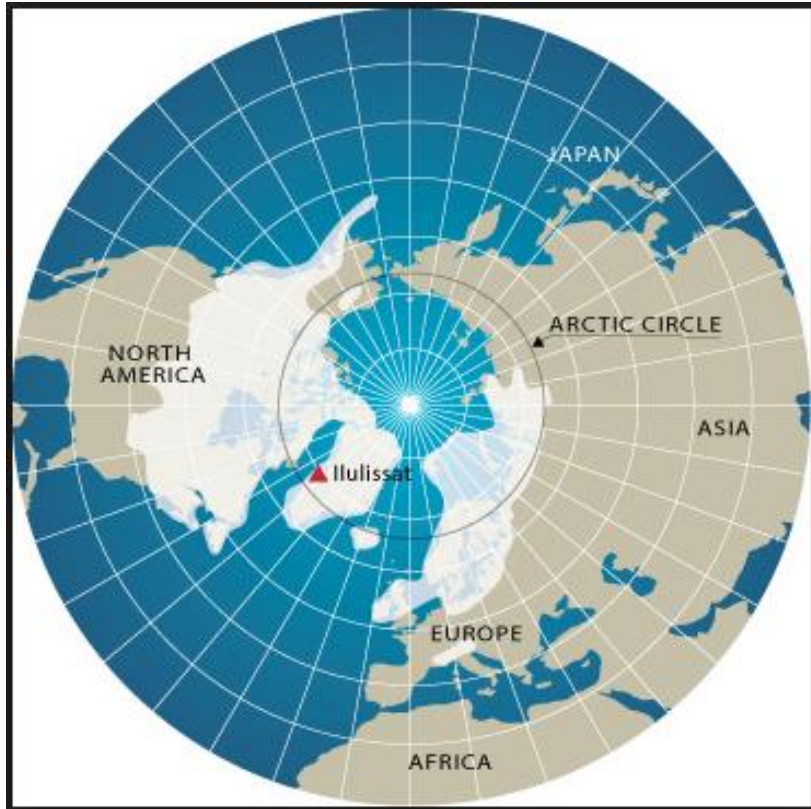


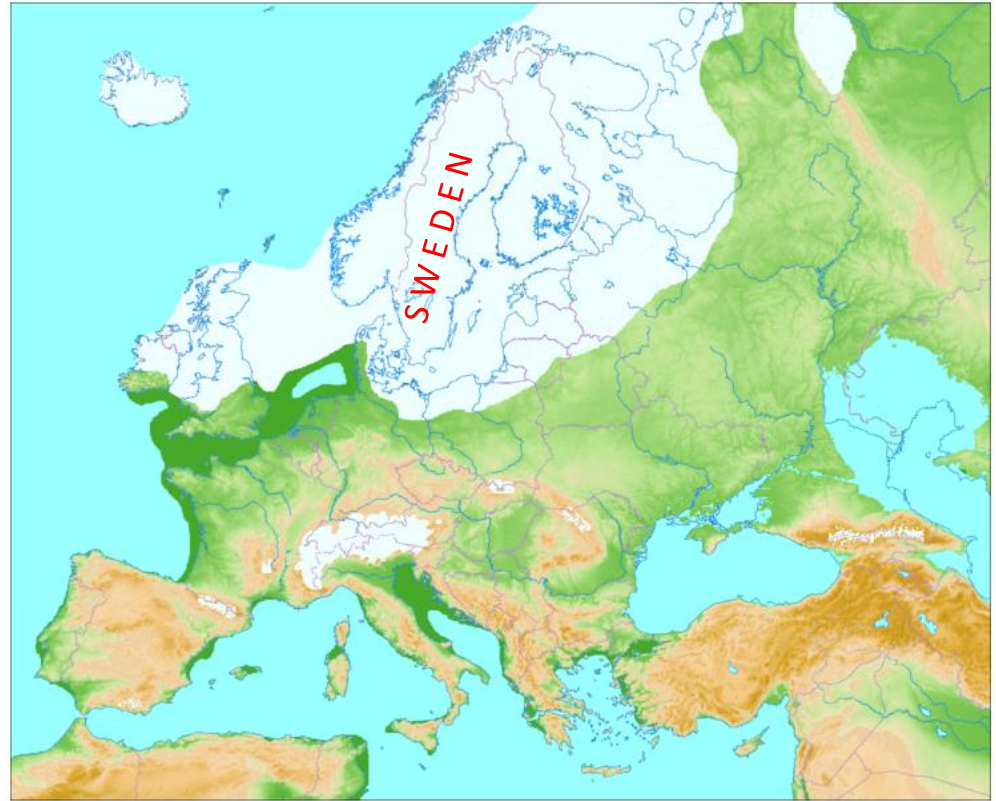
# GeoCost - assessment of groundworks and foundation reinforcement costs for buildings



# Sweden, covered by ice ~20.000 years ago...



[http://www.geus.dk/viden\\_om/voii/ilulissat-uk/voii03-uk.html](http://www.geus.dk/viden_om/voii/ilulissat-uk/voii03-uk.html)

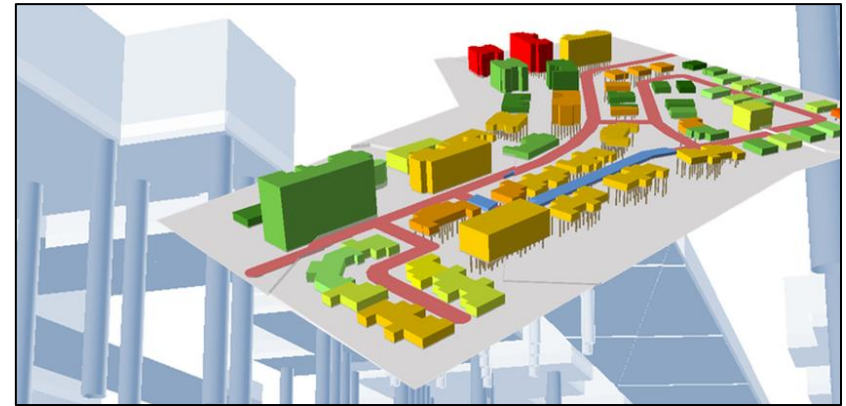


<https://commons.wikimedia.org/wiki/File:Weichsel-W%C3%BCrm-Glaciation.png#/media/File:Weichsel-W%C3%BCrm-Glaciation.png>

This has shaped soil formation of Scandinavia, Canada etc -  
important for foundation reinforcement methods

# What is GeoCost?

- An ArcGIS-based tool (Models) for estimating foundation reinforcement costs in municipal development (and infrastructure\*)
- GIS + Geotechnical engineer
- Large savings can be made by placing constructions in areas with the most favorable geotechnical conditions.
- Quickly calculates (alternative) costs for cut/fill, foundation reinforcement etc. Detailed elevation and soil data is used.
- Financed by the Swedish Government



<http://www.swedgeo.se/geokalkyl/>

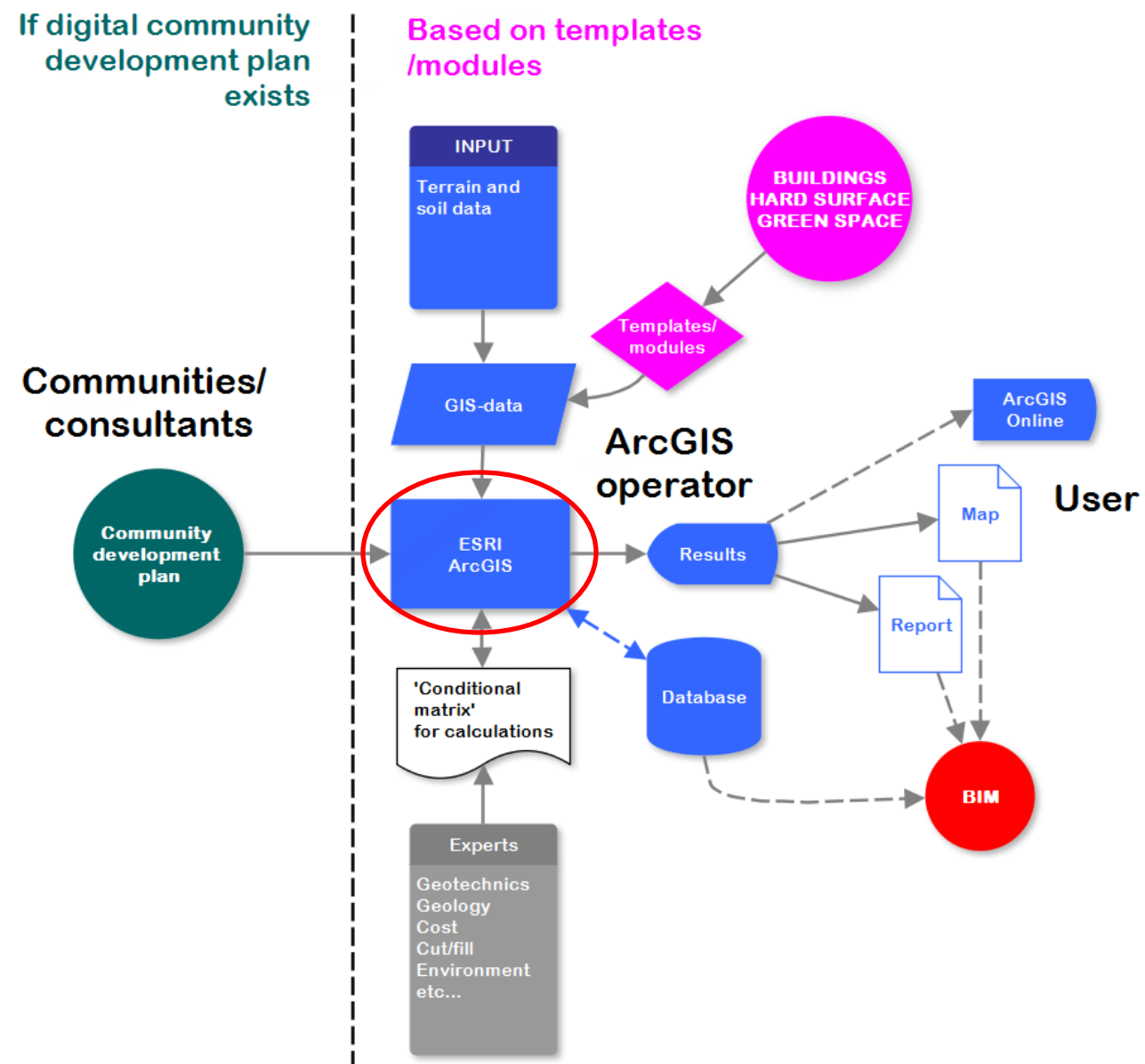
\*) Also used by Swedish Transport Administration

# Illustration of foundation reinforcement cost per m<sup>2</sup> and suggested reinforcement method

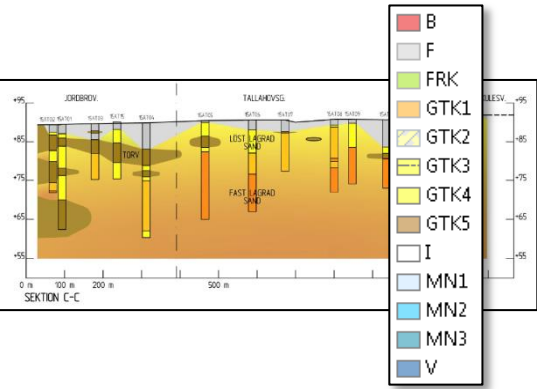
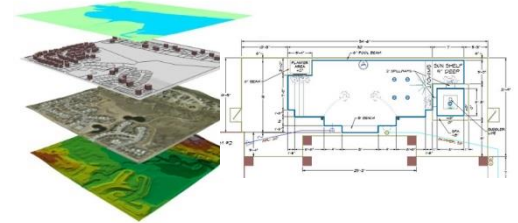


Also summaries of TOTAL cost and TOTAL cut/fill volumes

# System workflow



- Skills requirements:
- ArcGIS operator
  - Geotechnical engineer
- Software requirements:
- ArcGIS Desktop 10.2+
  - 3D-analyst
  - Microsoft Excel 2010+



Vilkorsbilaga 1 (GTK1, SIH)

Byggnad: Tältet grundtryck för byggnadsbeteendegrupp = 150 kPa

Byggnadsdel	X	Belastning (kPa)								
		1	2	3	4	5	6	7	8	9
101-001	1	1	1	1	1	1	1	1	1	1
101-002	2	1	1	1	1	1	1	1	1	1
101-003	3	1	1	1	1	1	1	1	1	1
101-004	4	1	1	1	1	1	1	1	1	1
101-005	5	1	1	1	1	1	1	1	1	1
101-006	6	1	1	1	1	1	1	1	1	1
101-007	7	1	1	1	1	1	1	1	1	1
101-008	8	1	1	1	1	1	1	1	1	1
101-009	9	1	1	1	1	1	1	1	1	1
101-010	10	1	1	1	1	1	1	1	1	1
101-011	11	1	1	1	1	1	1	1	1	1
101-012	12	1	1	1	1	1	1	1	1	1
101-013	13	1	1	1	1	1	1	1	1	1
101-014	14	1	1	1	1	1	1	1	1	1
101-015	15	1	1	1	1	1	1	1	1	1
101-016	16	1	1	1	1	1	1	1	1	1
101-017	17	1	1	1	1	1	1	1	1	1
101-018	18	1	1	1	1	1	1	1	1	1
101-019	19	1	1	1	1	1	1	1	1	1
101-020	20	1	1	1	1	1	1	1	1	1
101-021	21	1	1	1	1	1	1	1	1	1
101-022	22	1	1	1	1	1	1	1	1	1
101-023	23	1	1	1	1	1	1	1	1	1
101-024	24	1	1	1	1	1	1	1	1	1
101-025	25	1	1	1	1	1	1	1	1	1
101-026	26	1	1	1	1	1	1	1	1	1
101-027	27	1	1	1	1	1	1	1	1	1
101-028	28	1	1	1	1	1	1	1	1	1
101-029	29	1	1	1	1	1	1	1	1	1
101-030	30	1	1	1	1	1	1	1	1	1
101-031	31	1	1	1	1	1	1	1	1	1
101-032	32	1	1	1	1	1	1	1	1	1
101-033	33	1	1	1	1	1	1	1	1	1
101-034	34	1	1	1	1	1	1	1	1	1
101-035	35	1	1	1	1	1	1	1	1	1
101-036	36	1	1	1	1	1	1	1	1	1
101-037	37	1	1	1	1	1	1	1	1	1
101-038	38	1	1	1	1	1	1	1	1	1
101-039	39	1	1	1	1	1	1	1	1	1
101-040	40	1	1	1	1	1	1	1	1	1

**Prepare input data**

- 1) Buildings (incl. height etc), 2) Hard surfaces (road etc), 3) Green space (vegetation)
- Terrain data (e.g. 2m raster); Soil geology

**Calculate foundation depth & cut/fill volumes**

Based on "Geotechnical Terrain Class" classification (soil profile down to bedrock)



**Calculate foundation reinforcement methods (piles etc)**

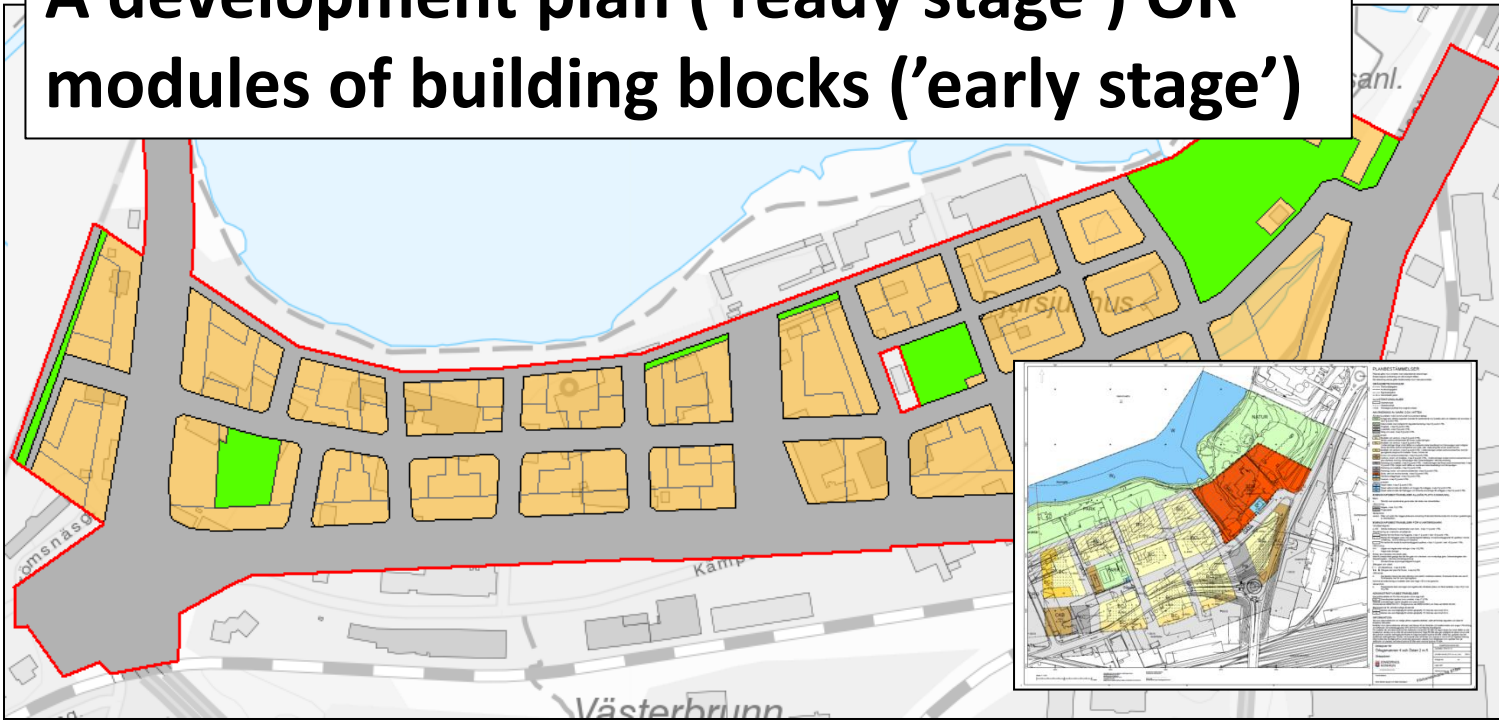
Based on Excel 'conditional matrix' created by geotechnical engineering practise (reinforcement metod etc, distance between piles etc), calculated using a series of ArcGIS Models

**Calculate costs/ generate 3D scene**

Based on Excel 'condition matrix', calculated using a series of ArcGIS Models

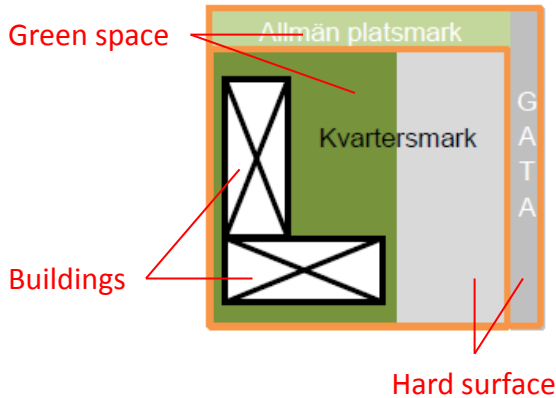


# A development plan ('ready stage') OR modules of building blocks ('early stage')

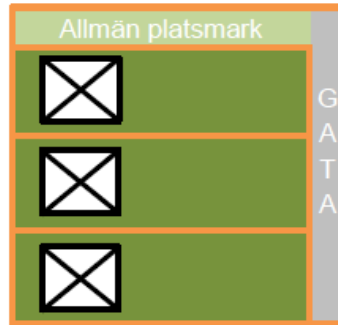


- HEIGHT/LEVEL ZONES
  - BUILDINGS
  - HARD SURFACE
  - GREEN SPACE
  - SOIL MAP
  - DTM/TERRAIN DATA
- Value  
High : 64,27  
Low : -0,74

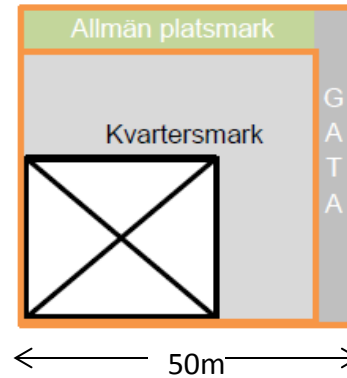
**Type 1**



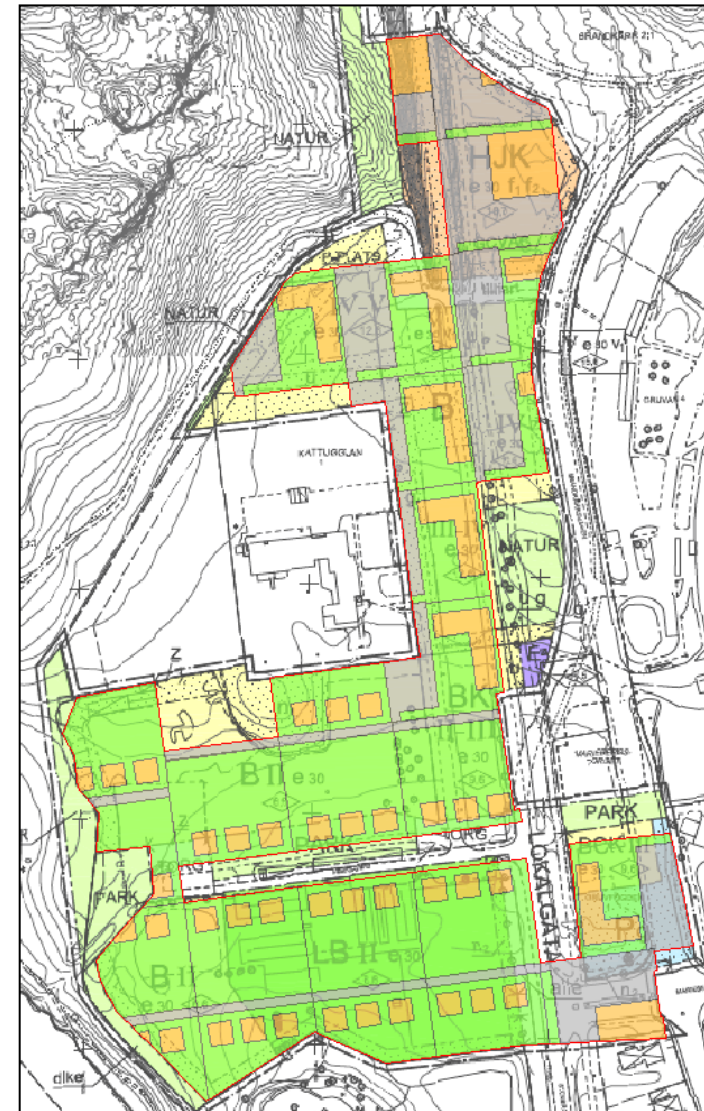
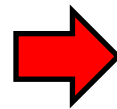
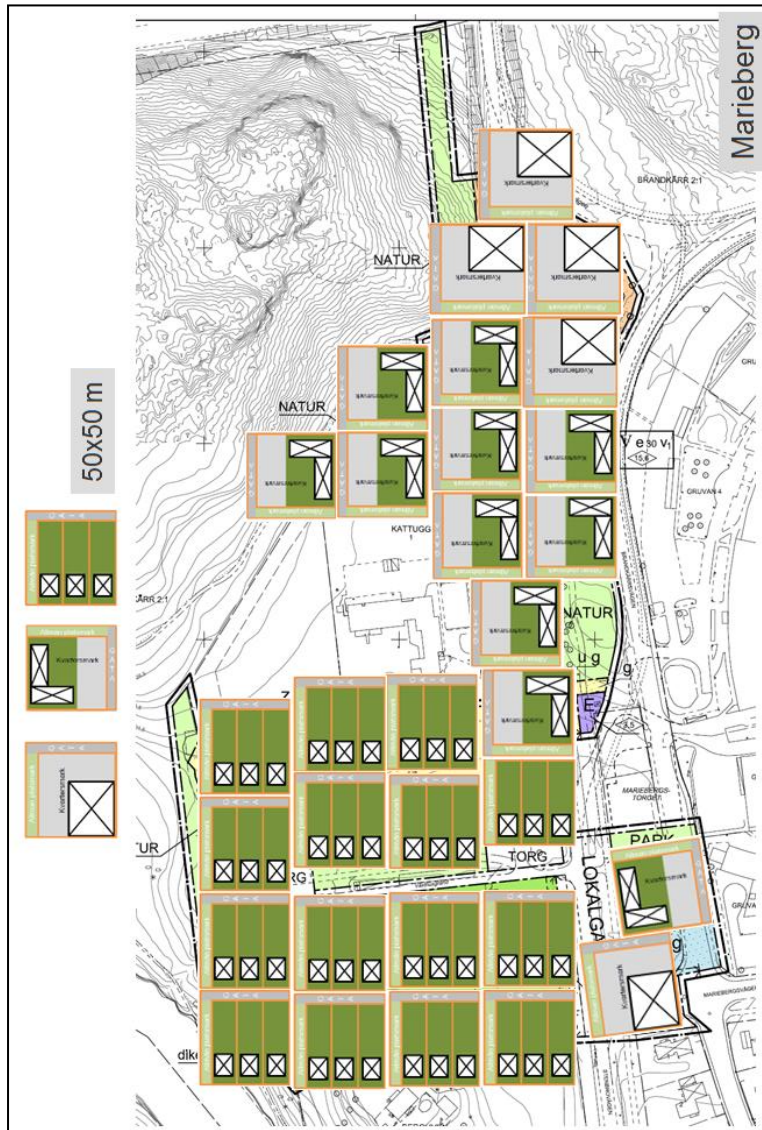
**Type 2**



**Type 3**



# Example of placement of modules and making consistent GIS-surfaces



- BUILDINGS\_3D
- HARD SURFACE\_3D
- GREEN SPACE\_3D

\*) consistent = adjacent, non-overlapping buildings; hard surfaces; green space



# Suggested reinforcement method



- Step 2 - REINFORCEMENT METOD
  - BUILDINGS
    - Reinforcement method
    - No action
    - Piling
    - Dig out/refill
  - HARD SURFACE
    - Reinforcement method
    - No action
    - Pre-load
    - KC Pile
    - Pile
    - Dig out/refill
  - GREEN SPACE
    -

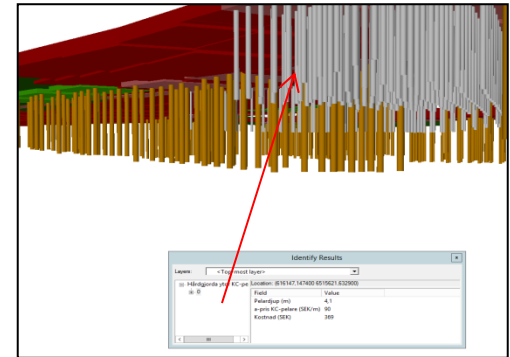
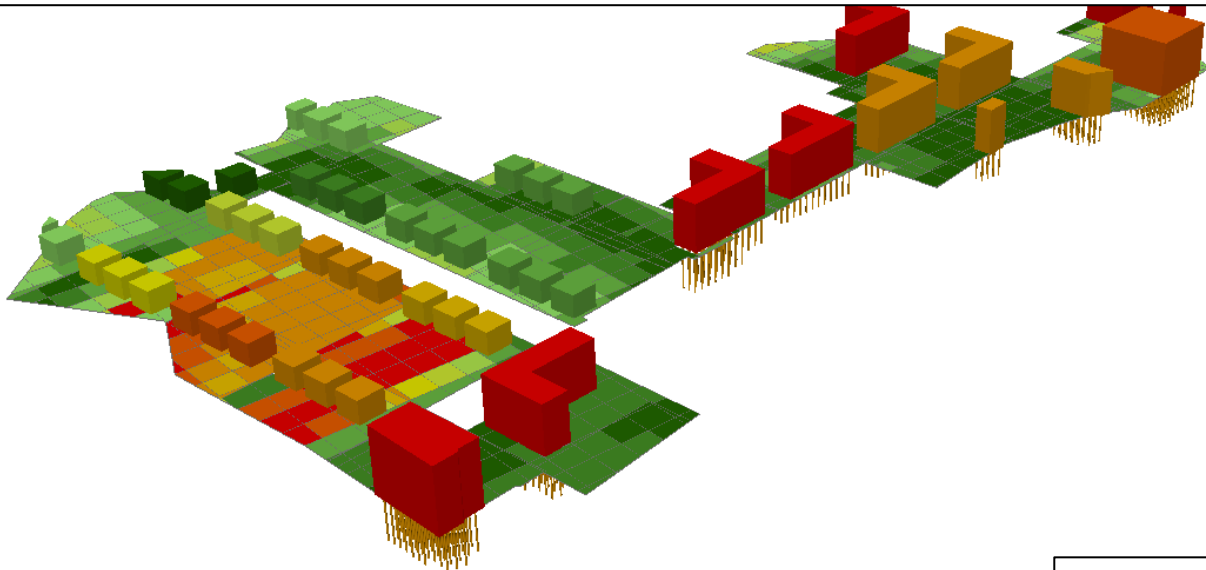
# Cost (for reinforcement) in Swedish Krona/m<sup>2</sup> [2D display]



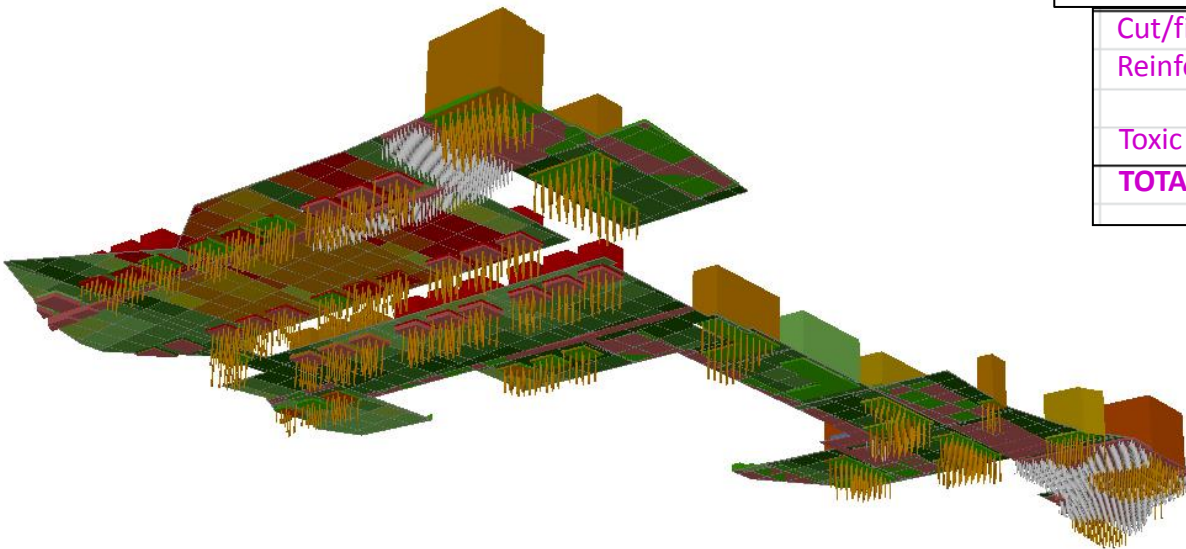
- Step 3 - COST SEK/m<sup>2</sup>
  - BUILDINGS SEK/m<sup>2</sup>
    - 0 - 100
    - 101 - 200
    - 201 - 300
    - 301 - 400
    - 401 - 500
    - 501 - 600
    - 601 - 700
    - 701 - 800
    - 801 - 900
    - 901 - 1 000
    - > 1000
  - GREEN SPACE SEK/m<sup>2</sup>
    - 0 - 100
    - 101 - 200
    - 201 - 300
    - 301 - 400
    - 401 - 500
    - 501 - 600
    - 601 - 700
    - 701 - 800
    - 801 - 900
    - 901 - 1 000
    - > 1000
  - HARD SURFACE SEK/m<sup>2</sup>
    - 0 - 100
    - 101 - 200
    - 201 - 300
    - 301 - 400
    - 401 - 500
    - 501 - 600
    - 601 - 700
    - 701 - 800
    - 801 - 900
    - 901 - 1 000
    - > 1000

E.g. 1000 SEK ~ 100 US\$

Cost (for reinforcement) in Swedish Krona/m2 [3D display in ArcScene]



Steel, concrete or lime cement piles



xls summary of TOTAL costs (tSEK)

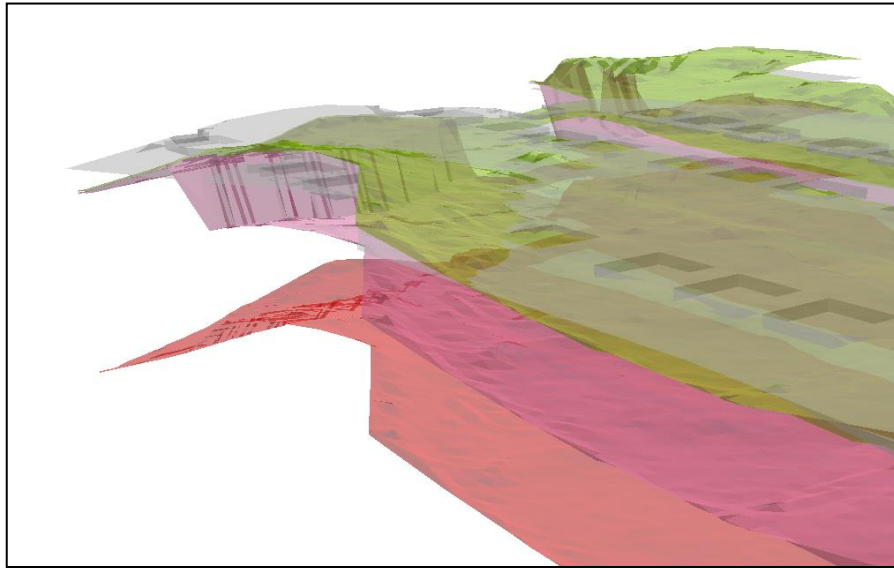
Cut/fill	8 813
Reinforcement	4 154
Toxic cleanup	6 744
<b>TOTAL</b>	<b>19 712</b>

~ 2 million US\$

xls summary of cut/fill volumes (m3)

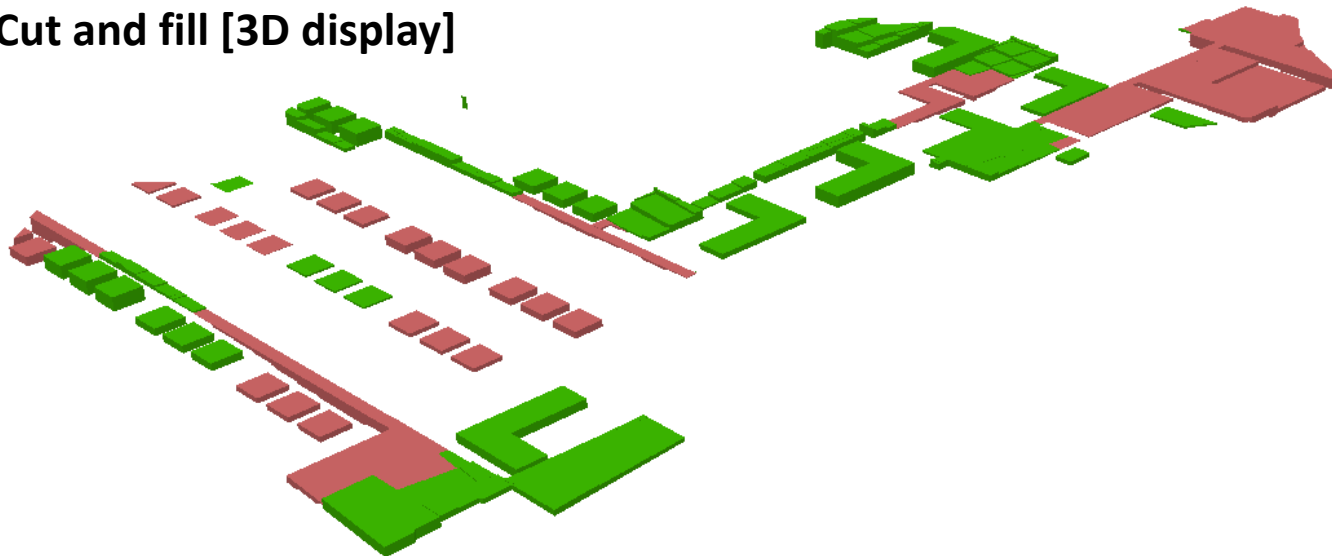
Cut	15 125
Fill	18 415

### 3D, top surfaces for various levels



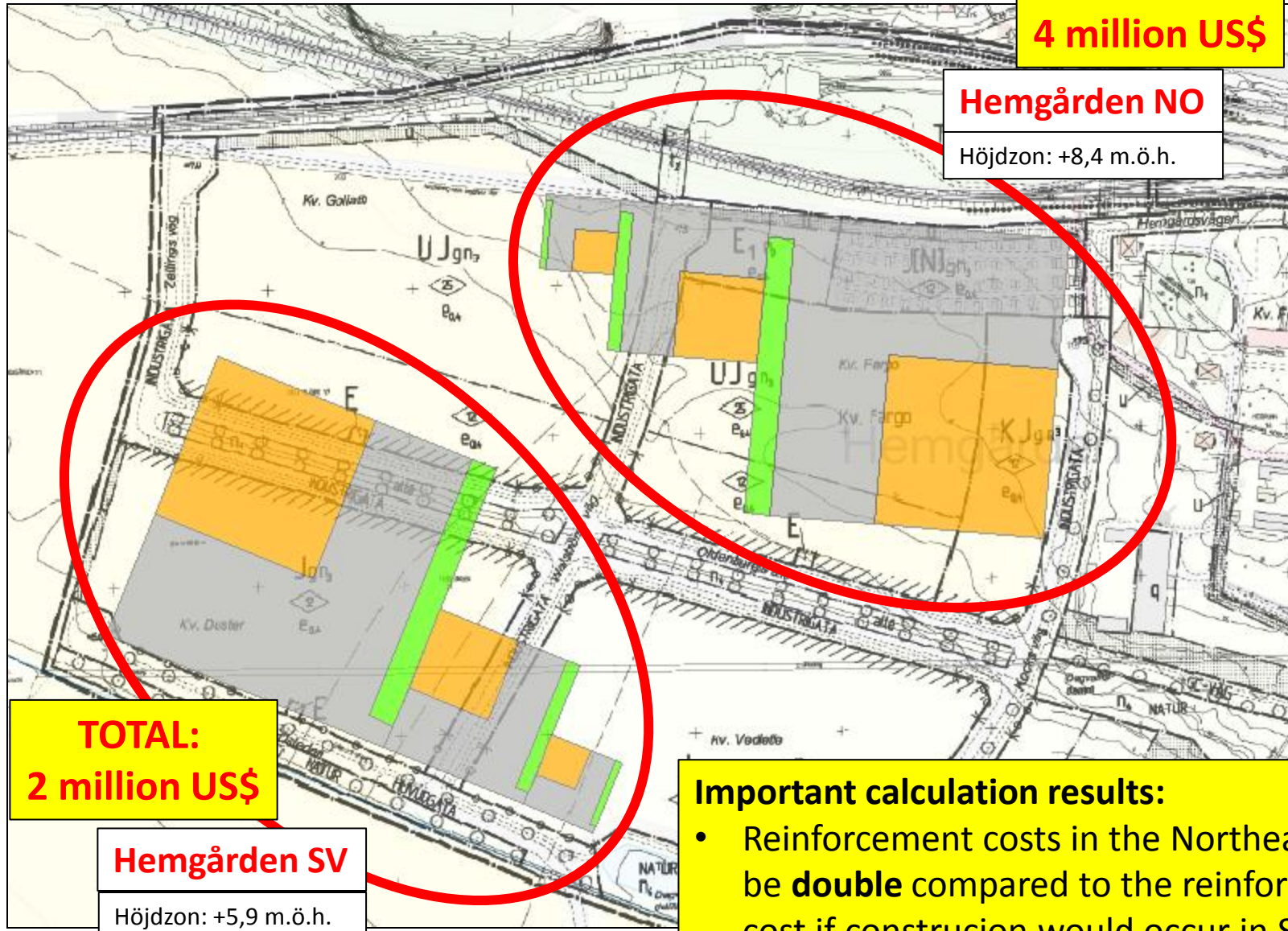
- Step 3 - 3D TRIANGLE MODEL
  - Level New (projected/to be constructed)
    -
  - Level Existing (according to terrain data)
    -
  - Level Friction soil
    -
  - Level Bedrock
    -

### Cut and fill [3D display]



- Step 3 - 3D BUILDINGS
  - Buildings Piles
    -
  - Buildings Cut
    -
  - Buildings Fill
    -
- Step 3 - 3D GREEN SPACE
  - Grönytor Schakt
    -
  - Grönytor Fyll
    -
- Step 3 - 3D HARD SURFACE
  - Hard Surface Cut
    -
  - Hard Surface Fill
    -

Two alternative locations for the same set of buildings...



**TOTAL:  
4 million US\$**

**Hemgårdens NO**  
Höjdzon: +8,4 m.ö.h.

**TOTAL:  
2 million US\$**

**Hemgårdens SV**  
Höjdzon: +5,9 m.ö.h.

- BUILDINGS\_3D
- HARD SURFACE\_3D
- GREEN SPACE\_3D

**Important calculation results:**

- Reinforcement costs in the Northeast would be **double** compared to the reinforcement cost if construction would occur in Southwest.

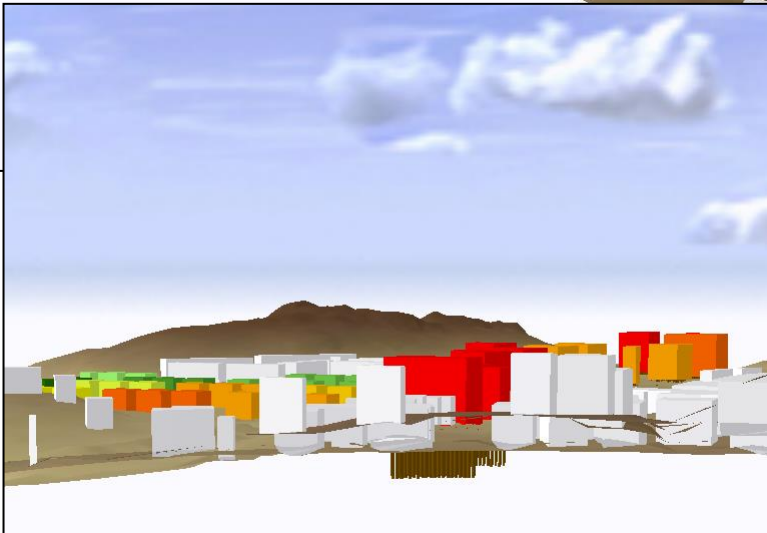
# 3D web display (with surrounding terrain and existing buildings) – ArcGIS Online/City Engine

marie\_1\_sxd\_export\_fewgroups  
<https://gis.swedgeo.se/geokalkyl/3ws/>

DELA HJÄLP LOGGA IN ARCGIS ONLINE

The screenshot shows a 3D web display of a terrain model with buildings and a river. The interface includes a search bar, navigation icons, and a layer list on the right side. The layer list includes:

- Lager
- Byggnader SEK/m2
- Byggnader Pålar
- Schakt och fyll
  - Byggnader Schakt
  - Byggnader Fyll
  - Grönytor Schakt
  - Grönytor Fyll
  - Härdgjorda ytor Schakt
  - Härdgjorda ytor Fyll
- Befintliga byggnader
- Vatten
- Lantmäteriet NH, bef. markmo...



The tool (mxd, tbx, sxd, example data, Manual, instruction videos) is free to download at <http://gis.swedgeo.se/geokalkyl/verktyget> (in Swedish...)

# Thank you!

## CONTACT

Mats Öberg (GIS-architect, M.Sc. Civil Engineering)  
**Swedish Geotechnical Institute**

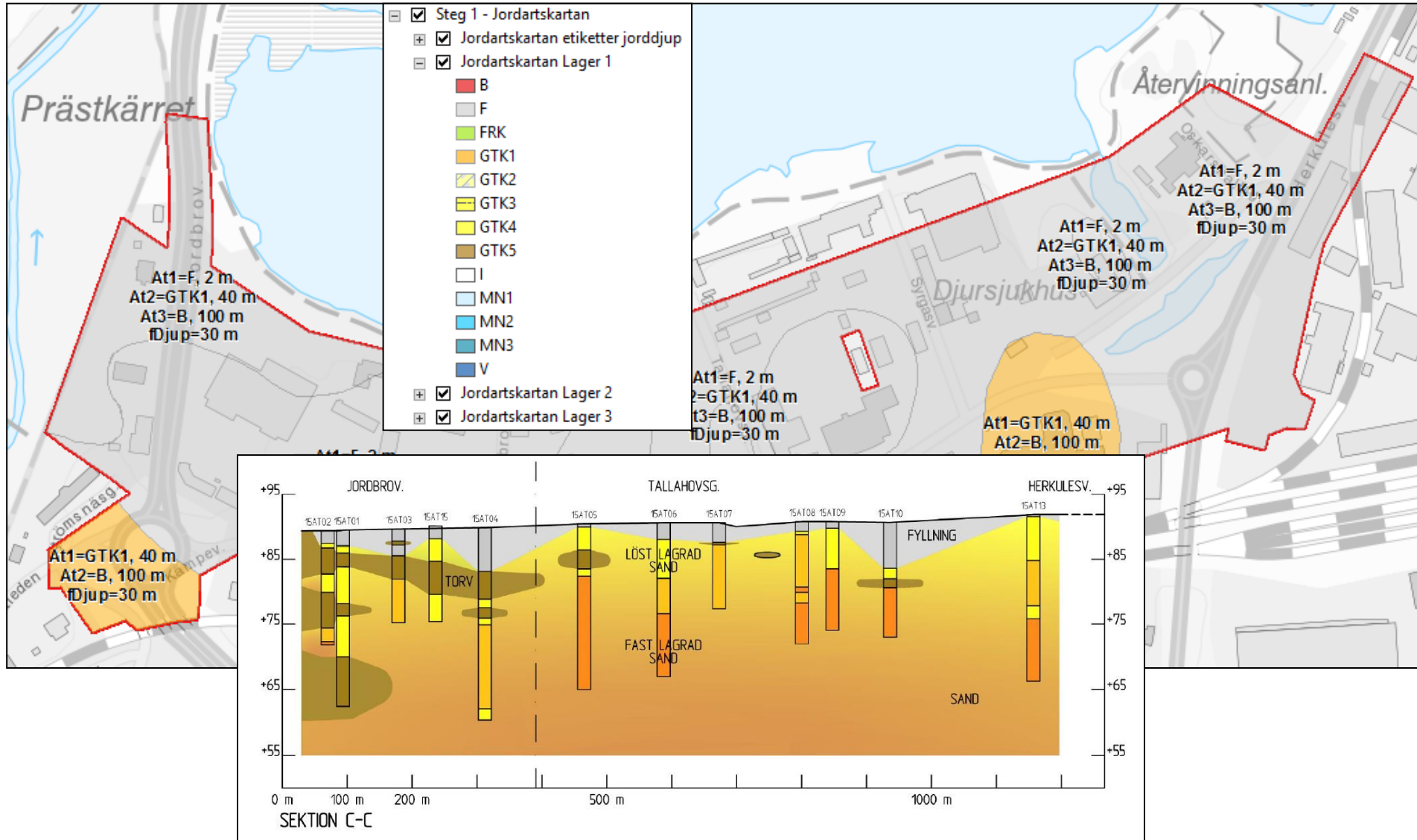
Hugo Grauers gata 5 B  
412 96 GOTEBORG  
Phone: +46 709 730 129  
E-mail: [mats.oberg@swedgeo.se](mailto:mats.oberg@swedgeo.se)

**EXTRA**



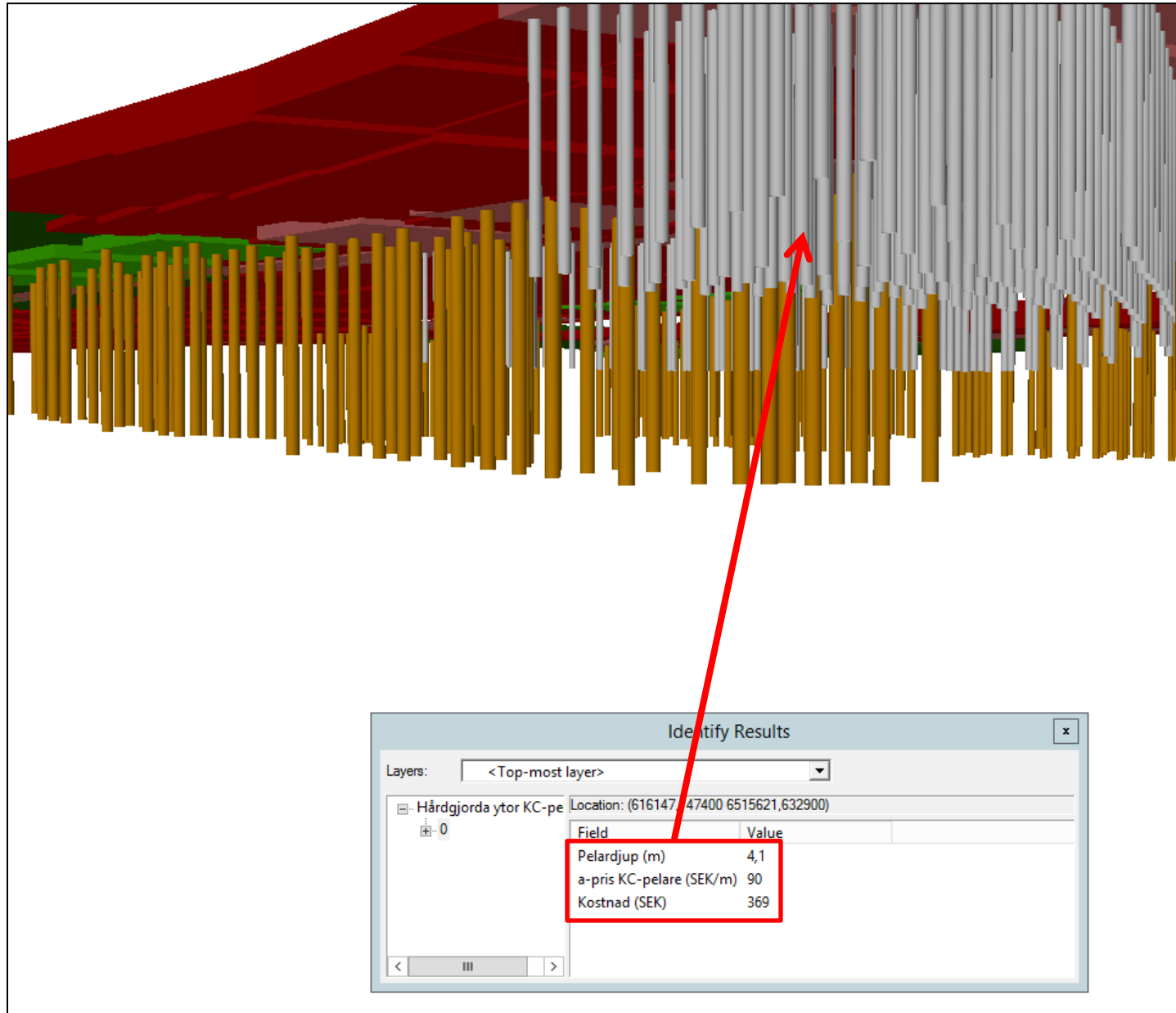
# GTK Geotechnical Terrain Class must be evaluated by geotechnical engineer

## The soil profile to bedrock may vary considerably!





## Item attributes may be shown



Conditional matrix

Villkorsbilaga 1 (GTK1, Silt)							
Belastning (kPa)							
Djup	kPa	Byggnader					
		<50	>=50<100	>=100<150	>=150<200	>=200<250	>=250<300
<1,5	1	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Urgrävn./återfylln.	Urgrävn./återfylln.	Urgrävn./återfylln.
>=1,5 <2,5	2	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Urgrävn./återfylln.	Urgrävn./återfylln.	Urgrävn./återfylln.
>=2,5 <3,5	3	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Urgrävn./återfylln.	Urgrävn./återfylln.	Urgrävn./återfylln.
>=3,5 <4,5	4	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=4,5 <5,5	5	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=5,5 <6,5	6	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=6,5 <7,5	7	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=7,5 <8,5	8	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=8,5 <9,5	9	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=9,5 <11	10	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=11 <13	11	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=13 <15	12	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=15 <17	13	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning
>=17 <19	14	Ingen åtgärd	Ingen åtgärd	Ingen åtgärd	Pålning	Pålning	Pålning

A specific Geotechnical Terrain class

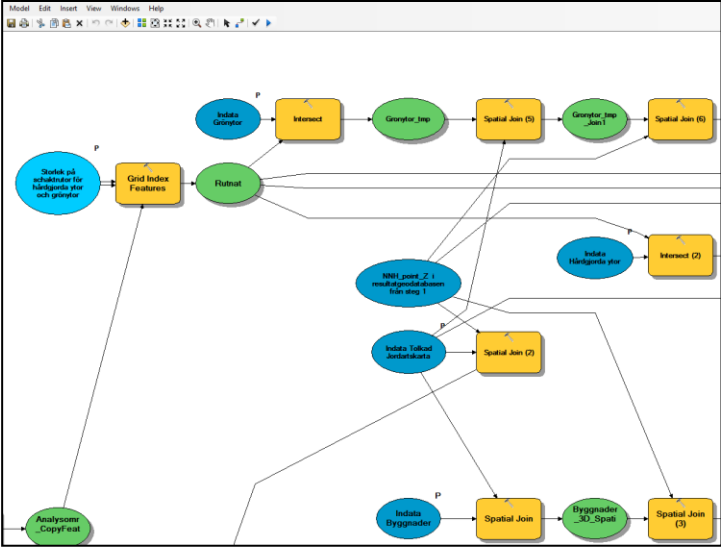
Load in kPa of a building

Various reinforcement methods applied

Förstärkningsdjup

Reinforcement depth

A small part of one of the Models



Developed by SWECO