Geotechnical mapping in the area of Covilhã, Portugal. A methodology using GIS

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Abstract: In the preparation of geotechnical maps and plans related to engineering problems, the prompt handling of large volumes of information related to geotechnical data and the results is only possible through the use of software such as the Geographical Information Systems (GIS).

Several methods for preparing geotechnical maps exist for engineering. This paper describes the method used in the production of a geotechnical map for the area of Covilhã (Portugal). The ultimate objectives were the creation of a Suitability for Construction Map and the building of a Geo-referenced database, and its development and application in a simple and rapid way, and the production of reliable results that can be used for the administration and support of the planning of the town.

Résumé: Dans la préparation de cartes du geotechnique et plans en rapport avec les problèmes de l'ingénieur, la manutention ponctuelle de grands volumes d'information a été en rapport avec les données du geotechnical et les résultats sont seulement possibles à travers l'usage de logiciel tel que les Systèmes de l'Information Géographiques (SIG). Plusieurs méthodes pour préparer des cartes du geotechnique existent pour l´ingénieur. Ce papier décrit la méthode utilisée dans la production d'une carte du geotechnique pour la région de Covilhã (Portugal). Les objectifs ultimes étaient la création d'une Carte de Convenance pour la Construction et le bâtiment d'une base de données Geo-référencée, et son développement et application dans un chemin simple et rapide, et la production de résultats fiables qui peuvent être utilisés pour l'administration et support de l'organisation de la ville.

Keywords: Engineering geology maps, Geographic information systems, Geotechnical maps, Database systems

INTRODUCTION

The town of Covilhã is located in a mountain region, with altitudes ranging from 400 m to 1600 m, with high slopes and deep valleys, all of this as result of a tectonic activity (Figure 1). This region makes part of the denominated Central Mountain region, characterized by great relief along a principal direction of ENE-WSW.

The great development of the town in recent years, has lead to increased landuse pressure in terms of land use, and because of this, and as result of poor planning, construction has been of new infrastructure in less suitable areas and those more prone to the occurrence of risk for buildings and human lives.

The current inexistence of geotechnical maps that could be used as support for the planning in new areas is one of the reasons for the development of areas with less favourable geotechnical conditions. The main objective of this work is to present the methodology used for the development of a geodatabase for the area of Covilhã, that works as support for the creation of different geotechnical maps (Inventory map, lithological map and suitability for construction map) that could be used for the administration and support for town planning.

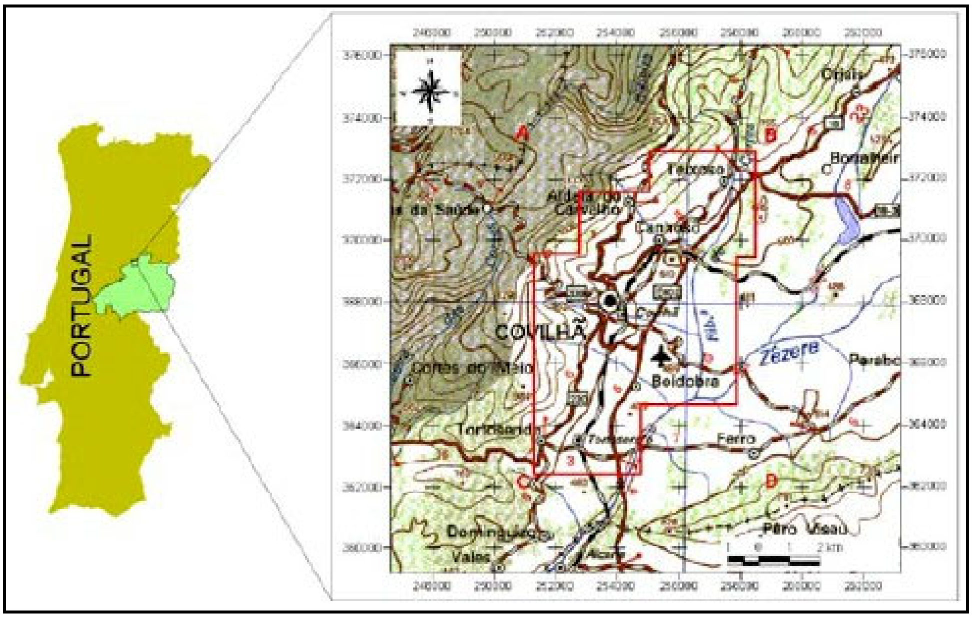


Figure 1. Geographical location of the study area

GEOLOGY

Geologically the study area is mainly constituted by eruptive rocks, mostly by very coarse-grained porphyritic granite, and by a medium to fine grained non porphyritic granite, with a small area of granodiorite. The weathering of these rocks varys from slightly weathered (W2) to a granitic residual soil (W5). Most recent formations, such as alluvial deposits occur along the main streams. Small areas of fluvial terrace deposits, fluvio-glacial deposits and soil deposits can also be found. The occurrence of metamorphic rocks belonging to the .Xisto-grauváquico. complex has also been reported in a small area, in the southwest of the study area. There are also several quartz veins along the whole study area, showing considerable thickness but, in general, they are not very important in length.

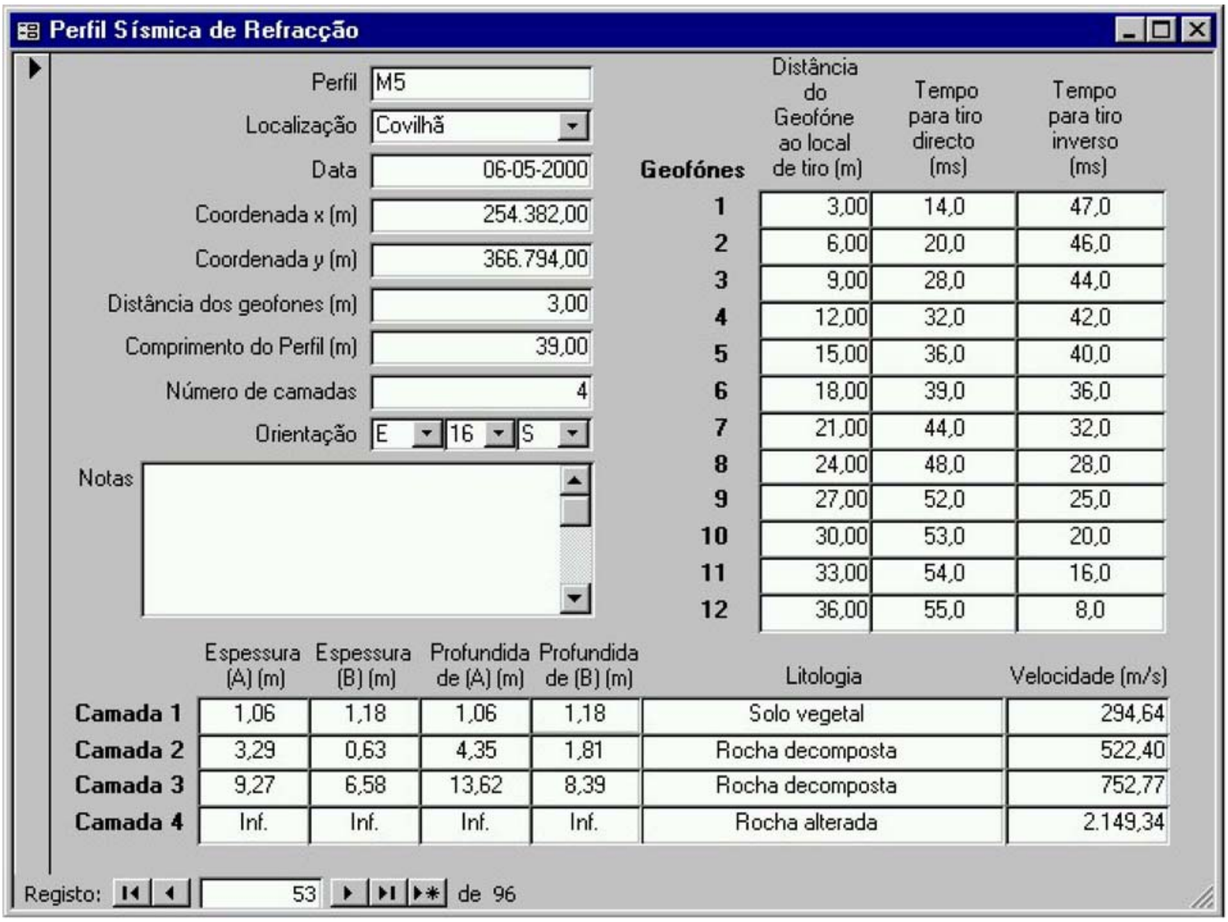
METHODOLOGY

The geodatabase described in this work, was made in a way that all the information contained in the database could be easily imported to a Geographical Information System (GIS) and displayed spatially. The database contains information about several in situ and laboratory tests, namely dynamic penetrations sounding (DPL, DPSH, SPT and CPT), seismic refraction, geoelectrical tests, Schmidt hammer tests, Windsor Pistol tests, soil identification tests (sieve analyses, atterberg limits, sand equivalent), compactation tests, direct shear test, odometer test, triaxial test and California Bearing Ratio test (CBR).

The data contained in the database, come from research works, technical reports and tests undertaken during this investigation. The database was developed in Microsoft ACCESS, first of all because is a very commonly used database program, and secondly because it could be directly linked to the GIS.

The database called GeoCovilhã XXI, was developed in a way that it could be used as an independent tool, so the user could visualize the data of the different geotechnical tests included in the database, make reports of those data and print out the information, but in this case the spatial location of these tests needed to be added manually, by using the inventory map that was created at the same time.

In this way, by using the GIS tools in conjunction with the ACCESS database, we could visualize the data of different tests, also we could automatically create the geographical location of those tests. This is possible because of the compatibility of the GIS with the ACCESS, and because the database was made in a way that, all the tables where the data are stored have fields with the X,Y coordinates of every geotechnical sounding and soil sampling point (Figure 2).



Perfil Sísmica de Refracção

Perfil: M5

Localização: Covilhã

Data: 06-05-2000

Coordenada x (m): 254.382,00

Coordenada y (m): 366.794,00

Distância dos geofones (m): 3,00

Comprimento do Perfil (m): 39,00

Número de camadas: 4

Orientação: E 16 S

Notas

Geofónes	Distância do Geofóne ao local de tiro (m)	Tempo para tiro directo (ms)	Tempo para tiro inverso (ms)
1	3,00	14,0	47,0
2	6,00	20,0	46,0
3	9,00	28,0	44,0
4	12,00	32,0	42,0
5	15,00	36,0	40,0
6	18,00	39,0	36,0
7	21,00	44,0	32,0
8	24,00	48,0	28,0
9	27,00	52,0	25,0
10	30,00	53,0	20,0
11	33,00	54,0	16,0
12	36,00	55,0	8,0

	Espessura (A) (m)	Espessura (B) (m)	Profundida de (A) (m)	Profundida de (B) (m)	Litologia	Velocidade (m/s)
Camada 1	1,06	1,18	1,06	1,18	Solo vegetal	294,64
Camada 2	3,29	0,63	4,35	1,81	Rocha decomposta	522,40
Camada 3	9,27	6,58	13,62	8,39	Rocha decomposta	752,77
Camada 4	Inf.	Inf.	Inf.	Inf.	Rocha alterada	2.149,34

Registo: 53 de 96

Figure 2. Example of a Seismic refraction data contained in the database.

This geodatabase was a very important base instrument for the production of several geotechnical maps for the area of Covilhã, especially for the inventory map, the lithological map and the geotechnical units map. This last map (geotechnical units map – Figure 3) was later used in conjunction with other geotechnical maps for the production of a Suitability for Construction Map for the urban area of Covilhã.

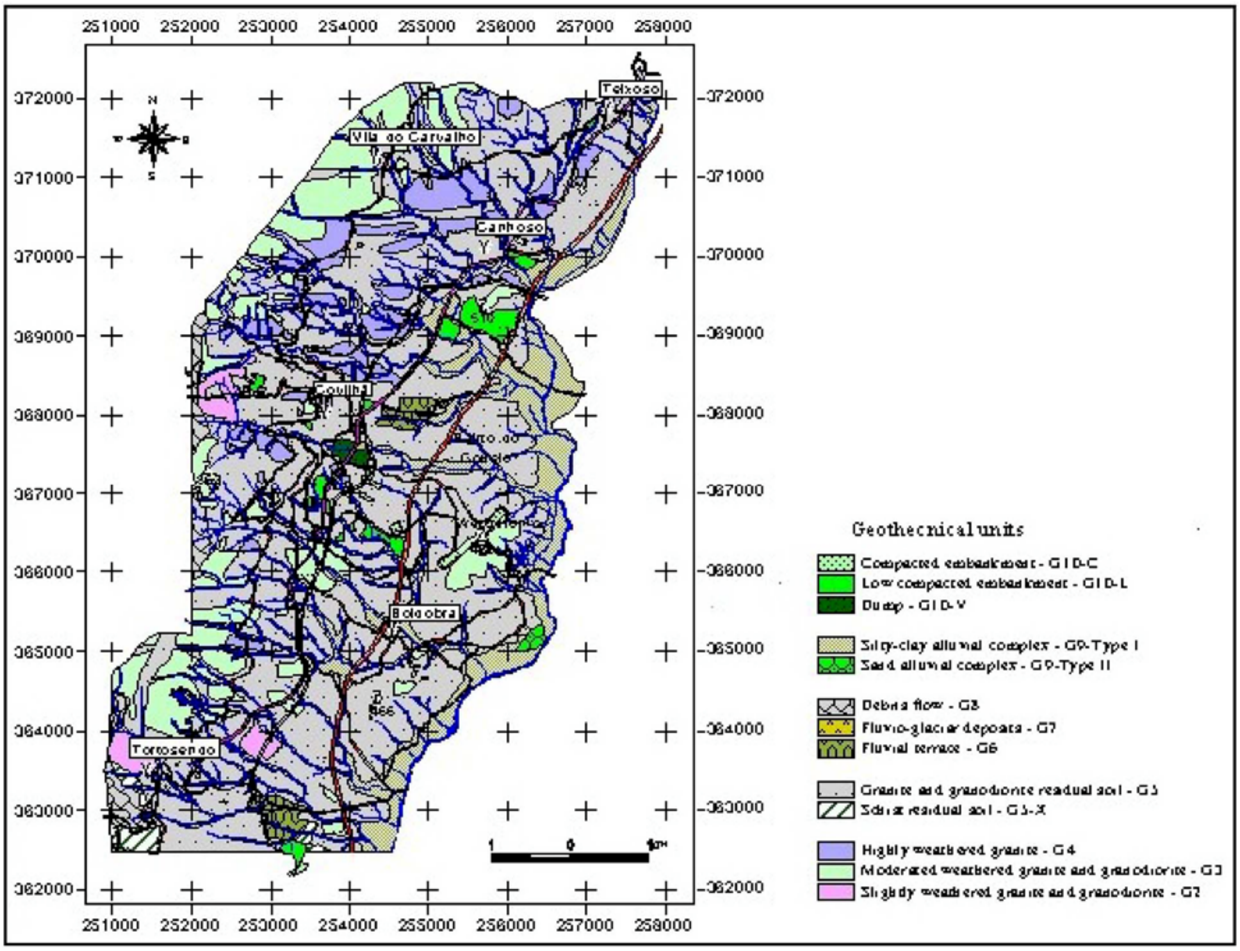


Figure 3. Geotechnical units map of the study area.

The Suitability for Construction Map was created by intersecting several thematic maps, as can be see in the flow diagram presented in Figure 4, created with the use of Geographical Information System software, namely a:

- slope map
- geotechnical units map
- landslide susceptibility map
- erosion map

The slope map was derived automatically from the digital terrain model created for the study area. The geotechnical units map was created by the joining of the lithological map and the results of the different tests stored in the geodatabase. The landslide susceptibility map was made by the overlay of the weighted geotechnical units map and the weighted slope map weighted by the different factors involved (geotechnical units types and slope classes) ranging from the most favourable (1) to the most unfavourable (6), and after intersecting the two maps, three classes of susceptibility (high, medium and low) were obtained. The erosion map was obtained by applying the USLE methodology with the aid of the Geographical Information Systems, and using some previous thematic maps created.

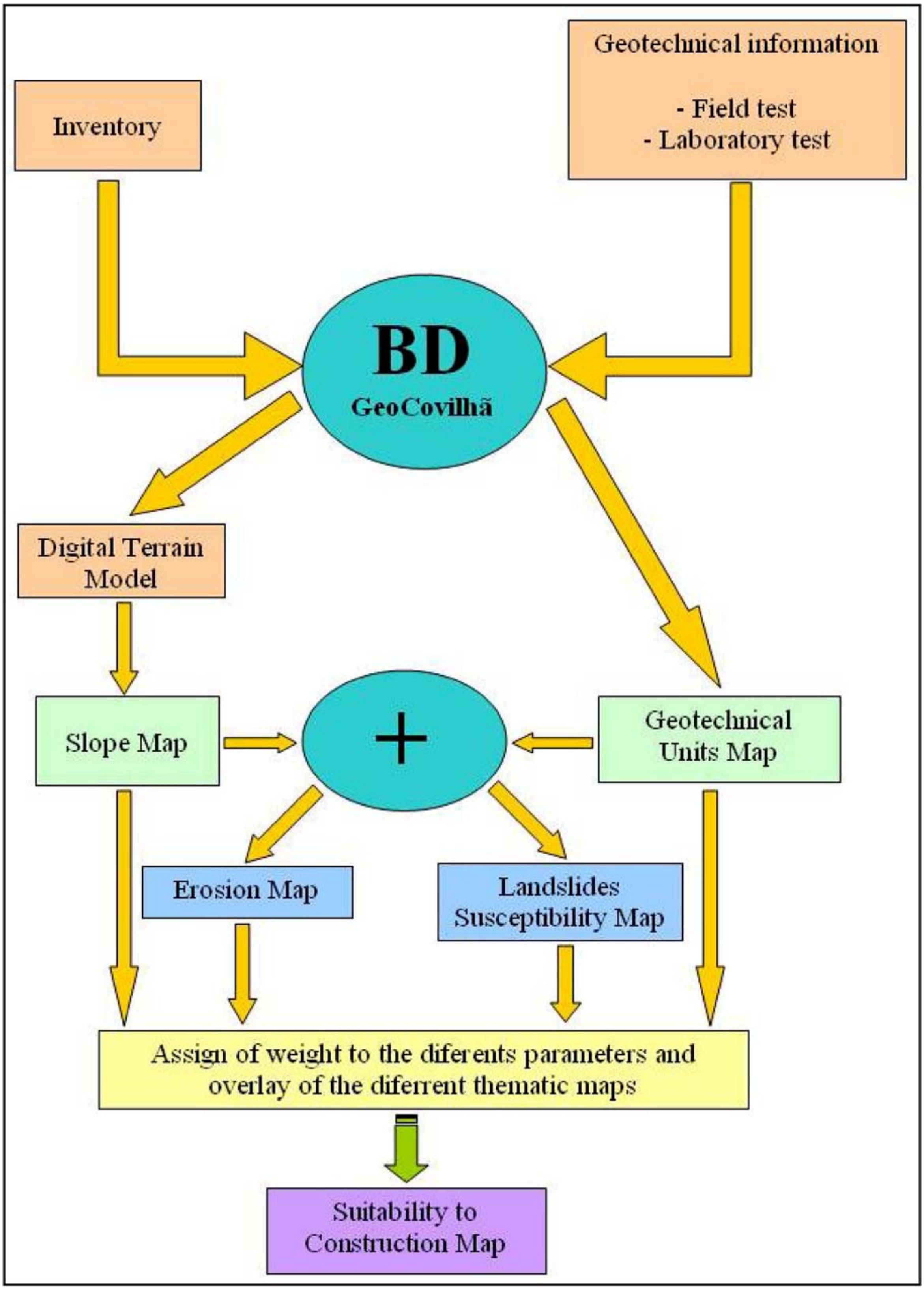


Figure 4. Flow Diagram with the methodology used for the preparation of the Suitability for Construction Map

After the creation of the different maps mentioned above, the intersection of those maps, made the map as seen in Figure 5, with previous work of assigning weights to the different factors involved, according to their lower or high contribution for a specific area to be considered more or less suitable for construction purposes.

The range of this weighting varies from 1 to 6. In the case of the slope map it was reclassified into three classes: < 8% was given a weight of 1; 8% - 15% was given a weight of 2 and > 15% was given a weight of 5. The geotechnical units map was reclassified given weight from 1 to 6. The landslides susceptibility map and the erosion map where reclassified into three classes, given weights from 1 to 3. In Figure 6 a scheme is presented with the different weights assigned to the several thematic maps used for the creation of the Suitability for Construction Map.

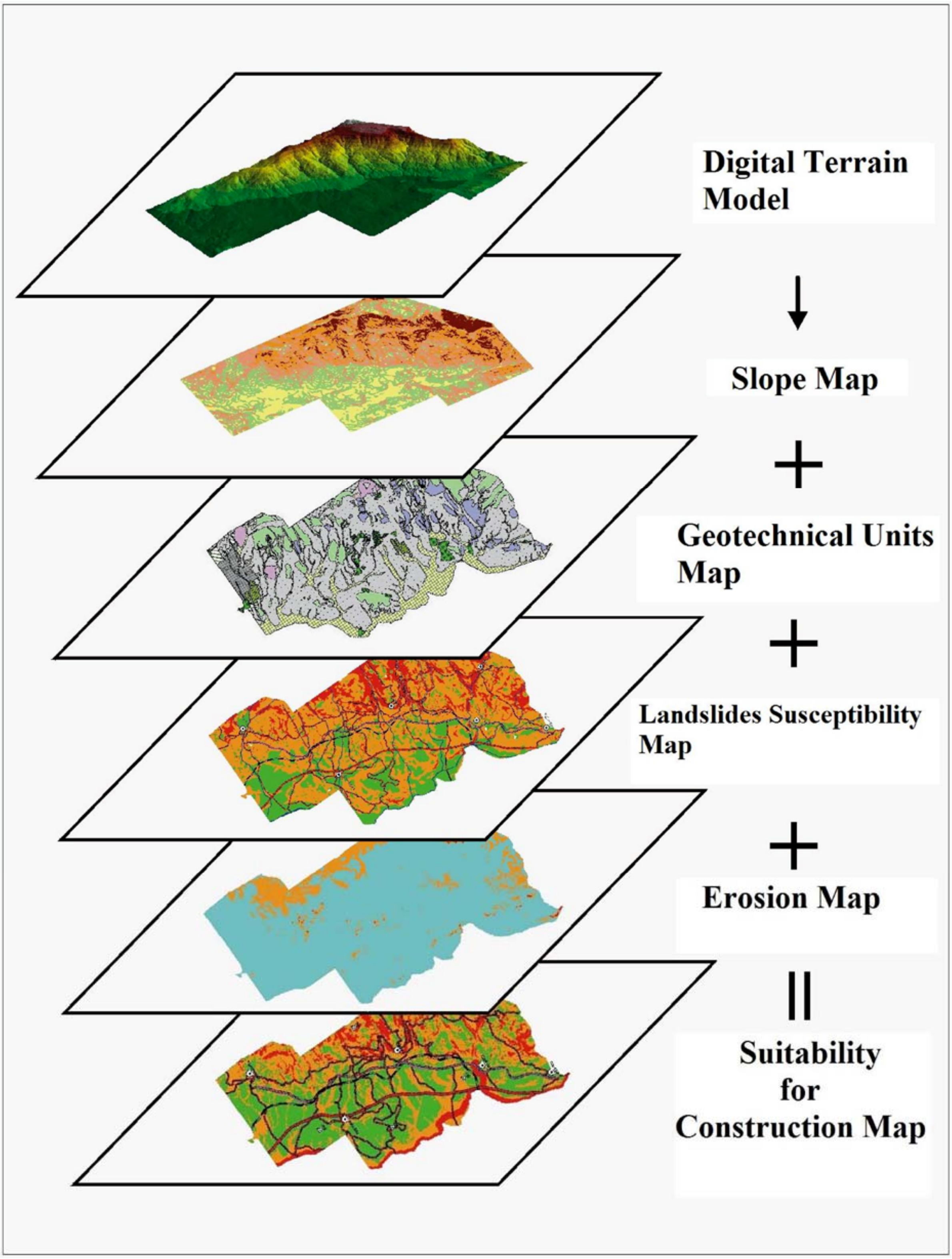


Figure 5. Sequence followed to create the Suitable for Construction Map.

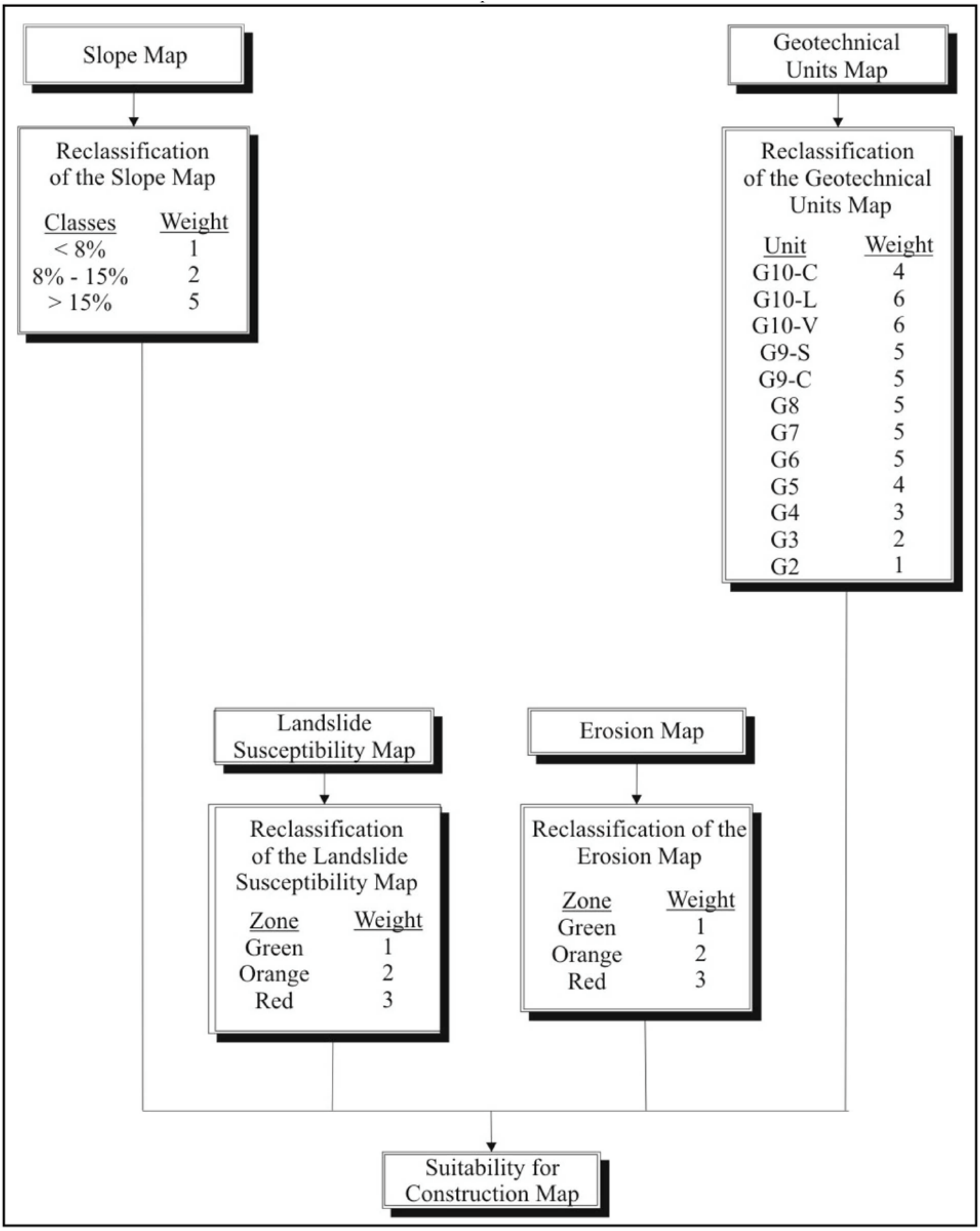


Figure 6. Scheme presenting the different weight assign to each of the thematic map used in the elaboration of the Suitability for Construction map.

The final map was divided into three classes of suitability: good suitability, conditioned suitability and not suitable.

The first class (good suitability) includes zones that do not present any problem for construction purposes in relation to the studied factors, however it doesn't rule out the need for geotechnical site investigation for specific construction projects.

The second class (conditioned suitability) refers to unfavourable areas to human occupation and areas to be reclaimed. These areas although barely favourable or even unfavourable to construction, can be used for other types of occupation, such as, green spaces and leisure areas.

The third class (not suitable) includes factors whose presence is enough to classify an area as not appropriate to urban occupation. They present poor geotechnical characteristics, such as slopes greater than 15% and areas prone to flooding.

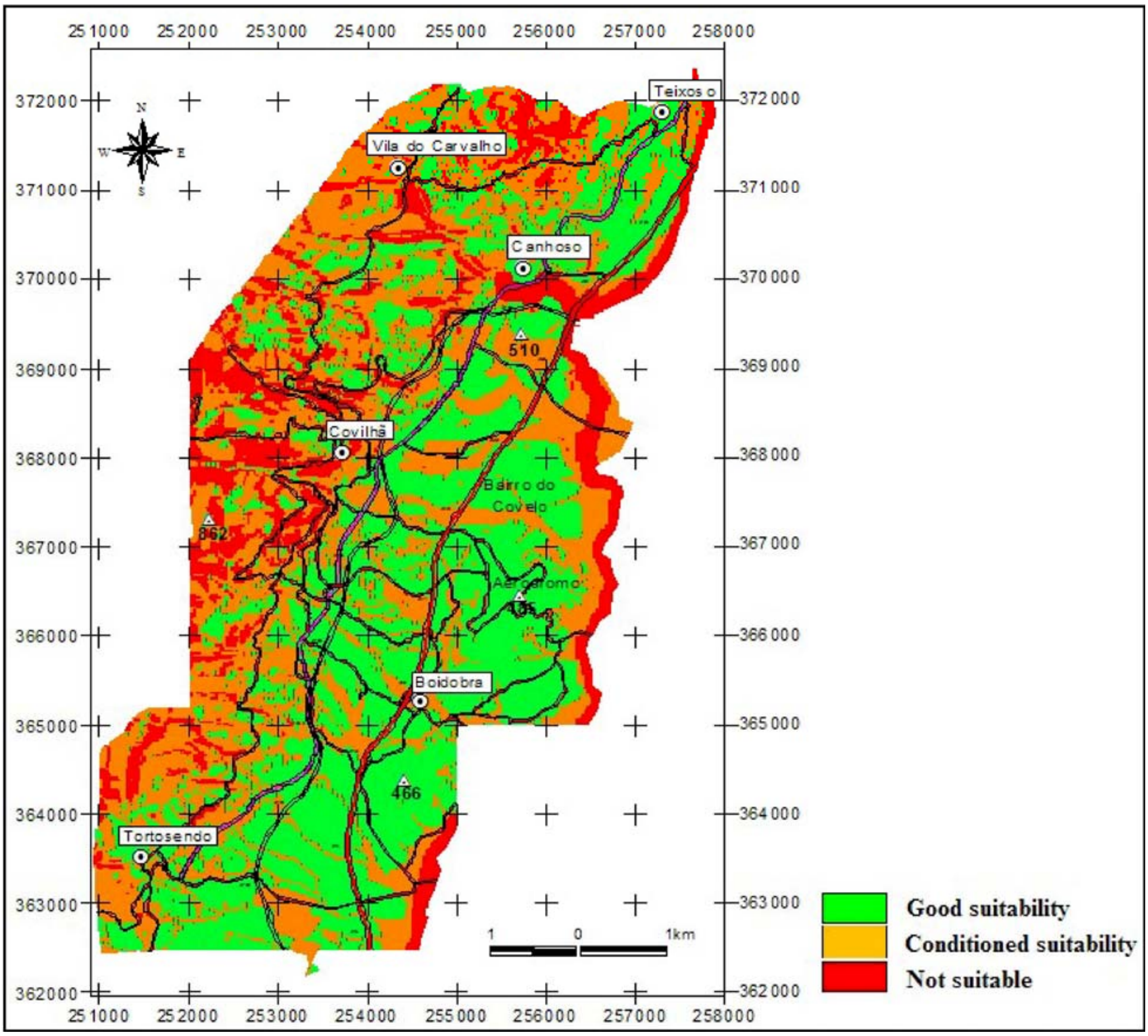


Figure 7. Suitability for Construction Map for the area of Covilhã

CONCLUSION

This work presents the contribution that the Geographical Information Systems in conjunction with a geodatabse, can give for the creation of different geotechnical maps that can be of great help for the planning of the cities.

The final Suitability for Construction Map presented in this paper, allows a wide group of users (planning technicians, civil engineer and others) to evaluate at a very early stage, if the land where they are planning to construct has a suitable character, in technical and economic terms, for the normal implementation of the project, and in this way avoids possible damage in future.

The geodatabase developed in this work, was created in a way that it could be very easily updated, and because of this the maps based on this database can also be updated more easily.

The methodology adopted in this paper provides enough information for the study area and further applications of this method are recommended to be used in other areas in Portugal of similar geological conditions, to help in urban and regional planning.

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