Government Office for Science

Future of the Subsurface: Subsurface space management in the UK

Foresight

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Overview

- **This document is an annex to the Future of the Subsurface report completed by the Foresight team in the Government Office for Science. It has been informed by a literature review and stakeholder engagement, and draws on a series of UK and international case studies to highlight current issues and potential solutions for subsurface space management. The document structure is outlined below, along with key points from each section.**

- **Introduction:** the review begins by introducing the subsurface as a vital resource underpinning modern society: it provides space for critical assets and services (inc. water, electricity, sewers, telecoms, building foundations, transportation) while also containing valuable resources such as water, geothermal heat, and minerals. It then introduces the challenges facing subsurface space management such as demand and competition for space above and below ground are increasing due to population densification,[1] economic expansion and the need for new or repurposed assets for technology rollouts,[2] the Net Zero transition,[3] and climate change adaptation and resilience.[4] This in turn presents growing challenges for effective planning coordination and prioritisation to manage conflicting demands and trade-offs.

- **UK examples:** the review then considers some UK examples, showing the consequences of uncoordinated underground development can pose significant challenges and problems, such as heightened infrastructure vulnerability and project delivery hazards, as well as a lack of safeguarded space for vital future infrastructure (including Net Zero solutions). It then highlights some evidence from innovative city planning bodies in the UK, suggesting the implementation of long-term subsurface strategies offers many opportunities: optimising limited urban space, enhancing resilience against extreme weather events, preserving cultural heritage, and creating new housing and park development.

- **International examples:** the review then considers some international examples. showing a number of different approaches that can be taken towards subsurface space management, some having a stronger role for national government and others seeing local government taking more responsibility for data, analysis, and strategic planning. Some of international examples show smart use of underground space in congested urban areas, and could be considered to address some of the challenges identified during this project.

- **Future challenges and solutions:** the review then considers future challenges to subsurface space management, and some potential solutions to these challenges, drawing on the examples shown throughout this evidence review.

- **Example of systems interaction:** the review ends with an example of a systems interaction. Space in the subsurface is finite and once decisions are made about its use, they are difficult to undo. Reliable and accessible subsurface data can help inform better decision making. The review outlines one example interaction developed in the project in consultation with stakeholders, based around utility data. It shows how initiating increased availability of reliable and accessible utility data could create a positive feedback loop, and allow underground space to be used more efficiently.

Introduction

The subsurface houses vital services for our daily lives and demand on space is growing. There are now over 4 million kilometres of underground services in the UK (~100 times the circumference of the Earth), with 4 million new holes being dug every year to access buried utility networks for repairs, upgrades, and installations.[5] HMG has pledged to invest £100 billion in infrastructure projects across the country over the next ten years, including major projects such as the High-Speed 2 (HS2) railway line and the Thames Tideway Tunnel. Such investments are creating significant demand for construction services.[6]

Subsurface space directly impacts a very high proportion of the population. Urbanisation is leading to particularly acute space competition in cities. Between 2018 and 2030, the urban population is projected to increase in all size classes, while the rural population is projected to decline slightly.[7] In the UK, the degree of urbanisation amounted to 84.4 percent in 2022, showing almost a three-percentage point increase over the past decade. The UK is also much more urban compared to the worldwide average.[8] Growing urban populations need more living space, increasing demand for new housing and utilities, as well as interventions such as basements – for example, 7,328 new residential basements underneath existing houses in London had been granted planning permission from 2008 up to late-2019.[9]

Issues related to urban subsurface space have been identified through a literature review and stakeholder consultation. A full list of stakeholders that the Government Office for Science team engaged with are included in the main report. Issues identified include:

1. **Congestion & infrastructure barriers:** Beneath city centres, the subsurface is highly congested with utilities, underground facilities, urban trees, and development such as tunnels and basements. In some parts of London, the

shallow subsurface is reaching capacity, as per the following statement from the City of London's website:

"Many of the City's narrow medieval streets are congested with cables and pipes, making installation of future infrastructure difficult. The City Corporation has explored with utilities providers ways to mitigate the impact of highway congestion such as removal of redundant cabling and use of old ducts to install utilities infrastructure, however this has done little to alleviate the growing problem of congestion under the highway." [10]

Project stakeholders stated that existing infrastructure poses a barrier to development of new projects (e.g., utilities, district heat networks) especially in urban areas.[11] There are around 60,000 accidental strikes every year – the estimated cost of underground utility strikes is £2.4billion annually. Unforeseen subsurface hazards are leading some developers to add a 20-30% 'risk premium' on all planning quotes, which is posing a challenge for scaling up of new low-carbon district heating infrastructure.[12]

2. **Unintended interactions:** Lack of effective coordination can lead to suboptimal planning outcomes, economic inefficiencies, and conflicts between infrastructure systems. Greater join-up of planning, delivery and data across regulatory and governance bodies could offer improved service delivery and resource management (e.g., space, groundwater, geomaterials, geothermal energy). For example, when installing sustainable drainage systems (SuDS), infiltration in the wrong places can trigger geohazards such as landslides and sinkholes.[13] The uncontrolled extension of basements can also lead to increased groundwater flooding due to interference with groundwater levels, aquifers, and flow, and this is explored further later in this paper. Some work to unlock the potential of vacant and derelict buildings could be undermined by a lack of understanding of the subsurface and what is in the ground. Unintended consequences can also include missing opportunities to maximise outcome and the efficient use of

capital, for example SuDS can be multifunctional and transport schemes could also be leveraged to address surface water issues. This is also true regarding cultural heritage, as the subsurface provides a space for heritage and supports heritage above the ground. New developments can affect groundwater levels for example, causing serious damage to heritage buildings and archaeological deposits surrounding it.[14] Proper subsurface policies and planning are therefore vital for their protection and preservation, and a whole systems approach can be applied when considering heritage.

3. **Strain on non-renewable resources:** Rapid urban growth can place strain on non-renewable subsurface assets such as minerals. Urbanisation and mining both benefit from and affect the natural environment in which they operate.[15] Minerals provide an essential contribution to the UK's prosperity and quality of life.[16] Some 178.5 million tonnes of minerals were extracted from the UK landmass for sale in 2021, and 66.8% of this was crushed rock for both construction and industrial uses.[17] Finally, it is worth considering space itself as a non-renewable resource, and exploiting subsurface space in an unsustainable manner could mean that it is not utilised to its full potential. Issues like this can endanger the longevity of these assets and place resources at risk of depletion, at the expense of future generations.

This evidence review explores space competition in the subsurface, considering the current status in the UK, drawing on real-world examples. It also considers international examples that can be drawn upon. The review then explores future challenges and opportunities related to subsurface space management in the UK.

Examples of subsurface space management in the UK: London and Glasgow

To illustrate space competition challenges as well as potential solutions, this paper uses London and the Greater London Authority (GLA) as domestic case studies. Sector-specific examples within the UK are also included in this section.

UK-based examples

London subsurface governance example

The 32 boroughs and the City of London constitute the main planning authorities, with the GLA acting as an intermediate administrative level. London has been ranked as the most congested city out of 1,000 cities across 50 countries for traffic, according to data from analytics firm Inrix.[18] There is constant demand for new utilities across London. Due to limited space, it is not practical to dig up roads every time new connections are required.

City Plan 2036 contains a new Strategic Policy on Smart Infrastructure and Utilities, accompanied by three development management policies: infrastructure provision and connection, infrastructure capacity, and pipe subways.[19]

These policies seek to minimise demand for new infrastructure; encourage early engagement between developers and infrastructure providers at an early stage of design; ensure designs incorporate connections to existing infrastructure; and ensure existing infrastructure is effectively utilised.

These policies seek to address current issues around space in the city and are an example of a shift towards more longer-term planning for the subsurface in London. By making smarter use of existing space this may free up space for future use.

London: Basement extensions in Hammersmith and Fulham

Creating a basement in a home historically required planning permission only in certain cases, usually when changing the look of the outside of the house or if the building is listed.[20]

Hammersmith and Fulham's average property price is higher than the average property price in England, and it is the 4th London borough when ordered by average property price and is 5th when ordered by property price growth rate.[21] In their study of luxury basement developments in London, Burrows et al (2022) reported that Hammersmith and Fulham accounted for over 18% of all basements builds – 1,337 in total. They also reported that Hammersmith and Fulham was the London Borough with the highest ratio of basement builds per resident household.[9]

Basements can 'sterilise' aquifer material, which normally store and conduct water, meaning these functions are lost.[22] The bedrock underlying the borough of Hammersmith and Fulham is mostly London Clay overlaid with superficial deposits of sand and gravel across the southern part of the borough, and there is a groundwater flood risk from permeable gravels along the historic floodplain of the river Thames.[23] Localised groundwater flooding occurs in excavations and basements when the water level within the gravel layer rises after heavy rain.

For the Borough of Hammersmith and Fulham, 30% of basement applications are at risk of groundwater flooding.[22] There are concerns of the cumulative effects of these basements in the future, as it could reduce aquifer capacity and change flow directions, leading to higher groundwater levels and increased flooding. This also leads to structural impacts from changes to soil properties.

London authorities are increasingly looking at planning applications more closely to help assess their impact on local ground conditions, responding to the problems highlighted above and as a reaction to citizens' complaints about large basement extensions. Basement Supplementary Planning Documents (SPDs) are now commonplace with the majority of the 32 London Boroughs.[24] Only two boroughs – Ealing and Havering – had these in place in 2008; the majority were developed after 2011 in line with the surge in applications.[22]

Glasgow subsurface governance example

This section looks at Glasgow City Council's approach to subsurface space management and planning as an example of a leader in the UK for integrating the subsurface into planning policy.

The city of Glasgow is the national urban regeneration priority for Scotland over the next 25 years, and approximately half of Scotland's population lives within an hour's drive of Glasgow.[25] The geography and geology of Glasgow combined with its legacy of mining means that there are a number of complex issues related to managing subsurface space in the city. This includes derelict land, contamination, and subsidence, alongside opportunities for energy generation from surface deposits and deeper mine workings.[25]

Glasgow City Council was the first local authority in the UK to formally recognise the subsurface within its proposed City Development Plan.[26] They are also a signatory to the Scottish Geodiversity Charter, making a commitment to enhance and protect geodiversity.[27] As there is no overarching national plan for subsurface management, most of the developments in subsurface planning in Glasgow have come from collaboration and partnerships.

The Clyde Urban Super Project (CUSP), led by the BGS in partnership with Glasgow City Council is a multidisciplinary project with a focus on improving knowledge of the subsurface beneath the city of Glasgow and to make geoscientific information more accessible to the wide range of users involved in Glasgow's development.[28] An output of CUSP is BGS' Accessing Subsurface Knowledge (ASK) Dataset. This data offers sub-surface descriptions of the Clyde valley, including both models and raw data. Individual datasets offer subsurface bedrock geology and uncertainty data as well as superficial deposits geology and uncertainty data.[29]

Sector-specific UK examples

Power

Power tunnels in south London: London Power Tunnels is a project by National Grid to reinforce the electricity transmission network in London by constructing new deep-level tunnels carrying high-voltage cables.[30] Tunnel alignment went under King's College Hospital in South London. It turned out that the building had 47 closed loop ground source heat pumps, but this information was only received two weeks before the tunnel boring machine reached the site, leading to a pause and review of the alignment to avoid the heat pumps. If this issue had been missed it could have led to the potential damage to the tunnel boring machine, the destruction of a third-party asset, and a risk of groundwater contamination from glycol emanating from the ground source heat installations.

Current regulation means that a record of these kinds of energy piles is not required. They do not need building regulations approval due to not being structural, and as they are not connected to an external utility, they are not recorded on any utility drawings. Consequently, these piles are not recorded on any construction drawings held by statutory bodies and so constitute a below-ground construction hazard that is not found via normal documentary searches. The absence of regulation enforcing a record of these energy piles could impact safeguarding alignments. Ground source heat pumps will become increasingly common in future, and new transmission lines will be required for the increase in power generation needed to reach net zero. Existing regulations mean that these kinds of hazards could continue to be overlooked.

Data

Subsurface data centres: The use of the subsurface for data storage is another noteworthy application because of the rise of AI companies that rely on cloud computing. Projects like the proposed "Project Natick" by Microsoft involve submerging data centres in water bodies.[31] By utilising the natural cooling properties of the water, these submerged data centres aim to be more energy-efficient and environmentally friendly.

Food production

London: Growing Underground in Clapham: Located in a disused underground World War II air raid shelter in Clapham, London, Growing Underground is an innovative agricultural project that utilises the subsurface for sustainable farming. The farm employs hydroponic technology, LED lighting, and vertical farming techniques to grow a variety of herbs and salad greens. This underground setup allows year-round cultivation, regardless of weather conditions, and reduces the need for pesticides and transportation costs.[32]

Culture and leisure

Roman Baths Clore Learning Centre in Bath: Heritage assets are an important part of subsurface space and are usually competing with other uses. The Roman Baths Clore Learning Centre, a state-of-the-art Learning Centre at the Roman Baths, opened 16 June 2022. This learning centre used existing underground spaces and built a tunnel to link to the famous landmark. The learning centre is an example of the use of existing subsurface space to engage future generations and preserve non-renewable subsurface resources such as cultural heritage.[33,34]

Underground brewery in Bath: Several microbreweries and beer producers in the UK have set up their operations in underground spaces. For instance, the Electric Bear Brewing Company in Bath operates in a former air-raid shelter, using the subsurface environment to create a unique brewing atmosphere.[35]

Underground concert venue in Glasgow: The use of underground spaces for concert venues is gaining popularity. The Sub Club in Glasgow, located in a basement, is an iconic nightclub that has been hosting underground electronic music events for decades. These venues offer a distinct atmosphere and acoustic experience for concertgoers and many such spaces in are fast appearing as new venues in the UK.[36]

International examples of subsurface space use

This section covers international examples of subsurface space management. The Netherlands, Finland, and Singapore are shown as examples of countries that have a particularly forward-looking approach to managing the subsurface. They each take a different approach to governance with some having a stronger role for national government and others seeing local government taking more responsibility for data, analysis, and strategic planning. These examples highlight a number of different approaches that can be taken towards subsurface space management. Other examples include Denmark, Malaysia and Canada, shown as examples of smart use of underground space in congested urban areas, which could be considered to address some of the challenges identified during this project, such as urban congestion and climate adaptation and resilience to extreme weather events.

Subsurface space management in the Netherlands: Basic Registration Subsoil - Basisregistratie Ondergrond (BRO)

In the Netherlands, spatial planning policy and its implementation are mostly shaped at the municipal level.[37] Municipalities can set regulations that they deem appropriate based on their knowledge of the local situation.[37]

The Netherlands takes a 3D approach to spatial planning, and the subsurface is included in spatial plans. The Basic Registration Subsoil (BRO) came into effect 1 January 2018.[38] It aims to create one uniform, digital and detailed register of soil and subsurface data in the Netherlands.

Part of this is new 3D subsurface models, providing a starting point to investigate risks and opportunities for subsurface use.[39] These "Digital Twins" make information both above ground and below ground transparent, understandable, and accessible for experts in civil engineering, policy makers and residents.[40]

Subsurface space management in Finland: Helsinki example

In Finland, governance is based on the principle of decentralisation, with three-tiers of statutory planning: national, regional, and municipal.[41] The country's Land Use and Building Act, which covers the use of land areas and associated building activities, explicitly mentions the subsurface.[42]

Regional Land Use Plans are drawn up and approved by the Regional Councils and set out principles of land use and designate areas for regional development. These are strategic in nature, leaving room for local interpretation and implementation. Municipalities are also able to purchase land for future development needs due to the several statutory land policy instruments available to them, such as Local Master Plans.[43]

Helsinki is a city that is particularly forward thinking in terms of underground space management and has a long history of using subsurface space. It is the first city in the world with an Underground Master Plan.[44] It shows both existing and future underground spaces and tunnels, including rock resources reserved for the construction of unnamed future underground facilities, as well as existing vital access links to the underground.

There is a network of bunkers and tunnels that spread out across Helsinki, including five thousand bomb shelters and 50,000 bunkers.[45] Helsinki began creating tunnels in the 1960s to house utilities. City planners then realised that the space could be used as air raid shelters. Some of these shelters have been converted to everyday use, such as an underground playground, hockey rink, and a swimming pool.[46] This is especially useful in winter, when the city only gets a handful of daylight hours, as it provides shelter from the elements.

Singapore example

Singapore is a city state with a centralised model and no local government. The country has many nationalised companies across different industries, and they have low taxes and minimal regulations to encourage private investment.

Singapore is increasingly considering underground space in planning to optimise land use in congested urban areas. The country has invested $188 million in underground technology research and development and reformed its land laws so that homeowners own only the underground space up to their basement, allowing the government to use the deeper land without facing private property issues.[47] The new default option for utilities is to go underground, even if this has initial higher upfront costs.

A new underground Special Detailed Control Plan (SDCP) has been introduced to enable better planning of underground space. This plan is in 3D, allowing for better visualisation. The SDCP includes a series of 3D maps of underground areas to allow planners to relocate infrastructure and facilities under the ground, in order to free up surface space.[48]

Stormwater Management And Road Tunnel (SMART), Malaysia

SMART was constructed to solve the problem of flash flooding in Kuala Lumpur and to reduce traffic jams during the daily rush hour. The tunnel has four different modes of operation:

- The first mode is under normal conditions with no rainfall, and the motorway section is open to motorists.
- The second mode is used in the event of a storm, where floodwater is diverted into the lower bypass tunnel of the motorway, and the upper channel remains open to motorists.
- The third mode is activated when a major storm occurs, and the tunnel is vacated and closed to motorists and floodwater is allowed to pass through.

- The final mode is activated if heavy rain persists after the third mode has been activated, where the tunnel remains used for flood passage and is closed for four days.

The SMART is an example of dual use of limited subsurface space in urban areas, where congestion and competition for space are high.

Copenhagen Climate Plan project, Denmark

The Copenhagen Climate Plan project is a city-wide initiative to reduce greenhouse gas emissions.[49] The project includes a plan to use the subsurface for a variety of purposes, including:

- **Sustainable energy:** The project includes plans to develop a district heating system that will use heat from the ground to heat homes and businesses.
- **Water management:** The project includes plans to develop a storm water management system that will use the subsurface to store and filter storm water runoff.

- **Transportation:** The project includes plans to develop a network of underground tunnels for public transportation.

Toronto, Canada

The city of Toronto has embarked on an initiative known as "Feeling Congested," which aims to address transportation challenges through an integrated approach.[50] As part of this initiative, the city is exploring the potential of subsurface planning to alleviate congestion. One proposal includes the construction of underground tunnels to accommodate various modes of transportation, freeing up surface space and improving overall urban mobility.

Future challenges and solutions for subsurface space management in the UK

This section considers future challenges for subsurface space management in the UK, and potential future solutions, reflecting on the examples shown above.

Future challenges

Balancing short-term issues vs long-term planning for subsurface space management: There is a tendency for shorter-term thinking in subsurface planning, which can come at the expense of sustainable urban development. This can be exacerbated by demands for rapid development, which does not leave sufficient time for joined-up planning and consideration of future trade-offs. The example of Hammersmith and Fulham shows that uncoordinated developments and later planning for subsurface spaces can increase an area's vulnerability to hazards such as flooding and cause further structural issues. If done in an unplanned way, subsurface development can lead to problems and challenges that can be difficult to undo. Project stakeholders stated the need to look beyond the planning and delivery stages of projects and consider long-term sustainability and stewardship for subsurface space.

Incomplete asset information: The lack of comprehensive and accurate subsurface data, such as underground utilities, basements, and infrastructure, poses another key challenge. Insufficient information about the location, depth, condition, and characteristics of these assets hinders effective planning and decision-making, leading to potential conflicts and disruptions during construction or maintenance activities.

Coordination and collaboration: Coordinating and collaborating among various stakeholders, including utility companies, local authorities, and infrastructure providers, is crucial for subsurface land use planning but is often fragmented. The lack of standardised data sharing protocols, coordination mechanisms, and clear responsibilities among these entities poses challenges in obtaining and integrating the necessary information for effective planning. Coordination between stakeholders working both above and below ground can also provide benefits by reducing the number of times a road is dug up, thereby reducing traffic congestion and delays, costs savings (shared traffic management/resident communications), and environmental benefits (vehicle pollution, reduced carbon footprint from works). For example, installing a planned cycle lane or pedestrianising a road at the same time as making repairs to buried utilities.

Future solutions

Optimal land use: Proper planning and utilisation of subsurface space can enable smarter and more efficient use of limited urban space. By moving certain functions underground, such as parking, storage, or utilities, valuable surface space can be freed up for other purposes like housing, parks, or recreational areas. Climate change and the drive to net zero will likely put pressure on infrastructure owners, promoters, and users. Data sharing and greater co-ordination could ease this pressure and help with prioritisation and planning in future when planning net zero solutions. A further example of this in the UK is that Glasgow is considering a net zero masterplan for the Drumchapel area, and subsurface issues are being considered under this such as soil contamination.[51] The subsurface presents opportunities for preserving and utilising cultural heritage. Underground spaces can be repurposed to showcase historical artifacts, create museum exhibits, or provide unique cultural experiences, as highlighted in the Bath example above.

Building resilience to extreme events: Developing underground infrastructure and facilities can enhance urban resilience to extreme weather events, such as floods or storms. Underground structures are generally more protected, ensuring continuity of essential services.[52] With the threats of climate change and extreme weather this will become increasingly important. The examples highlighted in Helsinki and Malaysia show how smart use of space can increase the resilience of cities. The subsurface can also provide protection to extreme heat. UKCP18 climate projections for London include an increase in average summers of 2-5 °C and increased frequency and duration of extreme summer temperatures and heatwaves.[53] In the short term, cool space strategies are surface based. There is potential for the future repurposing of subsurface structures to meet this need. In London, for example, subsurface venues are frequently repurposed for commercial venues (e.g., vaults and basements converted to pubs or available to hire as venue spaces, toilet, bars) but these are not yet identified as designated cool spaces for respite from heat.[53]

Supporting Innovation: Technological development provides an opportunity for the subsurface to provide a space for innovation, as highlighted in the international examples above. New technologies that make it easier and cheaper to measure, monitor, excavate, tunnel, and maintain the subsurface are on the horizon, but may need new policy or regulation to enable their widespread use. This project found that developing technological capability to solve subsurface challenges is a ‘low regret’ action and should be considered further.

Consideration of underground space in the planning stage of projects: Inclusion of underground space early in the planning process permits more effective selection of development options through robust cost-benefit analyses. It would also ensure that stakeholders who already utilise underground space are involved in the consultation process.[54]

Planning for the long-term: the examples highlighted in this paper show that building underground in congested cities can have all sorts of benefits with proper planning. Helsinki and Singapore have invested in longer-term planning for the subsurface and are seeing greater use of the subsurface in day-to-day lives, providing a space that protects people from the elements that also ensures that the city is prepared for the worst-case-scenario. The Greater London Authority (GLA) established the Infrastructure Coordination Service (ICS) to drive better collaboration in the planning and delivery of

London's Infrastructure through facilitating early engagement and using data and other tools to support decision making.[55] A key service of the ICS is the Streets Service (Streets service London City Hall) that is transforming the way street works are delivered across London by driving a 'dig once' approach between infrastructure providers.[56] In 2023 the ICS concluded an 18-month future proofing pilot project in the London Borough of Tower Hamlets to establish best practice for funding and delivering future proofing street works solutions by pre-empting future infrastructure needs through interventions such as installing extra ducting or reusing existing assets.[57] Such future-proofing reduces excavations on the road network and decreases future costs and disruption to London's streets.[58]

Collecting, maintaining and sharing subsurface asset data: the National Underground Asset Register (NUAR) provides secure access to privately and publicly owned location data about the pipes and cables underground.[59] The digital map gives planners and excavators standardised access to required data, to carry out their work effectively and safely. It also includes features to keep data secure and improve its quality over time. The initial version went live in April 2023, covering Northeast England, Wales, and London.[60] This includes data from major energy and water companies in these areas, as well as numerous smaller and public sector organisations. The economic benefits of NUAR are estimated to be £480m per year, alongside increased efficiencies in shared data and improved data quality, and reduced risk of accidental strikes.[61] In Scotland, the Community Apparatus Data Vault system (Vault) was introduced in 2012 and allows the display of information from disparate GIS systems on one screen at the same time to make data of buried pipes and cables accessible through the Scottish Road Works Register.[62] Participation was made mandatory through the Transport (Scotland) Act 2019.[63] In the future, data availability could improve through expanding initiatives such as NUAR and Vault, and more advanced technology could help with digitising legacy datasets and sensing what is below the ground.

Clearer regulation: Clearer regulation for the subsurface could give greater direction and consensus during the planning stage and ensure better management of valuable subsurface space in urban areas.

Example systems interaction

To illustrate some specific subsurface interactions, we have isolated and refined three example interactions, chosen in consultation with stakeholders as particularly interesting and illustrative of subsurface challenges, one of which is shown below in figure 1. These include both 'feedback loops' and linear chains of interactions, described below. Further information about the example interactions, including their development, is shown in the main *Future of the Subsurface* report.

Figure 1 shows one set of interactions developed, and is informed by the experience of developing the National Underground Asset Register (NUAR). It shows how initiating increased availability of reliable and accessible utility data could create a positive feedback loop.

As shown, increasing the sharing of high quality data could lead to fewer delays in streetworks caused by utility strikes and increase opportunities for coordination between utility companies, which could reduce costs and disruption for road users by reducing the number of holes that need to be dug. This would help to create a strong business case which in turn could lead to an increase in reliable and accessible utility data and smarter use of subsurface space.

Further consequences of increasing reliable and accessible utility data could allow underground space to be used more efficiently and increase confidence in other data sharing initiatives. Fewer holes dug would entail environmental benefits from reduced carbon emissions, and fewer utility strikes would improve worker safety. This diagram is an illustrative example of potential consequences of increased reliable and accessible utility data, and in reality, there could be much bigger implications.

Example systems interaction

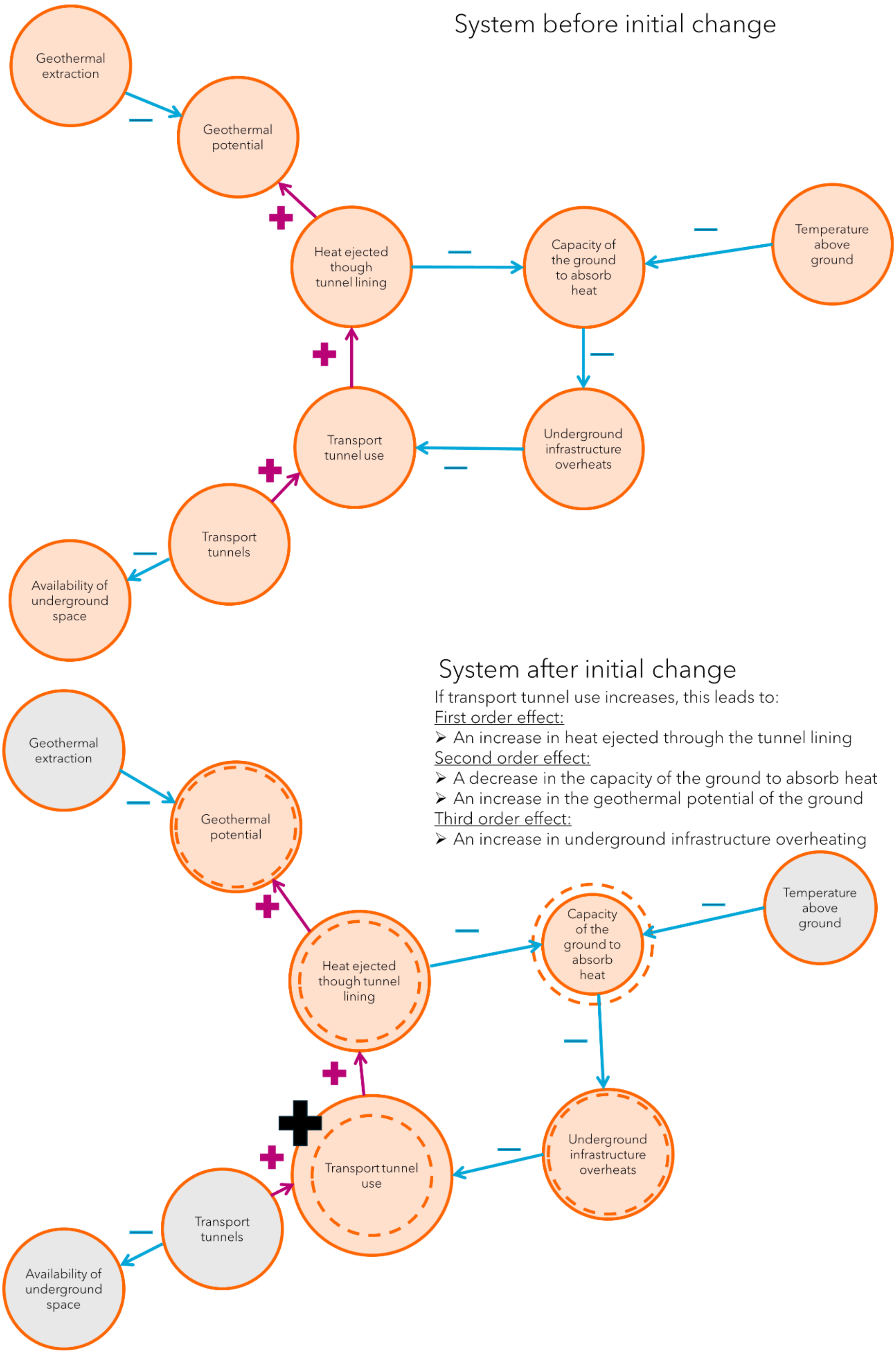

Figure 1: This figure shows an example interaction showing how increasing the use of transport tunnels could impact the ground through the heat this produces

References

[1] Macrotrends (2023). U.K. Population Density 1950-2024.
[2] Department for Digital Culture Media and Sport (2022). UK tech sector retains #1 spot in Europe and #3 in world as sector resilience brings continued growth.
[3] UK Government (2021). UK's path to net zero set out in landmark strategy.
[4] Local Government Authority (2023). Debate on the role of local government in reaching net zero, House of Commons, 5 June 2023.
[5] Geospatial Commission (2022). The National Underground Asset Register (NUAR) Consultation.
[6] Approach Personnel (2023). UK Construction Industry Growth: 4 Key Drivers for the Next Decade.
[7] Government Office for Science (2021). Trend Deck 2021: Urbanisation.
[8] Dyvik (2024). Share of urban population worldwide in 2023, by continent.
[9] Burrows et al. (2022). Bunkering down? The geography of elite residential basement development in London.
[10] City of London (2024). Pipe Subways.
[11] Based on conversations with Department for Energy Security and Net Zero (DESNZ).
[12] Evidence provided by DESNZ Clean Heat Team in direct correspondence with Government Office for Science.
[13] Cotterill and Bracken (2020). Assessing the Effectiveness of Sustainable Drainage Systems (SuDS): Interventions, Impacts and Challenges.
[14] de Beer and Boogaard (2017). Good practices in cultural heritage management and the use of subsurface knowledge in urban areas.
[15] Mulder and Bremmer (2005). Urbanization, Industrialization, and Mining.
[16] Department for Levelling Up, Housing and Communities (2014). Minerals.
[17] Minerals UK (2021). United Kingdom mineral statistics.
[18] INRIX (2022). INRIX 2022 Global Traffic Scorecard: London Tops List as Most Congested City, U.S. Cities Inch Closer.
[19] City of London (n.d.) City Plan 2036.
[20] Planning Portal (2023). Planning Permission.
[21] Varbes (2022). House Prices in Hammersmith and Fulham.
[22] Geosmart Information (2018). Basement Groundwater Flood Risk: Key issue for London Planning Applications.
[23] London Borough of Hammersmith and Fulham (n.d.). The Local Flood Risk Management Strategy.
[24] Bell Cornwell (2023). London councils dig a little deeper: basement policy.
[25] Glasgow City Council and British Geological Survey (n.d.). Glasgow.
[26] Glasgow City Council (2024). Subsurface.
[27] Scotland's Nature Agency (2018). Scotland's Geodiversity Charter.

References

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[28] British Geological Survey (2024). Glasgow and the Clyde Basin – Clyde Urban Super Project (CUSP)
[29] British Geological Survey (2023). British Geological Survey accessing subsurface knowledge data
[30] Tunnelling Journal (2022). Tunnelling Journal December 2022 / January 2023
[31] Roach (2020). Microsoft finds underwater datacenters are reliable, practical and use energy sustainably. Microsoft.
[32] Walsh (2021). Growing Underground.
[33]BBC News (2019). Bath's new heritage centre plans unveiled.
[34] The Roman Baths (2022). Opening of Roman Baths Clore Learning Centre.
[35] Electric Bear Brewing Company (2023). Our Taproom.
[36] The Sub Club (2023). Heritage.
[37] Government of the Netherlands (2013). Spatial Planning in the Netherlands.
[38] Zeiss (2018). Dutch portal sharing information about subsurface goes live.
[39] Basisregistratie Ondergrond (2023). Praktijk (Practice).
[40] Basisregistratie Ondergrond (2023). About the Key Registry.
[41] Purkarthofer, E. et al. (2023) Finland: Overview.
[42] Ministry of the Environment (1999). Land Use and Building Act.
[43] Ministry of the Environment (n.d). Land use planning.
[44] City of Helsinki (2009). UNDERGROUND MASTER PLAN OF HELSINKI.
[45] De la Cuetara (2022). Helsinki's underground city reflects tense position as Russia's neighbour.
[46] Hunt (2021). How cold war fears helped create Helsinki's subterranean paradise.
[47] Scruggs (2018). Singapore Is Creating a Subterranean Master Plan.
[48] Urban Redevelopment Authority (2023). Master Plan.
[49] City of Copenhagen (2016). Copenhagen Climate Projects.
[50] Feeling Congested (2023). Feeling Congested.
[51] East Dunbartonshire Council (n.d.). Westerhill Regeneration Area Masterplan - Executive Summary.
[52] Admiraal and Cornaro (2021). Future cities, resilient cities – The role of underground space in achieving urban resilience.
[53] Freeborough, K., Richardson, T., Laban, J., Munday, T. (2023). The Cubic Mile Project: Policy summary and overview.
[54] Broere (2016). Urban underground space: Solving the problems of today's cities.
[55] Mayor of London (2024). Infrastructure coordination.
[56] Greater London Authority (2024). The Dig Once approach.
[57] Greater London Authority (n.d.). Future proofing streetworks.
[58] Greater London Authority (2023). Embedding Change.
[59] Geospatial Commission (2024). About NUAR.
[60] Geospatial Commission (2023). NUAR available to users in first UK locations.
[61] Geospatial Commission (2023). NUAR - Economic Case Study.

References

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[62] Scottish Roadworks Commissioner (2018). Vault – Access to Information on the Location of Underground Pipes and Cables.
[63] Scottish Parliament (2019). Transport (Scotland) Act 2019.

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