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**MAPPING GEOTECHNICAL DATA BY GIS: A CASE
STUDY OF ELAZIG CITY, TURKEY**

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IN
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**by
Onur DEMİRTAŞ**

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**Mapping Geotechnical Data by GIS: A Case Study of Elazig
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in
Civil Engineering Department
Hasan Kalyoncu University**

**Supervisor
Assist. Prof. Dr. Nurullah AKBULUT**

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I declare that all the information and documents in this thesis have been obtained and presented in accordance with academic rules and ethical behavior. I further declare that I have fully cited and referenced all non-original materials and results from this work, as required by this rule and conduct.

Onur DEMİRTAŞ

ABSTRACT

MAPPING GEOTECHNICAL DATA BY GIS: A CASE STUDY OF ELAZİĞ CITY, TURKEY

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Elazig city has suffered from the effects of several strong earthquakes. Therefore, it has required to understand the ground conditions of Elazig for a successful urban planning, design and construction of new structures. Geological, seismic, hydrogeological and geotechnical properties are considered as the most crucial factors. Depending on the location of each structure, impact of these factors could have a different effect. To understand the effect of geotechnical factors of the soil underlying the site, subsoil exploration was examined. The main goal of the thesis was primarily to generate geotechnical maps, which saves especially the cost of soil investigations, time, and provide a quick source of information for engineering projects. Geotechnical maps are widespread nowadays due to the existence of Geographical Information Systems (GIS). The maps in this study were generated by ArcGIS software using Inverse Distance Weighted (IDW) method. In this study, 210 borehole samples were collected to determine the index properties and soil classification for the subsequent allowable bearing capacity evaluation. Furthermore, groundwater level, water content, shear wave velocity, compressional wave velocity, soil amplification and soil classification calculations and maps according to Turkish, NEHRP and EUROCODE 8 were generated. According to borehole analysis until 15m depth, groundwater could not be seen much and might be at deeper levels. Due this reason liquefaction analysis had not been made. Bearing capacity analysis based on SPT-N have shown that the results of Terzaghi & Peck and Meyerhof methods were close to each other. The compressional wave velocity values were higher than the shear wave velocity values in the study area. As a result of geophysical data`s, the soil classification presented that the study area was C (low hazard) according to Turkish earthquake regulations, B and C according NEHRP and A and B according to EUROCODE8. In addition, these maps will help in preliminary studies, feasibility studies, land use policy, design of urban planning for further studies and can represent the distribution of different geotechnical properties in an accurate easy to use manner.

Keywords: Elazig, GIS, geotechnical properties, NEHRP, EUROCODE 8.

ÖZET

GEOTEKNİK VERİLERİN CBS İLE HARİTALANDIRILMASI: ELAZIĞ İLİ VAKA ÇALIŞMASI, TÜRKİYE

DEMİRTAŞ, Onur
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Elâzığ ili, bazı şiddetli depremlerden zarar gördüğünden dolayı, iyi bir şehir planlaması, tasarımı ve inşası için zemin özelliklerinin incelenmesinin gerekliliği ortaya çıkmıştır. Jeolojik, sismik, hidrojeolojik ve geoteknik özellikler, incelemenin en önemli alanları olarak öne çıkmaktadır. Her yapının konumuna bağlı olarak zeminden kaynaklı farklı etkileri söz konusu olabilmektedir. İnşaat alanındaki zeminin geoteknik özelliklerinin anlaşılması amacıyla, zemin etüt incelemeleri gerçekleştirilir. Tez çalışmasının amacı, özellikle zemin etütlerinin maliyetini düşüren ve zamandan tasarruf sağlayan geoteknik haritaların oluşturulması ve mühendislik projelerine altlık sağlanmasıdır. Coğrafi Bilgi Sistemlerinin (CBS) ortaya çıkmasıyla geoteknik haritalar günümüzde oldukça yaygınlaşmıştır. Çalışmada kullanılan haritalar Mesafenin Tersinir (MT) yöntemi kullanılarak ArcGIS yazılımı ile oluşturulmuştur. Bu çalışmada 210 adet sondaj logu kullanılarak zemin endeks özellikleri, zemin sınıflandırılması ve taşıma kapasitesi hesaplamaları yapılmıştır. Bunun yanı sıra, Türkiye Deprem ve Bina Yönetmeliği, NEHRP ve EUROCODE 8'e uygun olarak zemin sınıflandırılması haritaları, ayrıca yeraltı suyu, su muhtevası, kayma dalgası hızı, sıkışma dalga hızı ve zemin büyümesi haritaları oluşturulmuştur. 15 metreye kadar yapılan sondaj analizlerinde yeraltı suyuna rastlanılmamış olup daha derin seviyelerde olabileceği düşünülmektedir. Bu nedenle sıvılaşma analizi yapılamamıştır. SPT-N değerleri baz alınarak yapılan taşıma kapasitesi analizlerinde Terzaghi & Peck ve Meyerhof metodu sonuçlarının birbirine yakın olduğu görülmüştür. Çalışma bölgesinde sıkışma dalga hızı değerleri, kayma dalgası hızı değerlerinden daha yüksek olduğu izlenmiştir. Jeofizik verilerin bir sonucu olarak, çalışma alanındaki zemin sınıflandırılmasının Türkiye Deprem ve Bina Yönetmeliğine göre C sınıfı zemin; NEHRP'e göre B ve C sınıfı zemin; EUROCODE 8'e göre ise A ve B sınıfı zemin olduğu görülmüştür. Bunlara ek olarak söz konusu oluşturulan haritalar, ön etütler, fizibilite çalışmaları, arazi kullanım politikası, şehir planlaması ve tasarımına yardımcı olacak, farklı zemin özelliklerin dağılımını doğru ve kolay bir şekilde temsil edebilecektir.

Anahtar Kelimeler: Elâzığ, CBS, geoteknik özellikler, NEHRP, EUROCODE 8.



My precious family

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ABBREVIATIONS OR SYMBOLS LIST

ASTM	American society for testing and materials
D	Disturbed sample
D	Depness (km)
M	Magnitude
NEHRP	National earthquake hazard reduction program
q_e	Bearing capacity (kN/m^2)
UD	Undisturbed sample
USCS	Unified Soil Classification System
SPT	Standard penetration test
V_p	Compression wave velocity (m/sec)
V_s	Shear wave velocity (m/sec)
V_{s30}	Shear wave velocity at 30 m
W_n	Water content (%)
σ	Poisson Ratio
B	Foundation width (m)
D	Foundation depth (m)
N	SPT pulse count
ϕ	Density modulus
w_L	Liquid limit
w_P	Plastic limit
PI	Plasticity index
S_H	S wave horizontal component
S_w	S wave vertical component

CHAPTER 1

INTRODUCTION

1.1. General

Soil improvement constitutes the most important stages of planning and projecting. Field observations, field tests and experiments are the most common applications used in field measurements applied from static and dynamic use of the soil.

It is extremely important in terms of Geotechnical Engineering to determine how the structural properties of the soil may change in cases where the soils are under the influence of dynamic and static loads, that is, the structural loads are transferred to the soil. In this way, it is possible to determine the structural suitability of the construction area, to design safely and economically, and to implement the construction phases without any problems. In order to carry out the aforementioned studies, it is necessary to obtain the soil parameters with appropriate examination methods at the construction site and to determine the structural properties of the soil by using these data.

In addition to the design of all kinds of buildings, the growth of cities and the increasing population have brought along the demands for new and high-rise buildings. For this reason, there has been a great increase in the construction of buildings (housing, hospital, school, etc.) in recent years. Due to the change in the number of soils and heights, as well as the difference in usage purposes, the need for more comprehensive soil investigations of the areas where the structures will be built has emerged.

In the design of reliable and economical structures, it is important to know the soil properties and depth of the soil under the area where the structure will be built. Today, the physical and mechanical properties of the soil are determined by using field test methods, laboratory test methods and geophysical methods.

These methods have advantages over each other as well as various disadvantages. In this context, examining the results together by using all three test methods will be the most appropriate method in determining the soil parameters. However, considering that ideal conditions cannot always be created, the data obtained as a result of the aforementioned soil investigation methods should be compatible with each other and reflect the real situation in the field.

Laboratory tests, one of the soil investigation methods, are used to determine soil parameters with the help of experiments performed on disturbed and/or undisturbed samples taken during borehole in the field. However, relative disturbances may occur during undisturbed sampling and preparation for laboratory experiments. Considering that soil strength parameters are directly related to deformations on soils, laboratory test results may need to be checked using other methods.

In this respect, since it is not possible to obtain undisturbed samples for every soil type, field tests and geophysical methods are also used to determine soil properties.

Field tests are methods used to determine soil parameters in situ. Since undisturbed samples cannot be obtained, especially in cohesionless soils, the soil is tested in its natural environment with field tests. In field tests, the probes are applied by pushing (static probing) or hammering (dynamic probing) into the soil and the reactions of the soil to these processes are measured and recorded.

In seismic methods, which are mostly used in geophysical methods, the basic principle is to determine the velocity of waves produced from a source as a result of reflections and refractions. Today, this method, which has a wider application area in civil engineering due to economic reasons, has started to be used more widely in geotechnical engineering for the determination of soil properties.

In this respect, the use of Geographic Information Systems provides great convenience in the effective use of the data obtained by the three methods mentioned above, namely the soil properties. In this context, large-volume databases are worked on, and rapid evaluation, viewing and querying of these databases can only be achieved with GIS.

Recently, larger buildings, larger roads and larger structures have been built to meet social needs. The developments in construction technology have increased the importance of research in soil mechanics. Determination of soil properties is the most important stage of the project of construction works. The fact is that laboratory tests, field tests and geophysical methods are the most common methods used to determine the behavior of soils under static and dynamic loads.

1.2. Objective of the study

In this study, using the data obtained from the studies carried out by the Municipality of Elazig, SPT calculation analysis, bearing capacity calculation analysis, groundwater level and water content analysis, shear wave velocity calculation analysis, USCS soil analysis, atterberg limits analysis, shear wave velocity analysis 30 m, compression Soil classification analyzes according to wave velocity, NEHRP (USA) earthquake regulation and EUROCODE 8, earthquake hazard level analysis according to soil amplification calculation was made. In this context, ArcGIS software was used to apply geographic information systems in geotechnical applications.

It is aimed to create a database for the study area by digitizing the SPT values obtained from the borehole data and other geotechnical data. Using the created database, it is aimed to create maps in the digital environment for different practical purposes.

1.3. Outline of the thesis

Chapter 1- Introduction: In this section, the importance of using the methods used to determine soil properties and the convenience provided by transferring the results taken from the methods to the GIS system is discussed.

Chapter 2- Literature review: In this section, previous studies with the GIS system, general properties of the study area, its geology and seismicity are mentioned. In addition, information is given about the GIS.

Chapter 3- Materials and Methods: In this section, the methods used in this study are mentioned.

SPT calculation analysis, bearing capacity calculation analysis, groundwater level and water content analysis, shear wave velocity calculation analysis, USCS soil analysis, atterberg limits analysis, shear wave velocity analysis 30 m, compaction Soil classification analysis by wave velocity, NEHRP (USA) earthquake regulation and EUROCODE 8, earthquake hazard level analysis according to soil amplification calculation are included.

Chapter 4- Results and Discussion: In this section, the maps and figures created within the scope of the research and relevant evaluations and discussions are included.

Chapter 5- Conclusions and Recommendations: The results and recommendations of the thesis are given.



CHAPTER 2

LITERATURE REVIEW

2.1. General

In this section, previous studies on the GIS applications are introduced. In addition, general properties of the study area, its geology, and seismicity are given.

2.2. Previous studies on GIS

There have been many studies in different areas using GIS applications. For example, a study of the use of GIS and field use for planning and adjustment of earthquake damage maps was conducted by Marx (1992) for Seattle. A study has been carried out on the use of GIS in city planning (Haala et. al, 1998). The GIS was used to create damage maps in India to mitigate the earthquake risk (Anand, 2000). Since interpolation can be made between two points by various methods with the help of GIS, a study was carried out on the soil properties between two boreholes in a geotechnically investigated region (Ündül ve Gürpınar 2003, Çetin ve Unutmaz 2004). Multimedia GIS database was created for tourism industry in Nigeria (Ayeni et al., 2004). The GIS database was used for the implementation of environmental emergency action plans (Spearin, 2004). A study was conducted on the preparation of maps showing soil properties using GIS. (Akbas ve Yıldız, 2004). A study was conducted on creating a zoning plan model for a medium-sized metropolitan area using GIS according to soil characteristics (Orhan, 2005). A study was conducted in Eskisehir by examining soil properties such as liquefaction potential, swelling potential, groundwater level, and susceptibility to flow. (Kolay vd., 2006). In a study on the use of GIS for Geotechnical purposes in Adapazarı, a study was conducted by creating the Adapazarı bearing capacity map, liquefaction map and damage maps with the help of MapInfo. (Sert vd., 2006). By using aerial photographs and Landsat images obtained with GIS at different times, how much the city of Kahramanmaraş has developed over time has been determined. (Karabulut vd., 2006). In health geography, spatial analysis models and methods with GIS, innovations related to the spatial situation of health services have

been researched. (Ergün ve Saraç, 2006). A study was conducted on the analysis of archaeological sites using GIS (Turoğlu, 2006). A study was carried out to create a noise map by entering measurements into the Mersin University Çiftlikköy Campus digital map with the help of GIS by measuring noise (Kumbur, 2006). Using GIS technology, modeled the change in soil amplification parameters in the region and classified the study area according to NEHRP by using the Vs values obtained in the field or calculated from the number of impacts (Beliceli, 2006). The distribution of liquefaction potential index in the GIS platform of the area around the Municipality of Gümüşler in Denizli province was investigated (Sen ve Akyol 2006). Maps of land slope and geological data layers were created with the help of GIS program (Kıncal, 2006). A study has been carried out that emphasizes the importance of the process and reduces the error loss of the data analysis while creating the soil maps (Karavul vd., 2006). They conducted a study with GIS to obtain information about the region between Büyükçekmece and Küçükçekmece Lakes, such as permeability status, geology, susceptibility of soils to liquefaction, groundwater, faults, hydrology and old landslide areas (Alparslan vd., 2006). Based on the data obtained from the soil survey reports received from Eskisehir Tepebası Municipality, different maps were created in the GIS environment for general soil profile extraction and accordingly to be used in geotechnical design (Seven, 2008). Prepared the soil liquefaction potential, ground water and soil properties of the places within the borders of Tepebasi municipality in Eskisehir using GIS software (Ayday vd. 2008). Created geotechnical microzone maps using GIS techniques (Kolat ve ark. 2012). The geotechnical properties of the soil along the east and west sides of the Tigris River were modeled electronically with the help of GIS (Alhasmey, 2015). Thematic maps and model maps were created by using the GIS method in order to determine groundwater potential and water quality in settlement areas and plains located within the borders of Batman province. (Yavuz, 2017). Earthquake hazard maps were created with GIS and Analytical Hierarchy Method (Savaşan, 2018). Geotechnical features of Malatya were evaluated by producing maps with GIS based software (Karabaş, 2019). Groundwater quality for Idlib City was evaluated with GIS software (Khateeb, 2020). Liquefaction potential maps were created by using GIS-based computer software for the liquefaction potential of soils in a certain region in the city center of Kütahya. (Karabaş ve Şengül, 2021). Erzincan city center geotechnique was evaluated with GIS. (Çabalar ve ark., 2021).

2.3. General properties of the study area

2.3.1. Location and of the study area

The province of Elazığ, which is the study area, is located in the south-west of the Eastern Anatolia Region, in the Upper Euphrates Section. Its surface area is 9.281 km², of which 8,455 km² is land, 826 km² is dam and natural lake areas. Elazığ, which is 1.067 meters above sea level, consists of mountainous areas, plateaus and plains in terms of landforms. The province area, which constitutes 0.12% of Turkey's lands, lies between 40° 21' and 38° 30' east longitudes, 38° 17' and 39° 11' north latitudes. Within this framework, the length of the territory of Elazığ province, which is roughly rectangular in shape, in the E-W direction is approximately 150 km and its width in the N-S direction is approximately 65 km (ÇŞB, 2020).

Due to its geographical location, it is located at the junction of the roads connecting the Eastern Anatolia Region to the west. The province is surrounded by the lands of Bingöl from the east, Tunceli from the north via Keban Dam Lake, Malatya from the west and southwest through the Karakaya Dam Lake and Diyarbakır from the south. The most important river within the borders of the province is the Euphrates and its branches. Hazar Lake, with an area of 86 km², is 30 km from the city center. In addition, our province is surrounded by important dam lakes such as Keban, Karakaya, Kralkızı and Özlüce (ÇŞB, 2020).

The general slope range of the study area is 0-50%, and the slope value on the slopes in the southern parts of the Harput castle is between 60-70% (EMDD, 2015).

The localization map showing the study area is given in Figure 2.1.

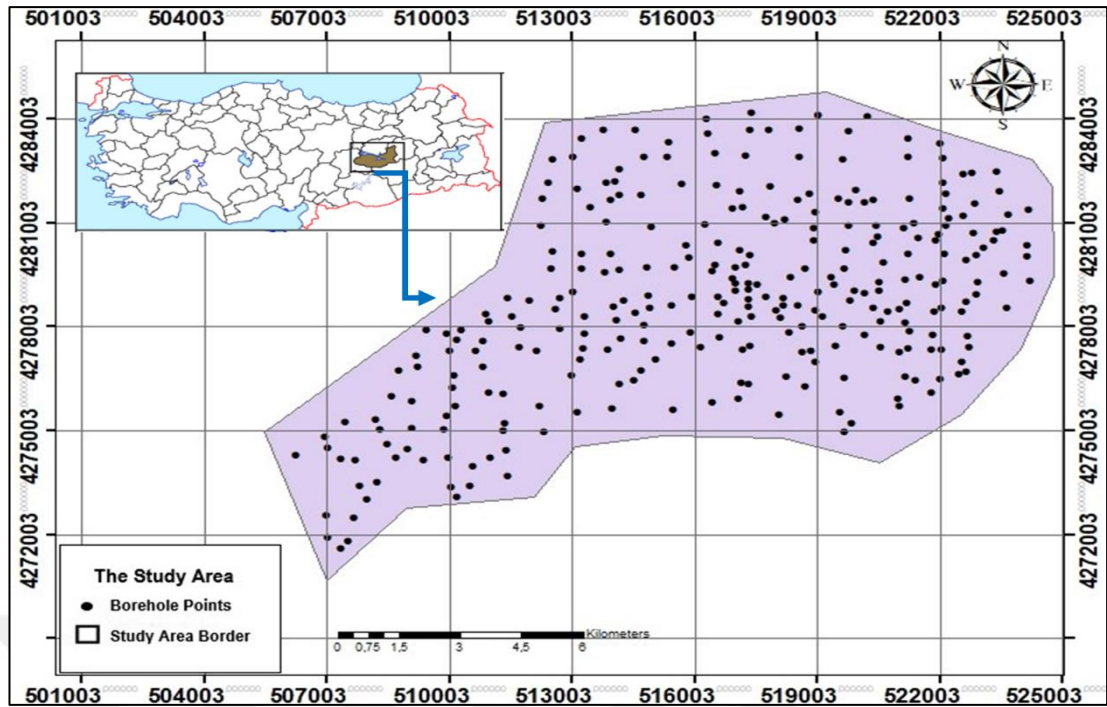


Figure 2.1 The map of the study area

2.3.2. Climate, temperature and vegetation

Elazig, where a continental climate prevailed in the past, has transitioned to a temperate climate with the effect of the dams that have been built or are being built. As a result of this process, especially the winters, which were very cold and heavy snowy before, are relatively milder. Elazig was established on a fertile plain. Since the continental climate is experienced, there are no large woodlands in the mountains as in the Black Sea. However, due to the dams built, Elazig has transitioned to a temperate climate as stated. Normally, in the Eastern Anatolia Region, summers are very hot and winters are very cold. Considering the ecological conditions, it can be said that approximately 90% of the Elazig province area between 950-1.950 m is within the natural forest ecosystem (EMDD, 2015).

2.3.3. General geological properties of the area

Geological information of the study area is created by utilizing "Geotechnical Report Based on the Construction Plan of the Elazig Municipal Settlement Site" prepared by the Elazig Municipality in 2018 and the "Elazig Province Environmental Status Report" prepared by the Ministry of Environment and Urban Planning in 2011 (Figure 2.2).

2.3.3.1. Geology of the study area

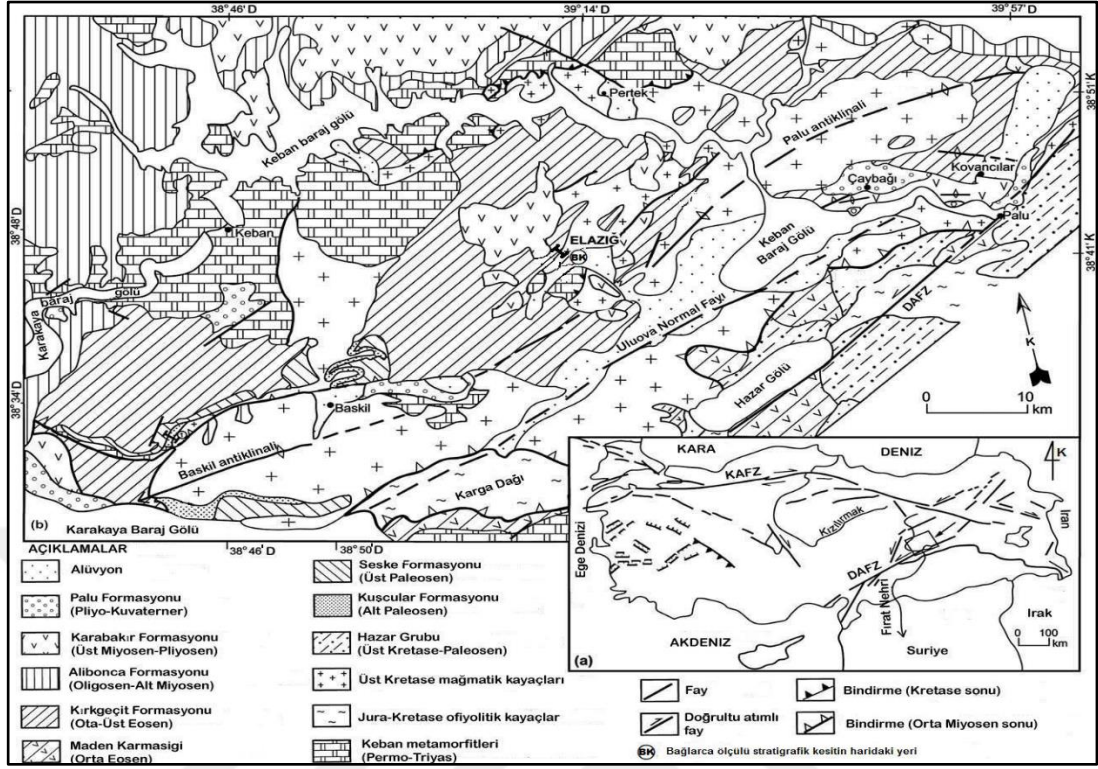


Figure 2.2 Geological map of Elazig (İbilioğlu, 2010)

2.3.4. Seismicity of the region

Understanding the potential of seismic activities depends on local geology, tectonic movements and seismic activities that have occurred in the region throughout history. When the subject is evaluated from this point of view, it will be useful to examine the location of Elazig province in the earthquake map, the active faults around it and the earthquakes that have occurred in Elazig before (Akçal, 2020).

As seen in Figure 2.3 and Figure 2.4, Elazig province is located in the first and second earthquake zones due to the high seismic activity in general in terms of geographical location. According to the earthquake regulations of 2018 and previous years, the earthquake map of Elazig and its surroundings is presented in Figure 2.3.

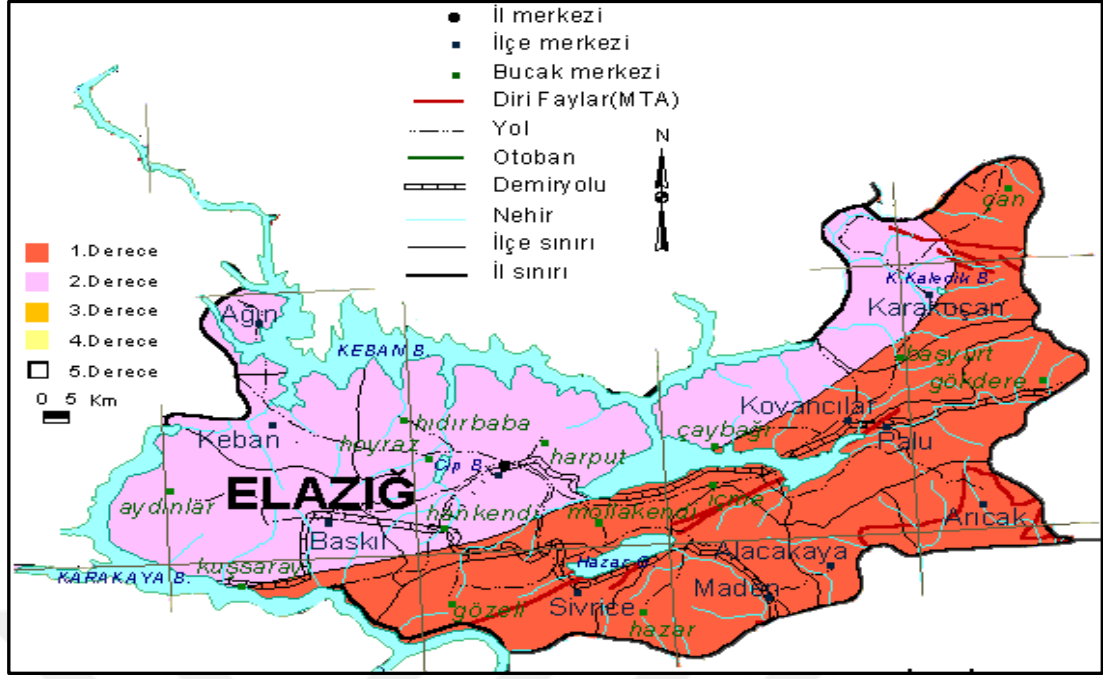


Figure 2.3 Map of Elazig earthquake region zones and active faults

There are five active faults in the study area and its surroundings. These faults; East Anatolian Fault, Southeast Anatolian Thrust Zone, Nazimiye Fault, Ovacık Fault (EMDD, 2015).

Within the framework of this study, it was determined that there were 184 earthquakes higher than $M > 4.0$ between 1900-2022 in and around Elazig, and it is presented in Figure 2.5. The number and magnitude of these earthquakes are given in Figure 2.6. The earthquakes that occurred in and around Elazig between 1900-2018 are presented in Table 2.1. (AFAD, 2021).

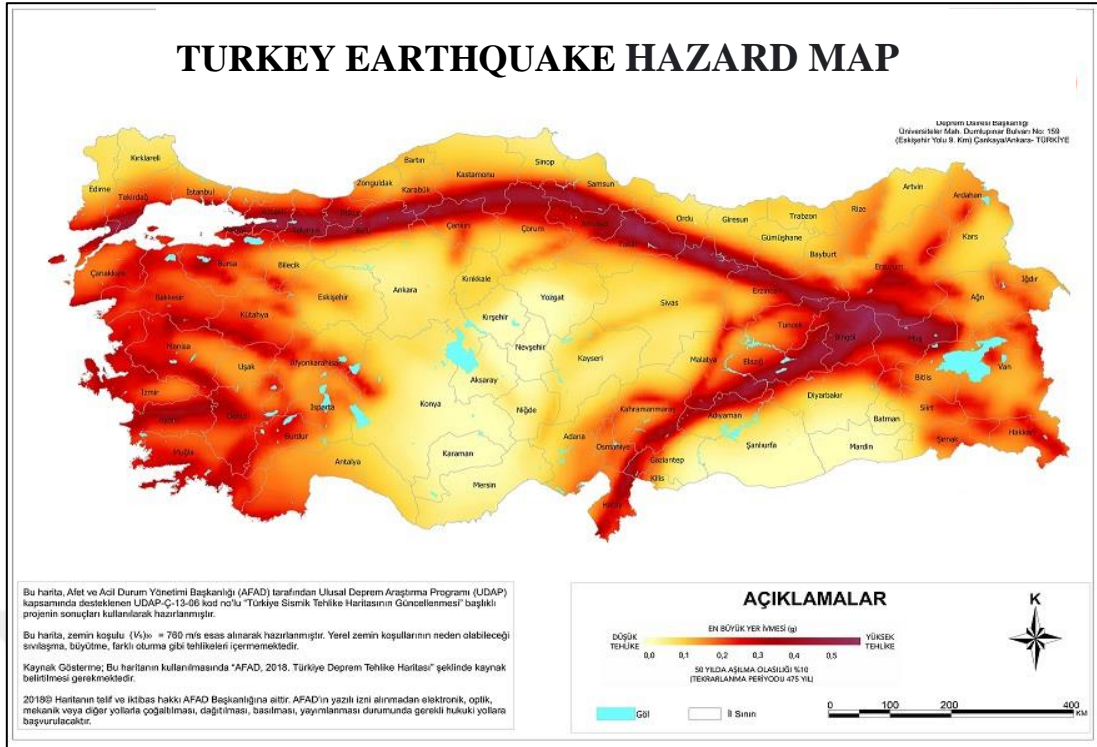


Figure 2.4 Map of Turkey's earthquake zone and active faults (AFAD, 2021)

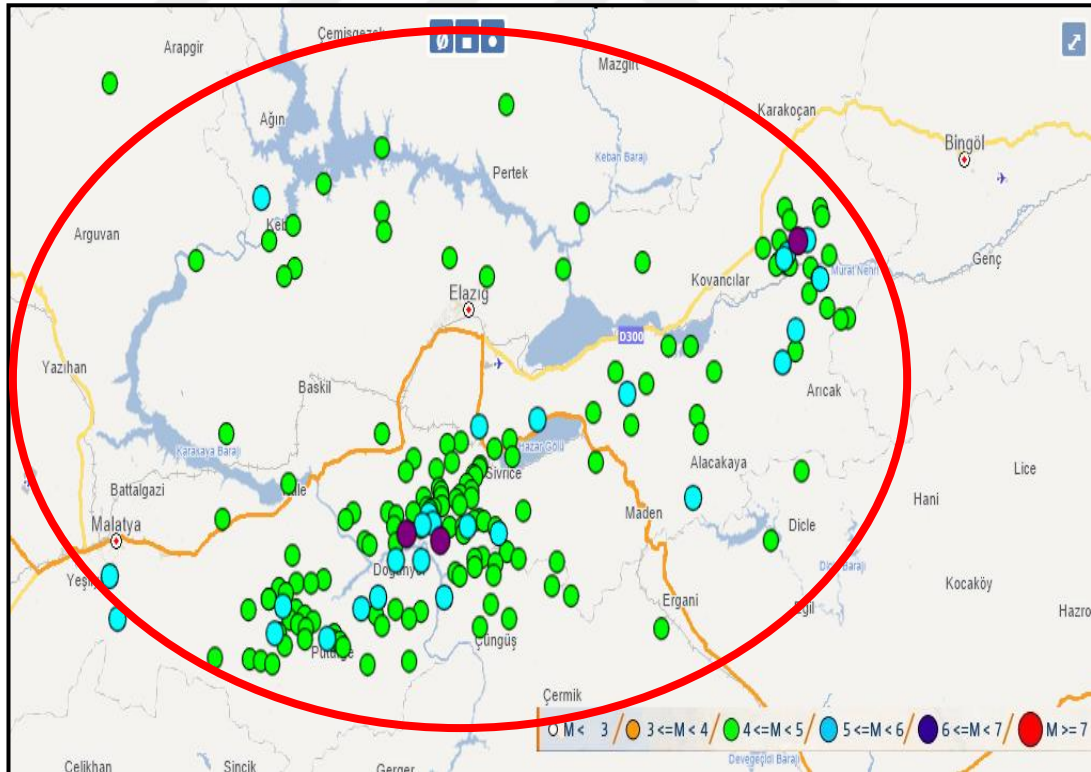


Figure 2.5 Distribution of earthquake magnitudes ($M > 4.0$) between 1900-2022 in Elazığ and surroundings (AFAD, 2021)

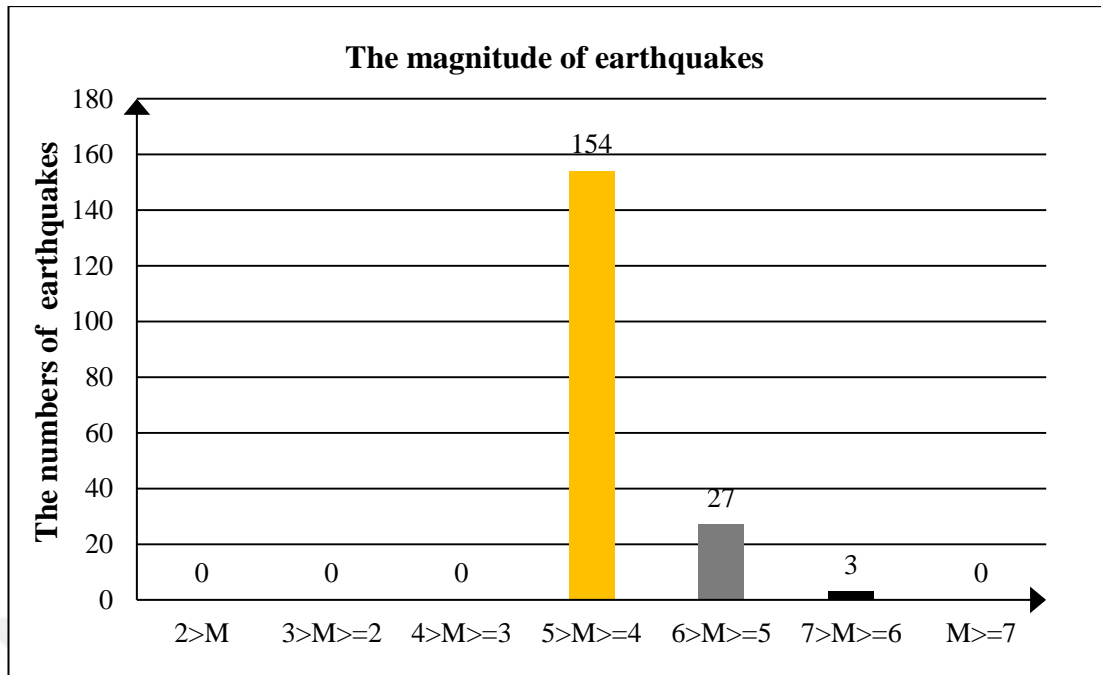


Figure 2.6 The numbers of earthquakes and magnitude between 1900-2022 in Elazig and its surroundings (AFAD, 2021)

Table 2.1 The important earthquakes occurred in Elazig and its surroundings between the years of 1900-2022 (AFAD, 2021)

No	Date	Time	Lat.-Log.	D	M	Location
1	01.01.1904	22.00	38.83 - 38.69	10	5.0	Merkez – Elazig
2	28.09.1908	06.27	38.35 – 39.15	10	6.1	Malatya- Near Elazig Border
3	08.11.1950	10.08	38.27 – 39.16	50	5.2	Sivrice – Elazig
4	10.09.1973	03.02	38.51 – 39.64	41.7	4.7	Keban – Elazig
5	24.06.1987	06.53	38.32 – 39.35	32.5	4.7	Kovancılar - Elazig
6	09.05.1998	15.38	38.25 – 38.94	17.2	5.1	Arıcak – Elazig
7	08.03.2010	02.32	38.77 – 40.07	5	6.1	Kovancılar- Elazig
8	11.08.2004	15.48	38.37 – 39.22	10	5.6	Sivrice – Elazig
9	04.04.2019	17.34	38.38 – 39.12	8.9	5.2	Sivrice – Elazig
10	24.01.2020	20.55	38.35 – 39.06	8.1	6.8	Sivrice – Elazig

D=Deepness (km), M:Magnitude

2.4. Geographic information systems

2.4.1. Introduction

GIS is a high-performance computer system that collects information about the objects that exist in the world and the events that occur, stores them in the computer environment, makes inquiries, maps and analyzes them in the desired format and scale. This system is a set of technological systems capable of collecting and storing all data belonging to objects and events with a geographical location, as well as updating,

querying, synthesizing and producing new options in a very short time (Tosun ve Orhan, 2007).

The ability to enter data for each geographical object, to make different types of queries on these data and to produce maps with GIS techniques increases the usage areas by providing significant convenience to the users. Researchers and practitioners have the opportunity to use the software for their purposes by making various changes in the face of emerging needs. GIS can be used in many earth science applications as well as urban INFORMATION system, mathematical modeling and vehicle tracking. Some of these studies on earth sciences can be listed as natural hazard analyses, general geological studies and geotechnical studies (Orhan, 2005).

GIS can evaluate local changes quickly and effectively. Because GIS has the ability to work with large data sets. In addition, GIS can combine and query various variables for decision support purposes. (Wylie ve ark. 1994; Pebesma, 1996).

Analyzes and maps made using GIS play an active role in the evaluation of the soil structure in the study areas and in taking the necessary precautions before the earthquake. Example maps that can be created with the help of GIS in geotechnical engineering are shown in Figure 2.7.

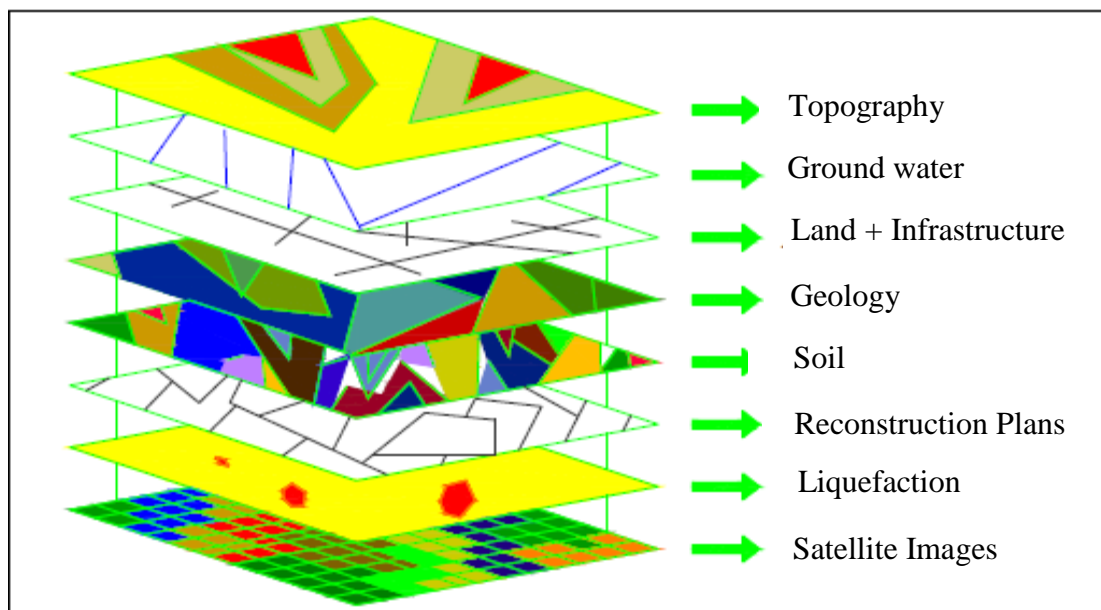


Figure 2.7. Layers of geographical information system (Seven, 2008)

2.4.2. How does a geographic information system work?

GIS stores information about the earth by treating it as geographically related thematic map layers. This is a simple but extremely powerful approach to evaluating spatial information. For example, it enables the solution of many real world problems, from the optimum load distribution of the transport vehicles that have undertaken the distribution task, to the detail records of the planning based applications, to the modeling of the changes in the atmosphere (Yomralıoğlu, 2000).

2.4.3. Components of geographic information system

GIS; It is a system consisting of human, software, data and management circle, which covers the processes of covering, managing, processing, analyzing, modeling and displaying the data whose location is determined in the space. Classically, GIS consists of five components (Köktürk, 2003).



Figure 2.8 Basic components of geographic information system (Kurnaz, 2011)

CHAPTER 3

MATERIALS AND METHODS

3.1. Introduction

Within the scope of the thesis study, the studies carried out within the scope of the soil survey reports prepared by utilizing the geological-geotechnical 210 borehole information were used in order to evaluate the suitability for the settlement area of the approximately 133.65 km² part of the Elazig Municipality in the province of Elazig. In this study, 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m, 15 m depths, SPT calculation analysis, bearing capacity calculation analysis, groundwater level and water content analysis, shear wave velocity calculation analysis, USCS soil analysis, atterberg limits analysis, shear wave velocity analysis 30 m, compression Soil classification analyzes according to wave velocity, NEHRP earthquake regulation and EUROCODE 8, earthquake hazard level analysis according to soil amplification calculation was made.

3.1.1. Soil investigation report

In Terzaghi's words, the foundations, which are seen as the last "majestic" structural element, should be tasked with maintaining the structural integrity of the soil while transferring the superstructure loads to the soil, and should also be designed without forcing the soil against excessive stresses. Otherwise, the soil may cause excessive settlement and/or slip failure in response (Coduto, 2001).

The soil survey data report is prepared by taking into account the structural features, local soil conditions, the geology of the region, the condition of the surrounding structures and regional seismicity. Field observations, boreholes, inspection pits, field and laboratory tests etc. made within the scope of the survey. All studies should be prepared as a "Soil Investigation Data Report", making use of the relevant standards, as a basis for the "Soil Investigation Evaluation Report" to be prepared later (IMO, 2016).

In the Borehole Log in Figure 3.1, there are issues such as borehole depth, sample type (D and UD), SPT impact number and graph, Geotechnical description, groundwater level, coordinate, borehole elevation, start-end date (IMO, 2016).

In addition, data obtained from seismic studies such as shear wave velocity and compression wave velocity, which are not included in the borehole log, and parameters such as dominant vibration period, soil amplification, and density are taken from the charts prepared within the scope of soil investigation.

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8	6	7.50	SPT		19	24	31	55															
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10	8	9.00-10.5	CR																				
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14	10	12.0-13.5	CR																				
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16	11	13.5-15.0	CR																				
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5-10	ORTA GEÇİRİMLİ			4-8	O. KATI	10-30	ORTA SIKI	50 - 75	A3	ORTA A.	10-50	S2 ÇOK SIK ARAL.											
10-25	GEÇİRİMLİ			8-15	KATI	30-50	SIKI	75 - 90	A4	AZ AYRIŞMIŞ	3-10	S3 SIK ARALIK.											
>25	ÇOK GEÇİR.			15-30	Ç. KATI	>50	ÇOK SIKI	90-100	A5	TAZE	1-3	S4 GENİŞ ARAL.											
				>30	SERT						<1	S5 KÜTLESEL											

Figure 3.1 An example of SPT boring report (EMDD, 2015)

3.1.2. Soil research

Soil survey studies and Soil Investigation Data Report to be planned by civil engineers should be prepared by the collaboration of civil and geology, if necessary, geophysical engineering disciplines. The distribution of duties according to the fields of specialization are given below (IMO, 2016).

Borehole wells, taking all kinds of disturbed and undisturbed samples, SPT and other field tests, soil and rock mechanics laboratory tests and reporting, under the supervision of civil or geological engineers, dynamic properties of the soil such as seismic refraction, seismic reflection, multi-channel surface wave analysis. Conducting and reporting of field tests for determination should be done by geophysical engineers (IMO, 2016).

Field and laboratory studies carried out in the soil survey data report should be presented in detail. In this context, soil survey data report; the purpose and scope of the research, zoning status, parcel information and topographic situation, general geology and geology of the study area, site plan of the research points (separately on the architectural site plan and plankote), logs of all borehole and inspection pits, soil sections and groundwater table, field and laboratory test data and laboratory test results.

Within the scope of the study by Rowe, the value of the cost of soil survey studies for different work items, determined as a percentage of the total investment cost and the cost of earthworks and foundation, is presented in Table 3.1.

Table 3.1 Soil exploration costs (Rowe, 1972)

Construction Type	Total Investment Cost In Percentage	In Percentage of Earthworks and Foundation Construction Cost
Earth Dams	0,89- 3,30	1,14- 5,20
Filling	0,12- 0,19	0,16- 0,20
Dock	0,23- 0,50	0,41- 1,67
Bridges	0,12- 0,50	0,26- 1,30
Buildings	0,05- 0,22	0,50- 2,00
Roads	0,20- 1,55	1,60- 5,67
Railways	0,60- 2,00	3,5
Overall Average	0,70	1,5

3.2. Standard penetration test

SPT is the most widely used field test all over the world. In the 19th century in the USA, boreholes were drilled with water and the soil type was defined from the soil grains in the borehole mud coming out of the well. Later, in 1902, Colonel Charles R. Gow developed a 1-inch (approximately 2.5 cm) diameter open sampler driven by a 110 lb (approximately 50 kg) ram to identify the soil type (Fletcher, 1965). Over time, different types of this sampler have been developed in the USA. SPT, Raymond Pile Co. in the USA. In the 1920s, it was used to have an idea about soil strength and to take a sample that allows the soil to be defined realistically (Douglas, 1983).

Terzaghi stated that in addition to the soil type, information about the firmness and consistency of the soil can also be obtained from the SPT. This proposed sampling method is very similar to the current SPT standard. Terzaghi and Peck (1948) suggested many design charts and correlations in the light of the data obtained from the SPT. After this date, the use of SPT has increased rapidly all over the world, starting from the USA and England (Erol and Çekinmez, 2014).

3.2.1. SPT method

SPT is a field test known as a dynamic penetration test, which also gives information about the firmness and consistency of the soil. SPT is applied by dynamically dropping a 63.5 kg rammer from a height of 76 cm and moving a standard sampler 45 cm into the soil. The total number of blows corresponding to the last 30 cm advance of the sample spoon into the soil is defined as the penetration resistance of the soil (SPT-N). This test can be applied in various soil types, from soft clays and loose sands to very hard clays and compact sands (Sivrikaya and Toğrol, 2010).

The approximate firmness of the soil, loss of bearing capacity and safety stress can be calculated by using the N impact numbers found in the SPT test made from the boreholes (Terzaghi and Peck, 1948).

The well is cleaned up to the level where the test will be performed and care is taken not to leave any disturbed part at the test level. The tube is lowered to the bottom of the well and driven 15 cm into the soil. The impact numbers (N) obtained from the 15 cm ramming of the tube are not taken into account. The aim here is to pass the

disturbed soil part at the bottom of the well. After the first 15 cm of progress, the tube is hammered again so that it enters the soil another 30 cm and the total number of blows for 30 cm of ramming is recorded. The recorded number of blows (N) is taken into account as the result of the experiment. If the number of blows obtained before the tube reaches a penetration of 30 cm is 50, no more pulses can be applied. The tube is pulled up and the disturbed sample in the tube is placed in a jar or bag and sent to the soil mechanics laboratory for soil identification and index experiments. The test is applied at intervals varying between 1.75 m and 1.5 m throughout the borehole. According to the practice in Turkey, the test is done every 1.5 m. If the soil is gravelly, the shoe at the end of the tube is removed and the conical tip with 60 beveled edges is attached (Aydin, 2010).

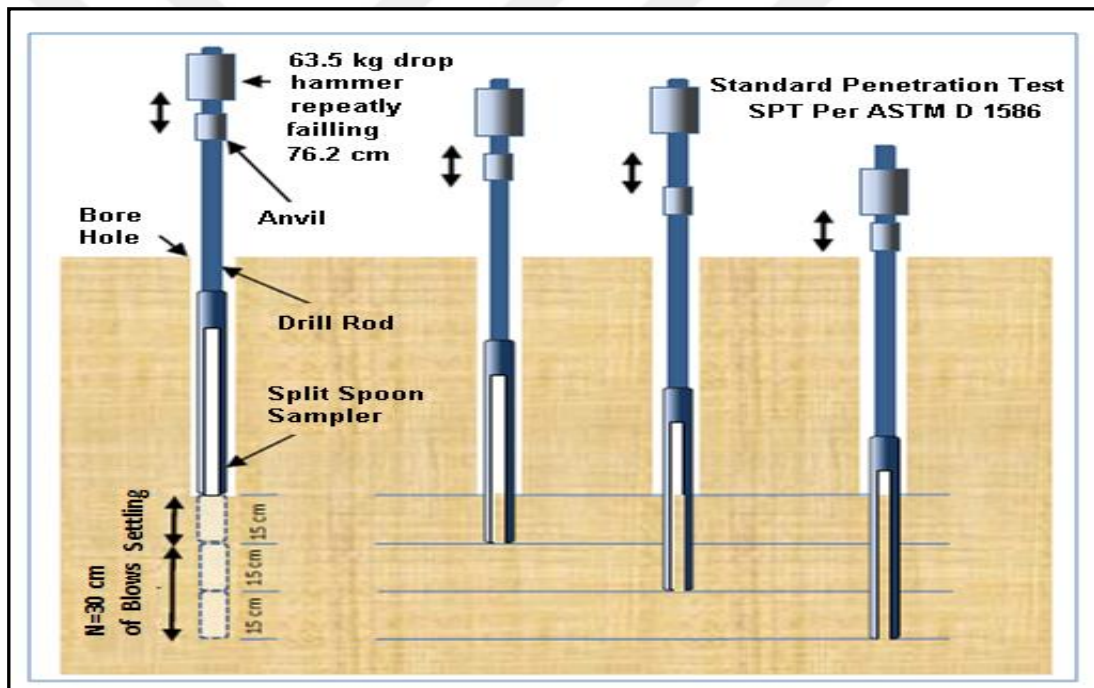


Figure 3.2 Steps of standard penetration test (FHWA, 2002)

3.3. Bearing capacity calculations

It must be able to transfer various loads from the structures to the soil safely. For this, it is extremely important that the foundations have sufficient security against collapse (bearing strength). Otherwise, there may be dangers of collapse of the foundation and consequent total or partial damage to the superstructure. In order to realize reliable and economical projects against these destructive effects, it is necessary to examine the

properties of the soil on which the structures will sit, and the soil strength data revealed should reflect the truth (Tonyalı, 2011).

Bearing capacity is used to mean the maximum base pressure that the foundation can carry without collapse. The bearing capacity of the foundations varies according to the unit volume weight of the soil, shear strength and deformation properties, the tension of the soil in the field, hydraulic conditions, geometric properties such as the depth, size, base shape and roughness of the foundation, the load values applied to the foundation and the construction methods (Kumbasar and Kip, 1999).

3.3.1. Terzaghi and Peck (1967) method

Terzaghi and Peck (1967) developed safe bearing capacity relations for situations where settlements that may occur in foundations do not exceed 25 millimeters. These relations were obtained as a result of experimental studies, and the relationship between the safe bearing capacity q_e , foundation width, B and SPT-N values are given in Figure 3.3.

The safe bearing capacity calculations of Terzaghi and Peck do not include issues such as depth and foundation length. In addition, it can be said that it is on the safe side, since it is one of the first studies on this subject and the analyzes are revealed with the help of experimental observations (McCarthy, 2007).

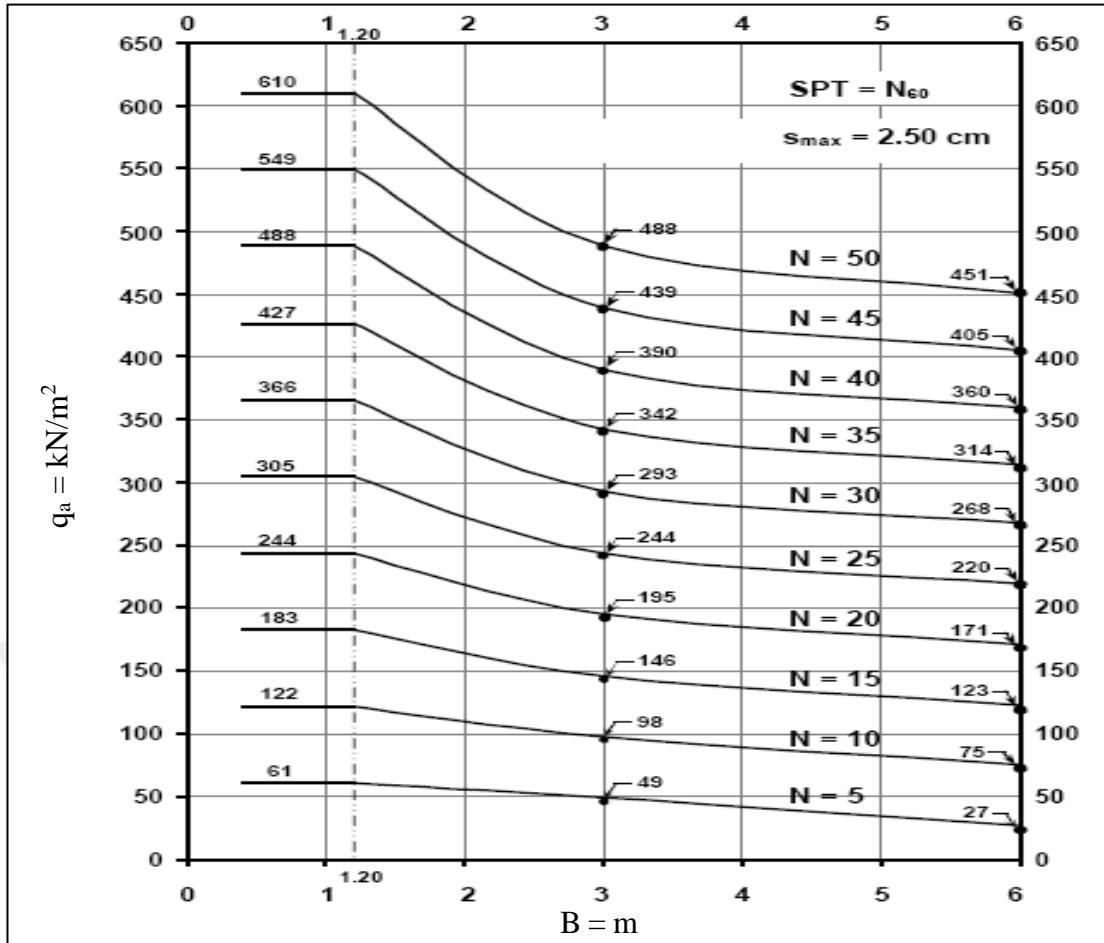


Figure 3.3 Change of allowable bearing capacity according to foundation width and SPT (Tonyalı, 2011)

3.3.2. Meyerhof (1974) method

Meyerhof developed bearing capacity formulas based on SPT-N values. Similar to the work done by Terzaghi and Peck, Meyerhof also limits the settlement at to 25 millimeters. Accordingly, the bearing capacity is calculated by using the following formulas (Bowles, 1996). The foundation width was chosen as 3 m. Accordingly, the safe bearing capacity is calculated using the following formulas.

$$q_e = 12 * N * K_d \quad (3.1)$$

$$q_e = 8 * N * ((B + 0,3505) / B)^2 \quad (3.2)$$

$$K_d = 1 + 0,33 * D / B < 1,33 \quad (3.3)$$

Here; abbreviations are used as:

q_e : Bearing capacity (kN/m^2)

N : SPT blow number

D : Foundation depth (m)

B : Foundation width (m)

In addition, Meyerhof gives the safe bearing capacity formula for raft foundations as follows, taking into account the depth of the affected area and the increased settlement amounts under raft foundations with a large width (Bowles, 1996).

$$q_e = 12,5 * N * K_d \quad (3.4)$$

3.4. Compression wave velocity (V_p)

These types of waves are known as compression or initial expansion. During the propagation of these waves, there is a cubic expansion or volume change. The direction of vibration, which represents compression and expansion in longitudinal waves, is the same as the direction of wave propagation (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

In wave propagation, there is a change in shape along with the change in volume. However, during this shape change, the angles do not change, so a cube-shaped element turns into a rectangular prism. Since P waves are the fastest waves in a medium, they are recorded first in earthquake records (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

Velocity of the P wave;

$$V_p = \sqrt{\frac{\lambda + 2\mu}{\rho}} = \sqrt{\frac{E(1-\sigma)}{\rho(1+\mu)(1-2\mu)}} \quad (3.5)$$

σ = Poisson Ratio

μ = Rigidity (Slip Modulus)

ρ = Density Modulus (Elasticity)

In the above formula, the velocity of the P wave carries a certain value even when the rigidity of the object is zero and the resistance to deformation ceases. This means that P waves can also pass through liquid and gaseous non-rigid materials (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

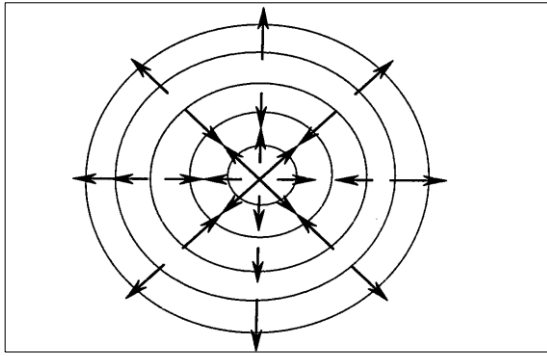


Figure 3.5 P wave global propagation (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

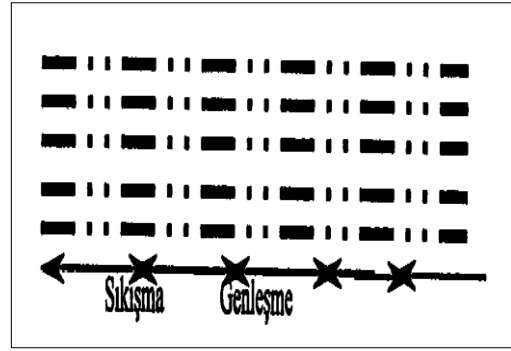


Figure 3.4 P wave emission (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

3.5. Shear wave velocity (V_s)

During the propagation of Transverse Waves, deformations of the elements, that is, changes in angles, are observed. This is because; is that the direction of vibration of the particles between wave propagation is perpendicular to the direction of wave propagation. These waves are called S waves (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

In the propagation of S waves, the transverse particle oscillation is called SH if the particle oscillation is on the horizontal plane, and SV if the particle motions remain on the vertical plane. The velocity V_s of the S wave is calculated by the following formula (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

$$V_s = \sqrt{\frac{G}{P}} = \sqrt{\frac{E}{2\rho(1+\mu)}} \quad (3.6)$$

The speed of S waves depends on the rigidity and density of the object they pass through. For this reason, S waves do not occur in liquid materials that do not have rigidity (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

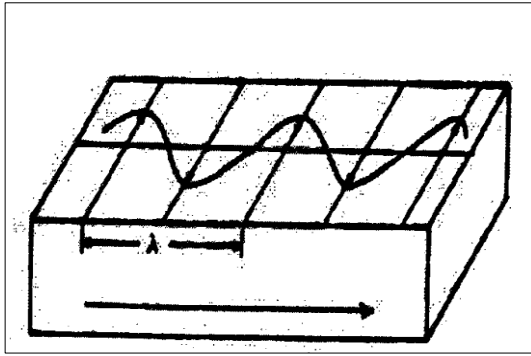


Figure 3.7 S_H wave (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

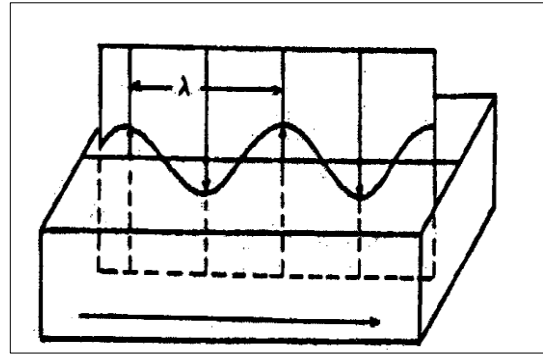


Figure 3.6 S_v wave (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

The ratio of P and S waves is calculated with the following formula.

$$\frac{V_p}{V_s} = \sqrt{\frac{2(1-\mu)}{1-2\mu}} \quad (3.6)$$

If the value of Poisson's ratio, which is usually $\frac{1}{4}$, is substituted in the above equation, the ratio V_p/V_s gets its value. This means that the P wave is 1.7 times faster than the S wave in solid objects. The velocity values of P and S waves in various formations are presented in Table 3.2 (Çaylak, 2002, Tatham, 1982, Klimentos, 1991).

Table 3.2 P and S Wave Velocities in Some Rocks (Clark, 1966)

Formation	P wave speed (m/sec)	S wave speed (m/sec)
Granite	5680	2950
Granodiorite	4780	3100
Diorite	578	3060
Gabbro	6450	3420
Basalt	8000	3200
Dunite	1400-4300	4080
Sandstone	2400	-
Conglomerate	1700-4200	-
Limestone	1700-4200	2955
Clay	1100-2500	-
Loose Sand	1800	500

Information on the stiffness of soils can be learned from the shear wave velocity. It is used to determine the behavior of the soils. It can be determined in the field or by calculation. V_{s30} is used in earthquake hazard analyzes and some soil classifications (Karabaş, 2019).

Soil shear wave velocity value is required in order to determine the soil dominant period, frequency and soil amplification coefficient, which are necessary to determine the dynamic behavior of the soil. The shear wave velocity value of the soil can be determined by seismic methods performed in the field. Most of these methods are labor and time-consuming, and also uneconomical (Akdeniz, 2012).

The differences in local soil properties cause damage to the soil caused by soil problems such as amplification, loss of bearing capacity, liquefaction and settlement during the earthquake. The parameter leading to the determination of whether there is a growth problem in the soil is the shear wave velocity value of the soil (Akdeniz, 2012).

3.5.1. Measuring shear wave and compression wave velocity in the field

In line with the tests carried out in the field, the surface fracture method is used and it is used to determine the information of the study area soil. In this method, the propagation of waves coming from the interfaces and the waves arriving directly are recorded. The energy source is created by using a hammer with a mass of 8 kg. S wave energy and recordings are created by striking the plate placed at a depth of approximately 30 to 40 cm. Geophones are used to create these records. Signal cumulative seismographs are used to accurately record the value of the S wave velocity. In this way, the shear wave velocity is calculated (Karabaş, 2019).

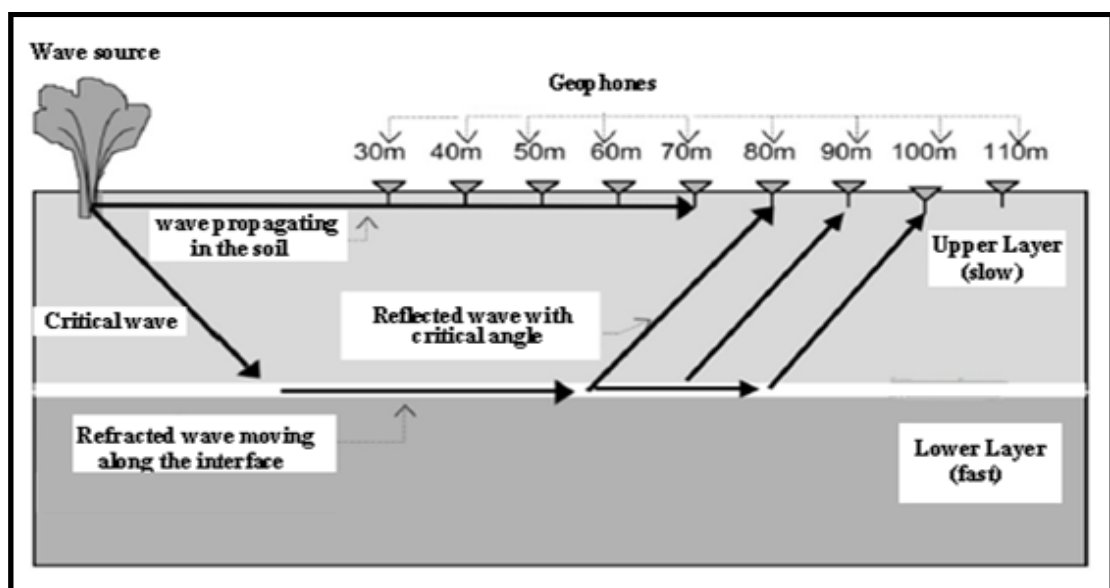


Figure 3.8 Movement of waves in the soil due to seismic method (Tonyalı, 2011)

3.6. Soil classification according to NEHRP

According to NEHRP, it is aimed to increase the strength of structures that are important during or after the shaking in the USA at the desired level. According to NEHRP, the soil class is determined in accordance with V_{s30} . The soil classes are given in Table 3.3. (Good, 2009).

Table 3.3 Soil classification criterias according to NEHRP (Güzel,2009).

Soil	Description	Properties
A	Hard rock	$V_s > 1500$
B	Rock	$760 < V_s \leq 1500$
C	Very dense soil/ soft rock	$360 < V_s \leq 760$
D	Stiff soil	$180 < V_s \leq 360$
E	Soft soil	$V_s < 180$

3.7. Earthquake hazard by soil amplification

The soil amplification value represents the rise in amplitude of seismic emissions when they pass through soil soils closed to the surface. This is due to the low density on the ground soils. During shaking, shaking waves become very large on loose soil. It is known that it causes great damage to the soil layers during an earthquake (Kurnaz, 2011). The formulation for soil growth is presented below.

Table 3.4 Soil amplification relationships with shear wave velocity (V_{s30}) (Midorikawa, 1987)

Researcher	Relation
Midorikawa (1987)	$A = 68V_1^{-0.6}$ ($V_1 < 1100$ m/sec)
	$A = 1$ ($V_1 > 1100$ m/sec)
A : Relative amplification coefficient	
V_1 : Shear wave velocity for depth of 30 meters	

By using the relation developed by the researcher in Table 3.5, the soil amplification values for the study area can be calculated by means of the average shear wave velocity data of 30 m from the surface.

According to the detected soil type, earthquake hazard levels are respectively; C (low danger) is dominant for values between 0.0-2.0, B (moderate danger) for values between 2.0-4.0, A (high danger) for values between 4.0-6.5 (Kurnaz, 2011).

3.8. The water content study area

In the event of an earthquake, very fast and short spreads occur on the soil. When the underground water is less distant from the soil surface, it eliminates the contact forces that keep the soil grains together during an earthquake. Thus, it reduces the soil strength. The soil behaves like a liquid instead of a solid in such situations. Therefore, groundwater directly affects the design of engineering constructions and the mechanical properties of soils (Karabaş, 2019).

The groundwater level is determined by measurements to be made after the static water level is obtained (following at least 3 consecutive days) so that the well is emptied from the boreholes equipped with perforated pipes of sufficient rigidity, in case of using borehole fluid, and the level that can represent the environment can be formed. If groundwater is encountered in the study area and the water level is close to the foundation level, water samples are taken and laboratory tests (sulphate content, pH, etc.) are carried out in order to determine the harmful effects of groundwater on concrete and other productions (IMO, 2016).

3.9. Soil classification according to EUROCODE 8

EUROCODE 8 is the European Regulations for buildings. "EUROCODE 8 is the design of earthquake resistant structures". It expresses how the constructions at dangerous points against earthquakes will be made and planned. It was approved by the European Standards Committee (Halaç, 2016).

Its purpose is to ensure that human life is safe and to reduce the possible damage that may occur during an earthquake. Buildings, bridges, etc., which are valuable within the scope of civil defense there is a need for safe use of the constructions even after the earthquake. According to EUROCODE 8, the soil class is determined by V_{s30} . The table of the soil classes in question is given in Table 3.5.

Table 3.5 Soil classification criterias according to EUROCODE 8 (Karabaş, 2019)

Soil	Description	Properties
A	Rock or other rock-like geological formation	$V_s > 800$
B	Very dense sand or gravel or very stiff clay	$360 < V_s < 800$
C	Dense sand or gravel or stiff clay	$180 < V_s < 360$
D	Loose to medium cohesionless soil or soft to firm cohesive soil	$V_s < 180$

3.10. Atterberg limits analysis

The consistency of the soil is the most basic feature that determines the adhesion strength between the particles, the shear resistance and stability against the load, the hardness that changes with water, and the stiffness it will have in which water content. As the water content of the soil increases, it shows a different consistency from solid to liquid. In addition, while different soils show different consistency in the same water content, they need different water to go from solid to liquid state. For this reason, it is important to determine the water content and consistency of the soil and to know the water content, especially in plastic and liquid consistencies. Cohesive soils show large volumetric changes as the water content changes, and most importantly, as the water content increases, their resistance to load decreases and they show great deformation. As shown in Figure 3.10, defined by Atterberg, a change in volume is observed according to the consistency (Öztürk, 2012).

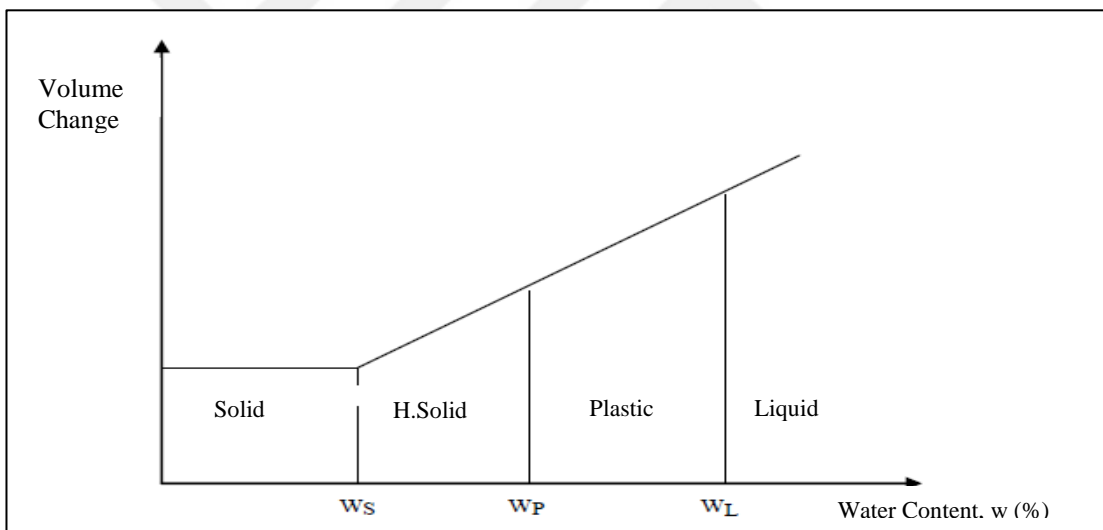


Figure 3.9 Soil consistency limits and volume change (Öztürk, 2012)

Liquid limit (w_L): It is the water content of the soil when its consistency changes from plastic to viscous liquid with increasing water content, and it indicates the consistency where the bearing capacity is practically the least or not (Öztürk, 2012).

Plastic limit (w_p): It is the water content in which the soil changes from semi-solid state to plastic consistency with increasing water content. If the soil is subjected to a load of this consistency, its value is the water content, which indicates the plasticity limit, since it shows permanent deformation rather than temporary deformation (Öztürk, 2012).

Shrinkage limit (w_s): As the water content of the soil changes, the volume change is linear in a certain range and curvilinear in a certain range. The point where the tangent drawn from the point where it passes from curvature to linearity and the tangent drawn from the point where the volume does not change, that is, the tangent drawn from the point where the volume remains constant, intersects, gives the shrinkage limit, or in other words, the limit where the volume change ends (Öztürk, 2012).

Plasticity index ($I_p = w_L - w_P$): It represents the range where the soil is in plastic consistency, it determines the volume change and cohesion properties of the soil. Because when the water content of the soil increases more than a certain amount, the cohesion decreases. The reason for this decrease is due to the fact that the water around the clay grains tries to slide on each other by creating a kind of lubrication. As it is known, as the diameter of the grain decreases, the surface area increases, thus creating a gravitational force, causing the water film around it to thicken, thus increasing the volume of the grains by pushing each other (Öztürk, 2012).

3.11. Unified soil classification system

Classification of soils can be thought of as a common language used among engineers. A few letters or numbers that can be assigned to a soil provide the engineer or technician with a very quick idea of the possible physical properties of the soil, even its mechanical behavior. It is the most common soil classification system in use today. The following criteria are used in classification with this system (Kurnaz, 2011).

- a-** Percentage passing through No.200 sieve
- b-** Percentage of coarse grains remaining on the No. 4 sieve
- c-** Grain distribution characteristics; C_u and C_r values
- d-** Consistency limits
- e-** The place on the plasticity card of those passing through the No. 40 sieve
- f-** Organic matter content

Using these criteria, the soil is divided into four main classes as coarse-grained, fine-grained, organic soil and peat, and the sample is given two or four letter symbols (GW, SM, GW-GM, etc.). In the combined system, the soils are listed according to their grain size (D) as follows;

Block >300 mm, **Stone** $75 < D < 300$ mm, **Gravel** $75 < D < 4.76$ mm (No.4),
Annual $4.76 < D < 0.076$ mm (No.200), **Examines** < 0.076 mm

CHAPTER 4

RESULTS AND DISCUSSION

4.1. SPT-N maps

One of the most used tests in the field is the SPT. The geotechnical data used in this thesis were obtained from 125 boreholes within the study area.

The maps in this thesis were prepared with the help of the IDW method and using the ArcGIS program for the depths of 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m and 15 m in order to determine the distribution of SPT values and the change of the soil profile to a depth of 15 m.

It has been determined that 43% of the SPT-N data of the boreholes at a depth of 1.5 m in the entire study area are between 1-20, 18% between 21-30 and 39% between 31-50. The map which is created according to this evaluation is presented in Figure 4.1.

1.5 m depth analysis of the study area;

- The SPT-N values of Fırat University, Gümüşbağlar and Alayaprak Villages which are in the northeastern part and Aşağı Demirtaş Village which is in the southwestern part are less than 20,
- The SPT-N values of Örençay village which is located in the southwest part, Yemişlik and Gümüşkavak Villages which are located in the southeast part, and Nuralı village which is in the northeast part are between 21-30,
- It has been observed that the SPT-N value of the study area between Nuralı and Sarıçubuk Village which are in the northeast part, Çatalçeşme which is located in the east part, the area around TED College which is in the south part, and the area around Banvit AŞ and Fırat University Communication Faculty which are in the southwest are between 31-50.

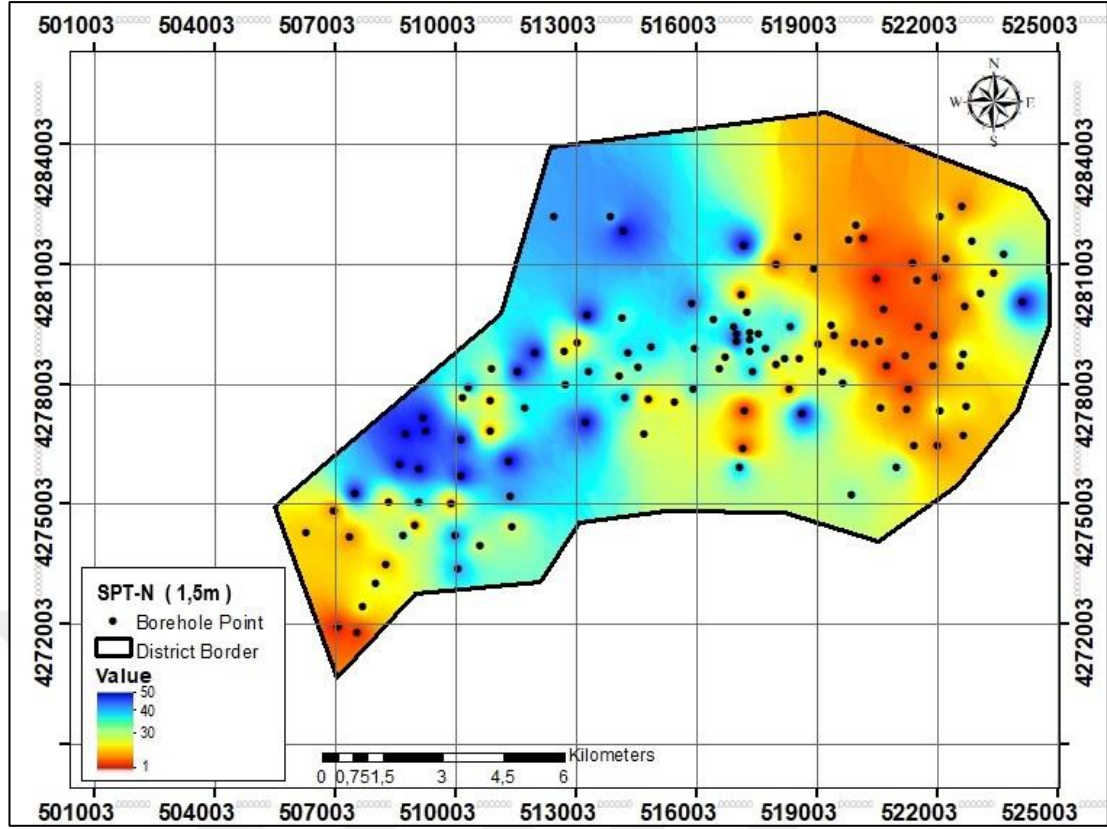


Figure 4.1 SPT-N map of the study area according to 1.5 m depth

It has been determined that 27% of the SPT-N data of the boreholes at a depth of 3 m in the entire study area are between 1-20, 18% between 21-30 and 55% between 31-50. The map which is created according to this evaluation is presented in Figure 4.2.

3 m depth analysis of the study area;

- The SPT-N values of Fırat University and Çatalçeşme which are in the east part and Aşağı Demirtaş Village which is in the southwestern part are less than 20,
- The SPT-N values of Gümüşbağlar Village and Alayaprak Village which are in the northeast part, Gümüşkavak in the southeast and Örençay Village which are in the southwest part are between 21-30.
- It has been observed that the SPT-N value of the study area between Nuralı Village and Sarıçubuk Village which are in the northeast part, Çatalçeşme which is in the east section part, the area around TED College, the Prison in the south and Yemişlik Village in the southeast, and the local area around Banvit AŞ and Fırat University Communication Faculty which are in the southwest are between 31-50.

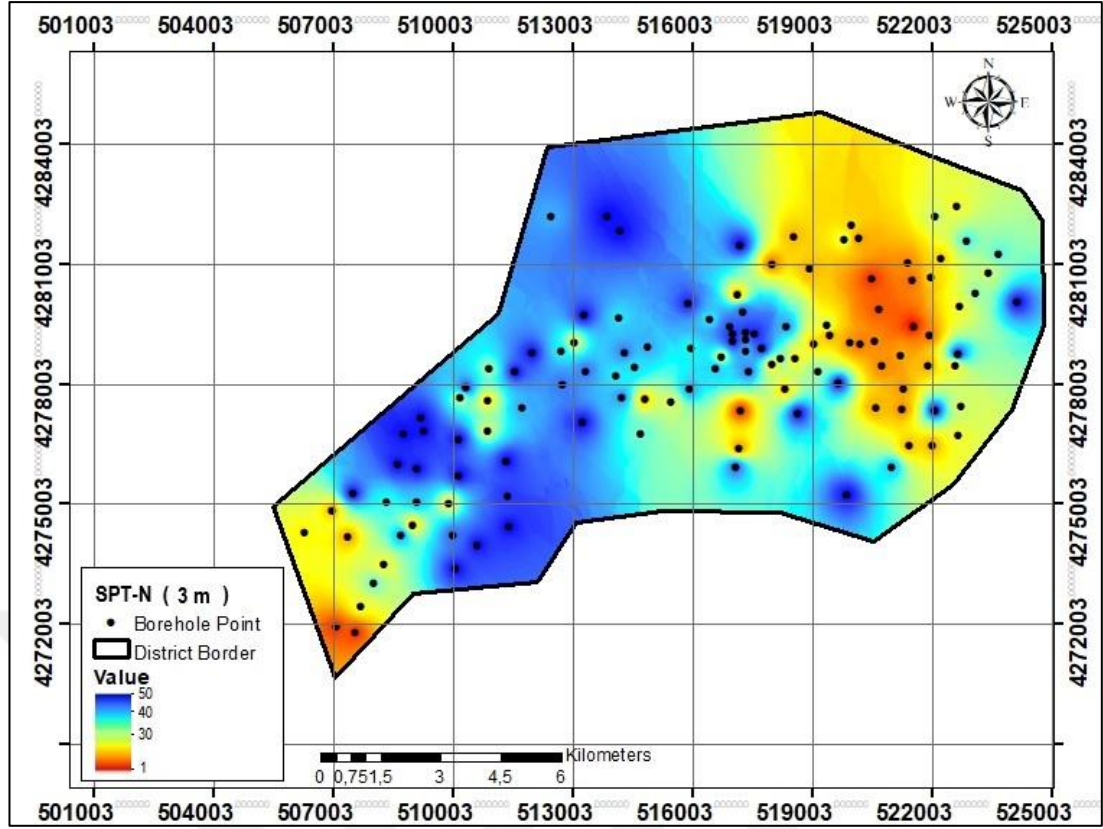


Figure 4.2 SPT-N map of the study area according to 3 m depth

It has been determined that 14% of the SPT-N data of the boreholes at a depth of 4.5 m in the entire study area are between 1-20, 26% between 21-30 and 60% between 31-50. The map which is created according to this evaluation is presented in Figure 4.3.

4.5 m depth analysis of the study area;

- The SPT-N values of Aşağı Demirtaş Village located which is in the Southwest part and of the local area between Fırat University and Çatalçeşme which are in the eastern part are less than 20,
- The SPT-N values of the local area between Gümüşbağlar Village and Alayaprak Village which are in the northeast part, the local area between Gümüşkavak and Çatalçeşme which are in the southeast part, and the local area around Örençay Village which is in the southwest part are between 21-30,
- It has been observed that the SPT-N value of the study area around Nuralı, Sarıçubuk and Alayaprak Villages which are in the northeast part, around Fırat University which is in the east part, around TED College and Prison which are in the south part, between Yemişlik Village and Gümüşkavak which are in the

southeast part and Banvit AŞ of the area in the Fırat University Communication Faculty area which are in the southwest are between 31-50.

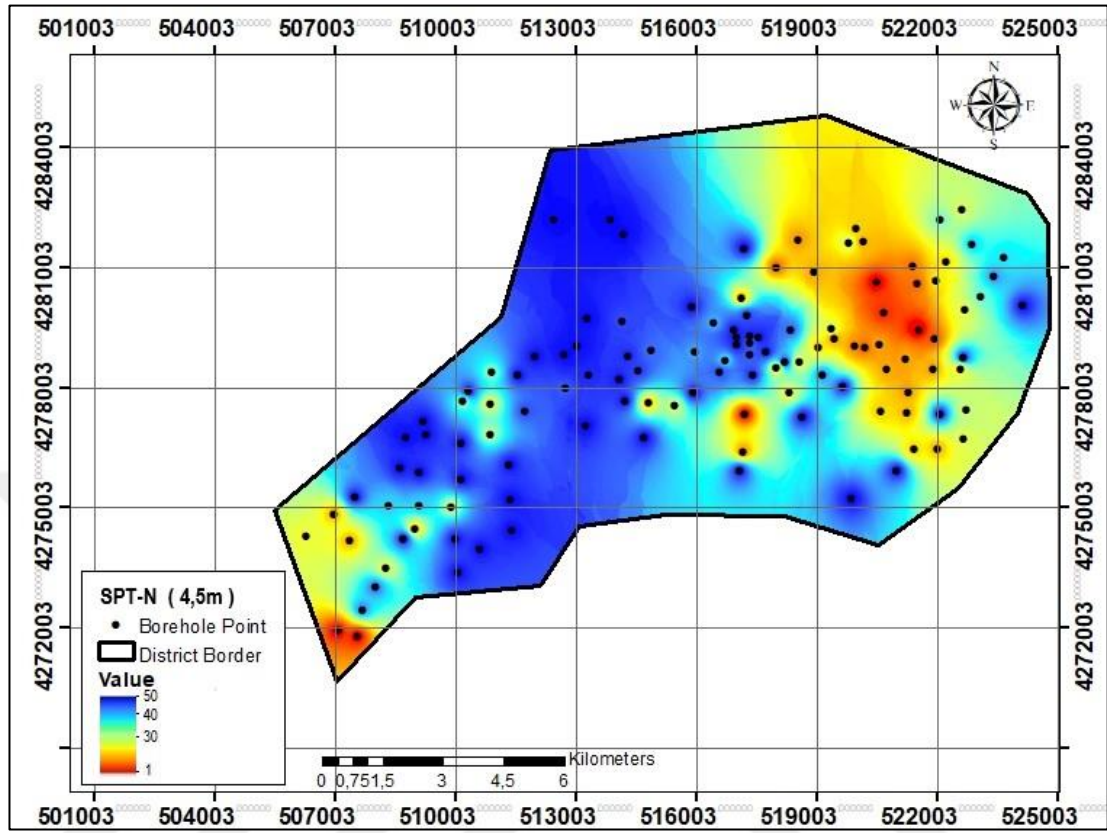


Figure 4.3 SPT-N map of the study area according to 4.5 m depth

It has been determined that 2% of the SPT-N data of the boreholes at a depth of 7.5 m in the entire study area are between 1-20, 10% between 21-30 and 88% between 31-50. The map which is created according to this evaluation is presented in Figure 4.4.

7.5 m depth analysis of the study area;

- The SPT-N values of the local area between Alayaprak Village, Fırat University and Çatalçeşme which are in the eastern part are less than 20,
- The SPT-N values of the local area Gümüşbağlar Village which is in the northeast part, the local area between the Fırat University and Çatalçeşme which are in the east part, and the local area between Örençay and Aşağı Demirtaş Village which are in the southwest part are between 21-30,
- It has been observed that the SPT-N value of the study area between Nuralı, Sarıçubuk and Alayaprak Villages which are in the northeast part, around Fırat University which is in the east part, TED College and Prison which are in the south part, Sugözü and Çatalçeşme which are in the northeast part, Yemişlik

Village, Gümüşkavak and Çatalçeşme which are in the southeast part, Banvit AŞ and Fırat University Communication Faculty which are in the southwest are between 31-50.

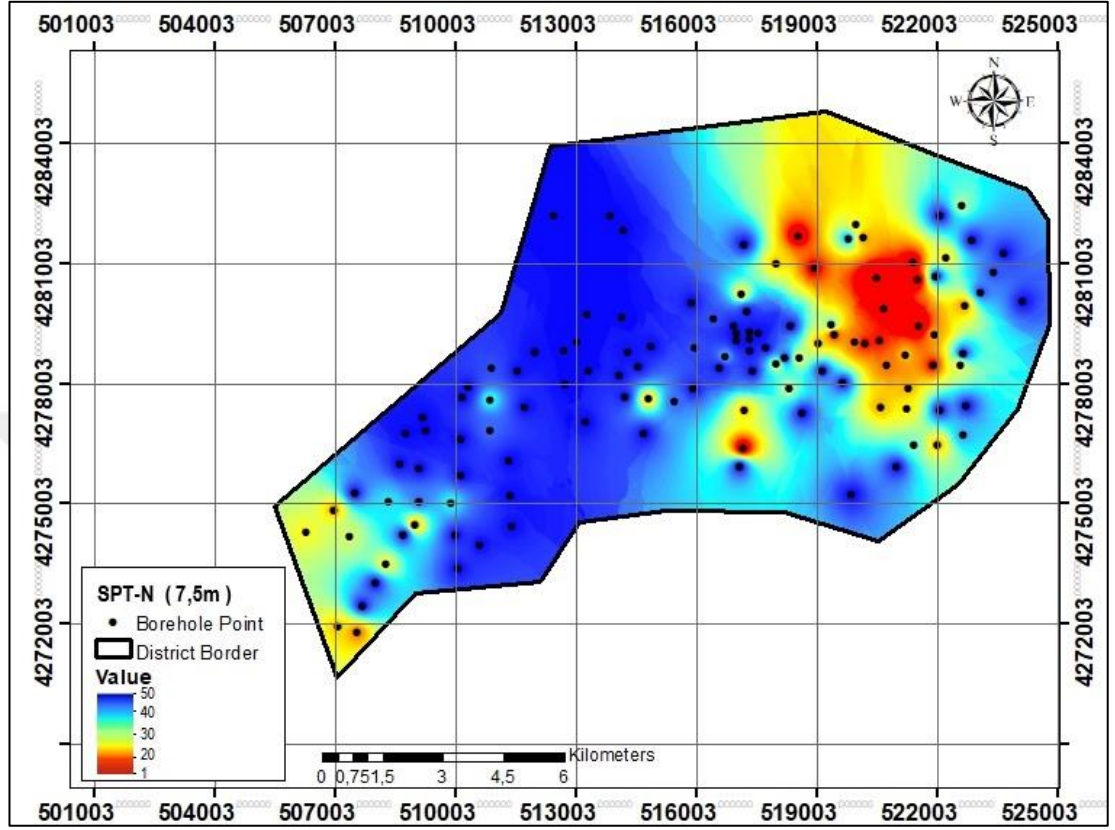


Figure 4.4 SPT-N map of the study area according to 7.5 m depth

It has been determined that 1% of the SPT-N data of the boreholes at a depth of 9 m in the entire study area are between 1-20, 4% between 21-30 and 95% between 31-50. The map which is created according to this evaluation is presented in Figure 4.5.

9 m depth analysis of the study area;

- The SPT-N values of the local area between Alayaprak Village, Fırat University and Çatalçeşme which are in the northeast part, the local area of Aşağı Demirtaş Village which is in the southwest part and the local area around Yemişlik Village which is in the southeast part are less than 20,
- The SPT-N values of the local area around Gümüşbağlar Village which is in the northeastern part is between 21-30,
- It has been observed that the SPT-N value of the study area between Nuralı, Sarıçubuk and Alayaprak Villages which are in the northeast part, around Fırat University which is in the east part, TED College and Prison which are in the

South part, Sugözü and Çatalçeşme which are in the northeast part, Yemişlik Village, Gümüşkavak and Çatalçeşme which are in the southeast part. Banvit AŞ, Örençay Village and the Fırat University Communication Faculty which are in the southwest are between 31-50.

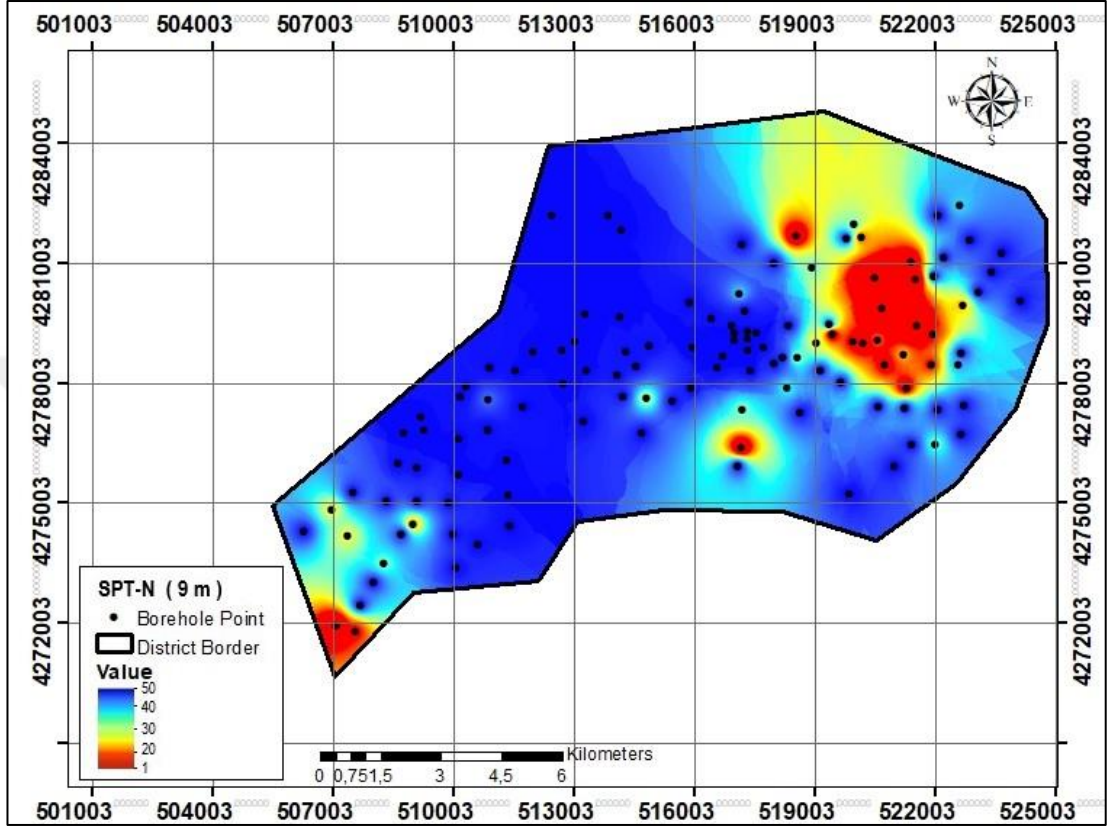


Figure 4.5 SPT-N map of the study area according to 9 m depth

It has been determined that 0% of the SPT-N data of the boreholes at a depth of 15 m in the entire study area are between 1-20, 0% between 21-30 and 100% between 31-50. The map which is created according to this evaluation is presented in Figure 4.6. It was observed that the SPT-N value of the study area was between 31-50 for a depth of 15 m.

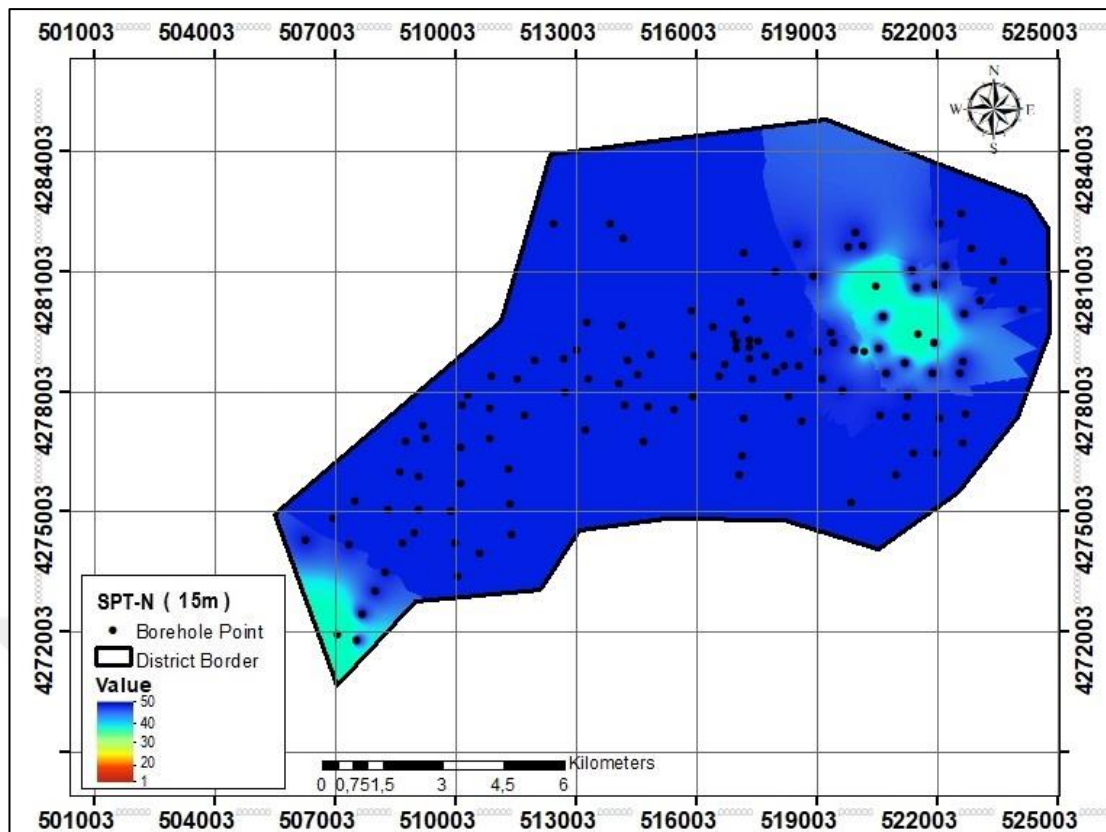


Figure 4.6 SPT-N map of the study area according to 15 m depth

Within the scope of the study, the calculated percentage comparison graph of the distribution of the SPT-N values found for 1.5, 3, 4.5, 7.5, 9 and 15 m for 125 boreholes, 1-20, 21-30, 31-50 values is presented in Figure 4.7. It is seen that the SPT-N value of 1-20 at 1.5 m depth is dominant, while the SPT-N value between 31-50 is dominant at other depths. Comparison of SPT-N values is important for evaluation of bearing capacity and liquefaction analysis as SPT-N is dependent on impact numbers.

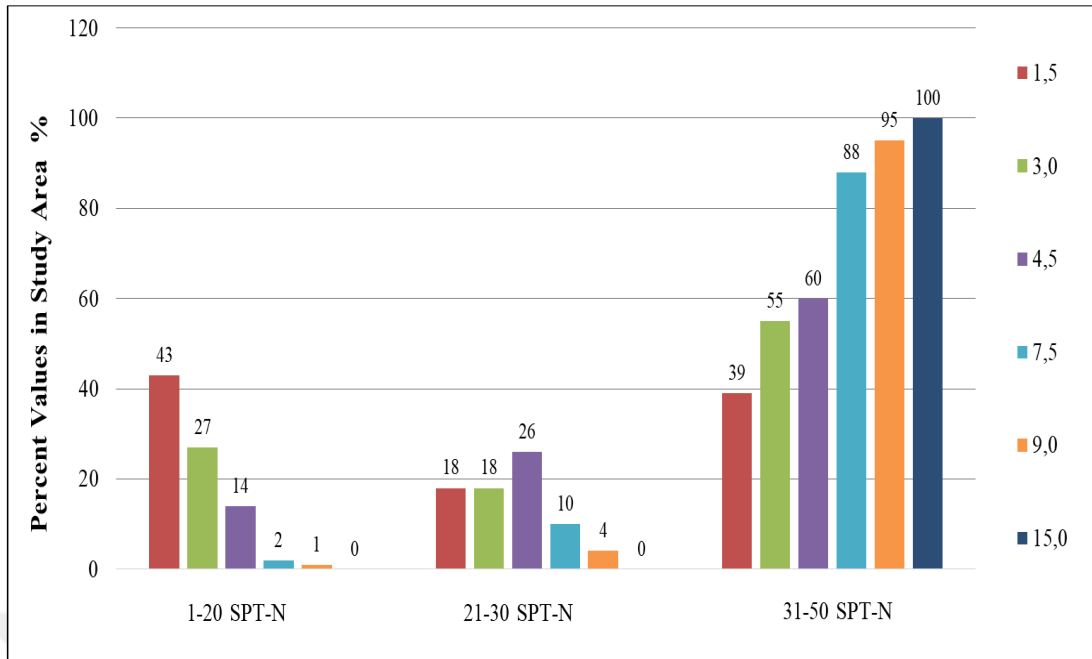


Figure 4.7 Boreholes according to their SPT-N values and boring depths

4.2. Bearing capacity analysis

The data obtained from 210 borehole points in the study area and the bearing capacities obtained by using Field Tests were examined and compared. Terzaghi and Peck Method and Meyerhof Method were discussed in field tests and bearing capacity calculation methods.

Comparative calculations were made for 210 borehole points in the study area, based on the values obtained from the surface up to a depth of 15 m, and based on a base width of 3 m.

The maps in this thesis were prepared with the help of the IDW method and using the ArcGIS program for the depths of 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m and 15 m in order to determine the distribution of bearing capacity values and the change of the soil profile to a depth of 15 m. While creating the maps, they were produced in 10 m grid size with the IDW method using the ArcGIS program.

The bearing capacity map for 1.5 m depth prepared by Meyerhof Method is presented in Figure 4.8, the bearing capacity map prepared by Terzaghi and Peck Method is presented in Figure 4.9 and the comparison table is presented in Figure 4.10. Values were found between 69-488 kN/m² in Terzaghi and Peck Method and up to 79-566 kN/m² in Meyerhof Method.

It has been determined that the bearing capacity of the local area located in the northwest of Gümüşbağlar, Alayaprak Village, Sugözü District, which is located in the Northwest part of the study area, and Gümüşkavak District, which is located in the Southeast section, and the local region, which is located in the Northwest part of the study area, is the lowest area of the study area according to both methods.

Values between 0-280 kN/m² according to Peck Method and 0-310 kN/m² according to Meyerhof Method were determined. Values between 280-488 kN/m² according to Terzaghi and Peck Method and 310-566 kN/m² according to Meyerhof Method have been determined locally in Banvit AŞ., TED College, Prison and Çatalçeşme region.

The bearing capacities between 7 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to 7 SPT-N values) is compared, the Terzaghi and Peck Method is 14.4% smaller than the Meyerhof Method at the time, and the largest SPT-N value (according to 50 SPT-N value) When the bearing capacity (calculated) is compared, it is observed that the Terzaghi and Peck Method is 16% smaller than the Meyerhof Method. As the SPT-N values increased, the bearing forces also increased in direct proportion.

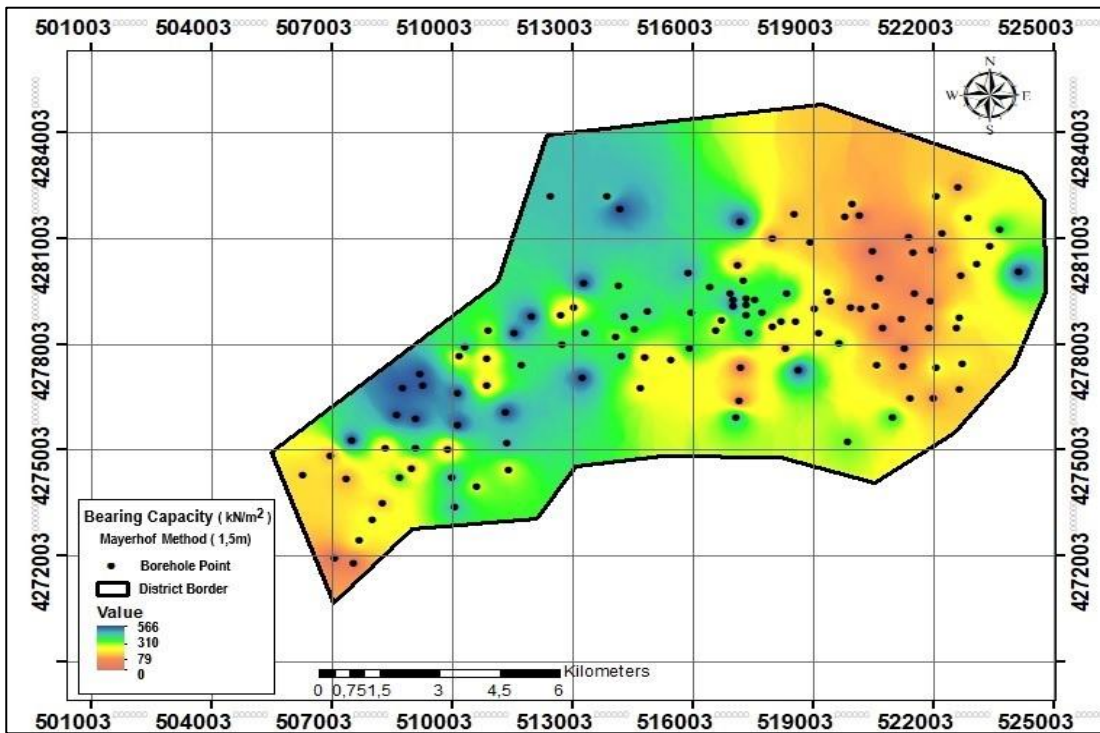


Figure 4.8 Bearing capacity map according to Meyerhof method at 1.5 m depth

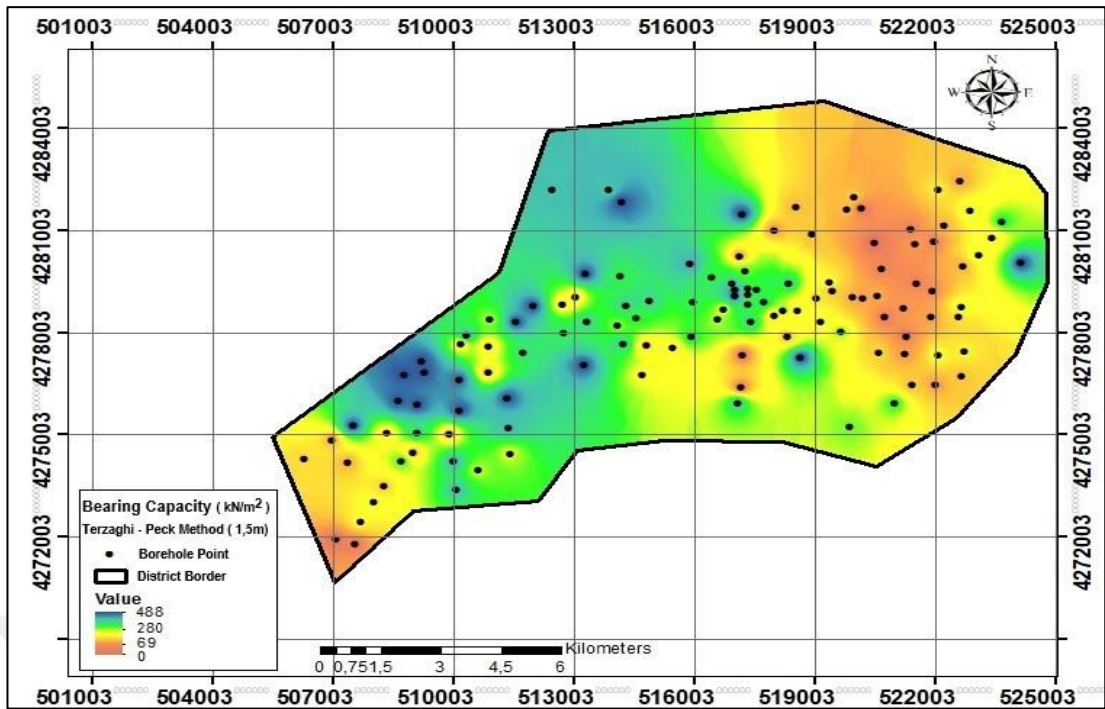


Figure 4.10 Bearing capacity map according to Terzaghi and Peck method at 1.5 m depth

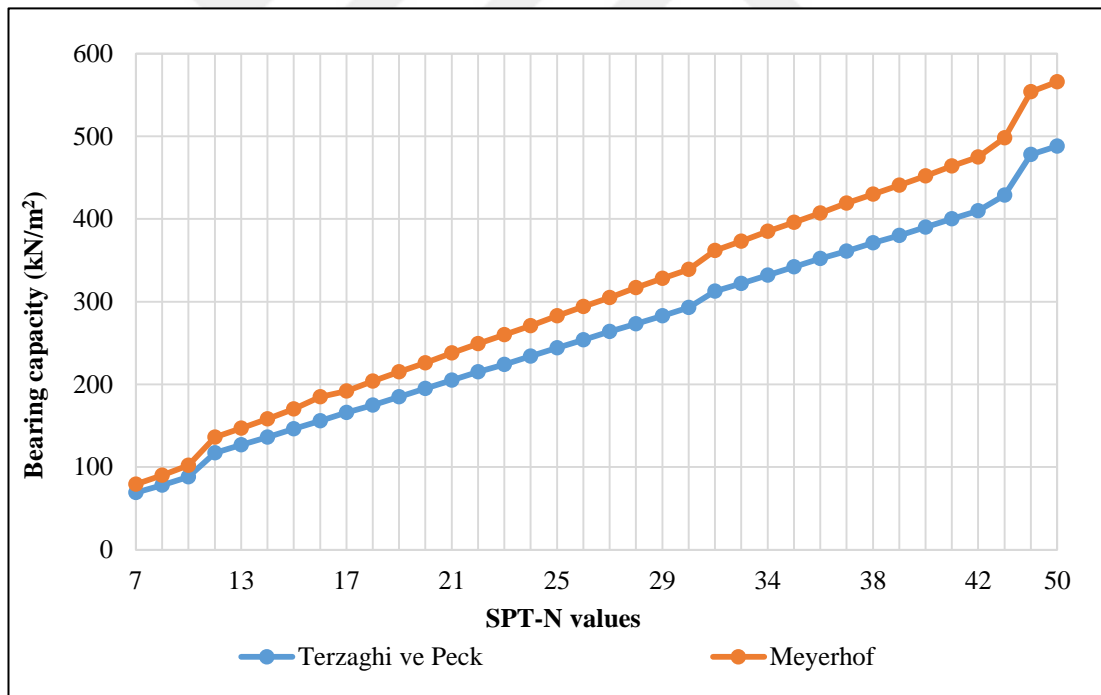


Figure 4.9 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 1.5 m depth

3 m depth of the study area, the bearing capacity map prepared by the Meyerhof Method is presented in Figure 4.11, the bearing capacity map prepared by the Terzaghi and Peck Method is presented in Figure 4.12 and the comparison chart is presented in Figure 4.13.

Values were found between 88-488 kN/m² in Terzaghi and Peck Method and up to 116-646 kN/m² in Meyerhof Method.

It has been determined that the bearing capacity of the local part located between Fırat University and Çatalçeşme located in the east of the study area and the local region located in the northwest of Aşağı Demirtaş Village is the lowest area of the study area according to both methods. It was determined between 0-280 kN/m² according to the Terzaghi and Peck Method and between 0-310 kN/m² according to the Meyerhof Method.

The bearing capacity in Sarıçubuk, Nuralı and Yemişlik Villages and the parts to the north of the Fırat University Communication Faculty, Prison which are in the were generally between 280-488 kN/m² according to the Terzaghi and Peck Method and 310-566 kN/m² according to the Meyerhof Method.

The bearing capacities between 9 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to 9 SPT-N values) is compared, the Terzaghi and Peck Method is 31.8% smaller than the Meyerhof Method, and the largest SPT-N value (based on 50 SPT-N values) When the bearing capacity (calculated) is compared, it is observed that Terzaghi and Peck Method is 32.4% smaller than the Meyerhof Method. As the SPT-N values increased, the bearing forces also increased in direct proportion.

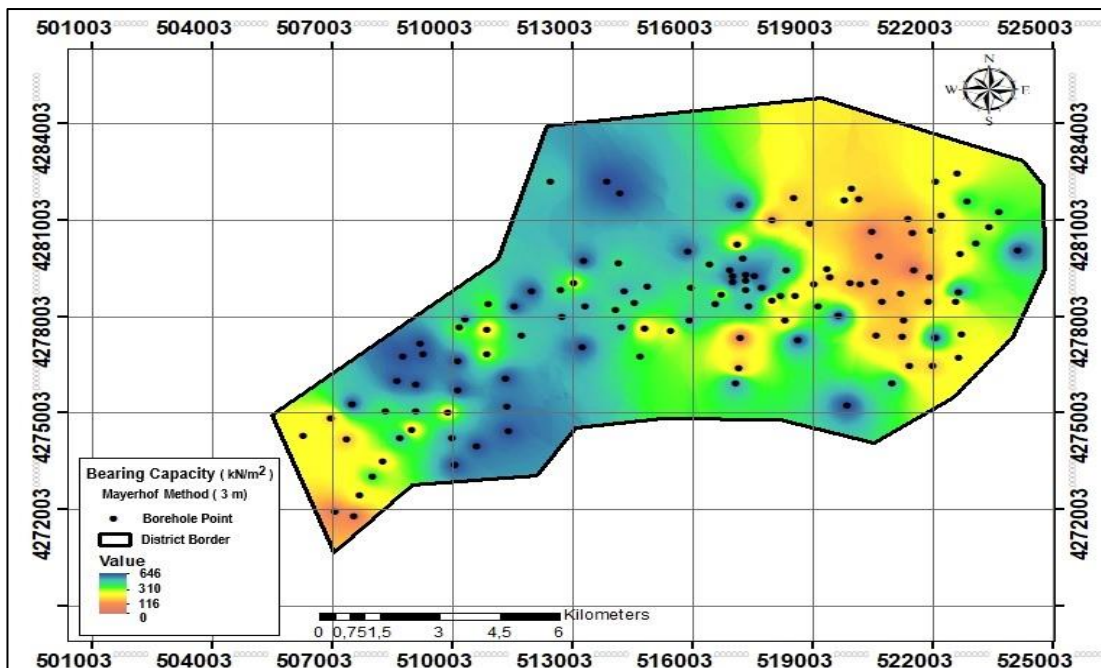


Figure 4.11 Bearing capacity map according to Meyerhof method at 3 m depth

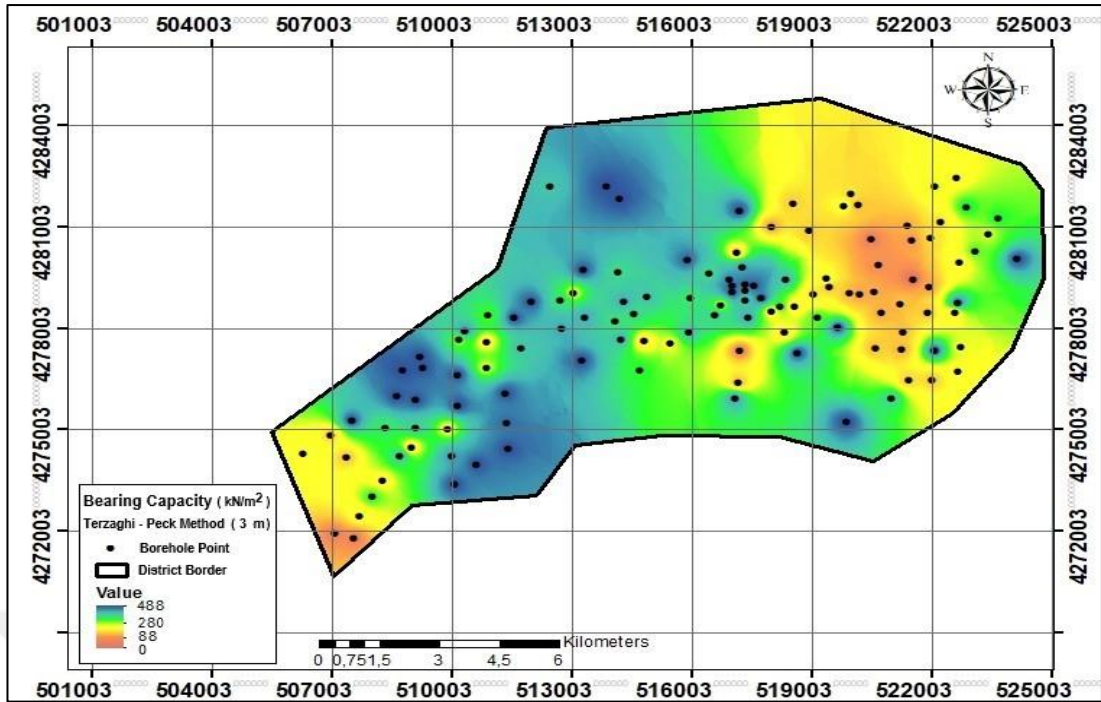


Figure 4.12 Bearing capacity map according to Terzaghi and Peck method at 3 m depth

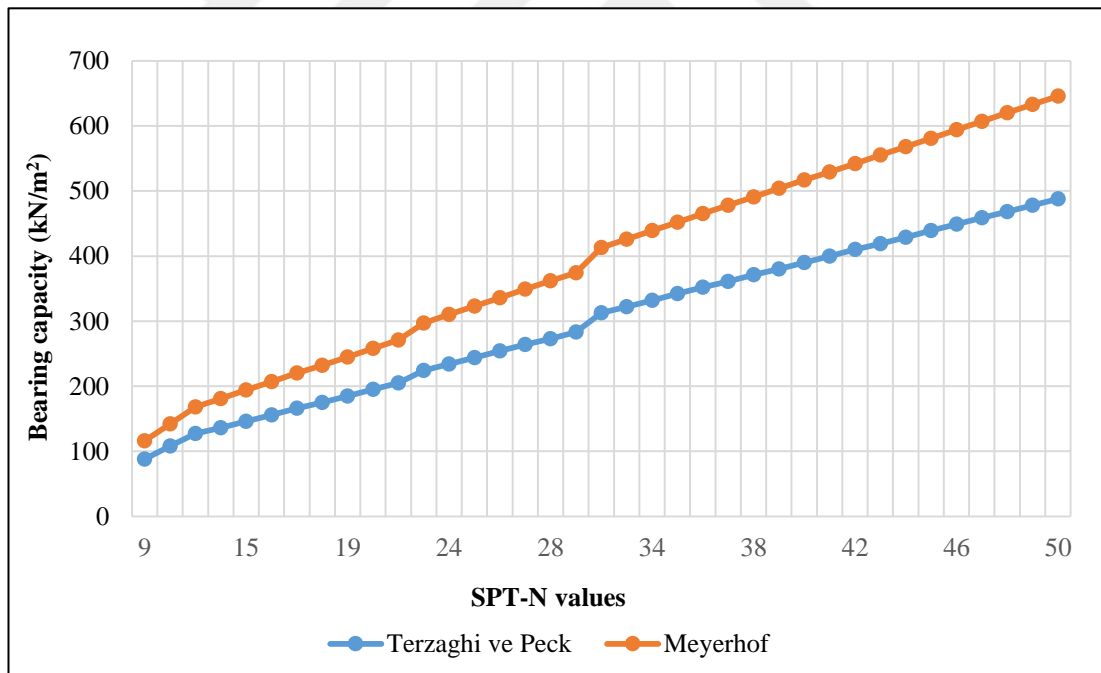


Figure 4.13 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 3 m depth

4.5 m depth of the study area, the bearing capacity map prepared by Meyerhof Method is presented in Figure 4.14, the bearing capacity map prepared by Terzaghi and Peck Method is presented in Figure 4.15 and the comparison chart is presented in Figure 4.16.

Values were found between 98-488 kN/m² in the Terzaghi and Peck Method and up to 145-646 kN/m² in the Meyerhof Method.

It has been determined that the bearing capacity of the region located in the east of the study area, around the Alayprak Village of Fırat University, and in the northwest of the Aşağı Demirtaş Village, is the lowest area of the study area according to both methods. Values between 0-280 kN/m² according to Terzaghi and Peck Method and 0-310 kN/m² according to Meyerhof Method were determined.

Part of Çatalçeşme, Gümüşkavak and Yemişlik Village, Prison, Banvit AŞ. and in the parts to the west of Sarıçubuk and Nuralı Village, values between 280-488 kN/m² according to Terzaghi and Peck Method and 310-646 kN/m² according to Meyerhof Method were determined.

The bearing capacities between 10 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to the 10 SPT-N value) is compared, the Terzaghi and Peck Method is 47.9% smaller than the Meyerhof Method, and the largest SPT-N value (according to the 50 SPT-N value) When the bearing capacity (calculated) is compared, it was observed that the Terzaghi and Peck Method is 32.4% smaller than the Meyerhof Method.

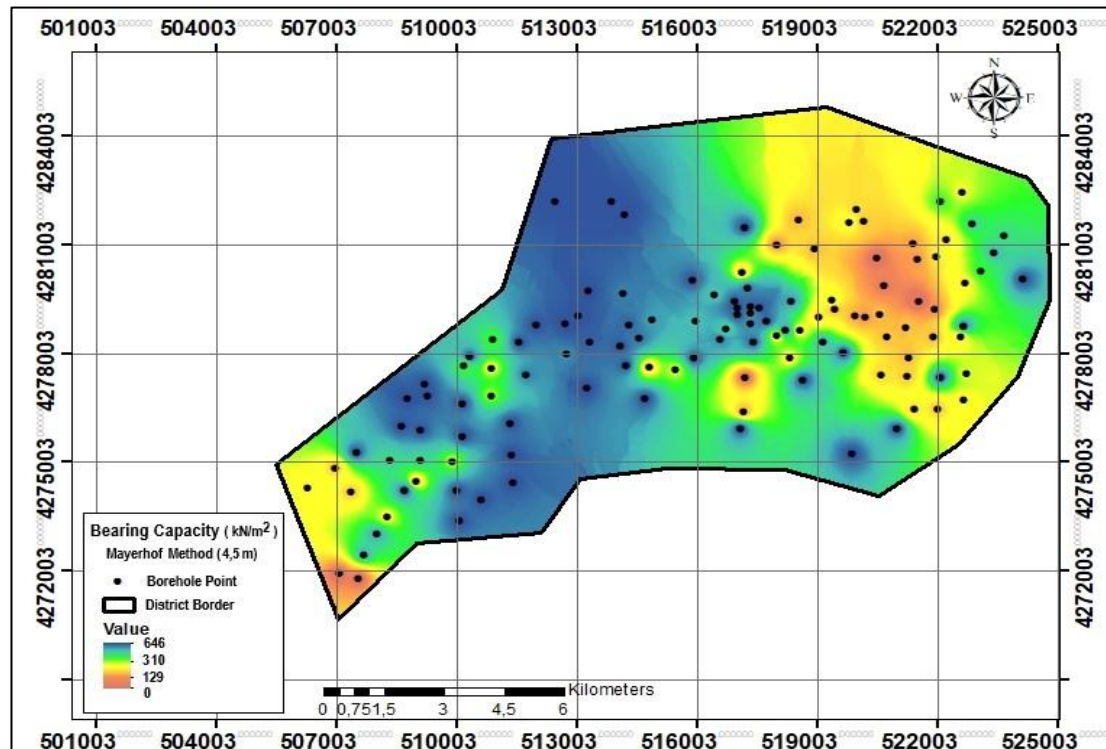


Figure 4.14 Bearing capacity map according to Meyerhof method at 4.5 m depth

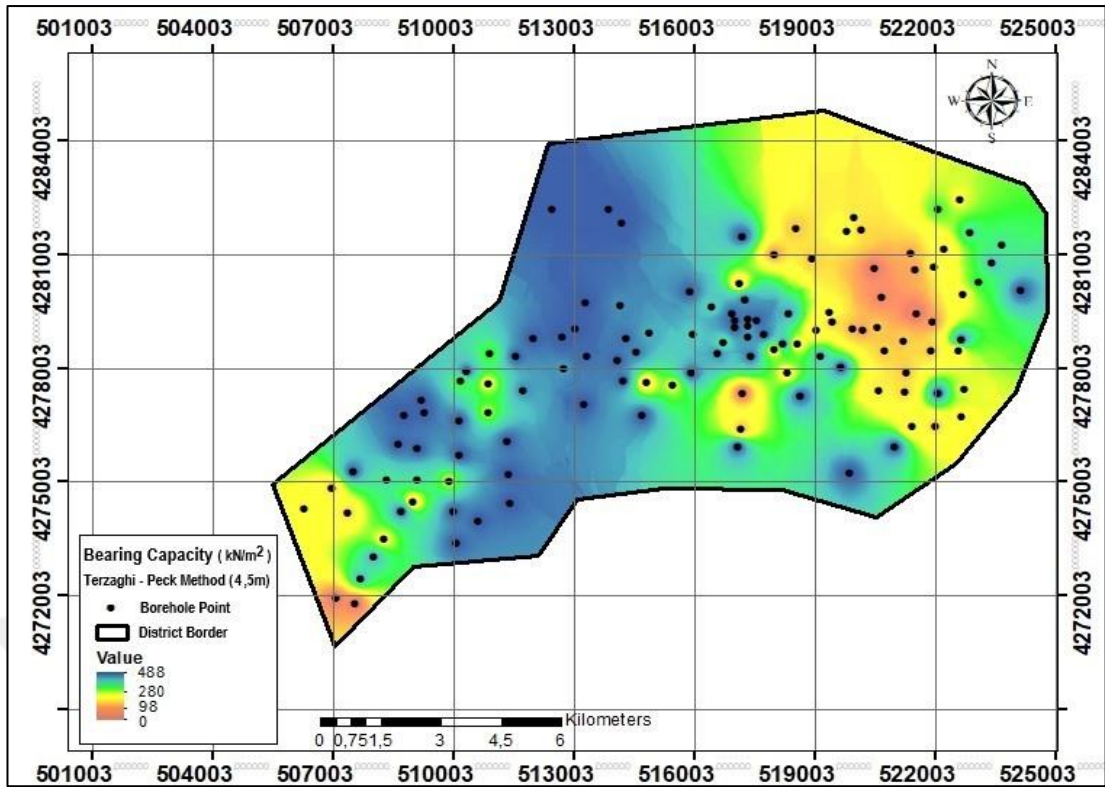


Figure 4.15 Bearing capacity map according to Terzaghi and Peck method at 4.5 m depth

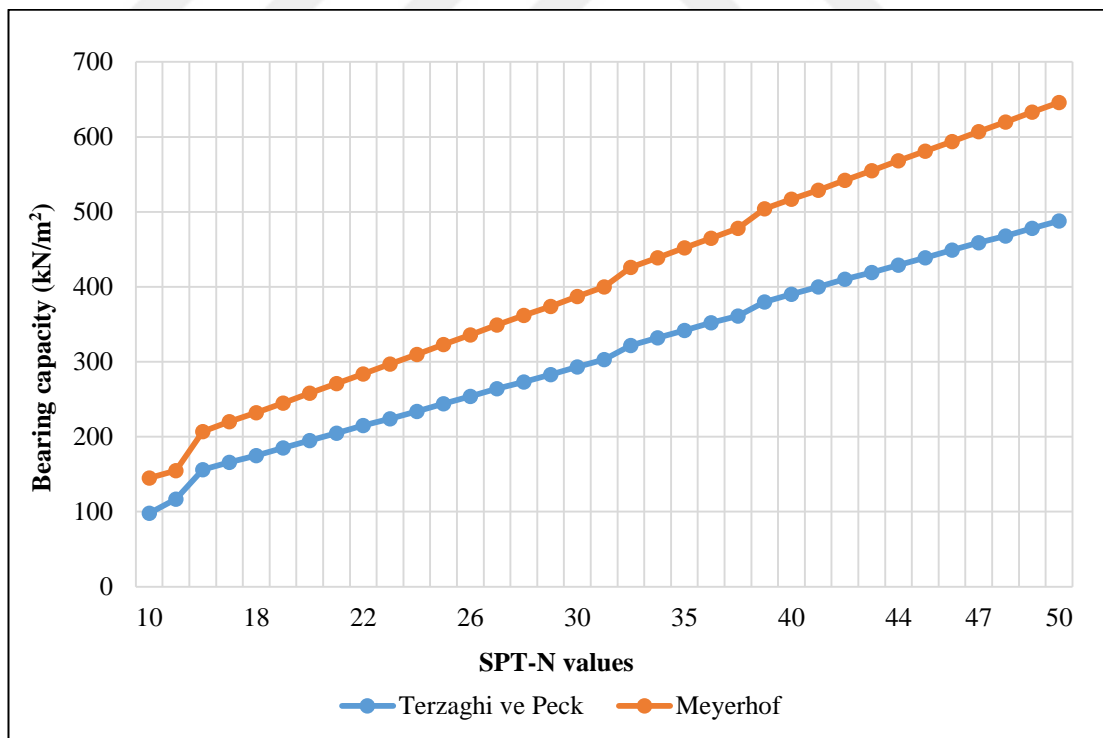


Figure 4.16 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 4.5 m depth

4.5 m depth of the study area, the bearing capacity map prepared by the Meyerhof Method is presented in Figure 4.17, the bearing capacity map prepared by the Terzaghi and Peck Method is presented in Figure 4.18 and the comparison chart is presented in Figure 4.19. Values were found between 166-488 kN/m² in the Terzaghi and Peck Method and up to 220-646 kN/m² in the Meyerhof Method.

It has been determined that the bearing capacity of the region around Alayaprak Village of Fırat University, located in the east of the study area, is the lowest area of the study area according to both methods. Values between 0-280 kN/m² according to Terzaghi and Peck Method and 0-310 kN/m² according to Meyerhof Method were determined.

Örençay and Aşağıdemirtaş Village in the southwest, FÜ Communication Faculty, Çatalçeşme in the east, Gümüşkavak and Yemişlik Village in the southeast, Prison, Banvit AŞ. and in the parts to the west of Sarıçubuk and Nuralı Village, values between 280-488 kN/m² according to Terzaghi and Peck Method and 310-646 kN/m² according to Meyerhof Method were determined.

The bearing capacities between 17 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to the 17 SPT-N value) is compared, the Terzaghi and Peck Method is 32.6% smaller than the Meyerhof Method, and the largest SPT-N value (according to the 50 SPT-N value) When the bearing capacity (calculated) is compared, it is observed that Terzaghi and Peck Method is 32.4% smaller than the Meyerhof Method.

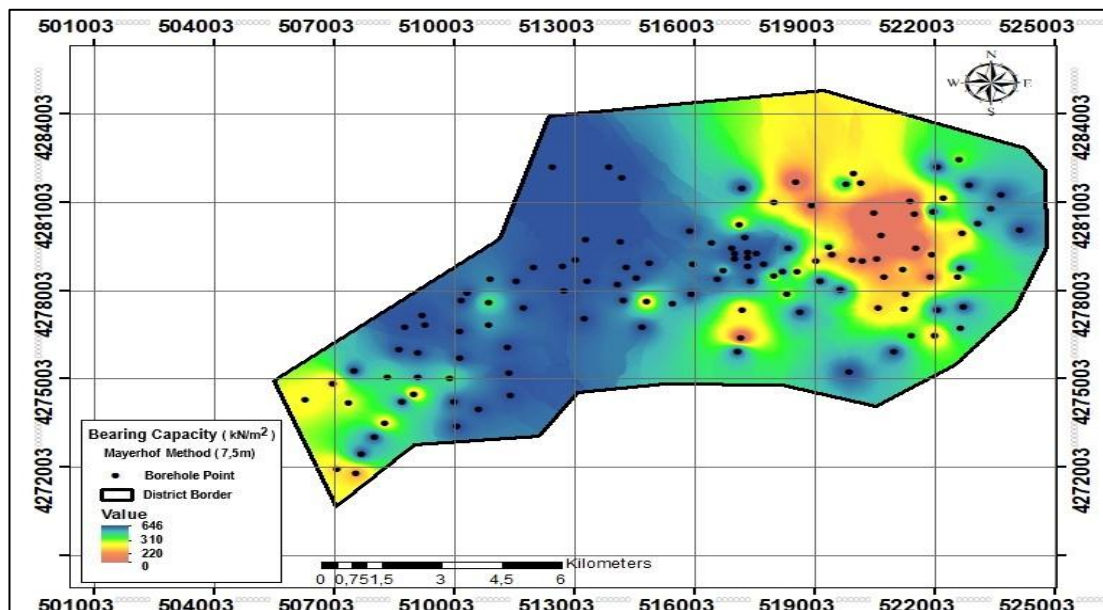


Figure 4.17 Bearing capacity map according to Meyerhof method at 7.5 m depth

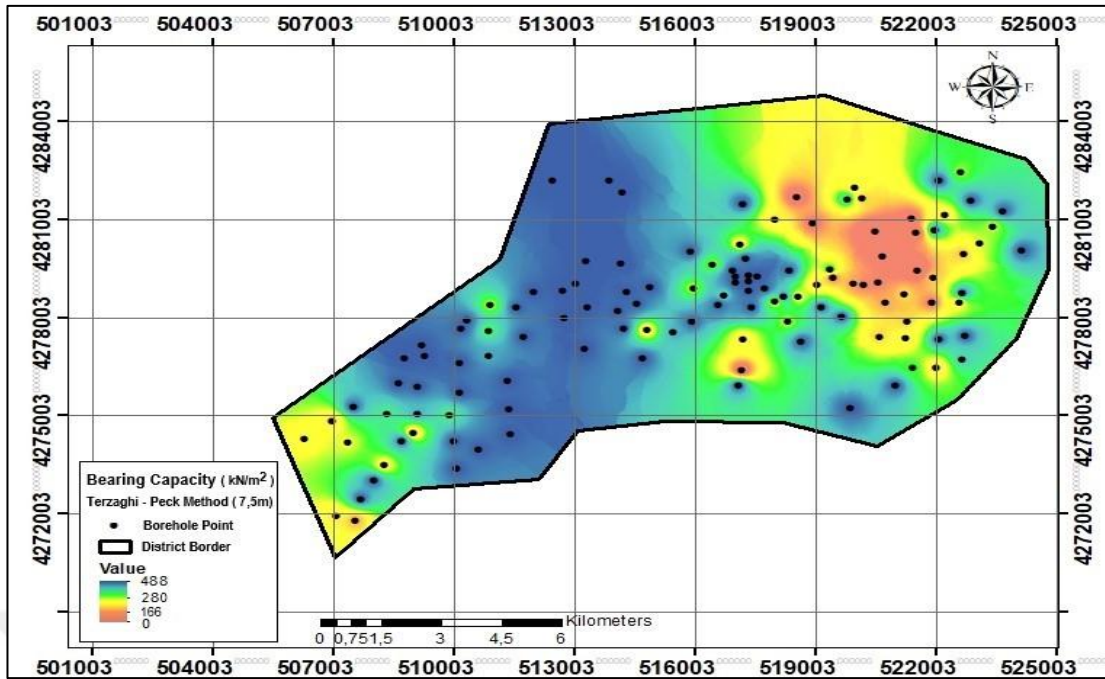


Figure 4.18 Bearing capacity map according to Terzaghi and Peck method at 7.5 m depth

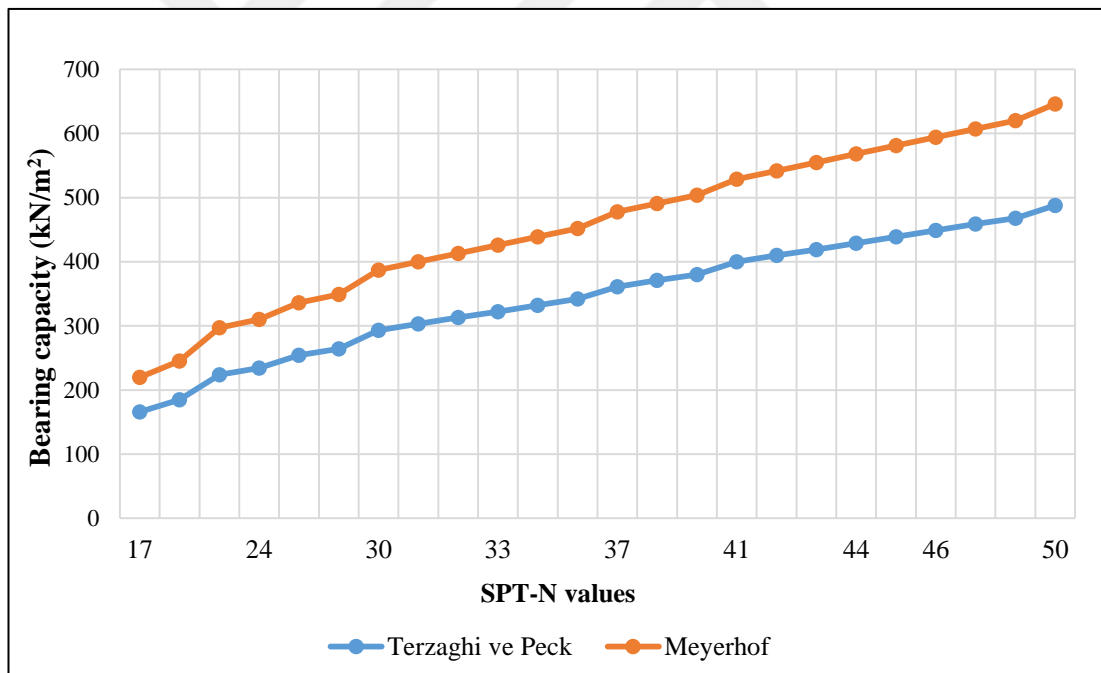


Figure 4.18 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 7.5 m depth

9 m depth of the study area, the bearing capacity map prepared by the Meyerhof Method is presented in Figure 4.20, the bearing capacity map prepared by the Terzaghi and Peck Method is presented in Figure 4.21 and the comparison chart is presented in Figure 4.22.

Values were found between 195-488 kN/m² in Terzaghi and Peck Method and up to 258-646 kN/m² in Meyerhof Method.

It has been determined that the carrying capacity of the region around Alayaprak Village of Firat University, located in the east of the study area, is the lowest area of the study area according to both methods. Values between 0-280 kN/m² according to Terzaghi and Peck Method and 0-310 kN/m² according to Meyerhof Method were determined.

Örençay and Aşağıdemirtaş Village in the Southwest, FÜ Communication Faculty, Çatalçeşme in the east, Gümüşkavak and Yemişlik Village in the southeast, Prison, Banvit AŞ. and in the parts to the west of Sarıçubuk and Nuralı Village, values between 280-488 kN/m² according to Terzaghi and Peck Method and 310-646 kN/m² according to Meyerhof Method were determined.

The bearing capacities between 20 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to the 20 SPT-N value) is compared, the Terzaghi and Peck Method is 32.3% smaller than the Meyerhof Method, and the largest SPT-N value (according to the 50 SPT-N value) When the bearing capacity (calculated) is compared, it was observed that the Terzaghi and Peck Method is 32.4% smaller than the Meyerhof Method.

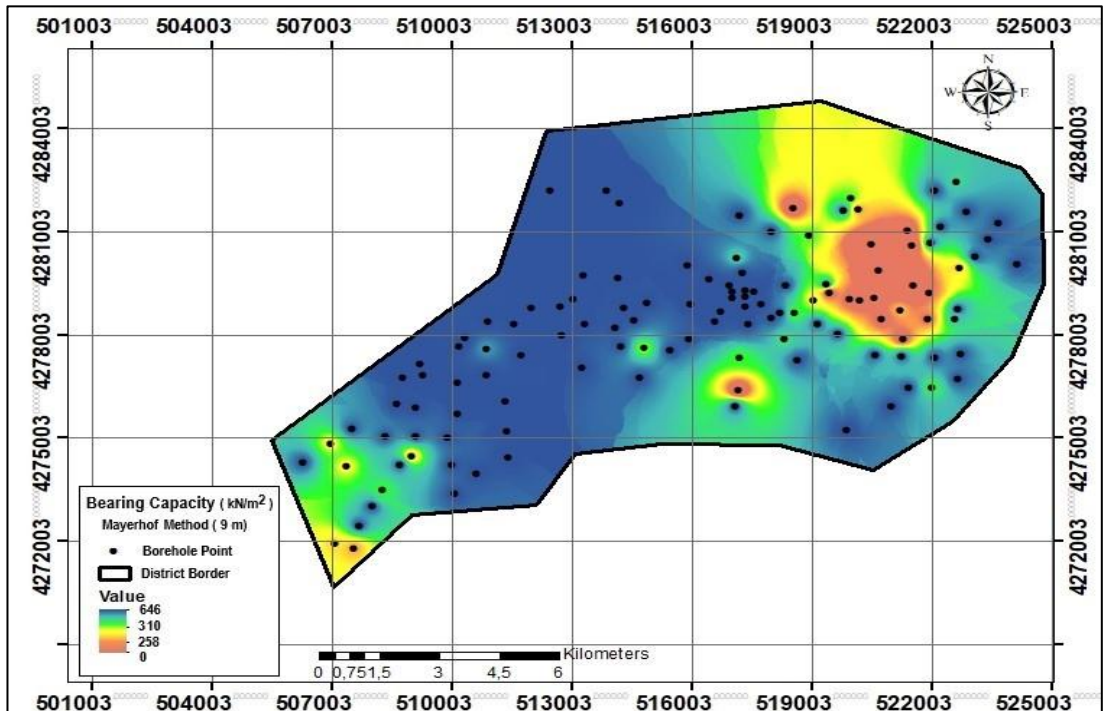


Figure 4.19 Bearing capacity map according to Meyerhof method at 9 m depth

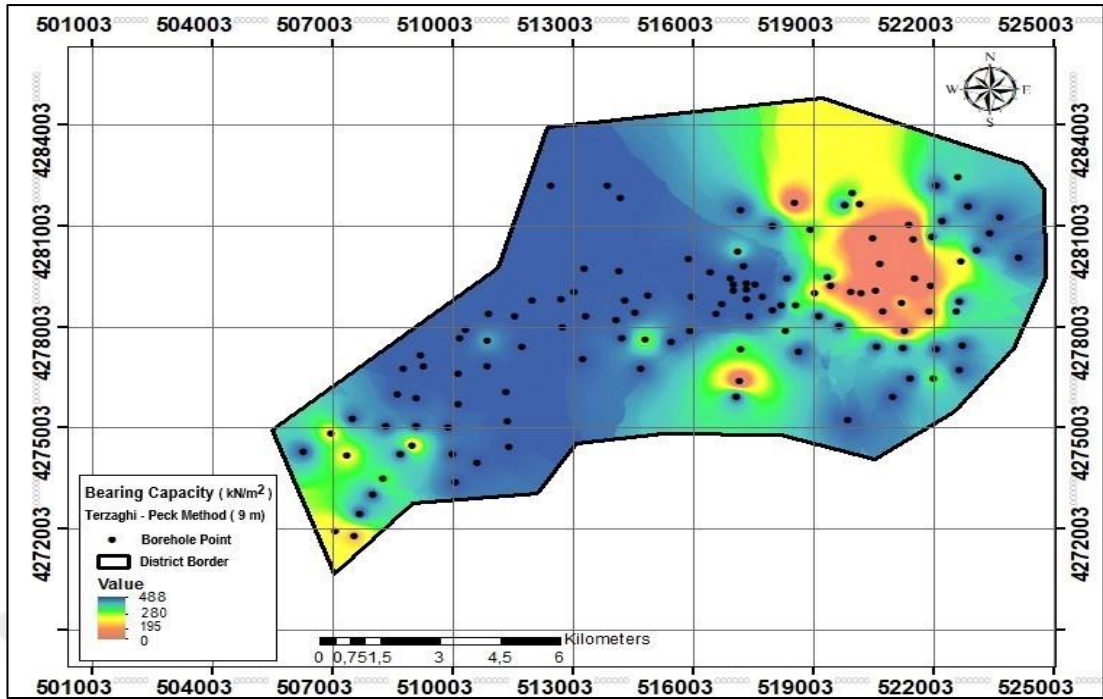


Figure 4.20 Bearing capacity map according to Terzaghi and Peck method at 9 m depth

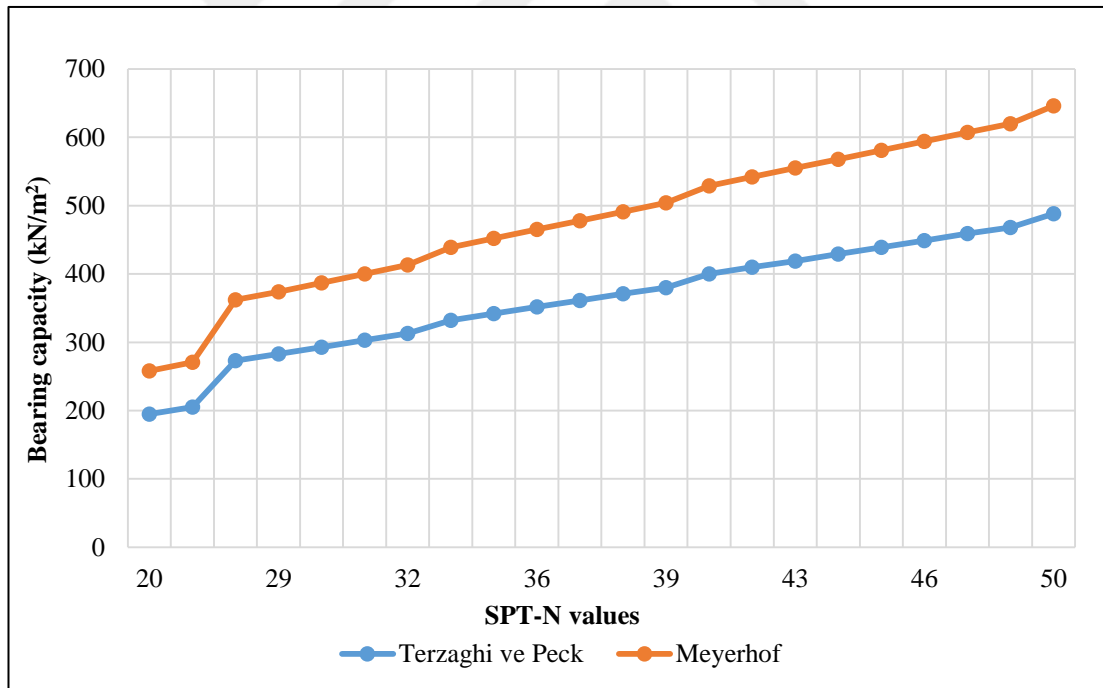


Figure 4.21 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 9 m depth

9 m depth of the study are, the bearing capacity map prepared by Meyerhof Method is presented in Figure 4.23, the bearing capacity map prepared by Terzaghi and Peck Method is presented in Figure 4.24 and the comparison chart is presented in Figure 4.25.

Values were found between 410-488 kN/m² in Terzaghi and Peck Method and up to 542-646 kN/m² in Meyerhof Method.

In the study area, the values between 280-488 kN/m² according to Terzaghi and Peck Method and between 310-646 kN/m² according to Meyerhof Method were determined.

The bearing capacities between 42 and 50 SPT-N values were compared. When the bearing capacity of the two methods at the smallest SPT-N value (calculated according to the 42 SPT-N value) is compared, the Terzaghi and Peck Method is 32.2% smaller than the Meyerhof Method, and the largest SPT-N value (according to the 50 SPT-N value) When the bearing capacity (calculated) is compared, it is observed that Terzaghi and Peck Method is 32.4% smaller than the Meyerhof Method.

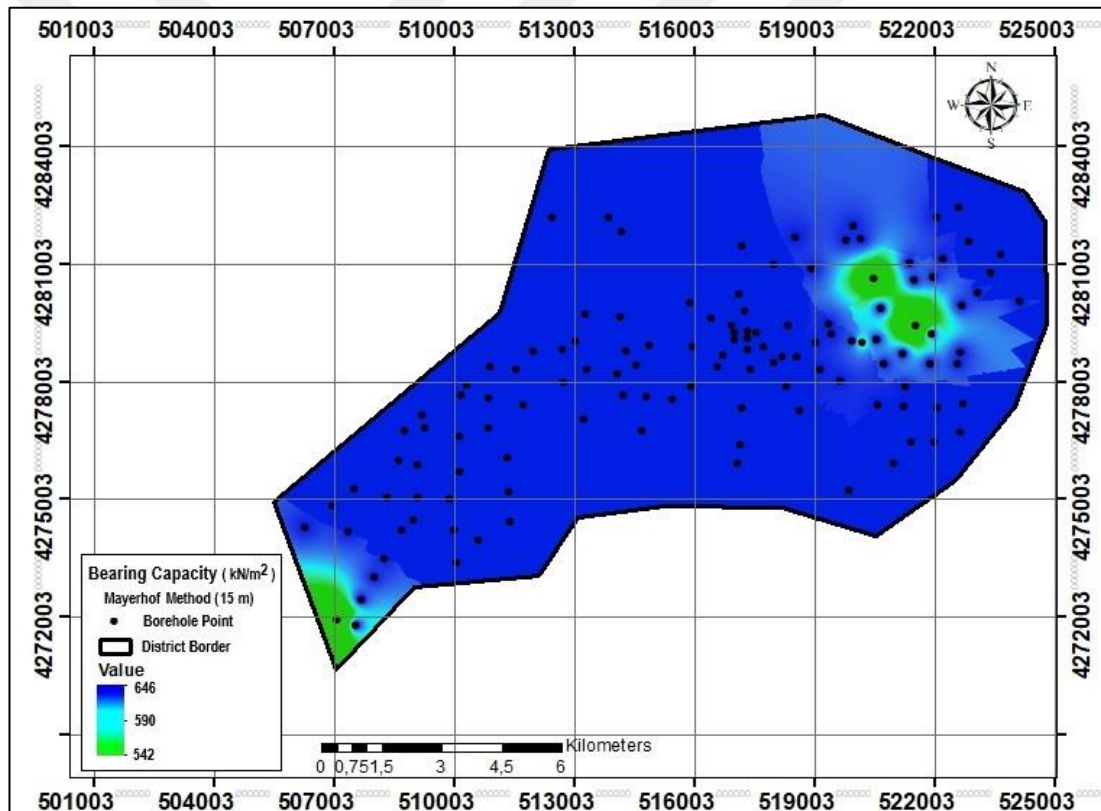


Figure 4.22 Bearing capacity map according to Meyerhof method at 15 m depth

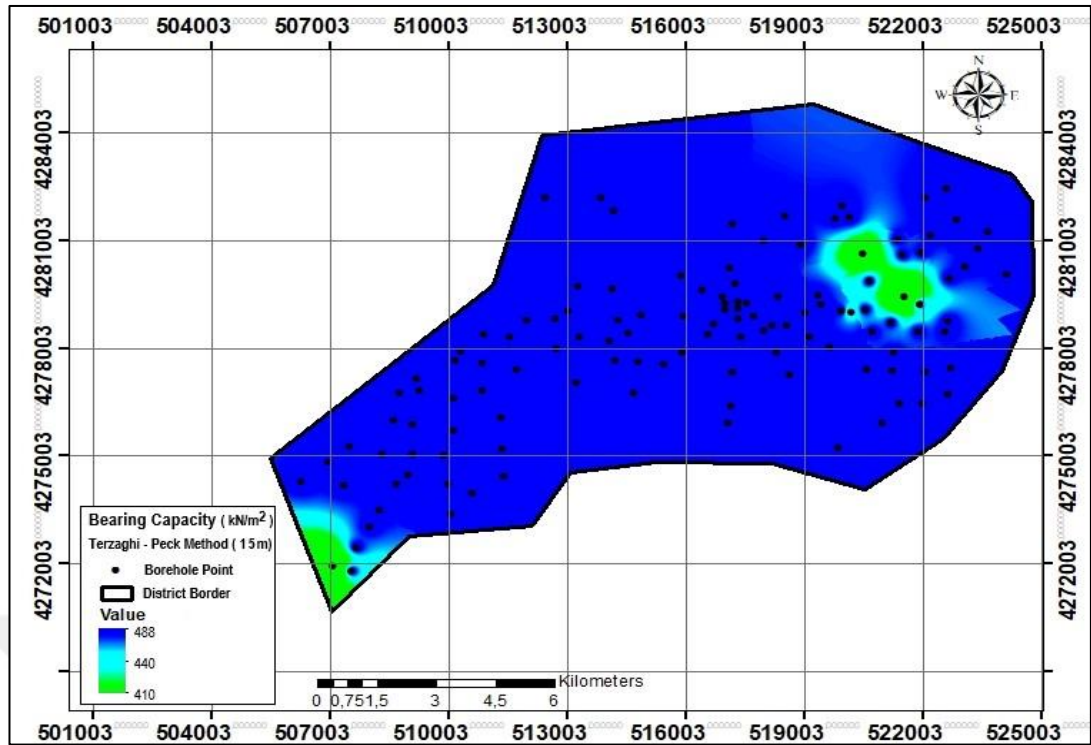


Figure 4.23 Bearing capacity map according to Terzaghi and Peck method at 15 m depth

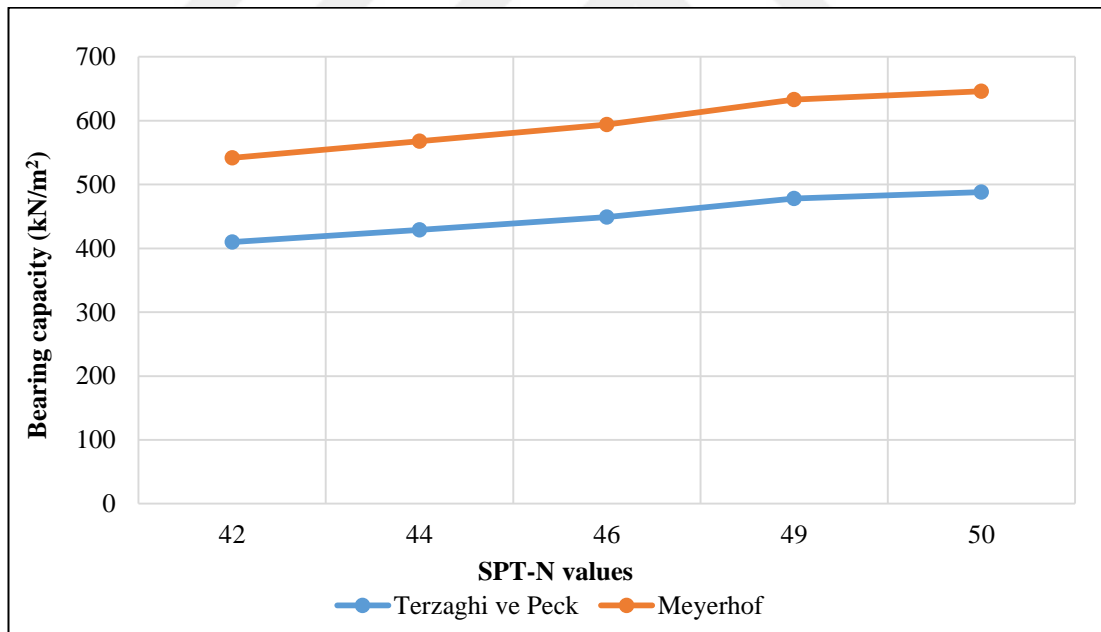


Figure 4.24 Bearing capacity versus SPT-N values according to Meyerhof and Terzaghi and Peck at 15 m depth

Starting from 1.5 m from the study forehead, 3 m, 4.5 m, 7.5 m, 9 m and 15 m depths, SPT-N value and calculations made according to the data, there is a harmony in the maps prepared with the Terzaghi and Peck and Meyerhof methods and the calculated values are close seen.

As can be seen from the comparison charts, it was observed that the ratio between the smallest SPT-N values in both methods increased up to 4.5 m depth, and decreased at 7.5 m, 9 m, and 15 m depths. However, it was observed that the Terzaghi and Peck bearing capacity values were smaller than the Meyerhof results because the SPT-N values increased as the impact value and depth increased.

4.3. Water level and water content analysis

The values obtained from 125 borehole points from 210 points in the study area were used to determine the Groundwater Level and Water Content. In the study area, a map was created by researching in order to see the water content from the surface to a depth of 20 m and its change with depth. It has been determined that the groundwater level starts from 10 m. The map prepared in this context is presented in Figure 4.26.

It has been determined that it is located in the local area between Gümüşkavak, Çatalçeşme Fırat University which are in the study area part. It has been evaluated that the study area is not rich in terms of groundwater.

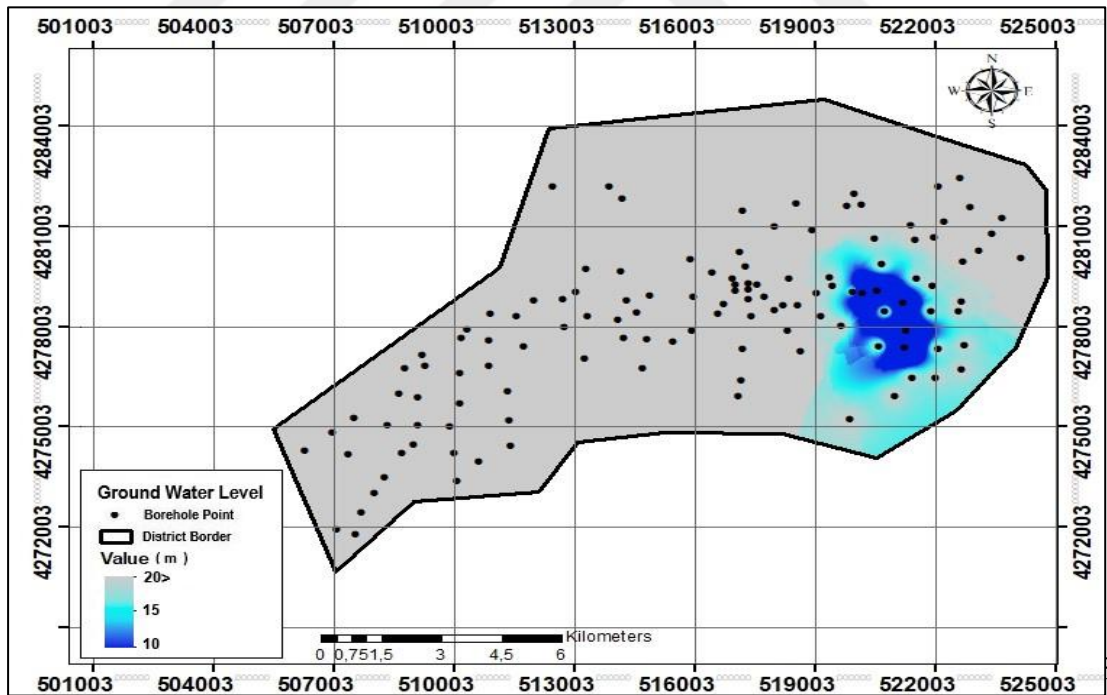


Figure 4.25 Ground water level

0-10, 52% is between 11-20, and 17% is between 21-30. It has been determined that 5% is between 31-44. The map which is created according to this evaluation is presented in Figure 4.27.

The water content around Nuralı, Gümüşbağlar, Alayaprak Village, Fırat University and Örençay Village, FU Communication Faculty Banvit AŞ, located in the northeast and southwest parts of the study area, is between 0-10% and 11-20%, and the water content around Sarıçubuk, Yemişlik Village, Gümüşkavak Prison. It was observed that it was between 21-30% and 31-44%, and the maximum water content was 33%.

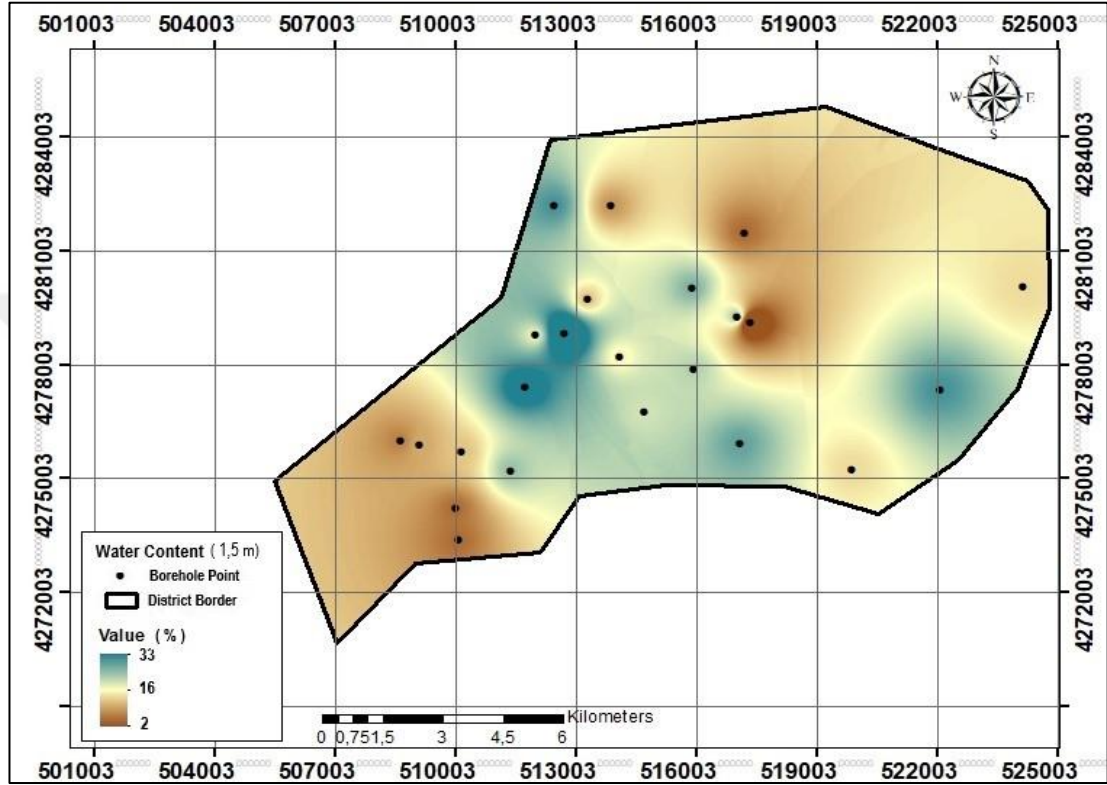


Figure 4.26 Water content (1.5 m)

In determining the water content as a percentage (%), in the data obtained from 79 borehole points for 3 m throughout the study area, between 0-10 of 17%, 11-20 of 33%, 21-30 of 25% of the study area. It has been determined that 25% is between 31-44. The map which is created according to this evaluation is presented in Figure 4.28.

It has been determined that 0-10% and 11-20% water content is dominant around Çatalçeşme, TED College, Sarıçubuk, Nuralı Village and the Prison. It has been determined that the water content in other local areas, mainly around Örençay Village in the southwestern part, is between 21-30% and 31-44%. It was observed that the maximum water content was 43%.

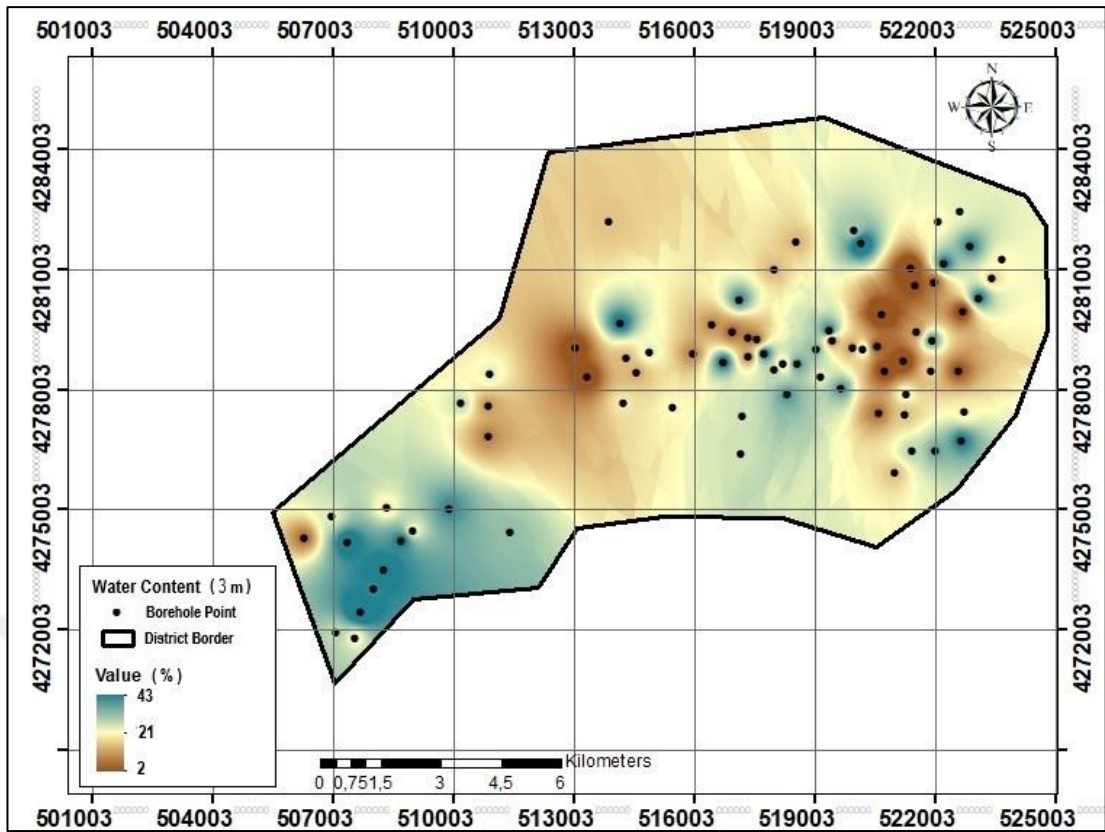


Figure 4.27 Water content (3 m)

In determining the water content as a percentage (%), in the data obtained from 26 borehole points for 4.5 m throughout the study area, 30% of the study area is between 0-10, 46% between 11-20, 12% between 21-30 and 12% were found to be between 31-44. The map which is created according to this evaluation is presented in Figure 4.29.

It has been determined that the water content is 21-30% and 31-44% in the vicinity of Sugözü in the northeast of the study area, Yemişlik Village in the southeast and Örençay Village in the southwest. In the remaining other regions, it was determined that the water content was included in the grouping between 0-10% and 11-20%. It was observed that the maximum water content was 43%.

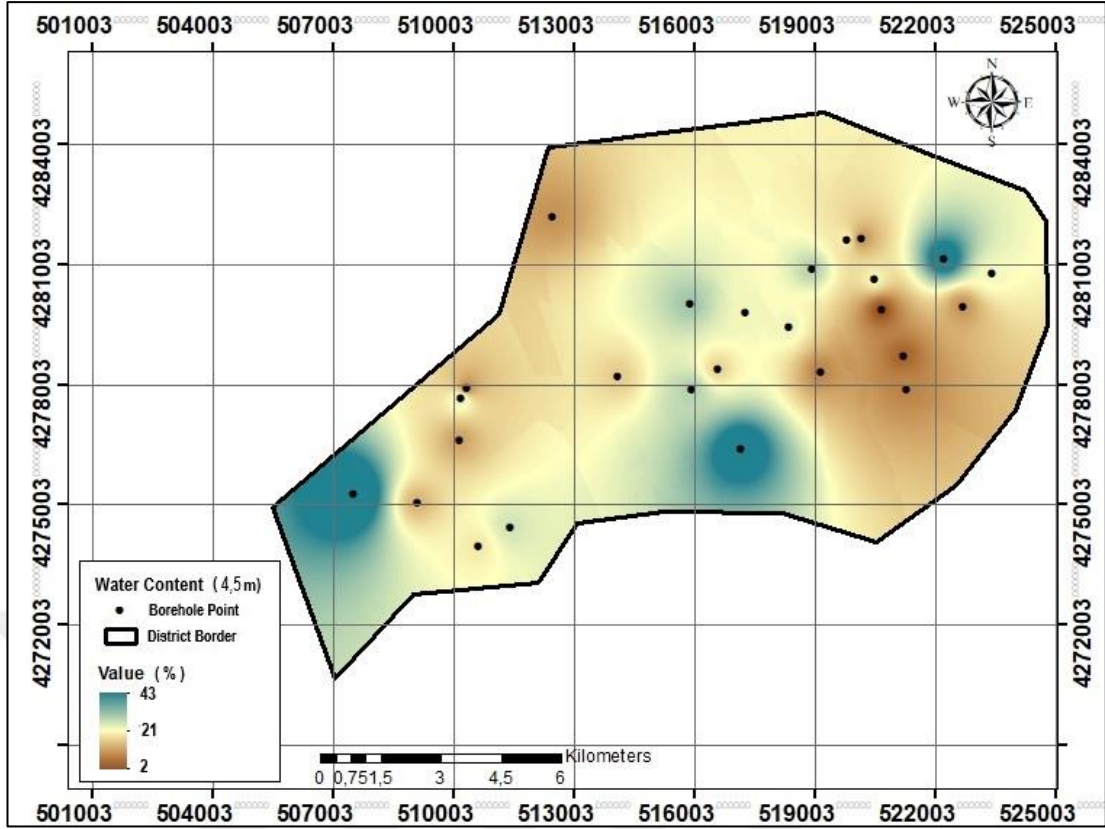


Figure 4.28 Water content (4.5 m)

In determining the water content as a percentage (%), in the data obtained from 47 borehole points for 7.5 m throughout the study area, 26% of the study area is between 0-10, 42% between 11-20, 23% between 21-30., 9% was found to be between 31-44. The map which is created according to this evaluation is presented in Figure 4.30.

In the area between Çatalçeşme and Fırat University in the east of the study area, around Yemişlik Village in the southeast and Örençay Village in the southwest, the water content was determined to be 21-30% and 31-44%. In the remaining other regions, it was determined that the water content was included in the grouping between 0-10% and 11-20%. It was observed that the maximum water content was 43%.

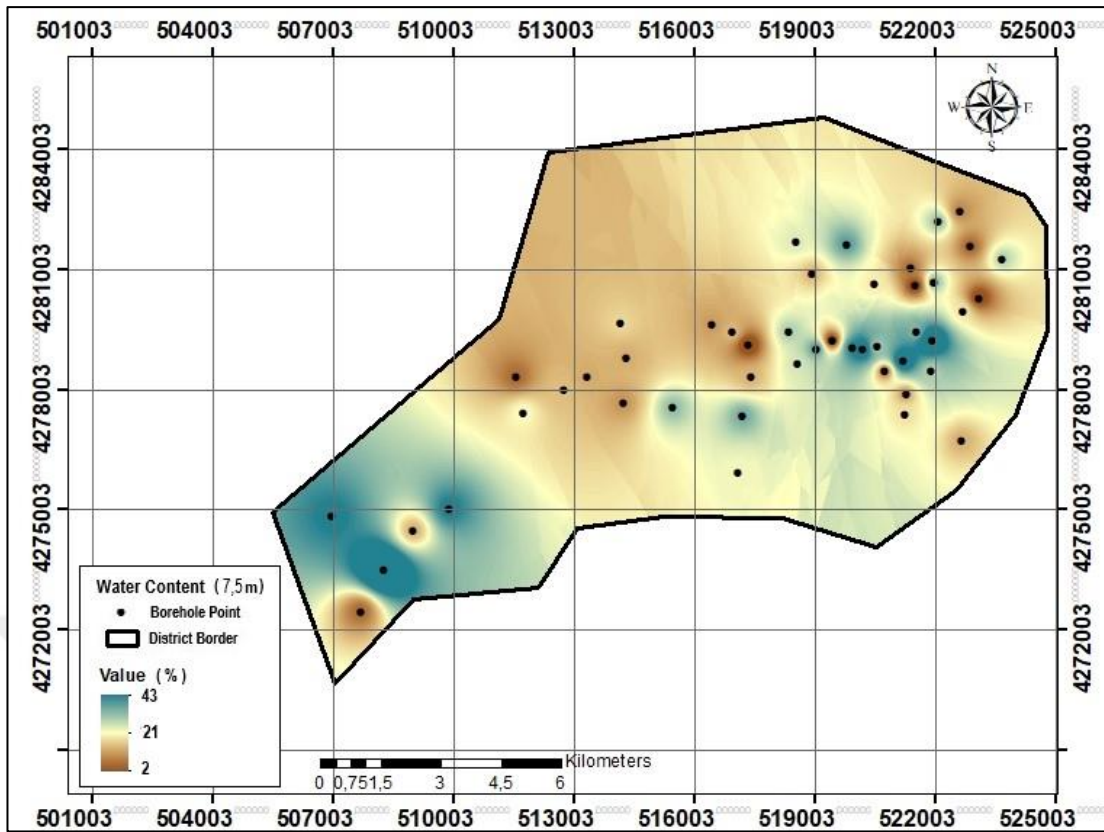


Figure 4.29 Water content (7.5 m)

In determining the water content as a percentage (%), in the data obtained from 33 borehole points for 9 m throughout the study area, 27% of the study area is between 0-10, 46% between 11-20, and 21% between 21-30. It has been determined that 6% is between 31-44. The map which is created according to this evaluation is presented in Figure 4.31.

It has been determined that the water content is 0-10% and 11-20% in the region between Çatalçeşme and Fırat University, located in the east of the study area, around TED College, Prison in the middle part and Örençay Village in the southwestern part. In the remaining regions, it was determined that the water content was between 21-30% and 31-44%. It was observed that the maximum water content was 43%.

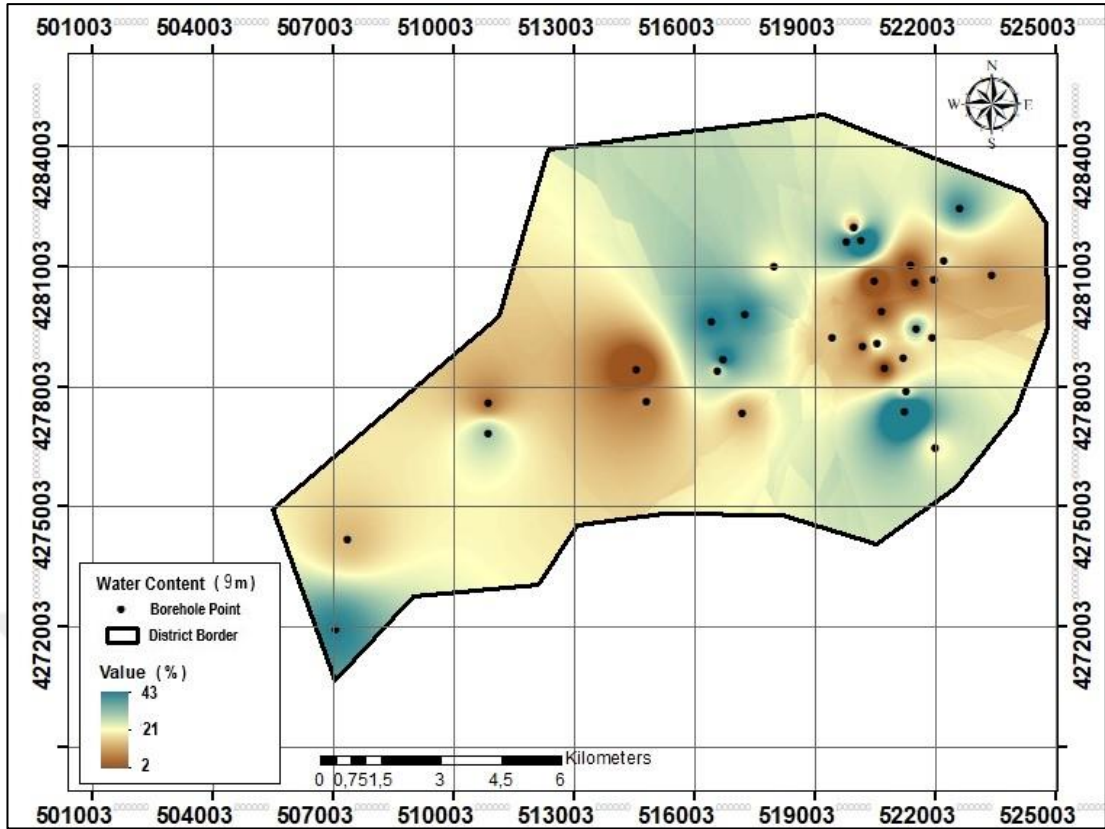


Figure 4.30 Water content (9 m)

In determining the water content as a percentage (%), in the data obtained from 33 borehole points for 15 m throughout the study area, 21% of the study area is between 0-10, 64% between 11-20, and 9% between 21-30. It has been determined that 6% is between 31-44. The map which is created according to this evaluation is presented in Figure 4.32.

It was determined that around Çatalçeşme and Sugözü located in the northeast of the study area and Yemişlik Village in the southeast region, the water content is 21-30% and 31-44%. In the remaining regions, it was determined that the water content was included in the grouping between 0-10% and 11-20%. It was observed that the maximum water content was 43%.

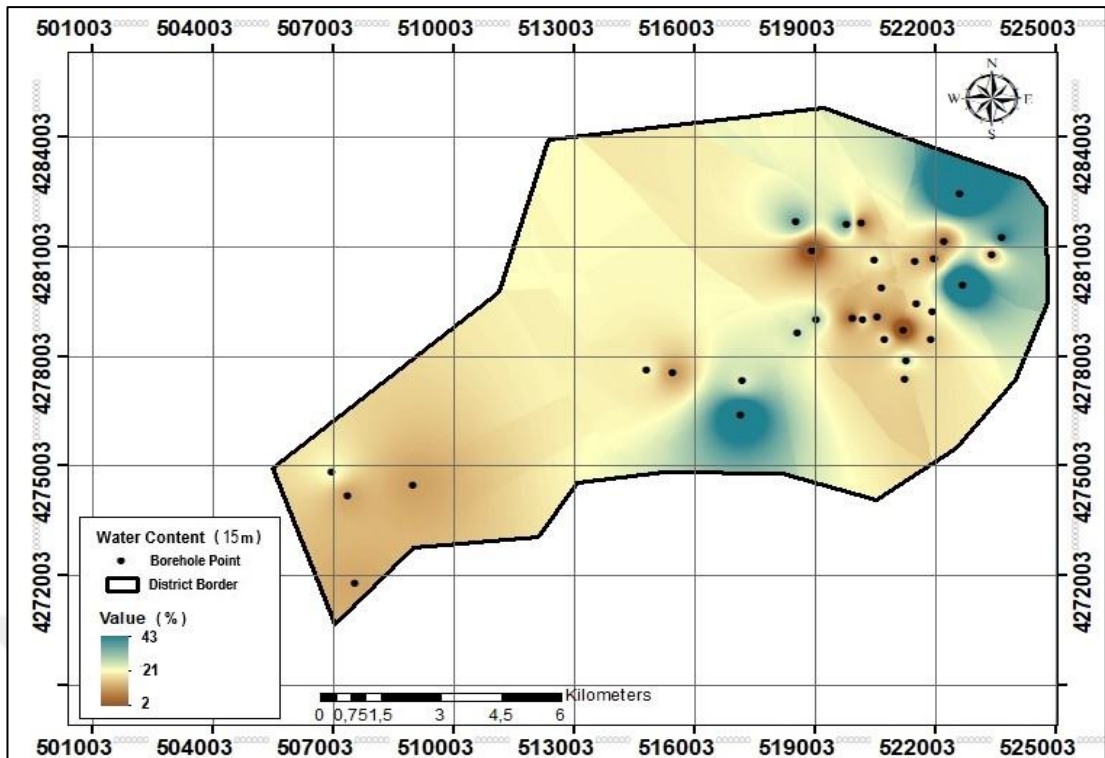


Figure 4.31 Water content (15 m)

Within the scope of the study, for the water content (W_n) values found for 1.5, 3, 4.5, 7.5, 9 and 15 m, the study values of 0-10% W_n , 11-20% W_n , 21-30% W_n , 31-44% W_n . The comparison graph showing the distribution in the area as a percentage is presented in Figure 4.33. It is seen that the value of 11-20% W_n is dominant in the study area.

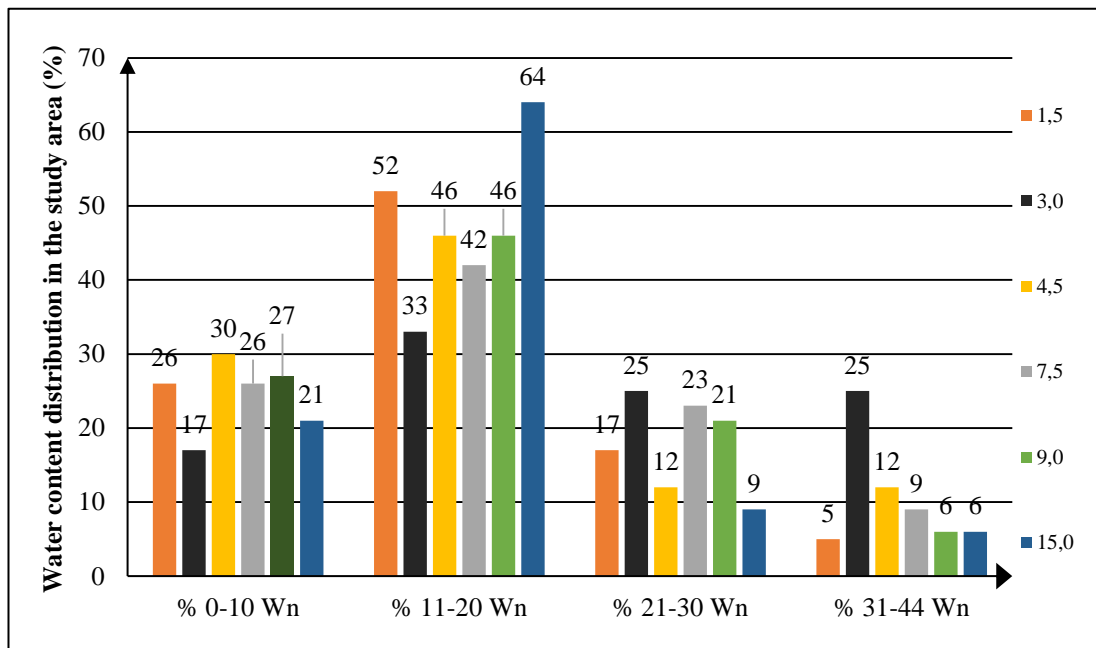


Figure 4.32 Water content values comparison chart by borehole depth

4.4. Atterberg limits analysis

In determining the consistency limits, the values obtained from 84 borehole points for Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) from 210 points in the study area were used. Within the scope of the study, the consistency limits for 1.5, 3, 4.5, 7.5, 9 and 15 m depths were determined. It has been observed that the highest value is dominant at 3 m.

A map and comparison chart were created in line with the LL values obtained from the 3 m borehole depth. The map in question is presented in Figure 4.34 and the comparison chart of 0-25 LL, 26-50 LL, 51-75 LL values is presented in Figure 4.35.

It has been determined that LL values of 26-50% are dominant in the Çatalçeşme located in the easternmost part of the study area, around the TED College in the middle parts, and in the areas to the north of the FÜ Communication Faculty located in the southwestern part. LL values of 51-75% were observed locally in Aşağıdemirtaş Village located in the southwestern part and in other regions. 0-25% LL values were not determined.

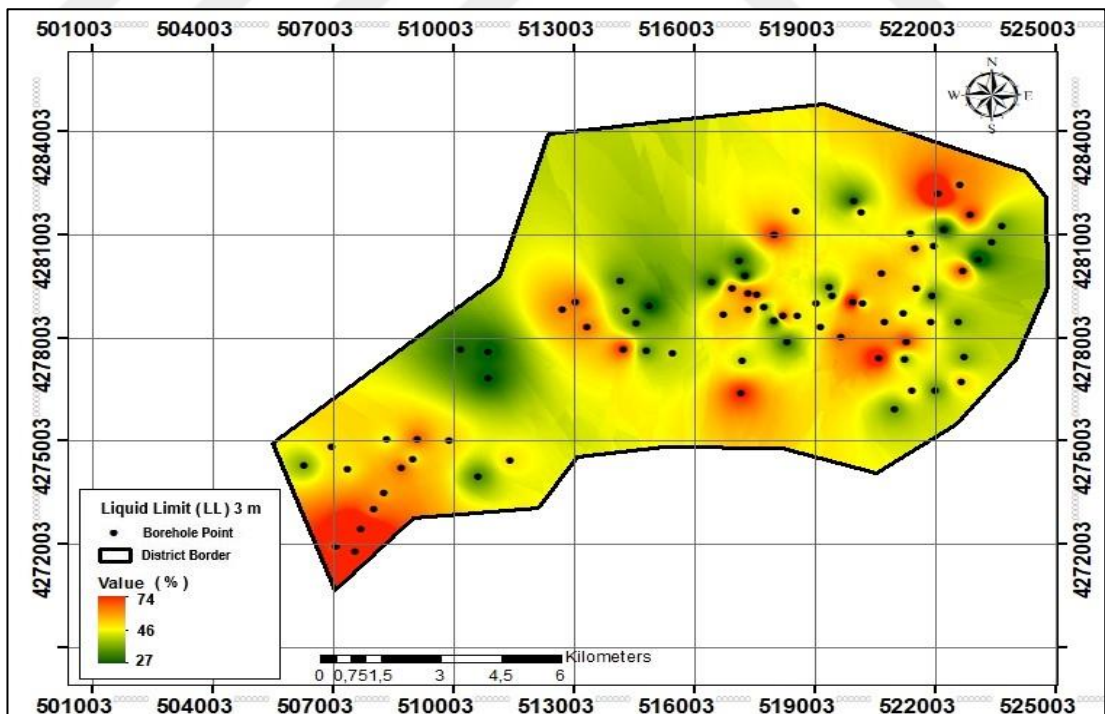


Figure 4.33 Liquid limit (3 m)

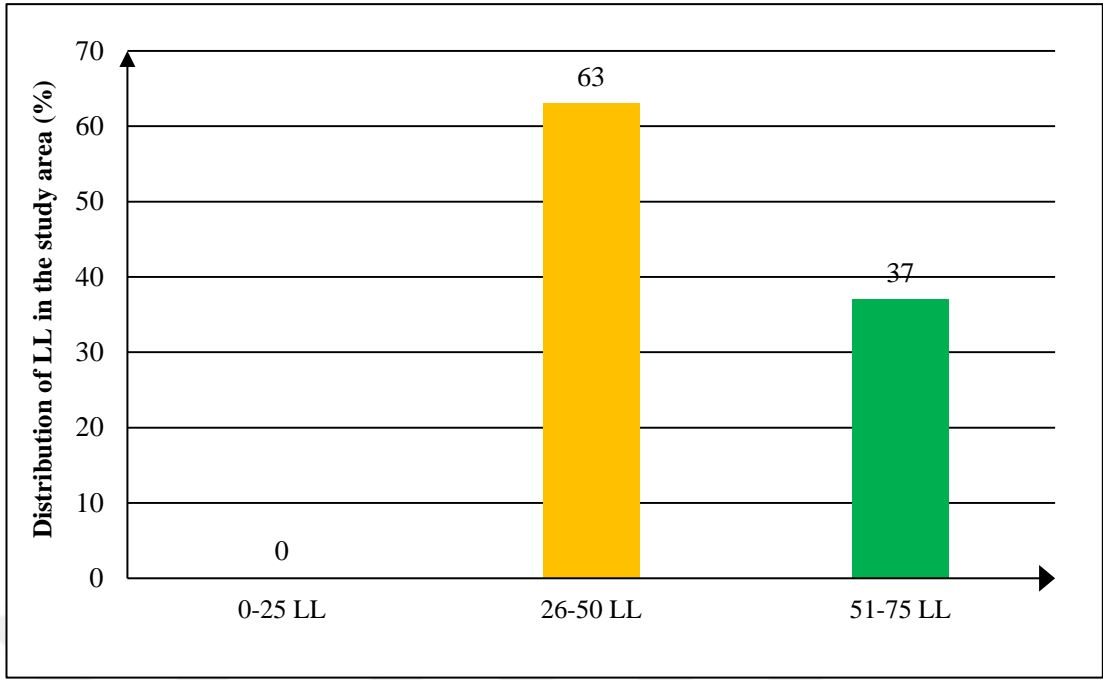


Figure 4.34 LL Values comparison chart by depth at 3 m

A map and comparison chart were created in line with the PL values obtained from the 3 m borehole depth. The map in question is presented in Figure 4.36 and the comparison chart of 0-25 PL, 26-50 PL, 51-75 PL values is presented in Figure 4.37.

It has been determined that 0-25% PL values are dominant in the Çatalçeşme, which is in the easternmost part of the study area, around TED College in the middle parts, and in the areas to the north of the FÜ Communication Faculty in the southwest part. PL values of 26-50% were observed in Aşağı Demirtaş Village in the southwestern part and other regions. 51-75% PL values were not determined.

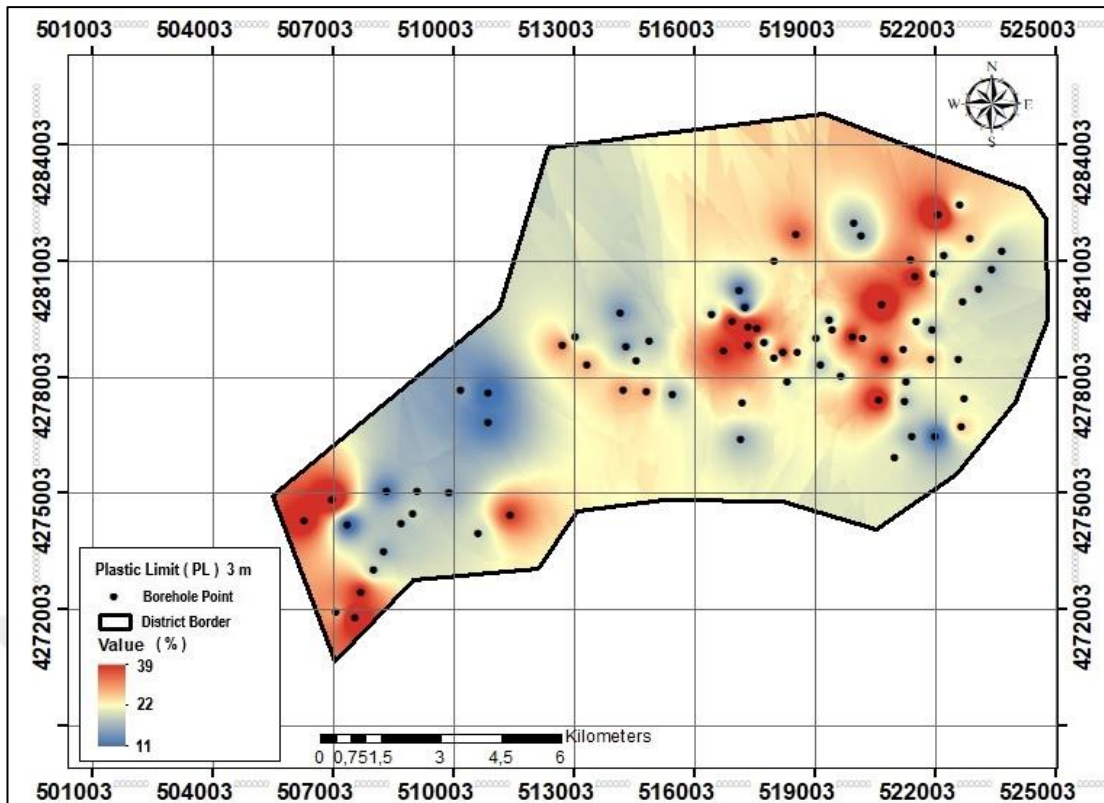


Figure 4.35 Plastic limit (3 m)

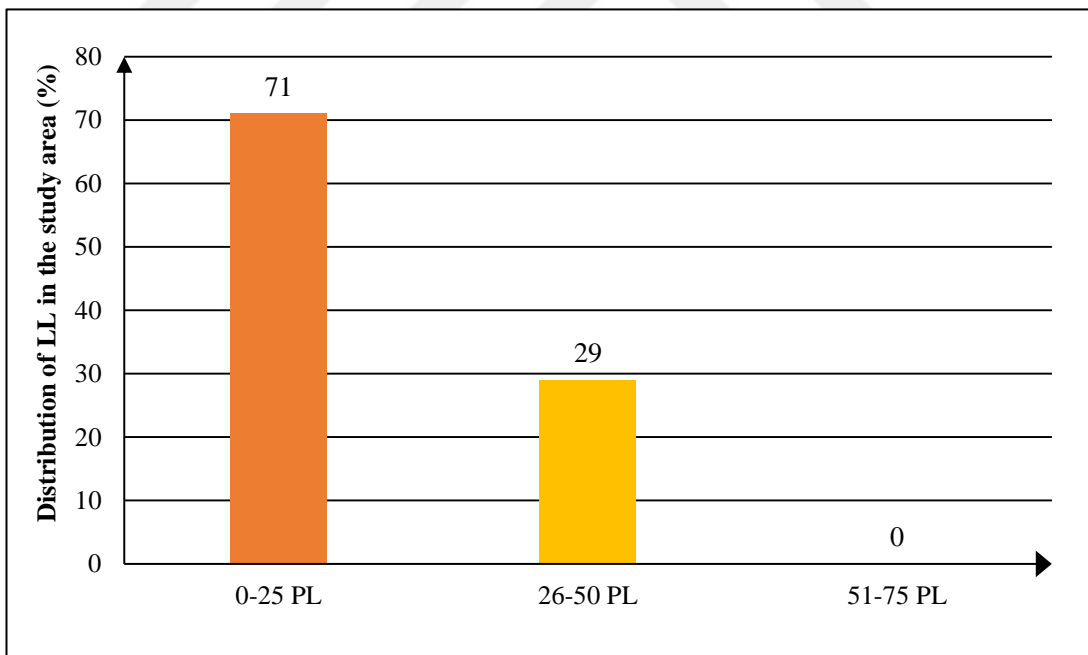


Figure 4.36 PL Values comparison chart by depth at 3 m

A map and comparison chart were created in line with the PI values obtained from the 3 m borehole depth. The map in question is presented in Figure 4.38 and the comparison chart of 0-25 PI, 26-50 PI, 51-75 PI values is presented in Figure 4.39.

It has been determined that PL values of 0-25% are dominant in the areas to the east of the study area, around Çatalçeşme, around TED College in the middle parts, and in the north of the FÜ Communication Faculty in the southwest. PL values of 26-50% were observed in Aşağı Demirtaş Village in the southwestern part and in other regions. 51-75% PI values were not determined.

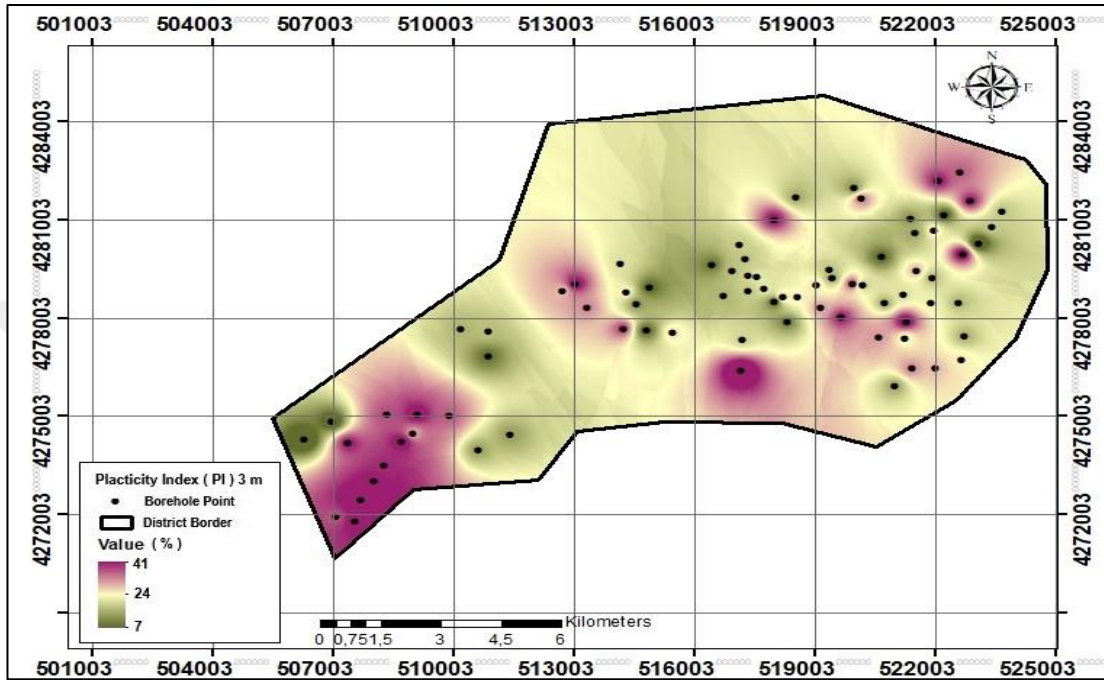


Figure 4.37 Plasticity index (3 m)

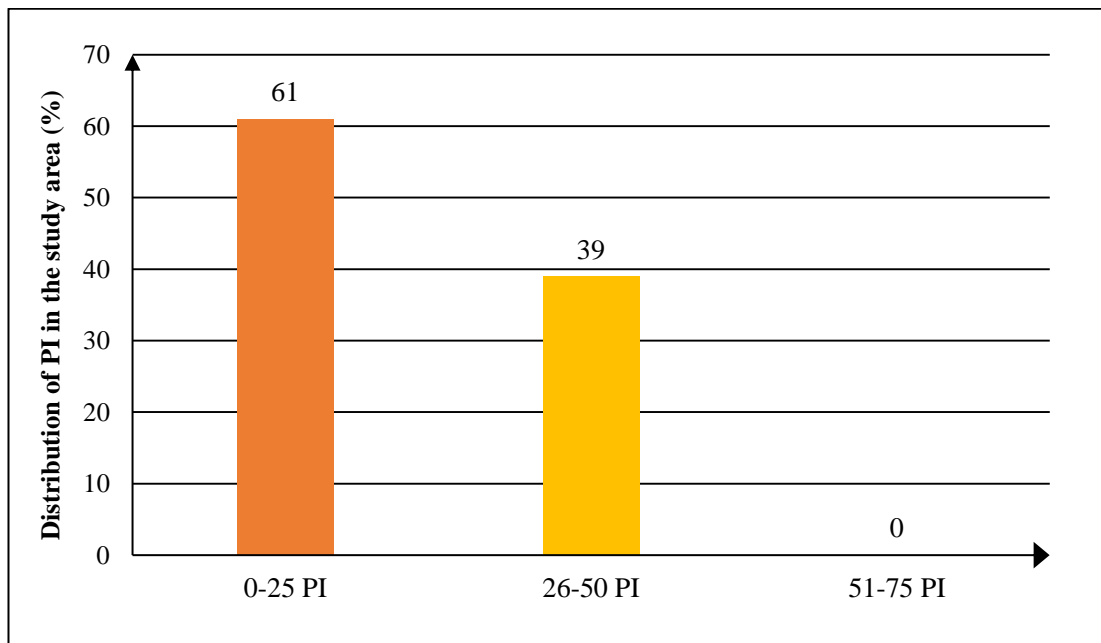


Figure 4.38 PI values comparison chart by depth at 3 m

4.5. Analysis of shear wave velocity calculation of the top 30 m

The V_{s30} of the soil is used in different soil classification systems and earthquake hazard analysis calculations. In this thesis, the values calculated by field measurements are used to create the average shear wave velocity map of the study area. The maps were created using the ArcGIS program and the IDW method. In the analysis, a shear wave velocity range ranging from 264 m/sec to 1950 m/sec was determined.

In the data obtained for 30 m depth throughout the study area with measurements made in the field, the value of 2% of the study area is $V_s > 1500$ m/s, the value of 69% is $760 < V_s < 1500$ m/sec, the value of 29% is $360 < V_s < 760$ m/sec. It was determined that there is no value between $V_s < 180$ m/sec and $180 < V_s < 360$ m/sec. The map which is created according to this evaluation is presented in Figure 4.40.

It has been determined that the shear wave velocity is between $360 < V_s < 760$ m/sec around Fırat University Sugözü and Çatalçeşme located in the eastern part of the study area. In the region between Örençay, Aşağı Demirtaş Village, FÜ Communication Faculty, TED College and FÜ located in the southwestern and central parts, shear wave velocity was determined to be between $760 < V_s < 1500$ m/sec in general. Located in the western and southwestern parts of the Prison, Banvit AŞ. and in the region to the north of these, shear wave velocity was observed as $V_s > 1500$ m/sec. In addition, the comparison chart of the values in the study area is presented in Figure 4.41.

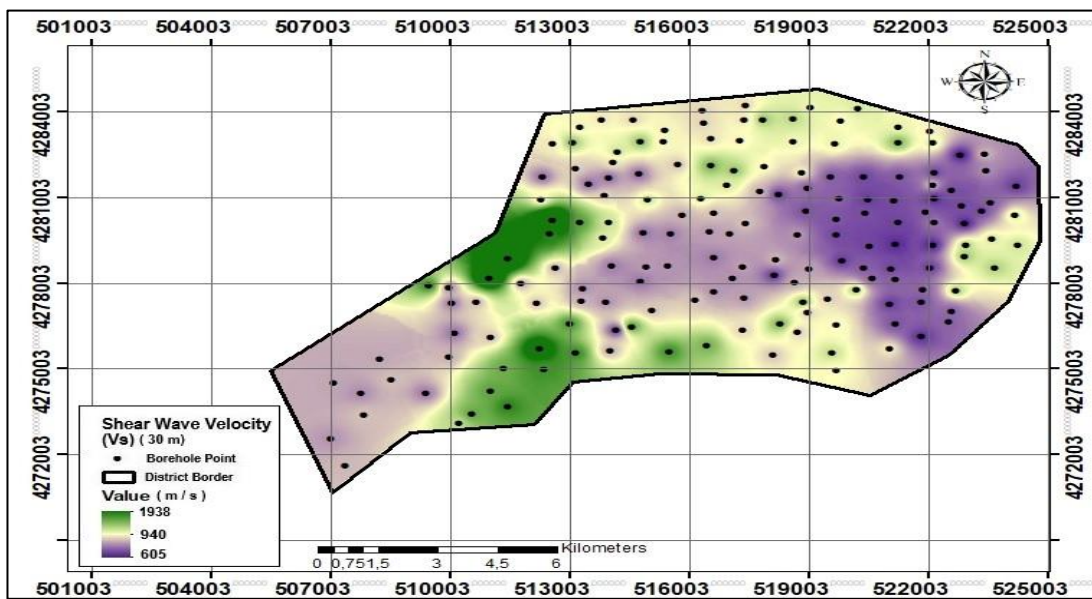


Figure 4.39 Shear wave velocity (30 m)

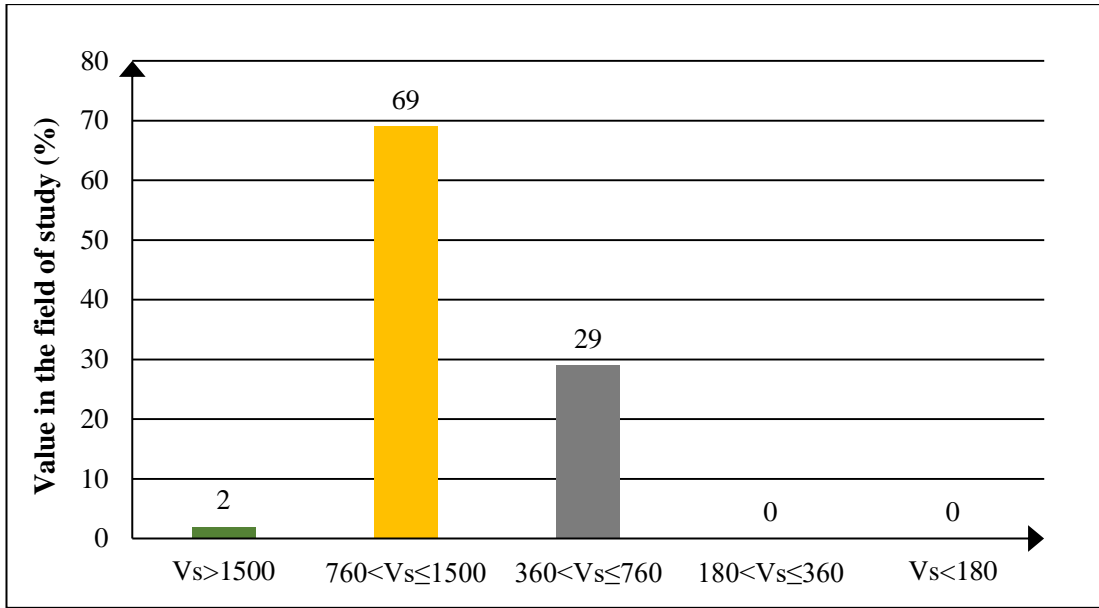


Figure 4.40 Comparison of V_s (30 m) value in the study area

4.6. Soil classification analysis according to NEHRP earthquake regulation

Soil class according to NEHRP is based on the average velocity of shear wave velocity up to 30 m depth. The necessary map for GIS analysis was created within the scope of the data obtained through the measurements made in the field. While creating the map, using the ArcGIS program, soil class values estimated maps according to NEHRP were produced with the IDW method in a 10 m grid size, and A, B, C soil types were determined on the prepared map.

It is determined that 2% of the study area is A, 69% is B, 29% is C is E based on the measurements made in the field. The map which is created according to this evaluation is presented in Figure 4.42.

It has been determined that the northwest part of the A class soil values is seen around Sariçubuk Village and it has 2% of the whole area. It has been determined that the B class soil values have 69% in general, excluding the local parts in the eastern and northeastern parts.

It has been determined that Class C ground values are mainly seen around Fırat University, Çatalçeşme, Sugözü and Gümüşkavak, which are in the east and northeast sections, and around TED College and FU Communication Faculty, and it has 29% of the entire area. In addition, the comparison chart of the values in the study area is presented in Figure 4.43.

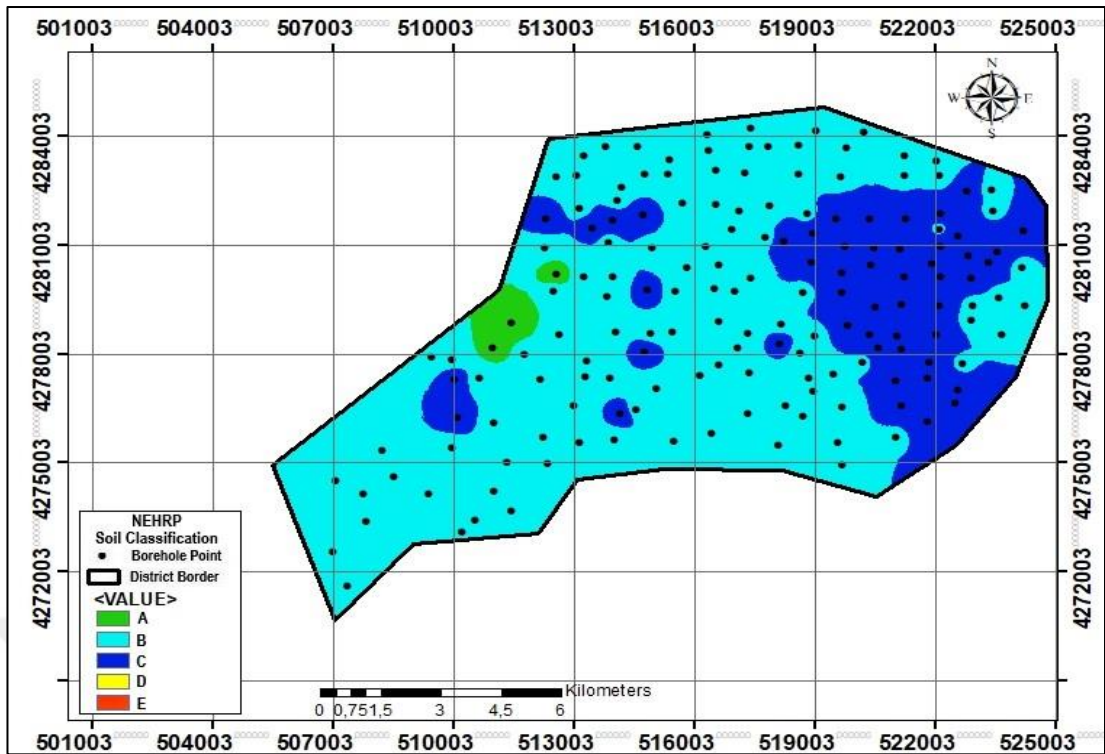


Figure 4.41 NEHRP soil classification

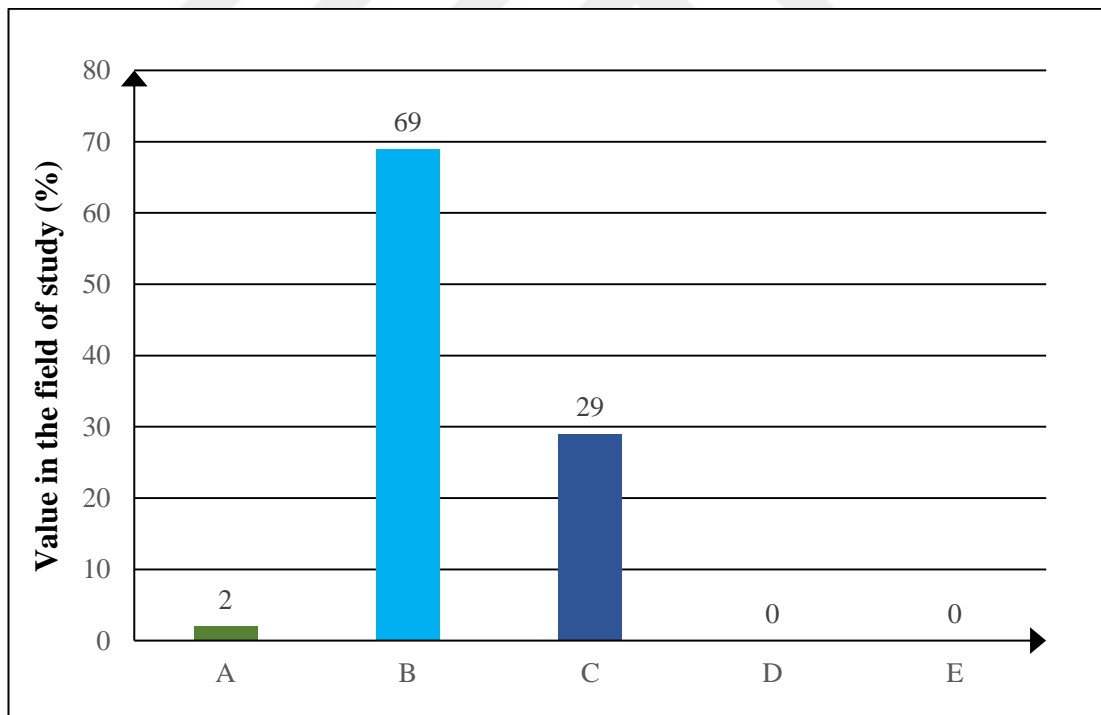


Figure 4.42 Comparison of its distribution in the study area

4.7. Analysis of the earthquake hazard level according to the soil amplification calculation

While planning the urbanization in the study area, it is important to determine the negative aspects of the earthquake strengthened by the local soil conditions in order to plan earthquake resistant buildings. V_{s30} was used to determine the local soil effect of the region (Karabaş, 2019).

Soil amplification calculations were made with the data obtained from 210 drilling points in the study area, which is required for GIS analysis. Values between 0.7 sec and 3.13 sec were determined on the maps. In addition, B (medium hazard) and C (low hazard) maps of the study area were created.

In the calculations, it has been determined that 1% of the study area is B (medium hazard) and 99% is C (low hazard). The map which is created according to this evaluation is presented in Figure 4.44.

It has been determined that 1% of the area around Sarıçubuk Village, located in the northwest part of the study area, is dominated by B (medium hazard) and 99% of C (low hazard) values in other areas. A (high hazard) was not detected in the study area. In addition, the comparison chart of B and C values in the study area is presented in Figure 4.45.

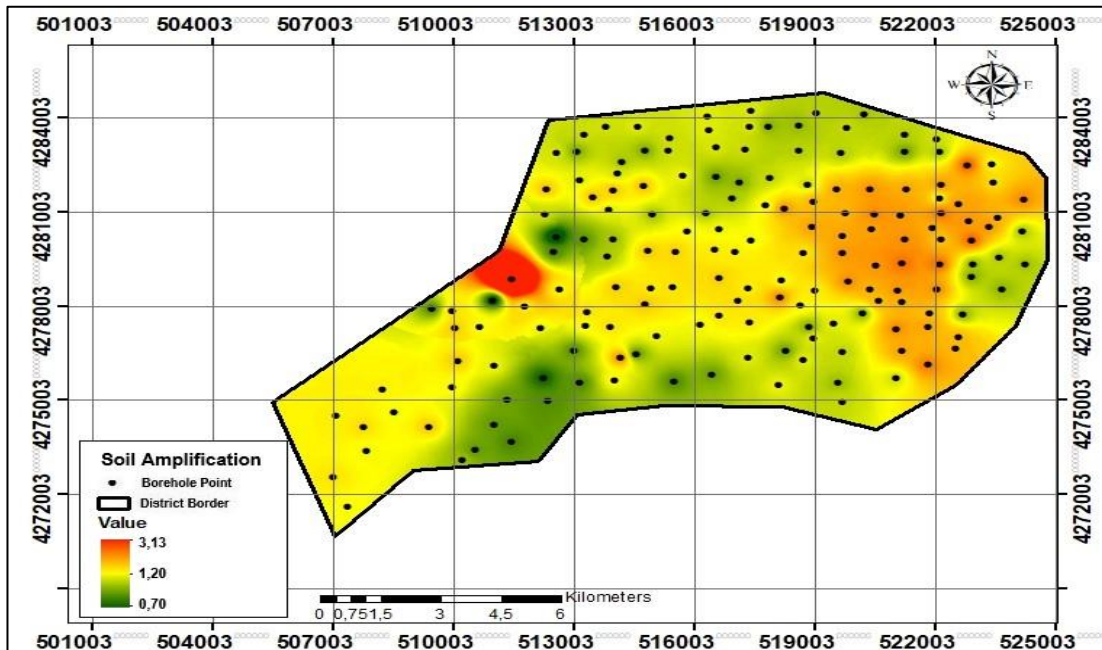


Figure 4.43 Hazard map according to soil amplification results

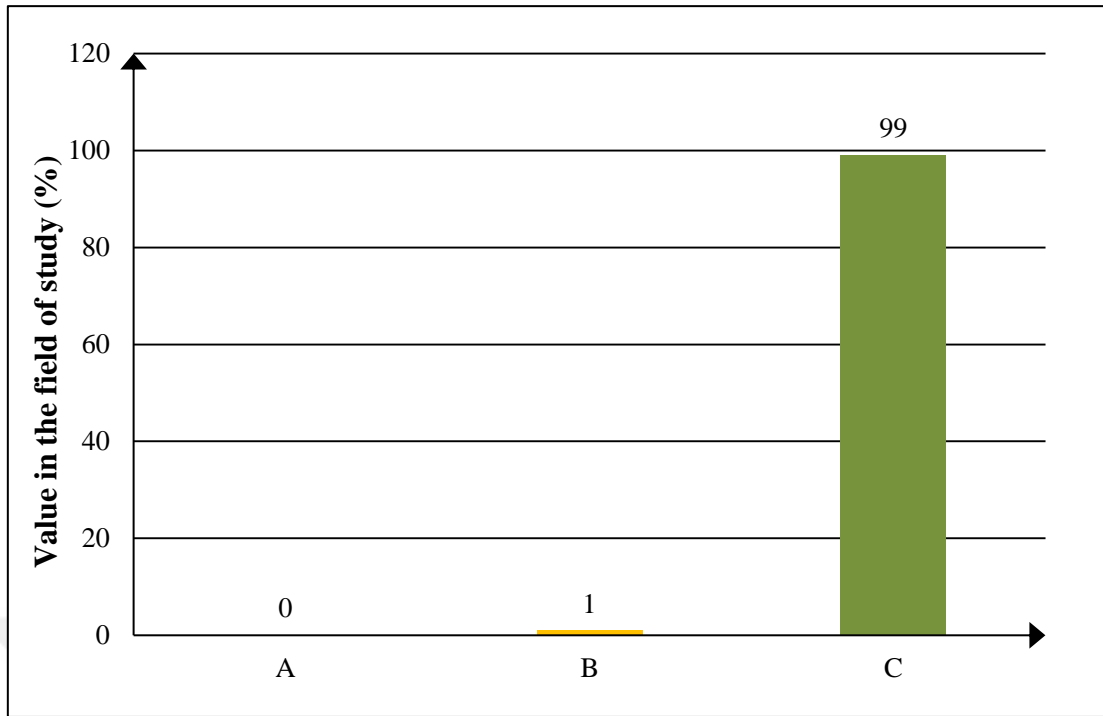


Figure 4.44 Distribution of hazard values in the study area according to soil amplification criteria

4.8. Soil classifications analysis according to EUROCODE 8

Soil class according to EUROCODE 8 is based on the average velocity of shear wave velocity up to 30 m depth. The maps required for GIS analysis are prepared within the scope of the data obtained by the measurements made in the field. The maps of soil classes A and B were determined according to the Eurocode 8 soil classification system.

With the measurements made in the field, it has been determined that 35% of the study area is class B and 65% is class B soil. The map which is created according to this evaluation is presented in Figure 4.46.

It was determined that B (medium hazard) values were dominant in 35% of the whole area, and C (low hazard) values were dominant at the rate of 65% in other areas, mainly in the eastern part of the study area. Soil type A was not detected in the study area. In addition, the comparison chart of A and B values in the study area is presented in Figure 4.47.

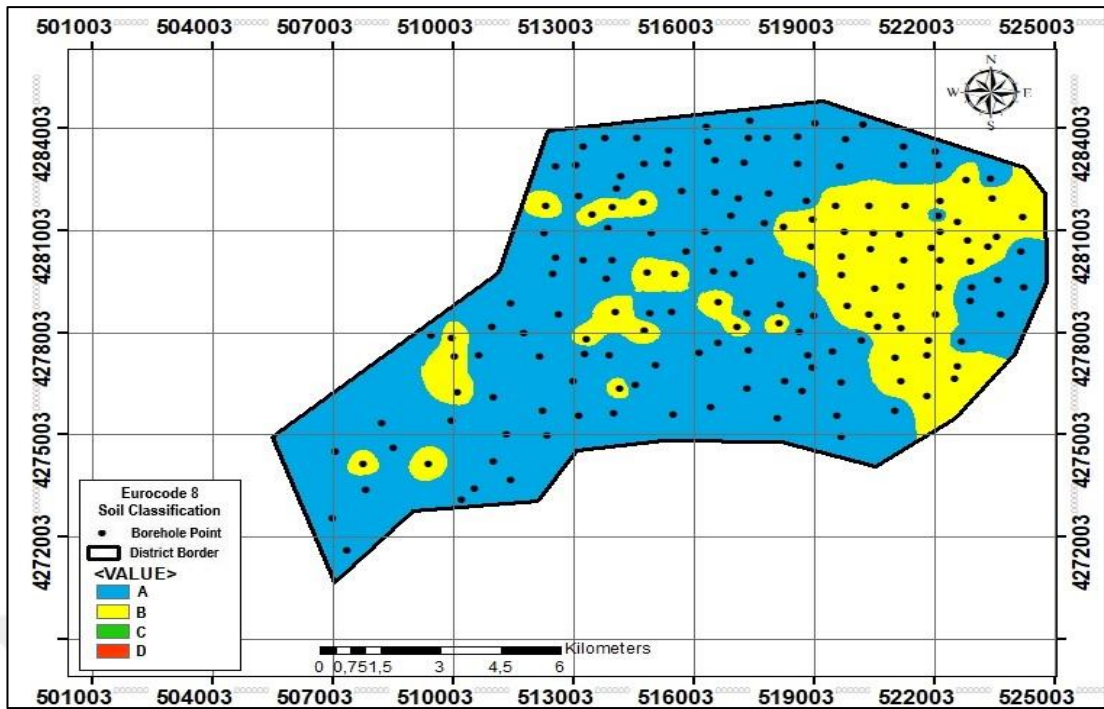


Figure 4.45 Soil classification map according to EUROCODE 8

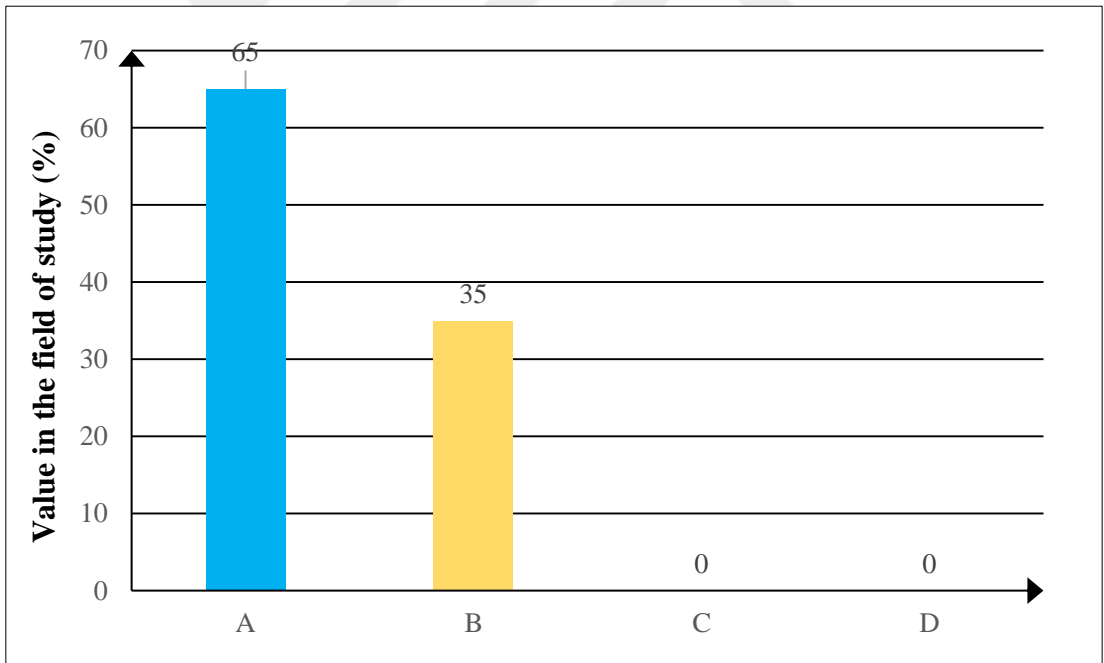


Figure 4.46 Distribution of soil classification values in the study area according to EUROCODE 8

4.9. Unified soil classification system analysis

Data were obtained at 21 points for 1.5 m from 210 points in the study area. It has been determined that there is a ML soil class around Nuralı, Gümüşbağlar, Alayaprak Village, Fırat University and Gümüşkavak in the part between the northwest and southeast. It is estimated that GM soil class will dominate in the southwestern part and the middle parts of the study area, while other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.48.

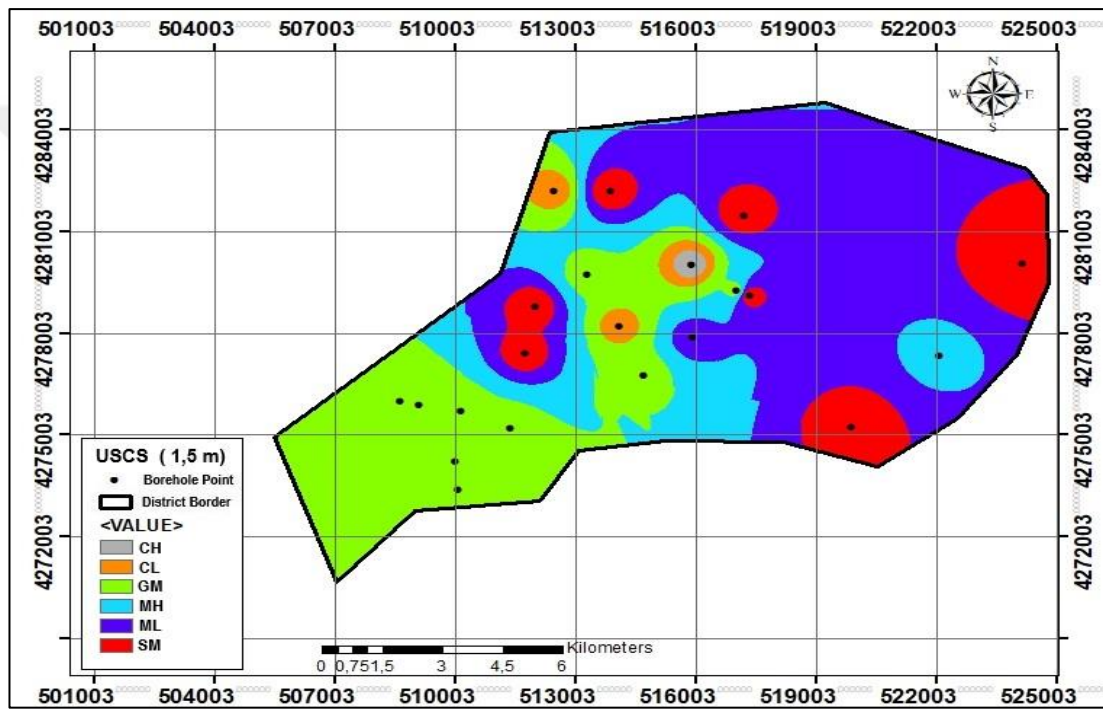


Figure 4.47 Soil classification according to USCS (1.5 m)

Data were obtained at 82 points for 3 m from 210 points in the study area. It has been determined that there is a CL soil class in the vicinity of FÜ Communication Faculty, Banvit AŞ located in the southwestern part, Fırat University in the middle part, Sugözü and Çatalçeşme Mahallesi in the south. It is estimated that GM soil class will dominate around Nuralı and Gümüşbağlar Villages in the South and Yemişlik Village in the North, while other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.49.

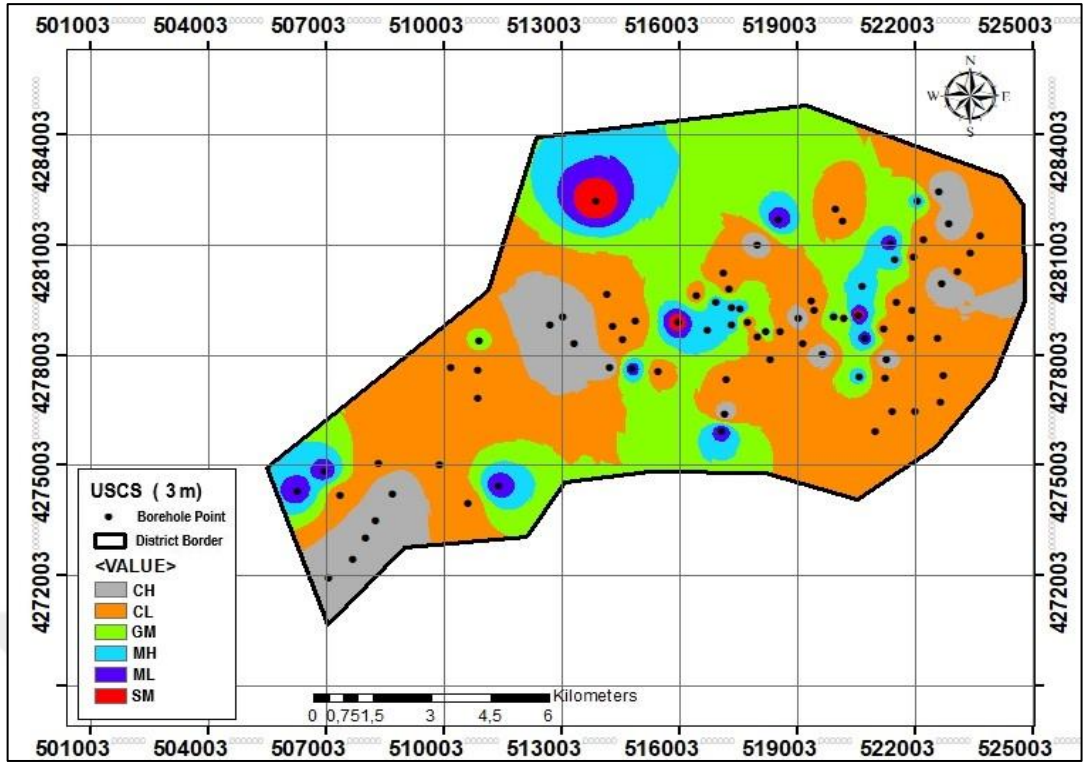


Figure 4.48 Soil classification according to USCS (3 m)

Data were obtained at 82 points for 4.5 m from 210 points in the study area. It has been determined that there is a CL soil class in the vicinity of FÜ Communication Faculty, Banvit AŞ located in the southwestern part, Fırat University in the middle part, Sugözü and Çatalçeşme in the south. It is estimated that the GM soil class will dominate around Nuralı and Gümüşbağlar Villages in the south and Yemişlik Village in the north, while other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.50.

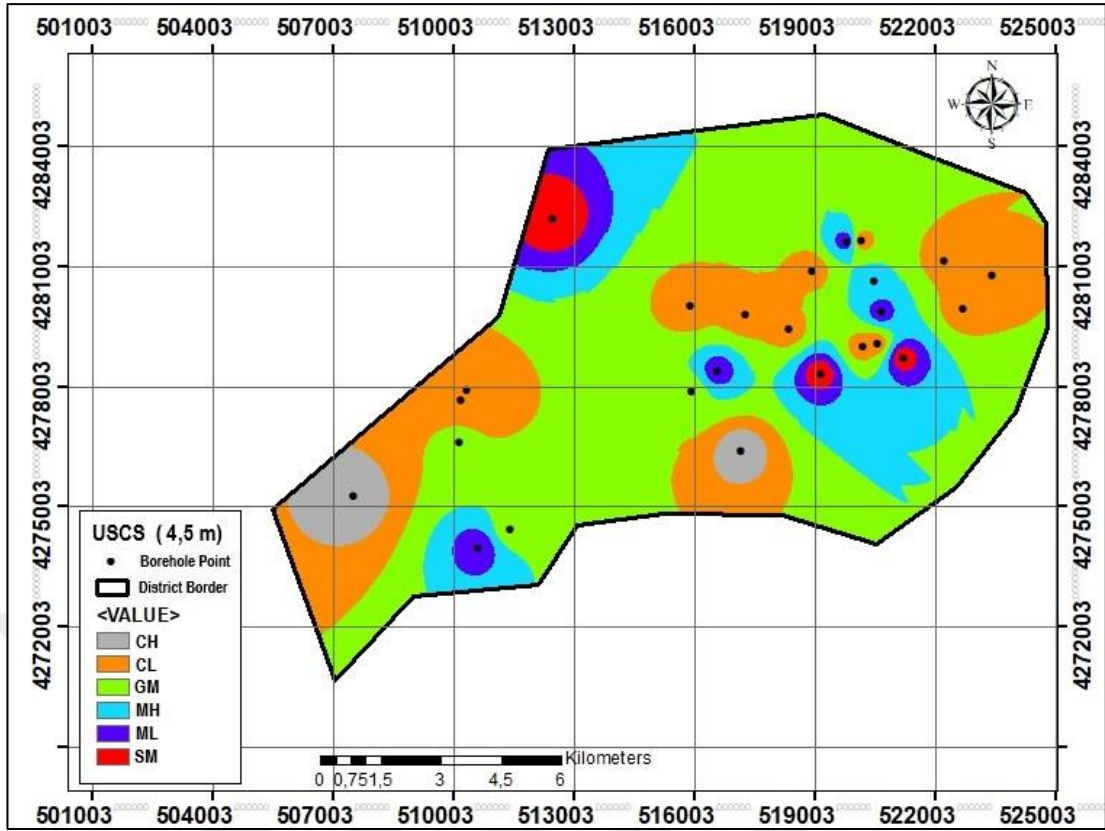


Figure 4.49 Soil classification according to USCS (4.5 m)

Data were obtained at 48 points for 7.5 m from 210 points in the study area. It has been determined that there is a GM soil class in the vicinity of Çatalçeşme, Gümüşkavak Mahallesi, Yemişlik Village in the southeast part and Fırat University in the middle part. It has been estimated that the MH soil class will be dominant in the areas to the west of Nuralı and Sarıçubuk Villages and FU Communication Faculty, Prison and TED College located in the southwestern part, while other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.51.

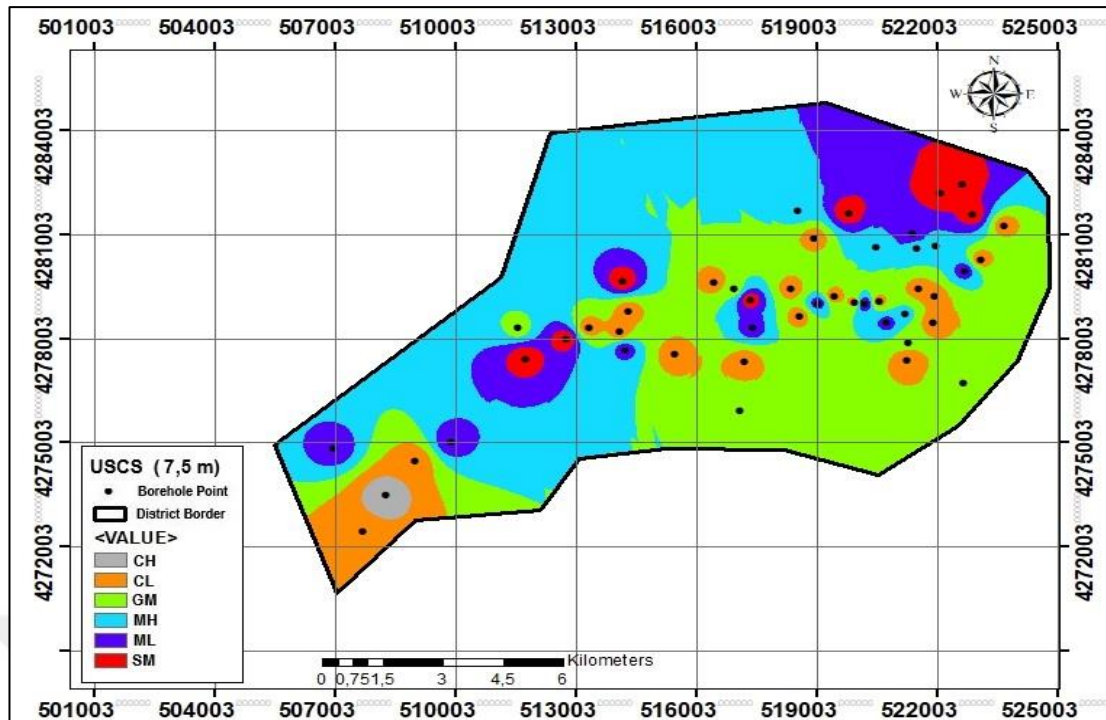


Figure 4.50 Soil classification according to USCS (7.5 m)

Data were obtained at 33 points for 9 m from 210 points in the study area. In general, it has been estimated that the MH soil class will dominate in most areas, while other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.52.

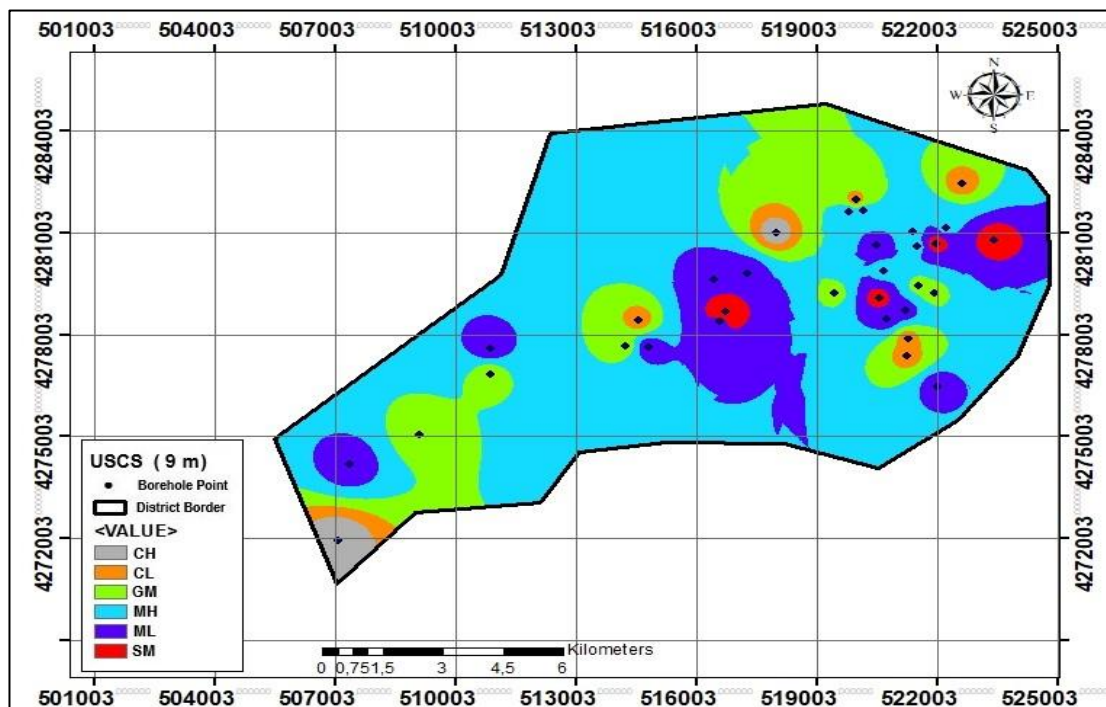


Figure 4.51 Soil classification according to USCS (9 m)

Data were obtained at 34 points for 15 m from 210 points in the study area. It has been determined that there is ML soil class around Gümüşkavak, Yemişlik Village located in the southeast part and Sarıçubuk Village located in the northeast. It is estimated that SM soil class will dominate in the northern and northeastern parts of Firat University, around Alayaprak, Nuralı and Gümüşbağlar Villages, GM soil class will dominate in the southwestern part and other local areas, and other soil types will be effective at various points. The map which is created according to this evaluation is presented in Figure 4.53.

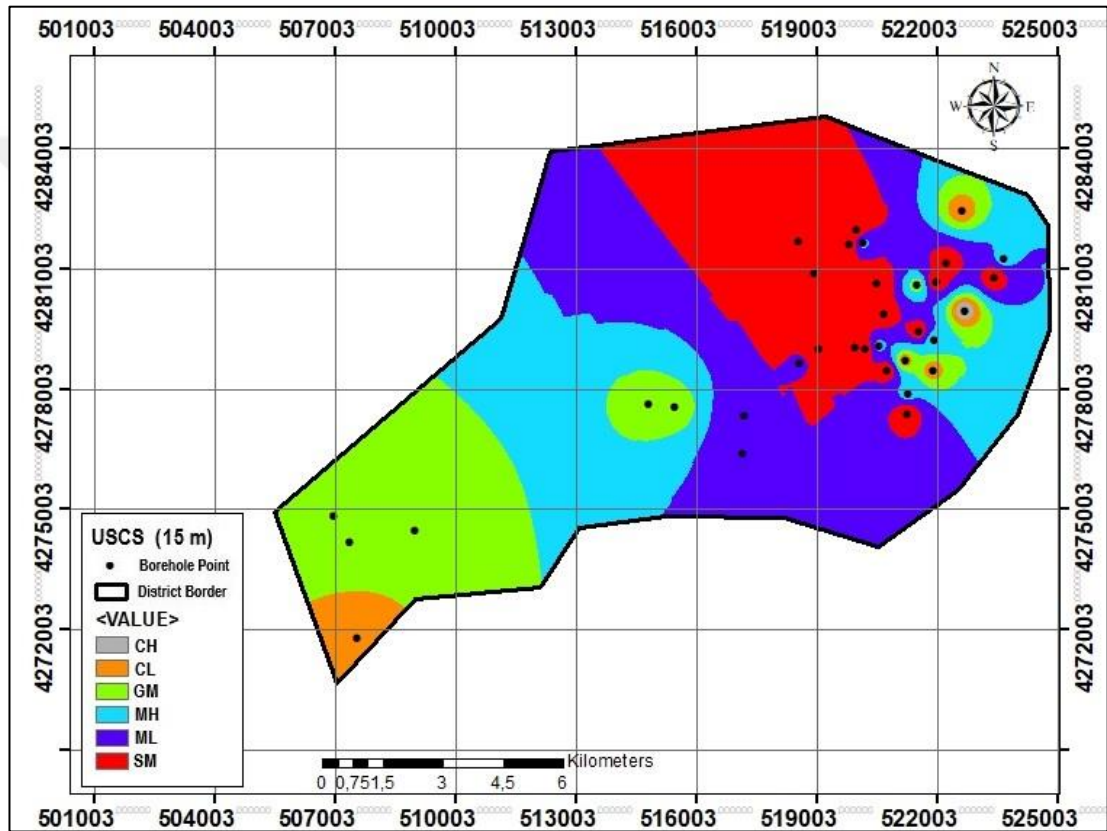


Figure 4.52 Soil classification according to USCS (15 m)

4.10. Compression wave velocity analysis

Data were obtained at 170 points for 7.5 m from 210 points in the study area. It has been observed that the compression wave velocity varies between 801-1,885 m/sec in the areas around the Sarıçubuk Village to the north of the central point, between Banvit AŞ and the Prison in the southwest of the study area, and in the regions around Nuralı and Gümüşbağlar Villages located in the southeast.

It has been observed that the compression wave velocity in the regions around Aşağı Demirtaş and Örençay Villages in the southwest and Gümüşkavak in the southeast varies between 386-500 m/sec, and in the remaining areas, the compression wave velocity generally varies between 501-800 m/sec.

The map showing the distribution of the measured value of the compression wave velocity at 7.5 m in the study area is presented in Figure 4.54. The graph showing the compression wave velocity values between 386-500 m/sec, 501-800 m/sec and 801-1.885 m/sec is presented in Figure 4.55.

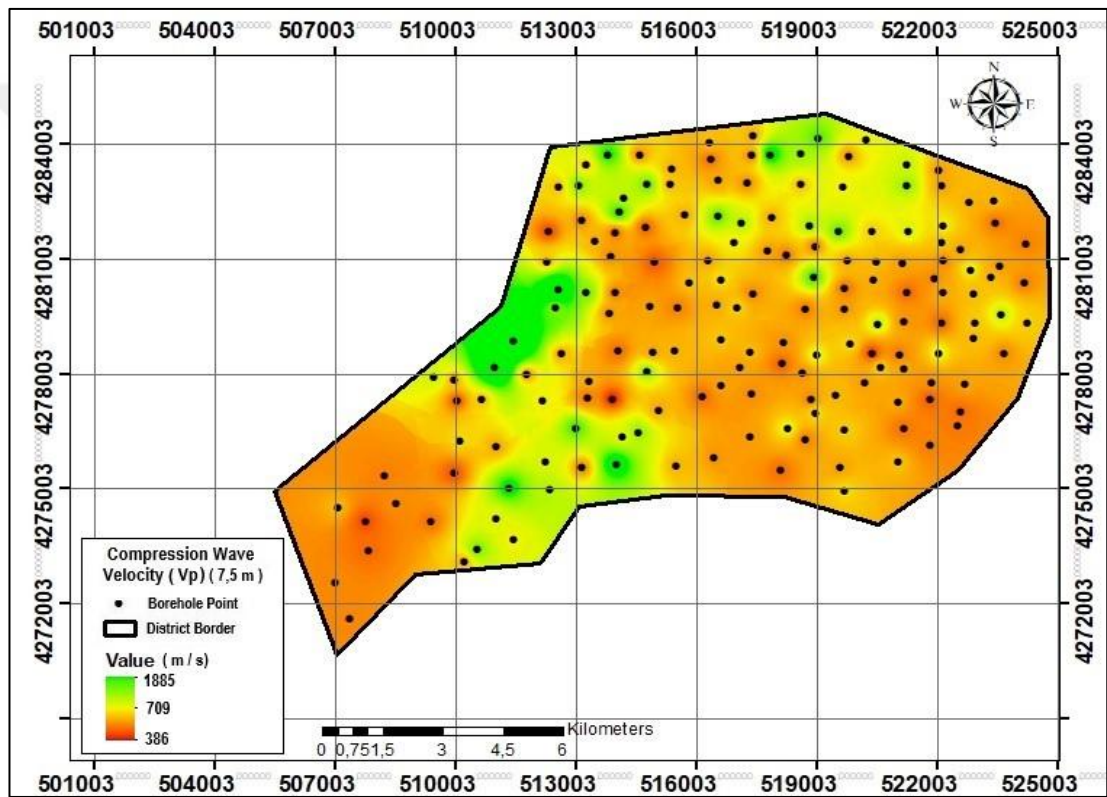


Figure 4.53 Compression wave velocity at 7.5 m

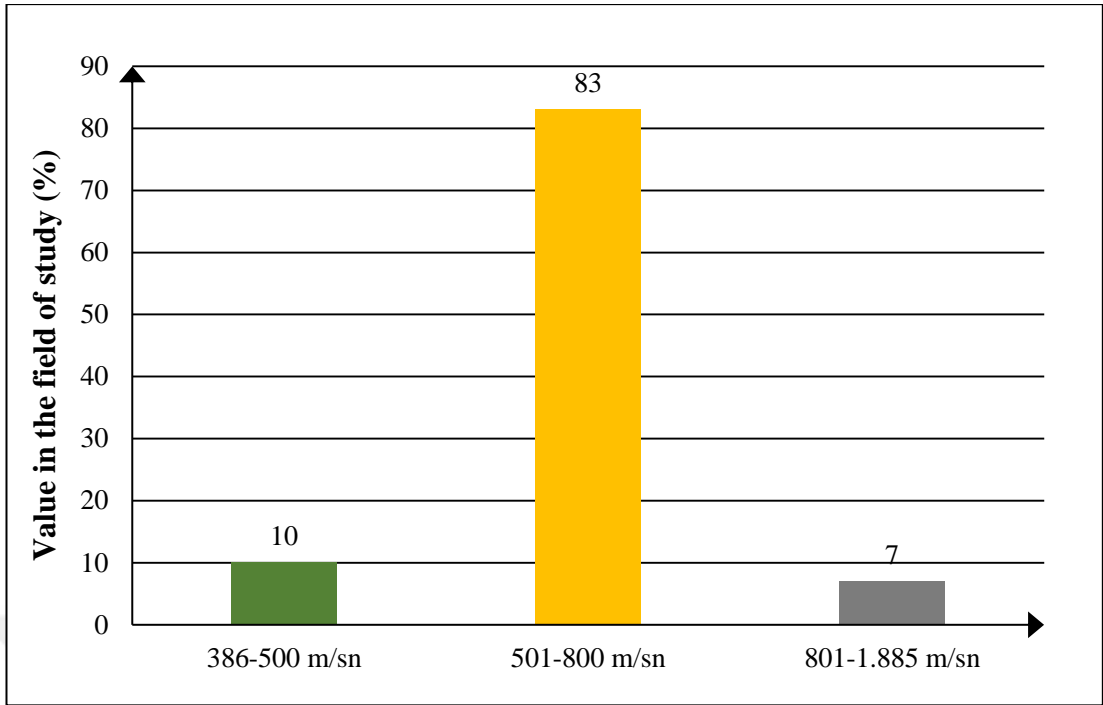


Figure 4.54 Distribution of the measured value for 7.5 m of compression wave velocity in the study area

4.11. Shear wave velocity analysis

Data were obtained at 170 points for 7.5 m from 210 points in the study area. It has been observed that shear wave velocity varies between 601-1.260 m/sec in the area between Banvit AŞ and Prison in the southwest of the study area, in the areas around Sarıçubuk Village to the north of the central point, and in the areas around Nuralı and Gümüşbağlar Villages in the southeast.

It has been observed that the shear wave velocity in the region around Aşağı Demirtaş and Örençay Villages in the southwest and Gümüşkavak in the southeast varies between 451-600 m/sec, and in the remaining areas, the shear wave velocity generally varies between 264-450 m/sec.

The map showing the distribution of the measured value of the shear wave velocity at 7.5 m in the study area is presented in Figure 4.56. The graph showing the shear wave velocity values between 264-450 m/sec, 451-600 m/sec and 601-1.260 m/sec is presented in Figure 4.57.

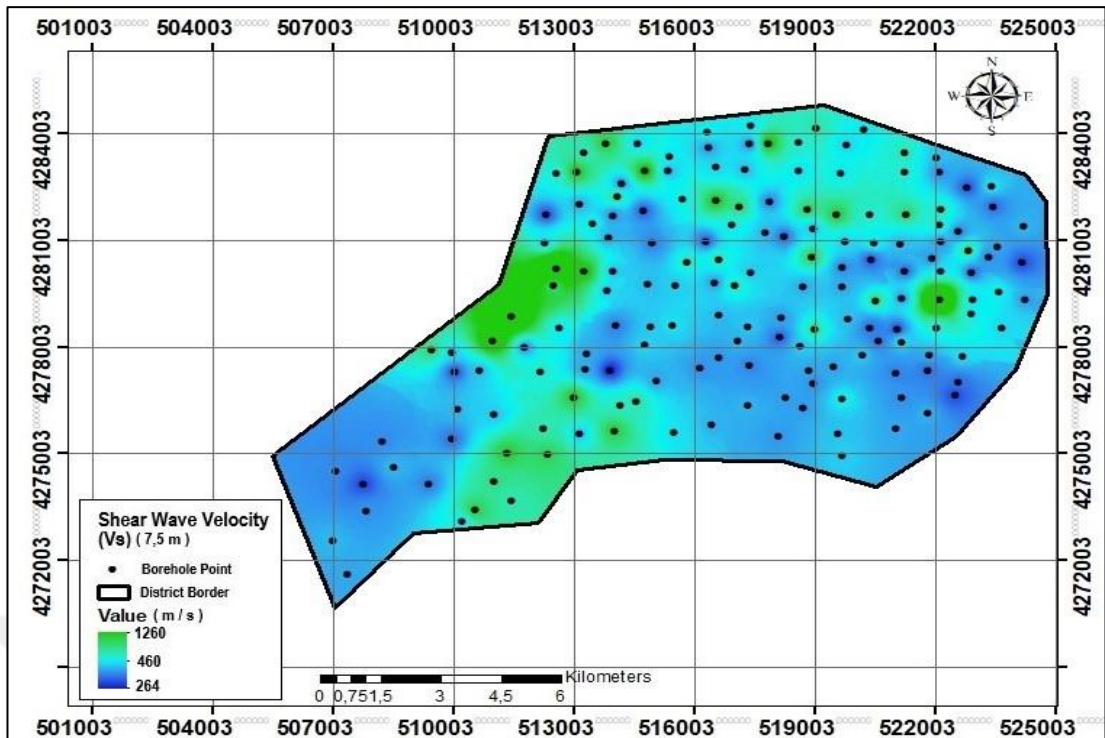


Figure 4.55 Shear wave velocity at 7.5 m

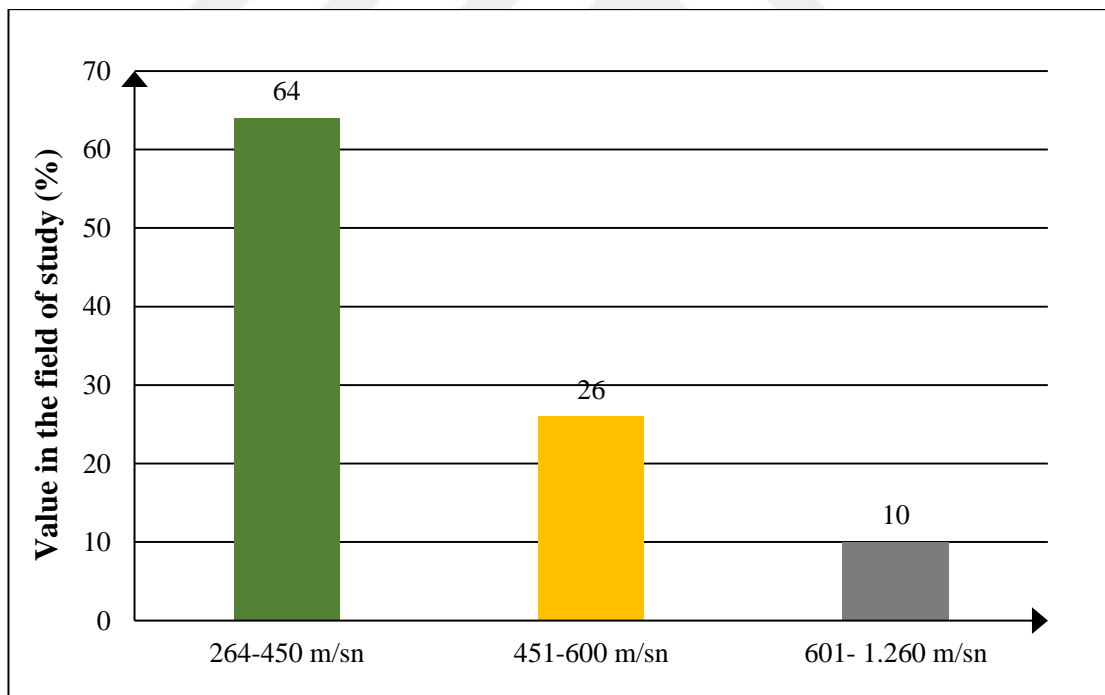


Figure 4.56 Distribution of measured value of shear wave velocity for 7.5 m in the study area

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

In this study, a database was created by utilizing the values obtained from the field and laboratory test results in the soil research reports in the archive of Elazig Municipality. By using geotechnical data in the database, the bearing capacity for various depths in the study area within the boundaries of Elazig Municipality with the GIS-based ArcGIS program, V_{s30} , SPT, NEHRP, EUROCODE 8, V_p , V_p , USCS, Atterberg Limits, Soil Growth Parameters and Groundwater Comparison graphics were created with maps. These maps allowed the visual evaluation of geotechnical data in the study area.

- A graph was created for the distribution of SPT-N values. It is seen that SPT-N values between 31 and 50 are dominant for all depths in the study area.
- Terzaghi - Peck Method and Meyerhof Method were used in field tests (SPT-N data) and carrying capacity calculation methods.
- It has been observed that the result values are close to each other in the Terzaghi - Peck and Meyerhof methods.
- However, when the impact value and depth increase, it is seen that the Meyerhof bearing capacity values are greater than the Terzaghi and Peck results.
- With the data obtained from 125 borehole points throughout the study area, groundwater was encountered at a total of 5 borehole points after 10 m. It has been evaluated that the study area is not rich in terms of groundwater.
- Within the scope of the study, it is seen that W_n values dominate 11-20% at all depths.

- As a result of the measurements made in the field for the 30 m depth of the shear wave velocity, the value of 2% of the study area is $V_s > 1500$ m/sec, the value of 69% is $760 < V_s < 1500$ m/sec, the value of 29% is $360 < V_s < 760$ m/sec it has been found to be between m/sec.

- The study area determined the soil class according to NEHRP; 2% part A (Hard rock), 69% part is B (Rock), 29% is part C (Very dense soil/ soft rock), 0% part is D (Stiff soil), 0% part is E (Soft soil). B soil class and C soil class values dominant throughout the study area.

- The study area determined the soil class according to EUROCODE 8; 65% part is A (Rock), 35% part is B (Very dense sand or very stiff clay), 0% part is C (Dense sand or stiff clay), 0% part is D (Loose to medium cohesionless soil). A soil class and B soil class values dominant throughout the study area.

- The earthquake hazard level are determined and compared in study area. It is seen that 1% part B (medium hazard) and 99% part C (low hazard) values are dominant throughout the study area.

- It has been observed that the highest value is dominant at 3 m in Atterberg Limits. It is seen that LL, PL and PI values between 26 and 50 for 3 m depth are dominant in the study area.

- As a result of the analysis of the maps prepared according to the USCS soil classification system, it has been seen that there are different soil types at different depths.

- As a result of the measurements made in the field for the 7.5 m depth of the compression wave velocity, it has been determined that 10% of the study area is between 386-500 m/sec, 83% is between 501-800 m/sec, and 7% is between 801-1.885 m/sec.

- As a result of measurements made in the field for shear wave velocity at 7.5 m depth, it was determined that 64% of the study area was between 264-450 m/sec, 26% was between 451-600 m/sec, and 10% was between 601-160 m/sec.

- Since the compression wave velocity is the first wave recorded at the time of the earthquake, it is expected to be greater than the shear wave velocity. Within the scope of the study, this result was confirmed and it was determined that the compression wave velocity was greater than the shear wave velocity.

- Since the study area is under the influence of the Eastern Anatolian Fault Zone and is located in the first and second degree seismic zones in the Turkey Earthquake Zones Map, the provisions of the "Regulation on Buildings to be Constructed in Disaster Zones" were considered appropriate.

- It has been evaluated that the buildings to be built in the working area of the Ministry of Environment, Urbanization and Climate Change and its immediate surroundings should be implemented exactly at the design stage.

- In our country, which is known as earthquake country, in order to reduce disaster damage and determine safe settlement areas, the geo-engineering properties of the ground should be evaluated and the design of the structures should be done before the settlement areas are opened for use.

- For this reason, it was concluded that disaster risk maps of the ground of settlement areas should be created within the scope of geo-engineering studies.

- Geotechnical data will be visually accessed more easily, thanks to the online use of GIS-based maps prepared within the scope of the thesis, by Elazig Municipality and other public institutions for the purpose of planning in settlements. Thus, it has been evaluated that each institution will save a great deal of time and labor.

- Also; It is considered that it is of great importance that the aforementioned mapping studies, which are among the 2023 targets of the National Earthquake Strategy and Action Plan, are supported by local governments and expanded.

- It is desirable to carry out further investigations, thanks to the work supported by local governments in our region and on a national basis. In this way, it will always be possible to improve our work done within the scope of the thesis and to enrich the database with the data obtained.

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T.C.
ELAZIĞ BELEDİYE BAŞKANLIĞI
Etüt Proje Müdürlüğü



Sayı : 25506309- 487
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14.05./2020

Sayın Onur DEMİRTAŞ

Zafer Mah. Mehmet Buyruk Cad.2'nci Or.K.lığı İs.Bşk.lığı İnönü Kışlası
Battalgazi/MALATYA

İlgi: : 06.05.2020 tarih ve bila sayılı dilekçe.

İlgi sayılı dilekçe ile belirtilen: Elazığ Belediyesinin 2015 yılında Akare Planlama Müş.Mim.Müh.İnş.Ltd.Şti. firmasına yaptırdığı yerleşim alanı imar planına esas jeolojik, jeofizik ve jeoteknik etüd raporunu yüksek lisans tez çalışmalarında kullanmak üzere müsaade istenilmektedir.

Söz konusu imar planına esas jeolojik, jeofizik ve jeoteknik etüd raporunun yüksek lisans tez çalışmalarında kullanılabilmesi için,bilgi ve belgelerin her türlü kullanım hakkının Elazığ Belediyesinde kalması şartıyla uygundur.

Bilgilerinize rica ederim.

Sebahattin UÇAR
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Belediye Başkan Yardımcısı