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Sub-Urban

TU1206-WG1-007

Helsinki

TU1206 COST Sub-Urban WG1 Report

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COST TU1206 Sub-Urban Report
TU1206-WG1-007

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City of Helsinki

Content

1. Introduction

1.1. Overview

City of Helsinki is the capital of Finland and one of the most densely populated areas in the country. Together with its surroundings it's called Greater Helsinki. It consists of metropolitan area including smaller urban Capital Region and commuter towns. These regions are located in the southern part of Finland, on the northern coast of the Gulf of Finland (Figure 1). The Capital region includes cities of Helsinki, Vantaa, Espoo, and Kauniainen (Figure 2) and has a population of about one million.

Figure 1. The City of Helsinki located on the northern coast of the Gulf of Finland. "© OpenStreetMap contributors"

City of Helsinki is located on the tip of a peninsula and 315 islands. The city is called the "Daughter of the Baltic". By decree of King Gustav Vasa of Sweden in 1550, the city was founded at the mouth of river Vantaa. From there, the city was moved further south to its present location in 1643. Helsinki has been the capital since 1812, three years after Finland became an autonomous Grand Duchy of the Russian Empire [1]. Helsinki continued as the capital after Finland gained its independence in 1917.

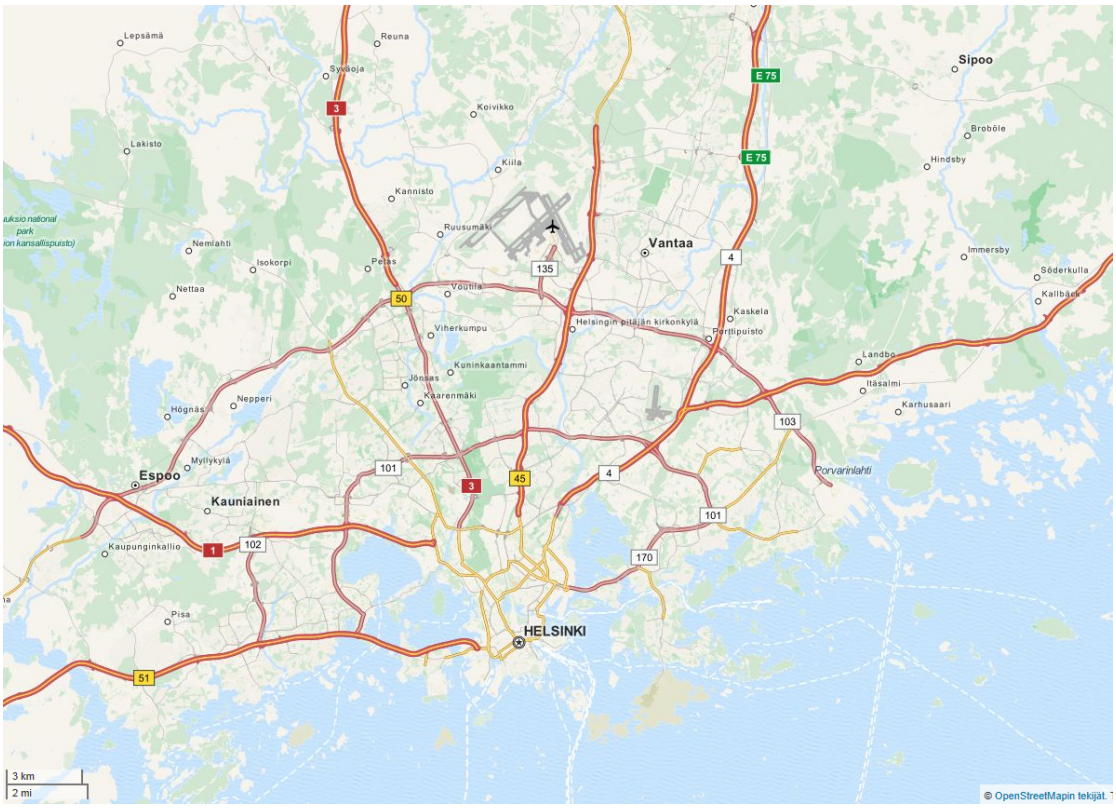


Figure 2. The Capital Region of Helsinki, consisting of the cities of Helsinki, Espoo, Vantaa and Kauniainen.

Figure 3. An overview of the City towards the south with the Gulf of Finland in the background. (Photo: Helsingin kaupungin aineistopankki/Suomen Ilmakuva Oy).

1.2. City description

The numerical facts about Helsinki are seen in Table 1 based on the data of Statistics and Information Services of the city [1].

Table 1. Numerical facts about Helsinki [1] based on the data of Statistics and Information Services of the City.

○ **Geography and environment** ▪ Total area 716 sq km Sea 503 sq km Land 213 sq km Islands 315	○ **Number of inhabitants** ▪ Total population (1 January 2013) 603,968 ▪ Population density (1 January 2012) 2,800 inhabitants per sq km
○ **Population** ▪ Total population (year 2013) 5,426,674 Category, Percent ▪ 0–6 yrs, 7.8 % ▪ 7–15yrs, 9.7 % ▪ 16–64 yrs, 63.7 % ▪ 65–74 yrs, 10.4 % ▪ 75–84 yrs, 6.1 % ▪ 85+ yrs, 2.3 % ▪ Men, 49.1 % ▪ Women, 50.9 ▪ Finnish-speaking, 89.7 % ▪ Swedish-speaking, 5.4 % ▪ Other languages, 5.0 % ▪ Finnish nationality, 96.4 % ▪ Other nationalities 3.6 %	○ **Housing** ▪ Dwellings total 331,485 ▪ Housing density, m^2/person 34.2 ▪ Detached houses, 13.2% ▪ Dwellings owned by occupier, 44.4% ▪ Rented dwellings, 44.7%
○ **Vehicles** ▪ Registered cars (31st December 2012) total 244,178 • per 1,000 inhabitants 404 ▪ Registered motorcycles on 31st December 2012 16,250 • per 1,000 inhabitants 27	○ **Transport** ▪ Public transport within the city • Journeys, year 2012, (in millions) ○ Buses 88.6 ○ Trams 57.2 ○ Metro 62.2 ○ Ferries 1.6 ○ Total 209.7 ▪ Local traffic of the State Railways, million journeys 41.9 ▪ Traffic at the Port of Helsinki, vessel calls 8,733 ▪ Traffic at Helsinki–Vantaa Airport • Domestic freight, tons 1,747

	• International freight, tons 180,420
○ **Communication** ▪ Number of mobile phones per 100 inhabitants, year 2012, 172 ▪ Internet users (15–74 years old year 2012) in percent of the population, 90%	○ **Underground land use** ▪ 9.5 million m^3 ▪ More than 400 premises ▪ Technical tunnels 220 km ▪ Raw water tunnels 24 km ▪ Utility tunnels "all in one" 45 km

2. Geological and physical geography

2.1. Bedrock

The Helsinki Region is located in southern Finland on Fennoscandian shield area. The shield is situated in the north-western part of the East European Craton and is the largest exposed area of very old Precambrian rocks in Europe. In southern Finland the ancient Precambrian bedrock is about 1.9 -1.8 billion years old and consists of gneisses and granitic rocks (Figure 4). Old shields are typically very stable areas where earthquakes, tectonic movements and natural movements of the ground are unusual. The structure of the bedrock reflects the metamorphic character. The rocks were originally sedimentary and volcanic, and the deeply buried, mixed and partly melted nature of the rocks is seen nowadays in form of banded gneisses and migmatites. Granitic rocks are also typical in the Helsinki area. All the gneissic zones in southern Finland have a strong, nearly E – W trend.

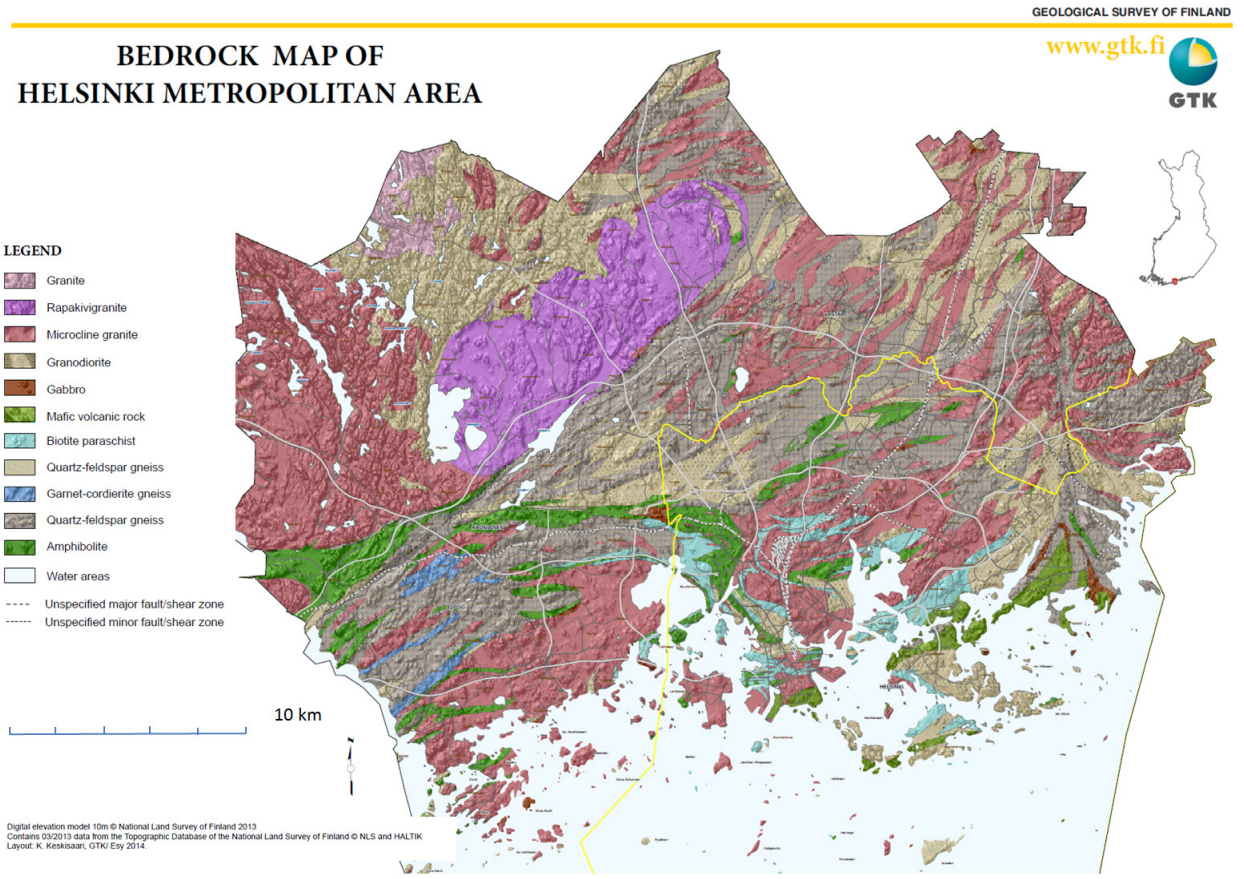


Figure 4.Bedrock map of Helsinki Metropolitan area and relief of the ground based on elevation model (National Land Survey of Finland), Geological Survey of Finland. Digital elevation model 10m © National Land Survey of Finland 2013. Contains 03/2013 data from the Topographic Database of the National Land Survey of Finland © NLS and HALTIK. Layout: K Keskisaari, GTK/ ESY 2014.

2.2. Quaternary deposits

The Precambrian crystalline basement is eroded quite flat as a result of continental erosion over millions of years and dips gently towards the south (in average the dipping is 2–3 m/km). The bedrock is usually overlain by a thin cover (1 – 15 m) of Quaternary glacial sediments. The topography of Finland reflects generally the ancient weakness zones in the bedrock surface with structures from brittle tectonics, which areas are usually eroded deeper (10 – 30 m).

Quaternary deposits in southern Finland consist of a thin till cover on the bedrock surface, sometimes overlain by glaciofluvial sand deposits. During the history of filling in the Baltic Sea Basin the soft clay sediments were in the entire study area (Figure 5). When the water table of the Baltic Sea lowered, the shorelines regressed, and exposure of the study area began . The

areas with higher elevations were sensitive to erosion of wave activity, and most of the surficial glacial sediments have been washed away from hill slopes. In a typical landscape, the hills with outcropping bedrock alternate with valleys filled with clay sediments.

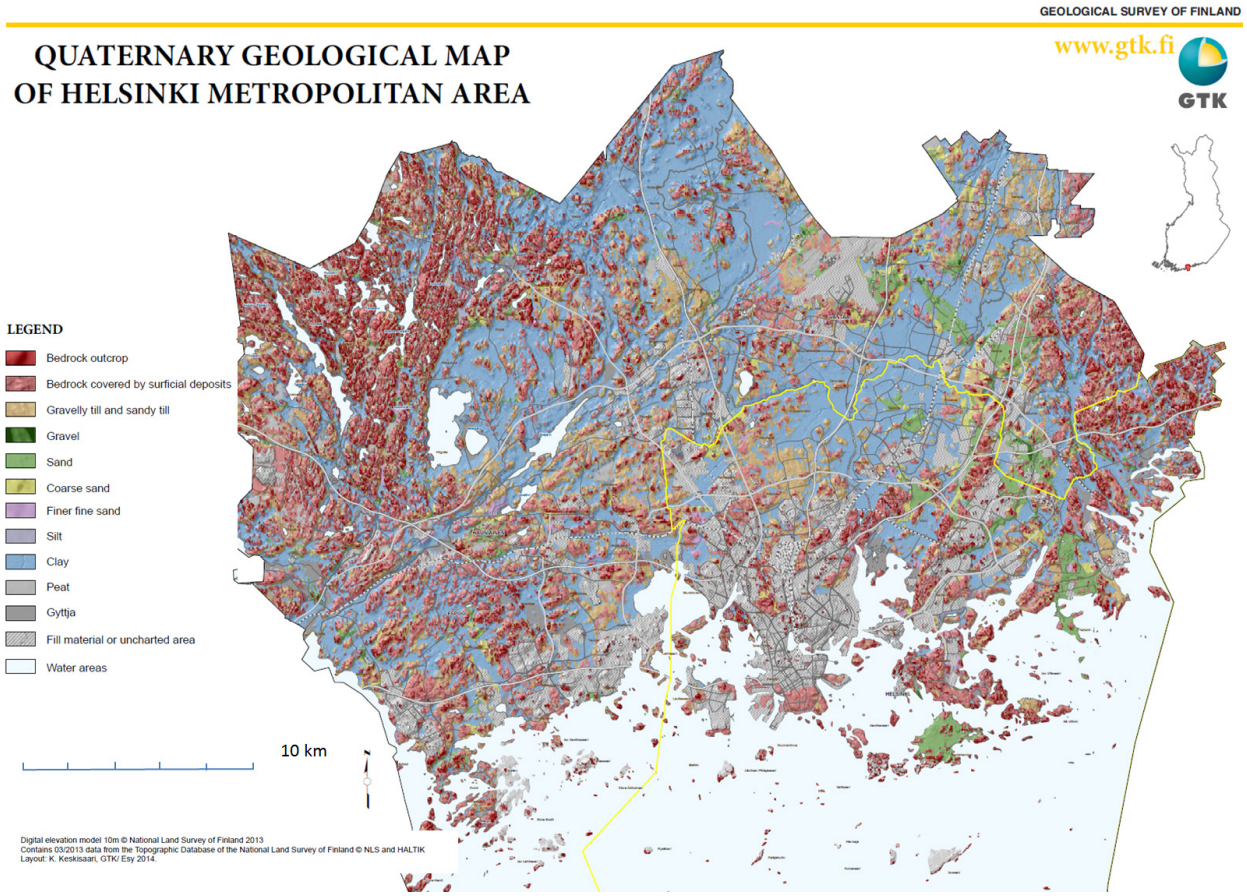


Figure 5. Map of Quaternary deposits of Helsinki Metropolitan area and ground relief based on elevation model (National Land Survey of Finland). Geological Survey of Finland. Digital elevation model 10m © National Land Survey of Finland 2013. Contains 03/2013 data from the Topographic Database of the National Land Survey of Finland © NLS and HALTIK. Layout: K Keskisaari, GTK/ ESY 2014.

2.3. Groundwater

The groundwater table in the Helsinki area is typically very close to the surface. In hilly areas with permeable coarse grained sediments overlain by impermeable clay sediments, the groundwater might even have overpressure. In central area of Helsinki city, the lowering of the groundwater level has caused damages to buildings and structures with foundations consisting of soil or wooden pillars in many places, especially in old town areas. The timber pillars are corroded because of groundwater lowering. The lowering of the groundwater table typically is caused by leaking of water to bedrock tunnels constructed underneath. Construction of a new

private tunnel in 1977 caused groundwater levels to fall in a larger part of the Helsinki city centre [4]. As a result, the city council ordered the Geotechnical Division and Building Inspection Department to monitor groundwater situation in the city centres. Today, in the greater City area, data from about 700 monitoring tubes are collected monthly.. The City of Helsinki has information of over 5 000 monitoring tubes (old and active) stored in their databases.

2.3. Earth resources

In the Helsinki Metropolitan area, large amounts of natural raw materials are consumed annually. Rock materials for infrastructure and building construction are brought in from a distance to the urban area. Sorted sand and gravel resources have been used long ago in the capital area. Rock aggregates will be used more frequently to replace gravel and sand, one part of that comes from tunnel excavation in the city area, but mostly from bedrock quarries in the vicinity of urban areas.

In the study area only some small old mining sites and mineral deposits have been found. These sites are so small that they do not have any significant influence on land use.

3. Engineering geological data and 3D- modeling

As a result of the strongly varying construction conditions within the Helsinki area, a large amount of data from geotechnical investigations have been collected. Subsequently, the location of , and in some cases, estimates of minimum volumes of bedrock resources for various purposes, are also well known and offer reliable and potential options for city development. The importance of the utilization of bedrock resources in city development is obviously great: Helsinki is the first city in the world which has developed and implements an underground master plan. A long experience in the use of underground space is reflected in The several new underground applications which have been developed.

The geotechnical properties of the ground in the city of Helsinki are strongly bimodal as it comprises of soft clay and hard bedrock. On one hand the bedrock makes a very hard, well bearing and stable basis for construction of foundations, but also has represents challenges in making flat areas for the construction of building. On the other hand, the soft and flat clay areas sometimes form very difficult conditions for construction, because of the easily settling surface and depth down to the bearing layer for pilars . The construction suitability of areas varies very much within the greater Helsinki area.

3.1. Geotechnical data

The Geotechnical Division of the City of Helsinki has a long tradition in storing geotechnical investigation data. The amount of geotechnical investigation data which have been reported is enormous, because of the varying foundation conditions. Data on geotechnical conditions have been collected during 30 – 40 years in digital databases, which contain data from about 450 000 investigation points [4]. Investigations typically include soundings (by applying Swedish sounding method), borings, drillings, laboratory measurements, and so on. Data are saved in standard national digital format, the so-called INFRA-format. Investigation data in INFRA–format is delivered to users with a map based information service, which is not public and intended to be used only for professional planners (Helsinki Soili -palely http://soili.hel.fi/public/login.aspx?ReturnUrl=%2f). Geotechnical maps, investigation points (soil survey points) and groundwater survey points are seen in an open map service (http://kartta.hel.fi/#, Environment, nature and habitation/Geotechnical maps, and Geotechnical material).

The investigation data in INFRA-format data can be simply applied using certain CAD-based planning and design applications. A large amount of data can be easily processed for different kinds of models, maps, geotechnical cross sections, 3D models and for use in engineering calculation programs. The Geotechnical Division has also developed software for its own use in 3D–ground modelling.

3.2. Modelling

Typically a 3D–modelling process starts with interpretation of investigation data by measuring the depth of different soil surfaces and bedrock surface. Usually the interpretation is made in separate points or in cross sections with several points of investigation data (Figure 5). Usually the interpreted points are triangulated to TIN–surface models. Modelled surfaces are typically the surface of the ground, the bottom surface of soft (clay) sediments and the surface of bedrock. The modelled area is usually small in engineering projects. City scale 3D–models are made seldom because of the very strongly varying topography and geology. Lidar (both terrestrial and airborne) Laser scanning technology, has provided the possibility to have exact high resolution 3D–pictures of the ground surface. Combining geological information with these Lidar 3D–models give new possibilities to interpret the small scale features of the geological formations on the ground surface (Figure 6). This data is important for land use planning and construction projects. Reliable 3D–surface models of the ground with different soil layers are based on a large amount of costly soundings and drillings. When the amount of data points on the ground surface is about 1 – 10 points per square meter (Lidar) the reliable points of other

surfaces in the model (geotechnical investigation, bedrock surface, bottom surface of soft sediments) is about one point per 500 square meters as its best.

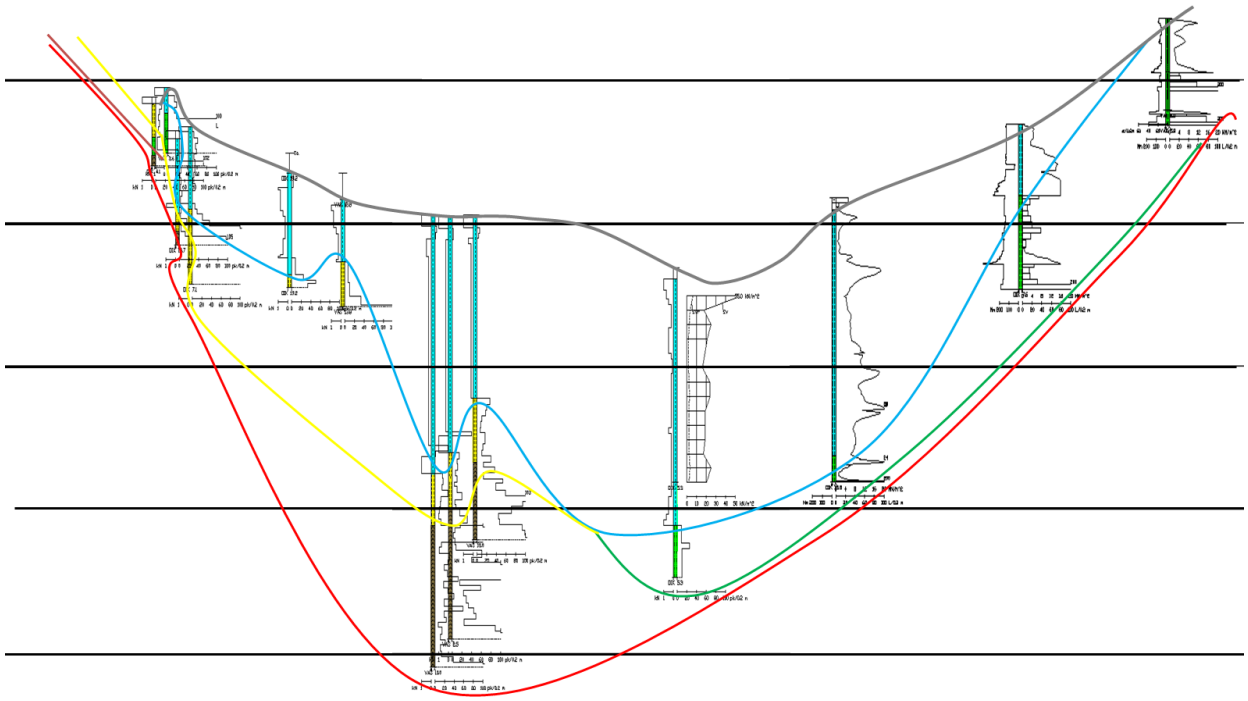
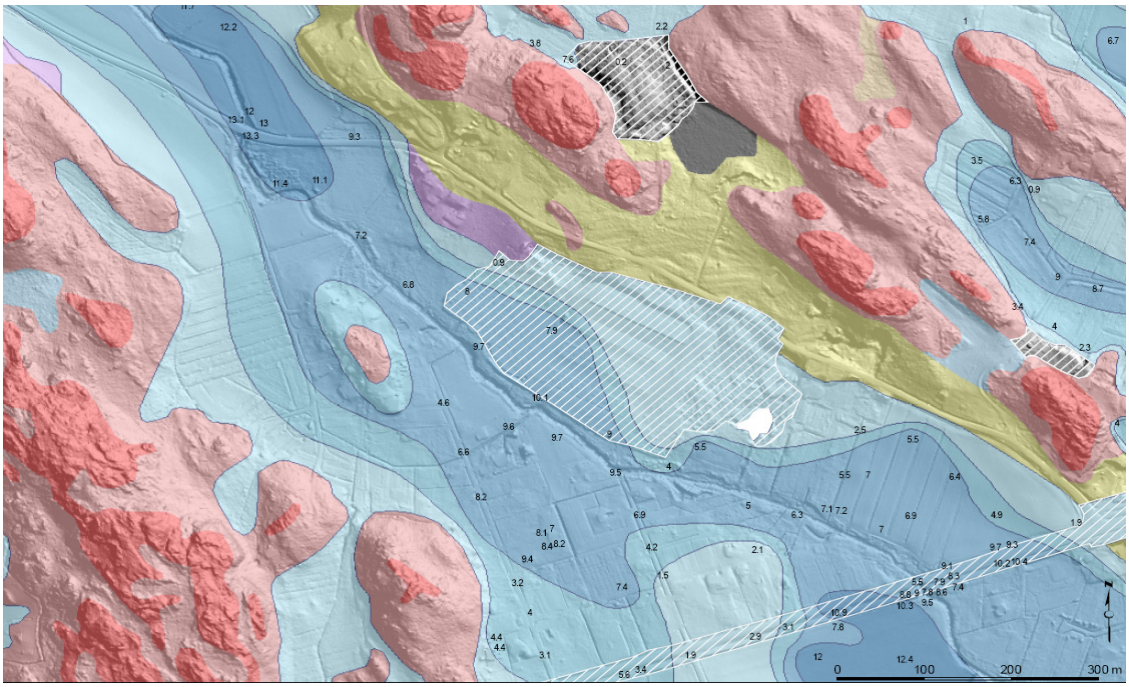


Figure. 5. Geotechnical investigations (weight sounding tests, percussion drillings, penetration tests (CPT-U), field vane tests, laboratory measurements) in gross section and interpretation of geological units. Blue=bottom of soft sediments, yellow and green=bottom of sand formations, red = bedrock surface, grey= ground surface. Height of the cross section is about 40 m and width 150 m.



Fiure 6. Map of Quaternary deposits and bedrock of Ostersundom area in Helsinki. Bluish colors = clay and other soft sediments, dark red= bedrock outcrops, pink= thin layer of moraine on bedrock (< 1 m), yellow= sand and gravel. Man maid fillings are cross hatched. Numbers on the places of soundings and signifies the depth of bearing bottom (moraine or bedrock, depth is also symbolized in the bluish colors and equal value lines). Map size about 2 km x 1.5 km. Geological Survey of Finland.

4. Urban planning and management

The Land Use and Building Act, which came into force in 2000 in Finland, shows three types of development plan: the regional plan, the master plan at the citywide or district level, and the detailed plan for individual sites [2].

The City of Helsinki's 2002 **master plan** covers the entire city [2]. It is essentially a land-use zoning map designating areas of land in terms of five broad categories (mixed metropolitan uses, housing, public utilities and technical services, commercial and recreation and parks). L**ocal plan** bridges the gap between the master plan and the detailed plan. The local plan outlines a development area's land uses and overall character, primary road network and transport connections, green areas, together with essential local services such as schools, nurseries, library, and local shopping facilities. The overall scale of development, maximum permitted floor space capacity, block plan layouts and parking requirements, all constitutes the central core of each local plan. The **detailed plan** level may vary from being a broad zoning document to an outline of a planning permission. Within Finnish city planning, this is deemed to

be the level at which control of development is implemented. It is only a detailed plan that has the legal sanction to establish development on a site or to change the land-use designation, although the master plan can determine land-use changes for larger areas. A detailed plan must broadly conform to the aims and policies contained within the city-wide master plan. The statutory master plan contains the guidelines for the detailed planning stage.

The Helsinki area is well suited to underground construction in rock because its bedrock is hard and located near the ground surface. As the urban structure becomes increasingly dense in Helsinki, various functions are placed underground more often. In recent years, the demand for underground facilities has grown dramatically in Helsinki's central city area. Helsinki's intent is to safeguard the continued utilization of its bedrock resources in connection with, for example, important traffic and infrastructure construction, as well as larger commercial projects. For this reason, the **Underground Master Plan** has been drafted in Helsinki (http://www.hel.fi/hel2/ksv/Aineistot/maanalainen/hgin_maanalainen_yleiskaava_kartta1.pdf) .

5. The Helsinki Underground Master Plan

Over a long period of time, the objective of urban planning has been to ensure the space for residential construction. Increasingly the lack of available undeveloped land areas for new buildings in the city's central area has been a problem like in all big cities in the world. The society has usually possibilities to expand both upwards and downwards. In the Helsinki area the downwards possibilities are considered as the most important option because the well known high quality of underground bedrock recourses. The hard and stable bedrock is usually very suitable for construction of different kinds of underground spaces. The use of rock construction in municipal facilities has brought up the possibility of replacing the above structures with corresponding underground facilities and thereby releasing the valuable land area above to be used for more important activities.

The Helsinki Underground Master Plan [3] (Figure 7) controls the locations, space allocations and mutual compatibilities of the newest, largest and most important underground rock caves, facilities and traffic tunnels. The Helsinki Underground Master Plan also safeguards the permanency and functionality of facilities already constructed. The Underground Master Plan contains 40 new areas reserved as rock resources and 100 new space allocations for future rock construction. Already built facilities are listed and classified. The Plan is a juridical plan binding property owners and public officials. The plan also serves as a guide when preparing aboveground zoning plans. Besides the space allocations indicated in the town plan map, future

construction is allowed as long as it does not conflict with the main underground functions indicated in the master plan.

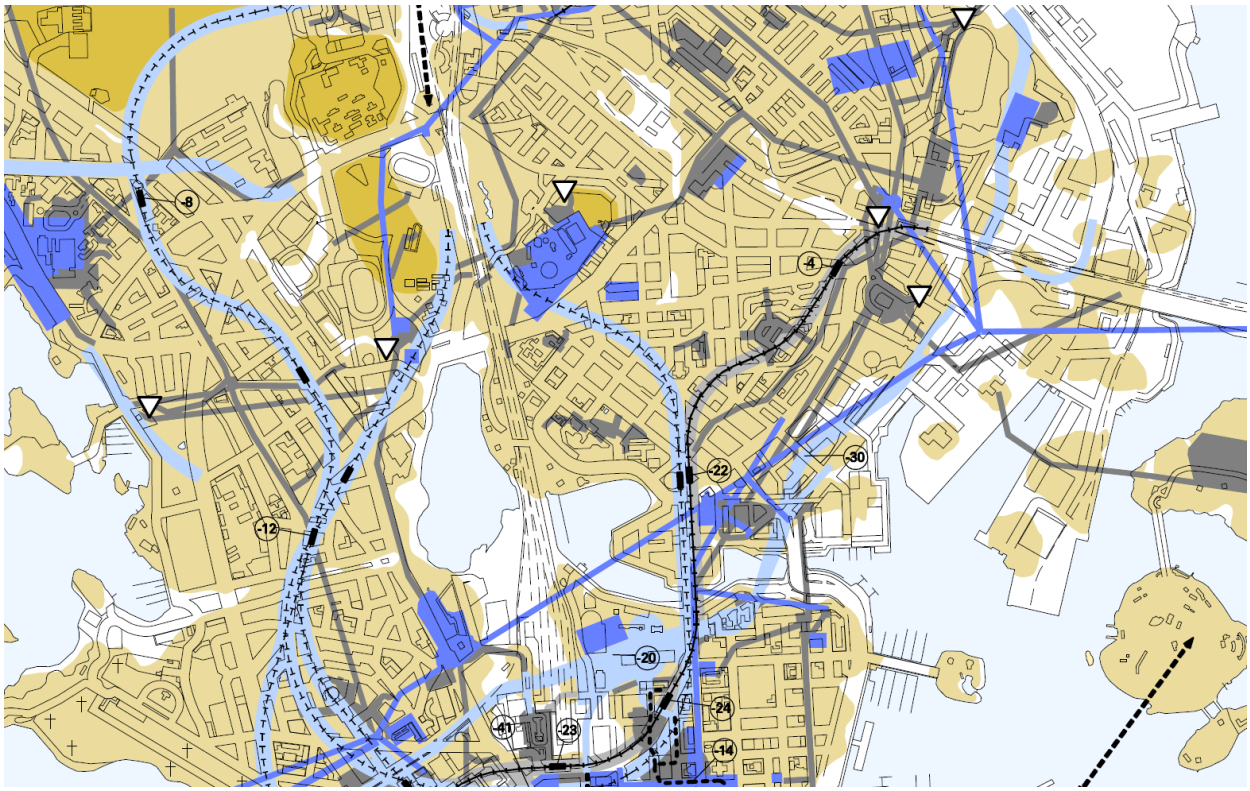


Figure 7. Map extract of the Helsinki Underground Master Plan. Grayish colors= current underground facilities and tunnels, bluish colors= planned future underground tunnels and facilities, brown= bedrock resources near the surface suitable for the underground construction, white triangles = access tunnels to underground spaces [3].

Underground reservations and existing facilities/tunnels have been divided into the following categories on the basis of their main purpose:

- Community technical systems
- Traffic and parking
- Maintenance and storage
- Services and administration
- Unnamed rock resource (does not yet have a designated purpose)

The reservations in the Master Plan are divided into the following four planning levels:

- Project plan
- Needs specification
- Provisional space requirement
- Space requirement

5.1. Ownership and rights of the underground

According to the law [5], the owner of a property has control over the underground part of the property, though the vertical extent of ownership is not specifically defined in legislation. When interpreting the extent of ownership, the lower boundary of a property has been limited to the depth where it can be technically utilized. In practice, this means the depth of 6 m from the lowest point of the building lot. The City of Helsinki charges also those companies using underground space, but the rent of “the underground building lot” is only c. 50% of the corresponding ground-level rent. Anyone constructing facilities underground must obtain agreement on the right to use the underground construction site. Right of ownership can be established either through voluntary transactions, agreements or redemption based on legislation. The prerequisite for obtaining a building permit is that the applicant has control over the construction site.

6. Bedrock resources and space reservations

In general, the bedrock in Helsinki is not far below the ground surface and therefore there are plenty of reasonable and safe locations suitable for the construction of underground facilities. An initial survey examined elevation levels and the areas in Helsinki suitable for the construction of large, hall-like spaces. To measure the bedrock resources, a model based on rock surface data was used applying a standard-sized measurement cave (WxLxD=50x150x12 meters). The model of the bedrock is based on base map data for exposed rock and land surface elevations; point data were obtained using drill machine borings (Figure 8). The survey also took into account local weakness zones and rock resources that have already been put to use [7].

The Underground Master Plan contains 40 new areas reserved as rock resources and 100 new space allocations for future rock construction. Outside the city centre 55 rock areas are found

that are sufficient in size to accommodate large underground facilities near major traffic arteries.

In many areas, future underground projects can make use of entrances to existing underground facilities, which have been marked with triangles on the Master Plan map. It is worth mentioning that thermal energy from bedrock is also a valuable resource. In general, it can be said that the bedrock in Helsinki is not far below the ground surface, and that there are plenty of reasonable and safe locations suitable for the construction of underground facilities.

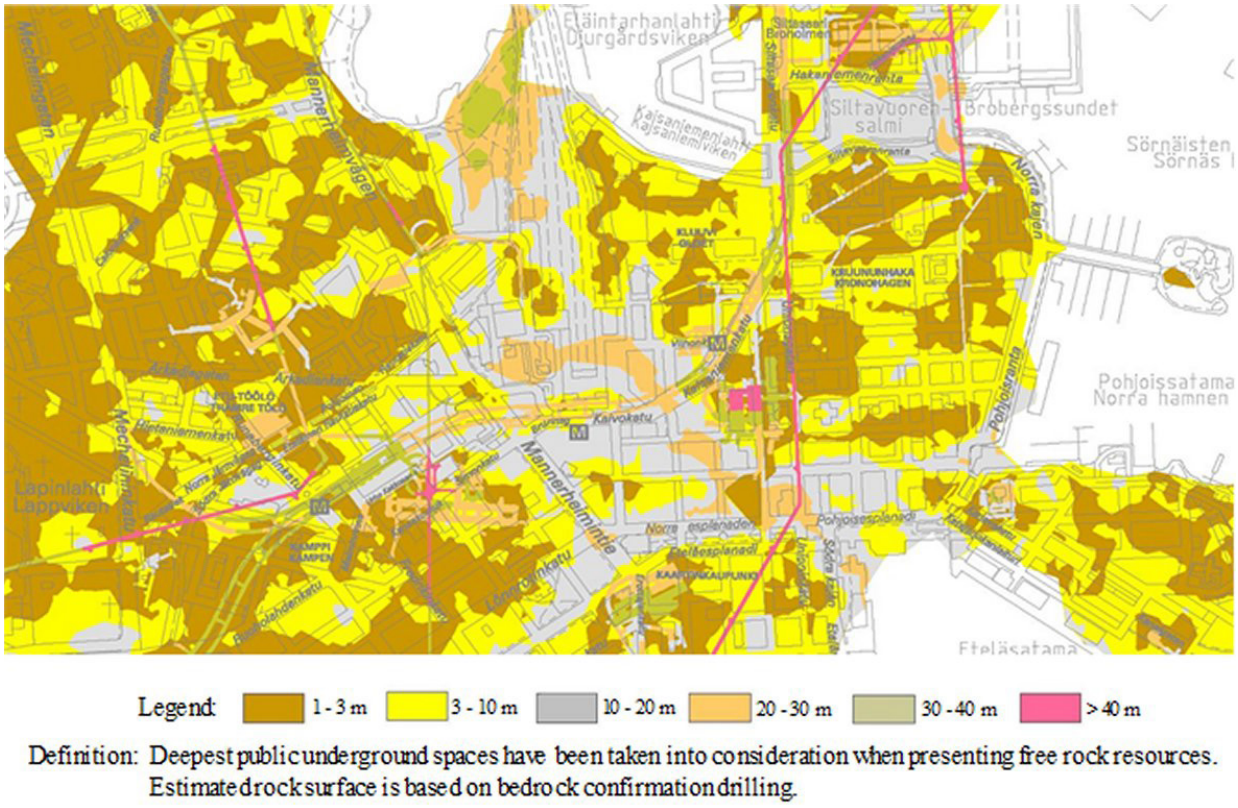


Figure 8. Map of bedrock resources in the Helsinki city center area. An Extract of the Rock Surface Model. (Image: City of Helsinki, Real Estate Department, Geotechnical Division).

7. Underground construction

The City of Helsinki has more than 200 km of technical maintenance tunnels, 60 km of which are utility tunnels used by a number of operators. Utility tunnels have been built since 1977 and house transmission lines and pipes for district heating, district cooling, electricity and water supply systems, as well as a large number of different cable link.

The raw water for the Helsinki region comes from Lake Päijänne (to the north of Helsinki) via a more than 100 km long rock tunnel.

Wastewater treatment is carried out centrally at the Viikinmäki underground wastewater treatment plant (Figure 9). The plant began operating in 1994. It replaced more than 10 smaller treatment plants, all above ground, thus allowing these sites to be zoned for more valuable uses. The Viikinmäki residential area with 3,500 inhabitants lies above the tunnels. It is located less than 10 km from the centre of Helsinki. The plant treats 280,000 m^3 of wastewater from about 750,000 inhabitants daily. The wastewater arrives at the plant via an extensive tunnel network. The treated wastewater is then discharged into the sea via a rock tunnel whose outlet is about eight kilometers off the coast. The tunnels in the treatment plant have a capacity of more than 1,000,000 m^3.

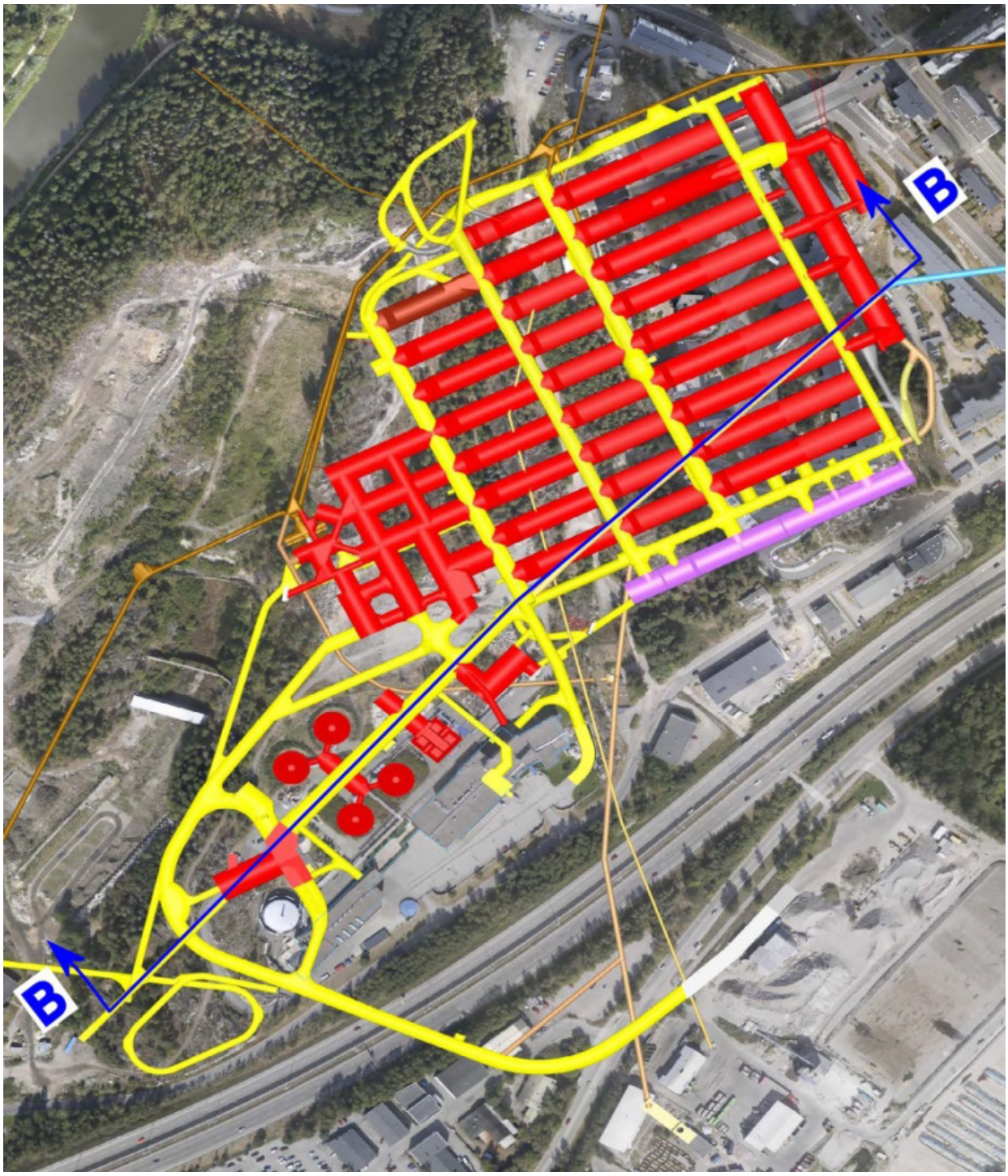


Figure 9. An aerial view of the Viikinmäki wastewater treatment plant. (Image: City of Helsinki Real Estate Department).

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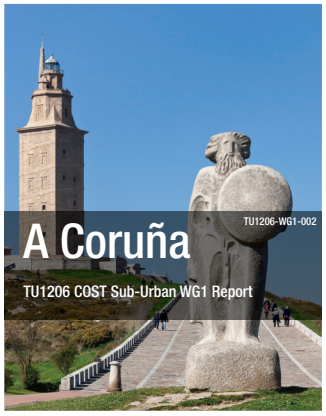

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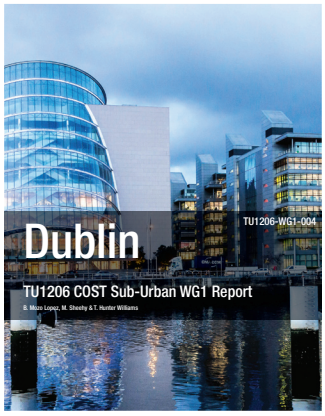

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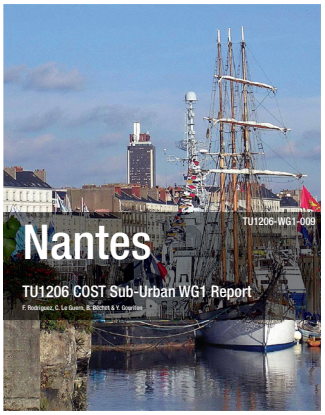

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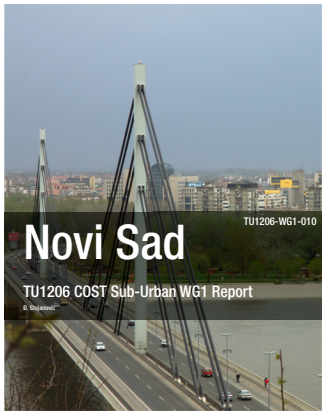

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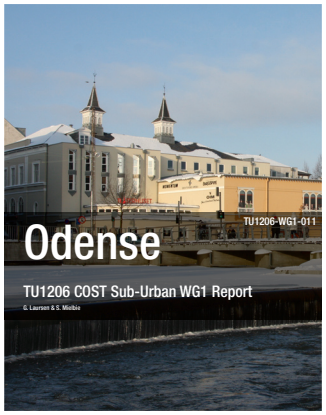

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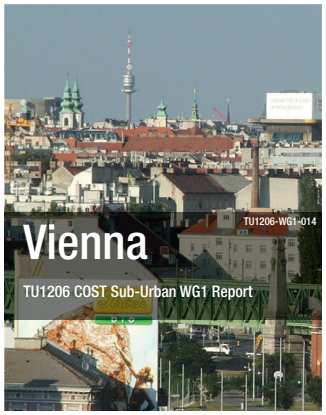

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