PATHWAYS & PITFALLS TO BETTER

SUB-URBAN PLANNING

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"The vision is for Future Cities that live sustainably and in harmony with the ground they are built on. Relevant policy at local, national and trans-national scales will be needed to support this.»

Dr Diarmad Campbell

GEOLOGICAL SURVEY OF NORWAY
- NGU -

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

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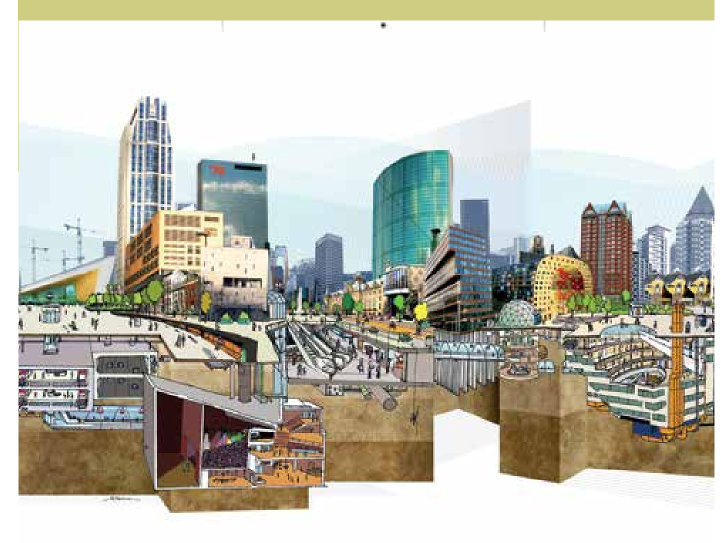
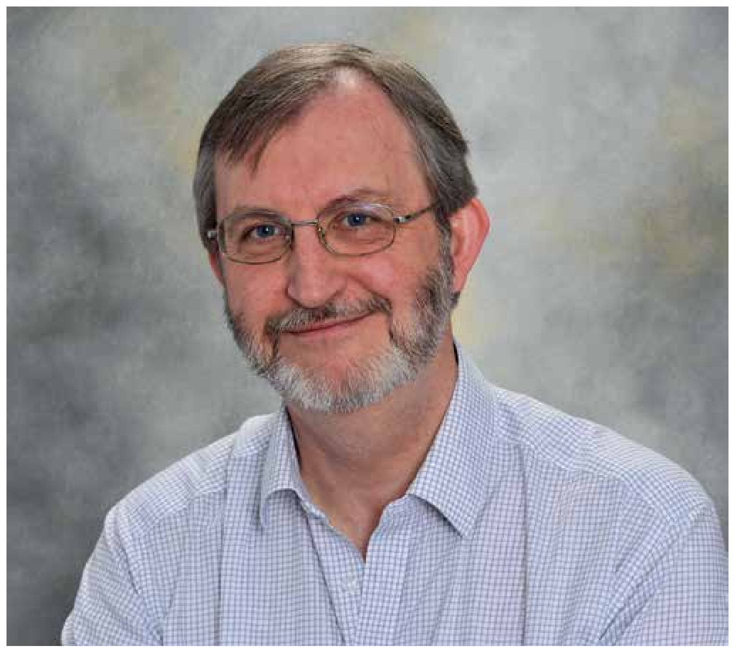
"For urban planners the subsurface remained synonymous with costs and delays"



"Can Ljubljana exploit the heating and cooling capacity of the groundwater?"

A word from the Chair:

Dr Diarmad Campbell
Chair of COST Action TU1206 Sub-Urban,
and Chief Geologist, Scotland at the British Geological Survey



In addressing the world's huge future challenges, the opportunities and constraints presented by the ground beneath cities, must not be over-looked. The subsurface can contribute greatly to development of Future Cities. But we can only do so if it is well enough understood by decision-makers, and its benefits used sustainably, and safeguarded for generations to come. Better urban subsurface knowledge, and its communication to decision-makers, has been the focus of the COST Action Sub-Urban.

The world's cities grow at an extraordinary rate – about 60% of humans will be urbanized by 2030, rising to 80% by 2050. The World Economic Forum (2016) estimates 60% of the area expected to be urban by 2030 hasn't been built yet. This pace of growth is potentially overwhelming. Achieving sustainable cities and communities is therefore one of the world's great challenges. Goal 11 ("Sustainable Cities and Communities") of The United Nations' 17 Global Sustainable Development Goals for "Transforming our world: the 2030 Agenda for Sustainable Development" acknowledges this.

Ambitious agendas are addressing these challenges. Digital data and sensor technologies lie at the heart of the SMART CITY revolution, and urban blue-green solutions, and uses of renewable and decarbonized energy systems are gaining favour. However, these initiatives largely focus on cities above-ground. The world beneath cities remains largely "Out of Sight, Out of Mind". Such an incomplete view of cities will overlook key constraints and miss valuable opportunities for sustainable development.

The vision is for Future Cities that live sustainably and in harmony with the ground they are built on. Relevant policy at local, national and trans-national scales will be needed to support this.

Adequate knowledge and understanding of the ground that cities are built on is essential. Although every city has its own unique typology, there are common themes and approaches that can be shared. This basic premise lay at the core of the COST Sub-Urban Action. Most European cities lack knowledge of their subsurface, but when this is available, early-stage intervention is crucial. Good practice, sustainable and innovative subsurface uses can thus emerge, and resources can be safeguarded. Ultimately, subsurface use must be planned, integrated, and managed with those above ground. They must also be considered in other largely above-ground agendas (SMART CITY, 100 Resilient Cities, JPI Urban Europe).

To achieve this transformation, better communication is essential, commitment of key stakeholders vital, and better sharing of subsurface data and knowledge key. Legislation can also lever this process. Meanwhile, digital transfer of subsurface data in standardized formats will bring the subsurface into line with data flows above ground. Geological surveys are well-suited to manage these data, other strategies are also viable, with greater roles for other research organizations, the private sector, and the cities themselves.

When digital subsurface data are readily available, increasingly sophisticated modelling becomes possible, and decisions better supported, even in "real time" with sensor data. GEOCIM, proposes City Quarter to Conurbation models that combine subsurface and above-ground models to enable: holistic urban planning; improved management of environmental impacts and geohazards (flooding, landslides); identification of subsurface opportunities (heating and cooling), and; economic benefits from reduced construction overspend and delay.

Sub-Urban's progress in Europe is being replicated elsewhere in the world. China has a national programme for collaborative use of the subsurface, and city-scale subsurface projects are underway in SE Asia and India. Sub-Urban's European solutions are having global application.

BGS 1835 British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Up on the downside?

Subsurface issues concern urban transitions

Jonas Bylund, JPI Urban Europe Management Board

As a science-fiction buff, whenever there is talk of the underground I tend to think of Asimov's hyper-urban settings in Caves of Steel or the city-planet Trantor in the Foundation series. Fantasy cityscapes that permeate Western and Asian popular culture, like those imagined by the creators of Blame! and Knights of Sidonia, all explore forms of human life. Common to these stories is that the underground is where we organise most of our city life, beyond over- or underground, towards the question of being outside or not. These visions have a paradoxical resonance in the Sub-Urban COST Action: current urban subsurface expansion is pursued precisely because we need to save the surface 'for the one function that cannot do without daylight and fresh air: living.'(Van der Meulen, et al., 2016).

Indeed, to support sustainable and liveable cities and urban regions it is pertinent to increase overall awareness about the expansion of infrastructures and systems 'downwards' to free the urban up-side for green open spaces, for Nature-Based Solutions, for walkability, for public spaces where humans can be both 'climatised' and attuned to what connects us all (Serres, 1992). Hence, the zoning on a 2D Euclidean territorial map – still seemingly the image of what planners 'do' by many urban experts – must go technicolour, so to speak. 3D mapping and monitoring of urban areas in all directions becomes common-sense. It makes sense, not just because this is a development in urban spatial practices, but because downward expansion is crucial to any integrated approach to urban sustainability transitions.

As the Sub-Urban COST Action makes clear, the urban subsurface space in most of Europe, if not all over the world, is layered with history and records of past urban ways of life, at times intertwined with current uses:

> *Many, if not most of the reasons for cities being where they are actually relate to past and ongoing geological processes, which determine landscape and the presence of resources. The subsurface is the product of these processes, and represents a hidden but integral part of the urban environment (Van der Meulen, et al., 2016).*

JPI Urban Europe has a stake in this with the ambition to be a knowledge infrastructure. The initiative supports urban research and innovation in ambitious intra- and transdisciplinary activities on a transnational scale. In this, JPI Urban Europe also aims to function as a gateway for knowledge on urban transitions towards sustainable and liveable urban futures, and to facilitate research on a scale which simply could not be carried out by any one national programme alone.

So, whether we look at the UN Agenda 2030 Sustainable Development Goal 11 or at practical workability and infrastructuring in local urban innovation ecosystems, at the current digitisation transitions in societies at large around Europe and globally, or capacity building in public administrations to take the lead in urban transformations, the subsurface is part of the landscape where we need to 'connect the dots' among urban imaginaries, sectors and silos, and logics for pathways (JPI EU, 2017).

What we must also take note of from the Sub-Urban COST Action is that having city authorities and public administration on board is imperative and a good benchmark for other actions and networking activities. So that urban researchers and innovators or any other group of stakeholders do not unwittingly sweep issues and challenges under the rug, so to speak, the co-creation with the affected groups – where you desire impact – is of utmost importance.

In this respect, the Sub-Urban COST Action shows that the urban subsurface is not about science fiction anymore. While we are certainly devoted to tackling the challenge of our skies falling upon us at any moment (climate change and the Anthropocene!), we cannot afford to lose sight of the ground beneath our feet.

URBAN EUROPE

Urban underground space is about connectivity

Han Admiraal, co-chair ITACUS

Human interventions below the surface date from long before the start of the Common Era. The Neolithic Flint mines found in Norfolk, UK, date back as far as 3,000 years BCE. Human occupation below the surface can be traced back to 221 BCE and the Qin Dynasty with the excavation of the house caves or "yaodongs" in China. What these interventions have in common is that they represent humankind colonising the subsurface without much thought other than the primary goal of the intervention itself, extraction of materials or creating physical space for habitation.

Not until the 20th Century did our understanding of the subsurface as the foundation of life through ecosystem services start to compete with the concept of the subsurface as an exploitable resource. With the advent of the 21st Century, we have entered the Anthropocene, the era where human interventions are influencing the Earth's processes and cycles. At no time in history has the necessity for humankind to balance its actions and find harmony with nature been more apparent.

Striking this balance also holds true for the use of underground space. Rather than intervening below the surface in an unplanned way and extending the colonisation through the power of technology, planning is required based on an underground urbanism. The big question in this respect is how the subsurface contributes to the urban metabolism. It is this question that mystifies most urban planners as without knowledge of the subsurface, the domain of geologists, and of possibilities, the domain of the engineer, it is almost impossible to conceive how the relationship between surface and subsurface can contribute to the future of our cities.

Connectivity is critical in this respect. Planners, geologists and engineers need to connect and engage, creating a joint understanding of the role of underground space in sustainable urban development and urban resilience. It is for this reason that ITACUS has developed an international network, working together with the planners through ISOCARP, with municipal engineers through IFME and with local decision makers through ICLEI.

The urban planner's task is not just to plan what is possible or what is already occupying the subsurface; this is exclusionary planning limited to the benefits of the few. The real challenge, one that we are only just beginning to understand is to plan inclusively, benefitting the masses in ensuring that through connectivity, underground spaces and networks form a new tissue that contains open and accessible public spaces. Only in this way can underground space integrate with the urban fabric.

itacus
for an urban underground future

Acknowledgements

Guri Venvik (COST Sub-Urban Participant, NGU)
Anne Liinamaa-Dehls (NGU, Formerly IUGS Secretariat, 1997-2016)
Cecilie Bjerke (NGU)

This brochure provides basic information about the work of the COST Sub-Urban network. Much of the text is based on publications of the network.

Scientists are usually able to communicate to like-minded nerds, and occasionally manage to trigger the interest and curiosity of those outside their field. Assisting non-specialists to understand all the jabbering might be even more challenging. We, a team of three women with different backgrounds and understanding have had a go. We hope that you will be interested in the result: The Sub-Urban glossy paper "Pathways & Pitfalls to Better Sub-Urban Planning". With each page of this document we strive to convince the reader that subsurface processes and elements, both manmade and natural, have a great impact on all our daily lives. Particularly, the stories from five cities presented in the latter half of the brochure is our attempt to decode the language of the subsurface specialist. We hope those stories will be of interest to non-experts.

We would like to thank all the members of the COST Sub-Urban network for the great collaboration since 2013 and onwards and especially thank those who were willing to contribute with their input to our writing experiment:

Diarmad Campbell (Chair of the action, BGS), Gert Laursen (Odense Municipality), Johan Linderberg (VCS Denmark), Susie Mielby (GEUS), Ingelöv Eriksson (Oslo Municipality), Mitja Janža (GeoZS), Ignace von Campenhout (Rotterdam Municipality), Jeroen Schokker (TNO), Carl Watson (BGS), Gillian Dick (Glasgow City Council), Helen Bonsor (BGS, NERC fellowship), Jonas Bylund (JPI Urban Europe), Han Admiraal (ITACUS) and Gudmund Løvø (NGU).

From the women behind the glossy paper,

Guri, Anne and Cecilie
April 2018

GEOLOGICAL SURVEY OF NORWAY
- NGU -

Sub-Urban

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

The old warfts in Trondheim, Norway. Photo: Aziz Nasuti

How it all began...

Sub-Urban was initiated in 2013, as a COST Action (TU1206), with the intention of **improving understanding and use of the ground beneath our cities.** The Action emanated from an initiative within the EuroGeoSurvey's Northeast Atlantic Geoscience Group, recognizing the increasing importance of urban issues within their strategies, especially of the impact being achieved by a multi-disciplinary project CUSP (Clyde-Urban Super-Project) then nearing completion at the time by the British Geological Survey. CUSP concentrated on the City of Glasgow (UK) and its surrounding catchment and was led also by the Sub-Urban Action's proponent.

COST is supported by the EU Framework Programme Horizon 2020

COST Action TU1206 **Sub-Urban** (2013-2017)

"COST, European Cooperation in Science & Technology, is the longest-running European framework supporting transnational cooperation among researchers, engineers and scholars across Europe. It is a unique means for them to jointly develop their own ideas and new initiatives across all fields in science and technology, including social sciences and humanities, through pan-European networking of nationally funded research activities. COST is supported by the EU Framework Programme Horizon 2020". See http://www.cost.eu and

http://www.cost.eu/COST_Actions/tud/TU1206

The aim of the Sub-Urban group

The Sub-Urban group set out to explore, promote and improve the use and management of the urban subsurface and the use of subsurface information in urban planning. Technical experts often speculate or philosophise about the needs of planners and policy makers they wish to serve, who in their turn speculate about, or are unaware of, technical (im)possibilities. The Sub-Urban COST Action has arranged interaction between the two, allowing all participants to keep to their trade, and to bring in what each does best. Even though (potential) providers and users of urban subsurface information do of course consult with each other, Sub-Urban has enabled a level of exposure between the two that is rare, both in duration and depth. The Sub-Urban group aimed to identify options for cities to grow and develop more sustainably, and to increase the predictability of ground conditions that are now considered unforeseeable.

A first general lesson learned from the whole exercise is that the Sub-Urban group has created a community of practice between the geoscience and planning communities, involving cities, universities and institutes. The municipal representatives who are taking part in Sub-Urban have found the interaction amongst themselves inspiring and useful. To some extent, the conditions for urban subsurface planning are already improving, especially where communication, mutual understanding and awareness raising are concerned. For better impact, however, this will have to be extended to decision makers, urban stakeholders and the public (www.sub-urban.eu).

As the critical mass of city decision- and policy-makers that is better aware of the subsurface and its sustainable use expands, the potential for higher level policy consideration of the subsurface grows, and a wider range of impacts will become achievable.

What is Sub-Urban?

The COST Sub-Urban Action (www.sub-urban.eu) has had the fundamental aim of closing the knowledge gap between subsurface experts and potential users of subsurface knowledge — urban decision-makers, practitioners and researchers. The Action assembled a network involving 31 countries, 26 actively participating cities, researchers, practitioners and urban decision-makers, to bring together the fragmented research current across Europe in sustainable urban subsurface use. Development of national exemplars has also been encouraged to inspire others by using a lighthouse-follower approach to cascade knowledge and good practice across Europe, and further afield.

Initially, expert groups from both sides of the knowledge gap were brought together to assess and synthesise the state-of-the-art in lighthouse cities in terms of urban subsurface knowledge, understanding, and use of that knowledge. This was achieved with 19 City Studies, with findings assembled in an over-view report "Out of Sight, Out of Mind" http://sub-urban.eu/city-studies/.

Expert sub-groups then identified good practice in subsurface data and knowledge locally, nationally, and Europe-wide. Their findings are highlighted in the synthesis report "Opening up the subsurface for the cities of tomorrow" and expanded on in seven topic review reports. These also identified key gaps in knowledge, and its use. A new concept, GEOCIM (Geo City Information Modelling) emerged for City Quarter to Conurbation scales, combining subsurface and above-ground models. Much like Building Information Modelling (BIM) which is growing in use in construction projects, GEOCIM will enable: a) holistic urban planning; b) identifying subsurface opportunities; and c) saving money and time by reducing uncertainty in ground conditions.

Finally, the Action's reports and outputs were integrated in an online toolbox, available on the Action's website (www.sub-urban.eu/toolbox). The Sub-Urban Toolbox, which is being developed further, promotes and disseminates good practice, and decision-support tools: a) to inform and empower city decision- and policy-makers about the urban subsurface and the vital importance of its early-stage consideration; and b) accelerate uptake amongst subsurface experts of subsurface data and modelling workflows. Users with different backgrounds and needs, require different access to, and appropriate translations of, the Sub-Urban Toolbox. Therefore, different entry points are provided for subsurface technical experts, urban planners, and decision- and policy-makers.
(Map Journal)

– why consider the subsurface in urban planning?

The subsurface is an important constituent of the physical environment of cities. We live on top of it; building and construction must deal with the structure and properties of the subsurface, and occasionally with the hazards it presents. Cities not only expand outward and upward, but also downward. More and more, subsurface space is used to relieve the increasingly crowded and congested urban surface, especially for networks, storage, and exotic applications such as shelter and protection. The more use we make of subsurface space, the more surface space we free for the one function that cannot do without daylight and fresh air: **living**.

OUT OF SIGHT, OUT OF MIND?

Out of sight, out of mind?

The subsurface's ability to record is a function that is particularly relevant to the urban domain. Just as rocks are a record of the geological past, the urban subsurface physically records the history of cities. Buried cultural heritage needs our protection, whether by preventing its degradation in situ, or by careful excavation before building and construction take place. The subsurface also reflects industrial legacies and their impacts in the form of polluted soils or unstable mine shafts. The importance of knowing the ground beneath cities may seem self-evident, but the urban subsurface is in fact still largely 'out of sight, out of mind'. It does not present a daily concern to city planners and managers, and when it does, there is often trouble.

The subsurface holds resources. Groundwater requires protection from urban pollution, and its exploitation and management – even when this occurs outside the city proper – may affect urban ground conditions. These challenges are evident in the examples from Ljubljana and Odense. Minerals, especially building materials, are typically quarried close to urban areas, restricting land use and creating stability problems when the cities grow over the sites that once yielded their resources. Mining, an industry that has been on decline in Europe for decades, evolved from a source employment to a source of concern, as abandoned shafts have caused subsidence and sinkholes in and near former mining towns. Glasgow city gives examples of how they solved such challenges.

Why consider the urban subsurface?

Cities are where they are for a reason. You will find them near water and arable lands, at military or logistically strategic points, or near mineral resources. After their establishment, world history and their own dynamics made cities what they are today, determining whether they are: small or large, powerful or peripheral, cosmopolitan or isolated, prosperous or poor. A city's competitive advantage may turn into a disadvantage. The river that was once a source of drinking water and food may be now a transport pathway or contribute to urban flooding. The mine that once brought prosperity may now bring instability. The location of most of today's cities is connected to the past and ongoing geological processes which determine landscape and the presence of resources. The subsurface is the product of these processes and represents a hidden but integral part of the urban environment.

Zooming in, the most practical importance of the subsurface is in the fact that a city is built on top of it. Building and construction deals directly with the structure and properties of the subsurface: the subsurface may determine what can or needs to be constructed, and where, and basically sets boundary conditions for design. The subsurface not only presents stability for constructions (or a lack of it), it also presents space. Intensification of urban land use and mobility leads cities not only to build up and out, but also down.

> ***"The subsurface does not present a daily concern to city planners and managers, and when it does, there is often trouble."***

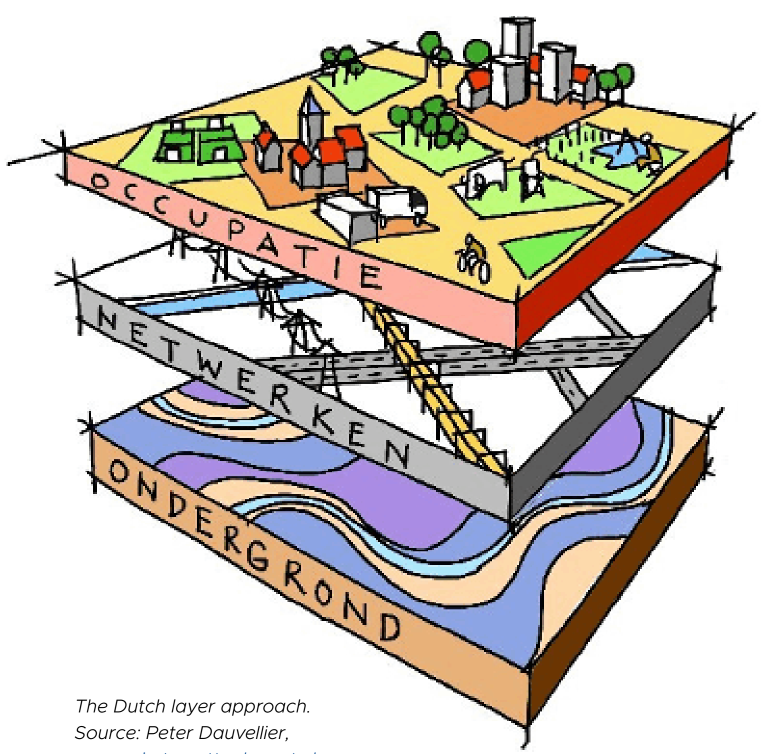
… so why don't we?

General awareness of the subsurface below cities typically only exists when either great opportunities are presented, think of boomtowns like Kimberly (diamond mining) and Dawson (Klondike gold rush), or great risks, for example in San Francisco (the San Andreas Fault) and Naples (the Vesuvius volcano). However, in the much more prevalent but less spectacular cases, beneficial subsurface conditions are taken for granted, and the subsurface is only considered when adverse conditions manifest themselves, in which case they often referred to as 'unforeseen'. So, the subsurface most often means nothing or trouble.

In the past, the typical response of a geoscience professional hearing about such trouble was, 'I could have told them, if they had just asked me.' Even when accurate, there is an element of self-serving in offering such wisdom in hindsight, which we feel should be replaced by a sense of an opportunity missed. We see rapid advances in the applied earth sciences and geo-information management, which we hope will ultimately make the term 'unforeseen ground conditions' something of the past.

What do we know?

Altogether, urban subsurface use is primarily a matter of knowing what one builds on and making optimal use of the additional urban space it offers. So, if one wants to know what the subsurface is like for urban planning purposes, who should one turn to? The traditional custodians of subsurface data and information are geological surveys. However, the geological map, which has been their prime output since the 19th century, doesn't usually show city geology. Cities will mostly not have been surveyed and are simply shown as 'built up'. But this situation is changing in two important ways. Firstly, geological surveys have started to work with third-party data, and are now starting to tap into and make sense of, the vast amounts of subsurface data that are acquired in cities, for instance in the preparation of building and construction projects. Secondly, there is a shift from 2D to 3D information products: a geological map is a representation of what geology is at or near the surface, but in cities you will want to know what lies beneath as well.

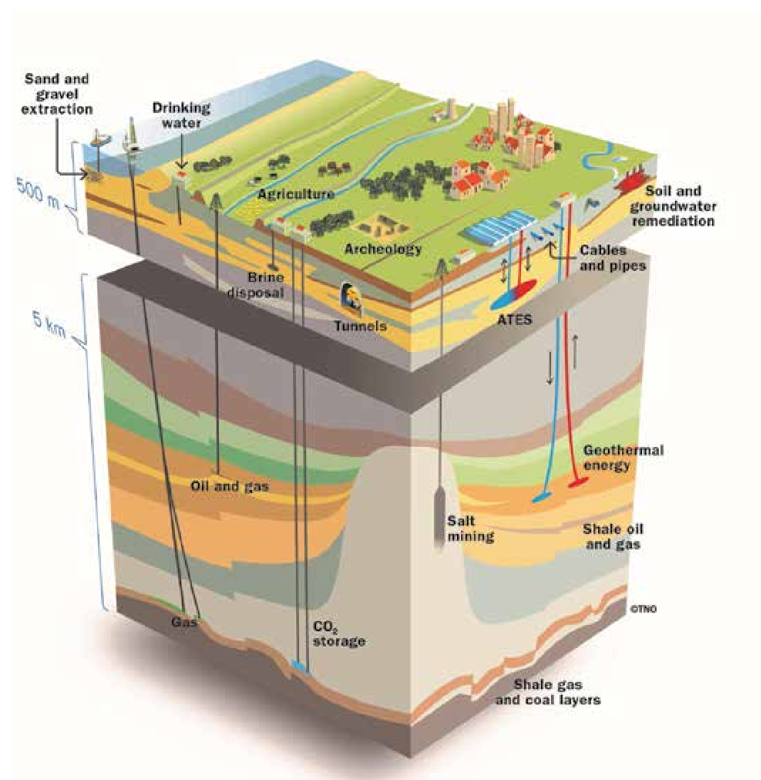


The Dutch layer approach.
Source: Peter Dauvellier,
www.ruimtemettoekomst.nl

The layer approach, a Dutch spatial planning concept that distinguishes between three layers, conceptual rather than physical, each having its own combination of properties, functions and dynamics. Buildings, and other primary land use functions are in the occupation layer. In terms of residence time and change, these functions are more dynamic than the transport infrastructure and utilities networks that connect them, and are put in the network layer. The subsurface layer is the least dynamic, not only because of the long life of underground constructions such as tunnels and mines, but also because geological processes such as deformation and groundwater flow are distinctly slower than superficial environmental processes we are more used to.

What is the challenge?

Irrespective of the application – urban or another domain – it takes time to get to know the subsurface. On a site scale and in the shallow subsurface (less than tens of meters below the surface), it is a matter of commissioning a ground investigation project. Such projects, typically conducted by engineering agencies, are not only site-specific but also problem specific, and in principle yield a one-off result. When, however, one wants to extend subsurface knowledge to the city in its entirety, and go deeper, a systematic rather than a project-based approach is mandated. This is how geological surveys are used to operate, making sure that a base level of geological information is there when it is needed. This is basically a matter of answering unanswered questions, simply because if one wants a geological map or a comparable product, it can only be delivered if it is already there. We argue that to serve the needs of city planning, systematic 3D mapping is required. This must incorporate third-party data, and it must be attuned to city needs. Geological surveys will have to accept and get used to this new responsibility.



Good management helps us save money.
Source: TNO

As a rule of thumb, in the deep surface we make money; in the shallow subsurface we avoid costs. This implies that the main financial benefits of using and managing the urban subsurface is in avoiding costs. In a broader sense, urban subsurface allows cities significantly to improve quality of life.

"no-man's land"

The outcome of the studies also mention gaps and limitations, one of which seems to be so generally acknowledged that it cannot go unmentioned here. The shallowest urban subsurface, referring to the zone of human interaction also due to constructions such as underground infrastructure and foundations, represents a physical separation between the subsurface and the world of urban planners, which focusses on the surface and above. Unfortunately, it also represents sort of a "no man's land". It is out of the comfort zone of urban planners for the mere reason that it is below-ground ('out of sight, out of mind'), as well as that of geoscientists: it is the subsurface, which is OK, but it is artificialized beyond their understanding. The exploration and characterisation of made ground presents a joint opportunity to further subsurface planning. Equally challenging is the 'urban scale': the urban environment is, compared to the scale at which subsurface geology is typically resolvable, a very detailed one and the expectations as to the resolution of subsurface model information are high.

> ***"Not only does information need to be fit-for-purpose, ready to be digested by planners, it also needs to be available early in the planning process."***

Baseline city needs

Beyond good practice and gaps, there are baseline needs when it comes to considering the subsurface in urban planning. At the highest level, as (pre)conditions for informed decision making. This means mutual understanding and communication between the planning and geoscience communities. To this, we add timing as a crucial element. Not only does information need to be fit-for-purpose ready to be digested by planners, it also needs to be available early in the planning process. Unless you are talking about new ground investigations or exploration, geological data and maps and/or subsurface models need to be readily available, at least in part, for early planning. Timeliness and readiness imply that considering the subsurface in planning urban requires all parties involved to be forward looking.

Common ground for comparisons?

Cities that tell their story here share some common ground. Our selection does not include cities that are very poor, very big, or (geologically) very dangerous. The cities share issues related to water, as well as those shared characteristics that primarily stem from being European. This implies that our cities are:

… **at least** several centuries old. Buried or superficial, all cities in our selection have cultural heritage that needs protection and exerts influence on town development. Our towns also share a number of historic events that determined, to a varying extent, their development, including for instance unification in the EU, the Cold War and its aftermath, two World Wars, and the Industrial Age.

… **redeveloping** rather than (strongly) developing. Population and economic growth rates in Europe are both in the order of about 1%. At such low overall growth rates, the focus in urban development is on maintenance and improvement, presenting a marked contrast with for spectacular urban growth in for instance Brazil and China.

… **post-industrial.** Most, if not all European cities have had seen more heavy industry in the past than at present, and industrial legacies present great redevelopment challenges.

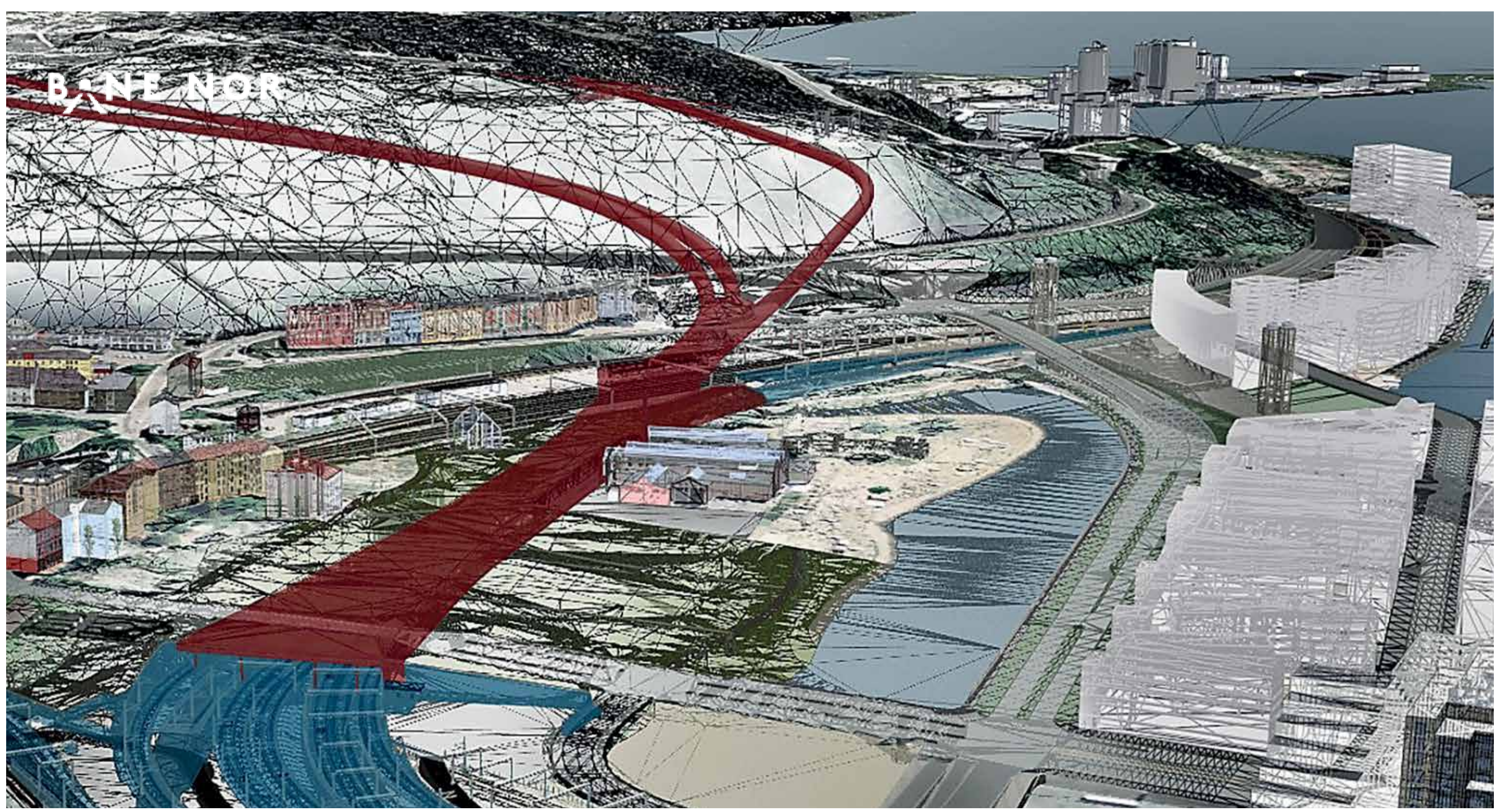
… **presently** under a fair to strong planning control. EU regulations on, for instance, environmental and public health, require a level of control on life in the city and on how a city develops. Beyond that, cultural differences prevail, e.g. between the post-communist and Scandinavian strong planning traditions, between the more liberal approaches to planning seen in Southern Europe, the northwestern countries taking an intermediate position.

… **prosperous**. Even though Europe is recovering from a crisis, and notwithstanding the fact that the economies in Northwestern Europe are stronger than the ones in the south and east, our cities are prosperous. The standard of living is fairly to very high.

Opening discussion of the subsurface

Open discussions about the challenges and opportunities of the subsurface are important for creating solutions. It is important to listen to each city's "story" to attain a general understanding. Most cities no matter their geographical location, economic or political status face similar difficulties.

The estimated cost of the 21 km long, high-speed Follo-line will be about € 3 bil. 19 km of the line runs through an underground tunnel between Oslo and Ski. At their closest the distance between the car tunnel and train tunnel is 1.5 meter.



In this drawing the blue represents above-ground line and the red represents the tunnel under the city's Medieval Ruin Park.

"In 2017, Oslo grew faster than any major city in Europe."

OSLO
THE VALUE OF THE SUBSURFACE

Fast-growing, fast-changing Oslo aims to be a liveable city that is resilient to economic, environmental and social challenges. An important resource is the subsurface, where the hidden workings of any city lie. The subsurface provides transport and storage for water, sewage, electricity and central heating – all services that a modern city depends on. Water held in the subsurface serves to stabilize older buildings and preserve cultural heritage.

The subsurface is also a source of building materials and renewable energy. The subsurface is often ignored and undervalued even though it contains infrastructure worth billions. The challenge is to realize the possibilities of the subsurface without disrupting the complex systems that support the city. Urban planners in Oslo are calling out for clear legislation to allow them to best manage the subsurface and face future challenges.

Geology meets City

Early Oslo settlements were built on an old seabed characterized by thick layers of unstable and sensitive marine clays. These layers are overlain by remains of past settlements, mostly organic. An anthropogenic layer may be of archaeological importance, but in some places downstream of Oslo's Aker River, this man-made layer only consists of waste from abandoned sawmills. In other areas, builders have gradually replaced naturally-occurring geological material with industrial aggregate. A major challenge in Oslo is subsidence that is caused by changes in groundwater pressure.

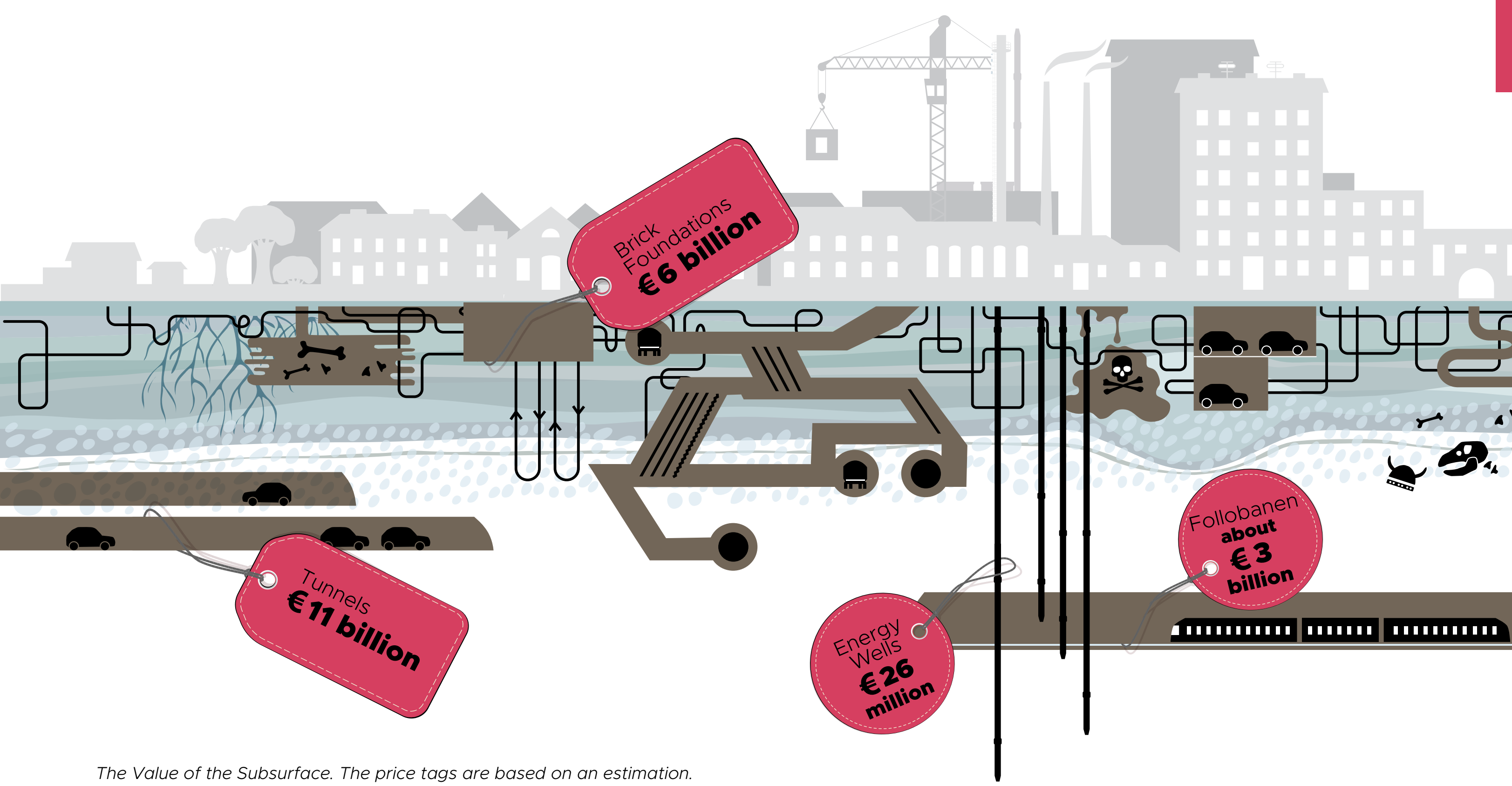
The depth to bedrock (solid foundation) varies throughout the city. Ground movement and landslide events are most often due to the presence of sensitive clays. The decaying uranium in the bedrock emits radon gas that can pose health risks, while the presence of sulphur can lead to construction problems. Already in the 1920´s, a comprehensive investigation of the sediments in Oslo was carried out that determined that the oldest parts of the city, such as the renaissance town Kvadraturen ("the quadrature") were built on the best ground. In order to expand the city, builders began to adopt new building methods to deal with more challenging ground conditions.

Green underground economy

In 2017, Oslo grew faster than any other major city in Europe. The population is expected to increase by 43 % by 2040, but the current transport capacity is insufficient to deal with this growth (OECD Resilient Cities Report, 2016). There is little space left above ground and building transport tunnels in the underground require both comprehensive information on the subsurface and targeted investment. At the One Planet summit in Dec 2017, UN Secretary-General António Guterres warned, "those who fail to bet on a green economy will be living in a grey future." Over the next years, Oslo will be investing large amounts of money in the subsurface. The city has discovered that the best path to a green economy lies beneath the city.

Value of infrastructure in the subsurface

Currently, 235 km of utility and transport tunnels lie under Oslo. The costs of building new tunnels will depend on many factors, including the diameter, depth, length and ground conditions. In general, constructing utility tunnels is less expensive than transport tunnels. The price tag for a new public transport tunnel is estimated to be around



The Value of the Subsurface. The price tags are based on an estimation.

€ 50 mil/km. The high-speed "Follo-Line" will transport people through a 19 km underground tunnel between Oslo and Ski. When the tunnel is completed, the value of Oslo's subsurface infrastructure is expected to be € 11 billion. And plans are already in place for 65 km of new tunnels, which may cost more than € 6.2 billion just to build.

A green economy means that fossil fuels must be replaced with renewable energy. Oslo municipality aims to reduce greenhouse gas emissions by 50 % by 2020 and 95 % by 2030. This will require further investments in the underground. In 2017, 4000 energy wells for shallow geothermal heating were registered with an estimated value of € 26 million. The electrical networks must be strengthened, too. New routes for pipes carrying renewable energy must be identified. And sites for additional ground heat systems must be located.

The subsurface also plays a role in extending the lifetime of existing buildings, many of them of historical value. Oslo has nearly 3000 old brick buildings that are at risk of subsidence due to soil compaction. Often this compaction is due to interference in the subsurface that has caused changes in groundwater levels. Some older buildings have wooden foundations. When wooden foundations come in contact with oxygen they start rotting, resulting in building movement and severe cracking. The cost of stabilising buildings that are at risk of subsidence due to compromised foundations is estimated at nearly € 6 billion. Even when foundations are secured to bedrock, pipes and cables are not. These utility lines can be strained and damaged by ground movement and can be loosened from buildings. Planners who use the available knowledge of the subsurface for new structures could reduce future maintenance issues and reduce demands on resources.

A green economy is also a circular economy: materials are re-used, and nothing is wasted. Subsurface experts, geotechnicans and geologists, can assist the municipality to collect data while they are developing the city; data that can be used again by others. Prior knowledge of the subsurface material to be excavated can ensure a high recycling rate. Finding local sources of building materials, either new or recycled, improves the climate and environment by reducing the heavy transport needs in and out of the city.

OSLO - THE VALUE OF THE SUBSURFACE

Oslo
Capital and largest city of Norway
Area: total 454.09 km²
Population: 672 061 (2017)
Population density: 1400 / km²
Elevation: 1-26 m

The Underground Project

Oslo City Council established the "Underground Project" (2013-2017) in response to urban planning challenges. The aim of this interinstitutional and interdisciplinary project was to increase the use of subsurface knowledge in the urban planning and sustainable management of the subsurface. Five municipal entities were represented in the project: The Cultural Heritage Management Office and the city agencies for Urban Environment, Property and Urban Renewal, Planning and Building, and Water and Sewage. Participants recognized that data and information is currently scattered amongst property owners, developers and consultants; management of data and information should be centralized to ensure accessibility.

To facilitate access to data, the project recommends the following actions at a **national level**:

- Revisions to national legislation to make compulsory the entry of geological and geotechnical data into the Norwegian National Database for Ground Investigations (NADAG) by drillers, consultants, geotechnicians after site investigations are conducted
- Improvement of the Norwegian national cadaster registration system so property can be entered in three dimensions (3D)
- Redefining zoning in the municipal plan to include areas particularly vulnerable to changes in groundwater levels
- Strengthening of the national regulatory framework (esp. under the Building and Planning Act) that directs both subsurface and surface development, so that it requires developers to apply for permission to use the subsurface (protect ground water, manage energy wells and heat pumps)

"The value of the subsurface is high, both socially and monetarily."

The municipal masterplan covers 354 km² and is currently under revision. At the **local level,** the project presented some recommendations to reduce subsidence due to groundwater changes and increase knowledge:

- Redefining zoning in the municipal plan to include areas particularly vulnerable to changes in groundwater levels
- Creating area development plans and detailed plans that indicate buffer zones and include the depths of large subsurface constructions already described in the municipal subplan
- Facilitating integration of relevant subsurface information into the planning process "subsurface information analysis"
- Establishing a systematic, continuous and comprehensive monitoring of the groundwater, throughout the city
- Strengthening the municipality's competencies and skills in the field of preserving cultural heritage

Subsurface legislation for safe management

In 2017, the Norwegian Water Resources and Energy Directorate (NVE) made changes to the Norwegian Water Resources Act strengthening certain provisions related to groundwater and the subsurface. These changes better protect property owners and the subsurface from the impact of nearby activity, like excavation. The reason for this is that disruption of groundwater flow within property boundaries structures outside property boundaries at risk of damage. Currently, however, the installation of subsurface structures is difficult to monitor because they are not always included in the building application process. Municipal officers currently have no say as to where shallow geothermal wells are drilled or heat pumps are installed. Oslo municipality calls out for more changes to national legislation to reduce current ambiguity and prevent future chaos. These necessary changes must be made to Norway's Building and Planning Act.

The value of the subsurface is high, both socially and monetarily. Local governments should be able to manage how the subsurface is used. In the case of cities like Oslo, securing necessary national regulations may be the best way of safely managing its investments below the surface.

Odense
Largest city on island Fyn, South Denmark
Area: total 304.34 km²
Population: 176 683 (2017)
Population density: 580 / km²
Elevation: 13 m

Statue of Danish author H.C. Andersen (1805-1875), holding his head above water. Photo: Gert Laursen, 2011.

An old city under pressure - from above and below

Thousand-year-old Odense city is under pressure from above and below. The annual mean precipitation has increased by about 100 mm since measurements began 140 years ago. Furthermore, extreme rainfall events are more frequent and more intense. There is also pressure from surface water; specifically, flooding due to extreme runoff from the rivers and seawater from Odense Fjord. Sometimes these storm and surface water flooding events occur simultaneously.

As the city grew, the abstraction of groundwater increased from one to seven million m³ annually. In 1854 a severe cholera epidemic led the water authority to find sources of reliable, potable groundwater outside the city limits. Like the rest of Denmark, Odense's public waterworks continues to heavily rely on groundwater, but the total amount of abstraction of groundwater has been reduced by 50%.

Two-thirds of Odense's potable water is abstracted from rural areas in the surrounding municipalities. After abandoning groundwater abstractions from the city area, the groundwater level within the city borders has dramatically risen over the past 25 years, back to its natural conditions. In some areas, the groundwater level is close to the situation back in the early 1900's, putting the city under pressure from below.

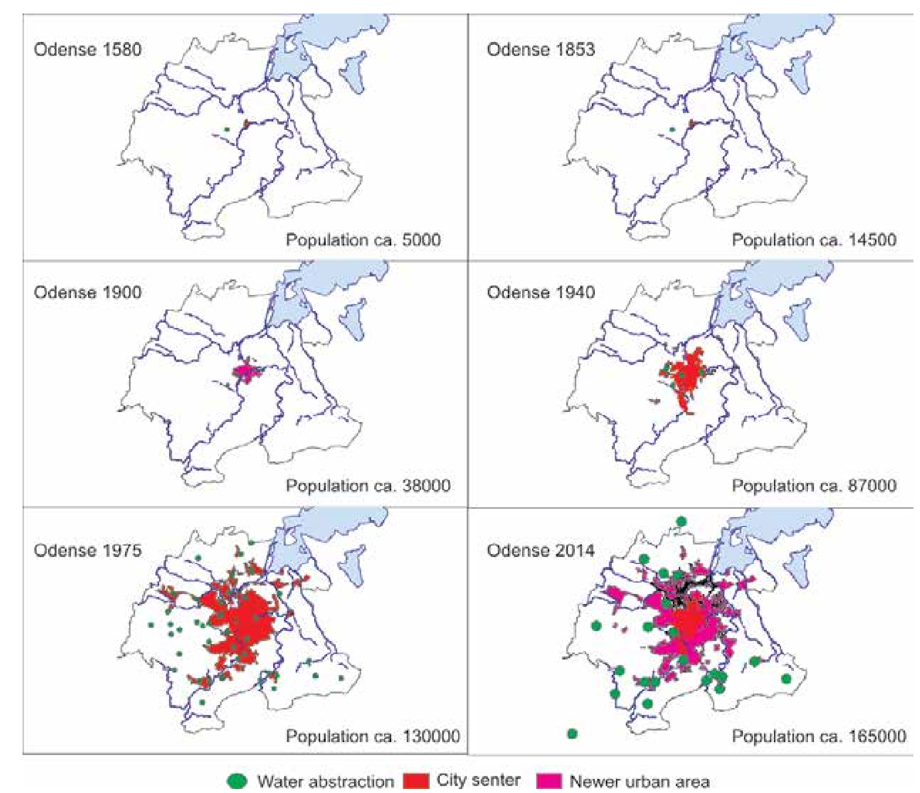
ODENSE - A DROWNING CITY

ODENSE
A DROWNING CITY

"The groundwater level is close to what it had been in the early 1900's, putting the city under pressure from below."

The 17th century author Hans Christian Anderson was born in Odense and drank the groundwater that was abstracted from within the city's limits. As abstraction grew, land areas began to dry out and residents took the opportunity to build.

As the urban areas in Odense grew, the demand for drinking water increased even more and the public water works established groundwater wells outside the city limits. They did not anticipate all the factors that could cause problems, such as the raising of the groundwater level. The drylands and new buildings began to flood. The citizens of Odense are now battling to keep their city from drowning.



Growth of Odense city from 1580 to today. The potable water source once was close to and within the city limits. Today it is located outside the city borders and in nearby municipalities. (Copyright: KMS).

Ejersminde street in Odense. Photo: Ejgil Juul Nielsen.

A Park with retention basin, as a measure to deal with flooding of the neighbourhood Sanderum. Once an area with seven private properties and homes, now functions both as recreational area and a storm water basin. Photo: Johan Linderberg. For more info see: www.klimatilpasning.dk

Who's responsible?

When water is abstracted from the ground in Denmark, the municipality is legally and fiscally responsible for any damage to buildings caused by the lowering of the water table. Conversely, municipal water works are typically not liable for damages due to the rise in groundwater level. Therefore, the landowner is left to deal with problems related to the natural return to past groundwater levels. Within existing legislation, the only solution is that the residents troubled by flooding establish their own local drainage areas. Despite the legislation, VCS Denmark (a Danish water and wastewater company) is very much aware of the conflict of keeping water levels down in residential areas, while the natural conditions imply a higher water level. Therefore, VCS Denmark annually conducts extensive monitoring of the water level in and around parts of the city.

Citizens take on the battle

Not so long ago, many homeowners became victims of frequent flooding in an area that had historically been farmland with small bogs and draining ditches. In the mid-1970's before the farmlands were transformed to residential land, bogs were drained, and open ditches were replaced with closed underground pipes. Residential development continued to increase over the decades, but the pipe system could not cope with the increased surface runoff from impervious surfaces of asphalt and concrete. This combined with increased downpour, flooding and groundwater rise, caused massive water damage to several estates. Homeowners recognized that expanding underground pipe systems was not a sustainable long-term solution to the recurrent flooding.

A practical solution to the flooding problem was proposed by the homeowners themselves. A few affected property owners suggested that the municipalities buy their homes at market value - prior to flooding. These homes would be demolished, and the area transformed into a retention basin. Today, it has become a well-used recreational area as well as a retention basin. The residents had won the battle. The case represented one of first times in Denmark where a sustainable and durable solution had been implemented, and the risk of further property damage was eliminated.

> ***"Even though the city of Odense has plenty of water issues, we do not have any real "burning platforms" that can turn the focus of our politicians and other relevant people in our direction. We experience pressure from all sides."***
>
> ***(Laursen & Linderberg, 2017)***

Taming groundwater

Historically, both rainwater runoff and raw sewage ran through common sewage systems. Old sewage pipes are in addition often broken and act as an extra drainage for both surface runoff water and groundwater. It is very expensive and often impossible to replace existing sewage systems to accommodate increasingly heavier rainfall events. Within the city limit of Odense, more than 1 billion Euro has been spent to lay down larger sewage pipes for retaining storm water in order to meet the EU-legislation. Large sewage pipes will reduce and delay the amount of untreated sewage water and runoff water from overrunning the system during intense and heavy rainfall and flooding events and entering the Odense River and Fjord. This is an effect when the capacity of the pipes is overloaded.

There is a growing interest in establishing local infiltration as an alternative to sewage pipes. As cities grow, areas are covered with materials that seal the ground. Allowing water to penetrate the urban subsurface via artificially or naturally enhanced infiltration, may be the solution. However, this intervention could stress the subsurface by elevating the groundwater level and increasing saturation. In addition, large-scale infrastructure like tunnels and underground parking facilities in the subsurface put a further strain on the challenging groundwater conditions, by altering the natural flow paths in the subsurface. Due to the rise in groundwater level the same subsurface infrastructure is challenged to keep from drowning.

Resilient solutions to the adverse impacts of climate change

To find a sustainable solution for Odense city, the municipality works together with VCS Denmark, the Geological Survey of Denmark and Greenland (GEUS) and the Region of Southern Denmark. Complex challenges need complex solutions: Knowledge about the subsurface is the place to start. 3D subsurface models can be useful tools to explain what is in the ground and where subsurface elements are located. In addition, 3D models help visualize how water moves, identify flood prone areas and predict the effects of climate change and sea level rise. This knowledge will help meet the challenges associated with preserving residential areas, infrastructure, historical objects, archaeological artifacts as well as the cities where most live.

Since the Middle Ages, Rotterdam has witnessed a myriad of engineering feats devised to reclaim and protect land from the forces of water. Networks of dykes, reservoirs and pumping stations have been built to keep the land dry.

A key component of the city of Rotterdam's recent new holistic urban development strategy is a change in policy and organizational restructuring. The city has defined the increasingly complex subsurface as a critical component of the urban infrastructure. Subsurface experts, engineers and urban planners work together to ensure that Rotterdam continues to be a city where people can live.

> "For urban planners the subsurface remained synonymous with costs and delays."

ROTTERDAM **TOWARDS RESILIENCE**

Illustration: The other half of Rotterdam.

A TIMELINE FOR ROTTERDAM CITY

© Resilient Rotterdam

Public Works of Rotterdam: emerging out from necessity

Rapid expansion of Rotterdam's harbour in the 19th century, was preceded by a major problem caused by overcrowding; namely, sanitation. The municipal "Water Project" sought to improve sanitation and to prevent and control recurring cholera epidemics. Citizens needed wells filled with safe drinking water, new canals, and a new sewage system. To oversee this an agency called Rotterdam Public Works was founded with engineers at its core. Engineers had to also ensure streets and homes were not flooded. Water must be continually pumped out, but carefully so not to disrupt groundwater levels. Further expansion of Rotterdam in the post-WWII led to subsequent health-risks a few decades later when it was discovered that homes had been built on contaminated soil. By the 1980's, several severely polluted locations were identified which required urgent remediation. Consequently, in 1987 the "Soil Protection Act" came into effect, and with the addition of environmental soil specialists, the engineering department of Rotterdam Public works doubled in size to 2000 and became one of the largest engineering organisations in The Netherlands.

The slow road from awareness to standard practice

By the end of the 1980's, the municipal engineering division had collected a large amount of subsurface data and assembled it in a dedicated soil and ground information database. Over the next two decades this comprehensive database allowed the Public Works department to provide basic services and make feasible large-scale construction projects, and for the management of the data a dedicated team (RoBIC) was set up. Eventually, developments in Geographical Information System (GIS) technology allowed this environmental and geotechnical subsurface data to be displayed along with other subsurface information, such as location of objects like cables, pipes, etc.

Soon the subsurface could no longer be ignored. The next decades saw more population growth and space became scarcer, both on the surface and subsurface. The city must adhere to Climate Change policies: Rotterdam must be built to sustain future sea level rise and heavier rainfall. The energy potential of the subsurface is now also known. To safeguard subsurface ecosystems and meet societal demands, a holistic knowledge approach of the surface and subsurface development is necessary.

A common language

The challenges of accessing spatial information within and between governmental agencies was not unique to the city of Rotterdam or most other cities in Europe. Situations like this that led the European Commission to set up a legal framework for its directive "Infrastructure for Spatial Information in Europe" (INSPIRE). Following this INSPIRE directive, spatial or geographical information should be more accessible and interoperable for a wide range of purposes supporting sustainable development. Various Dutch directives followed INSPIRE to assist governmental agencies and universities to harmonise their basic data management.

By 2006 the RoBIC team developed a regional GIS platform (RegioGIS) that could broaden the municipal and sectoral subsurface approach to a regional and wider spatial planning perspective. Other municipal department and neighbouring municipalities were willing to participate. It was hoped that this new GIS platform would effectively and clearly display necessary information and serve as a binding element between the agencies. The partners would be able to have quicker insight into each other's interests and expertise through a flexible exchange of information to be included early in the planning process.

Resilient city. In 2016 Rotterdam launched their Resilient Strategy. At the IABR 2016 three of the 100RC cities met to discuss the importance of the subsurface towards resilience. Left: Ignace von Campenhout (Rotterdam Municipality), Desiree Gotink (Resilience Team, City of Rotterdam), Diarmad Campbell (Chair of COST Action Sub-Urban, BGS), Arnoud Molenaar (City of Rotterdam), Paulo Prazeres Pais (Municipality of Lisbon) and Cathy Johnston (Glasgow City Council).

Learning from Rotterdam

Effective strategies to promote the relevance of the urban subsurface

Underground tour
Bring the public, school children and politicians, for a tour. Regularly, the pRODEO-team takes participants for a tour underground to gain better understanding about the symbiosis between the subsurface and urban development.

Interdisciplinary work sessions
Organize and join teams to share knowledge and bridge the gaps. Sessions are commonly organised by the municipality together with Delft University of Technology (TUDelft).

Traffic light mapping
Maps should be intuitive to the audience. Rotterdam has tailored maps to planner needs and used early urban planning process. Since 2009, this has been applied to projects in Rotterdam, the Hague and Haarlem.

Honest broker
Identify a person who is bridge-builder. They should have knowledge of all topics related to surface and subsurface planning, bridging the gap between disciplines.

3D Serious-Game
Develop a specialized applied gaming software for users to learn about the subsurface. To win, ensure cooperation between all stakeholders. The game was made in a collaboration between municipalities, the Geological Survey of the Netherlands (TNO) and the software company Strategis

http://www.strategisgroep.nl/en/products/serious-game-underground/

Subsurface vision statement
Establish a vision statement. In collaboration with several Dutch ministries and provinces, the city of Rotterdam published a vision statement. The statement, entitled "STRONG" offers a framework for the sustainable use of the subsurface, bringing forth possibilities and challenges.

Capacity Building
Train the NEXT generation of urban planners. Annually, 100 university students use "live" subsurface data in digital 3D-urban planning and design projects, a collaboration between the Urban Planning Faculty at TU Delft and Rotterdam Municipality. In 2017 a Climate Scan week was organized with the Universities of Rotterdam, Groningen and Gdansk for 90 students from Poland and Holland.

https://www.climatescan.nl/projects/2132/detail
Internationale city climatescan Rotterdam

International Architecture Biennale Rotterdam (IABR)
These events promoted the subsurface in the European architecture- and urban planning communities. In 2014 and 2016 the IABR Urban Underground day was organised in collaboration with COST Sub-Urban. During IABR 2018-2020 the plan is to organise an Urban Underground Week with several workshops around "live" projects, together with partners from the COST Sub-Urban network, ACUUS and ISOCARP.

https://iabr.nl/en/editie/iabr2018_2020

100 Resilient Cities
Join with other municipalities across the globe working towards resilience. Rotterdam is a member of a programme established by the Rockefeller Foundation that was designed to help cities world-wide to become more resilient to the challenges of the 21st century. By cooperating with our COST Sub-Urban partners Glasgow in UK and Lisbon in Portugal, also 100RC partners, Rotterdam city has demonstrated to other 100RC members that knowledge and good management of the subsurface can help make cities more resilient. Following this, the subsurface is part of Rotterdam's Resilience Strategy

http://www.100resilientcities.org/rotterdams-resilience-strategy/

Where and why did it fail?

The data platform developed by municipal engineers could not alone serve to bind the various subsurface specialists and urban planners. In pursuit of efficiency, specialists tended to work within the conventions of their specialized discipline, concerned mostly with communicating with those within their discipline. Hence, when various subsurface experts presented urban planners with information, it was often fragmented and incomprehensible. For urban planners the subsurface remained synonymous with costs and delays so the tendency was to avoid subsurface matters until the end of the planning process. Adding to the complexity, the national authorities had divided subsurface into three zones, each controlled by a different level of government: the Dutch National Ministry of Economic affairs (deep, under 100 m); provincial (middle, including groundwater which is often just 0,5 m. below the surface) and municipal (very shallow, above groundwater).

Turning point

In the end, it was a programme introduced in 2006 by the Dutch Ministry of Housing, Spatial Planning that would propel municipal agencies to view the subsurface in a holistic manner. Rotterdam, together with the cities of Enschede, Utrecht and Arnhem participated in this pioneering programme. By 2007 the RoBIC data management team transformed itself into a new team: "Professionals at the Intersection of Spatial Development, Sustainability, Energy and the Subsurface" (pRODEO). It was pRODEO that would take the lead to demonstrate the need of this interdisciplinary approach: Subsurface experts and urban planners would have to work hand in hand. By 2013, Rotterdam Municipality merged the engineers and the urban planners into one cluster: Urban Development. In 2016, in their holistic vision for urban development, the city of Rotterdam has defined the subsurface a critical component of the urban infrastructure.

Focusing on communication and needs, the city of Rotterdam has witnessed an improvement in its urban planning process: diminishing costs, optimizing the potential of the subsurface, and creating a healthier and safer living environment. However, there is still a long way to go.

Rotterdam
Second largest city in the Netherlands
Area: total 325.79 km^2
Population: 635 389 (2017)
Population density: 3 043 / km^2
Elevation: 0 m

"This new GIS platform would effectively and clearly display necessary information and serve as a binding element between the agencies in the planning process."

LJUBLJANA - SITTING ON A TREASURE

Ljubljana
Capital of Slovenia
Area: total 275 km²
Population: 279 756 (2016)
Population density : 1 708 / km²
Elevation: 295 m

Photo: Ivan Stanič.

"Can Ljubljana exploit the heating and cooling capacity of the groundwater?"

LJUBLJANA
SITTING ON A TREASURE

The citizens of the picturesque city of Ljubljana are living on top of their most vital resource – pure drinking water. The Sava River feeds the groundwater aquifer that lies beneath the city. The ongoing and future challenge is to protect the city's treasured drinking water from contamination.

As a heavily urbanized area, the city is prone to accidents and unusual events that can release health-harming substances, which can travel from the surface and pollute the aquifer. Can Ljubljana safeguard its high-quality, natural drinking water while applying new technologies designed to exploit the heating and cooling capacity of the groundwater?

Pure, Natural Water

The green areas of the country-side extend into the historical city centre via green wedges and corridors giving Ljubljana its distinctly green identity. The subsurface beneath Ljubljana city is ideal for storing large quantities of pure groundwater: 400 million cubic meters serve as a perfect drinking source. 100 meters of layered gravel and sand contain enough high-quality groundwater, which even untreated can supply the entire city Ljubljana with naturally purified water ready to be tapped.

The unsaturated zone above this water resource serves as a natural 25-meter buffer against pollutants on the surface. The aquifer is recharged by both the Sava River and precipitation. Approximately one cubic meter of groundwater is abstracted per second, mainly for domestic use and partly for industrial use. The abstraction for this drinking water supply is located in four water fields in Ljubljansko polje and represents approximately 90% of all the water in the system that supplies approximately 300,000 people with drinking water.

Guarding the treasure

For more than a century, Ljubljana has developed groundwater management strategies to protect its precious aquifer. Protection areas were designed. The municipality has designed protection areas to reduce the risk of contaminating the drinking water. These protection areas have been integrated into urban spatial planning. Human activity and land use that pose a threat to groundwater pollution within protected areas are restricted.

> *“Human activity and land use that pose a threat to groundwater pollution within the designated protected areas are restricted.”*

In addition, the water managers and supportive research team can respond quickly to any event or accident that results in the release of hazardous substances. This is made possible through the use of a computerized system which provides efficient access to information relevant for localisation of contamination sources and mitigation of groundwater contamination.

Photo: Ivan Stanič.

From fossil fuel to green renewable energy

To comply Ljubljana’s green identity and to follow the energy policies of the European Union, the city aims to increase the share of renewable energy in the final energy consumption. Fortunately, the subsurface has favourable natural conditions for the use of ground-source heat pump systems. This key technology allows access to renewable energy source to heat and cool the city. In pursuing this energy option, all the risks must be examined to ensure continued protection of the drinking water resource.

Today, a coal and biomass powered district heating system supplies 74% of the households in Ljubljana. This is complemented with natural gas. There is minimal use of shallow geothermal energy for heating and cooling. The municipality of Ljubljana set in its Sustainable Energy Action Plan several goals to be achieved by the year 2020 (with 2008 as baseline):

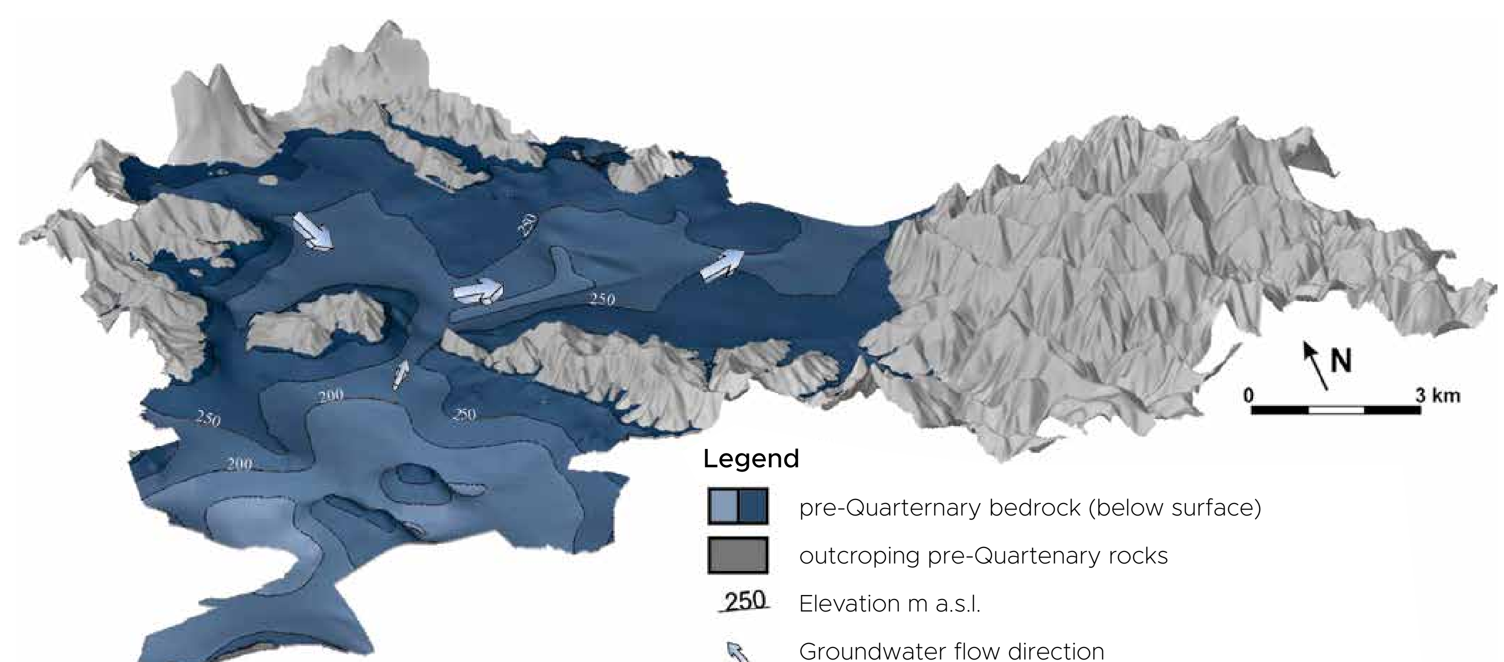
- Replacement of fossil fuels with renewable energy (25% of the final energy consumption)
- Improvement of the energy efficiency (20% less energy use)
- Reduction of the greenhouse gas emissions by 35%
- Intensification of research and introduction of new technologies for the utilisation of renewable energy sources.

Reducing fossil fuel use will both improve air quality and reduce the greenhouse gas emissions that contributes to climate change. However, there is risk associated with multiple-use of the subsurface, especially any action that might threaten the city’s drinking water source, such as pollution and over consumption that diminish the drinking source.

An integrative development and management strategy must be used to motivate the use of shallow geothermal energy. One of the main reasons for the low share of shallow geothermal energy in energy consumption is a lack of information. Information regarding the potentials and limits for shallow geothermal energy use is crucial for planning and design of geothermal installations.

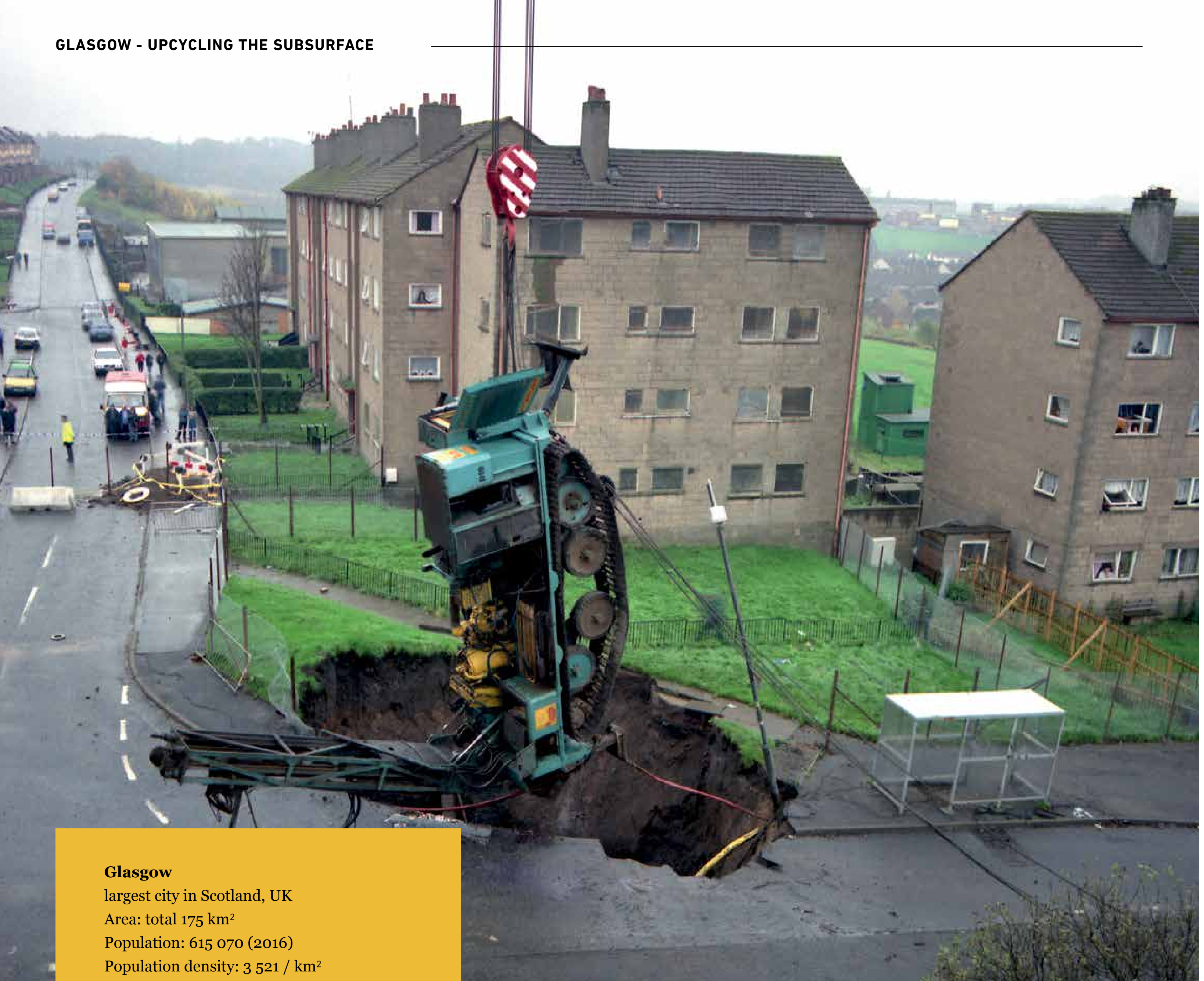
3D model of Ljubljana’s subsurface

Ljubljana’s subsurface conditions are favourable for two vital resources: energy and drinking water. Addressing the possible conflicts in advance is possible if knowledge of the subsurface is easily assessable and presented visually. With knowledge-based management of the subsurface both resources for renewable energy and drinking water is possible to treasure for Ljubljana city. The computer system already enables display of geological layers and groundwater movements. Monitoring systems that detect groundwater contamination can be used as a tool to forecast the impact of pollution of the drinking water source. Integrating the 3D hydrogeological and geothermal models will enable the city to manage its shallow geothermal energy and groundwater more efficiently and sustainably. This will help make this green city, even greener.



GeoZS Geološki zavod Slovenije

3D hydrogeological model in Ljubljansko polje.



Glasgow
largest city in Scotland, UK
Area: total 175 km²
Population: 615 070 (2016)
Population density: 3 521 / km²
Elevation: 1-20 m

A catastrophic collapse of an abandoned mineshaft. Photo: BGS

Subsurface hazards and potential

The geographical and geological setting of the Glasgow, combined with the legacy of mining and heavy industry gives rise to a complex subsurface environment. The natural terrain is comprised of sediments deposited from glaciers and rivers. Over a millennium, this sediment has given builders unpredictable ground conditions, particularly along the River Clyde and its estuary. In addition, there has been a significant disruption of the subsurface by heavy industrial activity. Together, the natural and human-made conditions have made Glasgow city residents vulnerable to various hazards, both slow-moving and catastrophic.

These hazards include: running sand, compressible ground and shrink-swell clay, heavy metal pollutants, flooding and collapse. But along with the hazards lies potential in the subsurface, including: water storage, infrastructure routing, basements, archaeological discoveries, ground source heat and mineral extraction.

GLASGOW
UPCYCLING THE SUBSURFACE

"Knowledge of the subsurface can help experts identify both the hazards in the subsurface and its potential."

Glasgow once served to power the Victorian economy through coal mining, iron works, shipping and trade. The third largest city in Europe in the early 20th century was reduced to a post-industrial wasteland after global economic shifts.

Fortunately, Glasgow is on the path to rejuvenation. The city's subsurface, riddled with abandoned mines, was first viewed solely as a problem. But in March 2017, the Council approved the City Development Plan which now explicitly recognises the value of the subsurface. Today, policies are being put in place to ensure the city benefits from the subsurface resources, including heat found in waters of old mine shafts. But subsurface specialists must work harder to make information more accessible to planners.

Urban planners and subsurface experts get together to solve a problem. Here Gillian Dick (Glasgow City Council), Jeroen Schokker (TNO) and Alina Radutu (UTCB) are discussing urban planning of Bucharest, Romania.

Upcycling the mine workings under Glasgow

Knowledge of the subsurface can help experts identify both the hazards in the subsurface and its potential, as in the case of the old mine workings. Coal, limestone and ironstone were mined over 300 years until 1966. Mines built in the early 1800's were shallow, and ceilings were held up by pillars. Once extraction was over, pillars were often removed, and the spaces caved in. However, often the pillars were not removed. The more recent failure of pillars and ceilings of these shallow mines constitute a hazard for many surface structures. Hence, Glasgow City Council has undertaken grouting to stabilise some near-surface mine workings to halt or prevent subsidence and mine collapse in many areas of the city. Mine operations in the 1800's to early 1900's typically exploited coal seams hundreds of meters deep. There are fewer subsidence issues related to this form of mining due to the controlled collapse of the mine roof, the greater depths and limited extent of the workings. Subsidence associated with the collapse of underground workings occurs in many areas of the city, and there are occasional incidents of catastrophic collapse of workings, shafts and levels.

Disused coal mines also serve as conduits for groundwater flow. The city is now planning ground source heat installations designed to extract heat from the water in the old mine shafts. More study is required to realize the heating potential of the mining waters, as well as the shallow geothermal renewable energy that can be extracted from superficial deposits and bedrock aquifers.

Communicating information to urban planners

The process of urban planning is inherently holistic, but with the planner can be discouraged with information overload. Certain categories of information are difficult to quantify; for example, social and cultural information. Concrete data on transport, pollution, topography, crime, etc. must be added too. Subsurface experts would like to contribute their data and insight on complex subsurface issues to this mix of information. Often, the subsurface information planners receive is neither relevant or easily understood. How can the subsurface specialist ensure their information and knowledge are well-placed in the data hierarchy and used at an early stage of city planning?

As described in our working group report "Opening up the Cities of Tomorrow", an urban planner is only as good as the information available. The subsurface specialist and urban planner must develop partnerships to foster vital communication about the subsurface. Subsurface information must harmonize with data already used by the urban planner and be displayed intuitively (or explained). Subsurface specialists must take care to make information easy to catch, reliable, organized, updated and ready to integrate in the planning and construction phase.

Slow change gives results

A National Environment Research Council (NERC) project is currently being undertaken by a geologist at the British Geological Survey. The project aims to harness the opportunity presented in Glasgow and to act as a national co-ordinator of the activities in Scotland across a large range of stakeholders. The development of a new mechanism of subsurface data capture is fundamental for more user relevant 3D subsurface models that integrate geology, groundwater, renewable energy and subsurface infrastructure into one model. Glasgow is a pilot city for this volumetric planning approach. The Scottish approach will be transferred to Cardiff, Bristol and Newport in England and Wales, where key partners and stakeholders are already in place.

Growing awareness among policy-makers

The collaboration between the British Geological Survey and Glasgow City Council has given awareness to the role the subsurface environment plays. Cities need effective remediation and regeneration, hazard mitigation, the management of resources, and development of a sustainable economy. In the absence of state legislation relating to the subsurface environment, developments in the application of subsurface data and spatial planning policy for Glasgow are arising through collaboration and partnerships. Progress is being achieved through knowledge exchange initiatives, voluntary agreements and the use of contractual obligations to commit private contractors to share data in exchange for access to 3D subsurface information provided by the Survey. The inclusion of geology and the subsurface in the new Development Plan for Glasgow reflects the growing awareness of policymakers of the importance of the subsurface environment and resources for the future development of the city.

> *"Glasgow is a pilot city for this volumetric planning approach."*

GLASGOW - UPCYCLING THE SUBSURFACE

The Subsurface implemented in the City Development Plan

In 2012 Glasgow City Council commissioned the Survey to undertake a Geodiversity Audit for the city of Glasgow. This audit identified and described 20 key geological sites in the city and forms the basis for recognition of geological sites within the Development Plan. Following the sustained collaboration between the Survey and Glasgow City Council, alongside the efforts of the Scottish Geodiversity Forum, the City Development Plan now incorporates consideration of the subsurface environment and resources in the planning policy framework. This development reflects an increasing awareness of the role of the subsurface in supporting a sustainable economy and vibrant, healthy society and environment. The City Development Plan, adopted in March 2017:

- Recognises the inclusion of geodiversity sites as protected Local Nature Conservation sites, selected for their values for scientific study and education, historical significance and cultural or aesthetic value.

- Includes an action that formalises the commitment of Glasgow City Council to continue to work in partnership with British Geological Survey and engage with other European partners.

- Commits Glasgow City Council to the development of supplement ary guidance in relation to the subsurface environment – incorporating utility services, district heating, energy and communication services, transport, sustainable urban drainage systems (SuDS) and water services in addition to ground properties and other ge ological conditions.

- Commits Glasgow City Council to the development of further guidance and planning requirements in relation to heat generating technologies including options such as renewable energy from ground source heat and other subsurface energy resources.

The reservoir for urban resilience

During various points in history, dozens of cities in Europe have been dragged through rapid industrialization and then burdened with the aftermath of a catastrophic economic and social decline. Glasgow city is a city that has been dragged through industrial dirt but has come out clean and green. Politicians are now beginning to recognize that the reservoir for urban resilience lies under the city. It is up to the subsurface specialists now to follow through with their promises and make data accessible.

Glasgow and the Clyde Basin – Clyde Urban Super Project (CUSP).

In the heart of the city are the Clyde Gateway and Clyde Waterfront areas — the national urban regeneration priority for Scotland over the next 25 years. The regeneration within Glasgow is intended to stimulate economic growth, drive smaller community regeneration projects, and tackle concentrated deprivation resulting from industrial decline. This transdisciplinary project aims to make geoscience information more accessible, relevant and understandable to the wide range of users involved in the sustainable regeneration and development of Glasgow and in particular the Clyde gateway area of the city. CUSP has the following research themes:

- 3D attributed geological modelling
- 3D geotechnical modelling
- 3D hydrogeological modelling
- 3D modelling visualisation
- Geothermal potential
- Groundwater in the Clyde Valley
- Knowledge transfer systems for developers, policy makers and planners
- Natural and contaminant geochemistry
- Sustainable Urban drainage (SUDS)

www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/clyde/

Accessing Subsurface Knowledge – the ASK Network

The ASK Network is a partnership of public and private sector organisations focused around the exchange and reuse of subsurface data and knowledge. It was formally launched in 2012. Data exchange has prompted collaboration between BGS and private sector consultants and contractors through bespoke model developments for particular sites, and provided a mechanism for feedback to BGS from model users to support ongoing model development. Through this collaboration exchange of borehole data to aid groundwater assessments and continued 3D subsurface model is developed.

http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/clyde/asknetwork/home.html

GeoCIM

GeoCIM

Reconnecting cities to the subsurface

Geo City Information Modelling (GeoCIM) aims to completely integrate information on the surface and subsurface. Easily accessible geological information will reveal the potential hazards and opportunities of the subsurface. Implementation of the GeoCIM process during initial phases of the decision-making and planning process will allow urban designers and decision makers to better balance economic, social and environmental interests. But how to introduce the GeoCIM concept into urban planning? Perhaps the incremental approach is best.

Urban mapping, planning and design, today and yesterday.

The hazards of neglecting the subsurface

For centuries architects and engineers have communicated complex plans using hand drawings, which seemed to be easily understood by builders and decision makers. As population grew, space became more scare and technologies were developed to control the challenges that nature brings, at least in the short term. On the surface, builders and city planners seemed to have conquered nature. But decay is inevitable. Geologists have from the very start communicated geology and the subsurface features by maps and cross-sections, with symbols and lines on paper to represent the location of underground resources and geological hazards. These maps are often well understood by like-minded subsurface experts but can be confusing to others. Since the 1970's, digital technology has served to communicate the same information. Geographers and geologists have replaced hand drawn maps with mapping in Geographical Information System (GIS) software programmes. Similarly, engineers and architects have replaced hand drawn blue prints with drawings produced by Computer-Aided Design (CAD) software. Despite these development, according to a 2015 TEDx talk on 'The future of Making Buildings', studies in the UK and USA suggest that approximately 35% of the costs of construction are wasted, often arising from poor communication of information from one expert to another (Phil Bernstein). An important factor seemed to be that authorities were still neglecting subsurface information. A better means of digital communication was required.

Building Information Modelling

To counter the communication issue, a recent initiative "Building Information Modelling (BIM)" encourages a more integrated approach to the construction process and better sharing of information. BIM has been used for construction and management phases of many projects over the last decade or more, including some high-profile projects. For example, we find that BIM was used during the construction of One World Trade Centre (2014) in New York that was built on the land where the Twin Towers once stood. A wide range of experts worked to solve complex problems of the subsurface. They determined that foundations must be made 20 metres into the ground to reach the bedrock but would have to accommodate an intricate arrangement of existing urban infrastructure (e.g. subway, tunnels, utilities and services). Out of necessity, they turned to 3D BIM software to create an information sharing platform for the complete building site, above- and below ground.

Since April 2016, the UK government has required that all government funded construction projects require fully collaborative 3D BIM. All project and asset information, documentation and data being electronic. The aim of the BIM policy is to realise a 20% reduction in the cost of constructing and operating new buildings.

It is important to note that BIM is not only about 3D models, BIM represents a crucial cultural shift in construction. BIM requires real sharing of information throughout the construction lifecycle. Shared information about a facility or building will form a reliable basis for decisions throughout the life cycle of a building. However, subsurface information is too often missing from BIMs. Another problem, is that BIMs often are created for a single building or relatively isolated small-scale site.

Reconnecting Cities to the subsurface

"On one hand (the city) concentrates the historical motive force, on the other hand, it (the city) disturbs the metabolic interaction with the earth" (Karl Marx). The buildings and city design of Marx's day were an expression of the industrial revolution. He suggested that the boundaries of our cities remain in a quiet and likely ruinous interface with the nature - earth and air. Under our cities human-made layers and natural-layers meet. Maybe Marx was longing for an urban environment that harmoniously connected cities to their natural setting?

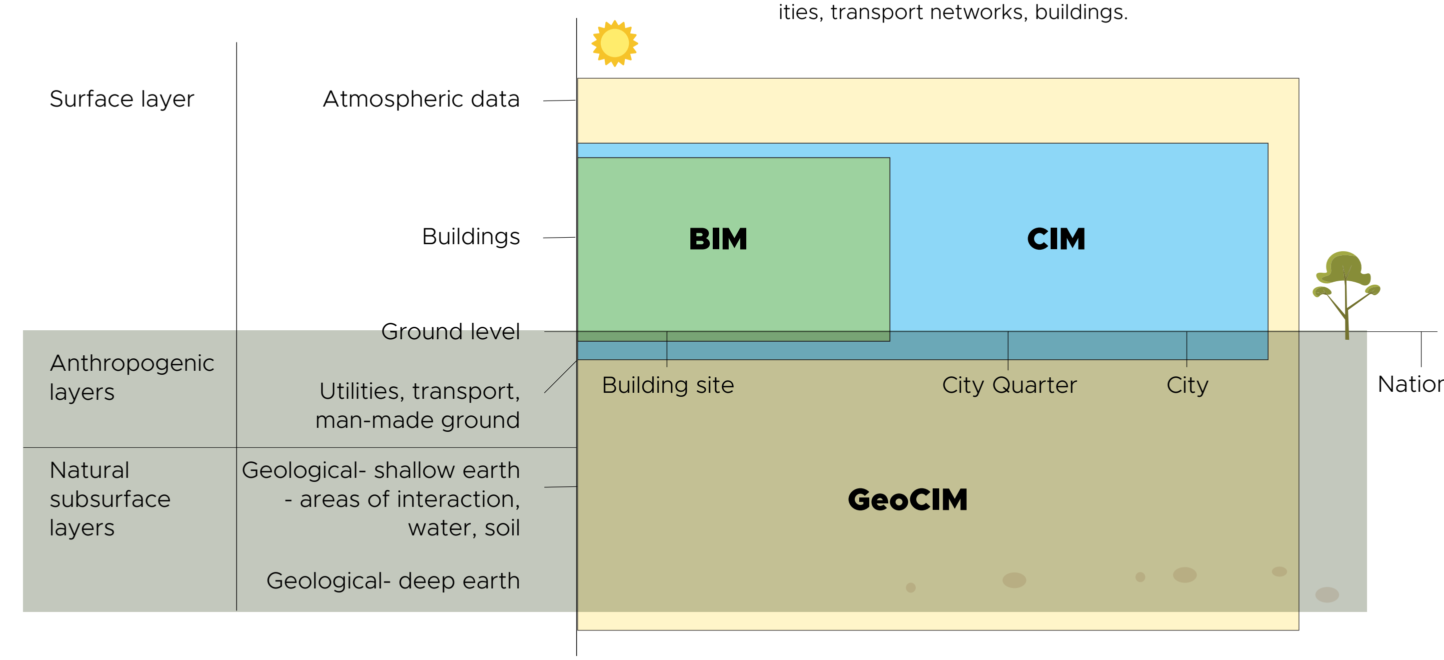
During the COST Sub-Urban Action, participants agreed that it was crucial that planners and builders have access to all the information available on the surface and subsurface. Inclusion of subsurface information would be particularly crucial for larger projects. The concept of a City Information Model (CIM) extends to this scope and has recently gained support amongst urban planning researchers (Gil et al., 2011). However, the implementation of CIM models tends to involve 2D or 2.5D GIS systems and lacks detailed subsurface information. The COST Sub-Urban participants also agreed that above- and below-surface data would have to be scalable to levels suited to city planning and included in BIM-CIM processes. Policies and administrative systems must be in place that encourage and guide sharing of large-scale spatial data at early stages of strategic urban planning. Information gathered through the one-project-at-a-time approach could be maximized and assembled to display a holistic view of larger urban spaces.

Geo City Information Modelling

Our proposed Geo City Information Modelling (GeoCIM) process aims to reconnect cities to the subsurface. GeoCIM is a process involving the generation, sharing, integration and sustainable management of digital representations of physical and functional characteristics of at least the following urban environment layers:

- Surface layer: natural and man-made on-surface features
- Anthropogenic subsurface layer: man-made ground, buried infrastructure, foundations
- Natural subsurface layer: geological units, hazards, resources and processes

GeoCIMs can communicate the numerous opportunities and challenges of the subsurface. Citizens and their governments could view information that will allow sustainable planning, decision-making, designing, construction, operation and maintenance of diverse physical infrastructures. Subsurface ecosystem and natural resources such as water, heat, power, minerals and aggregates could be viewed alongside utilities, transport networks, buildings.



Vertical and horizontal scopes for BIM, CIM and GeoCIM.

GeoCIM – a useful tool

Urban planners could use the GeoCIM platform to retrieve all key urban datasets in 3D or 4D. It should also be possible to incorporate environmental indicators such as data on water table, air-, water- and soil quality or pollution into GeoCIMs; this would support the integration of environmental assessments and planning if considered relevant. GeoCIM tools also allow subsurface experts to reach a larger audience with information on geology. These specialists will also benefit by being able to assess the interaction between man-made structures and subsurface processes such as groundwater flow or ground stability. Although there are no examples of GeoCIMs that fully satisfy the ambition of the Sub-Urban community there are examples that demonstrate how certain aspects of the GeoCIM definition have been met throughout Europe.

Best efforts in combining above- and below ground information

In the Danish city of **Odense** the above and below-ground layers have been integrated into a single model that informs surface and subsurface groundwater management projects (Mielby et. al., 2015; Schokker et al., 2017). Other examples in cities like **Helsinki** (Ikävalko et. al., 2016) and **Oslo** (Eriksson et. al., 2016) focus more on the integration of the two uppermost GeoCIM layers, while **Hamburg** (Taugs et al., 2016; Bricker, 2013) focus on the integration of anthropogenic and natural subsurface features. Each of these cities has concentrated on the integration of data that is readily available and most relevant to immediate development priorities. These partial implementations of the GeoCIM concept are actively used by subsurface specialists and city authorities to plan developments despite the lack of coverage or detail in some datasets.

Rotterdam in the Netherlands, maintains a GIS system with detailed spatial information on buildings and their foundations, infrastructure, surface water and much more. Relevant information from this system has been combined with 3D geological models of both the shallow and deeper subsurface. The result now forms a base to guide and optimise integrated 3D decision making during the reconstruction of the pre-World War II city quarter Bloemhof Zuid.

The largest knowledge gap in this subject area is how to initiate the GeoCIM process. However, it is not necessary to commit, up front, to creating the perfect, fully-featured GeoCIM from scratch. The biggest impacts of a GeoCIM are likely to come in the earliest phases of the decision-making and planning process, when a holistic overview of all relevant information can result in design changes that minimise cost and hazard risks.

Decision-makers should acknowledge the potential impact and benefits of GeoCIMs during early stages of the decision-making and development process. As heard from the cities represented here, including both above and below-ground city information in early strategic decisions will foster the health, security and economic well-being of our cities.

CAD:

Computer-aided design (CAD) is the use of computer systems 0(or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. (Wikipedia)

GIS:

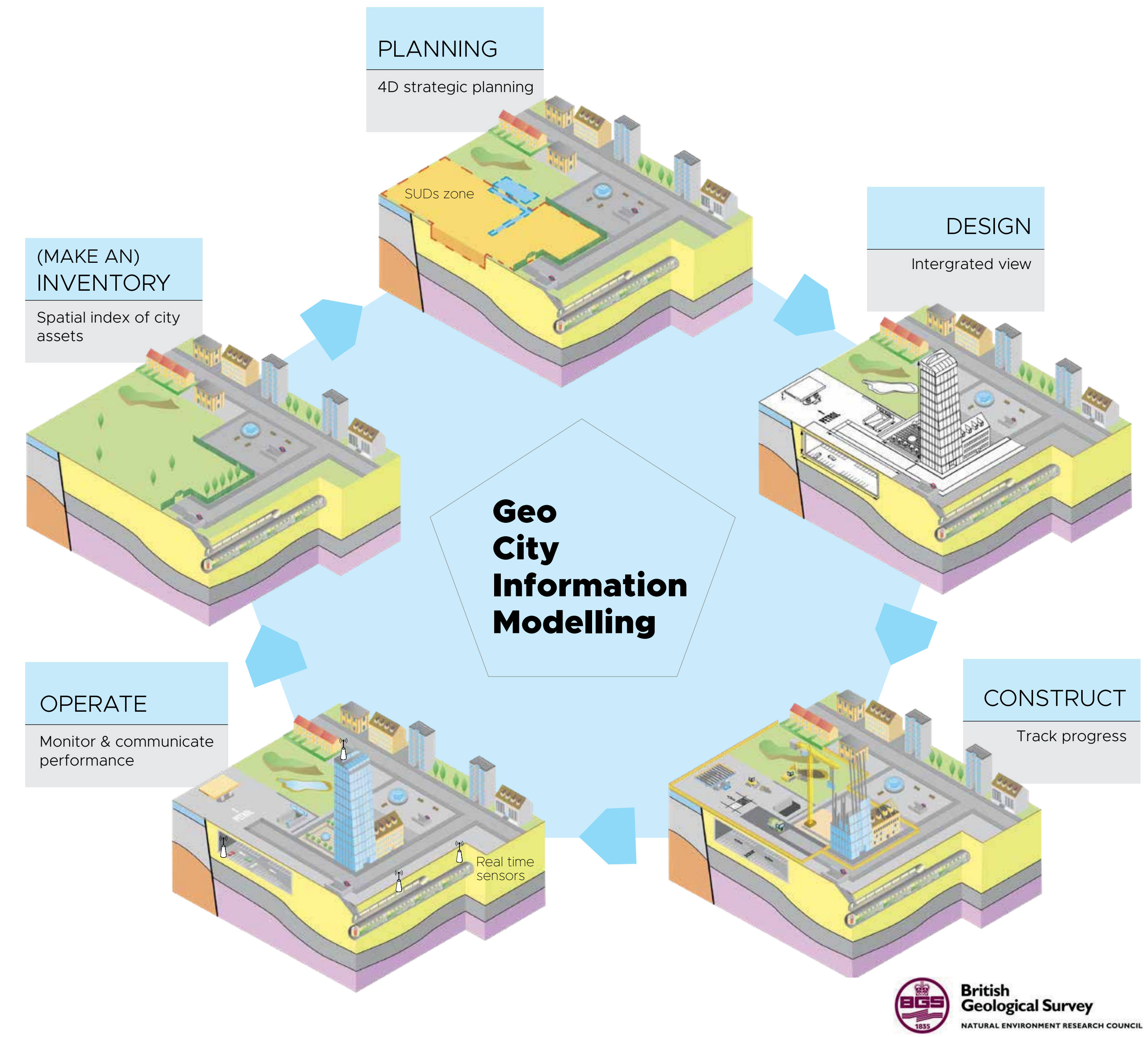
A geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data. The acronym GIS is sometimes used for geographic information science (GIScience) to refer to the academic discipline that studies geographic information systems and is a large domain within the broader academic discipline of geoinformatics. What goes beyond a GIS is a spatial data infrastructure, a concept that has no such restrictive boundaries. (Wikipedia)

BIM:

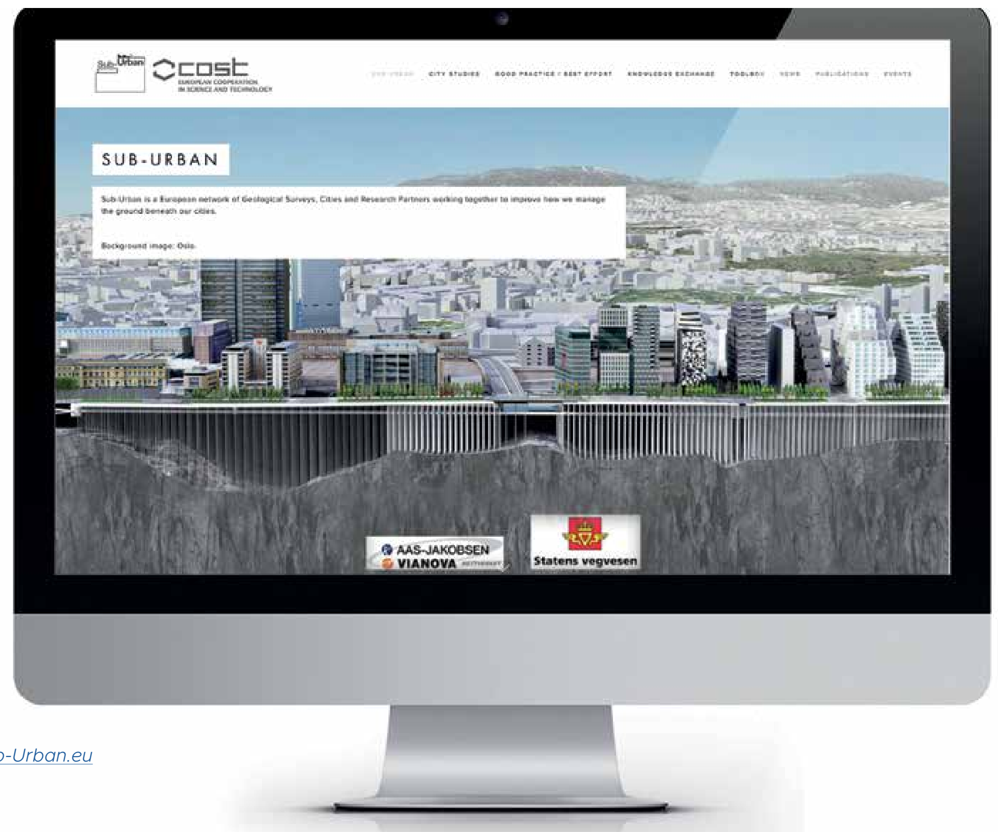
Building information modelling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of places. Building information models (BIMs) are files (often but not always in proprietary formats and containing proprietary data) which can be extracted, exchanged or networked to support decision-making regarding a building or other built asset. Current BIM software is used by individuals, businesses and government agencies who plan, design, construct, operate and maintain diverse physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, bridges, ports, tunnels. (Wikipedia)

CIM:

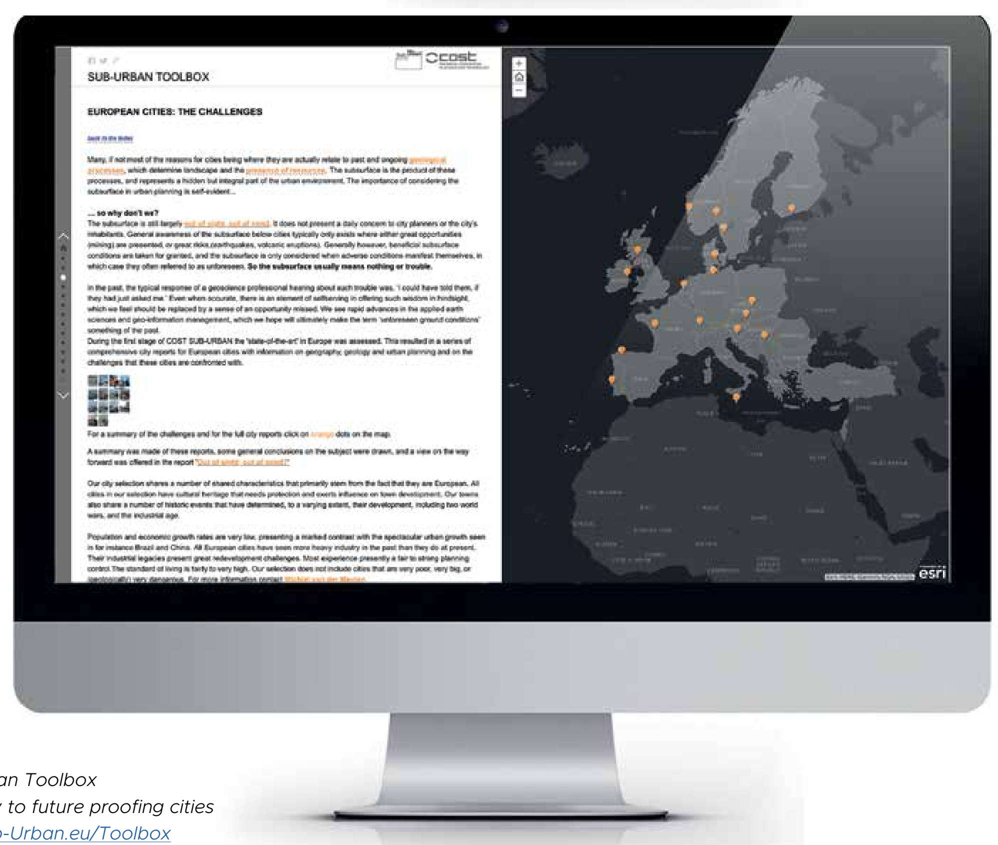
City Information Model or 3D city models are digital models of urban areas that represent terrain surfaces, sites, buildings, vegetation, infrastructure and landscape elements as well as related objects (e.g. city furniture) belonging to urban areas. Their components are described and represented by corresponding two-dimensional and three-dimensional spatial data and geo-referenced data. 3D city models support presentation, exploration, analysis, and management tasks in a large number of different application domains. In particular, 3D city models allow "for visually integrating heterogeneous geoinformation within a single framework and, therefore, create and manage complex urban information spaces." (Wikipedia)



GeoCIM information flow cycle.



www.Sub-Urban.eu



Sub-Urban Toolbox
Pathway to future proofing cities
www.sub-Urban.eu/Toolbox

Sub-Urban Toolbox

Smoothing the path to urban resilience

The Sub-Urban Action explored the management of the urban subsurface and the use of subsurface information in urban planning, with emphasis on sustainability in general. The main objective of the Action was to improve interaction between experts who develop urban subsurface knowledge and those who can benefit most from it - urban decision-makers, urban planners and practitioners. This European network will co-ordinate and accelerate the integration of world-leading research into subsurface modelling. The Sub-Urban Toolbox has been developed to assist in the dissemination of subsurface knowledge to urban planners and policy makers.

The Sub-Urban Toolbox identifies common pitfalls and pathways in urban planning as well as providing decision-support tools. Different pathways are provided for subsurface technical experts, and urban planners, and decision- and policy-makers:

- To help better inform and empower city decision- and policy-makers about the subsurface and the vital importance of its early-stage planning.“Future proof” cities and provide them with the tools and basis they need to make informed decisions.
- Transform relationships between subsurface specialists and urban decision makers especially during early stages of planning.
- Broadly share geoscience knowledge across the disciplines involved with urban development.
- Promote a common language.

Summary

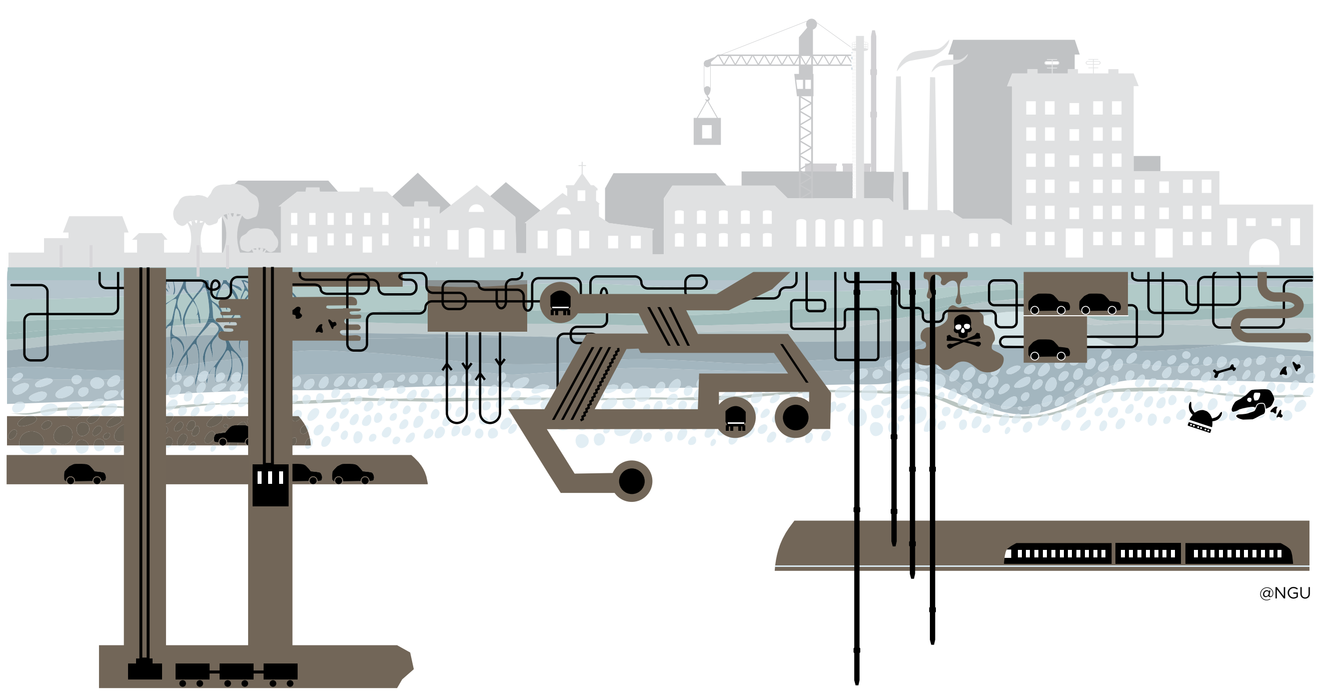
Opening up the subsurface for the cities of tomorrow

Increasing urbanisation challenges the sustainability and resilience of cities world-wide. At the same time, often overlooked are the resources and opportunities in the ground beneath cities.

This is one of the reasons why a European network of specialists joined together with the aim of improving the understanding and use of underground space. The participants of COST Sub-Urban Action (2013-2017) display a cross-section of skills and knowledge of subsurface issues in 31 European countries and 26 cities. After sharing their experiences, the common pathways (and pitfalls) to good planning became more evident. A key recommendation from this Action was improving communication between urban subsurface experts and urban planners.

The Sub-Urban project participants explored the general theme of sustainable use and management of the urban subsurface, and specifically examined how subsurface information was used in urban planning and development in numerous cities. They confirmed what several studies had already shown: the urban subsurface is largely 'out of sight, out of mind' for most people. Often it is only when problems arise that the subsurface seems interesting. The Sub-Urban group identified a possible source of this oversight: a knowledge and communication gap between subsurface experts, urban planners and decision makers. It was concluded that to bridge this gap, planners needed the right type of subsurface information, in the right format and at the right time.

The vital role of the subsurface in developing resilient cities is slowly becoming more evident. We need legislation that redefines property, now seen as land area, to land volumes that includes the subsurface. Volumetric (or 3D) urban development and design processes could be developed that integrate above ground design with below ground conditions and opportunities. This process would not only be used during project design and construction stages, but also early in strategic decision-making when planning policy and priorities are outlined, and land use and development priorities mapped out (Bonsor, 2016



@NGU

Stories from Five Cities

The COST Sub Urban group was joined by experts from 26 cities. During their workshops participants shared examples of how various types of subsurface challenges were being dealt with in their cities. In this final dissemination paper for COST SubUrban, stories from five cities have been retold: Glasgow, Odense, Rotterdam, Oslo, and Ljubljana. We selected these cities in hope that their stories would be of interest to those outside the field of urban geology, urban engineering and urban planning. We hope too that these stories might convince readers to look at the urban subsurface in the new way. Younger readers and non-specialists might be encouraged to view their city in a new way and want to find out more www.sub-urban.eu, as well as other publications and webpages that deal with the subsurface in their community. Here is a quick summary of the stories from cities in this report:

Glasgow

Glasgow has found many approaches to bridging the knowledge gap. High resolution 3D digital subsurface data excels at revealing the potential of the urban subsurface. For example, once the 100-year-old mining shafts buried under their city were viewed as hazards. Now these shafts could be upcycled to serve as energy wells.

Rotterdam

Rotterdam has been in the business of managing the subsurface issues since 1250. A large engineering department has been working for centuries to deal with keeping the city above water and protecting residents from contaminated soil. They take on the holistic approach, work hand in hand with urban planners, and even bring school children under the city to see how things work.

Odense

Odense demonstrates best how one should not ignore the capacity of citizens to solve their problems in their community. With the right information anyone can come with solutions. This strategy will become more relevant as the impacts of climate change are increasingly felt by everyone.

Ljubljana

Ljubljana might just have it all! Locally sourced water. Locally sourced energy. Right beneath their city. It is just a matter of careful monitoring and management of any human subsurface intervention.

Oslo

Oslo is growing fast, as are its investments in subsurface. Planners and subsurface experts are waiting for legislation to protect existing surface and subsurface structures from the wrong types of subsurface intervention. Improved knowledge is needed that permits sustainable management of subsurface resources (renewable energy, space, minerals).

Some pitfalls to collaborative urban subsurface planning:

- Lack of dialogue between parties involved
- Lack of municipal and state subsurface policies and legislation.
- Low awareness of subsurface assets and challenges
- Inadequate tools to make relevant information and data acessible

Pathways to collaborative urban subsurface planning include:

- Maintaining trust between parties
- Developing a simple common language (mutual understanding)
- Coordination early during planning and construction
- Understanding of responsibilities

Geo City Information Modelling (GeoCIM)

The GeoCIM concept (see story "Reconnecting cities to the subsurface"), is a tool proposed by COST Sub-Urban that can serve to smooth the path to good subsurface management. The tool can effectively bring together above- and below-ground data and knowledge at scales appropriate to city needs.

We propose various steps towards the improved provision and uptake of requisite subsurface knowledge and for ensuring its accuracy and its appropriateness. These include:

- A systematic approach that is based on the crafts and traditions that planners and geoscientists have developed over time
- (Open) Access to relevant data and updated knowledge
- Closer collaboration between planners and subsurface specialists.

Find out more about the subsurface of your city

Human activity is the driver for urban expansion and development. Societal needs must remain the focus, and the urban subsurface must serve these needs. Undervaluing the subsurface can put security, economy and health of our cities at risk, threatening the sustainability and liveability of cities. The Sub-Urban Toolbox provides 'fit-for-purpose' tools and guidance that allows and encourages the free flow of knowledge and relevant data needed for this task. Be sure to find out more about the subsurface of your city and find our toolbox here:

www.sub-urban.eu/toolbox or MapJournal

www.sub-urban.eu

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31 countries and 26 cities have participated in the COST Action TU 1206 Sub-Urban network.

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SURVEY OF
NORWAY

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