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The integration of the underground space in the planning policies for Lisbon in the future

L'intégration de l'espace souterrain dans les politiques d'aménagement de Lisbonne à l'avenir

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ABSTRACT: In the last decades, Lisbon Municipality has implemented a database – GeoSIG to collect, analyse and produce specific outputs suitable for planning and management, using geological and geotechnical data obtained through several work field campaigns. This information allows the identification of the main constraints to occupation, such as a high thickness of coverage deposits or low depth of the water level. In addition, the same information can be used as an input to promote sustainability actions, such as better underground water management or a more responsible underground occupation. Besides the geological and geotechnical setting, Lisbon has also been doing a 3D underground structures and infrastructures representation, considering the impact that these objects can have on natural resources, specific the water flow. To achieve this, the geological and underground information was joined to promote the development and implementation of policies regarding the underground occupation, considering the impact mitigation and the possibility of exploring underground resources, allowing better decision-making.

RÉSUMÉ: Au cours des dernières décennies, la Municipalité de Lisbonne a mis en place une base de données - GeoSIG pour collecter, analyser et produire des résultats spécifiques adaptés à la planification et à la gestion, en utilisant des données géologiques et géotechniques obtenues au cours de plusieurs campagnes sur le terrain. Ces informations permettent d'identifier les principales contraintes à l'occupation, telles qu'une grande épaisseur des dépôts de couverture ou une faible profondeur du niveau de l'eau. De plus, ces mêmes informations peuvent être utilisées pour promouvoir des actions en faveur de la durabilité, telles qu'une meilleure gestion des eaux souterraines ou une occupation souterraine plus responsable. En plus du contexte géologique et géotechnique, Lisbonne a également réalisé une représentation en 3D des structures et infrastructures souterraines, en tenant compte de l'impact que ces objets peuvent avoir sur les ressources naturelles. Pour ce faire, les informations géologiques et souterraines ont été combinées pour favoriser le développement et la mise en œuvre de politiques relatives à l'occupation souterraine, en tenant compte de la réduction de l'impact et de la possibilité d'exploiter les ressources souterraines, ce qui permet de prendre de meilleures décisions.

Keywords: GeoSIG; geotechnical database; three-dimensional modelling; underground water; thematic cartography.

1 INTRODUCTION

Lisbon Municipality has a significant amount of geological and geotechnical characterization data obtained through numerous prospecting campaigns conducted within the city over the past decades.

These data constitute a valuable resource and, when properly organized, can generate highly applicable information in several areas of urban planning and management. Given the potential of this information, Lisbon Municipality (CML) has been working to optimize it so that it can be integrated into its Territorial Management Instruments (IGT), including the Lisbon Master Plan.

The continuous growth of available information resulting from geological-geotechnical studies, raises some issues, regarding data organization, standardization, validation, and integration into a three-dimensional model. This is aimed at transforming the data into dynamic tools for urban planning.

Two fundamental steps were identified: 1) the creation of a database that would gather, in a standardized and georeferenced manner, the information contained in the existing geological-geotechnical reports, resulting in the GeoSIG Platform (CML, 2016); and 2) the integration of this geological-geotechnical information with existing data related to

the underground occupation (basements and foundations).

Given the current occupation of the consolidated area of Lisbon, urban expansion will preferably occur through in the underground. This occupation will not be only through parking structures but also to railway and road infrastructures, part of the city's mobility system. The volume occupied by these structures and infrastructures is not yet available, and when such data exists, it is not properly organized and systematized, which in a certain way constrains the management of Lisbon subsurface.

To enhance subsurface management, Lisbon Municipality has initiated a project called the Three-Dimensional Underground Occupation Model - MODSUB 3D (CML, 2021).

The project aims to use the information available in construction projects stored in Lisbon archives, including the geometry and attributes of buried structures and foundation elements. Through a specialized data loading tool developed for this purpose, this information will be used to maintain an integrated database and a geographical layer within the GeoSIG application.

This information will serve as a base for the development of a three-dimensional subsurface model. When combined with the ongoing development of hydrogeological suitability mapping within the CML, it will enable a more effective assessment of the impact of subsurface occupation on the local hydrogeological flow.

Once integrated into the planning instruments, this information becomes a crucial support and decision-making tool in the context of urban management.

2 GEOTECHNICAL DATABASE – GEOSIG

Lisbon Municipality has been working in the development of a database supported by a management system with the aim of updating the processes of data input and updating. This effort also enables logical data storage, effective data management, optimization of editing and querying processes, and the provision of results for the necessary outputs. This action was developed under the framework of the LISBOA-01-0527-FEDER-000894 - Geotechnical Mapping in Urban Areas - Application to Lisbon, a project financed by the European Regional Development Fund (FEDER).

GeoSIG – Geologic, Geotechnical, and Hydrogeological Data Management for the Municipality of Lisbon is a web application designed for managing geological, geotechnical, and hydrogeological data within the Lisbon municipality. The primary goal is to integrate and apply this data in urban planning and simultaneously seeks to manage a sparse and often incomplete asset that was predominantly in paper format, with limited accessibility and processing capabilities.

This application was designed based on specific functional requirements allowing data management, several users interaction, access control and the definition of specific outputs to decision support purposes.

Currently, access to GeoSIG is limited to internal use by the Lisbon City Council due to copyright restrictions on existing data in geological and geotechnical reports. However, the spatial distribution of the information can be accessed in Lisboa Aberta platform of Lisbon Municipality (CML, 2018).

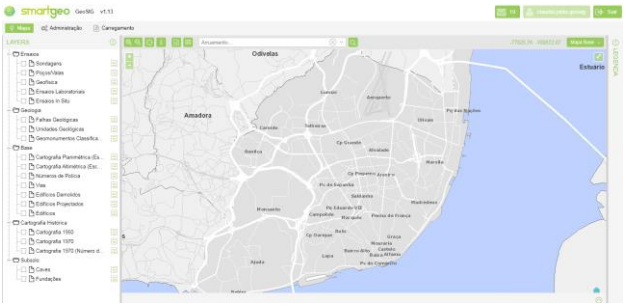

Figure 1. GeoSIG application main screen (Source: GeoSIG).

Until now, this platform integrates more than 13,000 boreholes, corresponding to 2,400 geological-geotechnical reports (Figure 2). The information from the geotechnical boreholes is added to the GeoSIG database by the municipality's technicians. This data comes from the geotechnical reports that are submitted by developers during licensing procedures, along with the excavation and peripheral containment projects.

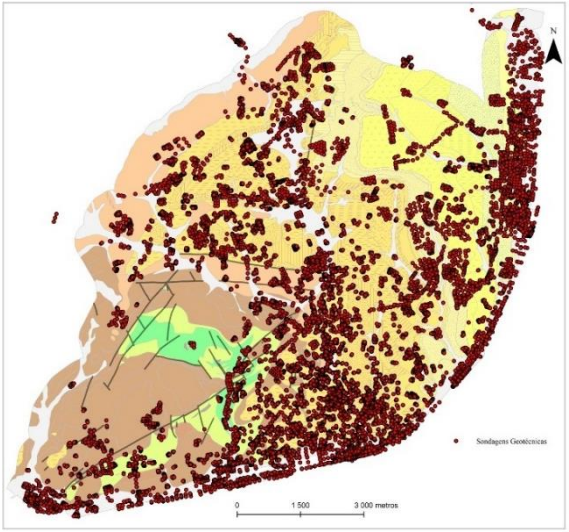

Figure 2. Distribution of geotechnical surveys available in the GeoSIG application (Source: GeoSIG).

Associated with each borehole are data related to the lithology, the water level, SPT test values, recovery rates, and other relevant information.

In addition, sample classifications submitted to laboratory analyses may be added, to record some physical properties of the samples, namely lithology, AASHTO, unified and RTR classes, as well as the granulometric index. It should be noted, however, that the vast majority of geological-geotechnical reports available do not include this type of information, so it will be incorporated into the platform at a later stage

The GeoSIG works in a georeferenced table format, where the depth value is associated with a parameters mentioned above. Currently this data are introduced into geosig by municipal technicians.

It should be noted that the GeoSIG database is intended to provide a macro-scale approach, which does not invalidate local studies. Thus, GeoSIG provides data for modeling more generic geotechnical characteristics, particularly lithology, lithostratigraphy, resistance (through SPT tests) and water levels. The information in the database is a fundamental tool for urban planning (Pinto et al., 2023) and can also be used to perform more specific studies (e.g., Oliveira et al., 2019)

3 THEMATIC MAPPING

To produce thematic mapping, it was necessary to implement a Geoscientific Information System which involve creating specific queries to the GeoSIG database to select the most relevant data for each purpose.

The thickness of coverage deposits and the water level are not limitations to urban development, but they can influence it due to problems related to land suitability and consequently construction costs. Therefore, modelling these factors can optimize projects and reduce costs, making it an essential tool in planning and management.

To achieve this, data obtained from geological-geotechnical boreholes were interpolated, specifically the depth of surficial fills and alluvial deposits, as well as the position of the water table. The operation was conducted using the IDW (inverse distance weight) interpolator.

The water table level was represented by points of different shades according to depth, and in the area, allowing the definition of depth classes. This knowledge facilitates the optimization of groundwater use and management.

From the analysis of Figure 3, it is clear that in the riverside area, the water table position is closer to the surface. Given that this area borders the Tagus River, this result was expected. In general, the water table is located between 3-6m, with exceptions in hilly areas where the water table is deeper. This is also related to the geological formation's permeability.

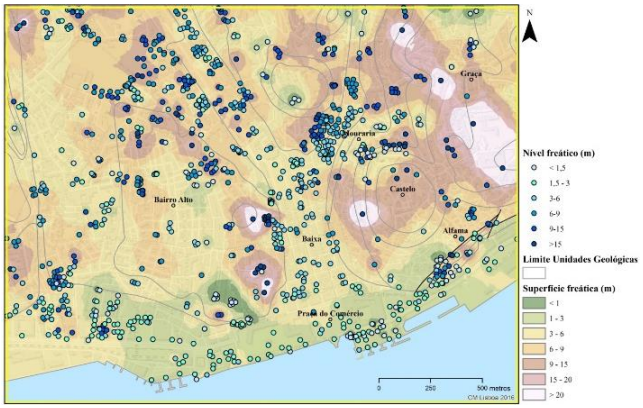

Figure 3. Factor map: Water level position (Source: GeoSIG).

4 MODSUB 3D

To support decision-making Lisbon Municipality has developed a tool that allows the input of the geometry and attributes of the structures and infrastructures existing in Lisbon subsurface – MODSUB 3D. These data will allow the development of three-dimensional models for the subsurface occupation in the city. This information combined with hydrogeological mapping, will enable the assessment of the impact of this occupation on the local hydrogeological flow. As part of the project implemented in pilot areas, data related to basements and foundations of 8,900 buildings were loaded.

The MODSUB 3D application is built upon a tool that allows the user to search for the building in question, make a spatial selection, and subsequently load the data obtained from the construction volume.

This tool allows the registration of the location, geometry, and alphanumeric attributes that define each of the information layers within the application, namely basements, tunnels, and foundations. It's important to note that basement and foundation objects must be associated with a building, while tunnel objects have geometries separate from the building stock.

The information loaded can be visualized through the GeoSIG application, as the geographic layers developed within the scope of MODSUB 3D have been integrated here (Figure 4).

Figure 4. Visualization of geographic information - GeoSIG application (Source: GeoSIG).

In addition to the thematic information presented here, the data included in MODSUB 3D also allows the generation of three-dimensional models. The example in Figure 5 demonstrates how it is possible to obtain a three-dimensional representation of an area (Parque das Nações), using information of the superficial and subsurface occupation.

Figure 5. Representation of the three-dimension model.

5 CONCLUSIONS

The GeoSIG application provides the bases to develop thematic maps and three-dimensional models for several purposes in a quick and efficient manner, making it an essential decision support tool. With this information, we identify the most critical areas of the city where it becomes mandatory to conduct geological-geotechnical and hydrogeological studies before construction works.

The developed working methodology can be easily generalized and replicated for other areas, as long as the basic information is available in a representative quantity for the territory and the data quality is adequate.

These tools can be used by several stakeholders, including designers, planning professionals, and others, to assess constraints and estimate costs related with with specific geotechnical projects. This, in turn, allows for project optimization and cost reduction from the early stages. Lastly, it's worth noting that the construction of underground infrastructure creates a physical barrier to the natural water flow. With these tools Lisbon services can perform a better management of this resources.

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