reduce the amount of repetitive work in the CAD environment.

One of the biggest issues is to combine data coming from different sources and therefore clear standards on how different fields of technology should prepare their information are needed. The goal of this master thesis is to develop a guideline how to prepare geotechnical objects for Open-VR.

Firstly software that could be used for preparing geotechnical data for Open VR were identified and described. Three products were chosen: NovaPoint, Civil3D, Power Civil. After that data were processed using the software chosen for comparison. Geotechnical objects (3D models of soil layers and 3D boreholes) were prepared for Open VR using these three products. The results were evaluated. Finally a guideline for preparing geotechnical data for Open VR was written. This guideline can be used not only for preparing the geotechnical data for Open VR but for any other product which can be used for the model coordination (for example, NavisWorks etc). This guideline can be used in any geotechnical project where geotechnical data of Swedish standard are used. This guideline can be used as it is in order to create 3D models of soil layers and rock surfaces with help of Civil3D. In case that another kind of software should be used, this guideline can be used as a basis, because the workflow is the same, but some correction can be done concerning what “button should be pressed”.

Recommendations were given depending on the project requirements and application area. Taking into account that WSP decided to not continue with NovaPoint and use Civil 3D and Power Civil instead, then it is recommended to use Civil 3D when it is necessary to create soil layers using field

investigations. Results of 3D modelling can be used in NovaPoint, loaded to Open VR and, if necessary, even be imported into Power Civil.

Power Civil can be used in large-scale projects where advanced 3D modelling is required or when all other area of technology use Power Civil for project design.

Even though NovaPoint does not have priority at WSP it should not be out of the game, it can be very useful in projects where the usage of BIM is a requirement. Considering that NovaPoint has good communication with GeoSuite and can produce smart 3D models it is recommended to have a license of NovaPoint at WSP in order being able to follow software development.

Keywords

Open VR, BIM, 3D, NovaPoint, PowerCivil, Civil 3D, GeoSuite, Filling, Clay, Friction soil, Rock

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2D - Two-dimensional/ two-dimensional space

3D - Three-dimensional/ three-dimensional space

4D - Four-dimensional/ four-dimensional space

API - Application programming interface

ASCII - American Standard Code for Information Interchange

BIM - Building Information Modelling

CAD - Computer Aided Design

CPT - Cone Penetration Test

DGN - Design (file format Microstation)

DWG - Drawing (file format AutoCAD)

GIS - Geographic Information System

MUR - Markteknisk Undersökningsrapport

OSS - Open Source Solutions

RDT - Data file format which is used in Geotech's field logging equipment

SGF - Svenska Geotekniska Föreningen (Swedish Geotechnical Society)

SGI - Statens Geotekniska Institut (Swedish Geotechnical Institute)

STD - Data file format developed according to SGF-standard

TRUST - TRansparent Underground Structure

VisSim - Visual block diagram language for simulation of dynamical systems and model based design of embedded systems

VR - Virtual Reality

WSP - is one of the world's leading professional services firms in its industry, working with governments, businesses, architects and planners and providing integrated solutions across many disciplines.

1. Introduction

1.1 Background

“The use of 3D virtual reality (VR) modeling for urban planning, building and infrastructure (highways, railways, underground systems) is widely appreciated by the public, designers and authorities. The ability to represent the existing buildings and the landscape by combining terrain data and aerial photography provides instantly recognizable views and drive-through sequences understood easily by local people. The level of realism and accuracy gives confidence that the proposals will look as designed and have the advantage of being set in the context of the existing landscape.” (Tullberg & Connell, 2008)

Moreover Building Information Modelling (BIM – abbreviations see Table of abbreviations) and VR are two of the main directions in the BIM- strategy of the Swedish Transport Administration. Starting from the year 2015 it is a requirement to use BIM even in tenders.

In order to meet all requirements, be attractive for customers and be competitive on the market WSP has developed their own product Open VR. This is a data platform for visualization, communication, planning, designing as well as a tool for documentation of new and existing environments.

Open VR is built on an open VR-engine from OpenSceneGraph. The advantage of using open source is the possibility to develop and customize the application over a long period. The application can be customized for every new project. The client can freely copy and use the models at will. This makes it very attractive for the usage.

The application uses CAD-files with 3D objects. The result is a world where anyone can navigate absolutely free and measure both in plan and height; or choose a section both horizontally and vertically.

Even though development of Open VR started for more than five years ago challenges still exist. One of the biggest issues is to combine data coming from different sources and therefore clear standards on how different fields of technology should prepare their information are needed.

Geotechnical analysis is an important part in most of the projects and affects the economy, the projects timeframes and further projects design greatly. Availability of good quality basic data is a requirement to succeed in a project. Inaccurate and late delivered rock and soil 3D models cause the problems at the design stage. Being able to quickly obtain accurate models would help considerably. A completely or partially automated process for creating 3D soil models using geotechnical database and models presentation in Open VR would provide both economic benefits and reduce the amount of repetitive work in the CAD environment.

1.2 Goal

The goal of this master thesis is to develop a guideline how to prepare 3D geotechnical objects – 3D models of soil layers and rock surfaces and 3D-models of geotechnical investigations (3D-boreholes). 3D models can be used in a project design by the geotechnical team, by other areas of technology who are involved in the project and interested in using geotechnical data, by the VR team in order to create the coordination model for the project using the Open VR or any other products which can combine 3D objects (for example, NavisWorks etc). The guideline can be used within the organization or by other companies who are working with geotechnical data because the principal ideas and workflow are the same even though one chooses software which is not recommended in this thesis.

The first step is to identify and describe software that can be used today for creating 3D models for soil layers and rock surfaces and for creating 3D-boreholes. The second step is to create 3D soil layers and 3D-boreholes by using chosen software and evaluate the results of the test (compare workflow, time spent for operations, number of steps, complexity of process and the data obtained during the tests). Finally, write a guideline how the 3D models for soil layers and rock surfaces can be created. The guideline can be used by any geotechnical team who is working with Swedish standard of geotechnical data. Created 3D models can be used in a project design and for creating coordination models by using, as it is in this case - Open VR, or any other suitable for this purpose software.

The Geotechnical Department of WSP in Stockholm specified “Usage of Open VR at all stages of designing” as one of the main directions of development for the year 2015.

That is why this Master Thesis is topical and will be useful and interesting for different parts. First of all it is of big interest of those who prepare 3D geotechnical models in a project, but also for the data coordinator at the VR Department who is responsible for the coordination model which can be created with a help of Open VR or other VR products.

1.3 Limitations

Software chosen for comparison in this master thesis is one of those which are used today at WSP. Criteria of comparison chosen for evaluation of software and workflow are related to the geotechnical field. Most important for this master thesis is how 3D models of soil layers and other geotechnical data that can be shown in Open VR can be created with different software.

1.4 Methods

The Master Thesis is carried out by studying previous experience of using VR within geotechnical team at WSP and other consulting companies, for example Sweco (Hedberg, 2007) and Ramböll. Experience in creating and using of 3D-models by geotechnical team at WSP, Sweco and Ramböll was studied. The course GeoSuite, Presentation 3D/ BIM was taken in May 2015. At this workshop, the course literature, the workflow recommendations, news for GeoSuite and other Vianova products were given. In addition it was possible to clarify all questions appeared at the thesis writing.

In order to define software which can be used for comparison in the thesis, projects performed in the previous years were studied. The experts in this area were interviewed. The software which can be used in order to create 3D models for soil layers, rock surfaces and 3D-boreholes and available on the market were analyzed.

The methodology for this master thesis is chosen so it covers the whole workflow starting from gathering of raw data and finishing with transferring this data to a VR-model.

In order to be able to make a correct and fair comparison of these different products, regarding their ability to create 3D-models of soil layers, the data coming from the same running project is used. A sample area with 140 points was defined. Area of investigation is around $45000m^2$ which is not so big and points are distributed quite regularly.

Firstly the database for the sample area is created. This step is the same for any software in the comparison.

Next step, which is also the same for any software in the comparison, is the automatic interpretation which is performed in geotechnical database GeoSuite.

When the interpretation control in GeoSuite is performed the 3D models for soil layers, rock surfaces and 3D boreholes is created with a help of chosen for the comparison software.

The results of the tests are evaluated and presented in the Table 1.

According to the results the recommendations are given.

Finally, the guideline “Workflow: Geotechnical data preparation for Open VR using GeoSuite and Civil 3D” (Appendix 1) is written. This document can be used by anyone who needs to create 3D models for soil layers and rock surfaces by using Swedish standard geotechnical data.

2. Virtual reality

2.1 Background

”Virtual reality” (VR) as a term was first used in the 1980s.

From the very beginning virtual reality was associated with a computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way by a person, esp. by means of responsive hardware such as a visor with screen or gloves with sensors; such environments or the associated technology as a medium of activity or field of study; cyberspace.

During the years the meaning of this word has deformed and became quite wide and is “used to describe applications in which we can interact with spatial data in real-time. At the same time this term is overlapping a number of groups of technologies, such as “virtual environments”, “visualization”, “interactive 3D”, “digital prototypes”, “simulation”, “urban simulation”, “visual simulation” and “4D-CAD”. (Whyte, 2002)

There are two terms that can be distinguished in connection to virtual reality:

- VR medium – when the term “virtual reality” is used to refer to the VR medium there is a focus on the virtual environment and the model created within the computer. There are three characteristics that define virtual reality as a medium:

  1. interactive –possibility to interact with models;
  2. spatial – representation of models in three spatial dimension;
  3. real-time – possibility to get a feedback from actions without noticeable pause.

  These characteristics can be presented differently, and they depend on the application. The extent of interaction can vary. The users can be limited in creating objects within the virtual environment, in changing some of objects’ parameters and conditions in which they can be shown. (Whyte, 2002)

- VR system - when the term “virtual reality” is used to refer to the VR system the focus is on the hardware and software. (Whyte, 2002)

Virtual reality systems support the use of an interactive, spatial, real-time medium and are comprised of the computer hardware and software, the input and output devices, the data and the users - Figure 1 Components of a VR system.

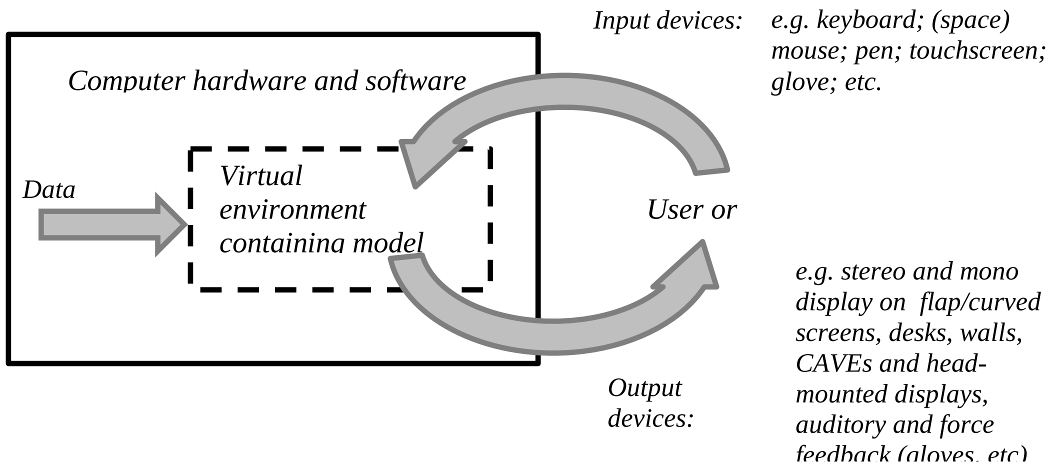


Figure 1 Components of a VR system

*Source: (Whyte, 2002)**

Virtual reality (VR) is a new tool for design, production and management of the built environment. Virtual reality is being used in industry for a range of different tasks. It is being used most widely at the later stages of design, but there is not one single approach to its use. Instead there is a set of related strategies, drivers and models. (Whyte, 2002)

Organizations are using virtual reality in conjunction with a range of other advanced technologies, such as object-oriented CAD, parametric modelling, laser scanning, photogrammetry and Geographic Information Systems (GIS). The use of these other technologies influences the strategies that organizations develop for building and optimizing VR models and for translating data to VR systems (Whyte, 2002)

BIM is one of the technologies which is used in VR in order to improve the process of project designing and coordination models efficiency. BIM objects can contain besides the objects coordinates some additional information. The geotechnical investigation, for example, can contain information about the equipment and the investigation method which is used, who and when performed it.

However, there are some similarities how organizations are implementing and using virtual reality. They make a distinction between models created for professional uses, for example, consultant engineers, constructors etc (models can be used internally within one organization or in conjunction with other professional organizations involved in the same project), and for those for wider interactions, for example, end-users, clients, managers, funding institutions and planners.

Virtual reality is just one of the possible media in which 3D data can be visualized. All visualizations in virtual reality are not the same. Different strategies can be used for building interactive, spatial, real-time models from 3D data and the modelers' priorities affect the visualization. The strategy chosen depends on the input data, the task and the system. (Whyte, 2002)

For built environment applications, many of the spatial models that are interacted with in real-time are created using data from CAD or GIS packages. (Whyte, 2002) Complex and highly detailed data require more computational time. In order to make models more suitable for usage they can be optimized by using texture maps, using primitive solids, using distance-dependent levels of detail, using billboards or selectively loading objects within the model depending on the viewpoint.

Early users of virtual reality struggled with translation of the data. Nowadays this problem is not as big as it was before however it still takes time in order to translate data from CAD environment into virtual reality.

There are three main approaches in translating the data to virtual reality:

1. "A library-based approach, where a library of components or objects is archived for reuse within the VR environment, eliminates the need for repetitive data transfer and optimization of common parts. Such an approach can also be described as object-oriented. Objects can contain information about their behaviors and processes, as well as their geometry. Significant time and effort is initially required to build up the library; however this time is compensated by the reuse of information" (Whyte, 2002) - Figure 2.

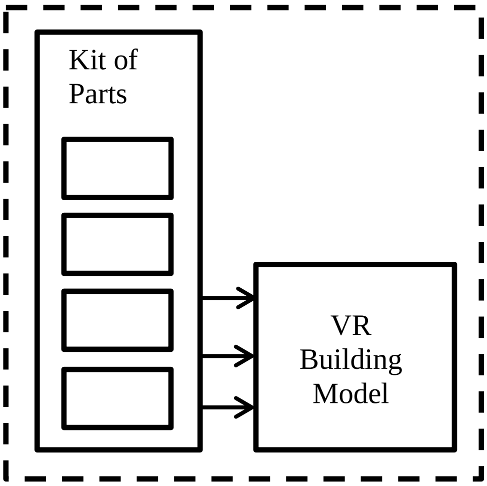


Figure 2 Library of forms approach

*Source: (Whyte, 2002)**

2. Simple translation approach is an approach where complete CAD models can be used to generate VR models by straightforward translation of the whole model, sometimes in conjunction with algorithms for optimization (Whyte, 2002) - Figure 3.

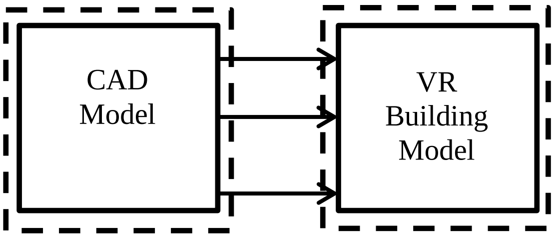


Figure 3 Simple translation approach

*Source: (Whyte, 2002)**

A translation approach has been used in projects where there are few repeated elements and the data is predominately geometric, or where the design process is completed and the design is fixed and unchanging. The result is typically a highly rendered or optimized model for presentation. (Whyte, 2002)

3. A database approach to VR creation uses a central database to control component characteristics and both CAD and virtual reality are used as graphical interfaces to that database - Figure 4. The building model is created in the central database and viewed through

the different applications, one of which is the VR package. A full implementation of such a system would allow updating of the model in both CAD and virtual reality. (Whyte, 2002)

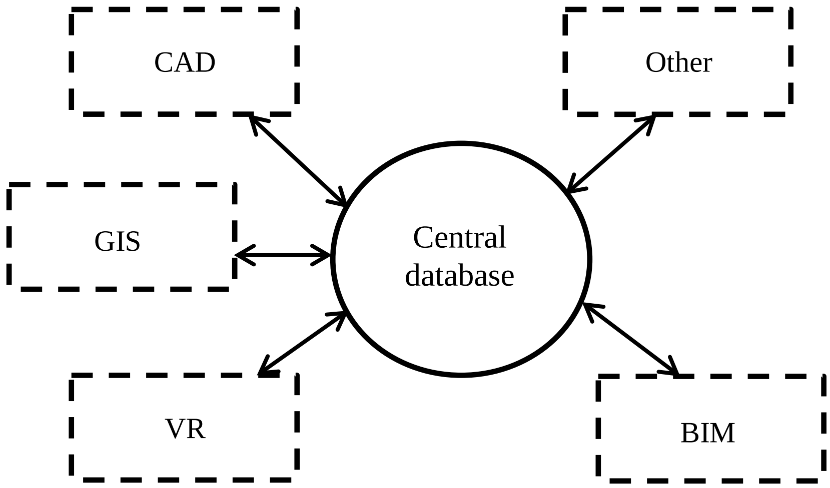


Figure 4 Database approach

”Organizations that use virtual reality for the representation of engineering and design data may or may not be involved in the creation and optimization of the models that they use.” (Whyte, 2002) Depending on how the process of creation and optimization of data is built, data can be integrated with other digital data or may be outsourced and be a part of responsibility of specialists.

2.2 Open VR

2.2.1 Background

Open VR is a VR-platform of high international standard which was developed for more than over ten years and is owned by WSP

Open VR consists of two parts - Figure 5:

- application (describes user interface and functionality);
- VR-objects which build VR-model.

The VR-application Open VR can be used for free by customers according to the rules which are defined at the projects start.

Open Source Solutions (OSS) consists of free open source in form of (C++) library. In this case libraries like Open GL, OpenSceneGraph, Open AL, ODE, SDL etc. They are downloadable both in source code form and in dll form.

Open source does not just mean access to the source code. There are a number of criteria which should be completed according to the distribution terms of open source, for example, free redistribution, license must not be specific to a product, etc. (Open Source Initiative, 2015)

“The OpenSceneGraph is an open source high performance 3D graphics toolkit, used by application developers in fields such as visual simulation, games, virtual reality, scientific visualization and modelling. Written entirely in Standard C++ and OpenGL it runs on all Windows platforms, OSX, GNU/Linux, IRIX, Solaris, HP-Ux, AIX and FreeBSD operating systems. The OpenSceneGraph is now well established as the world leading scene graph technology, used widely in the vis-sim, space, scientific, oil-gas, games and virtual reality industries." (OpenSceneGraph, 2012)

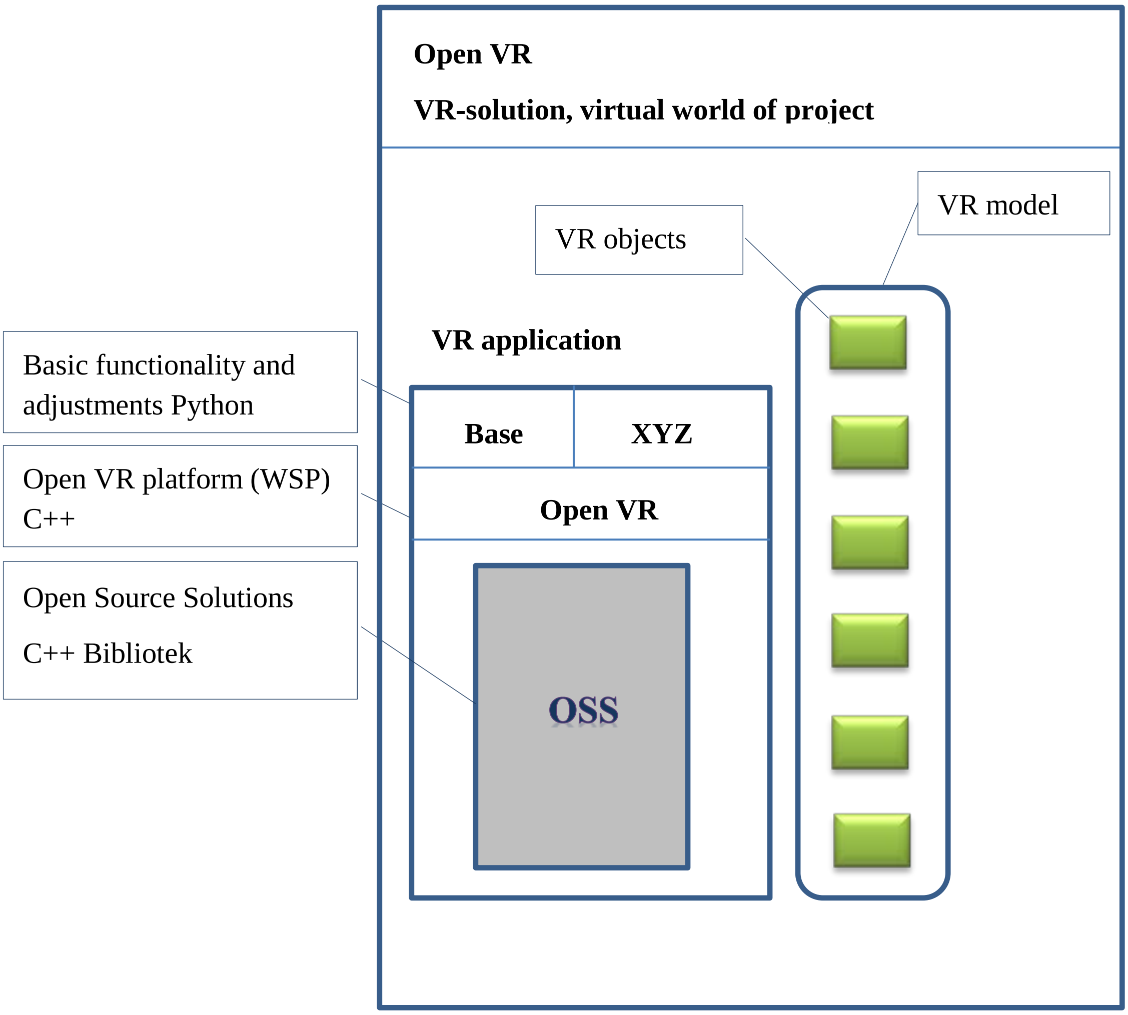


Figure 5 Open VR

"OpenGL is the premier environment for developing portable, interactive 2D and 3D graphics applications. Since its introduction in 1992, OpenGL has become the industry's most widely used and supported 2D and 3D graphics application programming interface (API), bringing thousands of applications to a wide variety of computer platforms. OpenGL fosters innovation and speeds application development by incorporating a broad set of rendering, texture mapping, special effects, and other powerful visualization functions. Developers can leverage the power of OpenGL across all popular desktop and workstation platforms, ensuring wide application deployment." (OpenGL, 2015)

In order to make Open VR suitable for built environment WSP used C++ Core functions and Python Wrapper.

A workflow of Open VR presented in Figure 6.

Objects which can be imported to Open VR have different formats and come from different sources.

CAD objects are usually prepared by designers/constructors of numerous field of technology and contain information about railway and road design, pipe system, earth surface, soil structure, constructions, buildings etc. Each field of technology has its own approach to work in/with 3D. They use different software (AutoCAD, ArchiCAD, Civil3D, Tekla, Microstation, Power Civil), that is why 3D objects may have different type, for example, 3D faces, solids, meshes, polyface meshes etc.

CAD, VISSIM and GIS data goes through 3D modelling program (in this case 3D MAX) and after that they can be imported to Open VR.

Base functionality like viewpoints, navigation, forms, activation of rides, light and extinguish objects, grouping of objects, etc are included in Open VR's basic support. All projects have VR-solutions customized for each particular case and interact via internet. A big advantage of Open VR is ability to manage big models, use textures of high resolution and that it quickly loads information. Moreover it supports direct connection to CAD and GIS data. In addition it is possible to take a section in Open VR environment and save it as dxf file, which can be used in CAD environment.

Open VR has a number of unique advantages:

- open format;
- open source code;
- free distribution of model and application.

VR objects, which are developed for the project, belong to and are owned by the customer.

This general platform for real time visualization of different activities can be used for clear communication from the very beginning of project design; it can be used as well as a platform for planning and constructional design; and even for documentation of existing and new environment.

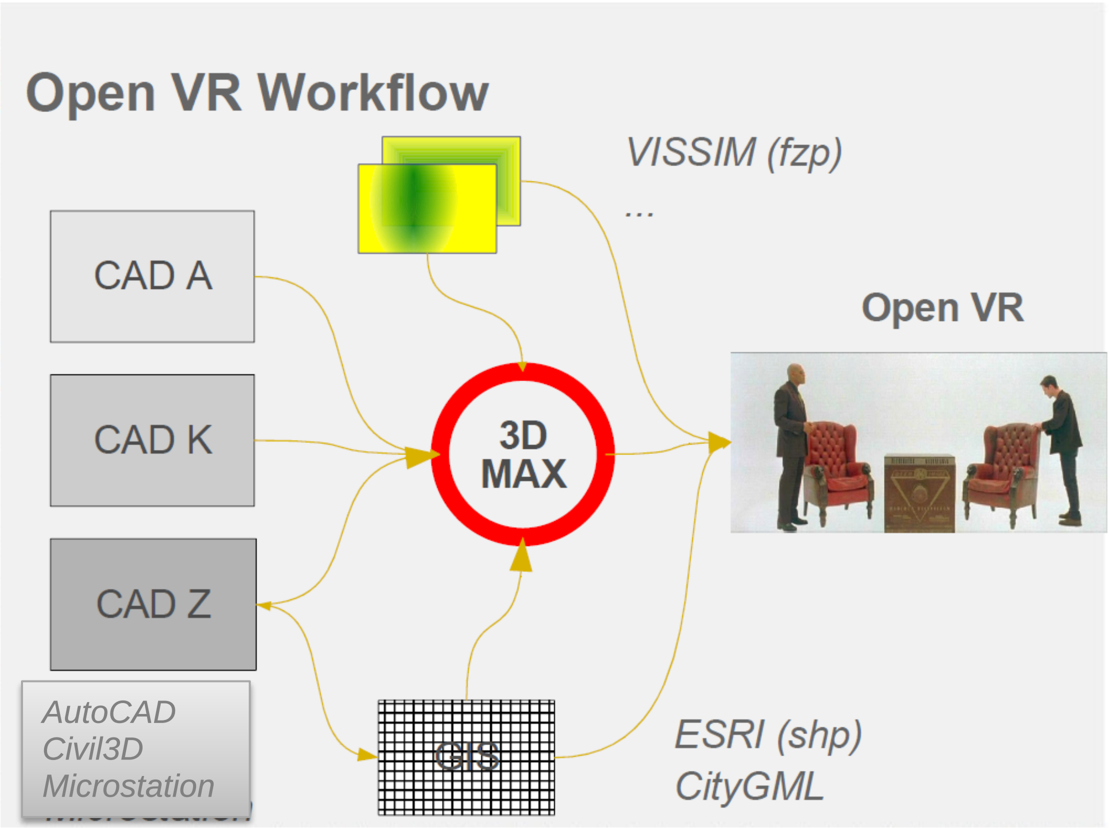


Figure 6 Open VR – Workflow

Source: (Tullberg, 2007)

As it was mentioned before Open VR combines and represents different kind of information coming from various area of technology. For most of the projects one of the most critical parts from the very beginning is soil condition. It is affecting the cost of construction, time for performing project design and its execution. Open VR can be an important and very useful tool in order to reduce the total cost of project execution. For this purpose a project can be presented in Open VR. Roads, pipes, railways, tunnels, constructions and soil layers as well as existing drillings can be uploaded to Open VR and clearly show in 3D environment the project conditions. Sections in critical areas can be taken for further analysis. Open VR can be sent to a customer who can use it for presenting and discussing with those who are responsible or influence the project development – municipality, politicians etc. An advantage of Open VR is that it can be very useful and understandable by both designers and customers. In order to carry out tasks to create Open VR efficiently without wasting time it is necessary that each area of technology prepare their data (3D objects etc) as soon as possible, in a format which is appropriate to load to the model. For that purpose it is important to have established a routine with a clear workflow: who is doing what, how, which software suites best in each particular case. Nowadays a lot of companies use outsourcing or assistance of sub-consultant or resources in the company. That is why this case study is so important for WSP. The purpose is to analyze the existing working approach at geotechnical department, make an analysis of accessible software, give recommendation for improvement and create a manual which can be available and useful for geotechnical staff in the whole company.

2.2.2 Example projects where Open VR is used

According to information presented by Odd Tullberg (Chef, department of Visualization and VR at WSP) at Visual Forum 2011 – Gaming and Visualization for urban planning, there are more than four hundred projects where Open VR was successfully used. (Tullberg, 2011)

All large projects at WSP use VR nowadays.

Appendix 2 gives an overview of projects where Open VR was used during the years 2003-2006. A short description of the project, customer and year of realization are given (document is in Swedish). Unfortunately I could not find a similar document for projects carried out after 2006, but I give a brief description of largest completed and ongoing projects where Open VR has been used.

Hagastaden – one of Stockholm's largest and most important urban development projects with estimated construction time 2010-2025. According to information presented on the web page of Stockholm municipality related to ongoing construction projects (Stockholms Stad, 2015), by 2025, the area of Norra Station between the city of Stockholm and Solna, will be built and developed into an entirely new neighborhood, with a mix of housing, parks and knowledge-intensive industries.

Open VR was used in order to coordinate activities of all actors involved in the process of rebuilding the Norra Station area. Otherwise it would have been very complex to understand what is happening in the project.

Stockholm Cityline (Citybanan) is a 6-km-long commuter train tunnel running between Tomteboda and Stockholm South, with two new stations at Odenplan and T-Centralen.

Stockholm City Line passes for the most part through rock, but in the waters of Riddarfjärden between Riddarholmen and Söder Mälarstrand it runs through a submerged concrete tunnel. (Swedish Transport Administration, 2014)

WSP was involved in all stages of this project starting from year 2003 (feasibility study stage) until now, when they started building. A VR - model over the big and complicated construction was created with specific focus on presentation of different soil layers (primarily rock surface) and geotechnical solutions, such as sheet piles etc.

The Stockholm Bypass (Förbifart Stockholm) is one of Sweden's largest infrastructure projects which will create a bypass of central Stockholm and will connect Kungens Kurva (E4/E20) in the south and Häggvik (E4) in the north. (Burleigh, 2012)

The entire project includes motorways, bridges and two tunnels. About 18 km of the total 21km rout will go in tunnels.

This is not only one project. This is 6 big projects with 5-6 enormous junctions and one very long tunnel. A lot of people are going to be involved in this project in different stages - it will be about 20 different disciplines.

In order to be able to work together in the project, communicate and interact, a VR-model was used. Before each meeting the VR-model was updated as much as possible: hand sketch, PDF files, GIS data of different formats, CAD etc. It was a bit slow in the beginning, because each field of technology had to prepare data for the VR-model, all participants learned how VR can be used, but later it was successfully used. The VR-model is a very helpful tool, and it went much faster and easier to discuss the problem issues in the meeting. The peculiarity of this project is that all versions and alternatives are presented in VR-model. Even though VR-model was used in most of cases the Swedish Transport Administration required producing drawings. That is why all drawings and documents are in the model as well.

Subway route Odenplan – Hagastaden – Arenastaden (TUB A)

In 2014 WSP got a big and prestigious project of designing the new subway route Odenplan – Hagastaden – Arenastaden - Figure 7.

Odenplan becomes an important transport point when the City Line will be completed. It will be possible to change here between subway and commuter rail and relieve the Central Station. From Odenplan a new metro line will go to the Arena City in Solna.

The subway will continue to Hagastaden – a new neighborhood with hospitals, universities, research institutes, enterprises, housing, culture and services that connect Solna and Stockholm.

From Hagastaden the subway continues north to the Arena City in Solna.

WSP started using Open VR from the project start. The VR-model is used by designers in everyday work, in meetings in order to better understand the issue discussed, to produce basic material and work sketches.

In order to make it easier to update the VR-model, each area of technology is responsible for data which should be presented in the VR-model. Different area of technology work with different software (Microstation, Power Civil, Civil 3D, NovaPoint, Tekla, SBG GEO, etc) and produce 3D-model in different ways and 3D objects of different format and types. In order to make the process of updating the VR-model economically and time-efficient it was decided that each field of technology should prepare data themselves; data should be exported/ saved in specified format (dwg) as 3D surfaces/objects.

However there are no instructions, descriptions or requirements how the 3D objects should be created or presented.

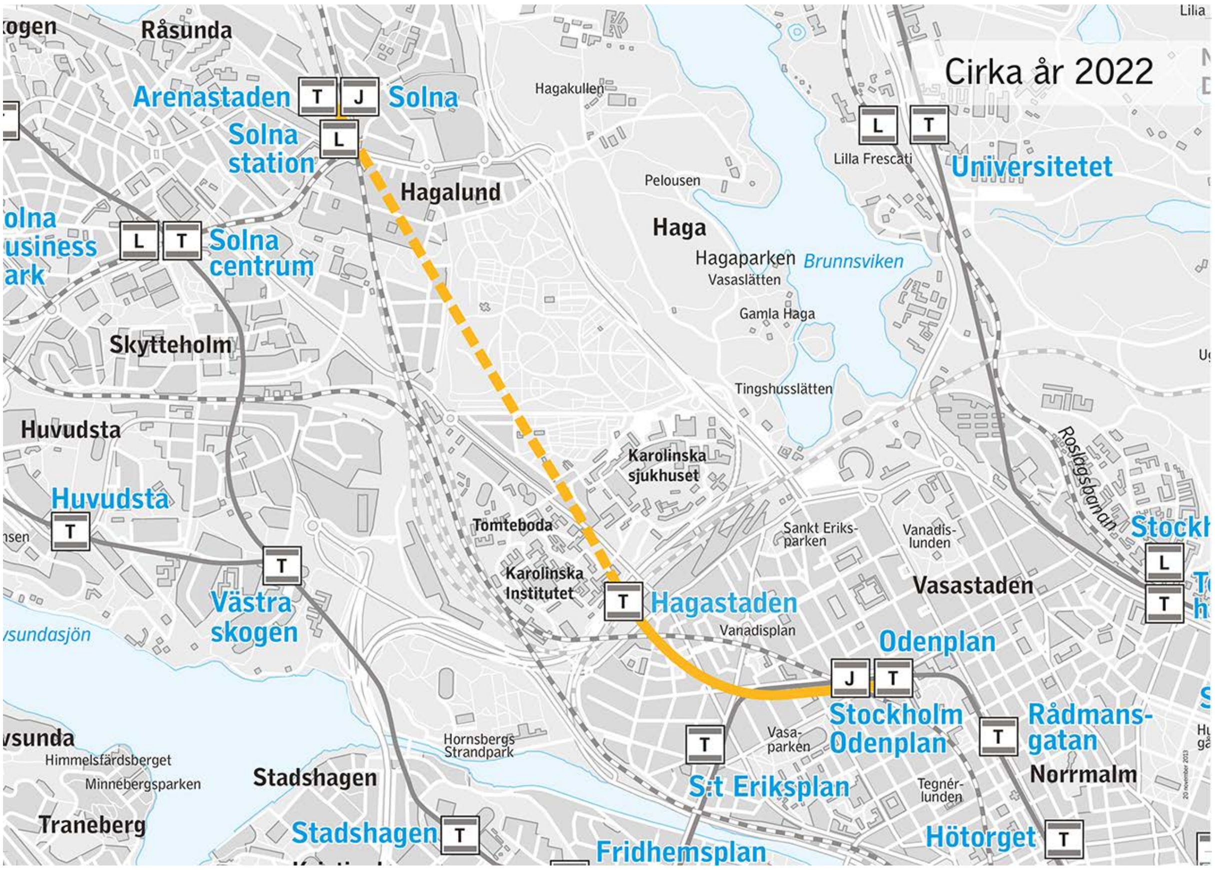


Figure 7 Map over Odenplan via Hagastaden to Arenastaden

Source: (Stockholm läns landsting, 2015)

I am, personally, responsible for preparing the geotechnical data for Open VR. Open VR is very useful presentation tool but the biggest issue is to prepare the 3D data. When 3D objects are created, than it does not take much time in order to create coordination model. First of all the rock surface should be created. It is used by other areas of technology in order to find most suitable location for tracks, stations, platform exits etc. Unfortunately there is no unified standard how the rock surface should be created, what kind of software should be used, what kind of data can be used etc. That is why the workflow often depends on a person who is performing a task, on the person's experience, and it can be difficult to follow what has been done in the project and it takes time in order to replace this person if it is necessary. It is good to know what kinds of tools are available; it makes it easier to work if there is a manual available with descriptions, tips and tricks. It was discussed at the geotechnical department that it is good to have "a backup person", so if something happens it is quite easy to replace a person in a project. Clear instructions and established workflow is extremely useful. Moreover, it is a very good help for new employees, both for those who will produce 3D models and for those who will estimate how much time and resources are necessary in order to create 3D surfaces.

3. 3D design in construction

3.1 Background

The key part of any virtual reality system is the data. Models may be built within the virtual environment, but are more usually imported from CAD. They can also be obtained directly from the physical world using techniques such as 3D laser scanning, photogrammetry or geometry capture from film. (Whyte, 2002) In this master thesis models obtained in or with help of the CAD environment will be discussed.

The construction industry is in the stage of moving from traditional 2D-drawings to model based design (3D). Thus BIM, where models include not only geometrical data but also information regarding spatial relations and semantics (Roupe, 2013), and VR-systems are being more relevant and are used more often.

If one looks at how BIM technology is used in different areas of technology it is easy to notice that BIM is quite widely used in house projects. But it was not so often used for underground constructions. Nowadays the situation is changing, but a number of issues should be solved, for example, which software is better suited for each particular case and project, what kind of data can be used, the format of result data, how additional information can be used and connected to different objects, etc.

Some years ago the Swedish Transport Administration (Trafikverket) together with Formas, Sven Tyrens Stiftelse and others started the TRUST project (TRansperent Underground Structure). The central part of this project is development of a BIM model for geotechnical purposes. This is a hug project which has as a goal to create better conditions for underground construction in Sweden.

According to Hagberg (2015) BIM applied to the geotechnical field (so called GeoBIM) has advantages such as:

- Improved interpretations and risk analyses.
- Improved communication between geotechnical engineers but also towards other professional players and maybe even to laymen.
- Provide possibilities for keeping track of the enormous datasets in large infrastructure projects.
- Refined assessment methods based on a more complete soil model in conjunction with the structural model.

Figure 8 shows a graphical view of the GeoBIM-model. In the model performed measurements are shown as well as the designed tunnel and the results of analysis of investigations. Moreover the existing buildings are presented.

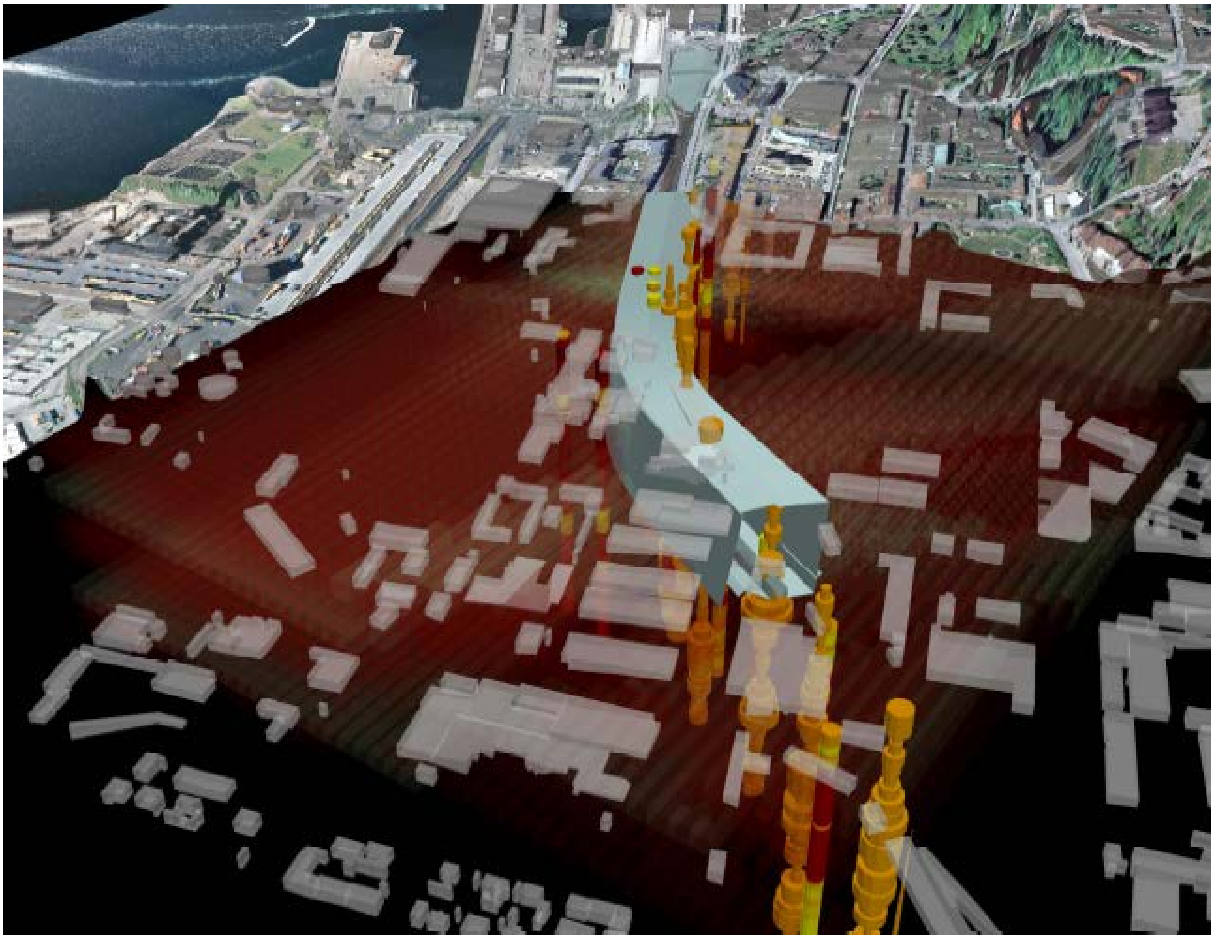


Figure 8 Example of usage of BIM-model

Source: (Hagberg, 2015)

Unfortunately this project is still under construction and geotechnical engineers still have to work in the traditional way when results of geotechnical investigations can be presented in plans or sections (2D). 3D models over soil layers can be also created.

There are a number of advantages to use 3D models in the project design. 3D-models can be used to find conflicts and collision. 3D-models can be used in order to make traditional plans and sections (2D-drawings); volume calculations can be performed and 3D-models can be used in VR-model for presentation and as a discussion material.

There are some disadvantages regarding 3D-modelling. One of them is that it can be complicated to combine models which are created by different designers in different software; it can be complicated to exchange 3D-data because they are not of the same type and cannot be used in the same way by everyone.

3.2 Experience in using 3D and GeoBIM in construction design

One of Northern Europe's largest road tunnel projects which were wholly performed in 3D is the infrastructure project Norra länken in Stockholm. Norra länken runs between Karlberg and Värtan. It is five kilometers long. Most part of it is housed in underground tunnels, with the longest single stretch of tunnel being about three kilometers long.

It was a requirement that everything in the project should be designed in 3D – it was a challenging task, time and economically consuming but it was an attempt to avoid mistakes which were made in similar project Södra länken and to learn how to work and think differently – in 3D.

3D-models for tunnels, roads, existing and planned constructions, pipes, soil surfaces etc were created. 2D-drawings were produced automatically using 3D-models. Usage of 3D-models helped to find and solve collisions in early stages and make volume- and cost calculations. For example, evaluate excavations volumes, value sheet-piles walls etc.

The practice shows that 2D-drawings can be produced easily and very fast but it can take a long time when the production can start. 3D-models for existing constructions can be created once and changes seldom (only if they should be taken away). 3D-models for designed constrictions can change a lot before the design and position of constructions can be locked.

The Norra länken project started a new trend of usage of 3D in underground constructions projects. City link (Citybanan) project used 3D-modelling a lot and in different ways. One example is that 3D-modelling was used in order to place in wall sheet piles and control placement and collisions of anchors and installed piles.

Within the Stockholm Bypass Project Trafikverket uses BIM (Wenander & Båtelsson, 2015). 3D models used as a basic for procurement of contractors. The models include rock models analyzed from an uncertainty perspective with the aim of creating an upper and a lower reference level applicable to contracts. (Wenander & Båtelsson, 2015) Results were presented by Karin Wenander at the conference "Grundläggningsdagen" on 12 Mars 2015 in Stockholm.

Even GeoBIM started to be used, for example, in the ESS Project (European Spallation Source). ESS is a planned materials science research facility using neutron scattering technique. This is a project which will enable scientists to sees and understand basic atomic structures and forces. Construction composed of six hundred meters long linear accelerator which accelerates protons and collides with a tungsten target.

The requirements to minimum subsidence are extremely high that is why geotechnical analysis is so important. GeoBIM-model was created in order to be able easier communicate and discuss alternative solutions and consequences from geotechnical perspective.

4. 3D modelling for Geotechnical Field Of Technology

4.1 Geotechnical data handling

When we are talking about 3D modelling related to geotechnical field it is possible to distinguish two groups of objects:

1. Surfaces which represent soil layers, for example, clay, sand, rock etc. They are created using the results of soil and rock drilling, and can be completed or corrected with other information such as outcrop data, measurements of excavations, information about rock level obtained at installation of poles and sheet walls piles. Soil surfaces can be completed with other “support” points or points with additional information about soil structure (seismic, gravimetrical data, geo radar etc).
2. 3D-modelling of geotechnical constructions and solutions, such as sheet walls piles, calk cement columns, and many others.

Due to time limits software analysis for 3D-modelling of geotechnical constructions will not be included in this report.

The creation of 3D models representing geological soil layers using the results of soil and rock investigations (geotechnical investigations) are of interest and will be reviewed in this master thesis. Further the term *geotechnical data and/ or information* will be used. Geotechnical data or information can be related to the data obtained at geotechnical investigations, samplings, laboratory testing; to the data which shows the results of soil interpretations and the results of 3D-modeling of soil layers and rock surfaces.

“Geotechnical investigation is investigation which aims to determine soil conditions in an area that is to be built. The study also includes the determination of the characteristics of occurring soils and rock. Field survey should provide a basis for an assessment of how land should be used, eg regarding appropriate foundation ways and needs of stabilization measures on slopes. As a basis for a geotechnical field investigation existing maps and aerial photographs are used. The survey in the field is usually initiated probe designed to assess handedness of various occurring soil layer, determine their firmness and define the depth to the bottom, eg, rock. In the next phase of the study is done sampling and groundwater measurements. With sampling referred uptake of soil samples for subsequent examination in the laboratory, the soil is classified and, where appropriate, tested for strength.” (Axelsson, 2015)

According to Geoteknisk Fälthandbok published by Swedish Geotechnical Society (SGF, 2013) geotechnical investigation refers to investigations which aim to examine soil and ground water conditions concerning levels and following order of soil layers, parameters and properties.

According to European standard geotechnical investigations can be divided in three groups:

- Field investigation (drilling (test-holes), in-situ test, geohydrology test)

- Samplings
- Laboratory testing investigations

Planning and performing of geotechnical investigations should follow European and Swedish standards, such as SS-EN 1997-2.

Investigations should follow some principal ideas; a number of steps should be performed before 3D-modelling of soil layers can be started, for example:

- Definition of goal of investigation, type of construction and geotechnical category;
- Archive inventory;
- Choice of investigation method and sampling class;
- Performance of investigation;
- Up taken samplings sends to laboratory;
- Preliminary site evaluation performs;
- If it is needed adjustment of the drilling and testing program implements.

Figure 9 shows steps of underground data processing. Visualization and information processing is important on all of these stages that is why they are shown concurrently.

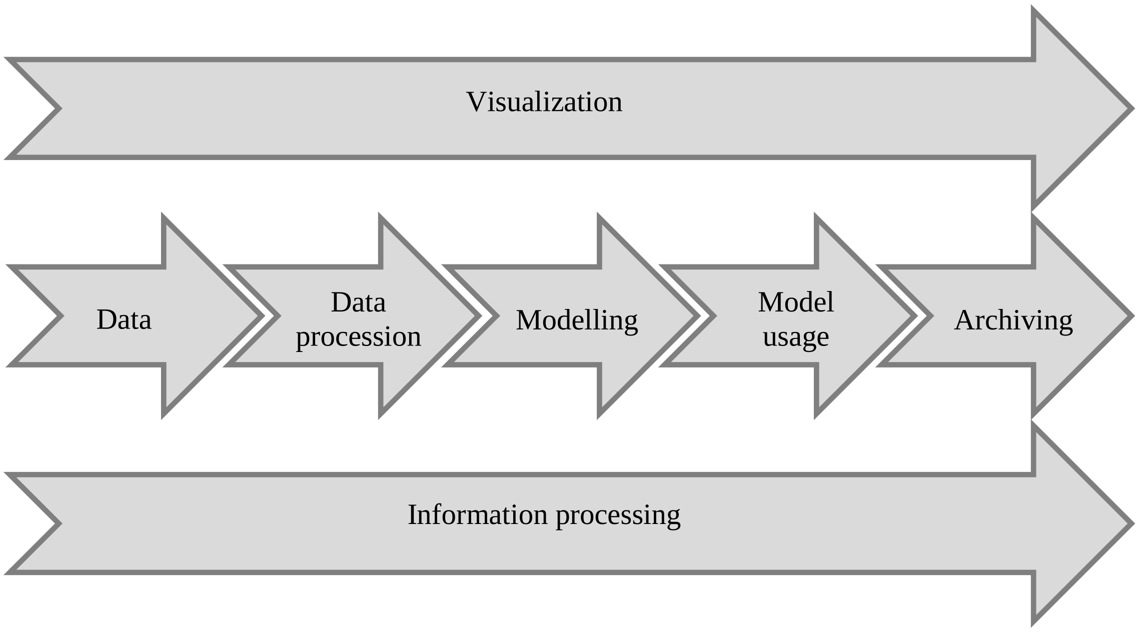


Figure 9 The process of underground data handling

Each processing stage presented in Figure 9 has special features and peculiarities which influence how easy or complicated 3D-modelling, BIM and VR can be used in a project.

4.1.1 Data collection

There are hundreds of different methods for gathering data. The choice of method depends on project area environment and purpose of investigations. New methods appears all the time, different kind of machines and equipment are used, information can come in different formats depending what kind of software and machines are used. While working in international projects or using off-shoring important to remember that data for same methods can look differently in different countries.

4.1.2 Data processing

Data processing is the procedure when values gained during investigation process are converted to geotechnical parameters which can be used for soil layer modelling and calculations. For example, a number of turns can be transformed to shear resistance or drill core can be interpreted to soil or rock. In Sweden nowadays all geotechnical investigation data after processing used to be gathered in GeoSuite database.

4.1.3 Modelling

Modelling of soil and rock surfaces is the process of interpreting of measurements at each point of investigation. Each bore hole has X and Y coordinate, Z – is measured as well and represent top level of investigation point. Depending on soil structure it can be different numbers of soil levels and Z-values which represent those levels at each particular point.

For geotechnical project management a product of VIANOVA – GeoSuite is used. It allows creating a project based on data obtained during geotechnical investigations. File extension is .snd for bore hole, .gvr ground water measurements, .prv for samplings, .mil for environment.

When all the data are gathered in the database it is possible to create separate files for different soil layers – for example, files which represent rock surface. The file is a .pxy format and can be saved as .txt file, copied to excel. Moreover, these files can be imported in some software for direct modelling of 3D surfaces. It will be shown and discussed later. File includes X, Y coordinates and level Z which represent chosen, while writing out, attribute.

At this stage an important role plays how experienced in geotechnical and geological field staff who is working with data processing.

4.1.4 Model usage

The created models can be used in different ways. They can be used as a layout for future construction design. Often design depends on functional requirements and then construction can be adapted to geotechnical conditions. Sometimes geotechnical conditions can be taken into account from the very beginning of project and the configuration of construction can be optimized.

Models can be used for a constructions calculation, drawings production, planning of production, volume and cost calculations.

4.1.5 Archiving

All processed information in form of models, processed and interpreted investigations can be saved in an archive and reused in future projects. There is no single 3D-archive from which information can be easily downloaded or obtained in another way. There exist a number of different geodatabases:

- Trafikverket
- Geoarkivet Stockholms stad
- Branchens Geotekniska Arkiv (SGI)
- Geodata.se
- SGU (Sveriges geologiska undersökning) web service with wells archive etc
- SGFs (Svenska Geotekniska Föreningen) dataformat

- SKB SICADA
- All consultants/ offices/ employees have their xls, GIS, AutoGraf data

4.2 3D modelling of soil layers – principal ideas

For each particular project it should be decided which 3D models over soil layers should be created. In some projects it is enough to have 3D model for rock surface but other projects require 3D models for other soil layers as well. When, for example, lime-cement columns are planned to be installed, it is necessary to have 3D models for clay.

Assume that all soil layers in the project should be created. We can generalize information in boreholes and minimize a number of layers to three which are used more often filling, clay, and friction soil. Sometime a layer of dry crust clay can be determined and modelled. The rock surface should be created also.

Figure 10, for example, shows a borehole with not homogeneous soil layers which should be generalized. The first soil layer, which goes down about 5,5 meters, consists of different materials, such as macadam, gravel and sand. All these materials can be joined into one soil layer – filling. Next soil layer is a clay which starts from the depth 5,5 meters and goes down to the depth 10,5 meters. As it shown in Figure 10 the clay layer has some disseminations of sand. Generalization should be applied for this soil layer also.

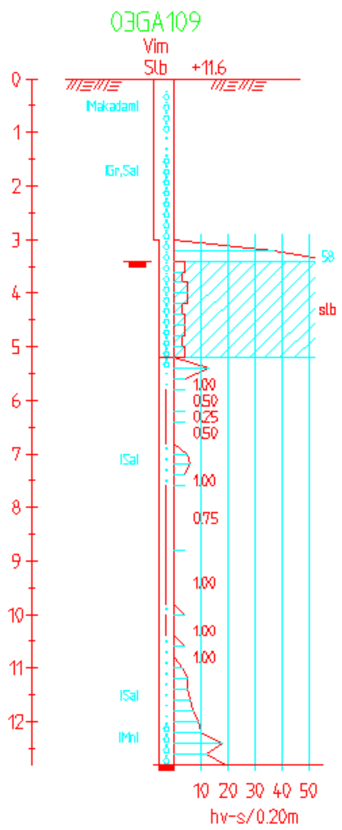


Figure 10 Borehole

The last soil layer in this borehole is friction soil layer which consists of sand and till, and they can be combined in one soil layer – friction soil.
Figure 11 shows the interpretation for this borehole made in the WinRit.

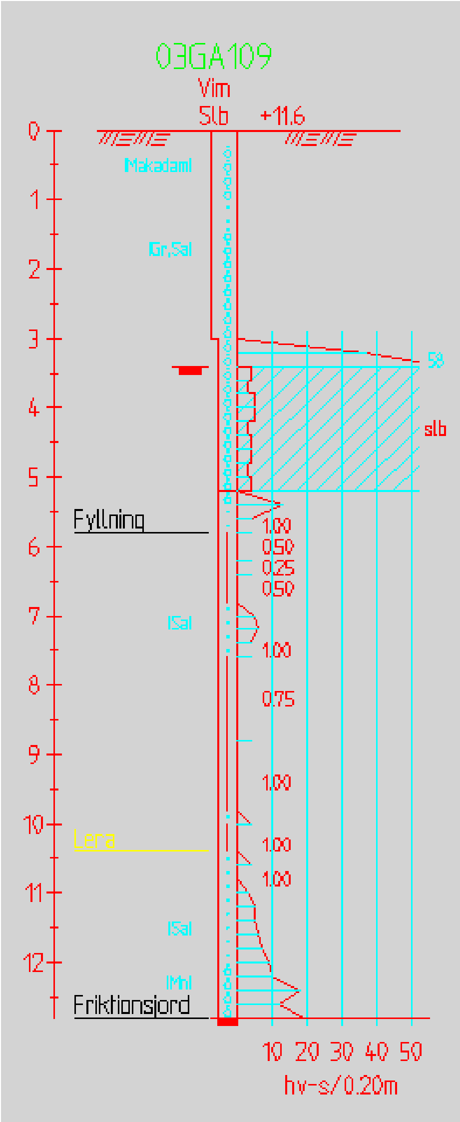


Figure 11 Interpreted Borehole in the WinRit

In order to get continuous 3D models for soil layers without collisions it is important that each borehole has only one interpretation indicator for each soil layer. Figure 12 shows one of boreholes with automatic interpretation performed in the GS Presentation. In this case clay layer has disseminations of other material and there are several indicators for clay layer. If one uses data from automatic interpretation without checking and adjustment there will be a lot of conflicts between created 3D models.

When interpretation for all boreholes in the project is performed, 3D models over soil layers can be created. TIN-interpolation is a method which is used most often in order to create 3D models over soil layers. Another method witch can be used is a grid interpolation.

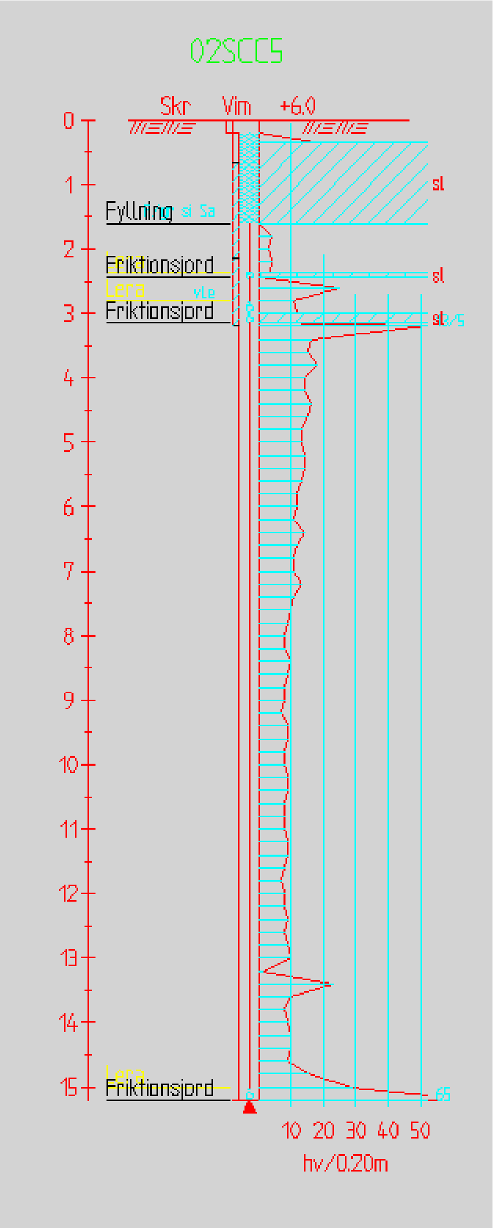


Figure 12 Automatic interpretation in the GS Presentation

5. Software available for investigations

In order to choose programs for analysis and discussion I used my own experience in this field, asked specialists who work with 3D-design and modelling in the geotechnical field, checked out literature, reports, presentations related to this topic. I even found a master thesis which was performed at Luleå Tekniska Universitet in 2007 where the author makes a similar analysis. I use his experience but complete with some new software which came out lately.

5.1 NovaPoint

NovaPoint was used at WSP during some years, but now WSP took a decision do not continue with this software and use Civil 3D and Bentley Products (Microstation and Power Civil). Today NovaPoint software is not supported at WSP and the idea is that all add-ons will be released for AutoCAD Civil 3D and shortly only a basic package of Novapoint will remain. That is why this product is not of big interest for analysis in this thesis. Hedberg (Hedberg, 2007) described in his master thesis Novapoint and analysed it. He recommended this product for creating drawings which should present data from 3D-models and show boreholes at the same time. Hedberg noticed at the same time that 3D-models created in Novapoint Terrain had worse esthetic visualization possibilities and designing tools are very limited compared to other software. Today we have new products available on the market which are more powerful, can maintain geotechnical information and 3D models. One of them is AutoCAD Civil 3D.

I give a brief description of the most important tools and functions of Novapoint from a geotechnical point of view.

Novapoint GS Archive

Novapoint GS Archive is the overall tool for creating new projects, organizing project structure and data, previewing existing data, creating new data by executing different tools for the actual need – slope stability calculation, acquiring soundings raw data format and presentation within national standards, designing sheet walls or pile groups or calculation of settlements due to impact of new structures. (Vianova Systems, 2015)

GS Archive supports exporting data from soundings to external databases. Various database platforms are supported – Access, SQL Server, Oracle, etc. Exported data can be accessed for GIS purposes and other needs. (Vianova Systems, 2015)

Appendix 3 includes GS Archive's product description. (Vianova Systems, 2015)

Novapoint GS Presentation

Novapoint GS Presentation is the central product of GS Toolbox. Much of the work associated with geotechnical investigations lies in collection of data and compilation of soil properties. Results are presented in standardized tables and charts - single borehole, plans and profiles. GS Presentation contains rational tools for administration and presentation of geotechnical data. (Vianova Systems, 2015)

Appendix 4 includes GS Presentation's product description. (Vianova Systems, 2015)

Novapoint GS Settlement

Novapoint GS Settlement is a user-friendly computational tools to perform calculations and sensitivity analyzes for future subsidence of the soil due to changes in load and / or pore water pressure. Various nonlinear soil models can be used, with the ability to account for creep effects. Input data and results are shown and verified in tabular and / or graphic. (Vianova Systems, 2015)

Appendix 5 includes GS Settlement's product description. (Vianova Systems, 2015)

Novapoint GS Stability

Novapoint GS Stability is a rational tool for stability calculations. By using sections as a layout modeling can be fast and safe. Profiles for modeling of undrained shear strength and pore water pressure provide powerful capabilities to simulate arbitrary state in the earth. Efficient control of input data reduces risks of erroneous models and wrong input data. The results can be presented in graphic form and in a detailed report. (Vianova Systems, 2015)

Appendix 6 includes GS Stability's product description. (Vianova Systems, 2015)

Novapoint Terrain

Novapoint Terrain is not a part of GS products but is useful tool even for geotechnical field. Novapoint Terrain helps to design the soil and terrain - both in 2 and 3 dimensions. With the unique elevation functions it is possible to create the new ground - directly in 3D. This we deal further with the help of powerful terrain tool with the ability to manage volumes, soil layers and 3D objects. (Vianova Systems, 2015)

Appendix 7 includes Terrain's product description. (Vianova Systems, 2015)

5.2 Autodesk - AutoCAD Civil 3D

AutoCAD Civil 3D software is a civil engineering design and documentation solution that supports Building Information Modeling workflows. It is one of the most used in civil engineering design software which is developed by Autodesk. AutoCAD Civil 3D, can help in better understanding of project performance, maintain more consistent data and processes, and respond faster to change.

With Civil 3D, is it possible for all in the project to work on the same basis with the terrain model (DEM model, mountain model and layers under the ground). By using shortcuts to different model files is it possible for everyone in the project to work with their own files, but with the same base material.

The tool Civil 3D is not available for Swedish needs in the same way as, for example, Novapoint where you can present cross sections, profiles and calculations according to the Swedish guidelines. Obviously, Civil 3D can calculate and draw out both profiles and cross sections. But we need to adapt it for Swedish guidelines. For this purpose Naviate can be used - it is a CAD tool based on AutoCAD Civil 3D functionality and has been adapted to a certain extent for the Swedish market. Version 14.0 of GeoSuite (the one which is used now at WSP) supports Civil 3D 2013 or 2014. The guideline (Appendix 1) includes description how models, representing different soil layers, can be created with help of Civil 3D; how surfaces created in Civil 3D can be shown on the sections with boreholes.

5.3 Bentley Systems

5.3.1 Power Civil for Sweden / InRoads

Bentley's Power Civil is a Microstation based product which is very similar to InRoads. If one compares product data sheets for these two products (Appendix 8 and 9) it is easy to notice that they have in general almost the same features, but InRoads has some extra tools, for example, it supports more read/write data formats; it is possible to attach multimedia files such as photo, movie, audio to any point or linear feature etc.

Table 1 gives an overview what kind of features are included in DTM (digital terrain model) analysis for these two products:

Features in Power Civil	Features in InRoads
*Information in Swedish:	
Generera konturer	Generate contours from data points accounting for breaks, random points, voids, edges, and other criteria
Kontrollera trianglars maximilängder	Control maximum length of triangles
	Control density of points on linear features for optimal surface presentation
Visa avgränsningslinjer för schakt och fyllning	Display cut-and-fill delineation
Visa och redigera egenskaper	View and edit feature properties
Färgkoda visning av trianglar, slänter, elevationer och aspekter	Color code display by triangles, slopes, elevation, and aspect
Visa släntvektorer	View slope vectors
Analysera marklinjer	Analyze line of site
Visa modeller med gridnät, profiler och elevationer	View gridded, profiled, and elevation models

Table 1 Comparison of DTM Analysis features for Power Civil and InRoads

According to Bentley's description of features for DTM analysis, it is possible to control density of points on linear features for optimal surface presentation using InRoads. This tool is not included in Power Civil.

The difference between these two products is not significant from the geotechnical point of view, and taking into account that WSP uses Power Civil, analysis and study of InRoads will not be performed.

Power Civil is a powerful tool for infrastructure projects. It provides complete drafting capabilities, powerful mapping tools, and design automation for civil transportation professionals. (Bentley Systems, 2015) Power Civil, in the same way as InRoads, does not support data format used in GS Presentation and can be used for 3D modelling only if layout (data) is prepared/ exported/saved in appropriate format.

DTM (3D model) can be created from graphics in a Power Civil, when data digitized in a drawing loads into a surface. The digitized data must be located in its correct position in a three-dimensional (3D) drawing file. When loading digitized contours, for example, each contour must be located at its proper elevation. Power Civil accepts text, circles, arcs, lines, polylines, points, 3D faces and even meshes. Each vertex of the mesh element is imported into the target surface as a random point.

It is possible to load DEM (Digital Elevation Model) data into a surface. It can be useful for site location and preliminary engineering.

It is also possible to load geometry point coordinates to the active surface. Geometry graphics can be loaded as random, breakline, interior boundary, or exterior boundary points. The elevations of the new points can come from the cardinal points of the horizontal alignment, the active vertical alignment belonging to the active horizontal alignment, or from an existing surface.

One more important function which is typical for Power Civil as well as for InRoads and Microstation is the ability of these products to read and create files in both dwg and dgn formats. It means that it is quite easy to use layout created in an AutoCAD environment in order to create 3D models in Power Civil (or other Bentley Products). It is possible as well to save data in Power Civil to dwg if it is necessary.

Surfaces created in Power Civil can be exported to LandXML. This is a very important feature, because LandXML files can be loaded to sections with boreholes.

5.3.2 GEOPAK

Bentley GEOPAK is a family of integrated civil design and engineering software ideally suited to civil engineering and transportation projects of all types. Developed and supported by practicing civil engineers and professional surveyors, GEOPAK applications offer a plan-production focus that enables engineers to concentrate on delivering high-quality projects in one continuous cycle, from survey to construction.

The GEOPAK software line represents a comprehensive, field-to-finish solution for transportation infrastructure, water resources and land development. (Bentley Systems, 2015)

GEOPAK contains MicroStation’s full suite of referencing, dimensioning, text and drawing tools. GEOPAK includes a suite of tools: geotechnical, road, site, drainage, water/sewer, survey, landscape.

Unfortunately, GEOPAK does not support Swedish standard data which are used at GS Presentation and boreholes cannot be imported and used for 3D modelling of soil layers. Because other functions of this program are almost the same as InRoads/ Power Civil, and this product does not used at WSP, this product will not be included in analysis.

5.4 Other programs

Other software which exist on the market were analyzed regarding the possibility to be used for creating 3D models for soil layers and rock surfaces using Swedish standard geotechnical data. A short description together with a motivation why they are not interesting for further studies is following.

5.4.1 Conrad

Conrad is a software, developed by SGI, which is used for presentation and analysis of CPT-investigations (Cone Penetration Test). Data obtained at drilling are loaded to Conrad, where they are processed and the results of the analysis are presented. (Conrad product data sheet – Appendix 10).

Conrad is used only for processing of CPT-investigations, does not contain any 3D-modelling functions and that is why it is not interesting for this thesis.

5.4.2 Edison

Edison is software developed by SGI. Edisons's function is to fill a gap between investigation made in the field and presentation performed in an office. Edison can be used directly in the field for data control, adjustment and borehole validation. A short description of this software can be found in Appendix 11. Edison does not have 3D-modelling tools, that is why it is not included in the analysis in this study.

5.4.3 GEO5

GEO5 software is developed by FINE. It helps to address a wide variety of geotechnical problems. Besides common geotechnical engineering tasks, such as stability analysis, excavation design, retaining wall design, soil settlement analysis, the suite also includes highly sophisticated applications for the analysis of tunnels, building damage due to tunneling, stability of rock slopes etc. GEO5 consists of a wide range of powerful programs based on analytical methods and the Finite Element Method. (Fine, 2015)

The Terrain program enables creation of a digital terrain model and subsoil layers from inputted points, edges or bore holes, respectively. Such model can then be used to create 2D and 1D geological profiles. These profiles are subsequently utilized in other GEO5 programs. (Fine, 2015)

The program enables a general data import. Therefore, it is possible to enter an arbitrary amount of measured geotechnical data. This proves particularly advantageous in case of extensive landslides, mines and dump slopes, for which continuously updated measurements are available. (Fine, 2015)

The program also determines volumes, i.e. the total volume of excavation works and built embankments in individual construction stages. (Fine, 2015)

Even though this program seems to be very powerful and includes a wide range of geotechnical software solutions it cannot be used for analysis because it cannot import the file format used in GS Presentation.

5.4.4 Soil Vision

SoilVision System Ltd. developed SoilVision software which applies new technologies such as automatic mesh refinement, unsaturated soils, and 3D analysis. (Soilvision Systems, 2015) This program can also not be used in this thesis because it is impossible to import data used in GS Presentation.

5.4.5 SBG Geo

Geo is SBG's office programs for surveying and construction measurement and helps in an easy and efficient way to manage daily tasks, from the coordinate calculation and volume calculation to 3D models, drawings and reports.

The systems advantages can be summarized as follows:

• Powerful - Does not require underlying CAD software

• Simple structure, but with many advanced features

• User-friendly

• Rational workflow

• The result of 30 years' development

• Used in over 20 countries

• Has been translated into many languages

• One of the world's most modern and powerful geodesy softwares

• Additional modules for alignments, volume calculation, terrain models, tunnel management, point cloud and network adjustment makes Geo a complete geodesy system. (SBG, 2015)

This software cannot import data used in GS Presentation and that is why it will not be analyzed in this master thesis even though it has tools for 3D modelling, volume calculation etc.

5.4.6 GIS software for geotechnical needs

A geographic information system (GIS) is a relatively new software tool for geotechnical engineers but has the potential to become a powerful tool. Its capabilities range from conventional data storage to complex spatial analysis and graphical presentation. (Hellawell, et al., 2001)

There is a number of softwares which includes GIS tools for solving geotechnical tasks. One of them is RockWorks developed by RockWare. This software was used as a standard in the petroleum, environmental, geotechnical and mining industries. (RockWare, 2015)

RockWorks can be used when evaluating construction and excavation sites in the beginning, middle or ending phase of a project.

The Borehole Manager allows bringing soil boring, sampling, well screening and other information into the program via a simple Excel or ASCII file import (Figure 13). It is not possible to directly import Swedish standard files which makes complicated to use this software in Sweden.

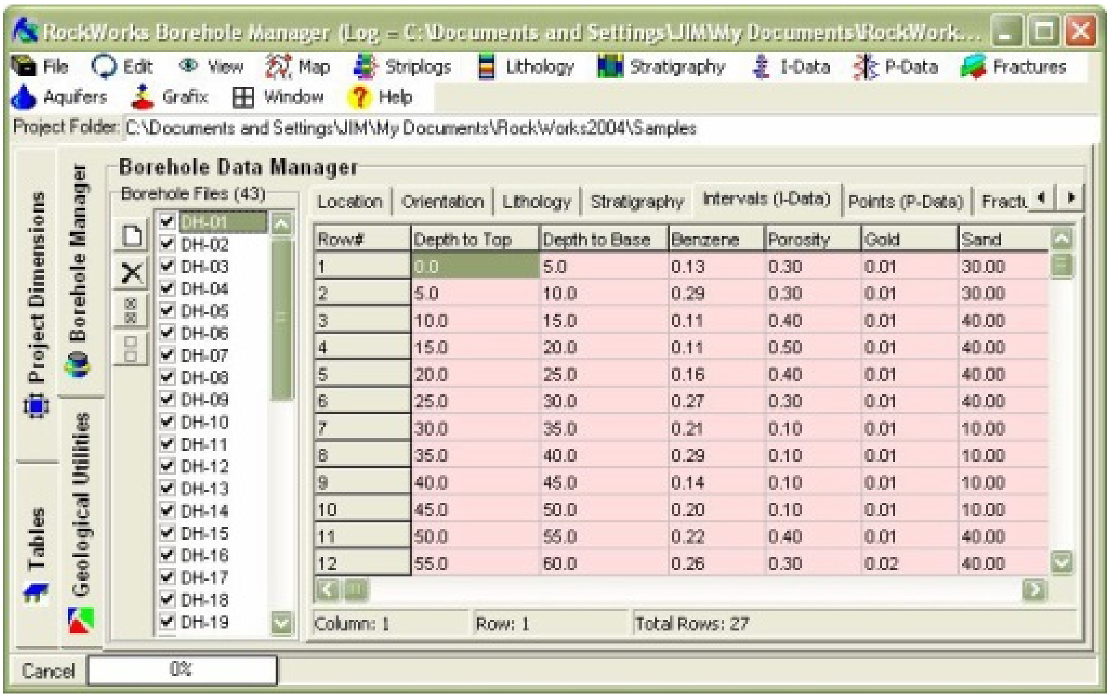


Figure 13 RockWork's Borehole Manager

Source: (RockWare, 2015)

RockWorks has a lot of useful tools and, for example, allows viewing downhole sampling information in 2D and 3D using a variety of methods and color schemes - Figure 14.

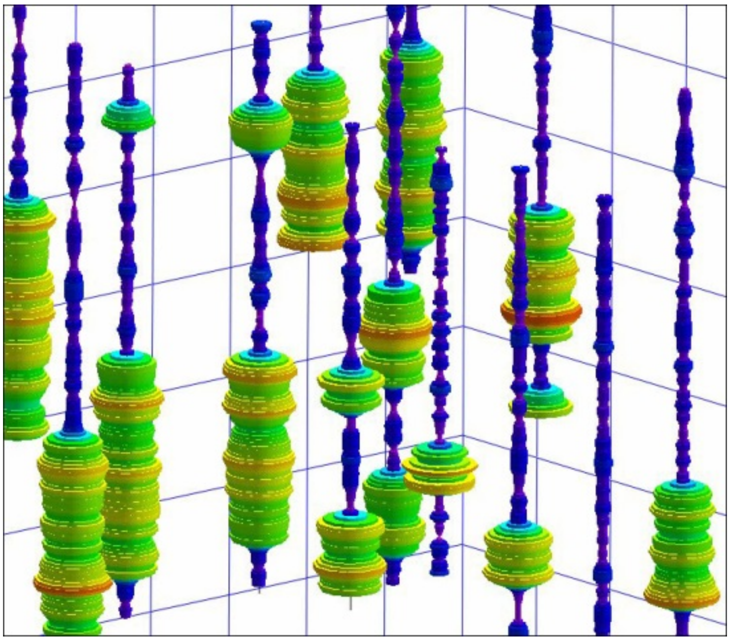


Figure 14 Presentation of downhole sampling information in 3D

Source: (RockWare, 2015)

RockWorks allows creation of sections showing modeled lithology and stratigraphy; generation of solid models and volumetric estimations of stratigraphy, lithology, and other downhole parameters; estimation of excavation volumetric - Figure 15.

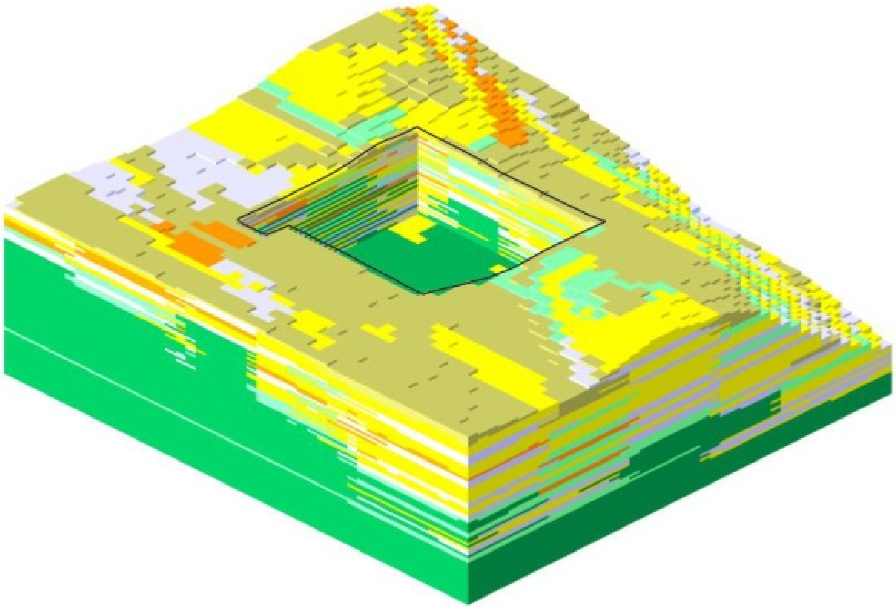


Figure 15 Estimation of excavation volumetric in RockWorks

Source: (RockWare, 2015)

Some other leading GIS software which support geotechnical needs: ESRI – ArcGIS; Pitney Bowes – MapInfo etc

It is obvious that integration of GIS in the geotechnical field will continue. To succeed in it requires a combination of geotechnical knowledge and the GIS-based skills. It can be achieved, for example, by training the geotechnical engineers in using the software as well as understanding the GIS concepts.

5.5 Analysis of software

5.5.1 Evaluation approach

In order to be able to make a correct and fair comparison of these different products, regarding their ability to create 3D-models of soil layers, the data used are from the same project is. From a project with more than 7000 investigations points a sample area with 140 points was defined. The area of investigation is around 45000m^2 which is not so big and points are distributed quite regularly.

A typical workflow for a geotechnical project includes:

- Inventory of previously conducted investigations;
- Planning of investigation program and data collection;
- Loading of investigations results to database;
- Data processing;
- Establishment of Soil Technical Investigation including drawings (plan, profile, section);
- Presentation of interpreted soil layers in profiles/ sections;
- Stability and settlement calculations;
- Drawings for geotechnical constructions and soil reinforcement;

- Establishment of Technical PM;
- Underlay for cost – and volume calculations

While choosing approach for evaluation I mostly looked at processes which influence the results of 3D modelling of soil layers and next following data presentation in Open VR. That is why in evaluation will be included the following processes:

- Raw data collection and editing
- Data processing
- Data Presentation and editing

The most significant part of the analysis is associated with the last third point, because here the chosen for comparison softwares are used. First and second points are important as well but they are performed before one starts using software for data interpretation and modeling. That is why these processes are described in section 5.5.2 and 5.5.3 but are not compared.

5.5.2 Collecting the data

Nowadays it happens very seldom that one starts a project in a place where there is no basic information about geology. That is why under collecting the data I mean not only new investigations, but inventory of the old ones.

Geotechnical information can come from different sources. In the early stages geotechnical information can be obtained, for example, from geological maps and existing investigations. The requirements on the accuracy of the data at this stage are quite low because the data is used for general recommendations. Detailed analysis, calculation and drawings production is coming in later stages when position of designed constructions is defined. This material can be further used as a basis for planning geotechnical investigations. The requirement on accuracy and scope of the geotechnical information increases when approaching the construction stage.

Compared to other disciplines geotechnical information can be described as a time independent. It is important, however, to control plan and height coordinate systems for “old” data; transform coordinates if it is necessary. It is important to sort out invalid points, for example, if the situation changed a lot, for example in case of excavations, rock blasting etc.

Field investigations are carried out using different methods depending on the stage, purposes and geotechnical conditions.

The studies carried out in the field are aimed to determine soil types, soil boundaries and geotechnical properties. Determination of soil types and characteristics are usually performed in laboratory, but some properties may also be determined in field.

Today there are two systems in Sweden for collection of field data in digital form: Geoprinter, which stores data obtained in the memory and Geologg that stores data on disk. Both systems follow SGFs list of field codes.

WSP Sweden AB has GM 75 GTT, GM 100 TT and Geotech 604 machines which are equipped in general with Envi data collection tool, except one machine which has Demon field logging equipment. Even though they have different manufactures and work differently, they give the same results and data can be converted to snd format which is used at GS Presentation.

STD – data file format developed according to SGF-standard in order to improve data communication. This data format can be imported by very few programs in Sweden and Norden. This brings limitation in software usage.

RDT – data file format which is used in Geotech's field logging equipment.

Even though both std and rdt file format can be imported by a small range of software, they have an advantage because they were created in order to exploit and forward information according Swedish standard without complex correction afterword.

ASCII (American Standard Code for Information Interchange) is a character-encoding scheme. Most computers use ASCII codes to present text, which makes it possible to transfer the data from one computer to another. For example, this format can be used in order to import data in form of text rows, representing x-, y- and z- coordinates.

Nowadays in Sweden there is no uniform system for collection of data from laboratory. Companies who carry out laboratory investigations have different systems for both collection and reporting of data. In many systems data are stored in such a way that a transfer between systems is possible.

SGI has developed a number of computer programs for storing and presenting laboratory data. Today it is almost impossible that laboratory application can communicate with other analytical and evaluation programs. However, the data format is quite general, which makes it possible to communicate and transfer data between different systems.

SGI is working on creation of database for laboratory investigations, where data collection, calculation and storage of results occur in a data-based system. The idea is that it will be possible to transfer data to other program or obtain data directly. (Viberg, et al., 2002)

5.5.3 Processing of raw data

SGI has developed a number of computer software to evaluate the parameters of laboratory data. The systems have been built in principle to both store and provide analytical values. Today, the possibilities are small for most applications to communicate with other analysis and evaluation programs. However, the data format is fairly general, which makes it possible to transfer data.

In our case ASCII format is not so interesting because it contains very little information from investigation and it can be very complicated to use such format because it needs a lot of additional work so it can be used.

The main programs which can be used are those which can read raw data files, such as std- and rdt-formats. Softwares which can read these formats are Edison, Conrad and GS Archive.

As was mentioned in 6.4.2, SGI developed the program Edison for control of data directly in the field. The program can import files created in geoprinter and geologger. Data can be presented on the screen both in graphical and alphanumerical form. It is possible to correct data and save the results in a new file.

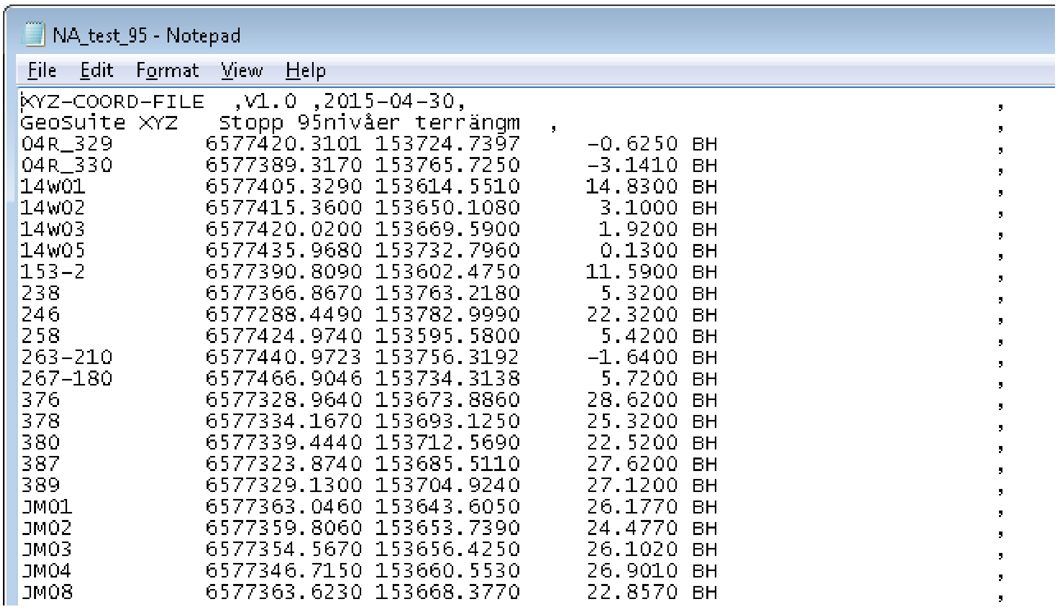
Conrad is described in 6.4.1, and used only for processing of CPT-investigations. This method gives better information about soil conditions compared to other methods. CPT-test generates a large amount of measured data which is transferred to Conrad. Data are processed in the program and results are shown in diagrams according to SGI standard.

The advantages of this software are that it is easy to use and has a simple interface. It is adapted to the latest standards and evaluation methods. (SGI, 2011)

When the diagrams are drawn there are no possibilities to process data further. It is not possible to export these data and use them for 3D-modelling. The only way, today, is to import std- and rdt-files to GS Archive.

Files should be imported to GS Archive, where a project can be created and investigations included in this project. From GS Archive one starts GS Presentation where all files can be viewed, corrected and interpreted. When interpretation of soil layers is performed the results automatically are saved in .tlk files. Each investigation has its own interpretation file where all interpreted layers are presented and have Z-level. While performing interpretation it is possible to correct performed interpretations, add or take away some interpretations and save changes.

One very useful tool in GS presentation is that it is possible to export interpretations of soil layers in separate files for separate soil layer using filter. It is possible to choose only rock or clay or some specific stop code. The list can be exported to *.pxy or *.kof format. An example of a pxy file is shown in Figure 16 and includes investigations names, coordinates and levels at stop code 95, which shows rock level.


NA_test_95 - Notepad

File Edit Format View Help

```
XYZ-COORD-FILE  ,v1.0 ,2015-04-30,                                        ,
GeoSuite XYZ    Stopp 95nivåer terrängm  ,                                ,
04R_329         6577420.3101 153724.7397    -0.6250 BH                    ,
04R_330         6577389.3170 153765.7250    -3.1410 BH                    ,
14W01           6577405.3290 153614.5510    14.8300 BH                    ,
14W02           6577415.3600 153650.1080     3.1000 BH                    ,
14W03           6577420.0200 153669.5900     1.9200 BH                    ,
14W05           6577435.9680 153732.7960     0.1300 BH                    ,
153-2           6577390.8090 153602.4750    11.5900 BH                    ,
238             6577366.8670 153763.2180     5.3200 BH                    ,
246             6577288.4490 153782.9990    22.3200 BH                    ,
258             6577424.9740 153595.5800     5.4200 BH                    ,
263-210         6577440.9723 153756.3192    -1.6400 BH                    ,
267-180         6577466.9046 153734.3138     5.7200 BH                    ,
376             6577328.9640 153673.8860    28.6200 BH                    ,
378             6577334.1670 153693.1250    25.3200 BH                    ,
380             6577339.4440 153712.5690    22.5200 BH                    ,
387             6577323.8740 153685.5110    27.6200 BH                    ,
389             6577329.1300 153704.9240    27.1200 BH                    ,
JM01            6577363.0460 153643.6050    26.1770 BH                    ,
JM02            6577359.8060 153653.7390    24.4770 BH                    ,
JM03            6577354.5670 153656.4250    26.1020 BH                    ,
JM04            6577346.7150 153660.5530    26.9010 BH                    ,
JM08            6577363.6230 153668.3770    22.8570 BH                    ,
```

Figure 16 PXY file for points with stop code 95

A *.kof is shown in Figure 17. It looks a bit different than a *.pxy file but includes in general the same information. In Sweden the *.pxy files are used, and the *.kof files are used in Norway.

```
NA_test_95 - Notepad
File  Edit  Format  View  Help
00 COORD-FILE   2015-04-30                                               *
00 GeoSuite XYZ    Stopp 95nivåer terrängm                               *
05 04R_329     BH        6577420.310  153724.740   -0.625                *
05 04R_330     BH        6577389.317  153765.725   -3.141                *
05 14W01       BH        6577405.329  153614.551   14.830                *
05 14W02       BH        6577415.360  153650.108    3.100                *
05 14W03       BH        6577420.020  153669.590    1.920                *
05 14W05       BH        6577435.968  153732.796    0.130                *
05 153-2       BH        6577390.809  153602.475   11.590                *
05 238         BH        6577366.867  153763.218    5.320                *
05 246         BH        6577288.449  153782.999   22.320                *
05 258         BH        6577424.974  153595.580    5.420                *
05 263-210     BH        6577440.972  153756.319   -1.640                *
05 267-180     BH        6577466.905  153734.314    5.720                *
05 376         BH        6577328.964  153673.886   28.620                *
05 378         BH        6577334.167  153693.125   25.320                *
05 380         BH        6577339.444  153712.569   22.520                *
05 387         BH        6577323.874  153685.511   27.620                *
05 389         BH        6577329.130  153704.924   27.120                *
05 JM01        BH        6577363.046  153643.605   26.177                *
05 JM02        BH        6577359.806  153653.739   24.477                *
05 JM03        BH        6577354.567  153656.425   26.102                *
05 JM04        BH        6577346.715  153660.553   26.901                *
05 JM08        BH        6577363.623  153668.377   22.857                *
05 JM09        BH        6577357.659  153670.071   23.356                *
05 JM10        BH        6577349.984  153674.119   23.671                *
05 JM11        BH        6577343.965  153677.292   24.165                *
05 JM13        BH        6577377.504  153678.100   18.135                *
05 JM14        BH        6577356.682  153682.938   22.674                *
```

Figure 17 KOF file for points with stop code 95

5.5.4 Presentation and editing of investigation point

Presentation of field investigations and laboratory tests are carried out at all stages in geotechnical production. As a rule, results of geotechnical investigations are presented on drawings and in text documents. The requirements that results of investigation shall be available in digital format are increasing. Today, in most of the projects it is a requirement as well that 3D-models created in a project shall be delivered, sometime even BIM-models should be delivered.

Regarding how results of investigations should be reported on different stages of geotechnical production, they can be divided into two parts. The first part can be called presentation of performed investigations. In this case investigations are shown in plan, profiles, and sections without showing interpretation of soil layers and results are included in separate report MUR. The second part is interpreted and evaluated data which can be used for planning and can be presented in interpreted plans, profiles and sections and be presented in technical description.

To present the results of field investigations and laboratory tests a program called GeoSuite is used.

Today there is not one standard how and in which program 3D-models should be created. Often it depends on knowledge and experience of the person who is performing 3D-modelling.

In Novapoint there is an option how 3D-models can be created: as a grid or as a TIN surface. Created 3D-models of soil layers can be exported to a dwg file for further usage in the Open VR. They can be also used for production of traditional geotechnical drawings but in this case, in addition to Novapoint, one of AutoCAD products (for example, Autodesk Map 3D), which is able to generate sections with boreholes and interpreted soil layers, should be used.

It is also possible to create a surface in Autodesk Map 3D by using created in GS Presentation pxy files for different soil layers. It is not possible to use pxy file directly in AutoDesk Map 3D. Pxy file should be first saved as txt file. When importing the txt file, columns should be defined before it can be imported in Autodesk Map 3D.

Autocad Civil3D can import pxy file directly and there is no need to specify columns. 3D-models created in Civil 3D can be shown quite easy on the sections with boreholes. These facts make AutoCad Civil 3D very attractive for geotechnical purposes. Moreover other areas of technology, for example, roads and highways, water and wastewater treatment, use Civil 3D applications in small and large projects.

Basic data for creating 3D models in Power Civil can be a dwg/ dgn files which can contain different kind of objects: points, blocks, lines, polylines, 3D polylines, 3D faces, text which represent heights or text which is, for example, a symbol “x” which has correct position in 3D (x, y and z coordinates).

It is also possible to import a txt file with coordinates in order to create 3D models. In Power Civil TIN interpolation is used while 3D models are created. Because the same approach is used in both Power Civil and Civil3D for creating 3D models, the results are the same or almost the same.

The advantage of using Power Civil is that this software has powerful tools for the design of roads, railroads, pipe systems etc. If all areas of technology are using this software in the same project then it is very easy to produce drawings (sections, profiles, plans) where all components can be shown. Tools for surface design, correction, manipulation and calculation are user-friendly. The software has a number of applications which are adapted to a specific subject with a wide range of special features.

While creating 3D models the data which can be included in it can be of different type. It is possible to add to the surface new data later on without starting the whole process from the very beginning; it is possible to exclude some data from triangulation by deleting specific features from the list of features. There are more advantages in using Power Civil: while creating profiles and cross sections objects are coming to the correct layer and have correct characteristics such as color, line type etc. Once created, the configuration file responsible for how objects are shown in plan, sections, profiles, can be saved and used later on. It saves a lot of time in drawing production and configuration file used in one project can be used later in other projects; the file can be changed, corrected and distributed.

One of the main disadvantages of Power Civil is that it requires changing software and it does not look similar to AutoCAD, that is why it makes it more difficult to be used by personal who are not used to work in such environment. Created in Power Civil 3D models, can be exported to LandXML and then imported to sections with boreholes.

The other option is to create sections and profiles in Power Civil and then copy them to sections with boreholes. It is important to remember that in this case there should be alignments created which are the same as section in GeoSuite.

When 3D models of different soil layers are created, they should be controlled and checked so they do not go into each other. It can happen if boreholes contain different number of soil layers, for example, not each borehole contains information about rock level or contains clay etc.

Civil 3D has a great tool which helps to control created rock 3D-models. It finds investigations which are not drilled to the rock surface but stopped at the level below interpreted rock surface. Results are presented in a dwg file graphically – rock levels coming from 3D model are shown together with level of borehole which lies under the rock surface. In this way it is very easy to find areas where support points can be added in order to solve conflicts between surfaces representing different soil layers, so they look more realistic and correct.

While using Civil 3D there are some options how support points can be added. It is possible to add some support interpretation points which can be exported to pxy files and to Civil 3D-model as well.

5.5.5 Presentation of the Analysis

As was described in 1.2 the goal of this master thesis is to identify and describe software that can be used today for creating 3D models for soil layers, rock surfaces and 3D boreholes which can be used further in coordination models, for example Open VR. The comparison criteria are mostly related to the building of 3D models but there are also other criteria which are important from geotechnical point of view.

Results of the comparison of the three chosen softwares NovaPoint, Civil 3D and Power Civil are presented in Table 2.

	NovaPoint	**Civil 3D**	**Power Civil**
Communication with GS Presentation	Works well.	Works well.	Files should be exported from GS Presentation and afterwards imported as a coordinates or graphically.
File format (Ability to communicate with other programs)	Works in own format. There is possibility to export data to dwg format	Works in dwg format	Works in both dwg and dgn format
Creating of 3D-models	Interpolation performs with help of grid network. It gives less exact and mathematically correct model compare to TIN-model	TIN-triangulation	TIN-triangulation
Editing of 3D-models	Can be done with help of support points. It is possible to add and edit points, but there is need to start AutoCAD in order to see sections with boreholes and soil layers and add support points using these sections	Easy to edit interpretation in borehole, add new or delete wrong points or interpretations. Possible to add support points for model correction. No need to change software.	There is no direct connection to database and that is way it is not possible to add, delete or edit interpretation of boreholes directly. But It is possible to add support points, lines etc

Presentation of borehole in 3D	Created in NovaPoint 3D boreholes can be exported to dwg and then be visualized in Open VR.	3D boreholes are generates automatically, created solids (different cylinders for different material) can be used for Open VR	Not available. Possible to create but needs a lot of manual input and editing.
Tools for farther 3D modelling	In order being able to make farther 3D design AutoCAD should be used. AutoCAD has connection with NovaPoint and in this way results of 3D design can be presented in NovaPoint.	There are tools for site grading, road and water waste system design.	Powerful functions for road, terrain, railway and pipe design.
Usability	It depends on previous experience. Nova Point 19 is more BIM oriented and requires from user see over routines and approach how to work but there are advantages as well in using this product, because all objects can have additional information.	It depends on previous experience. Autodesk products are used at WSP for a long time.	There is experience in using Power Civil by WSPs Geotechnical Team. Before was it possible to choose what to use as a platform AutoCAD or Microstation and it was easier for users to learn this product. Now this option is not available.
Possibility to use data for Open VR	3D boreholes and soil layers can be exported to dwg file and used in Open VR.	3D boreholes and soil layers can be used directly in Open VR.	Soil layers can be saved as dwg file and used in Open VR. Process of direct obtaining of 3D boreholes by using Power Civil is impossible.

Table 2 Software comparison

In order to create 3D models of soil layers, the results of investigations should be imported in GeoSuite (the only one option today for Sweden for geotechnical project management). The database for the sample area with 140 points was created in GeoSuite. 39 of the 140 investigation points are the ground water pipes which are not so useful for 3D modeling of soil layers and rock surface but they are important for the calculations and for the project design. 25 of the 140 investigation points show the rock level and were used for 3D modeling of the rock surface.

The boreholes should be analyzed and interpreted and surfaces should be created. In this study the points for the sample area were automatically interpreted in GS Presentation. The results of the interpretation were controlled in the WinRit. The further processes of 3D modelling of soil layers, rock surfaces and 3D boreholes were performed with a help of the software chosen for comparison. It means that all programs used for 3D modelling of soil layers should be able to communicate with the GeoSuite database directly or in another way.

This thesis does not study other options, such as alternative approaches in representation of geotechnical data etc, and concentrated mostly on the current situation in the industry.

As it is shown in the Table 2, there are two products which have good communication with GS Presentation: NovaPoint and Civil 3D. Power Civil does not have direct communication with GS Presentation and can be used for 3D modelling of soil layers if processed data are exported from GeoSuite to suitable format. While creating 3D surfaces products are using different approaches. Civil 3D and Power Civil use TIN-interpolation while NovaPoint has an option to create 3D models by using the grid approach as well.

Novapoint has good communication with GS Presentation, boreholes can be interpreted, edited and adjusted but there is need in using AutoCAD. In order to produce drawings there is also need to use AutoCAD; it means that for data preparation for Open VR there is need of two products instead of one. NovaPoint is BIM oriented and it can be a big advantage to use this software taking into account that in many projects it is a requirement to use BIM and 3D modeling.

Civil3D also provides good communication with GS Presentation and has a user-friendly interface for geotechnical data processing and 3D-modelling. 3D boreholes can be created easily and results can be saved in a dwg and can be used in Open VR. Another advantage of using Civil 3D is that other areas of technology use it as well. Working in the same environment makes the design process faster and more economically efficient. There is no need to import, export, transform or convert data to be able to use it.

Power Civil has advantages in the form of powerful tools for road, railway and water waste systems design. When all areas of technology are using Power Civil for infrastructure projects the drawing production and their updating can be easily performed. Models created in Power Civil can be used and exchanged freely between different users. Soil layers can be saved as 3D faces in dwg or dgn format and used in Open VR. As mentioned before there is no direct communication with GS Presentation, and that is why it is not possible to edit interpretations, delete or add support points for model adjustment.

Even though NovaPoint and Civil 3D have tools for automatic borehole interpretation, a lot of manual work remains. Depending on basic data and project size the process of soil layer interpretation and 3D modelling can take a lot of time.

6. 3D Modelling Workflow

6.1 Interpretation of soil layers

The first step in creating 3D models is to define soil layers in GS Presentation. Interpretation can be done according to field codes directly in GS Presentation window or graphically in WinRit window. Automatic interpretation of soil layers in boreholes and test samplings often needs adjustments and supplementing. In order to make the process of 3D modelling of soil layers easier it is a good idea to decide and choose the minimum needed number of layers while interpreting. For example, it can be decided for a project which layers need to be interpreted, as well as if there is need to distinguish between clay and dry crust clay. Often there are three layers which are distinguished and specified: filling, clay, frictional soil and rock top surface.

In order to get continuous and complete surfaces without collisions, when one of the surfaces goes into another, each borehole should contain information about all defined layers. Some investigations methods do not give information about the order of soil layers in a borehole and give, for example, only information about rock level. In order to define soil layers in such boreholes, it is possible to look at the nearest investigation points and define soil layers considering drilling protocol for this borehole and information about soil layers in the nearest boreholes. If all boreholes have information about all defined soil layers it reduce time for correction of soil layers, because in such case, a basic data (points) for triangulation for each soil layer has the same x, y coordinates and z value depends on the performed interpretation. In this case we will get surfaces where soil layers follow correct soil structure and order. It is not so easy to always follow this rule but it is good to do this when possible. If there is no clay in the area then the thickness of this layer will be 0 and bottom level of filling and bottom level of clay will be the same. In the first step we make interpretations which can be corrected and adjusted in further steps by editing the levels of interpreted layers and by adding support points which can help to get more reliable models. When triangulation is done we will get triangles in the areas where there is no clay and this should be taken into account, for example if one creates contour lines for clay based on a 3D model for this soil layer. If one wants to correct interpretation of rock level in a borehole it is not enough to change the interpretation of rock level in WinRit, it is necessary to make changes in the boreholes protocol.

It is even possible to make graphical interpretation in AutoCAD by creating sections, draw soil layers borders in the sections, control and edit interpretations if it is necessary.

6.2 Power Civil

6.2.1 PXY files for differents layers using filter options

The next step of the workflow depends on the software we are using. For Power Civil we have to create pxy files in GS Presentation using filter while exporting all interpreted layers - Figure 18. The pxy file contains information about points in a specific layer in form of list of coordinates (x, y, z).

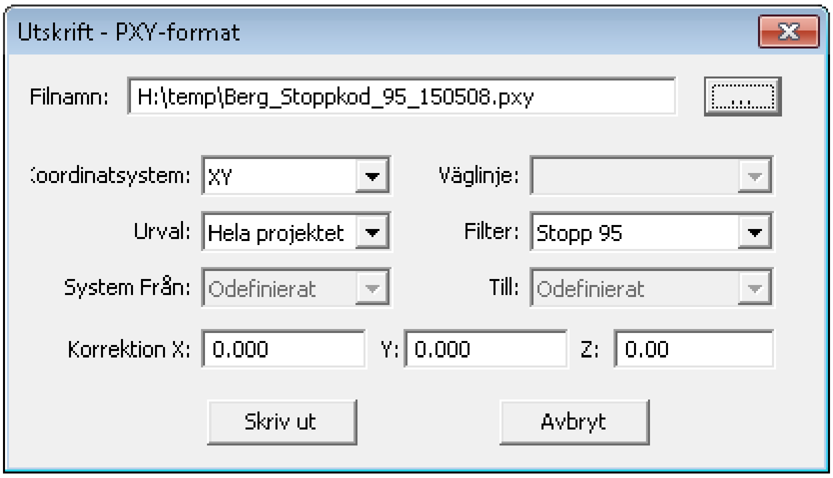


Figure 18 Export to PXY-file

6.2.2 Editing of pxy-files

There is no need to edit pxy files and they can be imported directly into Power Civil.

6.2.3 Read coordinates, soil layers

If one chooses Power Civil in order to create soil layers using pxy files, then they can be imported directly in Power Civil using the Text Import Wizard - Figure 19.

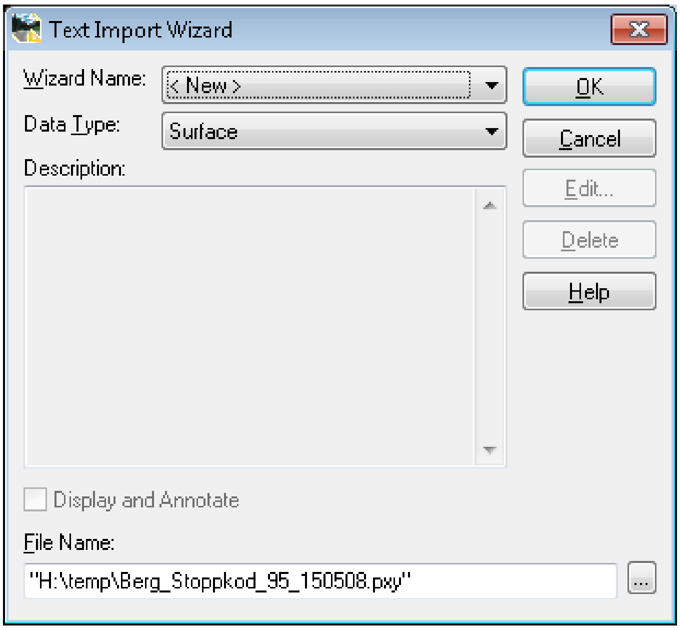


Figure 19 Text Import Wizard

The first two lines in pxy files can be deleted so that pxy files contain only coordinates, but this is not necessary because it is possible to specify in the *Text Import Wizard* which lines from the file should be imported *"Start import at Line"*- Figure 20.

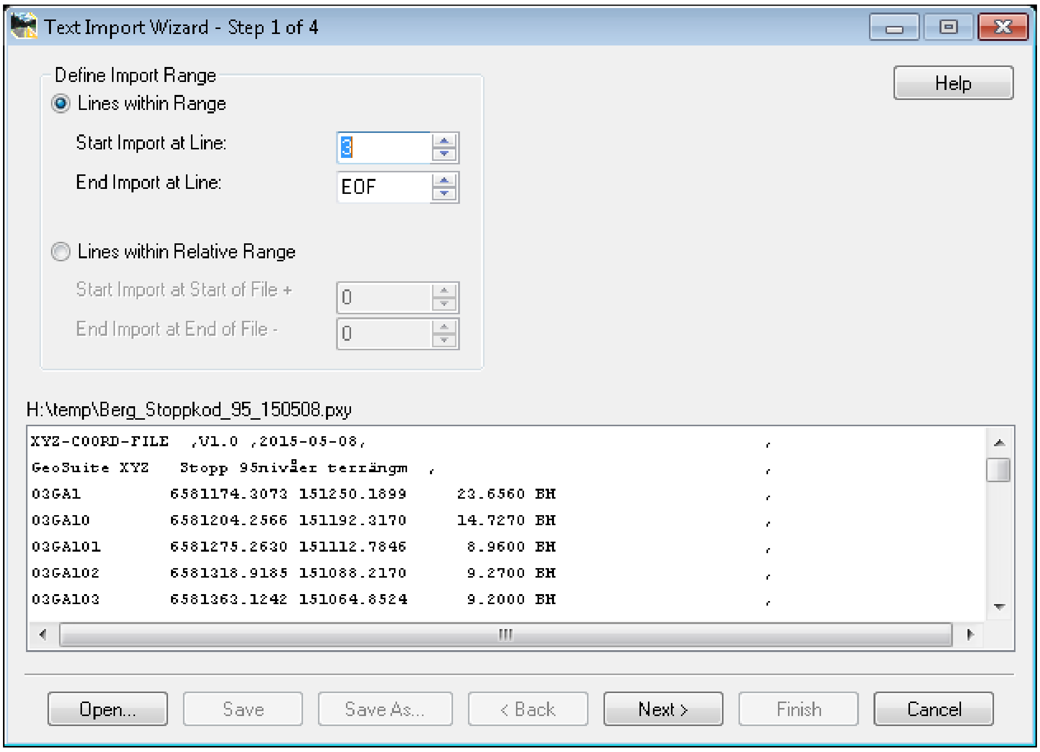


Figure 20 Text Import Wizard - Step 1 of 4

It is possible to decide what kind of information should be included while importing the data. For example, it is possible to skip some columns with irrelevant information and it is possible to specify what kind of information is in the column using *Column Data Format* which include such options as *skip, name, northing, easting, elevation, contour elevation, exclude from triangulation*, etc - Figure 21.

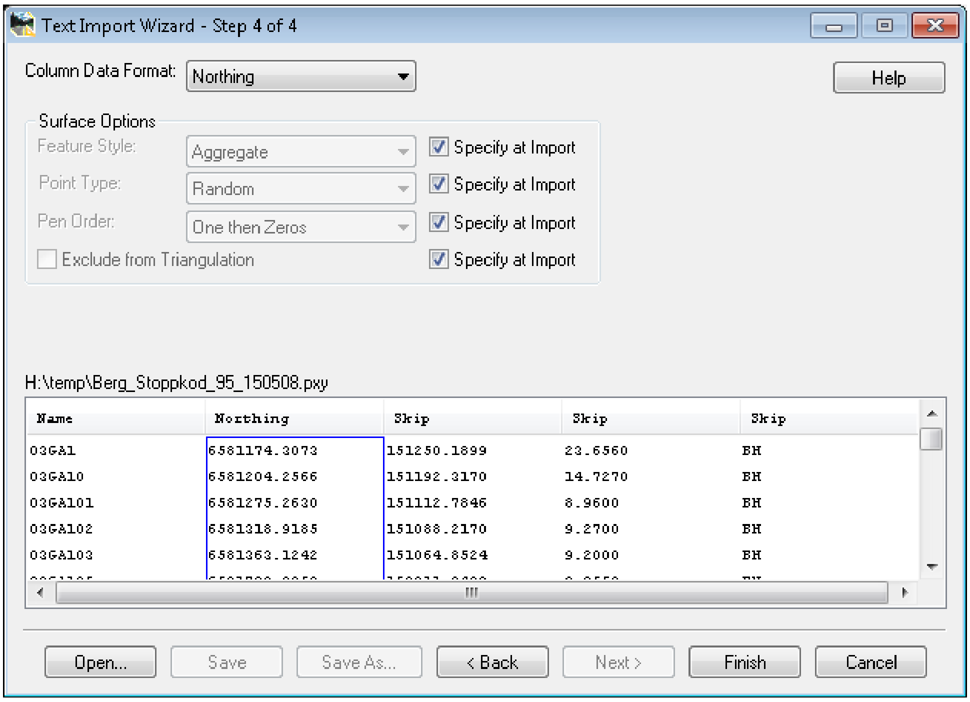


Figure 21 Text Import Wizard - Step 4 of 4

There is an option to import points graphically. It means that the dwg file with points for different soil layers should be created first. Points can be imported in Power Civil using *Import Surface From*

Graphics. The disadvantage with this method is that all points will be imported as one feature and it will not be possible to delete only one point using the *Delete Feature* tool shown in Figure 22.

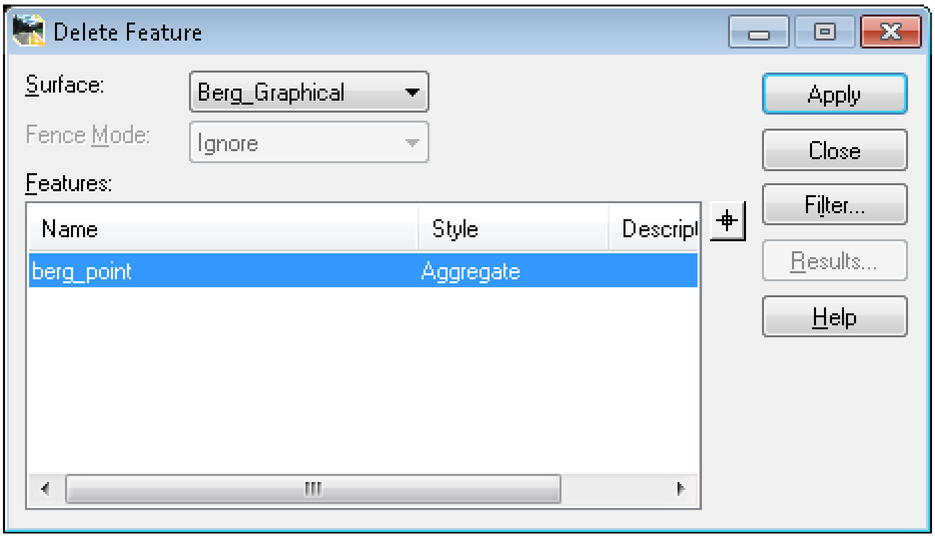


Figure 22 Delete Feature tool for Surface created using Import Surface From Graphics

If points are imported using the *Text Import Wizard* then it is easy to find points to be deleted (Figure 23) and it is very simple to edit, adjust or correct points using *Edit Feature Point* - Figure 24.

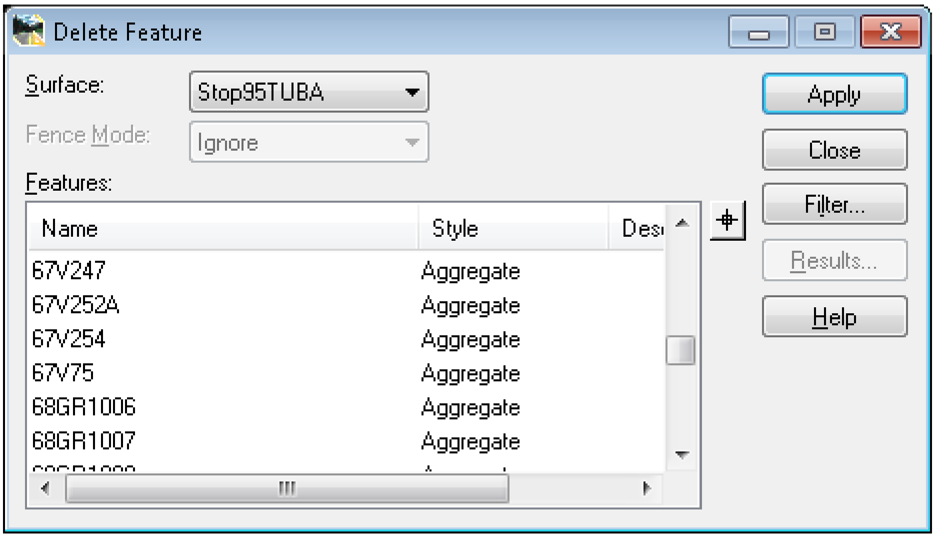


Figure 23 Delete Feature tool for Surface created using the Text Import Wizard

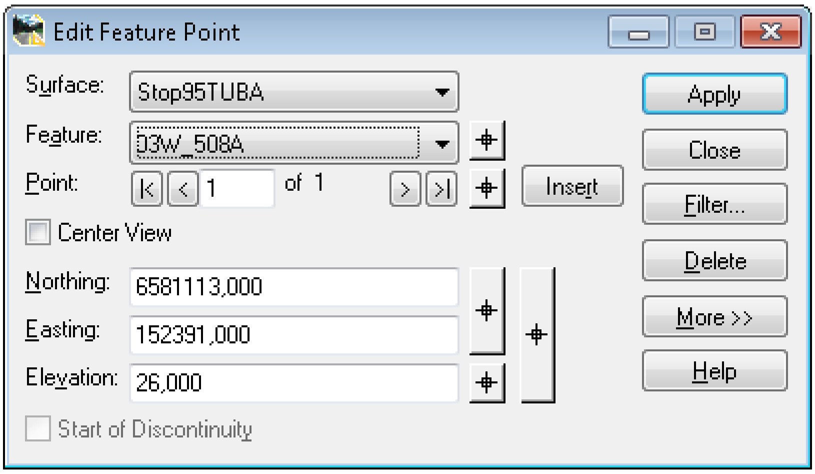


Figure 24 Edit Feature Point Tool in Power Civil

It is recommended to use the *Text Import Wizard* for importing data from the pxy file to Power Civil.

6.2.4 Create a surface

When data are imported they should be triangulated. It is possible to choose the maximum length of triangles. For example, if we do not want to have triangles for rock surfaces with length of triangle sides longer than 100 meter we can specify that and it will stay even though we re-triangulate surface or add new data to it -Figure 25.

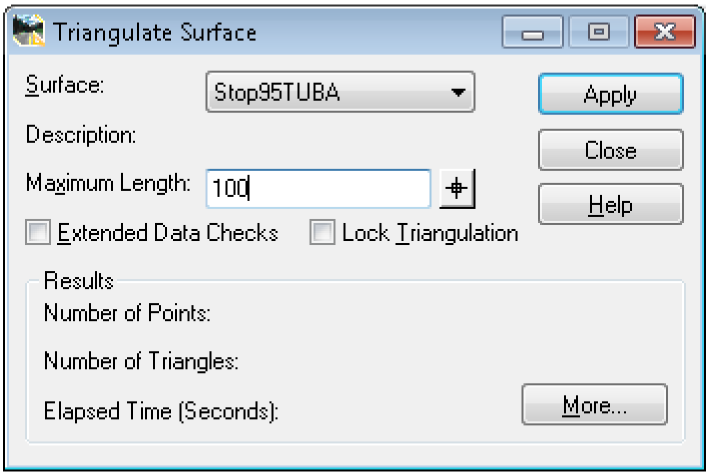


Figure 25 Triangulate Surface Tool In power Civil

Triangles can be deleted manually or using Filter where one can specify *Maximum Length, Minimum or Maximum Angle, Add Exterior Boundary* etc - Figure 26.

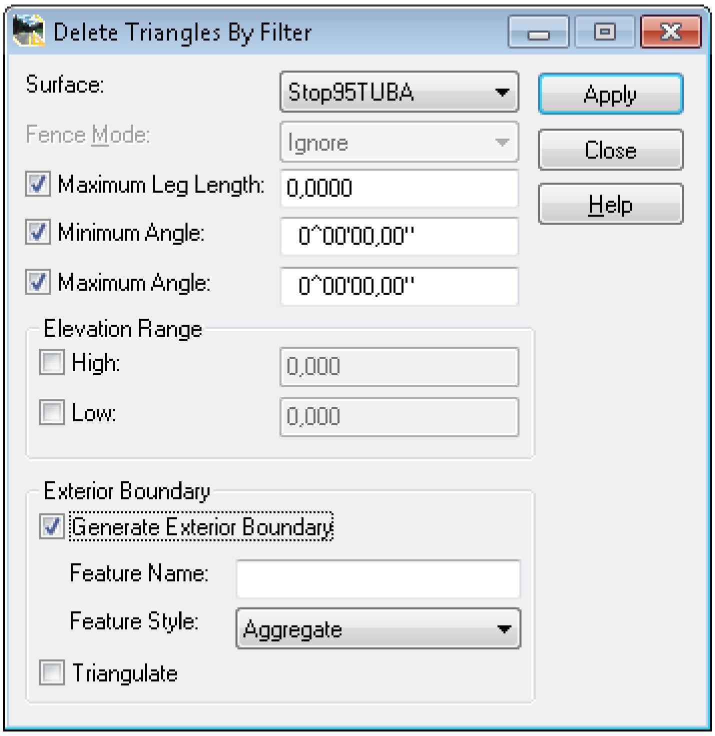


Figure 26 Delete Triangles Tool inPower Civil

A triangulated surface can be saved as dtm and used in the project by others if it is needed.

6.2.5 Editing of 3D models

3D models created in Power Civil can be corrected and adjusted by adding support points. This process looks differently compared to NovaPoint and Civil3D but if the database was created correctly, then a lot of options and possibilities in points adjustments and manipulations using database are available.

6.2.6 Data preparation for Open VR

Dwg files with 3D faces can be used for model coordination in Open VR. It does not take much work and time to load 3D objects in dwg files to Open VR. The better the quality of the dwg files the better the coordination model. Dwg and dgn files with 3D faces can be easily produced in Power Civil.

Creating 3D boreholes using Power Civil is as mentioned before a complicated process with a lot of manual work. It is easy to make mistakes, miss something and it is not economically efficient, especially in big projects. In small projects, with 10-20 boreholes, it is not critical and 3D boreholes can be created manually using, for example, *solid tool.* But it is impossible for big projects, like Tunnelbana project with more than 7000 boreholes.

The alternative is to create 3D boreholes using the export functionality in GeoSuite and create dwg the file with solid objects for interpreted boreholes there. Dwg can be used in Open VR straight away.

6.3 NovaPoint

If we work in NovaPoint or Civil3D there is no need to create pxy files (as it was before) because there is a direct connection between GeoSuite and these programs.

6.3.1 Loading to NovaPoint GeoSuite database

When the first step described in 8.1 is performed and we are ready with interpretation of the soil layers we can load GeoSuite database to NovaPoint by importing *autograf.dbs*, which contains the database for the whole project and interpretations for all layers. It is possible to load databases from different projects at the same time and this can be extremely useful when we need to create an overview of the geotechnical situation in the area of interest and we have several projects in this region.

Novapoint works with processes. Activities should be created and similar processes can be grouped under an activity. Everything we do should be placed in the correct activity, but it is possible to edit it if it is necessary.

Novapoint is model oriented. Everything is objects. If one clicks on the object, for example, CPT-investigation, its properties appear: name, status (current or designed), coordinates, coordinate systems information, depth of drilling, method etc

When we import the GeoSuite database we should specify a name of this process (for example, *Import TUBA*) and choose under which activity it should be saved - Figure 27.

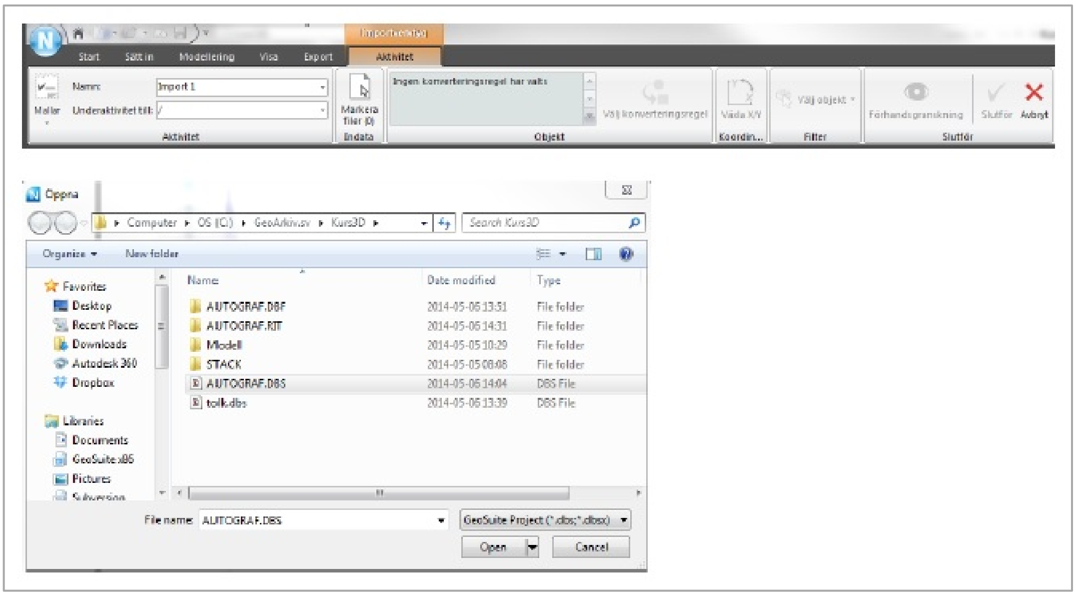


Figure 27 Import tool in NovaPoint

6.3.2 Creating surfaces

To create soil and rock surfaces in NovaPoint *Modellering – Underyta* tool should be used. Here we need to choose which activity this process should correspond to, give a name to the surface and choose a template for surface creation under *Mall*. It is possible to specify the maximum side length of the triangles in settings.

TIN-triangulation remains the default interpretation method in NovaPoint but it is possible to choose grid interpolation if needed.

Surfaces together with 3D boreholes are shown in the NovaPoint interface. Figure 28 demonstrates 3D boreholes with interpreted layers for each investigation shown with different colors and created rock surface.

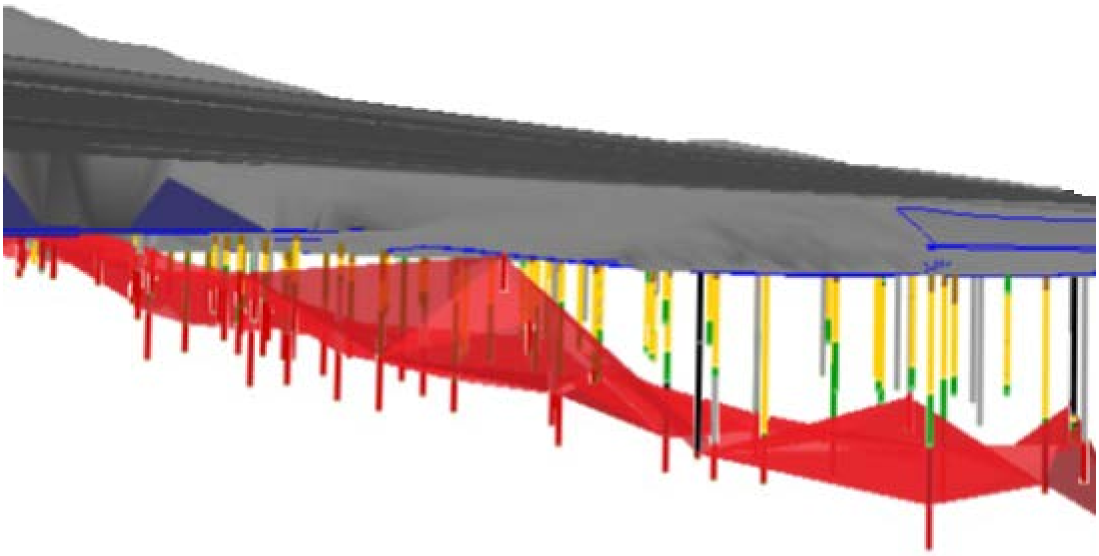


Figure 28 3D boreholes and rock surface in NovaPoint

Source: (Andersson, 2015)

6.3.3 Editing of surfaces

In order to control the quality of created soil layers in NovaPoint profiles or cross sections can be drawn and visual control can be performed. Profiles and cross sections show soil layers as lines, boreholes position in a section with a symbol and interpreted soil layers in each borehole presented as a vertical line with different colors - Figure 29.

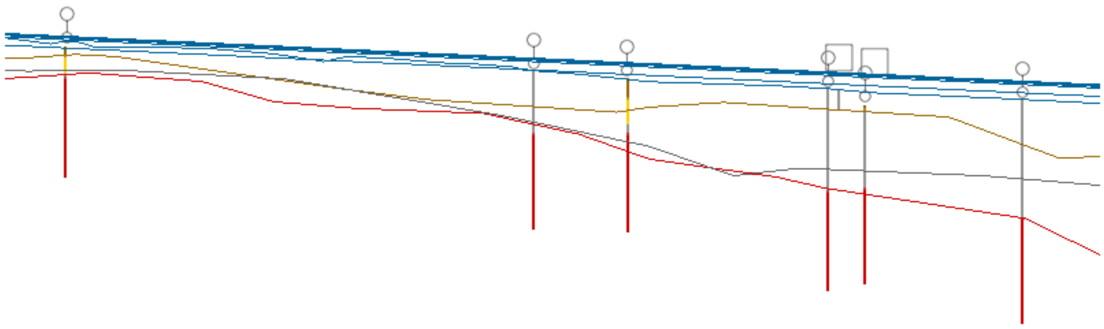


Figure 29 Profile in NovaPoint

Source: (Andersson, 2015)

It is not possible to see boreholes drawn in the traditional way directly in the NovaPoint environment and this can be counted as a drawback, because there is no possibility to see immediately what kind of investigation were performed and estimate if interpretations were done correctly.

It is impossible to edit interpretations directly in NovaPoint and AutoCAD should be used in order to make adjustments. In AutoCAD profiles or cross sections should be generated again. Alignments created in NovaPoint can be loaded into AutoCAD and sections can be taken in the same places as in NovaPoint. When sections are generated it is possible to load surfaces created in NovaPoint and bring them into generated sections with boreholes presented in the traditional way.

Before one can start editing interpretation of soil layers and add support points in order to correct models, in NovaPoint should an activity for this process be created. Support points can be saved as leveling points in GS Presentation and they can be used for surface updating.

6.3.4 Data preparation for Open VR

Surfaces created in NovaPoint can be exported to dwg files in order to be used in Open VR. The resulting dwg file contains objects for different soil layers in form of polymeshes. Unfortunately objects created in this way lose their BIM component and objects are not so “clever”. 3D boreholes can be exported from GeoSuite via 3D functions. Boreholes created in this way are solid objects which can be used in Open VR.

6.4 Civil3D

In order to establish a connection between Project in GeoSuite and Civil 3D plan drawings can be created from GS Presentation. In settings it is possible to choose if symbols for boreholes should have real Z level och Z=0.

6.4.1 Loading of GeoSuite database and creating surfaces

By using tool *3D model* in menu *Civil3D GS Plan* we choose boreholes which should be loaded and used for creating soil layers. If we want to exclude a borehole from triangulation and do not want to have it drawn in 3D we simply check it off from the list. We can refresh the list so that new and updated boreholes appear in the list. If the database is big it can take some time before all data are loaded. All marked boreholes are automatically presented as 3D cylinders divided into different colors depending on interpretation performed previously. In order to see a surface one should mark which surface should be shown in *Soil Surface* toolbar - Figure 30.

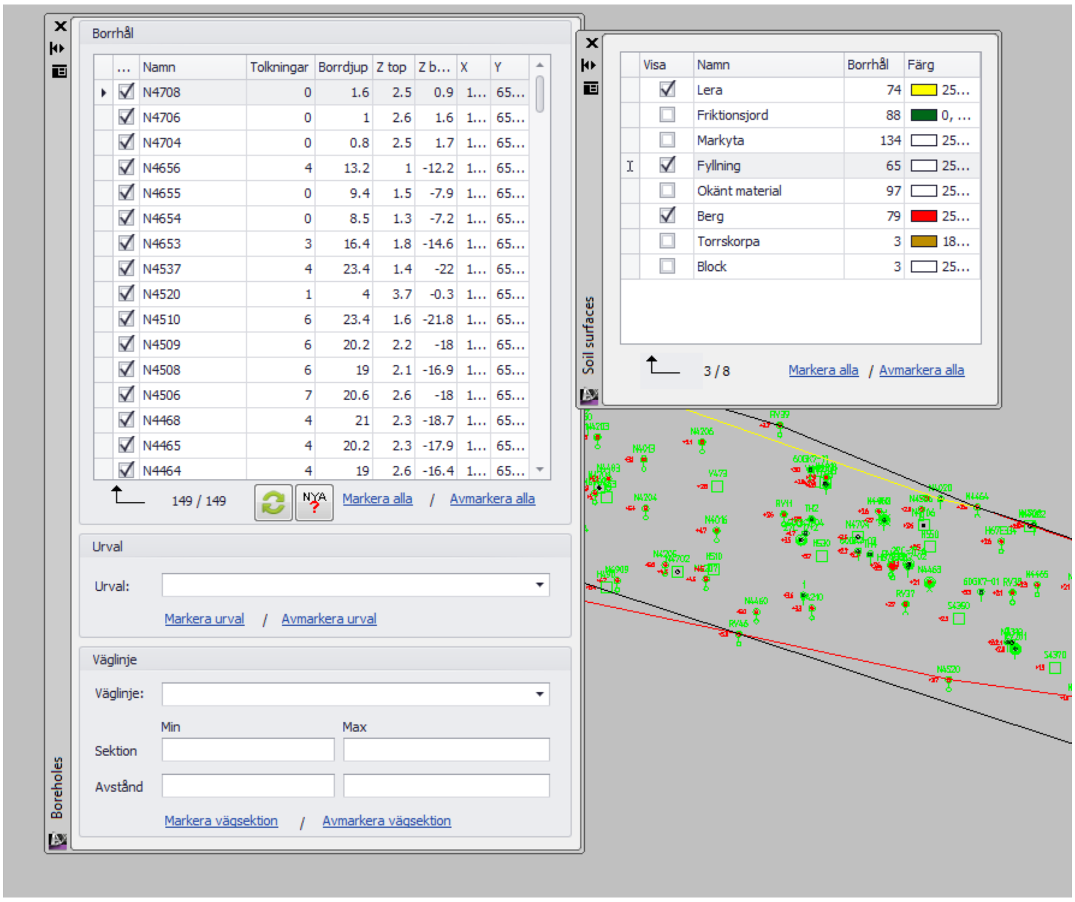


Figure 30 Dialog boxes in Civil 3D for Loading of Database and Surface Creation

It is possible to control the maximum side length of triangles in Civil3D by using *Surface Properties dialog box* for each surface in the *Prospector* window.

6.4.2 Editing of surfaces

It is possible to visually control surfaces, create sections in problem areas and surfaces created load in this section in order to look closely at specific borehole and estimate how the interpretation was made. It is possible to edit, delete or add interpretation in borehole, and add support points which can be included in the triangulation.

Civil3D has one very good feature which is not available in NovaPoint or Power Civil. It is possible to control rock surface. The program is checking all boreholes in the database which do not go to rock and compare their stop level to the rock surface. The result of this control is presented in dwg file with text in the problem area showing the stop level of borehole and the rock level from surface. Results of this control can be used in order to add support points and correct rock surface in areas where the program showed that the rock surface cannot be so high here.

In order to update surfaces it is necessary to first refresh the GeoSuite connection because the database with interpretations files (*.tlk) were updated. All previously layers will be deleted and updated. It is worth noticing that previously chosen settings for maximum side length of triangles will disappear.

6.4.3 Data preparation for Open VR

Surfaces created in Civil3D and 3D boreholes can be used directly in Open VR. Moreover Civil3D surfaces can be used by other areas of technology for design purposes. Most road and waste water projects are using Civil3D as a design tool. In this way it is very easy to present information coming from others on geotechnical drawings.

6.5 Comments

NovaPoint has a direct connection to GS Presentation, which stores field data and field data can be imported in NovaPoint environment with attractive BIM component. Surfaces and 3D boreholes with interpreted layers can be exported to dwg and used in Open VR. But there is a need to jump between NovaPoint and AutoCAD while making surface control, editing surfaces, adding support points. The requirement to create an activity for each process is quite new for “CAD users” in a geotechnical team and it will take some time to study this approach.

Power Civil has powerful tools for data processing; creating 3D models and further 3D design. Power Civil does not have a direct connection with GS Presentation but data can be loaded via pxy files. The process of model editing is different how it is done in NovaPoint or Civil3D and it can be realized both graphically and by editing the database. 3D soil layers can be saved in dwg or dgn format and used in Open VR but there is no possibility to automatically create 3D boreholes.

Civil3D has a good connection to GS Presentation. Boreholes can be easily loaded in Civil3D and surfaces for different soil layers can be fast created and updated. It has good possibilities for model editing and adding of support points for surface adjustment. Surfaces created in Civil3D and boreholes can be used in Open VR. Surfaces created in Civil3D can be imported in NovaPoint if it is necessary and can be used for project design by other areas of technology. Civil3D is a CAD environment and that is why it is familiar for users. Geotechnical sections can be created with boreholes and interpreted soil layers. 3D models from other areas of technology can be shown in geotechnical sections and updated if it is necessary.

Very often the client influences what kind of software should be used in the project. The geotechnical area of technology often depends on other area of technology and adjusts itself in question of choosing software. For example, in railway projects Power Civil (Microstation) is often used; in road and waste water projects Civil3D or NovaPoint is preferably used. NovaPoint is up to date with its BIM component and it makes it very attractive to be used especially in big and complex projects with many disciplines involved.

7. Results and Discussion

7.1 Results and Discussion

VR, BIM, GIS, 3D modelling in the geotechnical field of technology are very urgent questions. Development and researches are ongoing on different levels, including consultants, customers, conductors, authority, universities etc. The large, comprehensive project TRUST is going on with focus on a BIM model for geotechnical purposes - GeoBIM. The aim of this project is to create better conditions for underground construction in Sweden. It is supposed that in 2016 the method and model which can be used for interpretation and communication will be presented. It is not clear how and when the "ordinary users", such as consultants, will get access to GeoBIM and how it can be used not only for project overview, but for 3D modelling, possibility to make drawings, calculations and how it will be possible to use data from GeoBIM for coordination with other areas of technology and other participants in the project, for example, municipality. That is why it is still important to be able to produce own 3D models and present them together with other disciplines in coordination model using virtual reality.

Ten years ago 3D in the geotechnical field of technology in Sweden was a very new issue and was not well investigated; software were not adjusted to the tasks to be performed and there was a lack of alternatives available including programs for 3D modelling of geotechnical data and VR platforms.

Today all large infrastructural projects like Norra Länken, Citybanan, Mälarbanan, Tvärbanan, Tunnelbana etc in Stockholm, Västlänken in Gothenburg and many others are designed wholly in 3D, used 3D models to produce 2D-drawings or used 3D modelling on some special occasions, for example in order to perform collision control of existing and designed construction, calculations etc.

The process of choosing software for analyses in master thesis were limited by number of software available on the market which are able to use, read, import or in any way understand data obtained in a field and process them. This number is relatively low because not many software can communicate with GeoSuite, process data and present them according to Scandinavian standard. There is a number of powerful geotechnical software available in Europe and in the USA but they cannot be used in Sweden because they cannot read the file formats used here.

Virtual Reality is used more and more. Different software available for city modelling, such as CityEngine (ESRI), VCity3D (Virtualcity) etc But WSP decided to develop its own platform based on open source described in section 2.2.

Open VR collects all models in the project in a simple and user-friendly interface which can be installed by anyone in a project and be used in everyday work, meeting, creating basic documents etc. Today each area of technology and each particular constructor creates its own models in own way depending on professional experience and knowledge. Data coordinator should check each particular model how it looks like, if it can be imported in the Open VR directly or should be processed before. Often designers do not know what kind of information, which format, what kind of objects are better for the Open VR and this makes it more difficult and slows the process of transferring information from CAD/GIS/BIM to Open VR. It is good to have a manual for each field of technology for data preparation for Open VR.

As described in section 6 3D models of soil layers can be created quite easy and fast but it needs a lot of adjustments so models do not conflict with each other and look real. 3D models based on interpretation data can be complemented by other information, for example measurements of outcrop, data from installation protocols of piles, sheet piles etc. Created 3D models of soil layers can be used for a project design by geotechnical and other areas of technology. 3D models together with 3D boreholes can be imported in the Open VR for data coordination and, project design.

Programs which were analyzed in this thesis have their advantages and disadvantages. Two of the programs show good communication ability with GeoSuite – NovaPoint and Civil 3D. NovaPoint is BIM oriented and it makes it more interesting and up to date but there is a need to change software to AutoCAD in order to make sections, profiles, make graphical interpretation, and add support points etc. Working approach, when there is need to create activity for each process, differs from the one in geotechnical team and it will take time to learn how it works. Civil 3D has direct connection to GeoSuite Presentation, user-friendly interface to work with geotechnical information; profiles, sections can be created here and interpretation, editing of interpretation, adding of support points can be performed. 3D boreholes and 3D models for soil layers can be imported in Open VR and used by other field of technology in project design. All this make Civil 3D more attractive for usage in the projects. It is important to notice that Power Civil has a lot of advantages concerning 3D design but unfortunately cannot communicate with GeoSuite and produce sections with boreholes according to Swedish standard.

In conclusion it is worth to notice, that often the choice of software in a project depends on a client who decides how a project should be performed, what kind of software should be used, and how final result should be delivered.

The analysis of programs performed in master thesis was time limited, all three software are very powerful, have a lot of applications and have a lot of functionalities. Sometimes it was difficult to say where the software limits is. In order to be able to make deeper analyses it requires that one works with all three software some years and tests them in everyday work.

It is clear that 3D has a central role in project design nowadays. It is more and more often required that 3D models should be delivered as a final result in the project. 3D models of soil layers are used for drawings production and for data control in coordination models. Often special platforms, such as Open VR at WSP, are used for data coordination, project management and as a basic documentation in the project. Today BIM technology is named more and more often in the projects and a lot of researches are going on in this field. But today there are no standards in which say how 3D modelling for soil layers should be done and it makes it difficult to control results of 3D modelling.

Guideline created in this work can be used widely. It can be used in a projects where there is need to create 3D soil layers and rock surfaces by using geotechnical data which has Swedish standard (file format). If another kind of software is chosen for geotechnical data presentation and editing of soil layers and rock surfaces then this guideline can be used as a basis but adjusted according to the used product. It can be used as a guideline to prepare 3D geotechnical layout for any other product for model coordination which uses 3D models (for example, NavisWorks). This guideline can be used at WSP or any other Scandinavian company which uses GeoSuite for geotechnical project management.

7.2 Recommendation for WSP

Depending on the project requirements and application area recommendations can differ. Taking into account that WSP decided to not continue with NovaPoint and use Civil 3D and Power Civil instead then it is recommended to use Civil 3D when it is necessary to create soil layers using field investigations. Civil 3D has good communication with GS Presentation; it is possible to create both 3D surfaces and 3D boreholes with interpreted layers. Results of 3D modelling can be used in NovaPoint, they can be as well loaded to Open VR and if it necessary even imported in Power Civil as 3D faces.

Power Civil can be an option when all others field of technology uses Power Civil for project design, typically for railroad projects. It is good to use Power Civil in large-scale projects where advanced 3D modelling is required. For example, if we need to make 3D modelling of excavation, sheet piling, design other geotechnical constructions. In this case not only soil layers but models for geotechnical solutions can be produced, used for 2D-presentation, volume calculations and for data coordination in Open VR.

Even though NovaPoint does not have priority at WSP it should not be out of the game, it can be very useful in projects where BIM takes a central part. Taking into account that NovaPoint has good communication with GeoSuite, can produce smart 3D models and with help of AutoCAD even produce traditional geotechnical drawings it is good idea to have a license of NovaPoint even at WSP and be updated what happens there.

7.3 Recommendation for software developers

7.3.1 GeoSuite

- Develop communication tools between GS Presentation and Bentley products, for example Power Civil. If it will be possible to import data in Power Civil in the same way as it is possible in Civil 3D, or by using *Text Import Wizard* it will give more possibilities for project design.
- WinRit functionality can be improved so it is possible to choose many interpretations level to be deleted at a time. It takes quite a long time to delete one interpretation level and it is necessary to press button “Delete interpretation” every time you want to delete interpretation.

7.3.2 NovaPoint

Develop possibility to see boreholes in traditional way directly in NovaPoint environment.

- Develop functionality to edit interpretation of soil layers directly in NovaPoint Environment.
- Develop tools for adding support points for soil layers adjustments.
- Develop possibility to specify that there is no specific material in this area while creating 3D models of soil layers.
- Develop an option when one can specify how soil layers should be created; in this way upper layer will be forced to lay over down layer and it will reduce adjustments work of interpreted soil layers.

- Develop KCP (calk cement columns) functions in the same way as it done in Civil 3D. Develop piling, sheet piling tools with 3D and BIM component.

7.3.3 Civil 3D

- Develop tools for 3D design of geotechnical solutions, for example piling and sheet piling, in the same way as it realized for calk cement columns.

7.3.4 Power Civil

- Develop geotechnical functionality
- Develop approach to import boreholes' data from GS Presentation and being able to present them in plan, section and profiles.
- Develop tools to automatically create boreholes in 3D in order being able to load them in Open VR or other coordination model.

8. Conclusions

The process of 3D-modelling takes a central part in a project design nowadays. A lot of projects require that 3D models should be delivered as a final result in the project. 3D models of soil layers are widely used in a project design. They can be used for the calculations, the drawings production and for the data control in coordination models. Often special platforms, such as Open VR at WSP, are used for data coordination, project management and as a tool to store the documentation in the project. Such platforms can import and combine different types of data (CAD, GIS, BIM, etc) and present them in an easily understandable and recognizable by professional and local people view.

The process of 3D modelling of soil layers and rock surfaces, using the results of geotechnical investigations, is limited due to the Swedish data standard. Very few software are able to read or import the data directly from the GeoSuite (geotechnical project database traditional for Scandinavia). That is why a number of software which was used for analysis in this thesis is not high. The programs, which were analyzed in this master thesis, can be used for 3D modelling of soil layers, rock surfaces and creation of 3D boreholes. All of them have some advantages and disadvantages.

Two of the programs, NovaPoint and Civil 3D, have good communication with geotechnical database (GeoSuite). NovaPoint has BIM features, which makes this product very attractive to be used in the projects where BIM is required.

Civil 3D has a user-friendly interface for the 3D modelling of soil layers, rock surfaces and 3D boreholes. Moreover it is easy to use the created 3D models in order to produce traditional geotechnical 2D profiles and sections. The process of soil layers interpretation, editing of interpretation, adding of support points can be easily performed in Civil 3D. In order to improve the process of project designing and communication in the project the 3D boreholes and the 3D models for soil layers can be used in coordination models, such as Open VR, NavisWorks. The created 3D models can be used by other areas of technology in a project design. All this make Civil 3D very attractive for users and is recommended in this thesis to be used.

Power Civil has powerful 3D-modelling tools but unfortunately cannot communicate with GeoSuite and produce sections/profiles with boreholes according to the Swedish standard.

The guideline created in this work (Appendix 1) can be used widely. It can be used in a projects where there is need to create 3D models of soil layers and rock surfaces by using geotechnical data which has Swedish standard (file format). If another, as recommended in this study, kind of software is chosen for geotechnical data presentation and editing of soil layers and rock surfaces, then this guideline can be used as a basis but adjusted according to the used product. It can be used as a guideline to prepare 3D geotechnical layout for any product for model coordination which uses 3D models (for example, Open VR, NavisWorks). This guideline can be used at WSP or any other Scandinavian company which uses GeoSuite for geotechnical project management.

Finally, it should be noticed, that challenges still remain. The standardization of the process of 3D-modelling and BIM for geotechnical data should be completed. There is need in further developing of both the geotechnical database and software which can be used for 3D-modelling of soil layers, rock surfaces and 3D boreholes.

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Appendixes

Appendix 1 – Workflow: Building 3D models from geotechnical data

Appendix 1 has its own page and figure numeration and can be used as a separate document.

**The data from the same sample area with 140 investigation points was used for creating this guideline.*

Workflow: Building 3D models from geotechnical data

When all investigation data is uploaded to GeoSuite database it is possible to start processing the data: make interpretation of soil layers, create 3D models of soil layers, and perform models adjustment and control, prepare geotechnical basic data for Open VR.

1. Project settings
   Before starting working with a data it is a good idea to specify coordinate and height system for your project.
   Choose *Koordynatsystem* in menu *Projekt.* Specify coordinate and height system for your project and press *Beräkna Lat/Long från XY*. Press *spara* in order to save chosen alternative - Figure 1.

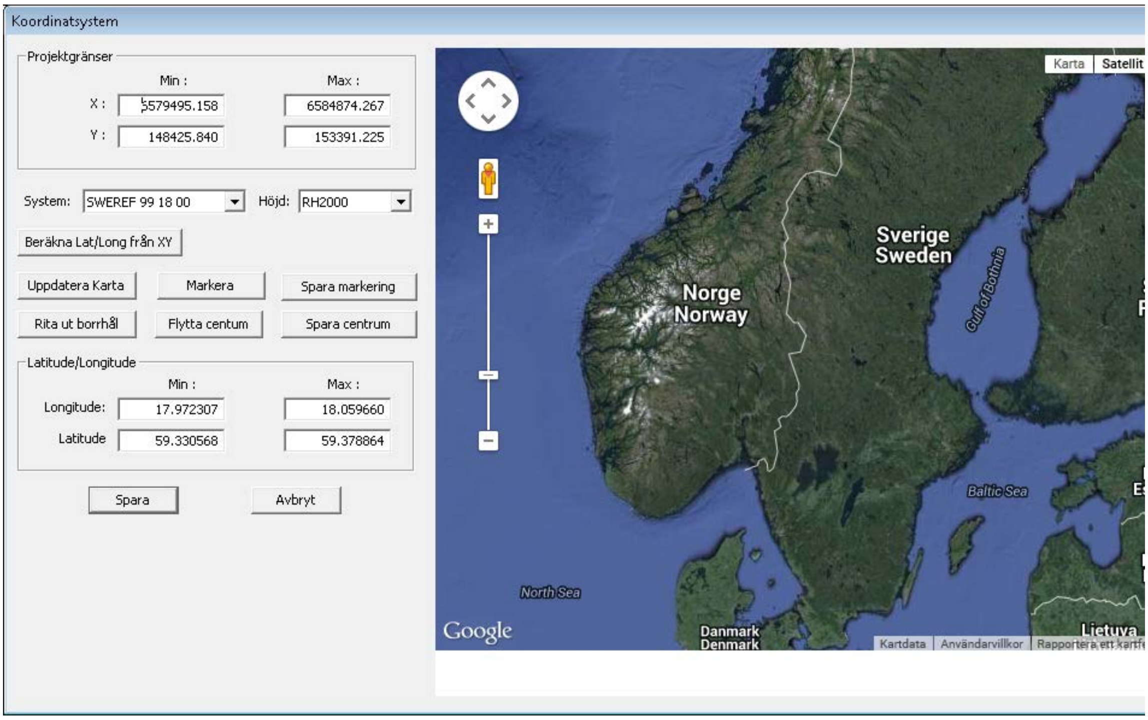


Figure 1 Dialog window Koordinatsystem in GS Presentation

Figure 2 shows the project borders with Google map in background. It is even possible to have a look at a project as it is shown in Figure 3.

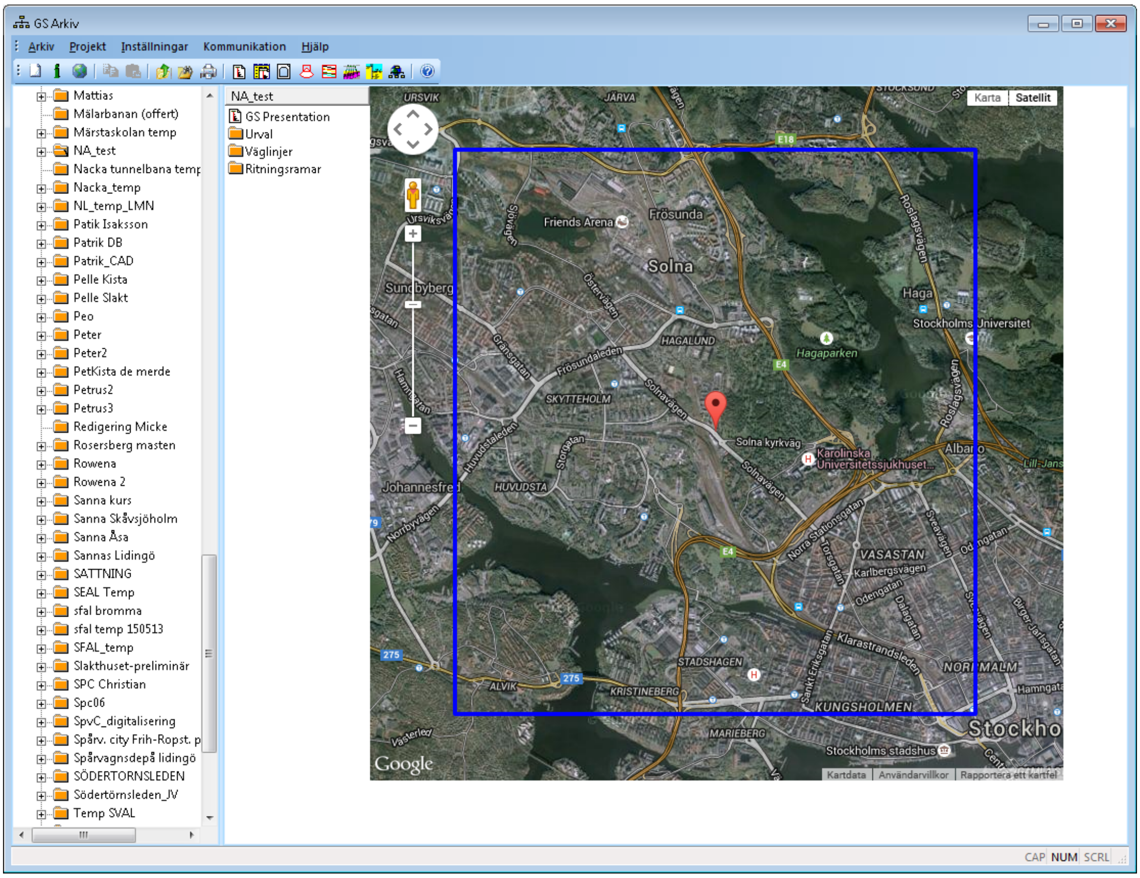


Figure 2 Project placement

Figure 3 Alternative view

2. Make the interpretation of soil layers in the GeoSuite.

Open a project in the *GS Presentation*.

If you want to make interpretation for the whole project then mark all points in the project, right click in the window with boreholes and choose *“Tolkning enl. Fältkoder…”*
If you want to make interpretation for a specific area (saved in *Urval*).
Right click in the window with boreholes and choose “Hämta Urval…”
In appeared window choose the selection (urval) you are planning to work with - Figure 4.

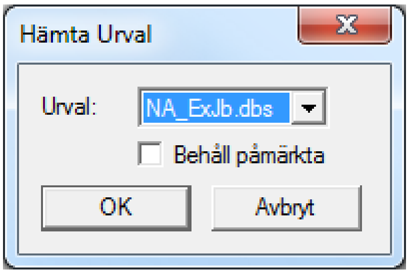


Figure 4 Dialog window to choose urval

After that right click in the window with marked boreholes and press *“Tolkning enl. Fältkoder…”*
In a dialog box we can choose if we want to replace existing interpretation and if we want that interpretation will be performed according to the standard interpretation - Figure 5.

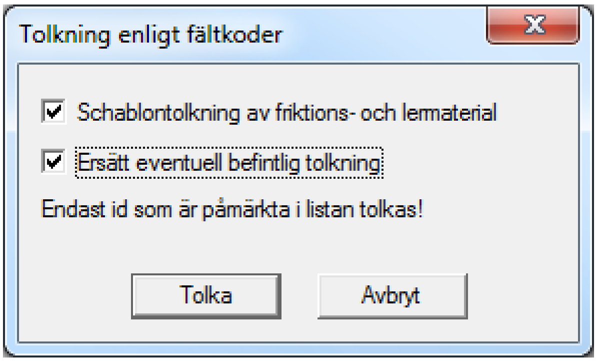


Figure 5 Setting for interpretation

When interpretation is completed the message saying that it is done appears and we can see how many boreholes were updated -Figure 6.

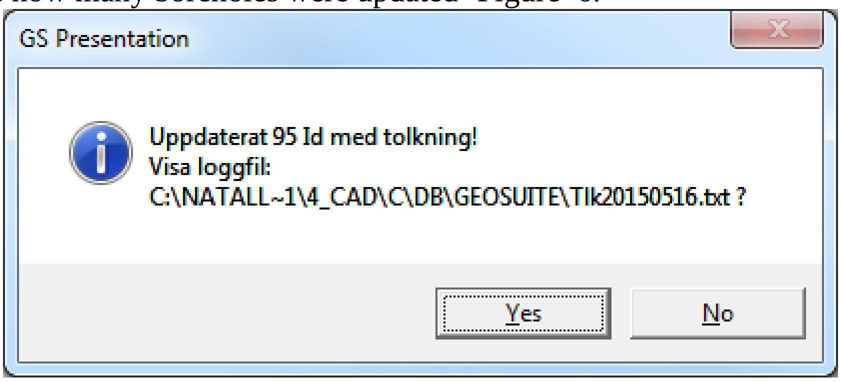
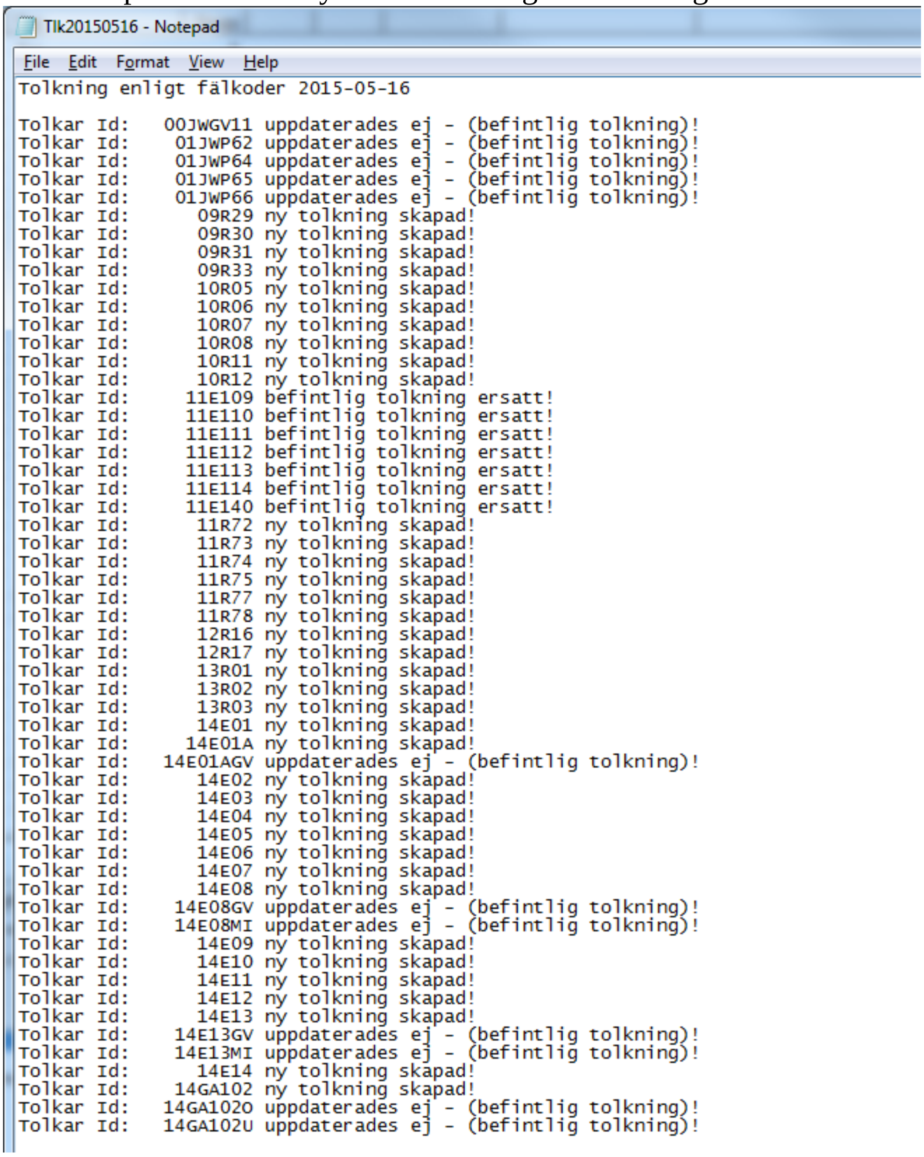


Figure 6 Message showing how many boreholes where updated

The created txt file shows if new interpretations were made for the boreholes, if boreholes were updated or if they were not changed at all - Figure 7.




```
Tolkning enligt fälkoder 2015-05-16

Tolkar Id:   00JWGV11 uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    01JWP62 uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    01JWP64 uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    01JWP65 uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    01JWP66 uppdaterades ej - (befintlig tolkning)!
Tolkar Id:      09R29 ny tolkning skapad!
Tolkar Id:      09R30 ny tolkning skapad!
Tolkar Id:      09R31 ny tolkning skapad!
Tolkar Id:      09R33 ny tolkning skapad!
Tolkar Id:      10R05 ny tolkning skapad!
Tolkar Id:      10R06 ny tolkning skapad!
Tolkar Id:      10R07 ny tolkning skapad!
Tolkar Id:      10R08 ny tolkning skapad!
Tolkar Id:      10R11 ny tolkning skapad!
Tolkar Id:      10R12 ny tolkning skapad!
Tolkar Id:     11E109 befintlig tolkning ersatt!
Tolkar Id:     11E110 befintlig tolkning ersatt!
Tolkar Id:     11E111 befintlig tolkning ersatt!
Tolkar Id:     11E112 befintlig tolkning ersatt!
Tolkar Id:     11E113 befintlig tolkning ersatt!
Tolkar Id:     11E114 befintlig tolkning ersatt!
Tolkar Id:     11E140 befintlig tolkning ersatt!
Tolkar Id:      11R72 ny tolkning skapad!
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Tolkar Id:      11R74 ny tolkning skapad!
Tolkar Id:      11R75 ny tolkning skapad!
Tolkar Id:      11R77 ny tolkning skapad!
Tolkar Id:      11R78 ny tolkning skapad!
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Tolkar Id:      12R17 ny tolkning skapad!
Tolkar Id:      13R01 ny tolkning skapad!
Tolkar Id:      13R02 ny tolkning skapad!
Tolkar Id:      13R03 ny tolkning skapad!
Tolkar Id:      14E01 ny tolkning skapad!
Tolkar Id:     14E01A ny tolkning skapad!
Tolkar Id:   14E01AGV uppdaterades ej - (befintlig tolkning)!
Tolkar Id:      14E02 ny tolkning skapad!
Tolkar Id:      14E03 ny tolkning skapad!
Tolkar Id:      14E04 ny tolkning skapad!
Tolkar Id:      14E05 ny tolkning skapad!
Tolkar Id:      14E06 ny tolkning skapad!
Tolkar Id:      14E07 ny tolkning skapad!
Tolkar Id:      14E08 ny tolkning skapad!
Tolkar Id:    14E08GV uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    14E08MI uppdaterades ej - (befintlig tolkning)!
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Tolkar Id:      14E11 ny tolkning skapad!
Tolkar Id:      14E12 ny tolkning skapad!
Tolkar Id:      14E13 ny tolkning skapad!
Tolkar Id:    14E13GV uppdaterades ej - (befintlig tolkning)!
Tolkar Id:    14E13MI uppdaterades ej - (befintlig tolkning)!
Tolkar Id:      14E14 ny tolkning skapad!
Tolkar Id:    14GA102 ny tolkning skapad!
Tolkar Id:   14GA102O uppdaterades ej - (befintlig tolkning)!
Tolkar Id:   14GA102U uppdaterades ej - (befintlig tolkning)!
```

Figure 7 Loggfil

Next step is to draw all interpreted boreholes in the WinRit window in order to estimate the results of performed automatic interpretation. Mark the boreholes which should be shown in the WinRit (it is possible to use function “Hämta Urval” in order to mark all boreholes in a sample (urval)) - Figure 8.

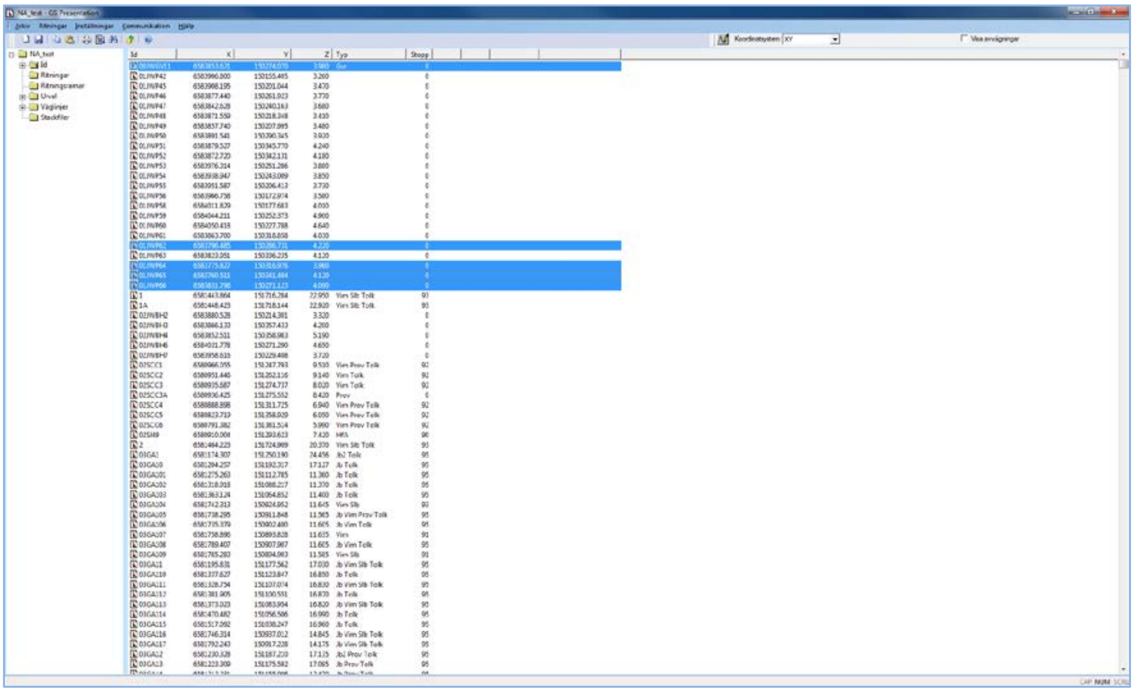


Figure 8 Mark interpreted boreholes in ID window

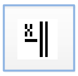
Press “*Rita Id”*symbol .
All chosen boreholes will be drawn in the WinRit window.
In order to visualize made for soil layers interpretation, press the *”Hämta tolkningar*” button. 

Figure 9 shows how it can look like. It is obvious that there is need to edit interpretation. It can be performed by using functionality which allows add, move or delete interpretation. When you are satisfied with made changes, save the interpretation by pressing the ”Spara tolkningar” button.

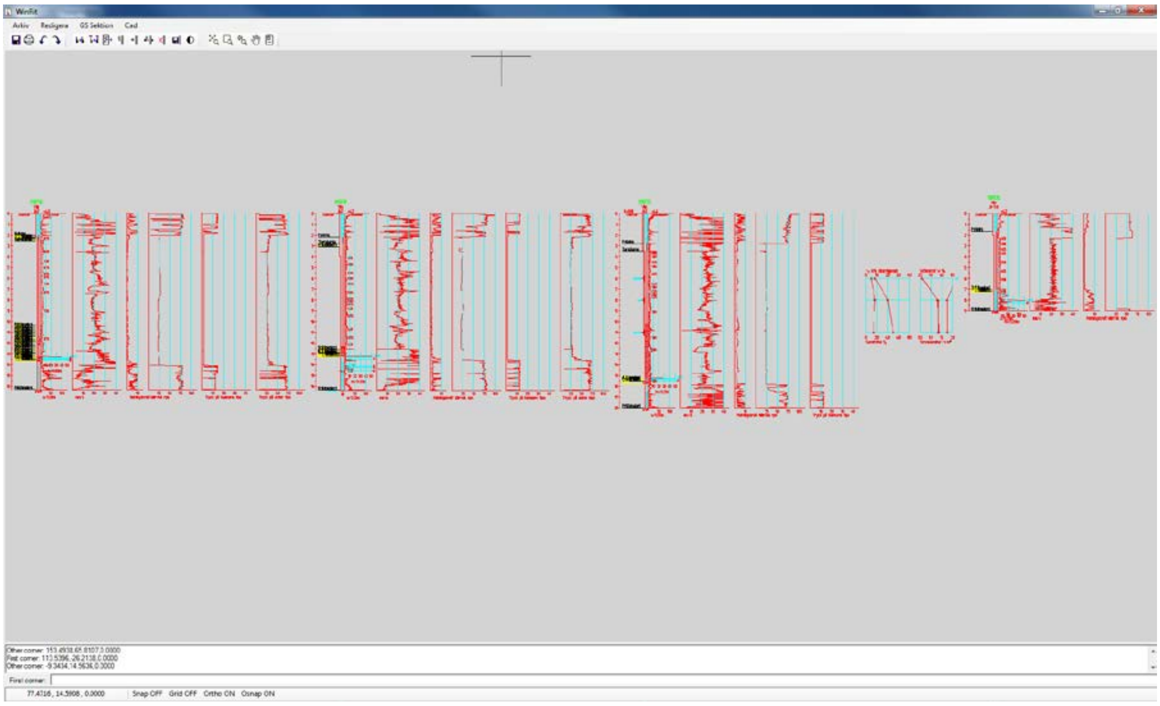


Figure 9 WinRit window with automatically interpreted boreholes

3. Draw the interpreted boreholes in 3D in Civil 3D

Version of GeoSuite 14.0 supports Civil 3D 2013 or 2014.
Version of GeoSuite 14.1 supports Civil 3D 2015.
In order to draw boreholes in 3D we need to specify in the settings that we want that boreholes will be shown in 3D - Figure 10. If we are not specifying that Z should have real value then everything will be drawn in 2D.

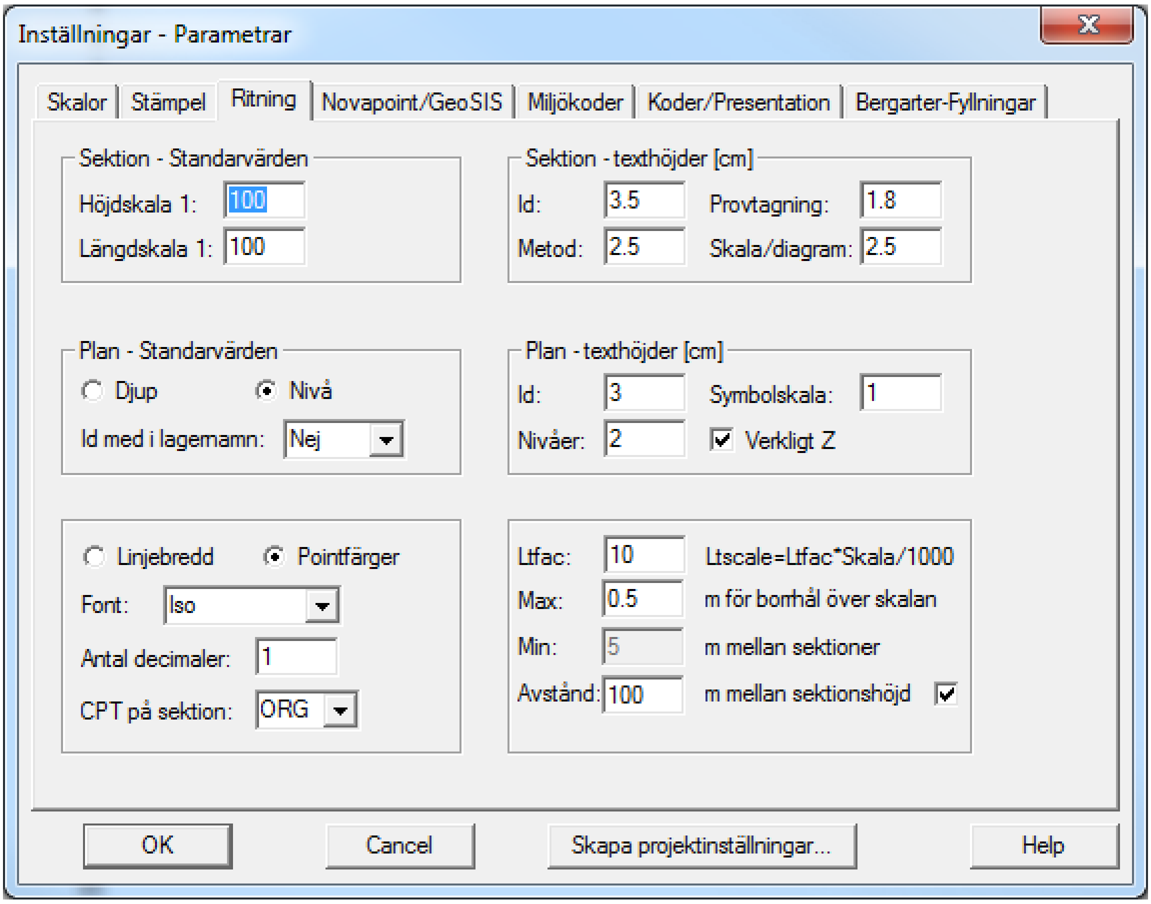


Figure 10 "Verklig Z" should be chosen

Next step is to generate a plan drawing. If we choose one of boreholes symbols and check the properties for it we see that symbol placed (draped) on a ground surface and has in this case Z=4.057 - Figure 11.

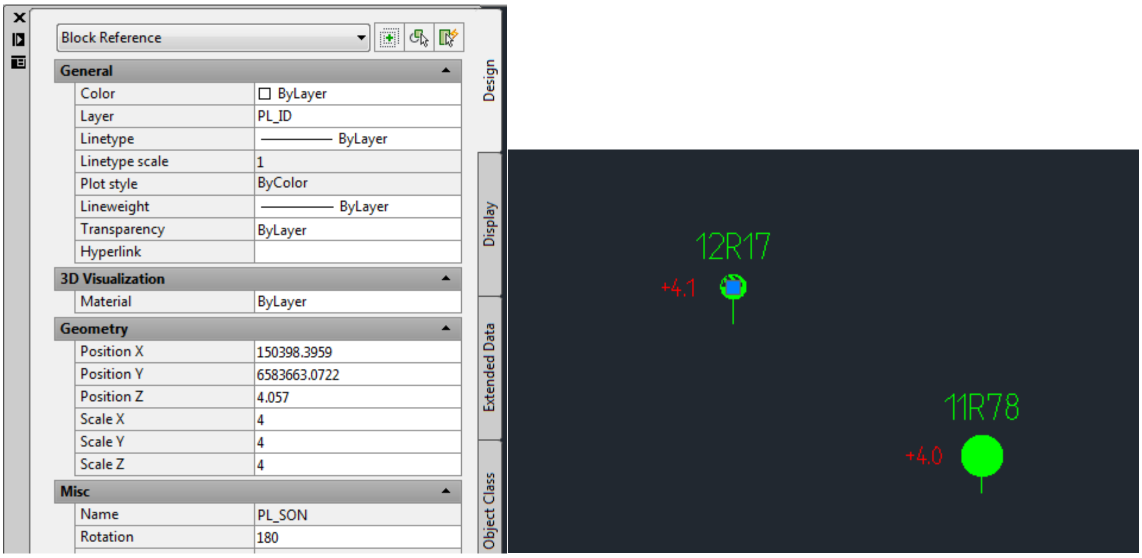


Figure 11 Plan drawing with properties window

In the *GS Plan* menu choose *Geoteknik Civil3D-modell.*
Two dialog windows appear: *Boreholes* and *Soil surfaces*.
If we choose *Markera alla* in Window *Boreholes* as it shown in Figure 12 all boreholes will be drown in 3D – Figure 13.

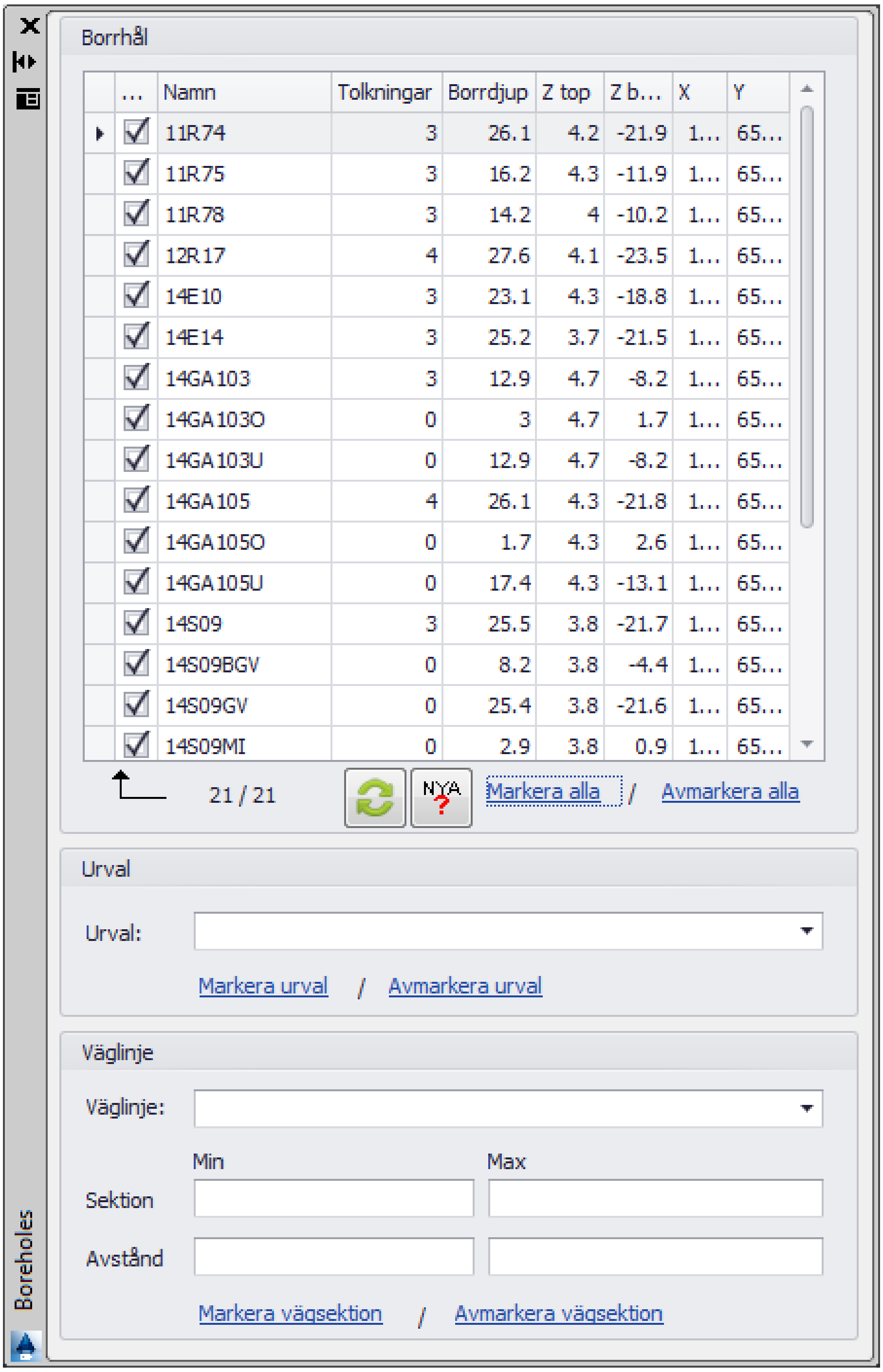


Figure 12 Boreholes - dialog window

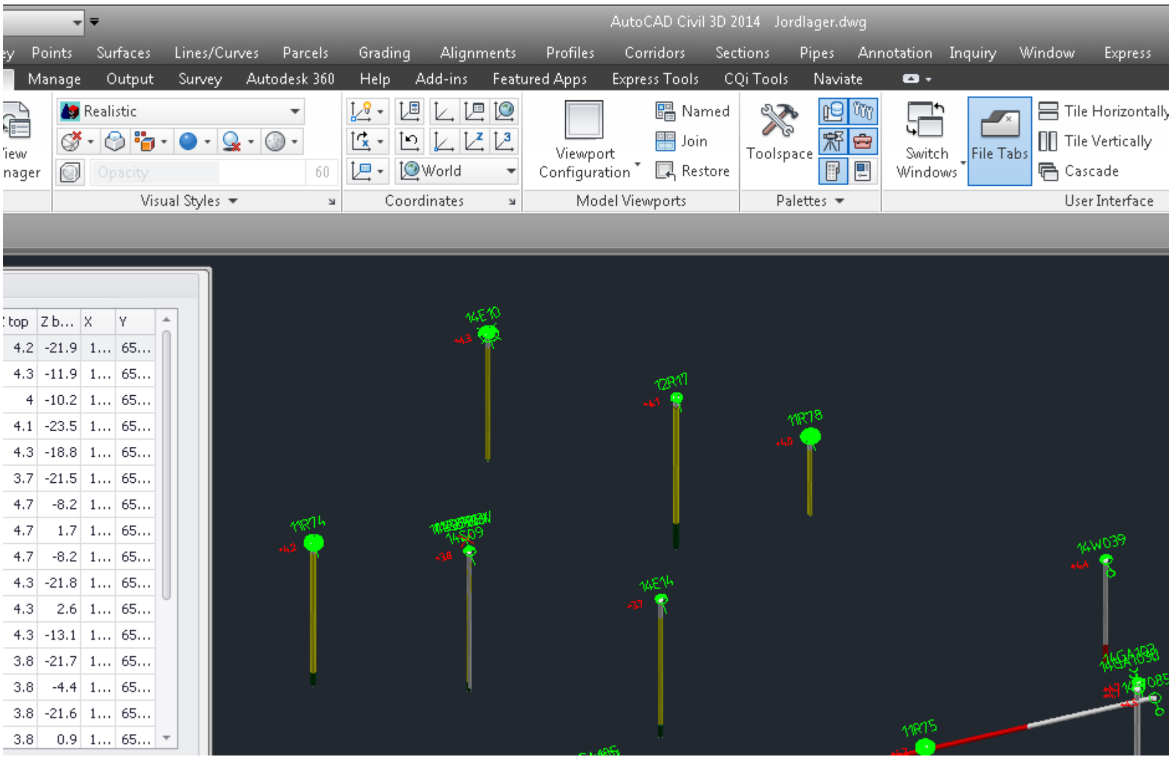


Figure 13 3D boreholes created in Civil 3D

The 3D Boreholes are 3D solids which have different colors and placed on layers depending on the interpretation.

4. Generate 3D surfaces in Civil 3D

In order to generate 3D surfaces for soil layers mark in the dialog window *Soil surfaces* those soil layers you want to generate – Figure 14.

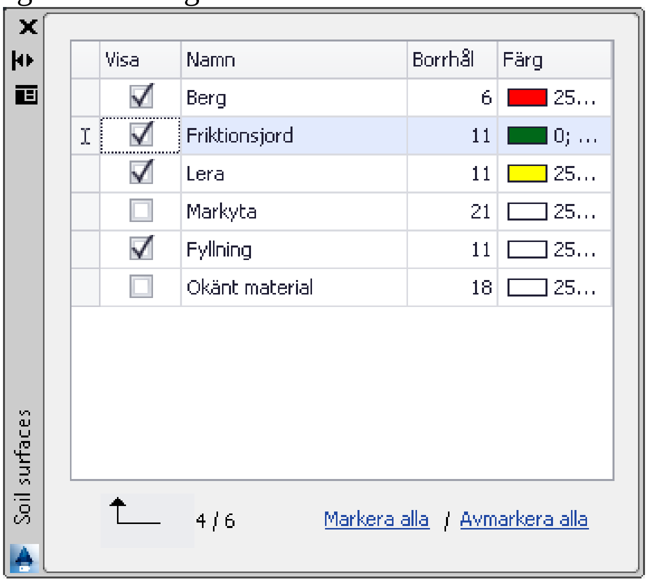


Figure 14 Dialog box - Soil surfaces

Figure 15 shows the generated soil layers.

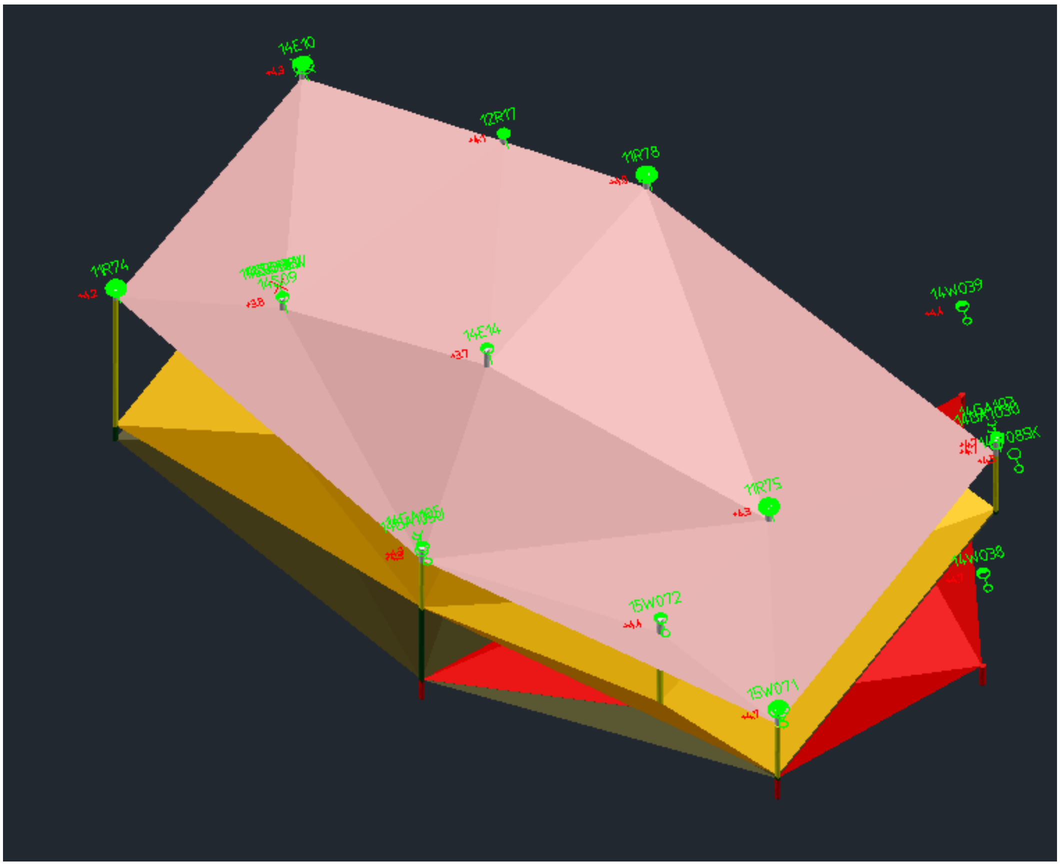


Figure 15 3D soil layers generated in Civil 3D

In order to set in the maximum side length of triangles right click on *Surface: Berg* in *Toolspace / Prospector*, choose *Surface Properties* and under *Definition* flick specify the maximum triangle length - Figure 16.

The same manipulations can be done for other surfaces in order to specify the maximum side length of triangles.

The created surfaces are TIN surfaces which have different colors and placed on respective layer. TIN surfaces can be used in Open VR directly or can be converted to 3D faces using *Explode* tool.

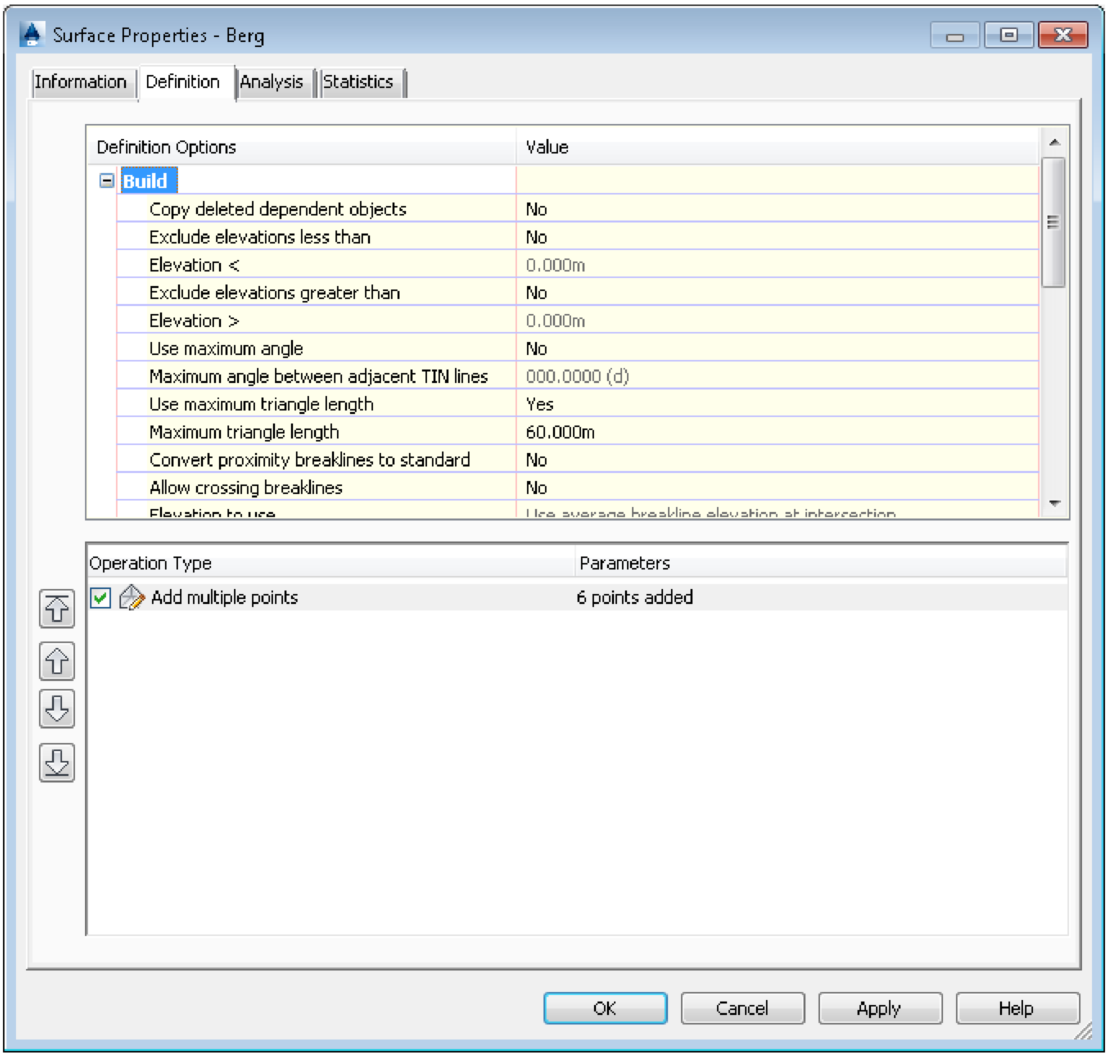


Figure 16 Surface Properties

5. The surface control

Firstly make a visual control of the created surfaces. Start with rock surface - Figure 17.

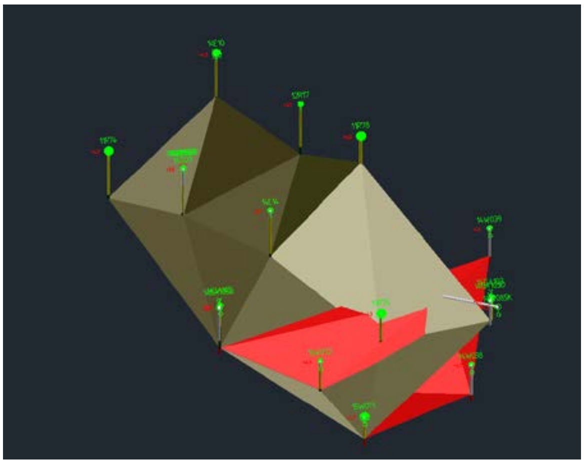


Figure 17 Visual control of the created rock surface

Rock surface were created using boreholes with interpreted rock levels. But often there are other boreholes in a project which do not go down to the rock. It is obvious that rock model should go under these boreholes. To make this control choose *Bergkontroll Civil 3D-modell* and specify that *.dbs file should be used for surface control. Accept layer *Berg* as our rock surface.

The program shows how many mistakes are founded, how many mistakes are more than 1 meter and a value of maximum mistake - Figure 18.

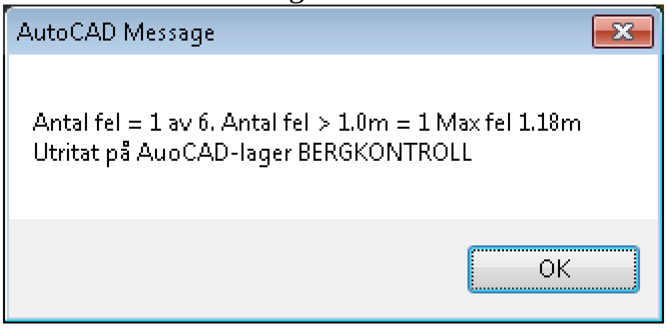


Figure 18 Message

On the drawing, where mistakes are found, the text showing different levels is placed - Figure 19. The level (-10.7) is coming from the rock model and the level -11.9 is coming from the investigation which does not go down to the rock.

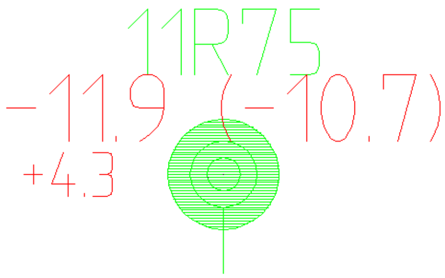


Figure 19 Rock control shown in drawing

6. The surface editing

In order to adjust rock levels in areas where mistakes were found it is possible to add some extra points with a rock interpretation or add interpretation of rock surface in this borehole. In order to add an extra point, choose *Digitalisera XY* and *Skapa nya ID* - Figure 20.

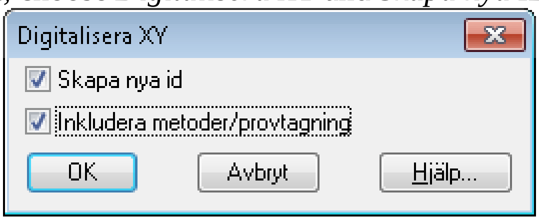


Figure 20 Digitalisera XY

Z level for created point should be placed depending on a situation, but place it a bit lower than existing borehole. In this case it is placed 0.6 meter under bottom level of borehole - Figure 21. Save the results.

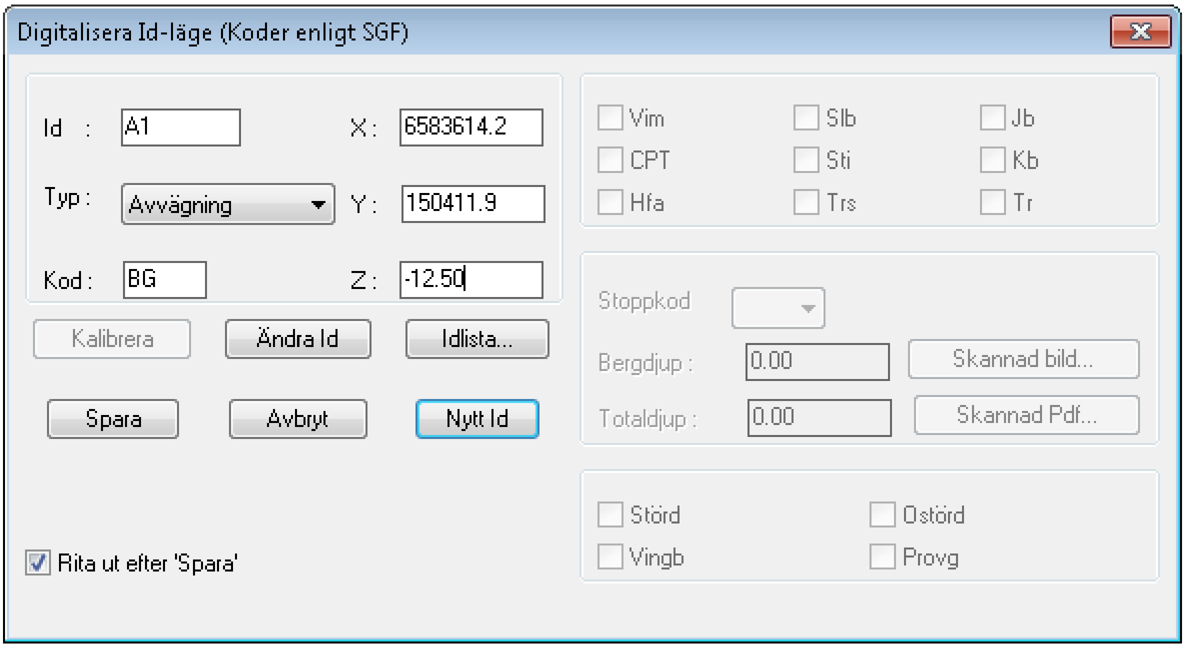


Figure 21 Dialog box - Digitalisera Id-läge

7. Update Civil 3D model

In the dialog window for selected boreholes choose *Ladda om GeoSuite kopplingen* in order to reload GeoSuite connection because the database was updated. All created layers will be first deleted and constructed again. OBS! The settings for maximum triangle length which were defined before will disappear. And it is required to make the settings changes again for each updated surface in the same way as it was described in section 3. Taking all this into account it is recommended to control model in 3D, plan and sections, edit model and after that make final adjustments for triangulation settings.

8. The surface adjustments by adding support points in the sections

Even though we added one support point in rock surface there is still conflict between two surfaces - Figure 22.

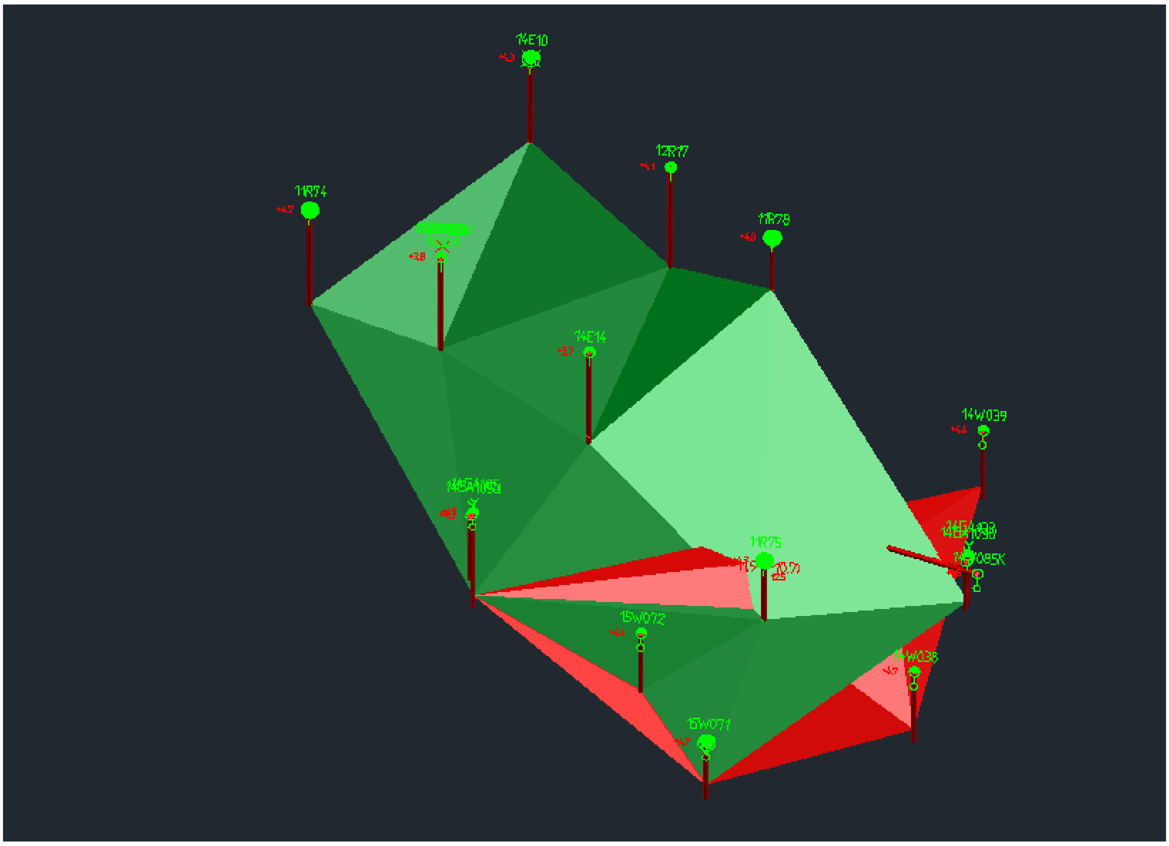


Figure 22 Rock surface after adding support point

We will look at this case, using sections, and will add support points directly in the sections. Generate a section using tool *Generera sektion* under the *GS Plan*. The result will be a traditional geotechnical section with boreholes – Figure 23.

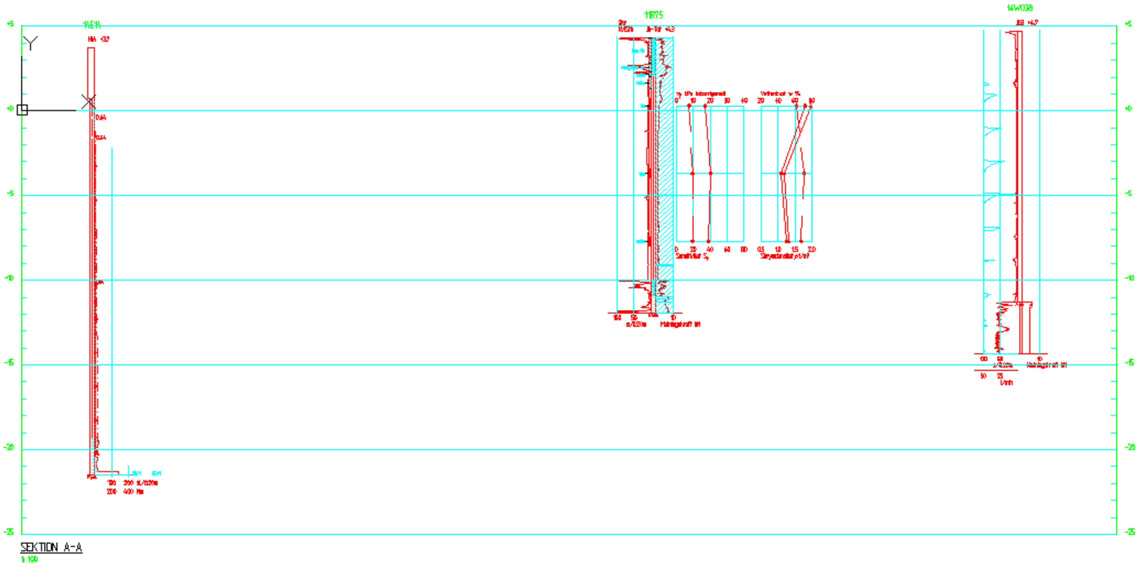


Figure 23 Traditional geotechnical section with boreholes

In order to show generated 3D models in the section, choose under the *GS Sektion* function *Terrängmodell Civil 3D*. The dialog window will appear - Figure 24.

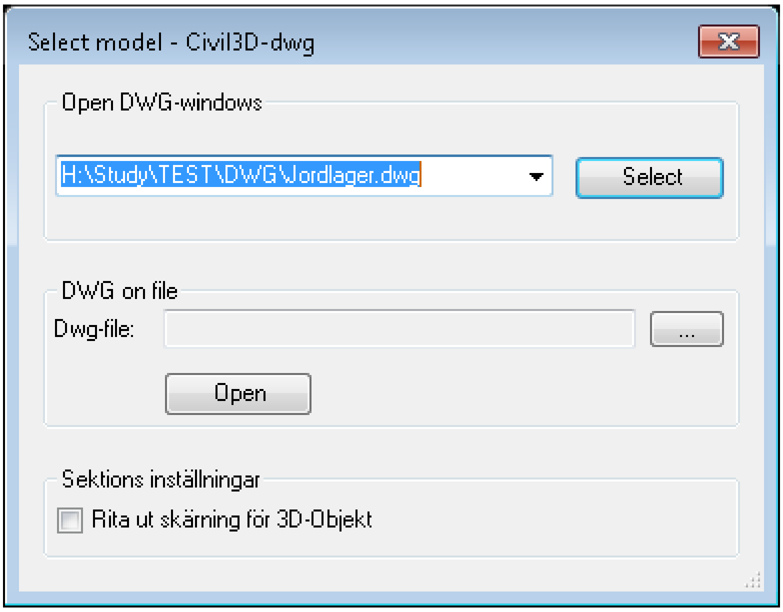


Figure 24 Dialog window - Select model

Specify where the surfaces, which we want to be shown on the section, can be found. If the dwg file with the surfaces is opened in Civil 3D then we choose it under *Open DWG-windows* as it shown in Figure 24. And press *Select*.

If dwg file with 3D surfaces is not opened we can use *DWG on file*. We choose the dwg file with 3D models which we want to use and then press *Open* - Figure 24.

Results are shown in Figure 25.

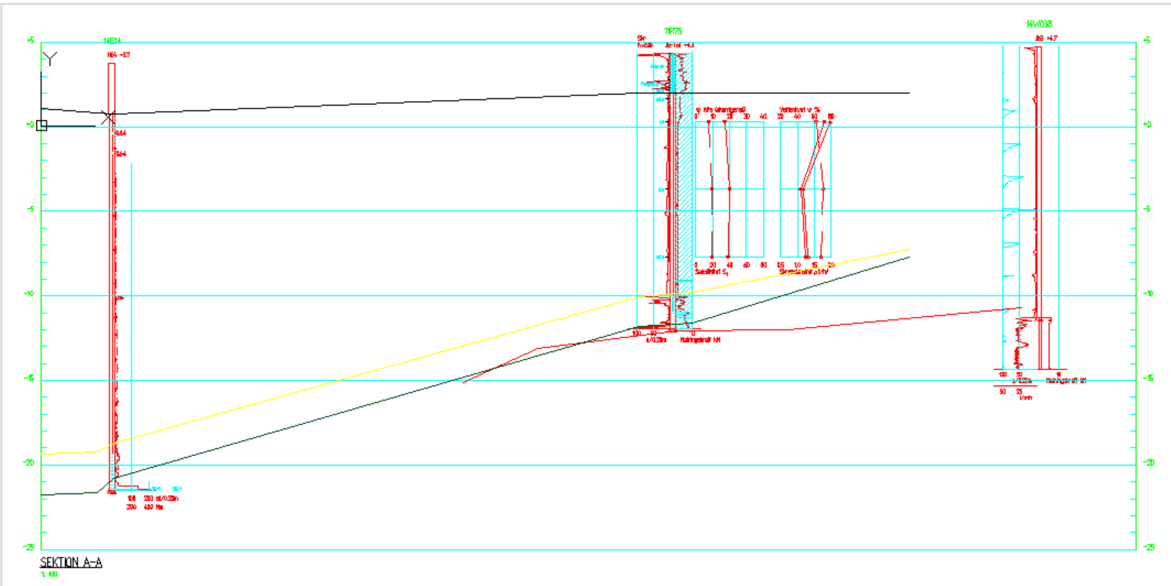


Figure 25 Section with boreholes and surfaces created in Civil 3D

Figure 25 shows that there is a conflict between two surfaces and to solve this we can add support point to surface *"Friktionsjord"* in order to rise it up a bit.

To do this choose under *GS Sektion/ Tolkning* tool *Lägg till Stödtolkning*. A dialog window will appear - Figure 26.

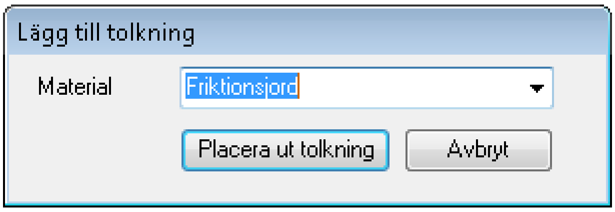


Figure 26 Dialog window "Lägg till stödtolkning"

Choose here a material for support point – in this case it is Friktionsjord and press *Placera ut tolkning* - Figure 26.
Mark on the section where support points should be added and press esc when you finished.
Symbols for added points look as it shown in Figure 27.

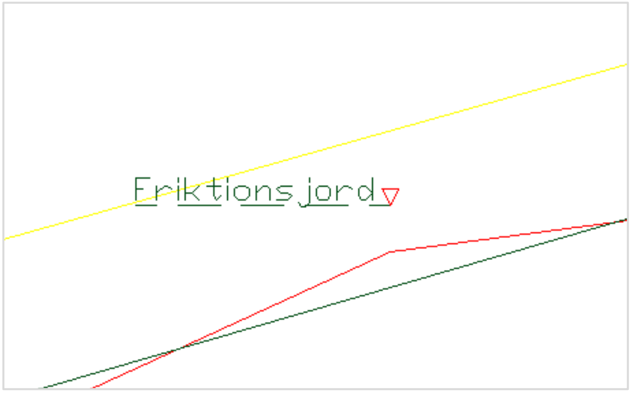


Figure 27 Symbol for point for support interpretation

Do not forget to save changes by pressing *Spara Tolkning* under *GS Sektion/ Tolkning.*
Refresh *GS Presentation* and press on *Avvägning* under *Id* - Figure 28.

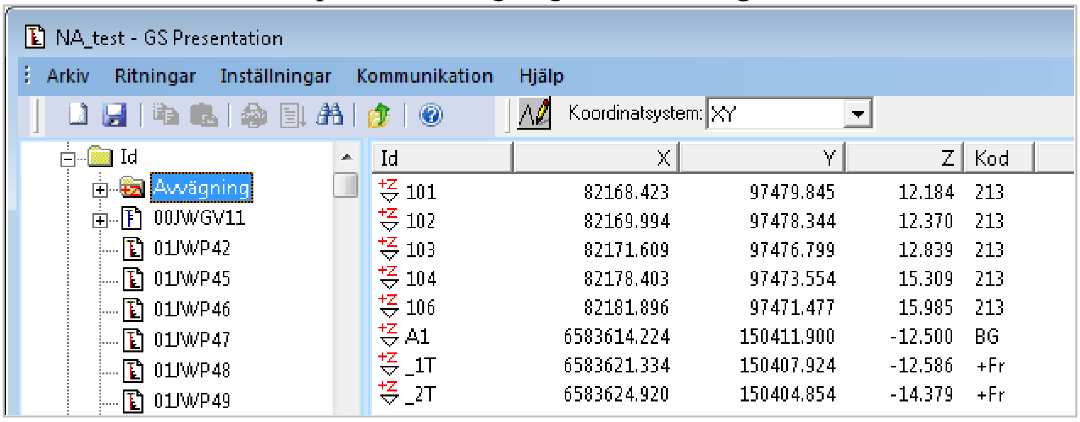
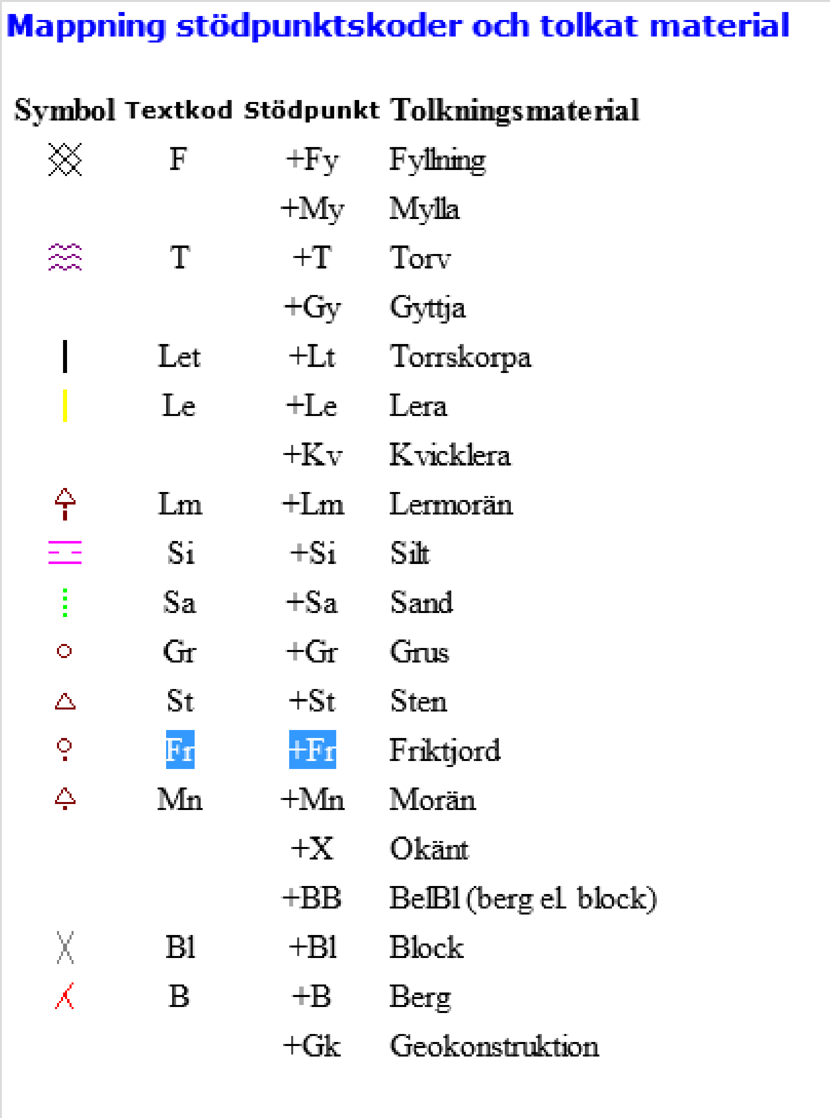


Figure 28 Support Points under Avvägning in GS Presentation

Two points with code +Fr appeared here. Code *+Fr* is used for *Friktionsjord* material.
The codes for other materials are presented in Figure 29 and can be as well founded under *GS Presentation Hjälp*.


Mappning stödpunktskoder och tolkat material

Symbol	Textkod	Stödpunkt	Tolkningsmaterial
	F	+Fy	Fyllning
		+My	Mylla
	T	+T	Torv
		+Gy	Gyttja
	Let	+Lt	Torrskorpa
	Le	+Le	Lera
		+Kv	Kvicklera
	Lm	+Lm	Lermorän
	Si	+Si	Silt
	Sa	+Sa	Sand
	Gr	+Gr	Grus
	St	+St	Sten
	Fr	+Fr	Friktjord
	Mn	+Mn	Morän
		+X	Okänt
		+BB	BeBl (berg el block)
	Bl	+Bl	Block
	B	+B	Berg
		+Gk	Geokonstruktion

Figure 29 Codes for support point

Go back to the plan drawing in Civil 3D and update the connection with GS Presentation and recreate 3D surfaces for soil layers as it is described in section 6.

Figure 30 shows the results of adjustment. It is clear that collision of two surfaces is solved.

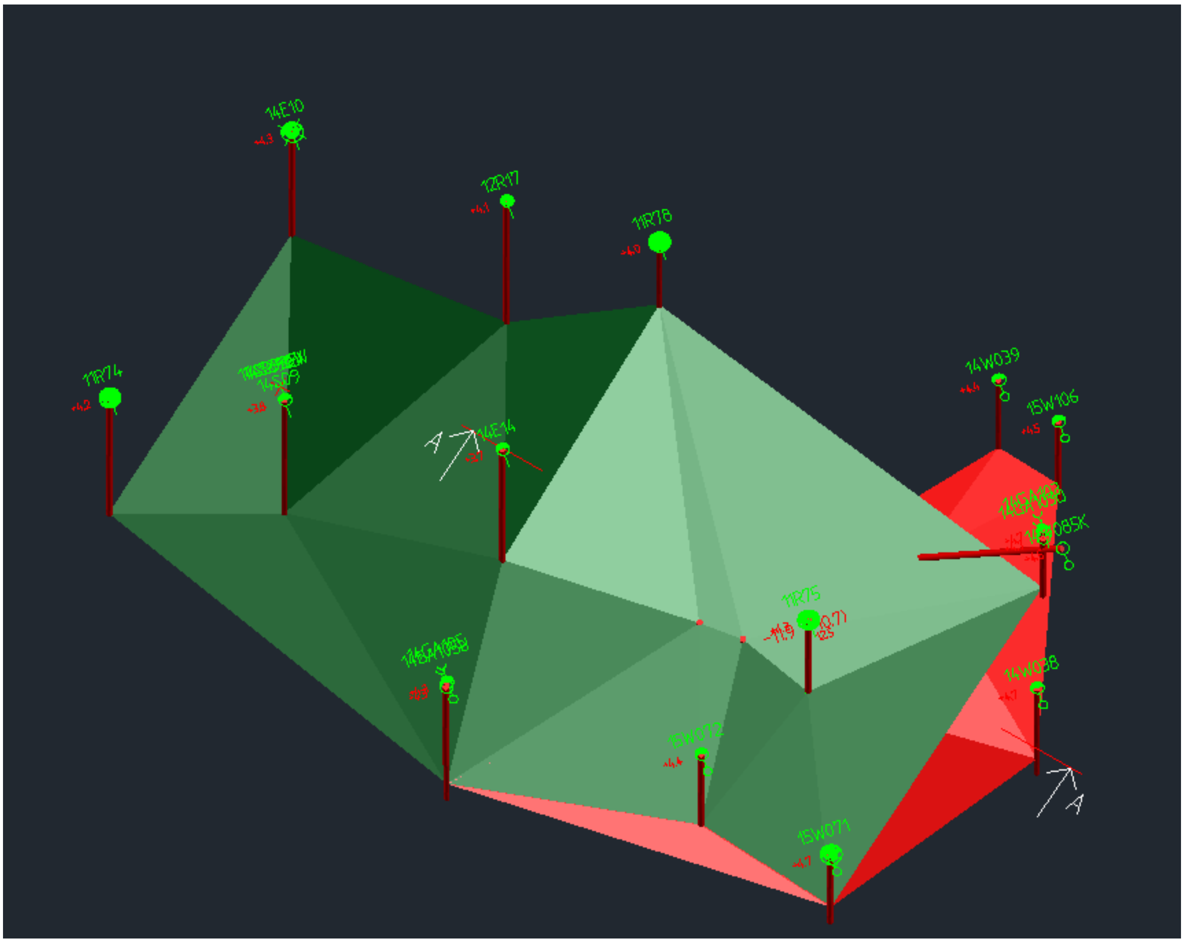


Figure 30 Results of adjustment using adding support points in section

We can update the section which we had drawn before and read in it updated soil layers in the same way as it was described before. The results are presented in Figure 31.

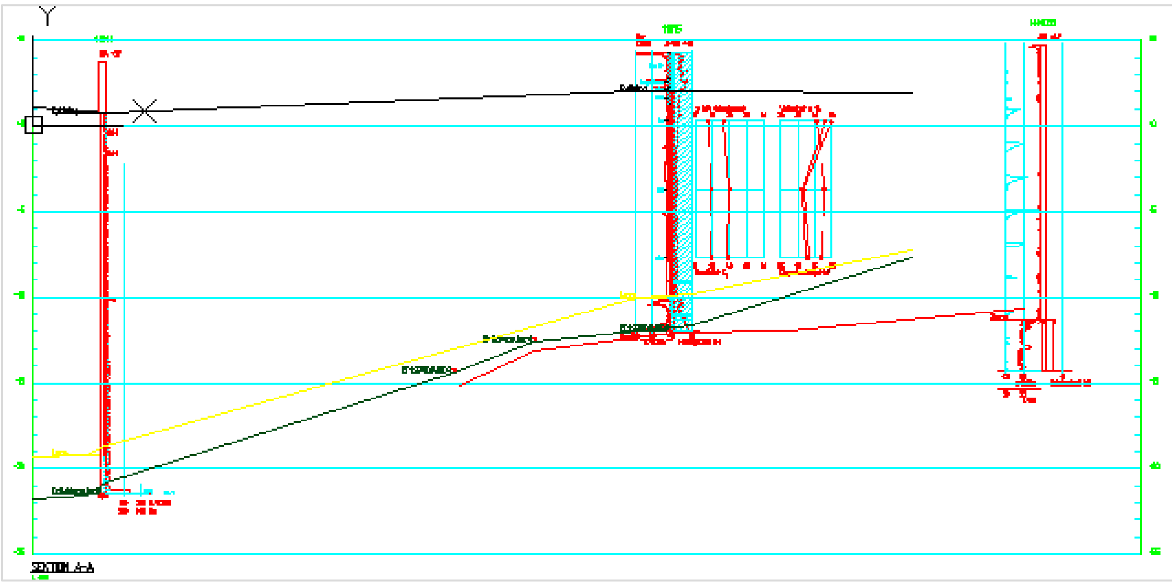


Figure 31 Section with updated soil layers

9. Soil Surface Settings

In Civil 3D the Data Shortcuts instead of XREF are used. In order the other areas of technology are being able to use the created drawing with 3D models for soil layers some operations should be done.

The first step is - right click on *Data Shortcuts* and choose *Set Working Folder…* - Figure 32.

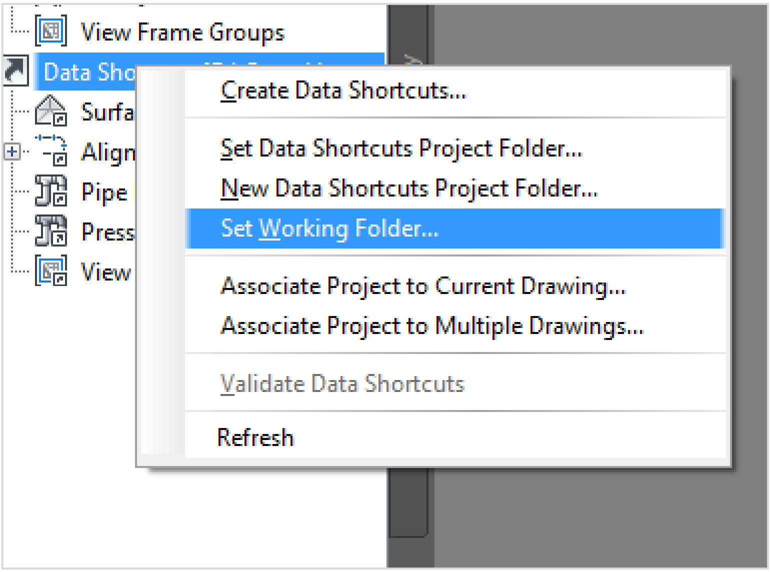


Figure 32 Set Working Folder…

When the working folder is specified, right click on the *Data Shortcuts* again and choose *New Data Shortcuts Project Folder…* - Figure 33, Figure 34.

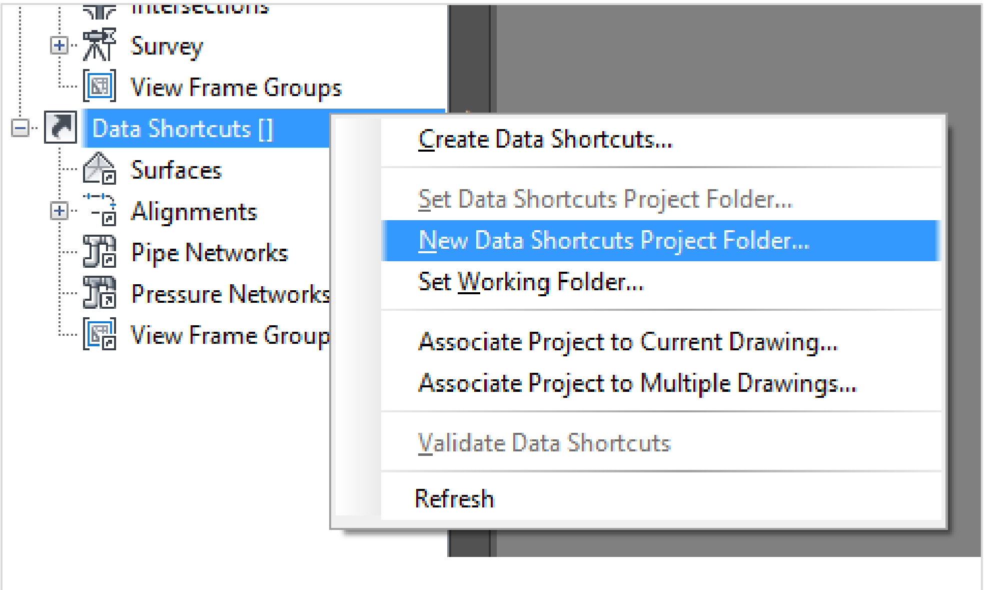


Figure 33 New Data Shortcuts Project Folder…

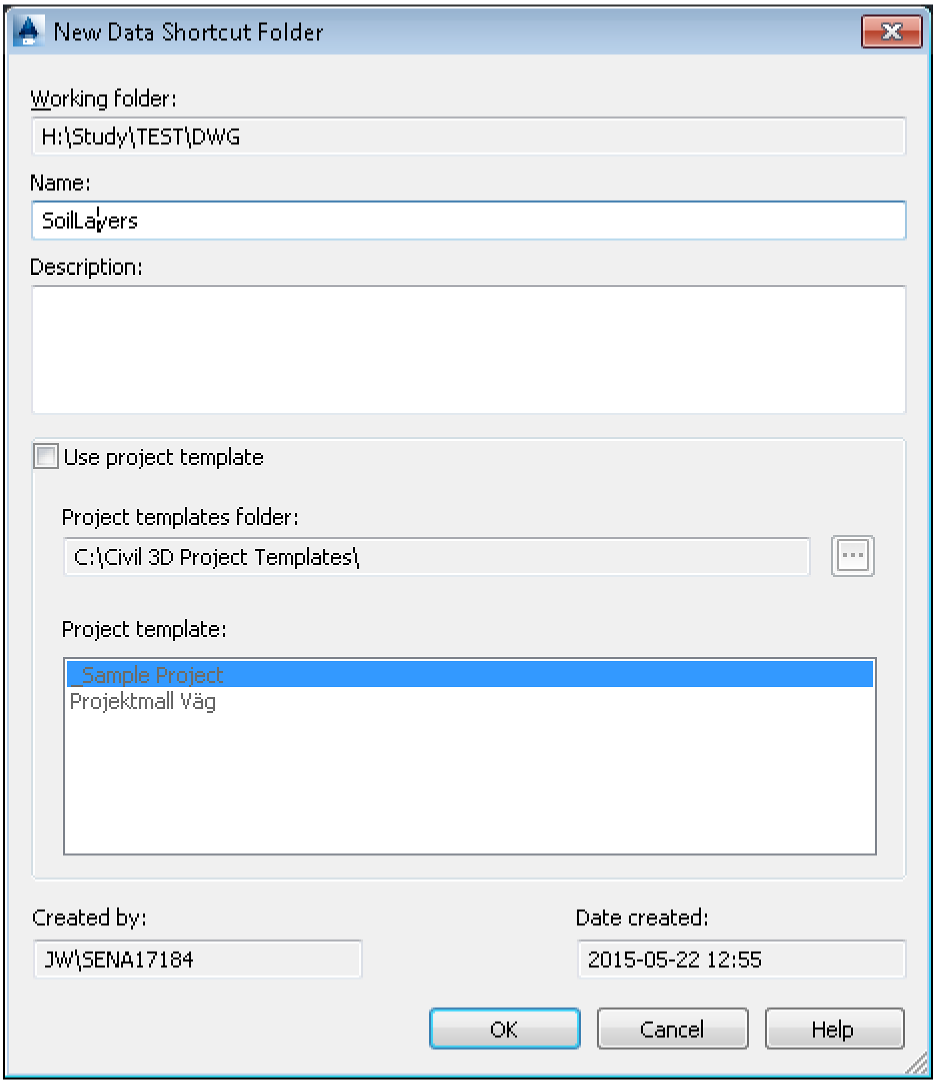


Figure 34 Dialog window for New Data Shortcuts Project Folder…

After that right click on the *Data Shortcuts* again and choose *Associate Project to Current Drawing…*- Figure 35.

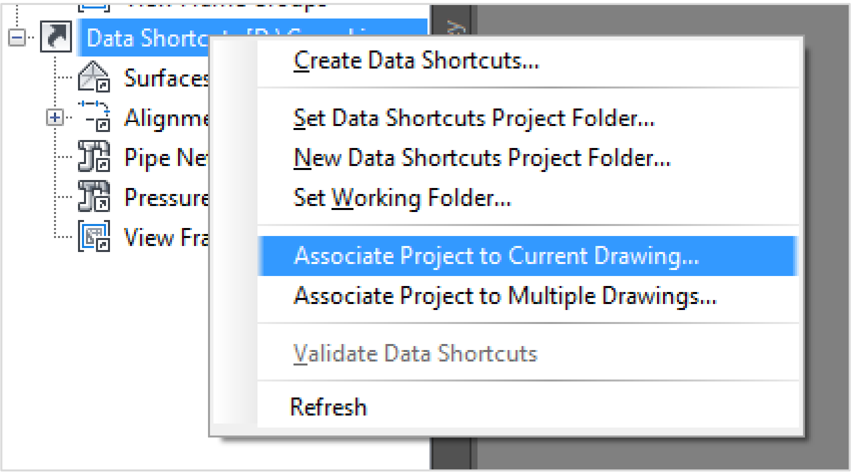


Figure 35 Associate Project to Current Drawing...

Select the project to be associated with the current drawing as it shown in Figure 36.

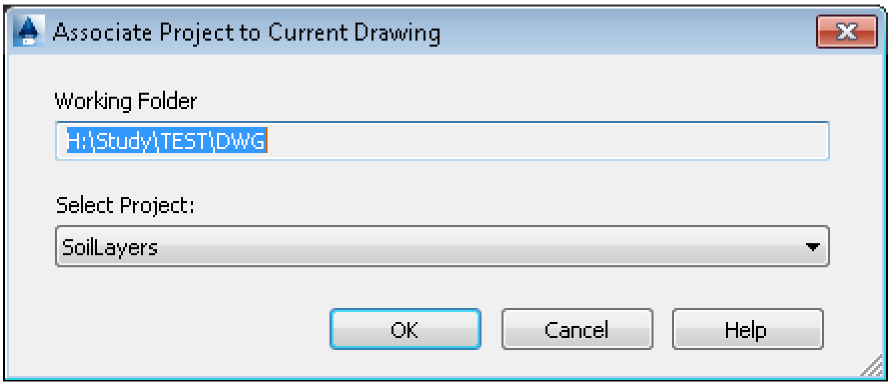


Figure 36 Project to be associated with current drawing

Right click on the *Data Shortcuts* again and choose *Create Data Shortcuts…* - Figure 37.

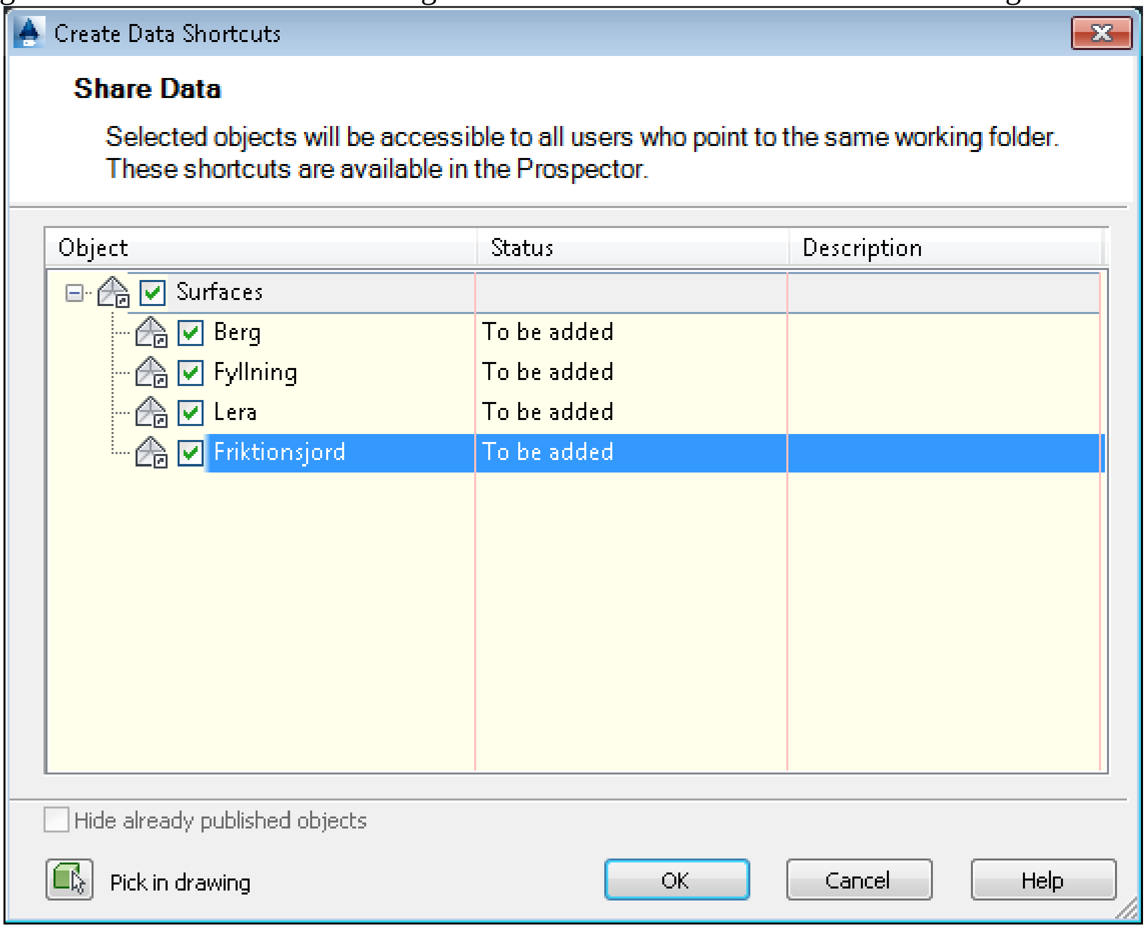


Figure 37 Create Data Shortcuts

Now other areas of technology are being able to use this drawing by using the tool *Create Reference…* as it is shown in Figure 38.

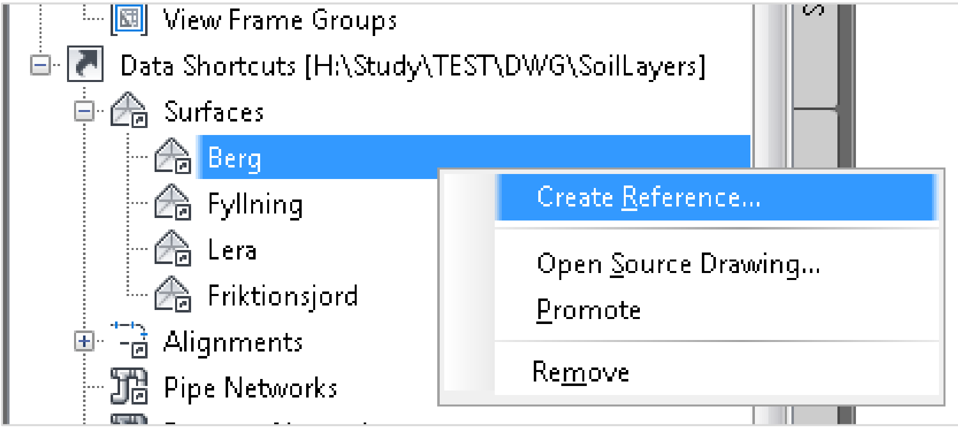


Figure 38 Create Reference...

In the opened dialog window choose a layer and a style for the surface. When you are satisfied, press *OK* - Figure 39.

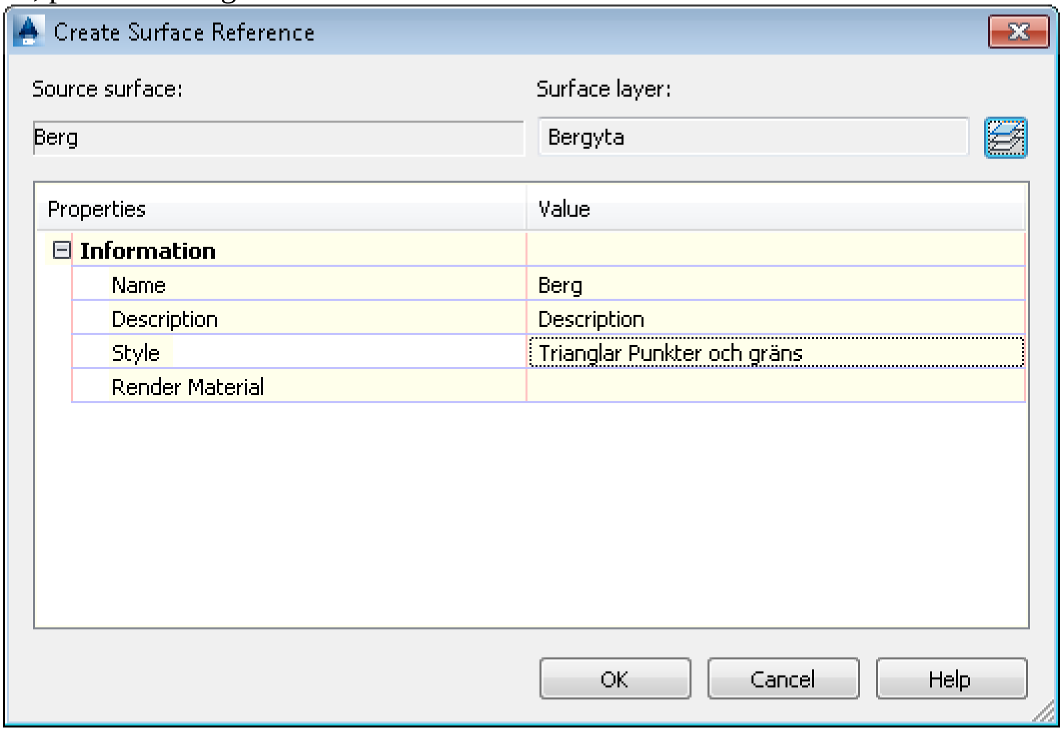


Figure 39 Create Surface Reference

Zoom/ Extend and check the results. In this case rock surface was used to be inserted in a drawing using function *Create Reference* - Figure 40.

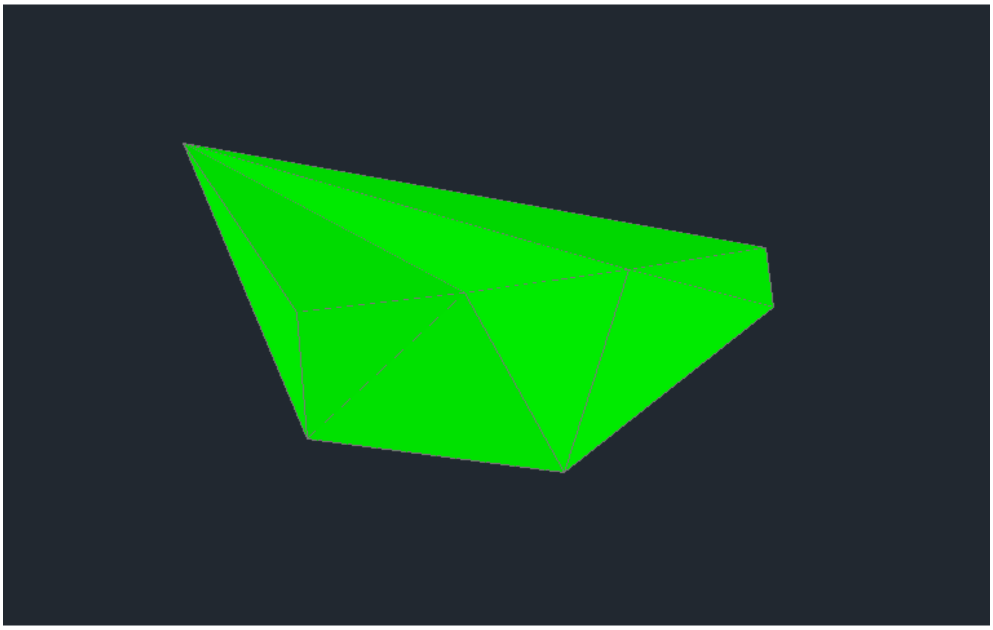


Figure 40 Rock Surface inserted using Create Reference tool

Appendix 2 – Overview of reference projects of Open VR

Nationalmuseum

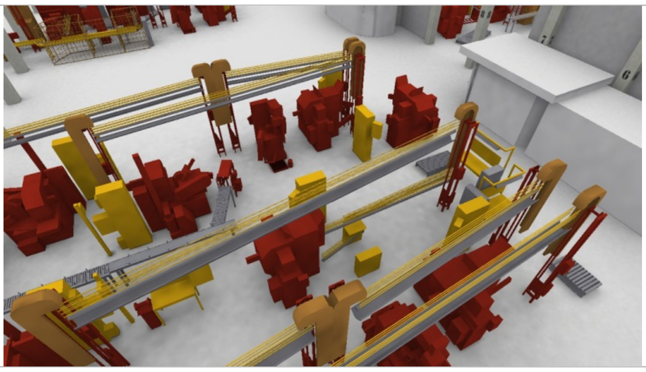
Framtagning av relationshandlingar och VR-modell över Nationalmuseum. Omgivning, fasader och interiört. Laserscanning och inmätning. Mycket höga krav på interiöra modellen. VR-modellen används för planering av Vernissagen

Statens Fastighetsverk, 2006-

Referens: Lisbeth Söderhäll

Kontakt WSP: Odd Tullberg, 031 7272612

SKF



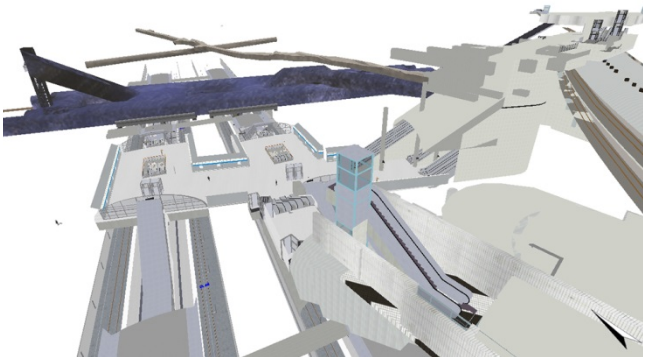
Layoutplanering i VR inför omfattande ombyggnad av fabrik för rullagerproduktion. SKF Open VR.

SKF Sverige AB 2006-

Referens: Jan Ek 031-337 17 26

Kontakt WSP: Monica Ek 031-727 28 28

Citybanan Open VR



Samgranskningsmodell i VR med anpassad funktionalitet. Citybanan under centrala Stockholm i samband med projektering av ny järnvägstunnel.

Almqvist och Ahlqvist Arkitekter, 2006-

Referens: Bengt Ahlqvist 0243-44 50 00

Kontakt WSP: Odd Tullberg 031-727 26 12

Roslagsbanan

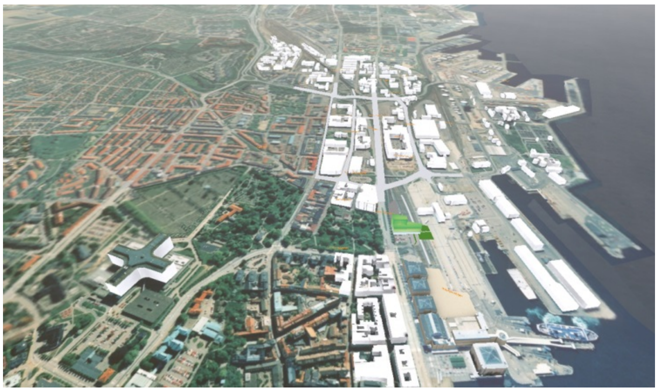
VR modell i samband med projekteringen av ny planfri korsning med järnvägsbro.

SL och Täby Kommun, 2006-

Referens: Lars Segerman

Kontakt WSP:Bertil Brodin, 08-688 66 57

Södertunneln



Visualisering av Knutpunkten och nya stationsområdet i Helsingborg med järnvägstunnlar. Hamnområde mm.

Helsingborgs stad projekt ”Järnvägstunnlar” 2006-

Referens: Bengt Lindskog

Kontakt WSP: Lars Halling 040-699 62 56

Gillbergavägen Eskilstuna

Visualisering av väg och järnväg i samband med projektering av planskild järnvägskorsning. VR-modellen användes internt samt som underlag för bilder till presentationsmaterial.

WSP 2006

Kontakt WSP: Monica Ek 031-727 28 28

E18 Sagån Enköping

VR-modell för bygghandling.

Vägverket i Mälardalen, 2006

Referens: P-O Borg

Kontakt WSP: K-G Lundström 054 - 13 21 29

Navet Kalmar

Visualisering av ny trafiklösning och nytt polishus i Kalmar.

Gatu- och parkkontoret i Kalmar 2006

Referens: Lars-Olof Olofsson

Kontakt WSP: Reino Erixon 036-30 43 20

Almedahls AB

Visualiseringsprojekt i samarbete med WSP Akustik och Almedahls inför Stockholm Furniture Fair där syftet var att illustrera med ljud och bild hur textil kan skapa en vacker miljö med god rumsakustik.

Almedahls AB 2005-2006

Referens: Johanna Lundgren 033-48 01 26

Kontakt WSP: Klas Hagberg 031-727 27 03

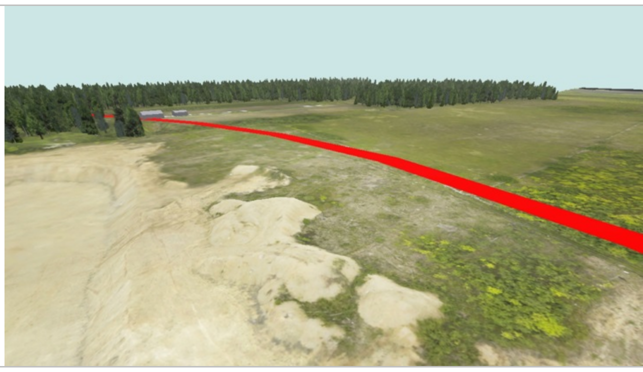
Sölvesborgsviken

Visualisering av alternativa vägskisser.

Sölvesborgs Kommun 2006

Referens: Vigert Göransson 0456-160 81

Kontakt WSP: Daniel Andersson 0455-447 97



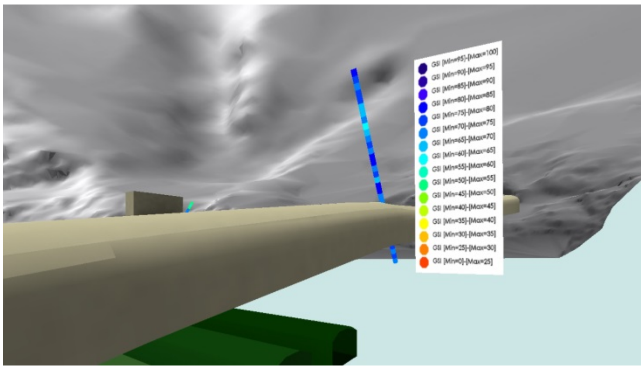
Henriksdal

Visualisering av geoteknik i samband med tillbyggnad av bergrum för reningsverk.

Stockholm Vatten 2006

Referens:

Kontakt WSP: Beatrice Lindström 08-688 64 36



Partihallsförbindelsen

VR-modell över omfattande trafikplats inklusive bro och tunnel i centrala Göteborg.

Vägverket 2004-2005

Referens: Bengt Johansson 0771-119 119

Kontakt WSP: Håkan Hakelöv 031-727 27 88

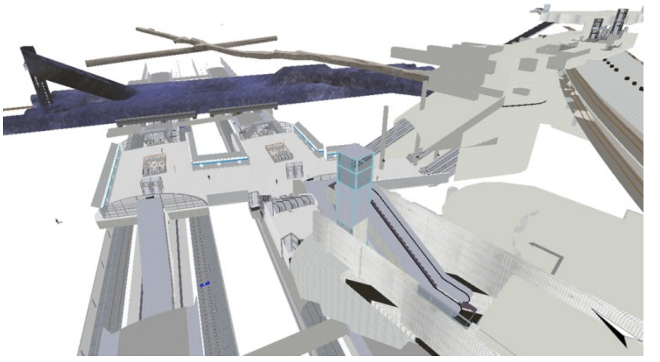
Citybanan

VR-modell över stor och komplex anläggning under centrala Stockholm i samband med projektering av ny järnvägstunnel. Berg- och geotekniskt fokus.

Banverket 2004-2005

Referens: Lennart Bergendahl 0243-44 50 00

Kontakt WSP: Odd Tullberg 031-727 26 12



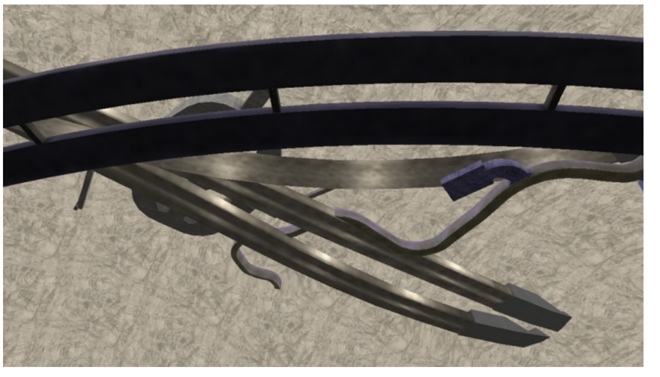
Västlänken

VR-modell över alternativa lösningar för ny järnvägstunnel under Göteborg. Inkluderar också resultat av geotekniska undersökningar såsom borrhål och seismik.

Banverket 2005

Referens: Per Lerjefors 0243-44 50 00

Kontakt WSP: Odd Tullberg 031-727 26 12



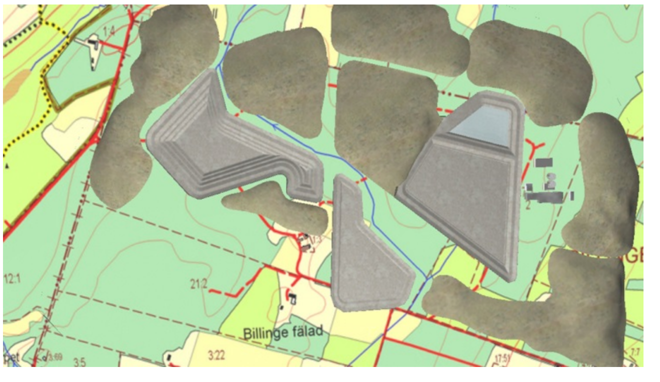
Kaolintäkt Billinge

Visualisering med VR-modell och animeringar som beskriver landskapspåverkan vid olika tidpunkter i samband med ansökan för ny kaolintäkt.

Prikon AB 2005

Referens: Olle Hedenström 043-577 95 60

Kontakt WSP: Monica Ek 031-727 28 28



Haningeleden

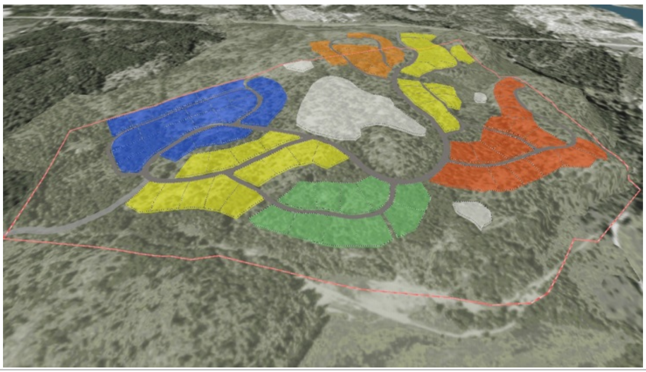
VR-modell över olika alternativa utformningar av trafikled söder om Linköping.

Linköpings Kommun 2005

Referens: Kjell Ivung 013-206724

Kontakt WSP: Jerker Hägglund 054-13 21 22

Lilla Åseröd



Visualisering av detaljplan för småhusexploateringsområde utanför Strömstad.

Veidekke Bostad AB 2005

Referens: Lars-Olof Rubin 046-19 94 00

Kontakt WSP: Monica Ek 031-727 28 28

Västra Hallerna II

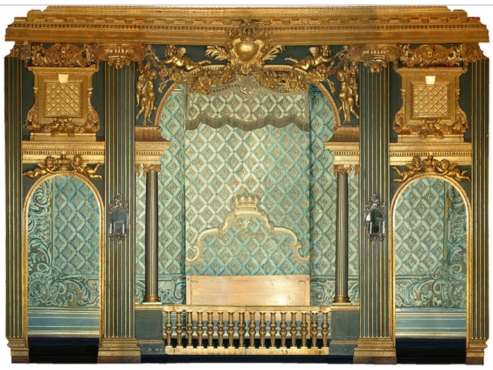
Visualisering av småhusexploateringsområde utanför Stenungsund med VR-modell som projekteringsverktyg.

HSB Boprojekt Väst AB 2005

Referens: Åke Nilsson 031-720 29 34

Kontakt WSP: Bo Näverbrant 031-727 27 86

Drottningholms slott



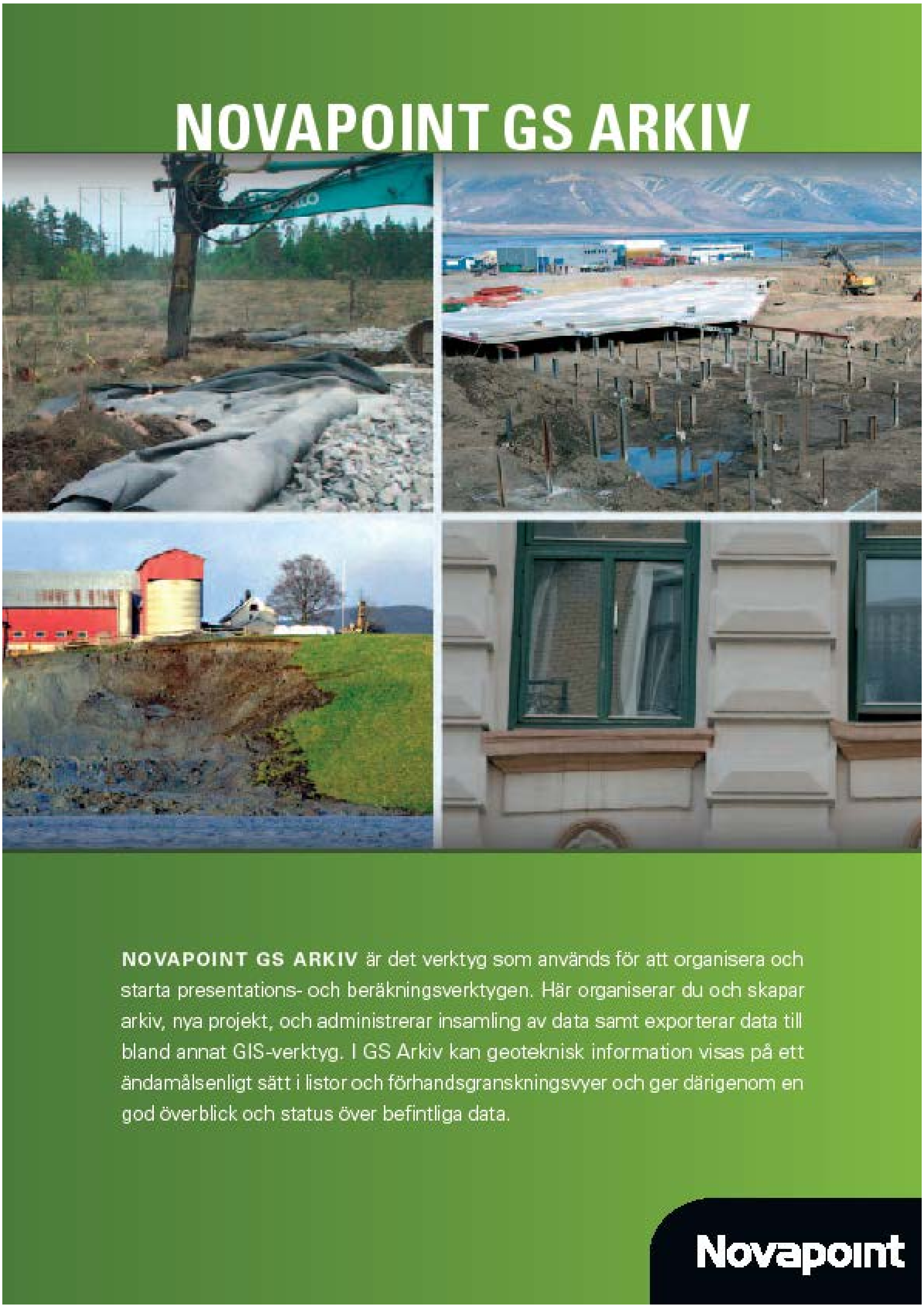
Dokumentation och visualisering med ortofoto av interiörer.

Fastighetsverket 2000-2004

Referens: Erland Montgomery, AIX Arkitekter 08-690 29 54

Kontakt WSP: Magnus Larson 031-727 26 91

Appendix 3 – NovaPoint GS Arkiv



- Project administration
- Import and export of data and projects
- Display project in Google Map
- Starting of calculation tools
- Preview of documents
- Overview

Project administration

GS Archive is the overall tool for creating new projects, organizing project structure and data, previewing existing data, creating new data by executing different tools for the actual need – slope stability calculation, acquiring soundings raw data format and presentation within national standards, designing sheet walls or pile groups or calculation of settlements due to impact of new structures.

Starting of calculation tools

All GS Toolbox products may be started from the toolbar or the menus.

All products within the Toolbox share a common data structure. The structure may to some extent be configured by defining additional user defined folders.

Import and export of data and projects

The Archive supports exporting data from soundings to external databases. Various database platforms are supported – Access, SQL Server, Oracle, etc. Exported data can be accessed for GIS purposes and other needs.

GS Archive supports drag and drop of projects from external sources. A project database from another company can easily be dropped into your own company's designed project structure.

Overview

By designing project archives in a structured way specific projects can easily be found. The projects can be sorted by project name, id or other specific data. An overall search function may be used to locate "missing" projects. Archives may also be reorganized.

Projects or parts of a project can be easily copied or moved between projects.

Documents within the project may be registered as valid document types. These documents are opened in the same manner as with the Windows Explorer.

Previewing AutoCAD dwg files makes it possible to examine the content of a specific drawing without starting AutoCAD.

Google Map

Projects according to EUREF or with known longitude / latitude are displayed in their extents in Google Map. Maps in Google Map may be displayed by project or by folder.

Appendix 4 – Novapoint GS Presentation

NOVAPOINT GS PRESENTATION

NOVAPOINT GS PRESENTATION är den centrala produkten i GS Toolbox. Mycket av arbetet i samband med geotekniska undersökningar ligger i insamlande av mätdata och sammanställning av jordegenskaper. Resultat av detta presenteras i standardiserade tabeller och diagram – enstaka borrhål, planer och profiler. GS Presentation innehåller rationella verktyg för administration och presentation av geodata.

Novapoint

Appendix 3. Novapoint GS Presentation

- Efficient drawing production
- Powerful maintenance of drawings
- Integration to Novapoint Road and Terrain model
- Surveying data stacks
- Edit of sounding data
- Import/Export facilities

Surveying of data stacks

GS Presentation interprets data from standard formats registered by drilling equipment. By converting the raw data into standard protocols, the initial raw data is always preserved.

Edit and verification of sounding data

By viewing the result from the soundings in protocol and graphics, complementary comments and interpretations may be added and quality check can be performed efficiently.

Efficient drawing production

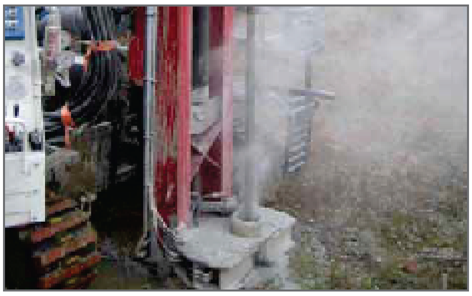
A central part of geotechnical design is to present results from field and laboratory tests in drawings. This is easily performed using built in tools. Complementary to ordinary plan views, cross sections and profiles, there are some specialized diagrams as groundwater variation diagrams, inclinometer diagrams, etc.

Maintenance of drawings

The ability to automatically update existing drawings with new data is very convenient. This reduces the need to generate new drawings whenever new data is added to the project – and it preserves previously performed editions of these drawings.

Import/Export facilities

Communication is a key word in modern design. GS Presentation has efficient tools for importing and exporting data. Not only national standard formats are supported (PXY in Sweden, KOF in Norway, etc.). A specialized communication protocol is also present towards other applications (Geoplot in Norway).



Integration

Even more important is the close integration to other domain users. As a member of the Novapoint family GS Presentation has a well-developed integration to Novapoint Road and Terrain model. By delivering interpreted soil data into the Qaudri database valuable information on road design and terrain data may be drawn directly on geotechnical drawings. Data from the presentation tool may also be used as input to the calculation tools within the Toolbox.

Appendix 5 – NovaPoint GS Sättning

NOVAPOINT GS SÄTTNING

NOVAPOINT GS SÄTTNING är ett användarvänligt beräkningsverktyg för att utföra beräkningar och känslighetsanalyser för framtida sättningar i jord på grund av ändringar i belastning och/eller porvattentryck. Olika icke-linjära jordmodeller kan användas, med möjlighet att ta hänsyn till krypeffekter. Indata och resultat visas och verifieras i tabellform och/eller grafiskt.

Novapoint

- Tabular and graphical presentation
- Automatic generation of stress distribution
- Easy to perform sensitivity analysis
- Non-linear soil models
- Possibility to vary loads
- Fast calculations

The user interface

The user interface is designed to be very easy to use. It consists of panes, representing logical steps within the calculation process – panes for project information, soil layering and properties, loads, pore pressure and control parameters. The results are presented in tabular and graphical views, and the results may be exported to other graphical presentation tools.

2D/3D calculations

Settlements are calculated by assuming uniaxial strain and vertical pore water flow (1D formulation). Settlements within a cross section or over a 3D area are performed by a set of 1D calculations. The 1D profiles may be copied and interpolated between existing profiles where the obtained soil layering and parameters may be revised before calculation.

Loads

Loads may be applied as a combination of uniformly and trapezoidal distributed loads over rectangular areas at defined depths. The stress distribution with depth is calculated either by Boussinesq equation for an infinite foundation or the simple 1:n method. The stress distribution may also be imported from an ASCII file generated by other methods. The loads may be permanent or varied with time. This gives for instance the opportunity to simulate the effect of surcharging.

Pore pressure

Time dependent steady-state pore pressure different from hydrostatic may be defined. This for instance may be used to account for 3D steady state flow fields and changes in ground water table with time. Time dependent excess pore pressure may also be defined. This can be used to include excess pore pressures that are not caused directly by excess vertical loads. Instead, the pore pressure may be shear induced or cyclical accumulated pore pressure or pore pressure from pile installation.

Soil model

GS Settlement supports various soil models – Janbu's model, Krykon and Chalmer's model. Krykon and Chalmer's model are taking creep effects into account, although the Chalmers model can also be used without if desired. In addition to these soil models there is a possibility for plugging in a self-programmed User model.

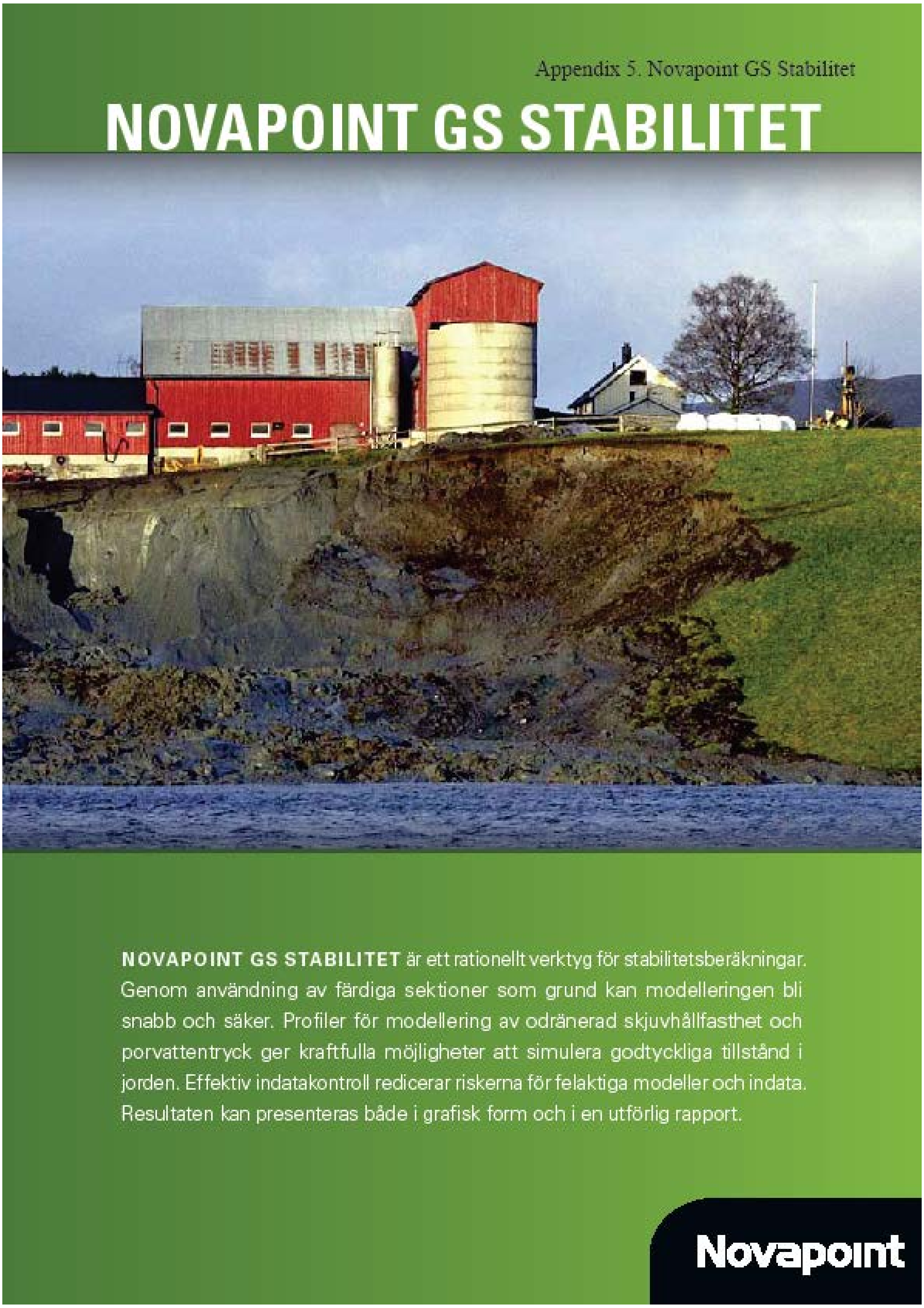
Results

The results: Displacements, strains, pore pressures and stresses are presented in graphical views. The results may also be tabulated and exported to other presentation tools. All crucial data for the calculation and the main results may be printed out as a report.

Sensitivity analysis

A sensitivity analysis is easy to perform by copying an existing calculation point and in the new calculation point changing for example a soil property or the pore pressure profile. The results for both calculation points can then be viewed in the same graphical view making a comparison of for example the displacement or the pore pressure possible.

Appendix 6 – NovaPoint GS Stabilitet



- Integration – cross sections
- Undrained shear strength profiles
- Lines for shear strength and pore water pressure
- Plain user interface
- Different calculation methods
- Soil nails

Powerful interface

By using cross sections with soundings as templates, the definition of the soil geometry is simple and fast. The soundings do not only give points in the soil where different soil layers are located. They also give input to the table of material properties for each soil layer. The user interface performs automatic control of the geometry – ensuring that the layers do not intersect.

Profiles

Profiles are a unique feature to represent the variation of undrained shear strength and pore water pressure in the soil layers. Any state of these properties can be simulated. The user gives the variation graphically by defining points in a section with a given parameter value. By plotting isolines for the resulting state gives good control of the achieved model. Profiles may be combined with other contributions like constant shear strength or hydrostatic pore water pressure from a defined ground water level.

Stabilizing structures

If needed stabilizing actions of the soil can be modelled. This can be achieved in three different ways using:

- Automatic procedure for calculation of needed height of banking.
- Simulation of lime cement blocks in the soil volume.
- Soil nails.

Solution methods

The solution methods within GS Stability are: Beast (two different models based on Morgenstern-Price) and Simplified and modified Bishop.
By using any Beast model the Swedish combined method may be used – easily selected by a checkbox. Within friction materials the drained shear strength may be modelled by giving a percentage of the undrained shear strength.

Presentation of results

The results from the analysis are presented, in addition to the critical shear surface, in a graphical diagram. The diagram shows the forces, moments and shear forces used within the solution for the critical shear surface. A complete documentation of input data and the results from the analysis, including graphics, may be printed out and saved as a calculation report.

Appendix 7 – NovaPoint Terräng

Appendix 6. Novapoint Terräng

NOVAPOINT TERRÄNG

NOVAPOINT TERRÄNG hjälper er att projektera mark och terräng – både i 2 och 3 dimensioner. Med de unika höjdsättningsfunktionerna skapar vi den nya marken – direkt i 3D! Detta hanterar vi vidare med hjälp av kraftfulla terrängverktyg med möjlighet att hantera volymer, markskikt och 3D-objekt.

Novapoint

- Dynamiska höjdsättningsfunktioner – i 3D!
- Terrängformer och 3D-objekt
- Volymberäkning mellan markmodeller
- Volymberäkning med rutnätsmodeller

Höjdsättning med Novapoint Terräng
Höjdsättningsfunktionerna i terrängsmodulen är fantastiskt enkla, men otroligt kraftfulla! Skapa den nya marköverytan med hjälp av punkthöjder som direkt hamnar korrekt i rymden – med synliga lutningar. Redigera, flytta, höj, sänk och ändra punkthöjderna – allt uppdateras direkt!

När vi är färdiga har vi höjdplanen och samtidigt 3D-data att använda i terrängmodellen. Ni tänker höjdsättning, verktyget räknar åt er! Dags att kasta linjalen och miniräknaren!

Projektera i 3D – arbeta i terräng
I terrängmodulen har vi en uppsättning verktyg som hjälper oss att nyttja terrängmodell för att skapa olika markformer, markobjekt och annan terräng. Vi arbetar med 3D-polylinjer och tar på allvar steget in i att projektera i 3D.

Volymberäkning
I arbetet med 3D-modeller har vi möjlighet att få fram volym mellan olika markmodeller och få den uppdelad i schakt/fyll-massor.

Vi kan dessutom arbeta med volymberäkning med hjälp av rutnätsmodeller. Här kan vi ange överbyggnadstjocklekar och låta de ingå i beräkningarna för schakt/fyll-volymerna. Detta kan sedan presenteras i planer och sektioner i rapporter.

Appendix 8 – InRoads - Product Data Sheet

PRODUCT DATA SHEET

InRoads® Suite

Proven Technology for Designing and Sustaining Transportation Infrastructure

Bentley's InRoads Suite gives engineers the flexibility to work the way they want with the power they need to complete their infrastructure projects. Running atop Bentley's flagship product, MicroStation®, InRoads Suite provides complete drafting capabilities, powerful mapping tools, and design automation for civil transportation professionals. InRoads Suite features constraint-driven, 3D parametric modeling with an innovative approach to designing civil components in a total-project context.

Provides divided highway design with independent horizontal and vertical control.

Includes excellent tools for commercial industrial land development as well as environmental remediation.

Civil Information Modeling

Today's engineers and designers face a paradigm shift. No longer are documents just for the current project or construction. An engineer must provide information and designs that can carry beyond construction into operations, maintenance, and rehabilitation – and back to design if necessary. InRoads Suite uniquely supports this evolution of civil engineering information, encompassing the entire civil project lifecycle. The information-rich modeling of InRoads Suite integrates with CAD, mapping, GIS, and even business tools like 3D PDFs, offering awesome power that makes the most of the engineer's acquired knowledge while supporting traditional, proven methodologies.

Design Sophistication

InRoads Suite is used for roads and highways, railways, and public works projects as well as commercial, industrial, and environmental land development. The software provides a greater level of design sophistication than standard tools through the application of design rules. Users are able to work in multiple views and dimensions. For roads and highways, Bentley's unique Roadway Designer provides an all-in-one visual tool for 3D parametric design of the complete road corridor. This and other fully developed capabilities produce impressive improvements in the areas of design productivity and project accuracy.

Project Versatility

Extremely versatile, InRoads Suite is used for all types and phases of civil projects, large and small, by users of every level of expertise. The software integrates all aspects of the civil project, from corridor studies to final design and production of construction deliverables. It handles a wide variety of complex tasks such as interchange design, roundabout design, survey data reduction, site development, sanitary and storm water network design, and production of construction staking reports.

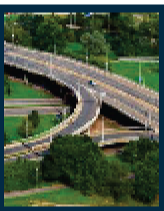
Flexible and Configurable

InRoads Suite and MicroStation deliver all the drafting and drawing production capabilities needed to complete your project. And the strengths of InRoads Suite are enhanced by Civil AccuDraw, the civil-specific version of MicroStation AccuDraw® – an intuitive, precision drafting tool that anticipates the user's intent, reducing the number of mouse clicks and other actions required to achieve drafting tasks. Civil AccuDraw streamlines the drafting process by supporting civil-specific drafting conventions with options for station and offsets, bearings and distances, azimuths, and more.

Because workflows can vary widely depending on the scope of the project, InRoads Suite offers users the flexibility to work in ways that best suit their specific needs. The software is fully configurable, enabling users to customize the InRoads Suite environment to meet project standards or personal preferences. Roadway libraries streamline repetitive tasks across projects and promote rapid evaluation of design alternatives for critical decision making. InRoads Suite automates the production of a complete array of design deliverables. Embedded project management capabilities help users stay on top of all project components and deliverables – capabilities that are tightly integrated with Bentley's ProjectWise® project collaboration system for connecting people and information across project teams.

Working With Field Data

A complete civil engineering solution, InRoads Suite offers a full complement of functionality that enables users to work automatically with survey, GPS, LiDAR, Point Cloud, and other forms of field data. The software supports the leading devices and formats, handling a broad array of existing topography information. Adjustments are calculated using any of the industry-standard methods. Users can modify and process the data as needed and when the design is complete, upload design data to data collectors for stakeout or automated machine guidance for site preparation.



InRoads features intelligent, intuitive 3D Civil Information Modeling for the full lifecycle of civil and transportation projects.

Integrated Mapping

InRoads Suite contains a comprehensive set of mapping and GIS data compilation and editing tools. These tools allow the engineer to combine engineering and GIS data for better decision processing in preliminary design, account for sensitive issues like wetland mitigation, and even publish maps for public approvals. The design process expands to enforce business and topological rules and adhere to administrative restrictions. By combining engineering and mapping tools, Bentley brings CAD and engineering design accuracy, ease-of-use, and efficiency to GIS. Overall, users make better-informed decisions through analysis, visualization, and presentation and better communicate through stunning maps and intelligent PDFs.

Feature-Based Surface Modeling

InRoads Suite enables users to create intelligent models containing not only terrain data but also roadway or site features. Features are visually distinguished by structure, appearance, and symbology. The software uses triangulated surfaces to represent terrain – for both existing ground and proposed design. Intelligent digital terrain modeling (DTM) lets users incorporate features such as roadway centerlines, pavement edges, or ditches in the surface model. These can be random features for non-uniformly occurring points or breaklines that represent features connected in linear segments – as in the case of ridges, edges of pavement, and curbs. Interior voids or holes represent building footprints, lakes, and so on. Exterior-boundary features can be placed around surface areas to maintain cut-and-fill lines in proposed designs. In addition, other topography features are represented in the 3D model, including utilities (both above and below ground), buildings/pads, or any topological data collected.

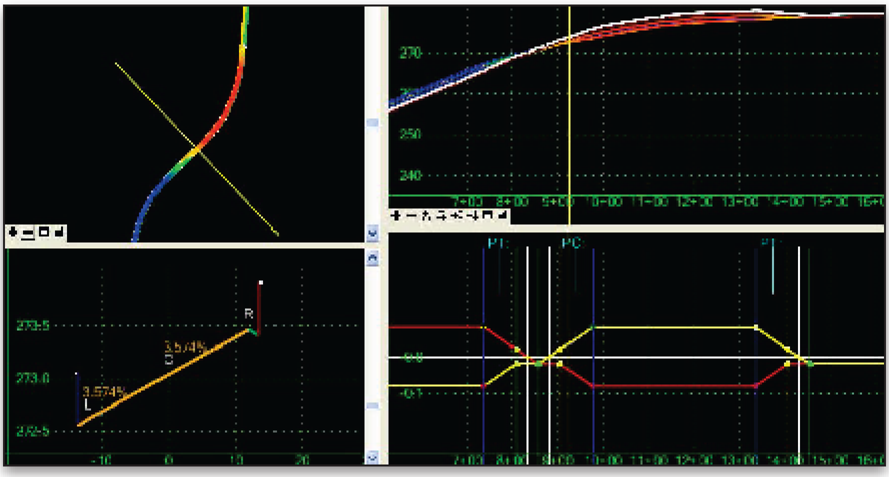
Flexible Geometry Creation

The full complement of coordinate geometry (COGO) and advanced alignment design capabilities of InRoads Suite enable fast creation of precision horizontal and vertical alignments as the three dimensional roadway is developed. Elevation profiles display surface information as well as vertical alignments associated with horizontal alignments. A combined, true 3D alignment constructed from the horizontal and vertical definitions can be displayed in the plan view. The software supports unrestricted viewing with unlimited geometry editing and manipulation either graphically or with precision key-in. A check integrity capability locates and allows removal of discontinuities and highlights other potential issues such as nontangential curves for resolution/correction.

In-Context Road Design

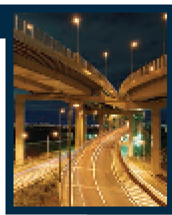
InRoads Suite offers in-context, smart design of 3D road corridors with Roadway Designer. This tool streamlines the complex development of every aspect of the roadway in a single, parametric presentation. Users can move rapidly along a corridor at controlled intervals, viewing and dynamically designing all roadway components in concert. The software automatically computes dynamic volumes to balance cut and fill.

Roadway Designer displays four-port views of the design – plan, profile, cross section, and superelevation. Users see immediate visual feedback in all views as the work progresses. The roadway is easily modified by direct manipulation of parametric graphical components or by precision input in context-sensitive dialog boxes. Roadway Designer's unique capabilities enable users to target known existing features. This allows the model to conform to on-ground demands. Color coding shows potential problem areas as the design develops. Users can test design decisions in Roadway Designer before applying them.



Design interactively in plan, profile, cross section, and superelevation using Roadway Designer.

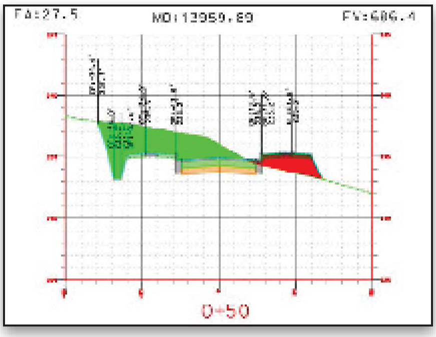
Roadway Designer's interactive, 3D modeling capabilities combine parametric, constraint-driven tools with engineering theorem, keeping engineers in total control over all software decisions.



Roadway Designer offers state-of-the-art design automation. From horizontal alignment, vertical alignment, and surface information, the software generates 3D models of the full corridor using predefined typical sections. The software automatically ensures conformance to standards as it speeds the corridor development process. When widening roads, Roadway Designer automatically creates transitions in numbers and widths of lanes in accordance with user design criteria. Users can interactively edit superelevation on the fly. End conditions can be computed at any point in the process.

Users can easily modify and create design-intelligent components – without programming – and apply design constraints that offer sleek control of the 3D parametric modeling process. Components can be open or closed shapes and include curb and gutter sections, sidewalks, asphalt layers, aggregate layers, medians, barriers, slopes, and ditches. Roadway Designer automatically creates surfaces for use in creating cross sections, performing volume calculations, and aiding visualization and rendering. Users can also merge components to create a single design surface or create a model of the entire corridor.

Designed with InRoads, this project by Creighton Manning Engineers features intelligent 3D modeling, machine controlled grading and stakeless construction and inspection.



Use end-area volume calculations to allow for compaction factors, removal of undesirable material, and correction for curvature.

Visual Design Verification

Design verification has never been easier. InRoads Suite allows users to virtually drive through the 3D corridor model and visually inspect it for any design deficiencies or physical conflicts. In 3D QA, engineers can fully view road features from all angles to identify gaps or misalignments, look for utility conflicts, and check clearances. They can also visually evaluate sight distance, pavement marking, and signing as well as try out multiple aesthetic treatments to reach the desired result. Using InRoads Suite with MicroStation's rendering features – for example, color fill, shading, lighting, and backgrounds – improves the design at any phase and adds a level of assurance in project constructability.

Comprehensive Results Evaluation

InRoads Suite provides flexible creation of cross sections from any baseline. Custom cross sections can be cut at skewed angles or broken-back sections, singly or in multiple groupings. The software automatically annotates each cross section as determined by the user or standard. A full array of civil components can be included in the cross section, including surface features, storm and sanitary structures, roadway components, and notations such as limits or stationing.

Users can choose from a variety of volume calculations that greatly enhance accuracy over traditional methods. Sophisticated end-area volume calculations let users determine the level of accuracy based on the frequency that cross sections are cut. Using this method, InRoads Suite also recognizes components in the cross section and accurately computes component volumes. The software offers the flexibility to process volumes based on straight-line or curved alignments. Calculation methods include Triangle Volume from Surfaces, Hybrid Triangle Volume by Station and Volumes by Grid Approximations. InRoads Suite handles multiple surface types – existing, designed, and substratum – and can ignore or void surfaces for calculation.

Site Design

For site design, InRoads Suite includes Bentley's dynamic Site Modeler, enabling engineers and designers to interactively create and manipulate models relative to one another. The dynamic setting allows users to move, rotate, and edit individual models and see the impact to adjacent models or to the entire project model. Additional site design tools are tailored to the specific requirements of site engineers, offering interactive site feature modeling within the intelligent terrain model. This allows users to manage every aspect of the land development process. The software accounts for lots, parcels, boundaries, property takes, right-of-ways, and other aspects of land ownership. It automates

System Requirements

Processors:
Intel Pentium-based or AMD Athlon-based PC or workstation

Operating Systems:
Microsoft Windows 7, Windows 7 x64, Windows Vista, Windows Vista x64, Windows XP Professional (SP3 or later)

Memory:
1 GB minimum, 2 GB recommended, (more memory typically results in better performance)

Disk Space:
405 MB minimum free disk space

Input Device(s):
Mouse or digitizing tablet (Digitizing tablet requires vendor-supplied WINTAB driver or Bentley's Digitizer Tablet Interface, the latter included with InRoads Suite installation.)

Find out about Bentley at www.bentley.com

Contact Bentley
1-800-BENTLEY (1-800-236-8539)
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Global Office Listings
www.bentley.com/contact

design for a full range of site features – including ponds, drainage ditches, building pads, and cul-de-sacs. Sophisticated surface-to-surface analysis helps users accurately balance earthworks and pinpoint best case construction scenarios.

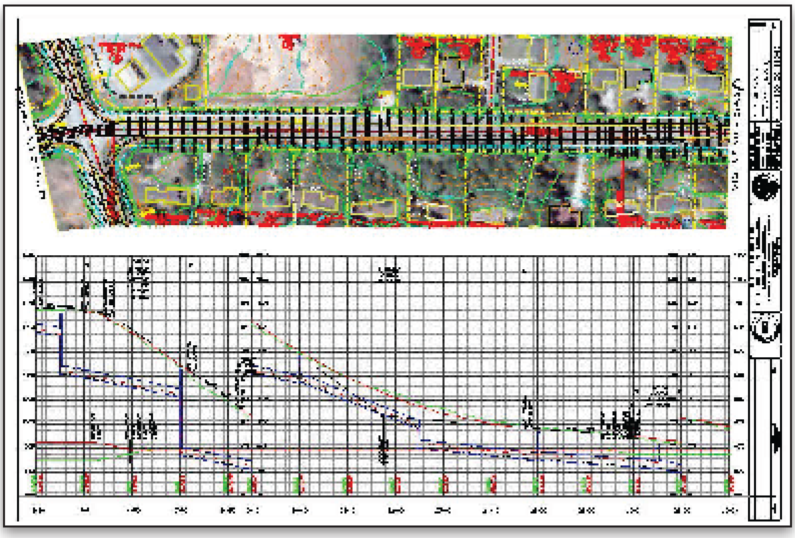
Storm and Sanitary Network Design

A comprehensive application for surface and wastewater collection systems rounds out InRoads Suite. InRoads Suite provides the ability to interactively create a 3D associative model relative to the existing and design ground models as well as road and site geometry. Users can manipulate networks in plan or profile views, displaying not only the InRoads Suite drainage model but also other utilities modeled in InRoads Suite. This allows users to plan for clash avoidance and identify potential problem areas before they occur. Users can model, analyze, and design complete storm water and sanitary sewer networks, replete with inlets, culverts, channels, catch basins, manholes, pumps, and pipes.

A robust set of computation tools account for the full array of surface runoff conditions and perform design checks to ensure conformance with minimum and maximum requirements. Industry-standard hydraulic methods are used to analyze and design the systems. Rational, Modified Rational, and Soil Conservation Service unit hydrograph modeling and pond-routing routines calculate hydrologic impacts for pond sizing and out-flow characteristics. Users can create the full set of hydrographs, drawings, and reports.

Project Deliverables

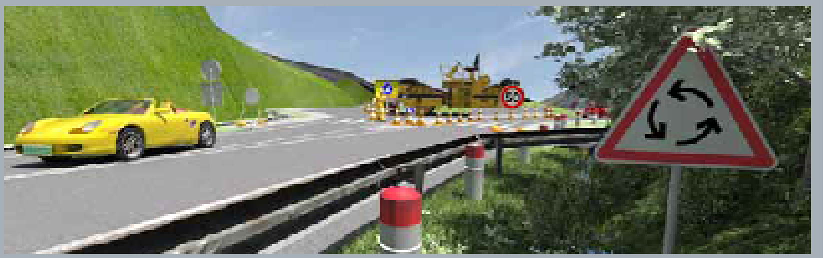
InRoads Suite provides design, volume, and cross section data in XML industry-standard format for data exchange. Project data can be used in multiple formats, including Excel spreadsheets, HTML or text files, PDFs, printable documents, and other output. Reporting tools automate the production of a variety of standard reports, including horizontal and vertical alignments, quantity takeoffs, clearance reports, stakeout, legal descriptions, surfaces, and more. InRoads Suite provides full support to create legal descriptions. The software outputs standard formats for Trimble, TOPCON, and Leica for machine-controlled grading and machine guidance.



Produce a full array of contract deliverables.

Appendix 9 – PowerCivil for Sweden - Product Data Sheet

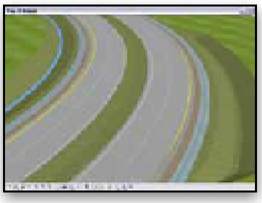
PRODUKTDATABLAD



PowerCivil for Sweden

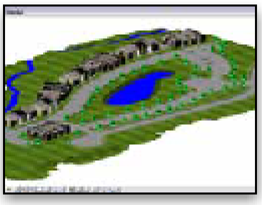
Beprövad teknik för att utforma och upprätthålla infrastruktur

Bentleys PowerCivil for Sweden ger ingenjörer flexibiliteten att arbeta på det sätt de vill och med den kraft de behöver för att slutföra sina anläggningsprojekt. Det erbjuder fullständiga skissmöjligheter, kraftfulla karthanteringsverktyg och automatiserad design för projektering. PowerCivil for Sweden tillhandahåller beroendestyrd, 3D-parametrisk modellering med ett innovativt synsätt på utformning av infrastrukturobjekt i hela projektet.



Erbjuder delad motorvägsutformning med av varandra oberoende horisontell och vertikal kontroll.

Möjliggör enkel och komplex bromodellering integrerat med vägprojektering



Inkluderar utmärkta verktyg för kommersiell markutveckling samt miljöreparation.

Anläggningsinformationsmodellering

Dagens ingenjörer och konstruktörer står inför ett paradigmskifte. Dokument används inte längre bara för aktuellt projekt eller konstruktion. En ingenjör måste erbjuda information och design som sträcker sig bortom konstruktion fram till drift, underhåll och restaurering – och tillbaka till design om så krävs. PowerCivil for Sweden stöder på ett unikt sätt denna utveckling av information om anläggningen vilken omfattar hela infrastrukturprojektets livscykel. PowerCivil for Sweden informationsrika modellering integreras med CAD, kartering, GIS och till och med affärsverktyg som 3D PDF:er. Den erbjuder också stor styrka som kan dra nytta av det mesta av ingenjörens förvärvade kunskap samtidigt som den stöder traditionella beprövade metoder.

Sofistikerad design

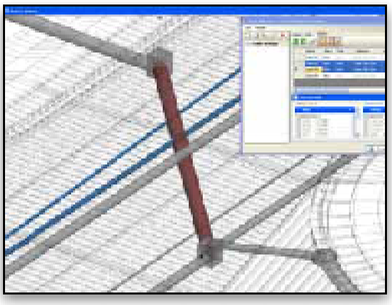
PowerCivil for Sweden används för vägar, motorvägar, järnvägar och offentliga projekt lika väl som för kommersiell, industriell och miljömässig markprojektering. Programmet erbjuder en högre nivå av sofistikerad design än standardverktyg genom att designregler används. Användare kan arbeta i flera vyer och dimensioner. För vägar och motorvägar erbjuder Bentleys unika Roadway Designer ett visuellt verktyg med allt-i-ett för parametrisk 3D-design av hela vägkorridoren. Denna och andra helt utvecklade möjligheter skapar imponerande förbättringar inom områdena för designproduktivitet och exakthet i projekten.

Mångsidighet för projekt

PowerCivil for Sweden är extremt mångsidigt och används för alla typer och faser av anläggningsprojekt, stora och små, av användare på alla kompetensnivåer. Programmet integrerar alla aspekter av anläggningsprojektet, från korridorstudier till den slutliga utformningen och produktionen av konstruktionsunderlag. Det hanterar ett stort antal komplexa uppgifter, t.ex. vägkorsningar, på- och avfarter, utformning av rondeller, hantering av inmätt data, design av dagvatten och avlopp samt produktion av rapporter om utsättning.

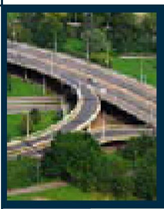
Flexibelt och konfigurerbart

PowerCivil for Sweden inkluderar alla möjligheter för produktion av skisser och ritningar i MicroStation® i ett enda program. Styrkan hos PowerCivil for Sweden förstärks av Civil AccuDraw, den för anläggningskonstruktion specialanpassade versionen av MicroStation AccuDraw® – ett intuitivt verktyg för precisionsskissning vilket ger en förhandsvisning av användarens intentioner samt minskar antalet musklickningar och andra åtgärder som krävs för att utföra skissuppgifter. Civil AccuDraw förenklar skissningsprocessen genom att stödja specifikt anläggningsanpassade skisskonventioner med alternativ för stationer och offset, vinklar och avstånd, asimut med mera.



Möjliggör automatisk kollisionskontroll och integration med Bentley Navigator.

Eftersom arbetsflöden kan variera mycket beroende på projektets mål, erbjuder PowerCivil for Sweden användare flexibiliteten att arbeta på de sätt som bäst passar deras specifika behov. Programmet är helt konfigurerbart vilket gör det möjligt för användare att anpassa användarmiljön i PowerCivil for Sweden så att den uppfyller projektstandarder eller personliga önskemål. Bibliotek för motorvägar förenklar utförandet av uppgifter som upprepas genom projektet och stärker snabb utveckling av designalternativ för viktigt beslutsfattande. PowerCivil for Sweden automatiserar produktionen av en fullständig uppsättning av konstruktionsunderlag. Integrerade möjligheter till projektledning hjälper användare att styra alla projektkomponenter och produktionsdokument – dessa möjligheter är nära integrerade med Bentleys projektsamarbetssystem ProjectWise för att koppla samman människor och information i projektgrupper.



PowerCivil för Sweden innehåller funktioner för intelligent, intuitiv modellering i 3D av information för hela livscykeln för mark- och vägprojekt.

Fullständig skissning, visualisering och publicering

PowerCivil for Sweden innehåller alla kraftfulla möjligheter för att skapa, redigera, visa, visualisera och publicera med MicroStation, Bentleys flaggskeppsprodukt i ett enda kraftfullt program för anläggningsprojektering. Vare sig du placerar enkel CAD-grafik, annoteringar eller detaljplaner för konstruktionsunderlag eller erbjuder en promenad genom en renderad designmodell kommer PowerCivil for Sweden att göra jobbet. Programmet stöder över 50 rasterformat, inklusive många format med georeferenser, vilket hjälper ingenjörer och konstruktörer att skapa konstruktioner och att lösa ingenjörsutmaningar. Eftersom inget projekt är fullständigt förrän resultaten har publicerats, inkluderar PowerCivil for Sweden möjligheter till utskrift och plottning på kända enheter, ange utskriftsvariabler för storlek, skala och symboler samt publicering till Adobe PDF – inklusive 3D PDF.

Arbeta med fältdata

I en lösning med allt-i-ett erbjuder PowerCivil for Sweden en fullständig uppsättning funktioner som gör det möjligt för användare att arbeta automatiskt med inmätningar, GPS, LiDAR och andra former av fältdata. Programmet stöder ledande enheter och format och hanterar ett stort spektrum av befintlig topografisk information. Justeringar beräknas med hjälp av någon av de metoder som är branschstandard. Användare kan ändra och bearbeta data efter behov och när konstruktionen är fullständig, överföra konstruktionsdata till datainsamlare för utsättning eller automatiserad maskinstyrning för markpreparering.

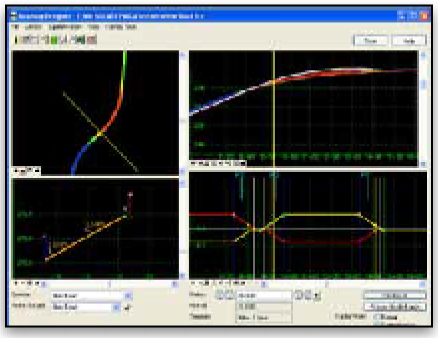
Integrerad kartering

PowerCivil for Sweden innehåller en omfattande uppsättning verktyg för kartering samt för kompilering och redigering av GIS-data. Med dessa verktyg kan ingenjören kombinera konstruktion och GIS-data och uppnå bättre beslutshantering i förstudiefasen, redovisa känsliga frågor som minskning av våtmarker och till och med publicera kartor för godkännande från allmänheten. Designprocessen utökas för att ta med branschregler och topologiska regler samt göra anpassningar till administrativa begränsningar. Genom att kombinera konstruktions- och karteringsverktyg tar Bentley med exaktheten hos CAD och konstruktionsdesign och effektivitet till GIS. Sammanfattningen är att användare tar beslut som är bättre underbyggda genom analys samt kan presentera och på ett bättre sätt kommunicera genom utökta kartor och intelligenta PDF-filer.

Egenskapsbaserad ytmodellering

PowerCivil for Sweden gör det möjligt för användare att skapa intelligenta modeller som inte bara innehåller terrängdata utan också väg- och markegenskaper. Funktionerna är visuellt urskiljbara genom struktur, utseende och symboler. Programmet använder triangulerade ytor för att representera terrängen – både den befintliga och den föreslagna konstruktionen. Med intelligent digital terrängmodellering (DTM) kan användare införliva egenskaper så som vägmittlinjer, trottoarkanter och diken i ytmodellen.

Dessa kan vara blandade egenskaper för punkter som inte är enhetliga eller brytlinjer som representerar egenskaper anslutna i linjära segment – så som är fallet vid kanter med nivåskillnader, trottoarkanter och kurvor. Inre tomrum eller hål representerar en byggnads bottenyta, sjöar och så vidare. Egenskaper för externa begränsningslinjer kan placeras runt ytområden för att begränsa linjer för schakt och fyllning till den föreslagna konstruktionen. Dessutom representeras andra typografifunktioner i 3D-modellen, rör för olika media (både under och över marken), byggnader/grunder eller andra topologiska data som har samlats in.



Konstruera interaktivt i plan, profil, tvärsnitt och skevning med hjälp av Roadway Designer.

Skapa flexibel geometri

Den fullständiga uppsättningen med koordinatgeometri (COGO) och möjligheterna till avancerad linjeföringskonstruktion i PowerCivil for Sweden gör det möjligt att snabbt skapa precisionsjusteringar horisontellt och vertikalt när tredimensionella vägar skapas. Elevationsprofiler visar ytinformation lika väl som vertikal linjeföring associerad med horisontell linjeföring. En kombinerad verklig 3D-linjeföring som har konstruerats från horisontella och vertikala definitioner kan visas i planvyn. Programmet stöder obegränsad visning med obegränsad redigering av geometri och manipulering antingen grafiskt eller med precisionsinmatning. En möjlighet till integritetskontroll hittar och medger borttagning av osammanhängande linjer samt markerar andra möjliga problem såsom kurvor som inte hänger ihop för upplösning/korrigering.

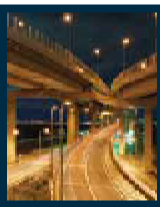
Sammanhängande vägkonstruktion

PowerCivil for Sweden tillhandahåller sammanhängande konstruktion av vägkorridorer i 3D med Roadway Designer. Detta verktyg förenklar den komplexa utvecklingen av alla aspekter av vägen i en enda parametrisk presentation. Användare kan röra sig snabbt längs en korridor, med kontrollerade intervaller samt visa och dynamiskt utforma alla vägkomponenter i ett sammanhang. Programmet beräknar automatiskt dynamiska volymer för att balansera schakt och fyllning.

Roadway Designer visar fyra olika vyer av konstruktionen – plan, profil, tvärsnitt och skevning. Användare får omedelbar visuell feedback i alla vyer varefter arbetet framskrider. Vägen kan enkelt ändras genom direkt manipulering av parametriska grafiska komponenter eller genom precisionsinmatning i sammanhangsberoende dialoger. Med de unika möjligheterna i Roadway Designer kan användare arbeta med just de egenskaper som går att redigera för det valda objektet. Detta gör att modellen överensstämmer med markkraven.

Färgkodning visar potentiella problemområden varefter modellen av vägen utvecklas. Användare kan testa konstruktionsbeslut i Roadway Designer innan de används. Roadway Designer erbjuder den bästa automatiseringen av konstruktionen. Från horisontell linjeföring, vertikal linjeföring och ytinformation genererar programmet 3D-modeller av hela korridoren med hjälp av fördefinierade typsektioner. Programmet ser automatiskt till att överensstämmelse finns med standarder varefter utvecklingsprocessen av korridoren framskrider. När vägar breddas skapar Roadway Designer automatiskt

Roadway Designers interaktiva möjligheter till 3D-modellering kombinerar parametriska, begränsningsstyrda verktyg med konstruktionsteorem vilket ger ingenjörer total kontroll över alla programbeslut.



övergångar för antal filer och bredder på filer i enlighet med användarens konstruktionskriterier.

Användare kan interaktivt och snabbt redigera skevning. Slutförhållanden kan beräknas när som helst under processen. Användare kan enkelt ändra och skapa konstruktionsintelligenta komponenter – utan programmering – och använda konstruktionsbegränsningar som erbjuder smidig kontroll av modelleringsprocessen med 3D-parametrar. Komponenter kan vara öppna eller stängda former och inkluderar sektioner med kurvor och avlopp, trottoarer, asfaltskikt, sammanslagna skikt, refuger, barriärer, slänter och diken. Roadway Designer skapar automatiskt ytor som kan användas i tvärsnitt för att utföra volymberäkningar och till hjälp för visualisering och rendering. Användare kan också sammanfoga komponenter och skapa en enda konstruktionsyta eller skapa en modell av hela korridoren.

Visuell verifiering av konstruktion

Verifiering av konstruktioner har aldrig varit enklare. PowerCivil for Sweden medger för användare att virtuellt köra genom 3D-korridormodellen och visuellt inspektera den för att hitta eventuella fel eller fysiska konflikter. I 3D QA kan ingenjörer fullständigt visa vägegenskaper från alla vinklar för att hitta gap och linjeföringsfel, leta efter konflikter med rör och kontrollera marginaler för frigång. De kan också visuellt utvärdera avstånd för sikt, markering av trottoarer och skyltning samt prova olika estetiska utformningar för att nå önskade resultat. Med hjälp av renderingsfunktioner i PowerCivil for Sweden – t.ex. färgfyllning, skuggning, belysning och bakgrunder – kan konstruktionen förbättras i vilken fas som helst och detta lägger till en säkerhetsnivå när det gäller projektets genomförande.

Omfattande utvärdering av resultat

PowerCivil for Sweden erbjuder ett flexibelt skapande av tvärsektioner från vilken baslinje som helst. Egna tvärsektioner kan skäras ut med sneda vinklar eller "broken-back" sektioner, enstaka eller i grupperingar. Programmet annoterar automatiskt varje tvärsektion som det bestämts av användaren eller som standard. En fullständig uppsättning med anläggningskomponenter kan inkluderas i tvärsnittet, inklusive ytfunktioner, funktioner för dagvatten och avloppsvatten, vägkomponenter och annoteringar, t.ex. gränser eller stationer.

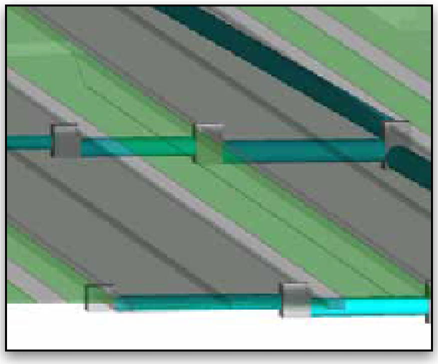
Detta projekt som har utformats med hjälp av PowerCivil for Sweden av Creighton Manning Engineers innehåller intelligenta funktioner för 3D-modellering, maskinkontrollerad gradering och utsättningsfri konstruktion och inspektion.

Användare kan välja mellan många volymberäkningar som i stor utsträckning förbättrar korrektheten jämfört med traditionella metoder. Sofistikerade beräkningar av slutlig volym gör det möjligt för användare att bestämma nivån av korrekthet baserat på den frekvens med vilken tvärsektioner är uttagna. Om du använder den här metoden känner PowerCivil for Sweden också igen komponenter i tvärsektionen och beräknar komponentvolymer korrekt. Programmet erbjuder flexibiliteten att bearbeta volymer baserat på raka linjer eller bågformade linjeföringar.

Beräkningsmetoderna inkluderar triangelvolymer från ytor, hybridtriangelvolymer via station och volymer via gridapproximering. Roadway Designers interaktiva möjligheter till 3D-modellering kombinerar parametriska, begränsningsstyrda verktyg med konstruktionsteorem vilket ger ingenjörer total kontroll över alla programbeslut. PowerCivil for Sweden hanterar flera yttyper – befintliga, utformade och underliggande – och kan ignorera eller undvika ytor för beräkningar.

Markkonstruktion

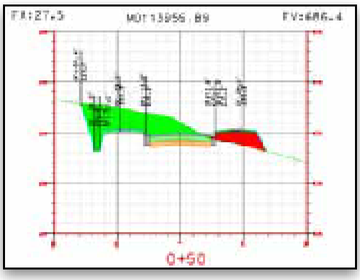
För anläggningsdesign inkluderar Bentleys program PowerCivil for Sweden en dynamisk markmodellerare som gör det möjligt för ingenjörer och konstruktörer att interaktivt skapa och manipulera modeller i relation till varandra. Med de dynamiska inställningarna kan användare flytta, rotera och redigera enstaka modeller och se påverkan på intilliggande modeller eller hela projektmodellen. Ytterligare verktyg för anläggningskonstruktion är skräddarsydda för de specifika behoven hos markanläggningsingenjörer och erbjuder interaktiv modellering av markegenskaper inom den intelligenta terrängmodellen. Detta gör det möjligt för användare att hantera alla aspekter av markprojekteringsprocessen. Programmet kan användas för jordlotter, tomter, gränser, egendomar, servitut och andra aspekter av ägande av mark. Det automatiserar konstruktion av ett stort antal anläggningsegenskaper – inklusive dammar, avrinningsdiken, byggnaders bottenyta, parkeringar och vändplatser. Sofistikerad analys av yta-till-yta hjälper användare att balansera markarbeten korrekt och hitta det bästa alternativet för konstruktionsscenarier.



Rör dig dynamiskt längs 3D-korridoren för verifiering av designen, visuell kollisionskontroll och kvalitetssäkring av modelleringen.

Design av dagvatten- och avloppsnätverk

PowerCivil for Sweden är ett omfattande program för system för insamling av ytvatten och avloppsvatten. PowerCivil for Sweden erbjuder möjligheten att interaktivt skapa en associativ modell i 3D vilken är relativ till befintliga modeller och konstruerade modeller lika väl som väg- och markgeometri. Användare kan ändra nätverk i planer eller profilvyer och inte bara visa avrinningsmodeller i PowerCivil for Sweden utan även andra funktioner som har modellerats i PowerCivil for Sweden.



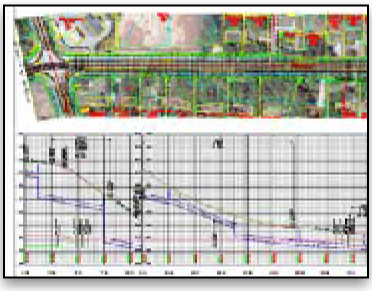
Använd beräkningar av slutgiltiga volymer för att tillåta jämförelsefaktorer, borttagning av oönskat material och korrigering av kurvor

Detta gör det möjligt för användare att planera så att inga krockar ska uppstå och att identifiera potentiella problemområden innan de uppstår. Användare kan modellera, analysera och utforma fullständiga nätverk för dagvattenledningar och avloppsledningar, komplett med brunnar, kulvertar, kanaler, insamlingsbassänger, inspektionsbrunnar, pumpar och rör. En robust uppsättning med beräkningsverktyg kan användas för en fullständig uppsättning med villkor för avrinningsytor samt utföra kontroller för att säkerställa konformitet med minimi- och maximikrav. Hydrauliska metoder som är branschstandard kan användas för att analysera och utforma system. Hydrografisk modellering med metoderna Rational, Modified Rational och Soil Conservation Service och riktning vid dammar beräknar hydrologisk påverkan på dammstorlek och egenskaper för utflödet. Användare kan skapa en fullständig uppsättning hydrografer, ritningar och rapporter.

Konstruktionsunderlag

PowerCivil for Sweden levererar data för konstruktion, volym och tvärsektioner i branschens XML-standardformat för datautbyte. Konstruktionsdata kan användas i flera format, inklusive Excel-dataark, HTML- eller textfiler, PDF-filer, dokument för utskrift och annan utdata. Rapporteringsverktyg automatiserar produktionen av ett antal standardrapporter, inklusive horisontell och vertikal linjeföring, volymberäkningar, rapporter över kollisionskontroll, utsättning, juridiska beskrivningar, ytor med mera. PowerCivil for Sweden erbjuder ett fullständigt stöd för att skapa juridiska beskrivningar. Programmet levererar i standardformaten för Trimble, TOPCON och Leica för maskinkontrollerad gradering och maskinhjälp.

Utforma avrinnings- och avloppssystem integrerat med väg- och markutformning.



Producera ett fullt utbud av konstruktionsunderlag.

Systemkrav

Processorer:
Intel Pentium-baserad eller AMD-Athlon-baserad PC eller arbetsstation

Operativsystem:
Microsoft Windows 7, Windows 7 x64, Windows Vista, Windows Vista x64, Windows XP Professional (SP3 eller senare)

Minne:
1 GB minne (minst), 2 GB rekommenderas, (mer minne ger normalt bättre prestanda)

Hårddiskutrymme:
1,25 GB minimum ledigt diskutrymme Indataenhet(er): Mus eller digitaliseringsbord (digitaliserings bord kräver leverantörsstödd WINTAB-drivrutin eller Bentleys digitaliserings bordsgränssnitt. Det senare är inkluderat med PowerCivil for Sweden-installationen)

Mer information om Bentley: www.bentley.com/sv-SE

Kontakta Bentley
1-800-BENTLEY (1-800-236-8539)
Outside the US +1 610-458-5000

Bentley Systems Sweden AB
Gamla Brogatan 26
111 20 Stockholm

Södra Gubberogatan 20, 2tr
416 63 Göteborg

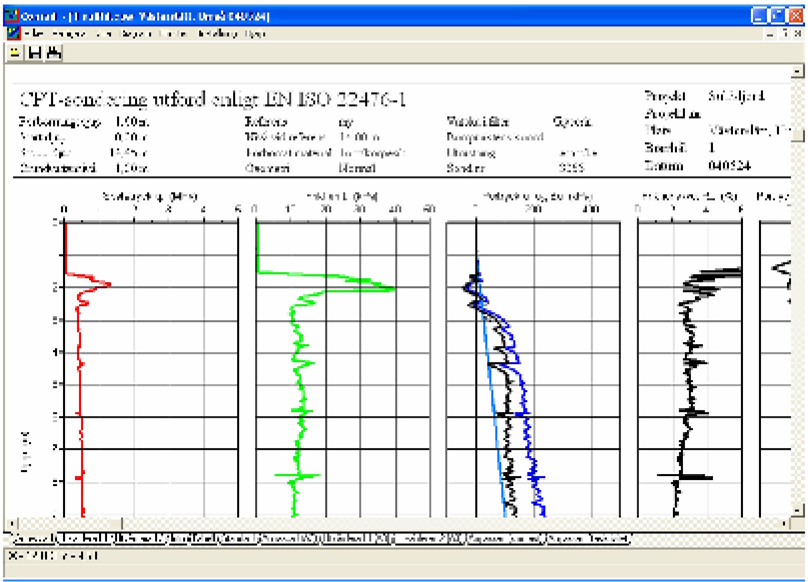
Kontor runt om i världen:
www.bentley.com/contact

Appendix 10 – Conrad - Product Data Sheet

Geotekniskt datorprogram

Conrad 3.1

Redovisning och utvärdering av CPT-undersökningar



CONRAD är ett datorprogram för redovisning och utvärdering av CPT-undersökningar. Programmet är utvecklat vid SGI.

CONRAD är ett datorprogram för redovisning och utvärdering av CPT-undersökningar. Ett program för geotekniker, utvecklat av geotekniker.

CPT-sondering används numera i stor omfattning vid geotekniska utredningar. Metoden ger bättre information om jordförhållanden jämfört med undersökningar med andra sonderingsmetoder.

En CPT-sondering genererar en stor mängd mätdata som överförs till CONRAD. Värden på jordparametrar beräknas med empiriska ekvationer, där CPT-resultaten utgör ingångsvärden. Redovisning och utvärdering underlättas av detta användarvänliga datorprogram, utvecklat vid SGI.

CONRAD är baserat på de principer som beskrivs i SGI Information 15, revision 2007.

Fördelar med Conrad

- Generellt - tillämpbart för alla CPT-utrustningar
- Lättanvänt - menystyrt med enkla och lättöverskådliga rutiner.
- Anpassat till de senaste standarderna och utvärderingsmetoderna.

Faciliteter

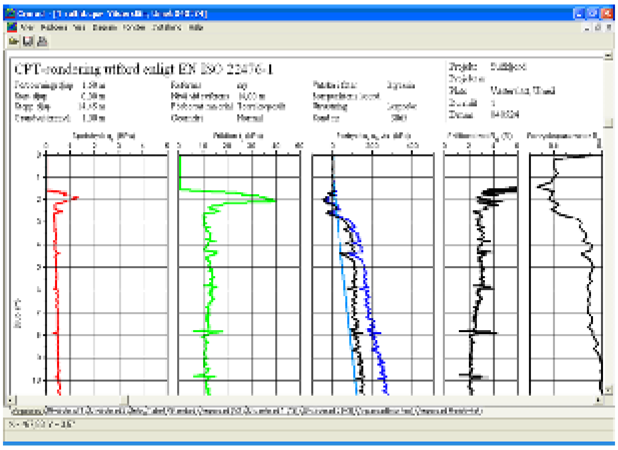
Nya funktioner i CONRAD 3.1 är:

- Möjlighet att utvärdera sulfidjord och lermorän.
- Fler exportfunktioner av data, bla export till Autograf.
- Möjlighet att lägga till egen utvärderingsmetod.
- Enklare inmatning av försöksuppgifter.
- Möjlighet att välja svensk- eller engelsk version.
- Bättre möjligheter att anpassa skalor.
- Redovisning anpassad till ny europeisk standard.
- Programmet finns numera också i nätverksversion.

Statens geotekniska institut
581 93 Linköping
Besöksadress:
Olaus Magnus väg 35
Telefon: 013–20 18 00
Telefax: 013–20 19 14
E-post: info@swedgeo.se
Internet: www.swedgeo.se

2011-02

CONRAD är ett verktyg för geoteknikern att sammanställa parametrar inför det analysarbete som ingår i den geotekniska utredningen. CONRAD är utformat så att utvärderaren själv väljer ut och redigerar de parametrar som ska användas.



Redovisning av mätdata

CONRAD hämtar data direkt från olika typer av datafiler, t ex Geotech CPT-log, import från Autograf eller från fältminnet. Steg 1 redovisar i diagramform de uppmätta parametrarna

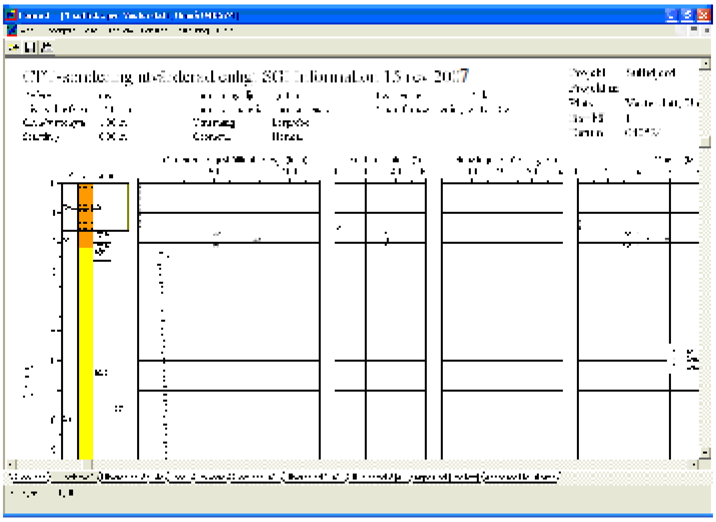
- spetsmotstånd q_t
- mantelfriktion f_t
- genererat portryck u, Δu and u_0
- friktionskvot R_f
- portrycksparameter B_q

Utvärdering av parametrar

Indata till CONRAD 3.1 är fältdata från CPT-sonderingen, grundvatten- och/eller portrycksmätningar och laboratorieundersökningar. Beräkning och presentation baseras på utvärderarens styrning och urval. Även här görs presentationerna i diagramform. Ju mer information som finns tillgänglig, desto bättre blir utvärderingen.

Steg 2 ger uppskattning och/eller beräkning samt redovisning av

- jordlager; jordart, fasthet, konsolideringsgrad
- odränerad skjuvhållfasthet (i lera) c_u
- friktionsvinkel (i friktionsmaterial) ϕ'
- lagringstäthet (- " -) I_D
- modul (- " -) M, E
- effektivtryck σ'_{v0}
- förkonsolideringstryck (i lera) σ'_c

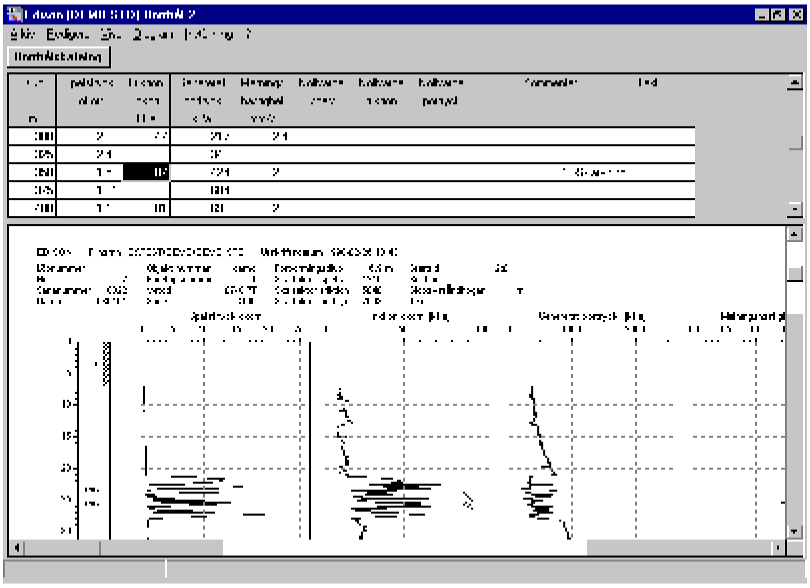


Appendix 11 – Edison - Product Data Sheet

Datorprogram för geotekniska fältundersökningar

Edison

Granska, redigera och kvalitetssäkra fältdata



Vad är Edison?

Edison är ett datorprogram som utvecklats vid SGI och som fyller ett tomrum mellan utförandet i fält och uppritningen på kontoret, genom att på ett rationellt sätt kunna granska, redigera och kvalitetssäkra borresultat redan i fält. Edison kan också med fördel användas på kontoret för att få en snabb överblick och uppritning av utförda borrningar.

Programmet kan läsa in filer som skapats i geoprinter eller geologger (filer lagrade i SGF-format). Filerna kan presenteras på datorns skärm både i grafisk och alfanumerisk form. Det går att redigera t ex felaktiga värden eller kommentarkoder och lagra resultatet i en ny fil.

I Edison finns också en lista på aktuella metodkoder, kommentarkoder samt parameterkoder. Här finns möjligheter att införa egna koder av olika slag, t ex för företagsspecifika metoder.

Edison redovisar alla uppmätta parametrar, d v s inte enbart de som ingår i den geotekniska redovisningen, utan också parametrar som kan ge en kvalitativ uppfattning om undersökningen, t ex matningshastighet vid olika typer av sondering.

Varför Edison?

- Uppritning av geotekniska fältundersökningar utförs idag nästan alltid med hjälp av datorer. Efter redigering i fält med Edison är filen klar för kontoret.

Statens geotekniska institut
581 93 Linköping
Beöksadress:
Olaus Magnus väg 35
Telefon: 013–20 18 00
Telefax: 013–20 19 14
E-post: info@swedgeo.se
Internet: www.swedgeo.se

- Den geotekniska omloppstiden minskar, t ex tiden mellan borrningar och geoteknisk rapport eller utlåtande. Detta tillsammans med kostnadspress gör att man fort vill se resultatet av det geotekniska arbetet. Med Edison är det möjligt att snabbt besluta om olika åtgärder.

Målgrupper

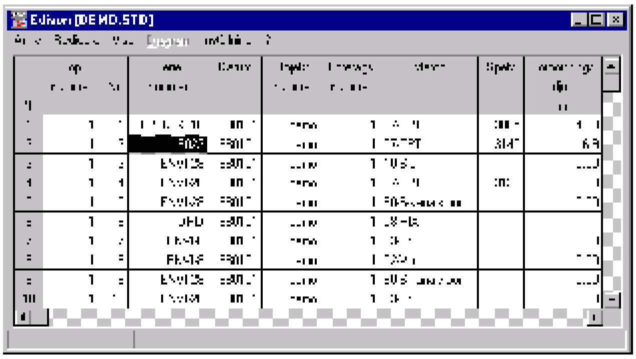
Målgrupper för Edison är fältingenjörer, borrningsledare och andra som hanterar geoteknisk fältdata.

Systemkrav

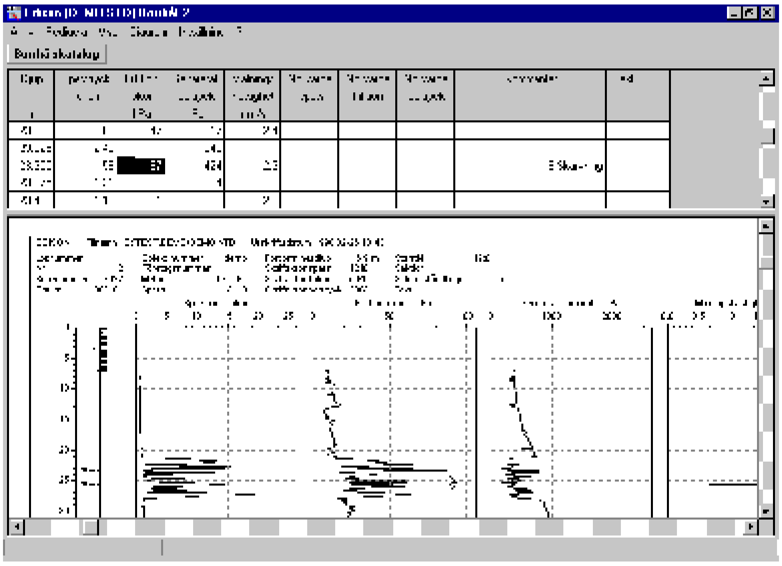
För att använda Edison behövs följande datorsystem

- Microsoft Windows 3.1x, 95, 98, NT eller 2000
- Minst 8MB internminne
- Minst 1 MB ledigt diskutrymme

Pris:	4.900 kr, exkl moms. Rabatt vid flera licenser.
Kontaktperson:	Hans Jonsson tel: 013–20 18 36 e-post: hans.jonsson@swedgeo.se



Borrhålskatalogen listar alla borrhål. Genom att dubbelklicka på ett borrhål visas borrhålet i både alfanumerisk och grafisk form.



Programmet i editeringsläge. Överst syns innehållet i filen i alfanumerisk form och under i grafisk form. Genom att peka på en punkt i den grafiska delen (se muspekaren) så markeras den ruta där parametervärdet finns.

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