The Cubic Mile Project: Recommendations and guidance for implementation

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Subsurface space is regarded as both a key potential future resource that could be utilised to support the resilience of society to climate change, and at the same time a blocker to surface climate resilience measures where areas are perceived as 'congested'. Understanding the current state of play, as well as available data and legislation, formed a key aspect of the UK Climate Resilience placement for both the City of London Corporation (CoLC) and the British Geological Survey (BGS). Discoveries from the Cubic Mile project have enabled a better understanding of the issues surrounding subsurface information and its relation to climate adaptation/resilience planning. Whilst underground space is **regulated to a degree** through spatial planning policy (e.g., conversion and subterranean expansion of residential property) and environmental licensing (e.g., water abstraction, mineral extraction, discharge and mining) there are no leading subsurface governing polices at the local level that support climate adaptation.

Accessing data about the subsurface is often resource heavy, both in terms of cost and time, and limited by licensing and spatial data coverage. The complex history of the City of London has resulted in a very congested subsurface with a history of around two millennia of development. A key part of the embedded researcher placement involved a review of existing data, identification of gaps and discussions with the City and other stakeholders identifying where improvements or changes could be made for future implementation of subsurface data in climate resilience planning. Whilst some suggestions could be realised as a quick win with regards to storage and sharing of internal information, other recommendations would be much more involved and relate to policy or a wider cultural change. These would require a strategic change implemented at higher level and a lead agency to take forward.

Key outcomes of the Cubic Mile subsurface data review for climate adaptation and resilience

- **Wider legislation is needed** to better regulate use of the subsurface, and documenting of subsurface data (e.g., mandated not voluntary depositing of sustainable urban drainage system (SuDS) schemes, recording of all ground source energy schemes, not just open loop schemes requiring licence controls of abstraction/discharge)
- **Changes are needed in the planning system to better record subsurface development and the resulting ability to investigate that data.**
- When it is available, information on subsurface assets is **stored in different places and formats**. It is frequently **bound by IPR, licensing and scale** of interest issues.
- Focus on collating data on subsurface infrastructure is mostly site-based and focused on **project works and development (strike avoidance)** rather than long term climate adaptation.
- Information on utility networks is still **difficult to obtain and access** even at local authority level, being **costly and very localised**. This makes more detailed opportunity mapping broadly infeasible at area overview scales at the current time.
- Further **review of anthropogenic deposits** (geological information) in urban areas is needed. Research is progressing to include climate scenarios on geological formations and geohazards.

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However, in urban areas with a greater depth of anthropogenic ground, better understanding is required on the potential influence of climate change on the behaviour of anthropogenic material, and the potential of geohazards under climate change.

- **Basement information** is not stored as an accurate data layer, or easily attainable. Commercial products are available but were not accurate enough in areas with high rates of development such as the City of London. There is much interest in compiling this information from stakeholders. Of key interest is how this affects the surrounding geology (e.g., redirection of groundwater flow, temperature of substrata) and the implications of this in future climate scenarios.
- Collaborations between stakeholders could **improve subsurface data collection and access to data**. Technological advances could be combined with new development to enhance data collection that is needed for wider climate research; for example, opportunities for sensors to be installed as part of new developments that could collate data on temperature or groundwater.
- CoLC had access to a selection of subsurface information stored internally, already in digital format. Identification of these datasets, combined with some open-source information and data accessible under licence, enabled successful trial of internal opportunity maps identifying potentially less congested spaces with potential for climate adaptation measures. Recommendations will be made to improve CoLC internal data that would support better understanding of subsurface space in the City of London for future climate and public realm research. Gaps in knowledge and data have been identified.
- Valuable historic local knowledge regarding situational changes can be gained from long term employees. This knowledge base needs to be better collated moving forwards to provide a 'real' understanding of the area to assist adaptation planning and share with wider stakeholders. This will ensure the introduction of future climate measures can be based on lived experience as well as model outputs (e.g., identification of basements that 'always flood' or disused subsurface space with potential for future development).

Lessons learnt from the geological data review

Geological information for the UK is widely available. Bedrock and superficial mapping is well-developed, including 3D outputs in some urban areas including the City of London. This is supported by local in-depth ground investigation data and borehole information. However, the pathways for movement of water, contaminants and gases underground are not fully considered.

Research is underway mapping climate data to geological information and assessing the influence on geohazards. National datasets are available that show potential change in subsidence due to changes in climate. They have been developed by combining long-term UK Climate Projection (UKCP) scenarios for rainfall and temperature changes with the geotechnical properties of the ground, to identify areas projected to experience the largest increases in susceptibility to subsidence over the next century.

The key issue for the City of London is the influence of artificial ground on climate-induced geohazard understanding. Whilst the methodology in hazard mapping includes scoring for made ground (anthropogenic deposits), the majority of the City is understood to be covered in a significant depth of anthropogenic deposits, which is not geologically mapped. Permeability, clay content and depth of made ground are all key influences on the response of the City to climate change and potential suitable adaptation measures. Whilst there were a number comments made alluding to the positive nature of artificial ground ("made ground is good for tree planting", "made ground is not always a hindrance",

"deep and fissured ground allows tree roots to penetrate"), there is a recognised wider knowledge gap related to urban areas with a greater than normal anthropogenic deposit thickness that will have on effect for understanding influences of climate change in the future.

Key recommendations for change resulting from Cubic Mile Project outcomes

- Strategy discussions with BGS product, mapping and engineering geology teams and associated stakeholders regarding improved mapping of artificial ground.
- Better geological model in the top 10-20m, with improved detail in the anthropogenic deposits. This is in part achievable with some of the data available, but in the longer term may require improved data collation at time of borehole logging.
- Of key interest is how subsurface structures affect the surrounding geology (e.g., redirection of groundwater flow, temperature of substrata) and the implications of this in future climate scenarios. Collaborations between stakeholders could **improve subsurface data collection and access to data**. Technological advances could be combined with new development to enhance data collection that is needed for wider climate research.
- Documenting information influencing the subsurface data should be mandated and not voluntary e.g., depositing of information on local SuDS schemes to records and registration of all ground source energy schemes (not just open loop schemes subject to license controls on abstraction/discharge).

Lessons learnt from the cool spaces (below ground) review

A unique complexity to central London is specific security concerns surrounding some subsurface structures, such as reported underground Ministry of Defence spaces, with an acknowledgement that some information will never be accessible for wider audiences and especially not in the public domain. Whilst some spaces are well-known (such as the Post Office Railway), with some even explored by so called 'urban explorers', collectively mapping these for formal resilience and climate adaptation planning will prove elusive.

Part of the project initially attempted to understand the spatial distribution of building space under the City, including basements. Basement data was required for two reasons: **identification of potential cool spaces** (either designated as cool space now or potential for future repurposing); and the identification of basements **as potential blockers to climate resilience schemes** (e.g., mapping of basements that may extend under street level at shallow depths, preventing planting schemes). Research was also focused on accessing depth information; whilst some general information is in the public domain (e.g., '4 stories of basement reported for the Leadenhall Building') and an average '3m per basement storey' is used as a catch-all, the team found limited repeatable factual information. It was determined that sadly, much is implied rather than quantifiable.

Commercial models that include basement information are available to licence. Whilst these will be more reliable in some urban and residential areas, in the City of London trial data was not considered accurate enough to pursue. This is part due to the constant development in the City but also potentially related to security of information. Example of basement mapping services included:

- Verisk - UKBuildings | Property Mapping | 3D Buildings | Verisk Analytics
- OS data – planned for future release

The City of London has a unique sense of place including a complex development history. Not enough information is stored in an accessible and reliable form and thus sourcing and accessing information

is time consuming and repetitive, even accessing at a high-level overview. Within the City, the constant change and development has resulted in thousands of planning applications even with in a relatively small area.

Within planning records, detailed basement and subsurface information is inconsistent and not separately recorded, only being interrogable in free text planning descriptions. Planning processes mean that there may be multiple plans and submissions for a single development on a site. These are not always updated to confirm which plan relates to the final as-built structure. Machine learning applications could be utilised to extract information; however, it is likely that manual editing would still be required for accuracy. In consultation with stakeholders, it was clear that due to the lack of singular repository, site-specific searching is currently the norm for surface and subsurface development, which is again costly and time consuming (Crossrail, Arup, pers comm). Furthermore, there is currently no formal record of empty or occupied structures (basements or otherwise) that could be repurposed for cool spaces, and therefore no reliable record of disused space. There needs to be a coordinated approach for repurposing should this be something that the City (or other urban areas) wish to pursue in the future. There are also on-going issues with accessing information and security.

Key recommendations for change resulting from Cubic Mile Project outcomes

Internal focus – City-owned buildings and assets

- Update internal database to include basements as separate, searchable field in planning records. This could then be accessed on a tiered system internally.
- Collate information on abandoned structures (e.g., disused below street toilets)

Changes to wider planning process policy

- There is wide agreement that the inclusion of a separate field in planning applications regarding subsurface features would benefit multiple parties and stakeholders. Ideally this would include any subsurface structures and a separate field for number of basement levels or storeys.
- The London Plan currently includes a policy to include publicly accessible areas in tall buildings where appropriate, particularly more prominent tall buildings where they should normally be located at the top of the building to afford wider views across London. (London Plan 2021 Policy D9 Tall buildings (D)). We suggest that in the future a similar policy is formulated to include wording for publicly accessible subsurface spaces that may be accessible during periods of higher temperatures or (re)purposed for climate adaptation.
- As discussed above, sensors could be added to new developments to enhance data collection that is needed for wider climate research.

Lessons learnt from the ground source energy data review

Interest in local heat networks and heat pumps is increasing as focus shifts to lowering the UK's reliance on fossil fuel heating for homes and businesses. Much of this focus is on residential property, which is less applicable to the City of London due to a low residential population. Data accessed for the City of London indicated many scheme enquiries had been submitted to the Environment Agency, however only a limited number went on to development. There needs to be a better understanding as to why schemes did not go ahead. One issue for the City of London could be the large developments

that are sold off in blocks once completed, meaning maintenance and uptake of a building GSHP system may be more complex than anticipated after initial development has occurred.

Geothermal energy is not recognised by law as a natural resource in the UK (like water or gas), and there is currently no bespoke regulatory system for the licensing, ownership, and management of the geothermal resource. Currently, only open loop ground source heat pumps are required to be licensed by the Environment Agency using water resource regulations. Schemes classified as closed loop are exempt from licensing control. The local licensing policy position is that for all new open schemes, and the majority of existing schemes, any abstracted water must be discharged back into the aquifer, in order to maintain a stable water table and reduces the potential for large volumes of water being removed from the aquifer. There are also schemes which may have the ability to swap their abstraction and discharge points around. This can assist in the longevity of a scheme or flexibility in the operation of the scheme. Closed loop schemes are not required to be registered although may still affect temperature of surrounding strata. Data on GSHP abstraction schemes is stored by the Environment Agency and is available on request, and was accessed for this project. A different register is also in use for residential properties, however registration on this database is still voluntary.

Whilst BGS maps indicate there is a potential for more GSHP schemes, there is still an issue of congested space in the City and the limited potential for length of pipelines (horizontal) and available depth (vertical) due to presence of subsurface structures (e.g., TfL tube lines). There are still discussions on the number of larger schemes that are viable within an area without affecting the aquifer more than is allowed in variation; it is understood that there is no official advice or legislation on this yet. Heat leakage from basements, buried services, leaking mains and underground railways can impact aquifer and this is not yet fully understood; some schemes may be negatively affected by increased temperature making them less efficient or inoperable. Groundwater in London also needs careful monitoring, and as a result licences may require monitoring of abstraction volume and groundwater conditions.

The City of London does have heat networks. Citigen is the key example, using existing subways, tunnels and car parks for pipework; despite this, roughly one-third of the pipework still had to be buried. Decarbonisation plans are underway using new ground source heat pumps. CoLC has good relations with E-on, Citigen's operator, so data on pipelines was available to access via internal channels.

Other examples of local schemes include the Portsoken Pavilion, which uses disused subways for circulation and cooling. Just outside of the City of London is the Bunhill District Heating system, using waste heat from tube vent shaft as source for heat pumps. Research to support the City of London Local Area Energy Plan in partnership with Arup was started in summer 2022 and this offer a detailed economic assessment of the ground source energy potential on its completion.

Key recommendations for change resulting from Cubic Mile Project outcomes

- Assigning of a single, bespoke geothermal regulator, or an agency that coordinates the approval process for schemes, in consultation with local authority and regulatory bodies.
- Change in policy for registration – introduction of mandatory registration for all schemes (both open and closed loop) and data accessible by local authorities.
- Standardised labelling in documentation to enable improved keyword searching in data records (e.g., GSHPs)
- Records and databases need to be kept up-to-date

- Further discussions are required for the potential for GSHP within the City of London and the potential limitations; it is acknowledged this will likely happen as part of the 2022 initiated local Area Energy Plan).

Lessons learnt from the discussions surrounding utility data

All stakeholders interviewed mentioned utility data as a key issue for subsurface understanding. Typically, utility owners/operators will respond to interactions on a request-by-request, site-by-site basis. Information is not accessible as an overview for a larger area, which is required to address the issue of opportunity mapping and climate vulnerability.

A local authority overview of utility data to assist climate adaptation planning would be very useful, but this is currently unobtainable at the 'area overview' scale. Utilities remain obstacles to trees, greening and SuDS that whilst not complete barriers, adds a complexity and cost implication to projects. Common issues remain with data sharing, complexity of accessing data (the number of utility operators within the City of London is estimated at around 37) and concerns regarding security and accuracy. Some localised spatial data is available in internal systems and is available for some through managed access, and occasionally information from radar scans from previous projects. However, accessing this data is only possible if staff are made aware that it exists in the first place.

The key for utilities resilience is understanding how locally implemented measures may be mutually beneficial for the longer term climate resilience of utility infrastructure. An overview assessment of utility vulnerability within local authority boundaries could help focus surface climate resilience measures to where they may mutually support resilience of buried utilities. The potential for 'general overview' density heat maps were discussed for future collaborations.

The National Underground Asset Register (NUAR) and its trial has made a vast step in asset data sharing; however, this is confined to the use case of strike avoidance for the foreseeable future. Additional applications and benefits, over-and-above strike avoidance, that may be realised have been discussed previously, and a further twelve use cases for NUAR have been reviewed and prioritised. Resilience planning (including flood risk) was one of the top five use cases identified. Underpinning future development in resilience planning, including climate change adaptation and resilience planning, is streamlined access to high quality and reliable subsurface information, such as the NUAR platform.

Key recommendations for change resulting from Cubic Mile Project outcomes

Internal focus – City-owned buildings and assets

A spatial representation (e.g., GIS layer) of the locations of previous radar surveys could be created that would be visible on internal GIS. This would avoid having search through folders by specific people and could be accessed or requested easily. The underlying data could be protected, but access could be requested to a certain area should this be of interest. This would improve internal knowledge of where scans had been carried out and utility data might be held by the CoLC.

Changes to wider policy

- The potential future expansion of NUAR – future use case development. The partners in the Cubic Mile project will continue to liaise with the Geospatial Commission and the NUAR project to provide an evidence base for utility and subsurface information in the sphere of Climate adaptation and resilience.
- Improved understanding: How much focus on climate resilience is there? There is a need for better aligned thinking between LA and subsurface infrastructure managers. Utility companies

could consider release of heat maps indicating more congested areas (high-level overview) accessible for LA use, with key security and limitations of use addressed.

Lessons learnt from the review of City of London Corporation-owned data

CoLC have a variety of information stored in their systems applicable for an assessment of subsurface congestion with a focus on future climate adaptations. There are different levels of access in internal systems, and a good selection is published online as part of the INSPIRE EU Framework Directive, incorporated into UK law since 2009. Communications that occurred as part of the Cubic Mile project directed members of the Environmental Resilience team to previously unknown or unconsidered resources. An example of this included historic ground radar surveys that have been carried out as part of highways and public realm projects, giving detailed subsurface data at specific locations. These valuable datasets are not stored spatially or directly available to all; access requires communication with key contacts and searching through a specific folder by a named member of staff.

Understanding the collation of data is important. Taking the GLA SuDS information tool as an example, it could not be guaranteed that the map is a comprehensive overview or that all SuDS schemes were captured during the initial data collection phase. This is because the reporting to the scheme is voluntary rather than mandatory. Uncertainties are also present in data quality due to variations in borough submissions e.g., in some areas each rain garden on a street is a separate point, whereas in another areas, one single point indicates numerous rain gardens on a street.

Further limitations are present in terms of security of data and access limitations e.g., accessing lists of City of London-owned assets (to investigate potential under-utilised spaces below ground) is limited to select employees for commercial sensitivity reasons.

Key recommendations for change resulting from the Cubic Mile Project outcomes:

- The Scheduled Ancient Monuments layer could easily be improved to assist future asset mapping of the subsurface by the addition of a field indicating if the structure is above or below ground. For example, this would clearly indicate to external users that the Roman Amphitheatre located beneath the Guildhall is a subsurface feature, or which sections of the London Wall are above or below ground, compared to an above-ground monument or statue. Whilst the information does not change how climate adaptation in the vicinity could be implemented next to an identified scheduled monument, it would assist in the conversations on what is a blocker or barrier to implementing measures.
- It is suggested that an internal spatial layer is created indicating whether surveys exist from different stakeholders, such as highways or public realm projects team. This should include the file name, any restrictions to the data and a key contact. This would add value to existing information held, and users in other sections could easily view where there is existing understanding and/or subsurface utility mapping. The data itself would still be protected, but this would allow a wider understanding of where the more detailed utility information is stored. This could support future planting schemes, SuDS, flood resilience projects, utility vulnerability planning and assist in Local Area Energy planning.
- SuDS reporting, in both public and private space, should become mandatory to the local authority, not voluntarily requested. This would support the future SuDS, flood resilience projects, utility vulnerability planning and any also target work done on assessing adaptations.

Concluding comments from the Cubic Mile data review

The above paragraphs outline recommendations the Cubic Mile project has identified that could support subsurface investigations for climate adaptations in the future. Implementing changes could create maximum benefits to a number of stakeholders working in climate adaptation and resilience through:

- A change from site-specific to regional overview opportunity mapping
- Integrated risk assessment and modelling (e.g., flood modelling, assessment of impacts on underground assets)
- Linking assets that can affect different hazards (e.g., pathways creating unnatural flow channels)
- Climate and adaptation induced natural resource and geological conditions

Suggestions are not just at local authority level but would support conversations and resilience planning across multiple sectors. Still for discussion is who has the responsibility for gathering the information where it is not readily available, as this is resource-intensive and often repeated in silos by different stakeholders. Wider legislation is needed to better regulate use of the subsurface and documenting of subsurface data. Changes are needed in the planning system to better record subsurface development and the resulting ability to investigate that data.

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