# Use of Underground Space and Geo-Information in Helsinki

Ilkka Vähäaho, Juha Korpi, Usko Anttikoski

City of Helsinki Geotechnics, Helsinki, Finland

**ABSTRACT**

This paper describes the compilation, contents and use of the City of Helsinki's geotechnical data in city planning, engineering design and building supervision. These operations have continued in the same way for nearly 50 years. This has made those who engage in underground construction and in city planning familiar with the city's foundation engineering and underground construction resources. Therefore there has been little damage in construction to date, even though Helsinki's geotechnical conditions are demanding from the perspective of foundation engineering and tunnelling.

## 1. HISTORY OF GEOTECHNICAL INVESTIGATIONS AND GEOTECHNICAL MAPS

Helsinki (0.56 million people) is located in a variable region with respect to soil conditions, in which bays, soft clay areas and steep rocky outcrops alternate. 35% of the city's surface area of 185 km² consists of soft clay residue from the ice ages (shear strength s = 5-15 kPa and water content w = 50-150%) (Figure 1). The thickness of the soil cover is usually 5-30 metres. Precambrian bedrock contains weakness zones. Groundwater surface is at a depth of only 1-3 metres.

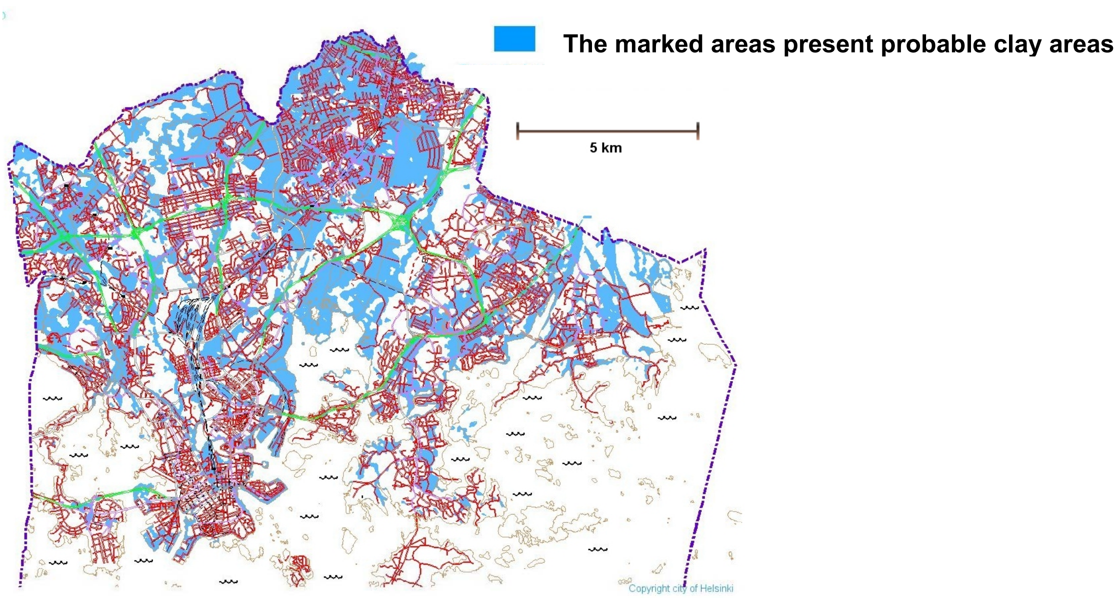


Figure 1. A geotechnical soil map of the city of Helsinki area taken from www.hel.fi/kv/geo/

The city's site investigations, which started in 1903, were initially prompted by the needs of port construction. In 1955, the city council established a geotechnical expert's post. This initiated the systematic appraisal of the construction potential of lots when they were reserved for the needs of the city. Geotechnical Division was established and started soil and bedrock investigations for city planning. In 1956, the surveys located a new weakness zone next to the Central Railway Station, which was named Kluuvi Cleft after a former bay. Initially researchers used old maps, depicting the 'natural state' shorelines, altitude contours and rock exposures. This material served as the foundation for a map (1:2000) of the natural landscapes of central Helsinki in 1958.

At the same time, soil surveys were also initiated for all of the city's zoning and construction sites. They were done in the form of casing drilling, percussion drilling, weight sounding, vane testing and dynamic probing. The first soil maps for central Helsinki (1:500) were completed in 1958-65 and for the whole city (1:2000) in 1960-70. A more detailed geotechnical soil map (1:10,000) for the city was printed in 1972 and the first bedrock map in 1978. A foundation map showing groundwater risk areas in the city centre (1:2000) came out in 1983 (Anttikoski and Raudasmaa, 1981). The geotechnical soil map was reprinted in 1989, now also including constructed tunnels and the buildings that are founded by wooden piles. A rock resource map of the city centre, which serves planning of new tunnels, was completed in 1992 (Figure 2). The map also contains information on constructed tunnels.

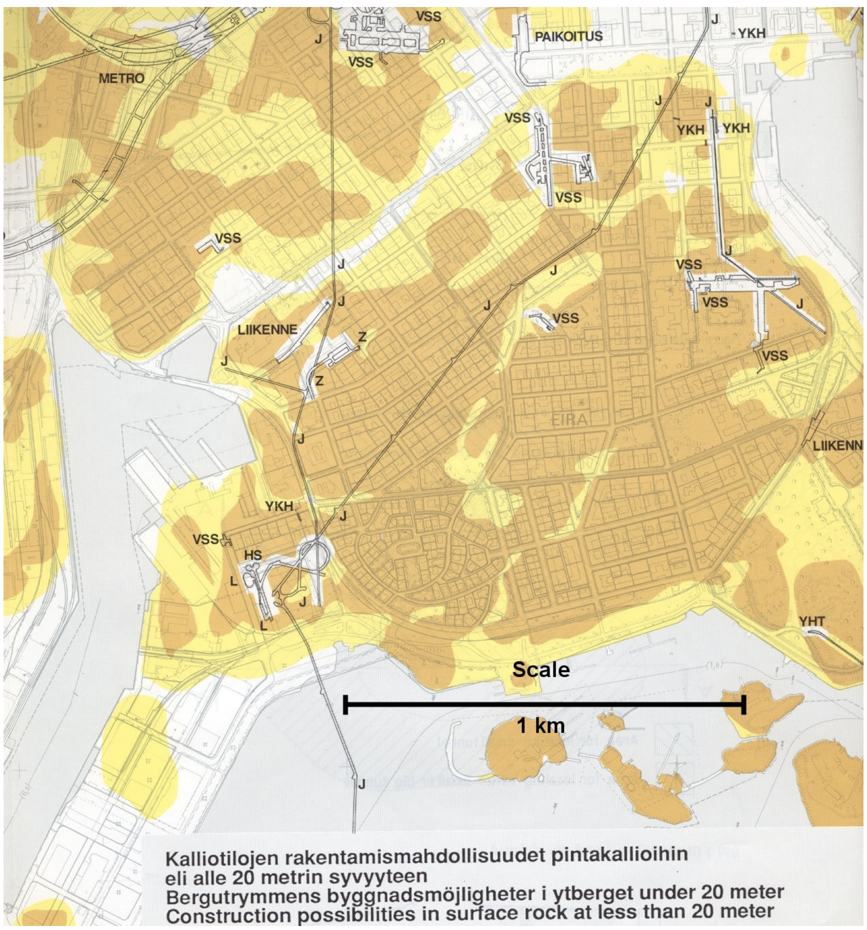


Figure 2. A rock resource map of the city from 1992

Currently, soil investigation data can also be accessed by means of a spatial database covering information from 200,000 survey points and 4500 groundwater observation tubes (Vähäaho, 1998). The environmental database will be expanded in 2000-2005 to include information on contaminated soil materials (Vähäaho et al, 2003). The environmental information can be viewed and handled simultaneously with the geotechnical information. Figure 3 presents the use of environmental and geotechnical information by different city departments.

## 2. USE OF THE GEOTECHNICAL DATABASE

City engineers via the city's rapid information network can access geotechnical data. However, engineers from other companies cannot directly access this information. Rather, a geotechnical engineer first collects the relevant information with the applications at his or her disposal, completes the geotechnical plan and then sends it to the other engineers through the internal network. The city's internal network makes the transfer of information between city engineers efficient (Figure 4).

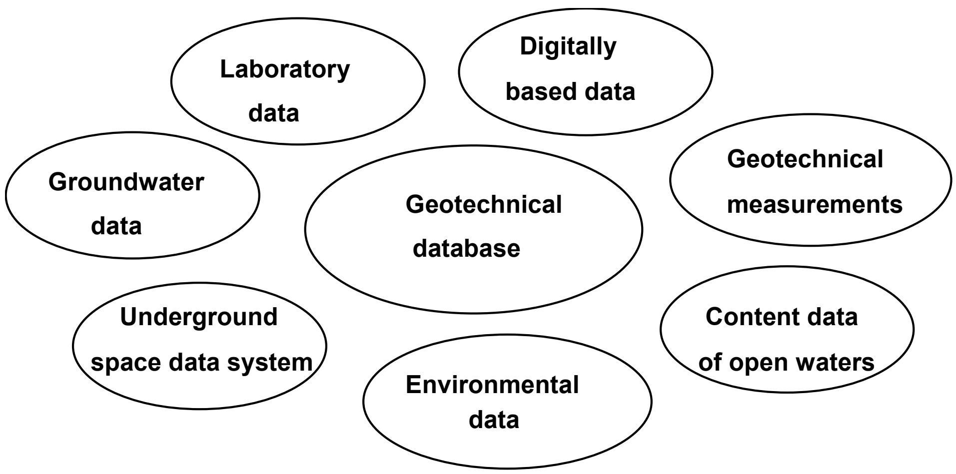


Figure 3. Overview of the Helsinki Geotechnical Database

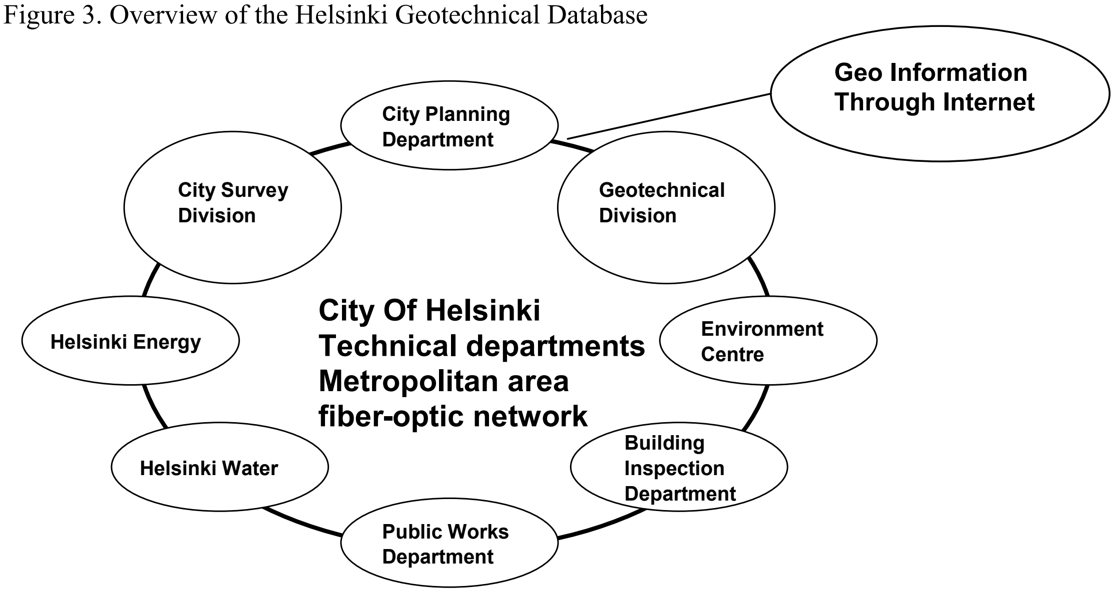


Figure 4. The technical information network of the city transmits geotechnical data like maps, cross-sections, and 3D models as well as data from the single spatial databank

The ordering party pays for the relevant share of the geotechnical system's maintenance costs. The information as such is not invoiced. Maintenance costs arise from the running of the system, its development, backup copies and various hardware and software service agreements. The costs are reviewed each year, after which the prices of the different information services are established.

A typical cost unit is a survey point or, in digital maps, a surface area. Currently, the survey point prices vary between EUR 0.10 – 3.60 per survey point. It is also possible to order an A4 printout depicting a map of the site, including cross-sectional presentations. The price is usually EUR 6.00 for each A4 printout (Anttikoski et al, 2002).

## 3. GROUNDWATER MONITORING IN CONJUNCTION WITH BUILDING SUPERVISION

In cities with similar geotechnical conditions, falls in groundwater levels have caused considerable damage. Helsinki has learned from cities such as Stockholm, Oslo, Tallinn and St. Petersburg. For this reason, the city has made groundwater management a key priority.

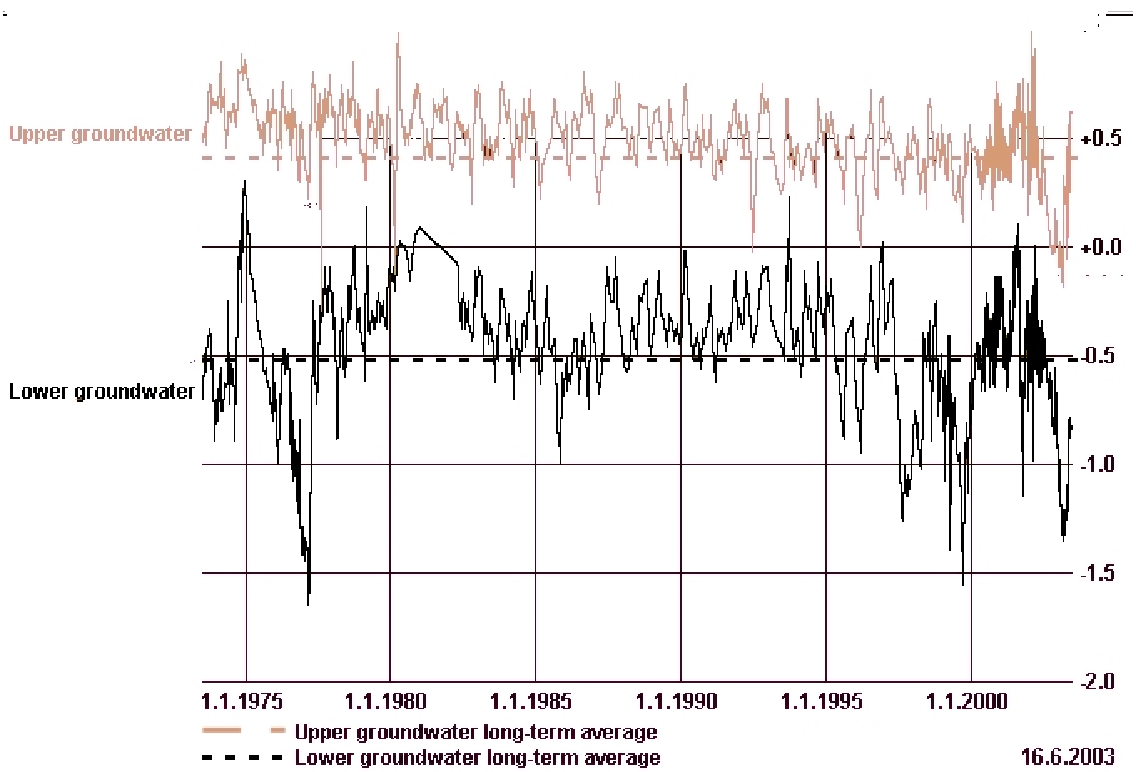


Figure 5. Live groundwater levels in Helsinki Central Station (www.hel.fi/kv/geo/vesikuvaeng.htm)

One risk area with respect to falling groundwater levels is a former bay called Kluuvinlahti. The buildings in this area are usually founded with piles of 5 – 25 metres in length. The old buildings on wooden piles in this part of the city centre include Main Post Office, Central Railway Station, National Theatre and the stock exchange building. City’s strategy is that timber piles should not be corrupted because of groundwater lowering.

When the construction of the metro began, groundwater management was poor. A move to more comprehensive management was started in 1972, when the metro tunnels were getting closer to the city centre. It started with the more detailed observation of groundwater levels. Cellar leaks were reduced, and the leaks were measured in cellars and tunnels. The old foundations of houses next to the metro were investigated.

Construction of a new private tunnel in 1977 caused groundwater levels to fall in a large part of the city centre. As a result, the city council ordered Geotechnical Division and Building Inspection Department to monitor the city centre's groundwater situation. Information was collected on the foundations of buildings in the city centre and limits were set on pumping in cellars. On the geotechnical division's initiative, building owners studied the foundations of their own buildings, which provided further important information on groundwater levels and the condition of wooden piles. Thanks to the construction of the metro, sufficient will was found to tackle groundwater issues, while property owners became more aware of the problem through various reports.

The city centre's groundwater situation has remained good after the construction of the metro tunnel even though there have been further deep construction projects. The geotechnical division's website (www.hel.fi/kv/geo/) provides live groundwater information collected from groundwater measuring stations (Figure 5).

## 4. CO-OPERATION WITH CITY PLANNING

Zoning projects include geotechnical design and the costs of foundation engineering (Anttikoski et al, 2002). Issues that have been prominent in recent years relate to contaminated areas and the stability of filled areas. Because of the wide scope of the geotechnical database, we can usually go a long way without recourse to field investigations. When new investigations are needed, they can be accurately targeted with the help of archived data.

Geotechnical engineering plays an important role in making soft, unstable or contaminated land fit for construction. In co-operation with the city's financial authorities, we have created a method for making poor soil firmer by investigating soil conditions in advance and then improving weak soils with pre-construction methods (such as pre-loading, deep mixing and piling). The city's pre-construction financing covers such work 1-3 years before actual building. In the past twenty years pre-construction has amounted to about 7 hectares a year.

The city's hard bedrock is conducive to tunnel construction. The city has established a tunnel building team, with representatives from City Planning Department, Geotechnical Division, Helsinki Energy and Helsinki Water etc. Tunnels have been especially popular for the locating of large transferring lines.

Underground construction in the city centre demands much co-ordination. Information on the area's underground spaces, including non-public spaces, has been saved with City Survey Division. City Planning Department also keeps a future underground reservation plan. As data on soil, bedrock, groundwater and risky foundations is easily available, it is possible to compile the basic information needed for new underground construction projects with little effort. In 1980-2000, the city's underground construction (rock areas) varied between 100,000-500,000 m³/year (Anttikoski et al, 1994). The construction of the metro in the city's nuclear centre in 1970-80 fostered the development of underground construction, and led to an increase in underground construction (Anttikoski, 2001).

A volume of the city underground spaces is now 8.8 million m³. A quarter is currently in the nuclear centre. This volume of underground space (1.7 million m³) is distributed as follows:

| | | |
|---|---|---|
| Underground spaces before the metro (1980) | 0.5 mill. m³ | |
| Metro areas (1980-2000) | 0.3 | ” |
| Cellars and connecting tunnels (1980-2000) | 0.2 | ” |
| Parking areas, civilian shelters and storage (1980-2000) | 0.6 | ” |
| Municipal technical tunnels (1980-2000) | 0.1 | ” |

However, within 5 years (2000-2005), the nuclear centre may have up to 2.5 million m³ of underground space, due to the many underground projects currently under construction. They include:

- The Kamppi commercial centre, underground bus terminal and car park.
- The re-location of the Helsinki Energy power plant's coal reserves to an underground silo at Salmisaari (Figure 6).
- A tunnel to be jointly used by Helsinki Energy and Helsinki Water, volume 150,000 $m^3$ total and length 4 km. This will increase the total length of Helsinki's utility tunnels to 36 km and create a good basis for the city's technical maintenance (Figure 7).

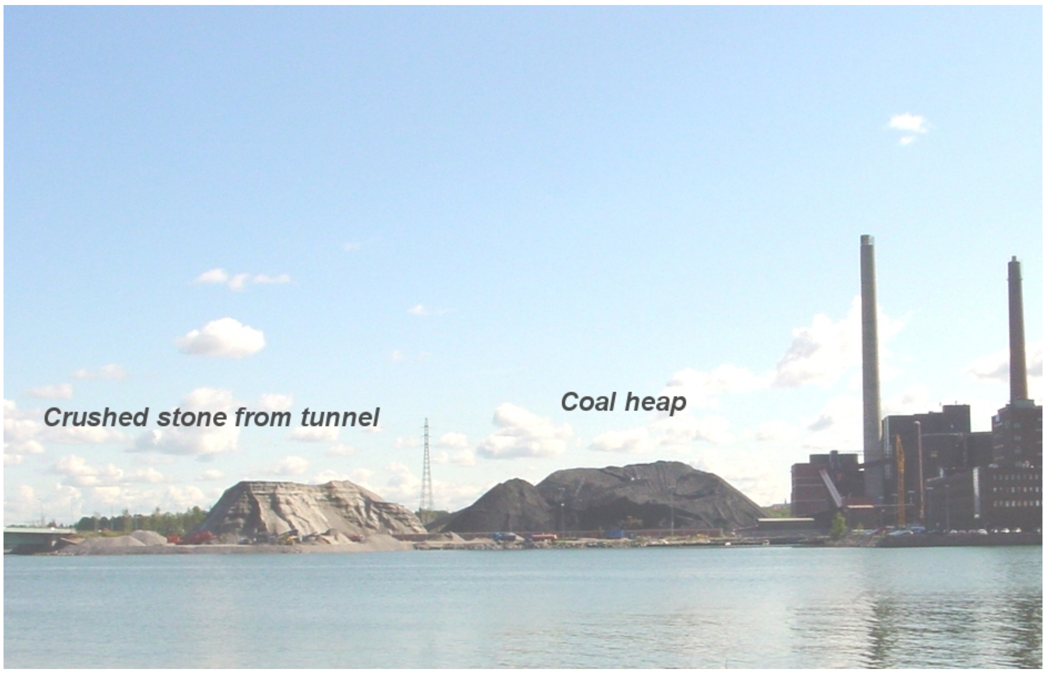


Figure 6. The new 400,000 $m^3$ coal stock silos of the Salmisaari power plant will be built into the bedrock, while offices will be built above ground. Pictured here (2003) are a pile of coal and a pile of quarried rock.

## 5. ACTION ON BEHALF OF SUSTAINABLE DEVELOPMENT

In 1998-2002, the City of Helsinki established a programme for sustainable development (Local Agenda 21 in Helsinki 2002). The work was led by the city's Environment Centre and involved various offices, municipal boards and citizens' associations. The city council approved the programme in 2002.

Helsinki sees tunnelling as a cost-efficient additional resource in city construction. Bedrock tunnels have a long life span and their costs are reasonable. Tunnelling also frees land suited for residential building and decreases environmental emissions. Thus extensive tunnelling has great importance for the sustainable development of Helsinki. The current situation regarding tunnelling is as follows: (i) Helsinki's energy and water management is for the most part already located in bedrock tunnels; (ii) every citizen can be housed in an underground shelter in the event of a major crisis; (iii) Helsinki metro operates in tunnels in the city centre; (iv) most car parking facilities in the nuclear centre are located underground, half of them in bedrock tunnels; (v) good mineral aggregate for construction is obtained from spaces/tunnels made in the bedrock.

From the geotechnical perspective, the following factors are important to sustainable development:

- Helsinki and many other Baltic Sea cities have built their municipal technology and the lowest floors of buildings at a level close to sea level. The flood level value in Helsinki should during 100 years be raised from +1.3 to +2.3 and new zoning should strive to raise the level of landfills.
- Cleaning of contaminated sites and construction of new rock tunnels help to sustain bio-diversity.
- Much attention has been paid to preserving old wooden foundations by controlling the levels and quality of groundwater since construction of the metro began in 1972.
- Power plant ash has been successfully re-utilised in the last 20 years. Building experiments show that mass stabilised surplus clay can be used in street structures. Many recreational hills have been constructed from surplus mass in different parts of the city.

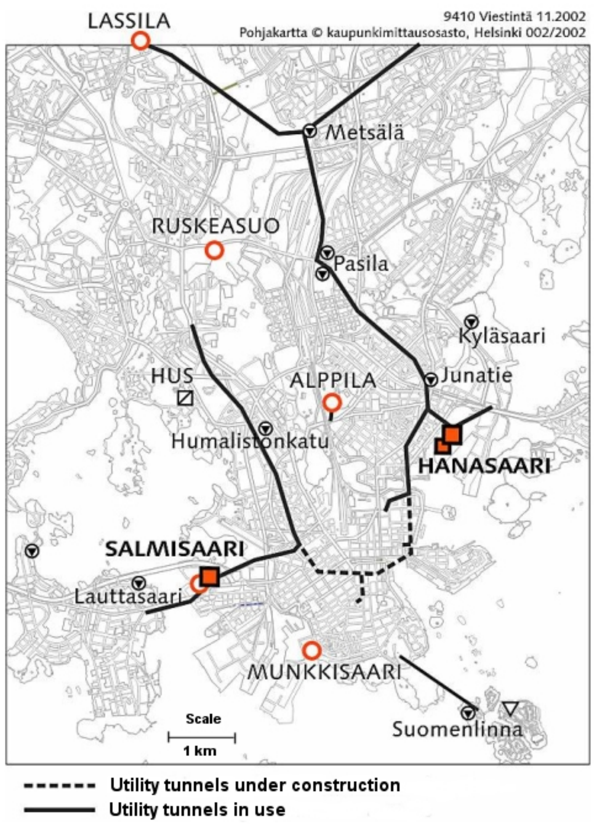


Figure 7. A utility tunnel map of the central city (2003)

## 6. CONCLUSIONS

Helsinki's geotechnical database has served city planning and construction for over 40 years. Engineers in various fields now use it in their design work. This has led to economic and safe foundation engineering solutions, because it has been possible to take ground-related factors into consideration from zoning onwards.

Underground construction is extremely long-term work. In Helsinki, the rate of tunnel construction has been approximately 200,000 m3/year (or 4 km/year). The work has been divided fairly evenly over many years, and has involved several generations.

The city's good bedrock has supplemented its otherwise scarce building sites, while simultaneously reducing the environmental load.

From the experience gained in Helsinki we can say that what makes a modern city ”unbeatable” is an efficient infrastructure, with its major elements being located in bedrock tunnels.

The future of tunnelling in Helsinki looks good, as the bedrock underneath the city provides unlimited possibilities and the city's very useful geotechnical database allows easy access to city planners and citizens alike.

## REFERENCES


Anttikoski, U, Niini, T, Ylinen, J, Ruoppa, A, 1994. Bedrock Resources and Their Use in Helsinki. Tunnelling and Underground Space Technology 3/1994.

Anttikoski, U, Raudasmaa, P, 1981. The map of building foundations. Proceedings of the 10th International Conference on Soil Mechanics and Foundation Engineering, Vol. 3. Stockholm.

Anttikoski, U, 2001. The influence of the Helsinki metro on underground construction. Rock Mechanics a challenge for society, Proc. of the ISRM regional symposium Eurock 2001 Espoo. Balkema.

Anttikoski, U, Korpi, J, Raudasmaa, P, Vähäaho, I, 2002. Geotechnical Database of Helsinki in City Planning Process. Proc. of the 2nd Int. Conf. on Soil Structure Interaction. Zurich.

European Commission, Directorate-General XII for Science, Research and Development, COST Action C7, Soil-Structure Interaction in Urban Civil Engineering, Working Group D, Geotechnical and Geo-Environmental Engineering for Urban Planning. Hidden Aspects of Urban Planning. In. Paul,T, Chow, F, Kjekstad, O, (eds). Thomas Telford Publishing. London. 2002.

Geotechnical Division, Real Estate Department, City of Helsinki, 2003. Geotechnical Database of the City of Helsinki. ( www.hel.fi/kv/geo/).

Holopainen, P, Kämppi, A, 2001. Extension of the Viikinmäki underground sewage plant. Rock Mechanics a challenge for society. Proc. of the ISRM regional symposium Eurock 2001 Espoo. Balkema.

Finnish Tunnelling Association. The Fourth Wave of Rock Construction 1997 (eds) Rönkä, K, Ritola, J, WSOY. Porvoo. (www.mtry.org/).

Local Agenda 21 in Helsinki 2002. (www.hel.fi/ymk/agenda/index_agenda.html).

Vähäaho I, 1998. From geotechnical maps to three-dimensional models. Tunnelling and Underground Space Technology, 13/1998.

Vähäaho I, Korpi J, Hatva E-M, 2003. Use of Existing Geotechnical Information in Urban Planning. Land Use & Spatial Planning in Ireland. The Institute of Geologists of Ireland. Dublin Castle 2003.