Stantec

TECHNICAL NOTE

Job Name: South Oxfordshire Karst Susceptibility Hazard Map

Job No: 332511146

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Prepared By: [redacted]

Approved By: [redacted]

Subject: **South Oxfordshire Karst Susceptibility Hazard Map Rev01**

1. Background

1.1. Stantec UK Ltd (Stantec) has been commissioned by South Oxfordshire District Council (the Client) to produce a GIS-based Karst Susceptibility Hazard Map of the county of South Oxfordshire, United Kingdom. The area is referred to as the 'study area' as detailed by the red line boundary and contour data (Doc Ref: *OS55_Contour_Data.zip*) provided; each detailing an area measuring approximately 310km^2 in size (Email Correspondence: *Roche-Edmonds 27th April 2022*).

1.2. It is first important to understand the difference between Hazard and Risk. A hazard is anything that could cause harm, while a risk is a combination of the chance that the hazard will cause harm, and how serious that harm could be.

1.3. Under the right circumstances, Chalk, a soluble, carbonate rock can develop extensive karstic geomorphological landforms which can include potentially hazardous features (geohazards) such as sinkholes, solution pipes and swallow holes. Ground instability associated with these features can pose a significant health and safety risk to the public and can in some circumstances lead to catastrophic ground collapse and subsidence damage to existing services, infrastructure, and buildings, contamination and in rare instances injury and death. It is therefore becoming an increasingly crucial task as these features can be influenced by the effect of climate change to gain an early understanding of the spatial distribution of these hazardous karstic features and the complex risks geotechnically and financially to the public, the environment, new developments and the maintenance of existing assets.

1.4. Further detailed appraisal of sites being considered for development would need to be undertaken on a case-by-case basis and this tool should only be utilised for land use planning purposes at coarse resolution.

2. Methodology

2.1. In 2001, Dr Clive Edmonds published "Predicting natural cavities in chalk" within Griffiths, J. S. (ed) Land Surface Evaluation for Engineering Practice, geological Society, London, Engineering Geology Special Publications. The paper discusses the spatial characteristics of natural cavity occurrences in chalk which was determined from an extensive collection of data undertaken by Edmonds, later forming a spatially related database, the Stantec Cavities Database, and was scrutinised to determine the factors that most favourably influenced cavity occurrence.

2.2. The key factors that pertain to cavity development relate to the geological, hydrological, and geomorphological setting of the site. Below is a summary of the factors used with in the formula to determine the karstic hazard rating (Edmonds *et al*. 1987).

Geological Factors

- Lithostratigraphic horizons of the Chalk (G_1)
- Presence of post-Cretaceous cover deposits overlying the Chalk (G_2)
- Lithology of post-Cretaceous cover deposits (G_2)

Hydrological Factors

- Groundwater level in relation to the Chalk surface and cover deposits (H_1)
- Effects of topographic relief upon surface water drainage subsurface groundwater infiltration (H_2)

Geomorphological Factors

- Terrain unit setting (H_2)
- Locations of former surface water drainage and subsurface groundwater infiltration (GM_1)
- Effects of glaciation (GM_2)

2.3. From Stantec's project experience and ongoing data collection and analysis of records in the Cavities Database, climate change is anticipated to have a significant influence on the frequency of ground instability associated with karstic hazards. Increased numbers of recorded events have occurred following prolonged periods of heavy (high intensity) rainfall immediately following prolonged spells of dry weather, conditions which are becoming more frequent in nature. While this hazard assessment presents the likelihood and susceptibility of certain areas to these ground stability hazards it is important to highlight that it cannot currently truly predict the time of an occurrence, or the influence of climate change, or determine the risk.

3. Hazard Ratings

3.1. The result was a qualitative spatial analysis which established substantial evidence for causal relationships between natural cavity occurrence and certain controlling factors. Factors were then ranked into major, moderate and minor categories, depending on their specific influence on cavity formation. To express the qualitative influential factors in a quantitative manner, factors were assigned a numerical value based on their influence on cavity development, i.e., the more influential a factor is to cavity development, the higher the assigned value, and inserted into the Subsidence Hazard Mapping Formula (SHR_N), as below:

$$SHR_N = (G_1 + G_2 + H_1 + GM_1 + GM_2) * H_2$$

3.2. The resulting SHR_N value can then be split into the below hazard ratings whereby the higher the value, the greater the statistical chance of natural cavities occurring and presenting an associated ground instability hazard.

Hazard Rating	Geological Conditions
Very High	
High	Favourable
Moderately High	
Moderate	
Moderately Low	
Low	
Very Low	
Negligible	Less Favourable

4. Production of GIS Karst Susceptibility Hazard Map

4.1. To apply, implement and model the major influential factors, the following datasets were either acquired or created by Stantec:

- BGS Bedrock Geology (G_1) (Licensed from British Geological Survey)
- BGS Superficial Geology (G_2) (Licensed from British Geological Survey)
- Depth to Groundwater (H_1) (Processed by Stantec UK Ltd)
- Topographic Relief (H_2) (DTM received from Client, processed by Stantec UK Ltd)
- Former Surface Water Drainage Path (GM_1) (Processed by Stantec UK Ltd)
- Glaciation Factor (GM_2) (Processed by Stantec UK Ltd)

4.2. The above data was then joined in layers to a 100m diameter hexagonal (hex) grid, with each layer having values dependent on what influential factor that layer pertained to. Within these layers it was possible to determine which values intersected each hexagon, therefore producing a value for each parameter in the equation. As a result, the hex grid ultimately had numerical values for each influential factor in the SHR_N equation which is in turn formulated and classified into their respective hazard rating categories.

5. Overview and Application

5.1. In areas of South Oxfordshire that are underlain by Chalk, the interface with cover deposits often forms a karstic horizon where dissolution features (solution pipes, sinkholes and swallow holes) are found. The most prominent karstic horizons are the Palaeogene/Chalk interface, and the Quaternary/Chalk interface; either one of these interfaces are present across the majority of South Oxfordshire. In areas where these karstic horizons are present, the quantitative analysis duly awards a higher hazard rating in contrast to those with less favourable ground conditions, such as where groundwater is at, or above the Chalk interface, or where the course of the Proto-Thames formerly dissected the region. It should be noted that in areas where chalk is absent, a hazard rating of "Negligible" is applied.

5.2. When viewed with the Stantec Cavities Database, a positive correlation exists between the spatial distribution of known natural cavity locations and areas of higher hazard ratings. Such a correlation is to be expected given that the higher numeric values applied to the major influencing factors were determined following cross examination of the spatial distribution of natural cavities held within the database. It should be noted that areas with lower hazard ratings still present a potential for dissolution features, or adverse ground conditions, to be present, however the statistical likelihood is comparatively lower.

5.3. All hazard ratings presented within the Stantec Karst Susceptibility Hazard Map should be used as a preliminary guide only for identifying areas susceptible to dissolution features and adverse ground conditions. While this tool has been designed to provide useful guidance for land use planning purposes, it is possible that a higher resolution spatially of hazard susceptibility at a site scale could be modelled by having a suitably experienced engineering geologist/geotechnical engineer undertake geomorphological field mapping of a given site and additionally by the interrogation of digital LiDAR data which can be used to check for previously unrecorded surface hollows that might be indicative of dissolution features.

5.4. It should also be noted that the Stantec Cavities Database is continuously updated, and any thematic mapping tools developed from the data represents a single point in time. As additional data becomes available, such as known new dissolution features occurrences, any such thematic mapping and hazard calculations derived from the dataset should also be updated. For this reason, the Stantec Karst Susceptibility Hazard Map will require periodic updates to prevent the mapping from becoming outdated. Updates are not included in the current agreed scope of works; however, these can be discussed with Stantec.

5.5. Due to the preliminary nature and application of the Stantec Karst Susceptibility Hazard Map, it is recommended that communications between the Client and Stantec remain open during the operation of the tool. If required, Stantec can be contacted to provide further input, which could, for example, include preparation of interpretive Cavities Occurrence Assessments for sites, a report which is typically required by the National House-Building Council (NHBC).

5.6. It is recommended that a geotechnical engineer with suitable karst experience and understanding of the ground conditions across South Oxfordshire is consulted on land purchase requests, planning applications, or developments that are located within a 250m radius of a High (or higher) hazard hex-grid, and/or within 250m of a natural or mining cavity record. In such scenarios, the geotechnical engineer should offer specialist geotechnical and geohazard services to formulate a suitably designed forward approach, or ground investigation, as appropriate, tailored to the Client or end-user's needs.

5.7. A list of primary Stantec contacts are listed below:

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Appendix – Technical Definitions

Cretaceous Period - A geological period that spans 79 Mya (millions of years ago) from the end of the Jurassic Period 145 Mya to the beginning of the Palaeogene Period 66 Mya. Across the area of South Oxfordshire, this period is represented geological by the Chalk Group and the Glauconitic Marl Member and the Upper Greensand Formation.

Glaciation – During the Quaternary period, the UK was subjected to two extensive glaciations. The first of these was the Anglian Glaciation which occurred between 480-430 Kya (thousand years ago) and extended across two-thirds of the UK down to Oxfordshire and North London. The second glaciation was the late Devensian glaciation which occurred to 27 Kya but only extends as far south as northern England. These glacial periods subjected the existing ground conditions to intense cold with large areas of frozen ground. When the ground was frozen, karstic development was not possible, however as the ice degraded, the cold water and runoff could percolate downwards and initiate karstic weathering of the chalk surface where favourable circumstances allowed.

Karst – a term referring to a landscape where natural weathering processes are dominated by dissolution of soluble rock (such as chalk) caused by the passage of percolating water (acidic in nature) through the rock. The weathering process can result in an irregular surface or subsurface, where covered with other deposits, and the development of dissolution features including sinkholes and swallow holes.

Lithostratigraphic horizons of the Chalk – A surface or boundary between stratigraphic units. For the application of the SHR_N formula, this is used to define between the “Upper”, “Middle” and “Lower” chalk formations.

Palaeogene Period – A geological period that spans 43 million years from the end of the Cretaceous Period 66 Mya (million years ago) to the beginning of the Neogene Period 23 Mya. Across the area of South Oxfordshire, this period is represented geologically by the London Clay and the Lambeth Group.

Quaternary Period – A geological period that spans 2.5 Mya from the end of the Neogene Period to present day. Across the area of South Oxfordshire, this period is represented geologically by proto-Thames deposits, alluvial deposits, fluvial terrace gravels, Clay-with-Flints, and solifluction (Head) deposits.

Sinkhole – A closed surface depression that can occur as either a:

- *Collapse sinkhole* - formed by collapse of rock into a cave passage or chamber.
- *Solution sinkhole* – formed by dissolutional lowering of the soluble host rock in and around zones of drainage into a cavernous rock.
- *Subsidence sinkhole* – formed when soil is washed down into underlying cavernous rock.

Solution Pipe - A cone or pipe-like cavity in vertical section, tapering downwards, typically infilled with overlying deposits that have subsided into the cavity created by dissolution of the soluble host rock. They are generally circular or elliptical in plan and may or may not be accompanied by an overlying closed depression (sinkhole) seen at the surface. They can occur singly or in groups.

Swallow Hole – A surface feature where a void in the soluble host rock continuously or intermittently “swallows” wholly or partially a surface stream i.e. the point at which the stream disappears from the surface to flow underground. They can occur singly or in groups and are usually recognisable as hollows along a stream channel.

TECHNICAL NOTE

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