AN ANALYSIS OF THE RELATIONSHIP BETWEEN SETTLEMENTS, WATER RESOURCES AND ROCK TYPES IN ÇANKIRI PROVINCE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF GEOLOGICAL ENGINEERING

MAY 2005

Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

AN ANALYSIS OF THE RELATIONSHIP BETWEEN SETTLEMENTS, WATER RESOURCES AND ROCK TYPES IN ÇANKIRI PROVINCE

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May 2005, 91 pages

This study introduces an approach that seeks a possible relationship between settlement locations, water resources and rock types. The method is applied to Çankırı province (central-north Anatolia) which covers approximately an area of 8380 km^2.

Three main data sets used in this study. These are settlement, water and rock type data.

The methodology of the study is composed of five steps. The first step is the conversion of all water data into a standardized point data. Total number of point data for water is 23911 after this step. The second step is to find the distances between water resources and settlements. In the third step the densities of water resources and settlements are derived and then tested for the rock types in particular areas. The fourth step is the overlay analysis in which all three data sets are combined to find preferred and avoided regions of settlements in relation to water resources and rock types. In the last step all analyses are integrated to extract information on effect of two parameters on the selection of a site.

The main conclusions derived from the analysis are that: a) the mean and median distances between settlements and water resources are, 285 m and 163 m respectively, b) there is a strong relationship between water resources and settlement area, c) old clastics is the mostly preferred rock type whereas the carbonate rocks are mostly avoided.

Keywords: rock type, water resources, site selection, Çankırı

ÖZ

ÇANKIRI İLİNDE YERLEŞİM, SU KAYNAKLARI VE KAYA TÜRÜ İLİŞKİSİNİN ANALİZİ

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Tez Yöneticisi: Prof. Dr. Vedat Toprak

Mayıs 2005, 91 sayfa

Bu çalışma, yerleşim yeri, su kaynakları ve kaya türü arasındaki olası ilişkiyi araştıran bir yaklaşım geliştirmektedir. Yöntem orta-kuzey Anadolu'da yeralan ve yaklaşık 8380 km^2 'lik bir alanı kaplayan Çankırı iline uygulanmıştır.

Bu çalışmada inceleme alanına ait üç veri kümesi kullanılmıştır. Bunlar yerleşim, su kaynakları ve kaya türü verileridir.

Çalışmanın yöntemi başlıca beş aşamadan oluşmaktadır. İlk aşama tüm su verisinin nokta verisine dönüştürülülerek standardlaştırılmasıdır. Bu aşama sonucunda elde edilen noktasal su sayısı 23911 dir. İkinci aşama yerleşimler ile su kaynakları arasındaki uzaklıkların bulunmasıdır. Üçüncü aşamada ise su kaynaklarının ve yerleşim bölgelerinin yoğunlukları çıkartılmış ve öne çıkan bölgeler kaya türü veri tabanı ile de ilişkilendirilmiştir. Dördüncü aşamada üç veri tabanını çakıştırılarak su ve yerleşim yeri ilişkisi ışığında kaçınılan veya tercih edilen bölgelerin bulunmasıdır. Son aşamada ise bulunan sonuçlar değerlendirilerek su kaynakları ve kaya türünün yerleşim yeri seçimine etkisi açıklanmaya çalışılmıştır.

Analizlerden üretilen üç ana sonuç şunlardır: a) yerleşim yeri ve su kaynakları arasındaki uzaklıkların "mean" ve "median" değerleri sırası ile 285 m ve 163 m dir, b) su ve yerleşim yeri arasında güçlü bir ilişki vardır, c) yaşlı klastikler yerleşim yeri için en çok tercih edilen kaya türü olurken karbonatlar en çok kaçınılan kaya türü olmuştur.

Anahtar kelimeler: kaya türü, su kaynakları, yer seçimi, Çankırı

ACKNOWLEDGMENTS

I would like to thank;

My wife, for her patience and existence,

My parents and Kıvanç for their patience and assistance,

To my supervisor Vedat TOPRAK for his supervision, valuable suggestions and endless support,

My friend Taner Çiğdem, for his support on software, and his brilliant programs,

My old pal Arda, for his support.

To my friend Tibet,

Friends from ERG Group and all members of RS/GIS lab.

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CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope

It is widely accepted that selection of the location of a human settlement depends on so many local or regional factors that can have physical, environmental, cultural, social and political aspects. There is not, however, a single work that can rank these variables into a certain order and claim the importance of any of these factors on the selection of a site. Therefore, sometimes, a hot spring, a rock quarry or a morphological parameter can play a role in the selection of sites.

The main objective of this study is to find out the possible effect of the rock types and water resources on the selection of settlement location. The main emphasis in the study will be given to the methodology that seeks a relationship between these three parameters. Other factors such as proximity to main roads, land-use of the area, topographic conditions etc. will not be considered in the analysis.

The method will be applied to Çankırı province. Two main reasons for this selection are: 1) The area is relatively away from industrial regions and is not affected by recent technological development; therefore, it is believed that most of the settlements are old enough and already existed in the area before 20th century; 2) Two sets of data other than water data (rock type and settlement data) are already available in digital format that surved to save time.

1.2 Location of the Study Area

The study area, Çankırı province, which covers 8380 km^2, is located northeast of Ankara (Figure 1.1). The study area is covered within 89 1:25.000 scale topographic maps.

The area is generally mountainous and characterized by deeply dissected valleys oriented in E-W direction mostly due to the North Anatolian Fault zone that cuts across the area in its central parts.

Elevation in the area ranges from 400 m to 2400 m at Ilgaz Mountain, north of Ilgaz. The major rivers in the area are Kızılırmak, Devrez Çayı, Acıçay, Melen Çayı, Sogan Çayı, Terme Çayı and Uluçay.

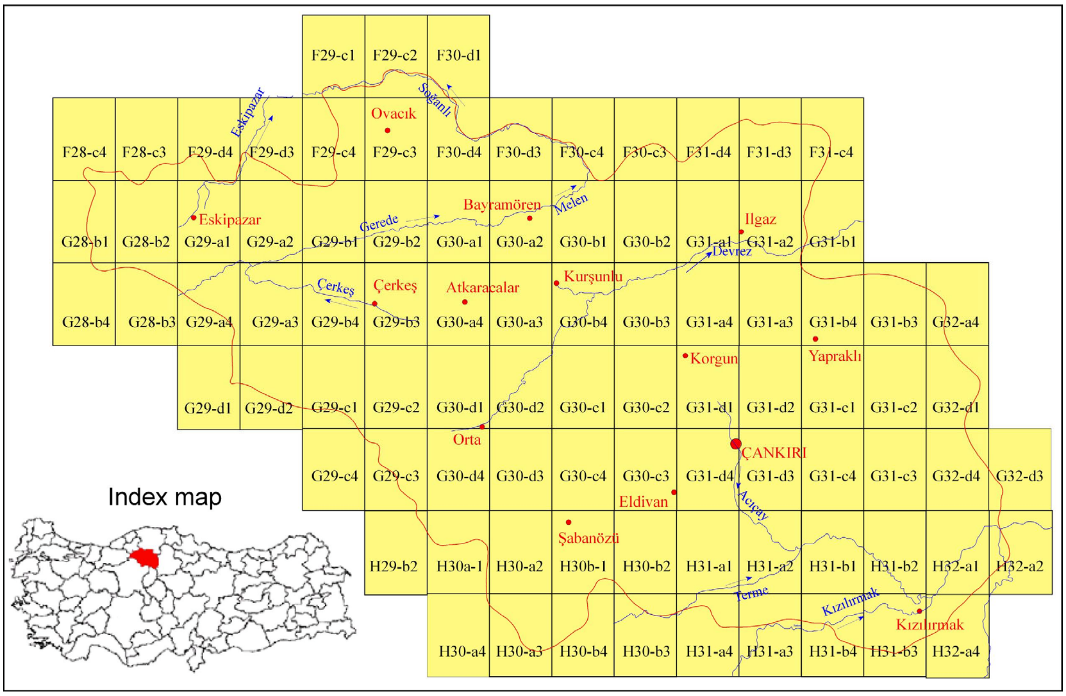


Figure 1.1: Location map of the study area. The map shows 1/25.000 scale topographic maps used in this study, the major settlements and rivers existing in the area.

1.3 Previous Works

The most prominent previous studies are three MS thesis carried out in the same area (Çankırı province) with almost similar purposes of this thesis. These are the works of Özdemir (2002), Sürmeli (2003) and Erdoğan (2004).

Özdemir (2002) investigated the relationship between the settlement site and the rock type. Topography is assumed to be the main factor controlling this relationship. Three data sets are used, rock types, settlements and topography. The methodolgy is calculating the percentages of settlements in rock types after non – suitable areas masked due to topographic conditions. Analysis indicated that there is a relationship between settlements and rock types at least for particular rock categories.

Sürmeli (2003) investigated the relationship between the locations of settlement in relation to the morphological classes. She suggested four morphological classes in the area as top, slope, valley and flood. Her method is composed of three major steps: masking topographically unsuitable areas; seeking the relationship between the settlements and landforms; and searching further analysis of the relative location of the settlements within the landform. She reached to a conclusion that people preferred to settle in the transitional zone of valley to slope.

Erdoğan (2004) analyzed effect of bright sunshine duration on the selection of a settlement. In his methodological approach he used topography to calculate the sunshine duration on daily basis. The result he obtained did not show any clear relationship between sunshine duration and settlement site.

A popular subject in the literature about the location of the settlements is the predictive modeling that tends to locate an unknown site using certain decision rules. These predictive models powered by the aid of GIS can provide accurate probability estimates of prehistoric site location in sample-surveyed study areas. Examples of such studies are those carried out by Parker (1981, 1985); Atwell and Fletcher (1987); Kvamme (1983, 1985, 1988, 1990, 1992); Brandt et al.

(1992); Maschner and Stein (1995); Duncan and Beckman (1996); Warren (1990) and Vanacker et al (2001).

Another commonly investigated subject is on the settlement pattern formed by the distribution of the sites in a region. These studies mostly apply certain statistical methods or use GIS in their solutions. Some examples of these studies are Wood (1978); Bettinger (1979); Evans (1980); Arnold and Ford (1981); Adams and Jones (1981); Kellogg (1987); Dewar (1991); Stea and Turan (1993); Lourens (1994); Kintigh (1994); Kuiper and Wescott (1999); Choquette and Valdal (2000) and Warren and Asch (2000)

Both group studies are commonly applied to archaeological sites. A short description of some of these studies is given below.

Wood (1978) developed a model that describes settlement space in relation to critical variables derived from the ranks of distances from sites to critical resources. He emphasizes that with additional data, the assessed optimality of site locations could be devised.

Parker (1981) emphasized that there is a direct importance in the settlement pattern in relation to the management of the surrounding natural resources. In the selection of a settlement location, three sets of processes and criteria are involved. These are social system, the aggregated "culture" and the structural information. He attempted to develop a methodology for generating exploratory site location models.

Parker (1985) generated a model for the settlements in Sparta area. In this model he used variables by selecting a portion of the basic life supporting properties for the settlement location. These are a permanent water supply, food resources, trees (for firewood), construction materials, hazard-free safe locations.

Kvamme (1985) analyzed environmental, ethnographic and social effects on the location of prehistoric sites. During his investigation major environmental factors were selected to be hydrology, landform (slope and relief), soil and vegetation. Slope and local relief were found to be significant factors at the location of sites which are interpreted as agents for reducing energy costs of movement.

Kvamme (1990) emphasizes that the distance to water sources, slope, aspect and elevation are important input parameters for regional scale settlement analysis. He also propesed that GIS is a very important tool in such analyses.

Stea and Turan (1993) analyzed in detail the natural environment effect on the location of settlements. They applied their study in two regions, Central Anatolia of Turkey and Pajarito Plateau of New Mexico very similar in terms of geology and morphology, but differ greatly in cultures. They point out that the "place making" is a complicated an integrated process with physical, economic, cultural and political components.

Lourens (1994) studied densely populated tribal areas in South Africa to identify suitable areas for urban settlement. Hydrology, geology, soil types, topography and nature conservation are identified to be factors influencing the settlement area. In the model used in the study, first, a general probability model is built up from the probability index of each factor, and then current settlements are compared with this model. Results show that recent settlements are located in non suitable areas and large areas with high agricultural potential have been invaded.

Kuiper and Wescott (1999) focused on the use of GIS based predictive mapping to locate prehistoric archaeological sites. The knowledge of the environmental variables influencing the activities of the inhabitants to produce the GIS layers represents the spatial distribution. Location of water, type of water source, soil, elevation, slope and topographic settings are used in the study. They used known prehistoric sites to predict locations of unknown ones.

Choquette and Valdal (2000) attempt to develop an archeologically potential predictive model using GIS. They used five main GIS layers as predictors. The archeological sites are evaluated by the intersecting layers of the GIS environment. There are four main iterations in their model. Each iteration is compared against a known set of archeological sites. It was decided that nothing more could be added to the model after fourth iteration. They claim that the results of the potential and non potential areas resulting from the fourth-iteration-query should be tested in the field.

Warren and Asch (2000) used GIS to create a high-resolution predictive model of prehistoric archaeological site locations in a poorly drained upland prairie region of central Illinois. The model is based on a logistic regression analysis of sample data using qualitative and quantitative measures of the natural environment as independent variables. The modeled distribution of settlement appears to reflect complex prehistoric strategies of resource use, but it also could have been affected by geomorphic processes of landscape evolution.

1.4 Geological Setting

Two aspects about the geology of the area that should be mentioned here are:

1) The rock units of the area are the main concern of the study. They will be explained in detail in the next chapters. Therefore here only a brief explanation will be given.
2) Structural features and other geological information such as folds, faults, landslides etc are not involved in this study considering the scope of the thesis.

Geological map of the study area prepared by MTA (General Directorate of Mineral Reseach and Exploration) at 1:500.000 scale is shown in Figure 1.2. Rock units exposed in the area, according to this map, are categorized into 11 types. These are from the oldest to the youngest: Two Quaternary clastic units exposed among the major streams; a Neogene continental clastic unit exposed as two belts in the central and southern parts; an Oligo-Miocene gypsiferous unit exposed in the southeastern part; a volcanic unit observed in the western part; an Eocene clastics (flysch) composed of several scattered exposures; a Cretaceous sequence observed in the northen parts; an ophiolitic sequence of

Cratecous age extending as a belt from SW to NE; an undifferentiated Jurassic to Cretaceous sequence with small outcrops exposed in the western part; and two metamorphic sequences of Mesozoic and earlier ages.

North Anatolian Fault zone is the most important structural element in the area. This zone is also one of the effective tools that determine the location of water resources (particularly springs) exposed in the region. This zone is oversimplified in the geological map (Figure 1.2) and is illustrated with three strands.

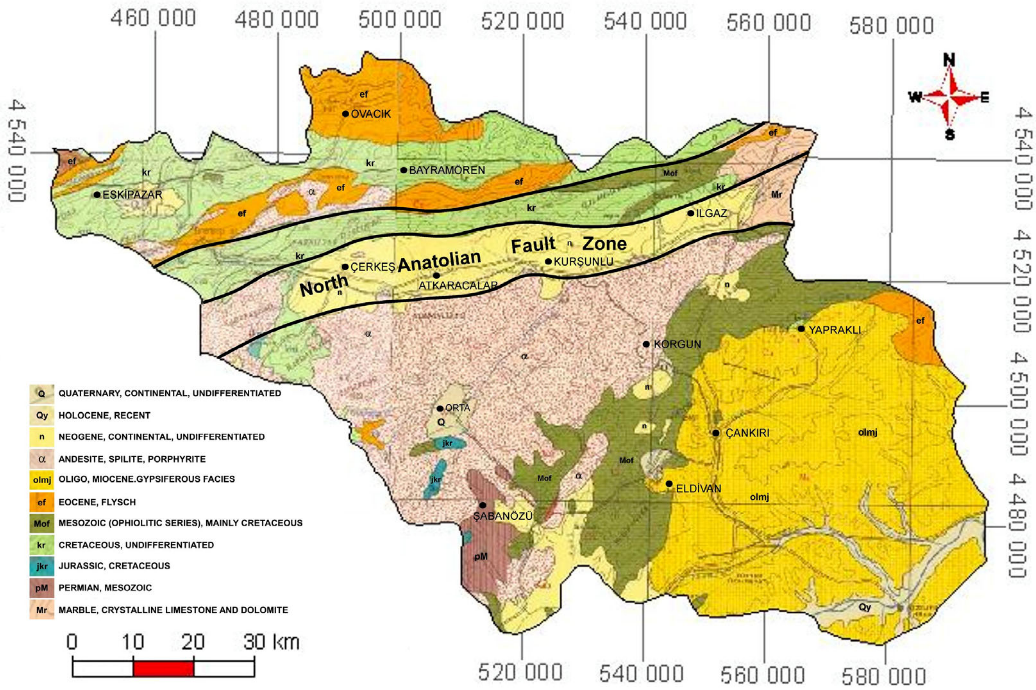


Figure 1.2: Geological map of the area from 1:500000 scale map of Turkey (above) and simplified map (below)

1.5 Software packages used

The study is based on office work consisting of creation and evaluation of various data sets. Following software packages were used during the preparation and evaluation of data in the study:

- TntMips (v6.8) : Digitization of water data
- AutoCAD : Preparation of the data and overlay analysis
- "macro" : Overlay analysis
- QBASIC : Density and distance analyses
- RockWorks : Preparation of the histograms
- Surfer : Evaluation of the density maps and basic statistics
- Microsoft Excel : Compilation of data; preparation of histograms

1.6 Organization of Thesis

The rest of this thesis is organized as follows:

- Chapter 2 describes and introduces the data sets, which are created and used for this thesis.
- Chapter 3 describes the method and the analysis used for the investigation of the relationship between settlement locations, water resources and rock types.
- Chapter 4 discusses the data used in the study and the result obtained after the analysis.
- Chapter 5 states the main conclusions of this thesis.

CHAPTER 2

DATA

Three sets of data are used in this study. These are 1) rock units, 2) settlements, and 3) water resources existing in the area. Major characteristics of these data will be introduced in this chapter.

2.1 Rock Units

Rock unit data used in this study are generated from 1/100.000 scale geologic maps obtained from MTA (Mineral Research and Exploration, Turkey). Özdemir (2002) reclassified the rock units in these maps and prepared a map to be used in her study carried out in the same area. She scanned, registered and digitized the maps from which the final map was prepared. The boundaries of the rock units are not modified and no field study is performed for the verification of these boundaries (Özdemir 2002). In addition, geological information other than "rock types" for example fault lines, landslide areas, and various planar and linear measurements are not taken into consideration.

In the original geological maps, 93 different rock units exist. A short description of each rock unit available in the original maps is given in Appendix-1. This large number is due to the differences either in the age or rock characteristics of the units. For example a sandstone body that has similar physical characteristics can exist in the area in five different ages. In this case, sandstone will be recorded and mapped as five different rock units. To prevent this repetition and minimize the total number, all rock units are re-evaluated and re-classified in accordance with the purpose of the study by Özdemir (2002). She considered physical properties and age of the rock units in her study and obtained a total of 11 rock categories after re-classification. This new classification is analyzed and seems to be consistent with the purpose of this study. Therefore the classification of Özdemir (2002) is assumed to be correct and adopted and used in this study.

In this classification, alluvium represents a unique group by its discrete nature. Clastic sedimentary rocks are separated into three different units considering their depositional environment and the degree of compaction. Volcanic rocks are re-grouped into three categories based on their stratigraphic position, degree of chemical alteration and distinct spatial distribution in the study area. One class of carbonates is formed by gathering all units rich in calcareous material. Metamorphic group is composed of metamorphosed material existing in the area. The last two groups are olistostrome and ophiolite which are composed of heterogeneous material specific to the zone of collision.

Summary of information about these rock types is given in Table 2.1. Resultant geological map and areal extend of the rock categories are given in Figures 2.1 and 2.2. A short description of each rock category is given below based on the description of Özdemir (2002).

Alluvium: This group forms 9.53 % of the total area and is composed of only one rock type in the original map. The age is Quaternary; it is exposed along the major streams of the area (Figure 2.2).

Soft clastics: This group is formed by Pliocene clastics and comprises 9.44 % of the total area. It includes only 2 units from the original dataset characterized by unconsolidated, non-layered continental clastic rocks (Figure 2.2).

Layered Clastics: These rocks are composed of clastic and evaporitic rocks of Oligocene to Miocene age. This is the most dominant class in the region and comprises 23.60 % of the total area. It involves 11 units in the original dataset. They are mainly restricted to southeastern part of the area and exposed on both sides of Kızılirmak River (Figure 2.2).

Old Clastics: This category is composed of well compacted and consolidated layered sedimentary units. Dominant rock types are marine shale, sandstone, siltstone and conglomerate. They form 12.02 % of the area and involve 25 units of the original dataset. Age of rocks in this category ranges from Mesozoic to Early Oligocene (Figure 2.2).

Table 2.1: Summary table of re-classified rock categories (Özdemir, 2002).

Rock Categories	No of Classes in the original data	Area covered (%)	Age
Alluvium	1	9,5	Quaternary
Soft Clastics	2	9,3	Pliocene
Layered Clastics	11	23,4	Oligocene to Miocene
Old Clastics	25	11,9	Mesozoic to early Oligocene
Pyroclastics	9	20	Miocene
Lava Flows	10	4,4	Late Cretaceous to Pliocene
Old Volcanics	7	4,4	Jurassic to Cretaceous
Carbonates	14	4,9	Jurassic to Quaternary
Metamorphics	8	1,5	Pre-Cambrian to Jurassic
Olistostrome	2	3,6	Permian to early Eocene
Ophiolite	4	7	Jurassic to Cretaceous

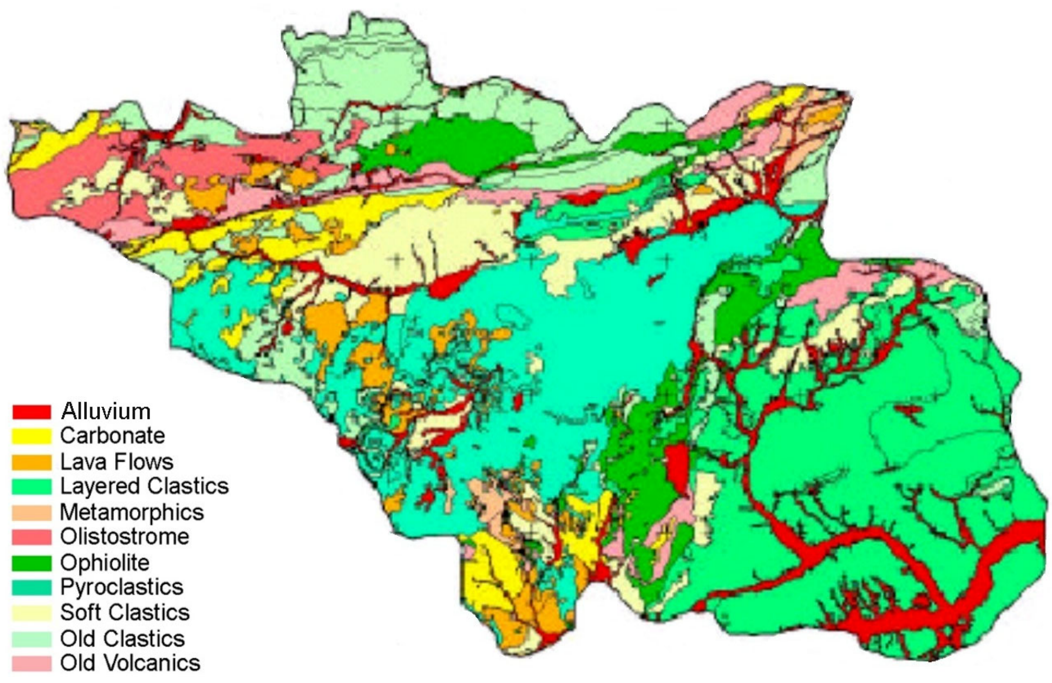


Figure 2.1: Resultant geological map of Çankırı province after re-classification of rock units (from Özdemir, 2002).

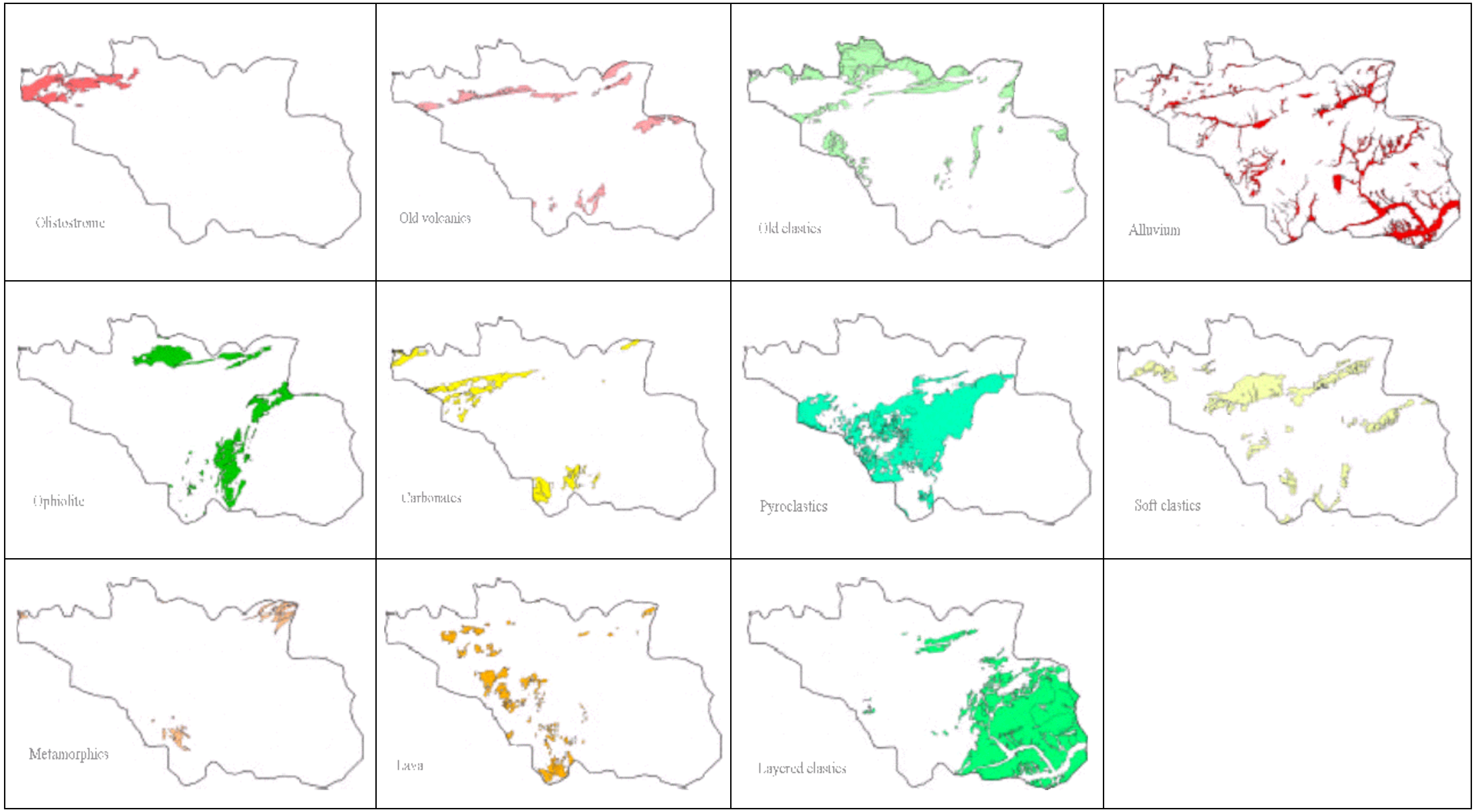


Figure 2.2: Distribution of rock categories in the area (modified from Özdemir, 2002)

Pyroclastics: These are volcanic products other than lava flow composed of Miocene volcaniclastics (tuff, agglomerate) of andesitic, dacitic and basaltic composition. It class is the second major class with 19.47 % and involves 9 units from the original dataset. They are exposed in the western and central part of the area (Figure 2.2).

Lava: This category is represented by lava flows erupted at different time periods (Late Cretaceous to Pliocene). Dominant lithologies are basalt, andesite, rhyolite and dacite. Few very small outcrops of granite and granodiorite are also included in this group. The group involves 10 units from the original dataset and comprises the 4.56 % of the total area (Figure 2.2).

Old volcanics: Older volcanic rocks are grouped into a separate category considering their age, degree of their alteration and distinct spatial distribution. The group is composed of andesites, dacites, basalts, agglomerates and tuffs. They are Jurassic to Cretaceous in age. The group involves 7 units from the original dataset and comprises the 4.32 % of the total area (Figure 2.2).

Carbonate: This group is composed of limestone, travertine and chert. It involves 14 units from the original dataset and comprises the 4.97 % of the area ranging in age from Jurassic to Quaternary (Figure 2.2).

Metamorphics: These are the oldest rocks in the area (Precambrian to Jurassic) composed of meta-granitoids, meta-olistostromes, meta-clastics, schist, phyllite and marble. The group involves 8 units from the original dataset and comprises the 1.55 % of the area (Figure 2.2).

Olistostrome: This group is a mixture of heterogeneous material ranging in age from Permian to E. Eocene. It involves 2 units from the original dataset and comprises the 3.57% of the area (Figure 2.2).

Ophiolite: Ophiolite is composed of mafic/ultra-mafic rocks (ophiolite, chert-basalt-shale-ophiolite, gabbro-ophiolite and mélange with an age range from

Jurassic to Cretaceous. The group involves 4 units from the original dataset and comprises the 6, 99% of the area (Figure 2.2).

A total of 974 polygons are digitized and stored by TNTMips.

2.2 Settlement Data

Settlement data used in this study are obtained from the work of Sürmeli (2003). She identified 891 settlements using topographic maps of 1984-1997 at 1:25.000 scales. During the creation of the settlement database, following criteria are applied (Sürmeli, 2003):

- No distinction is made between the settlements (village, district or city) considering their size, population or administrative structure. They are all counted in the database and considered as a single settlement.
- Each settlement is considered to be represented by a definite point on the map which is, most probably, the initial location of the settlement. Therefore, the later growth in size and boundaries of the settlement is not important in this study.

The database created for the settlements holds Id no, easting and northing measurements of the settlements. Distribution of settlements used in this study is shown in Figure 2.3.

2.3 Water Resources

Water data used in this study are obtained from topographic maps of 1984-1997 at 1:25.000 scale by manual digitizing. During creation of the water database the resources are divided into three main types which are:

- Linear resources: Streams
- Point-like resources: Springs; Wet fountains and Dry fountains
- Polygonal resources: Lakes

Measurement, storage and general characteristics of these five water resources (streams, springs, wet fountains, dry fountains and lakes) are described below.

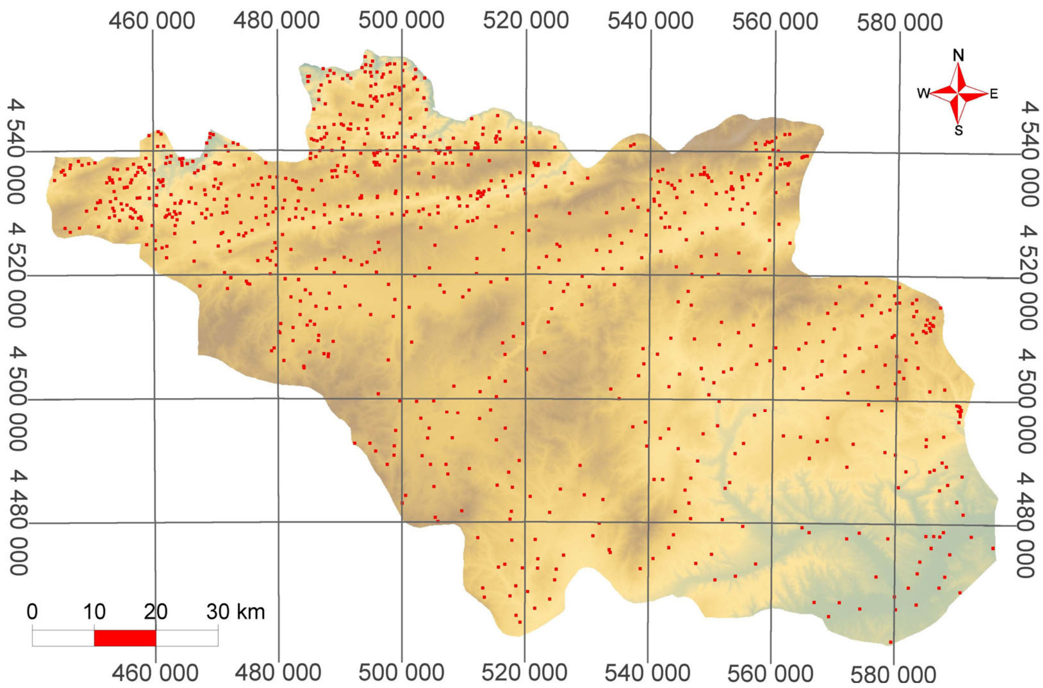


Figure 2.3: Location map of 891 settlements used in this study

2.3.1 Streams

Stream database is created by on-screen digitization using TNT-Mips software. The data belong to the main streams (Kızılırmak, Devrez Çayı. Acıçay, Melen Çayı, Sogan Çayı, Terme Çayı and Uluçay) existing in the area and their tributaries. Following criteria and assumptions are applied during digitization:

- Only permanent streams are digitized. Dry or intermittent streams are not considered in this study since they do not contain water. However, digitized streams are not justified with any external information. Therefore, the resultant stream data is manual interpretation basing on "solid blue line" provided in the map and the shape/size of the valley.
- For each stream channel only one line is drawn whatever the valley-size or discharge of the stream is. For certain parts of some streams (such as Kızılırmak stream), the flood plain is larger than 3 km and the stream is observed as two or more parallel channels. In such cases only one channel is

digitized and others are not considered. The main reason for this is that the lateral shift and bifurcation of the stream channels is a common process in the flood plains and can have different patterns from time to time. Considering the purpose of the study, these variations are not linked to the location of a settlement and, therefore, are ignored in this study.

- Streams are considered to be continuous lines from head to the next junction. Therefore, a "solid blue line" which is not connected to a major stream is not digitized, and a gap represented by "dashed blue line" between two solid sections is digitized as stream.

Figure 2.4 shows general distribution of the streams digitized and used in the calculations in this study. Certain areas in the figure are free of streams that correspond to mountain tops in the region. The southeastern part of the area belongs to the drainage basin of Kızılırmak river and has a coarser drainage texture compared to the other parts of the area. Total length of the streams is around 3700 km.

2.3.2 Springs

Springs constitute one of the point-like water resources in the area. They are digitized from 1/25.000 scale topographic maps using standard blue symbol for springs. Following features should be noted for the spring data:

- Springs are searched and digitized manually on the screen.
- Each spring symbol is marked for one spring.
- No distinction is made between the springs of different discharges. No data is available to test the discharge. Therefore, all the springs in the database are assumed to have the same weight in the analysis.
- Study area is cut by active faults that can affect location of the springs. Therefore, a change in the position of the springs can be expected anywhere, anytime. Accordingly, coordinates of the springs included in the database belong to the period the maps, namely, 1984-1997.

The database created for the springs involves a total of 5254 records. Figure 2.5 shows general distribution of springs in the study area.

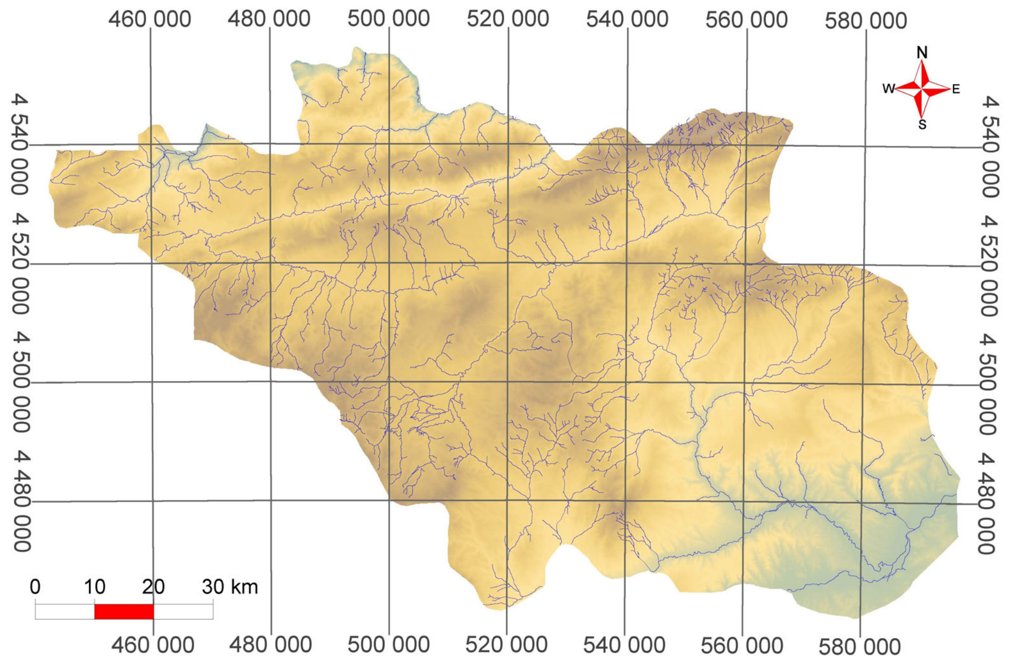


Figure 2.4: Stream map of the study area

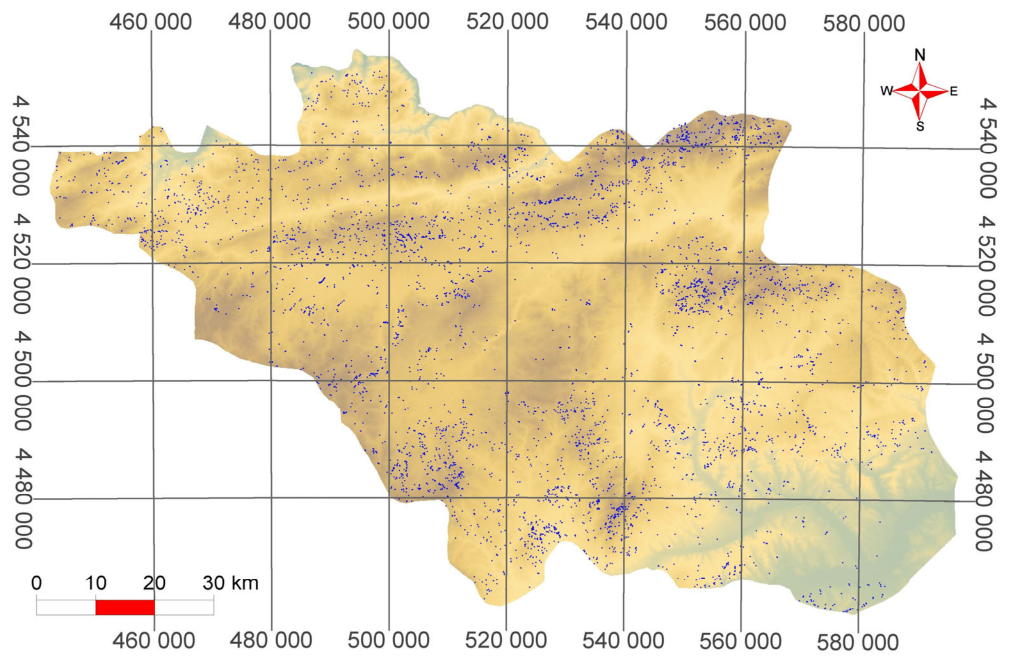


Figure 2.5: Spring distribution in the study area

Although, the springs exist everywhere in the area, some clusters are observed in certain parts. Particularly, in the central north part of the area, a cluster extending NEE-SWW (parallel to the North Anatolian fault zone) is overemphasized.

2.3.3 Wet Fountains

Wet fountain is the second type of the point-like water resource. Although some of the fountains might be in-situ, some others may be transported from its original location. There is, however, no data to estimate amount and direction of transportation for these data. The rules for detecting and digitizing these data are similar to the rules mentioned for springs. "Blue fountain symbol" is used to digitize them. A total of 2076 wet fountains are identified in the area (Figure 2.6). Wet fountains in the northwestern part of the area are distinguished by their abundance compared to other parts.

2.3.4 Dry Fountains

Dry fountain is the third type of the point-like water resources. Although they are very limited in number (27 fountains) they are digitized and included in the database (Figure 2.7). Most of them are located to the northern part of the area where North Anatolian Fault zone is exposed. Therefore, they are good examples of the change in the location of the springs in the area due to tectonic movements that occur in the area.

2.3.5 Lakes

The last types of the water resources are the lakes which are polygonal water bodies. A total of 45 lakes are identified in the area. The boundaries of lakes are digitized and stored in the database as polygons (Figure 2.8).

Artificial lakes constructed as reservoirs are not taken into consideration, because such lakes might be very new and may not play a role in the selection of a site. Therefore, only natural lakes which are earlier than any settlement in the area are dealt with.

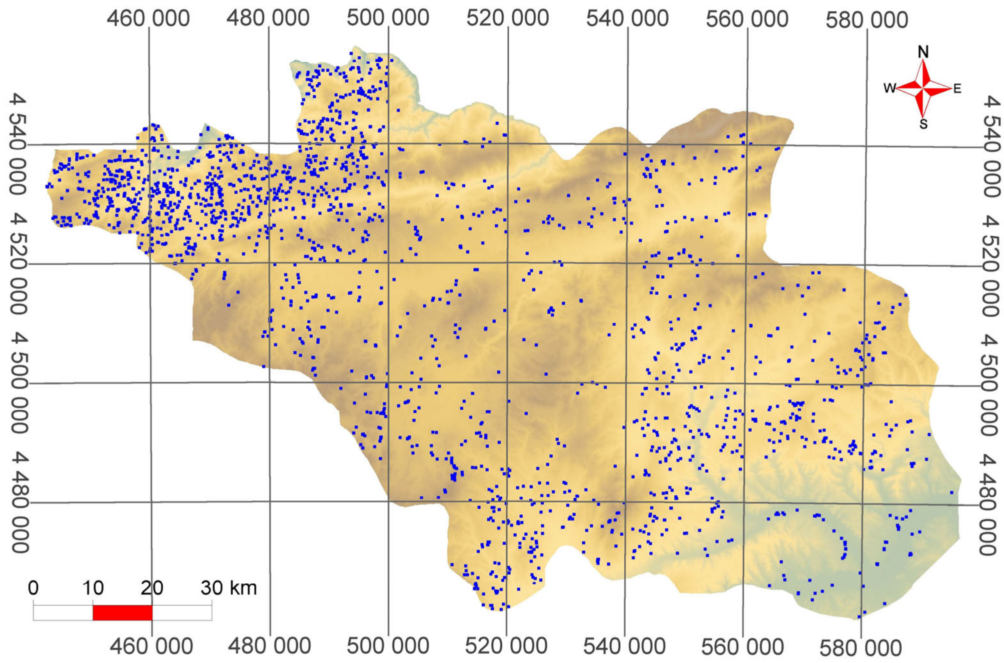


Figure 2.6: Wet fountain distribution in the study area

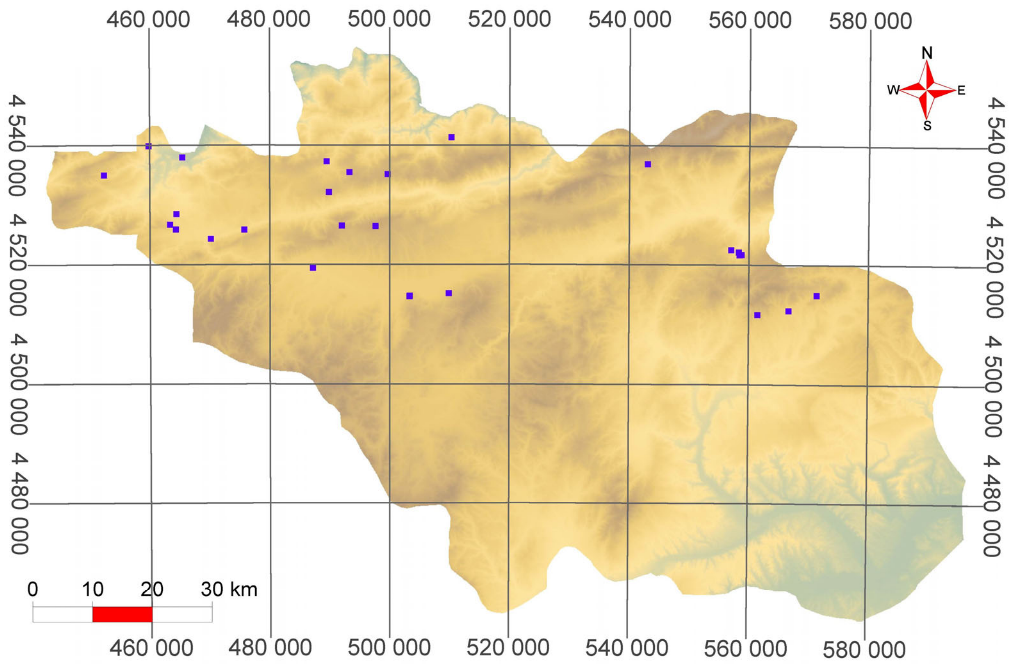


Figure 2.7: Dry fountain distribution in the study area.

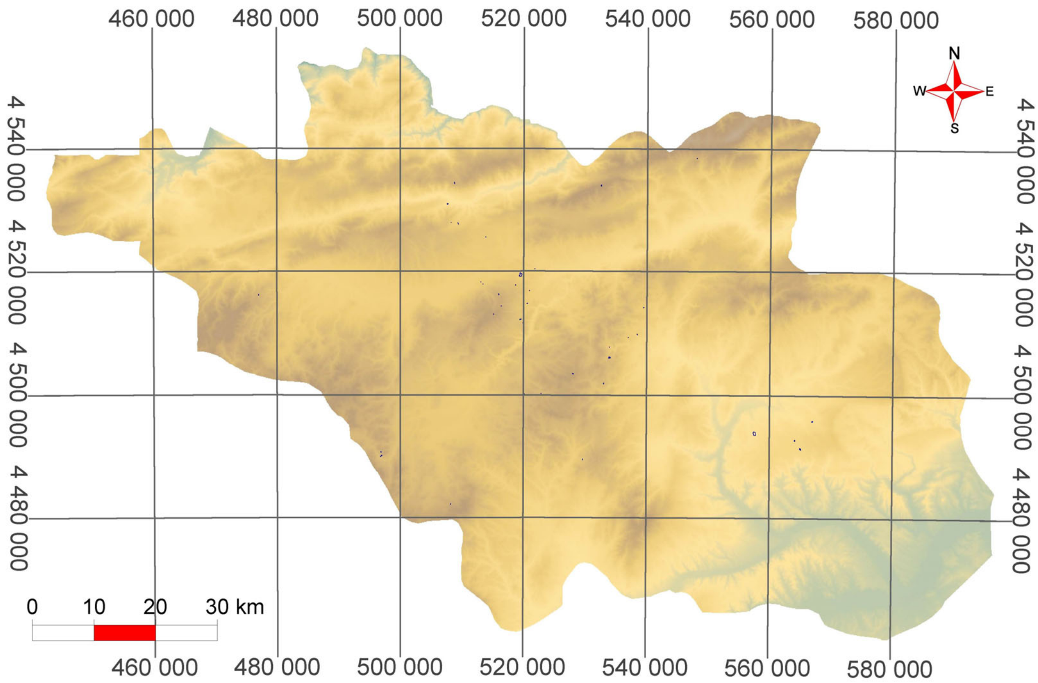


Figure 2.8: Lake distribution in the study area

CHAPTER 3

METHOD AND ANALYSIS

This chapter describes the methodology used in the study and analyses carried out to seek a relationship between the water resources and location of settlements.

3.1 Methodology

Methodology used in this study is composed of five main steps (Figure 3.1). Each step is explained in detail in the following sections. A short description of these steps is as follows:

Step 1: Handling of water data: Water data used in this study involve different types of water resources. In this step all types will be converted into one type to have a final water database.

Step 2: Distance analysis: The purpose of this step is to analyze the distance between water resources and the settlements.

Step 3: Density analysis: This section describes the methodology that seeks a probable relationship between water, settlement and rock units.

Step 4: Overlay analysis: In this section the spatial relationship between water resources, rock types and settlements will be investigated.

Step 5: Results of the previous sections will be merged to comment on the location of a settlement in relation to water resources and the rock types.

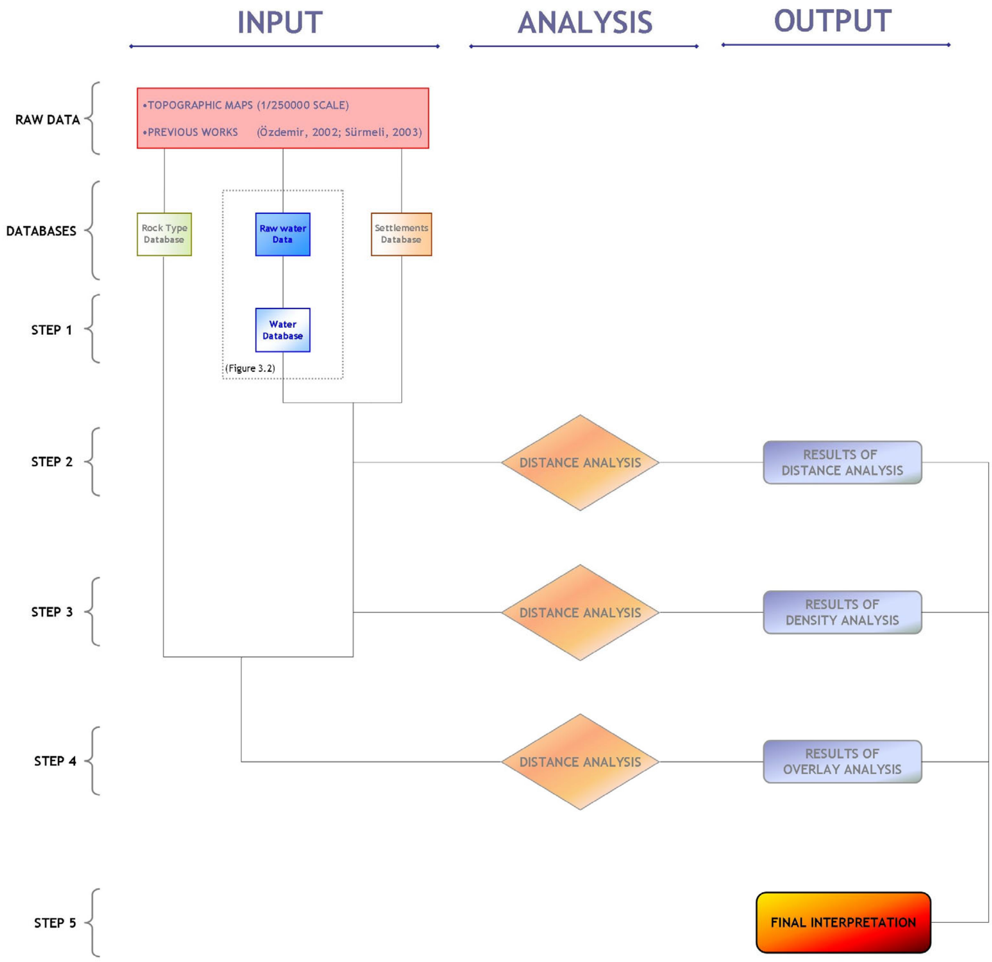


Figure 3.1: Flowchart showing major steps of the methodology used in this study.

3.2 Handling Water Data Set

Water data collected in this work and stored in the database are in three formats, namely, point, line and polygon. The first difficulty, therefore, encountered in the method is to convert all these into one type in order to keep the consistency among various types. The best solution for this is to convert the whole data into "point-data". Accordingly, the stream data which are stored as lines and the lake data which are stored as polygons should be converted to point data. General characteristics and the conversions made for the water data are shown in Figure 3.2.

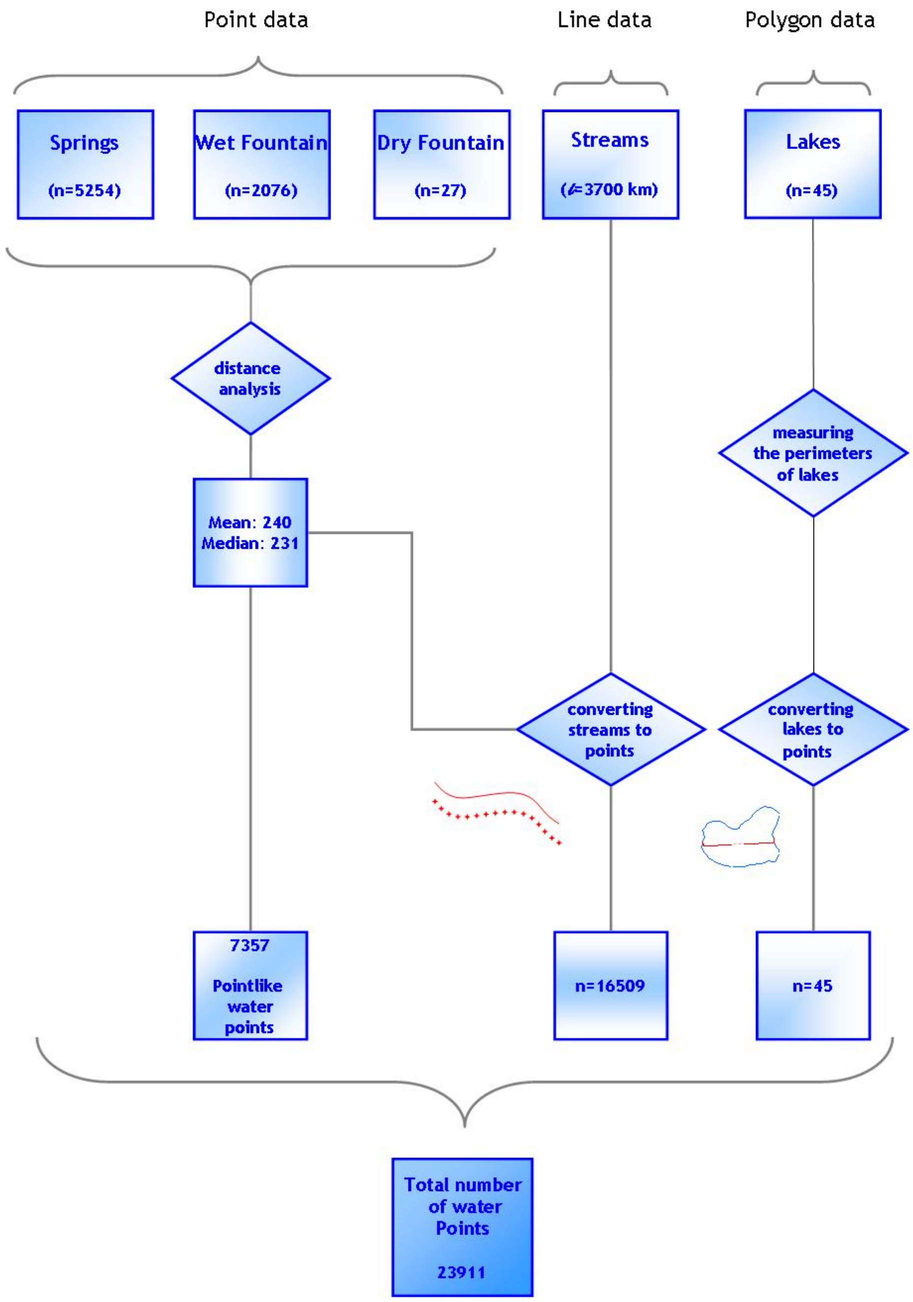


Figure 3.2: Flowchart showing steps of the methodology used for handling water data.

Conversion of stream data: The conversion of stream data into point data is practically easy since most of the software packages are able to divide a line with a given constant interval. The length (distance) of this interval, however, should be based on a logical reason. Otherwise, a bias will be added to the data either in positive or negative way. For example, the division of stream by 100 m or 1000 m intervals will produce totally two different point sets in which the weight of streams will be more or less than the springs, respectively.

To overcome the problem, this interval is decided to be determined by the average distance between other point-like data existing in the area. To find this optimum distance all point-like data (springs, wet fountains and dry fountains) are added to form a single "point-like database". This database contains a total of 7357 point data. A program is written in BASIC language to find the distance to the nearest point (Appendix 2). Histogram of the resultant file is shown in Figure 3.3.

Histogram in the figure is drawn according to 50-m bin interval. The maximum concentration, accordingly, is between 50 and 100 m. The mean and the median of the data are 340.9 m and 231 m, respectively. The median value is selected as "unit length" to convert the stream data into point data. Conversion process is made by AutoCAD software and final stream database in point data is obtained. Total number of the points in this database is 16509.

Conversion of lake data: The conversion of lake data into point data is more problematic compared to the former one because the lakes are represented by polygons that have a certain surface. Two main difficulties in this case are: 1) by how many points the lakes should be represented, and 2) where to put this/these points on the lake polygon.

To solve these problems the perimeters of the lakes are measured by AutoCAD software and analyzed. Minimum and maximum perimeter lengths are 78 and 1724 m, respectively (Figure 3.4). The mean and median, on the other hand, are 320 and 220 m. Maximum concentration is observed with a percentage of 22 at 100-150 m interval.

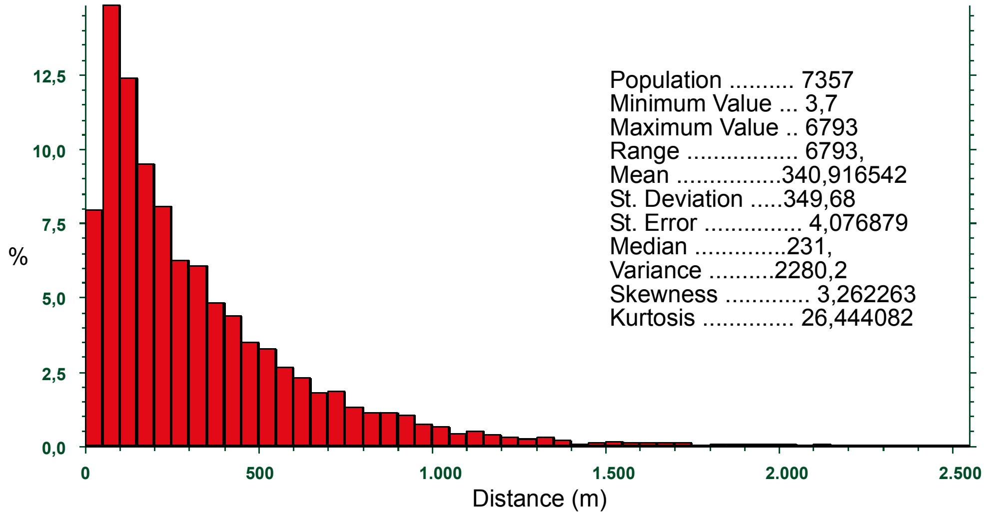


Figure 3.3: Histogram of the distances between point-like (spring, wet fountain, dry fountain) water resources. (Right tail of histogram is truncated).

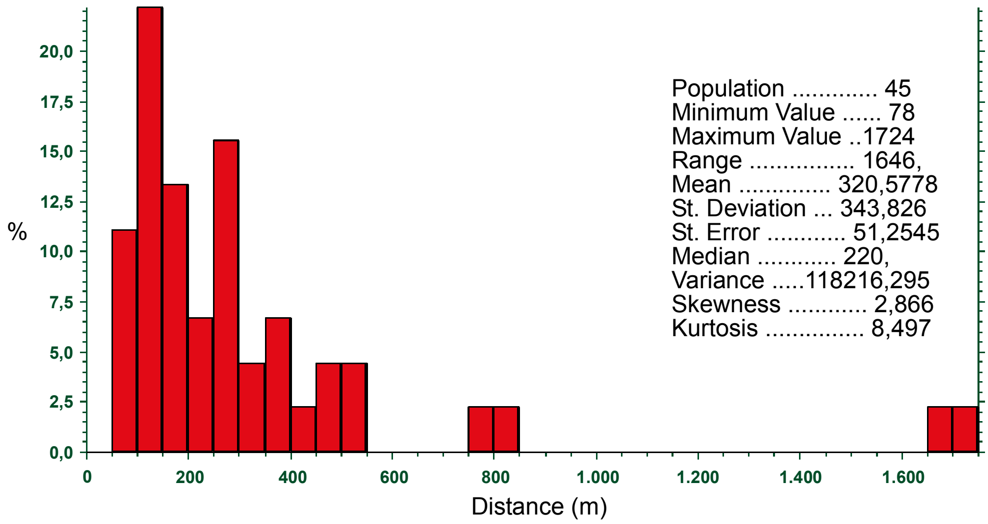


Figure 3.4: Histogram of the lake perimeter lengths.

Radii of these lakes are calculated using the equation perimeter=2*Π*r (Table 3.1). Diameters of these values (the distance from one margin of the lake to the other margin) are twice these distances. Accordingly, the maximum diameter is about 580 m with mean and median values of 104 and 71 m, respectively.

Whether based on the peripheral distance or on the diameter across the lake, the average distance for lake is less then the one selected for streams. Therefore, it is decided that each lake should be represented only by one point. This decision is compatible with the fact that most of the lakes would not be suitable to be selected by more than one settlement considering the space problem. Although the shapes of the lakes are not perfect circular, an attempt is made to locate the points manually to the center of the lakes.

Table 3.1: Basic statistics of the radii of the lakes in study area

	Minimum	Maximum	Mean	Median	Sd. Dev.	Sd. Error
Radius	12.6	279.1	51.9	35.7	55.6	8.3

After conversion of lake data, all the water data are collected in a single database that contains 23911 records. Summary of these data is given in Table 3.2. Accordingly, 69 % of the whole water data is composed of stream data and the rest by point-like data including the lakes.

Table 3.2: Summary of the water data used in this study

Water type	Frequency	Percentage
Springs	5254	22,0
Wet fountains	2076	8,7
Dry fountains	27	0,1
Lakes	45	0,2
Stream	16509	69,0
TOTAL	23911	100.0

3.3 Distance Analysis

Distance analysis aims to evaluate the distances between settlements and water resources. A program is written in BASIC language to calculate the distances (Appendix 3). The program reads X and Y coordinates from two input files (settlement database and water database) and finds the nearest (minimum distance) water resource. The program is executed three times to find three nearest distances which are: a) distance to point-like water resources including, springs, wet fountains, dry fountains and lakes, b) distance to linear water resources (streams) and, 3) distance to any water resources. The reason for this is to analyze the difference in the distances to two types of water resources. Basic statistics of the results are given in Table 3.3. Plots of the results are shown in the histograms in Figure 3.5. Following observations can be made based on these results:

- The mean and median distances to the springs are 518 and 282 m, respectively (Figure 3.5-A). Maximum concentration is at 0-100 m with a density of 22 %. About 40 % of the springs are within 200 m distance, and 70 % within 600 m.
- The mean and median distances to the streams are 937 and 546 m, respectively (Figure 3.5-B). Maximum concentration is at 100-200 m with a density of 15.4 %. About 40 % of the streams are within 400 m distance, and 70 % within 1500 m.
- Results of the first two analyses suggest that the settlements are closer to the point-like water resources. The ratio of this difference is almost 1/2 as indicated by both mean and median values.
- If no distinction is made between the type of the water type, the nearest distance considerably drops to lower values (mean: 285 m; median: 163 m). About 70 % of the all water resources is within 300 m distance (Figure 3.5-C)

Table 3.3: Basic statistics of the distances between settlements and water resources. A: nearest point-like water, B: nearest stream, C: nearest any water

	Minimum	Maximum	Mean	Median	Sd. Dev.	Sd. Error
A	3	5909	518.0	282	633.8	22.2
B	5	6600	937.4	546	1023.6	34.3
C	3	4167	285.0	163	377.3	12.6

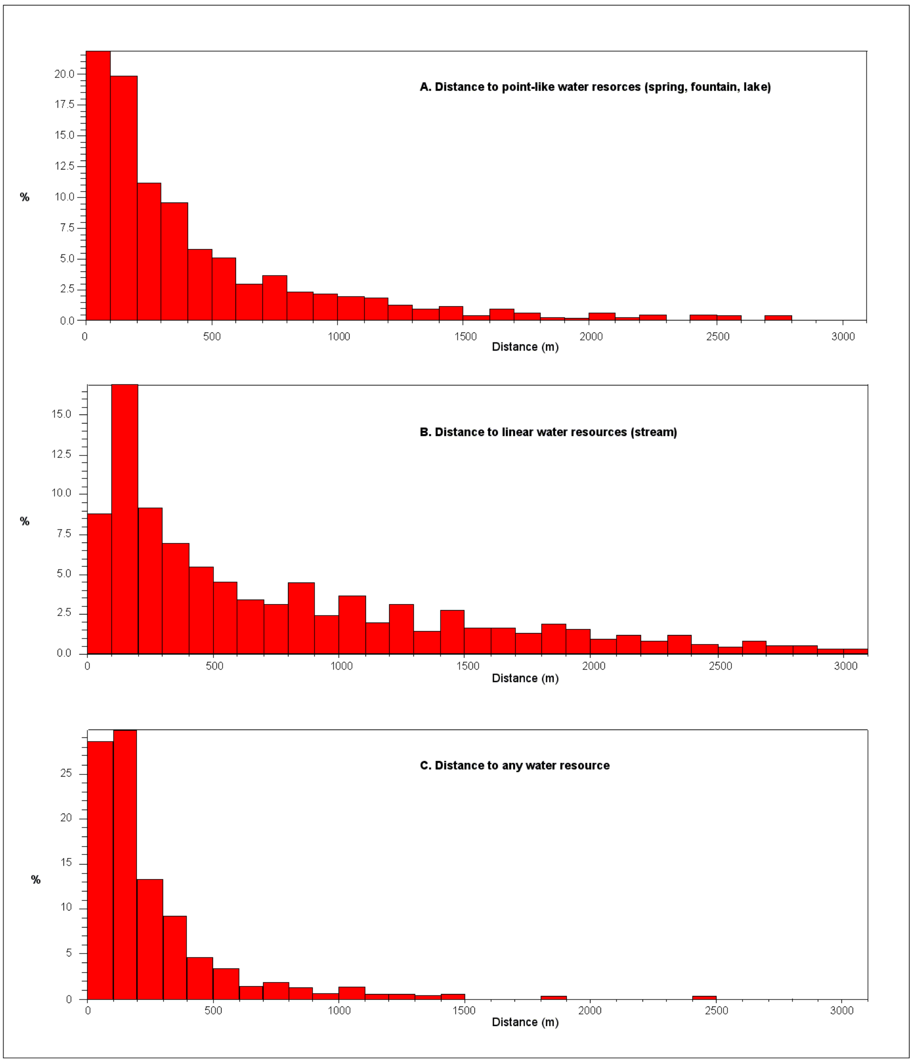


Figure 3.5: Histograms showing minimum distances between settlements and water resources.

3.3 Density analysis

The purpose of the density analysis is to find out where the data are concentrated within the study area. The density maps are prepared for water database and settlement database because these two data sets are of points. This process is completed in three stages:

1- Generation of two density maps for two datasets

2- Overlaying these two maps to find inconsistent areas (one set has high, the other has low values or vice versa), and

3- Checking rock units in these inconsistent areas.

Stage 1: The procedure of the density analysis is illustrated in Figure 3.6. Numbers of data (settlements and water points) are counted within a circular area whose search radius is 5 km and grid spacing (shift amount) is 1 km. This number is assigned to the grid that corresponds to the center of circle. A BASIC program is written to count the number for each grid and to move the circle from left to right for all columns and top to bottom for all rows (Appendix 4).

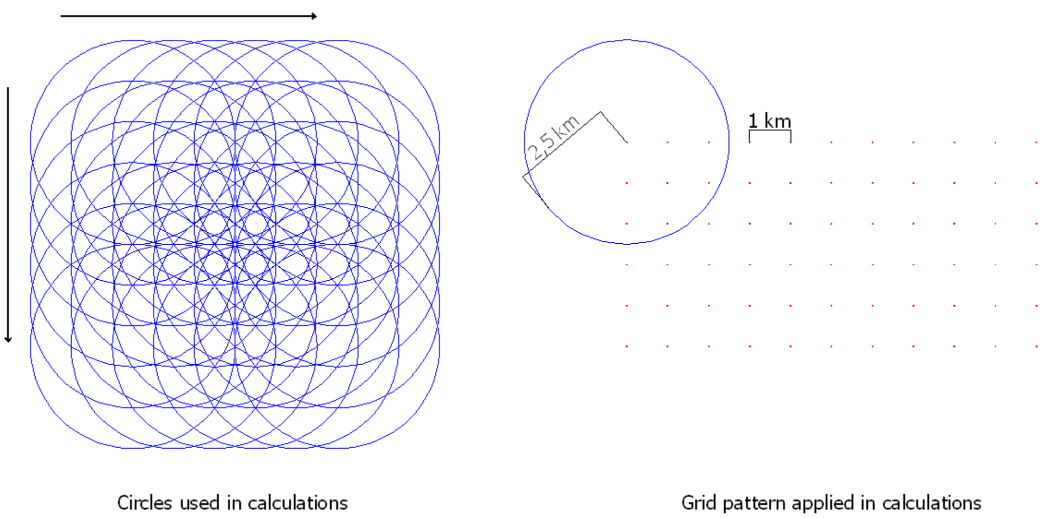


Figure 3.6: Principle of the density analysis carried out in the study (Modified from Ayhan, 2004)

The outputs of this stage are illustrated in two density maps in Figure 3.7. In both maps blue color corresponds to lower values and red to higher. Higher concentrations of the settlements are confined to the northwestern part of the area (Figure 3.7.A). The water data, on the other hand, has a patch of concentration in the northwestern parts and other smaller concentrations in the central and southern parts (Figure 3.7.B).

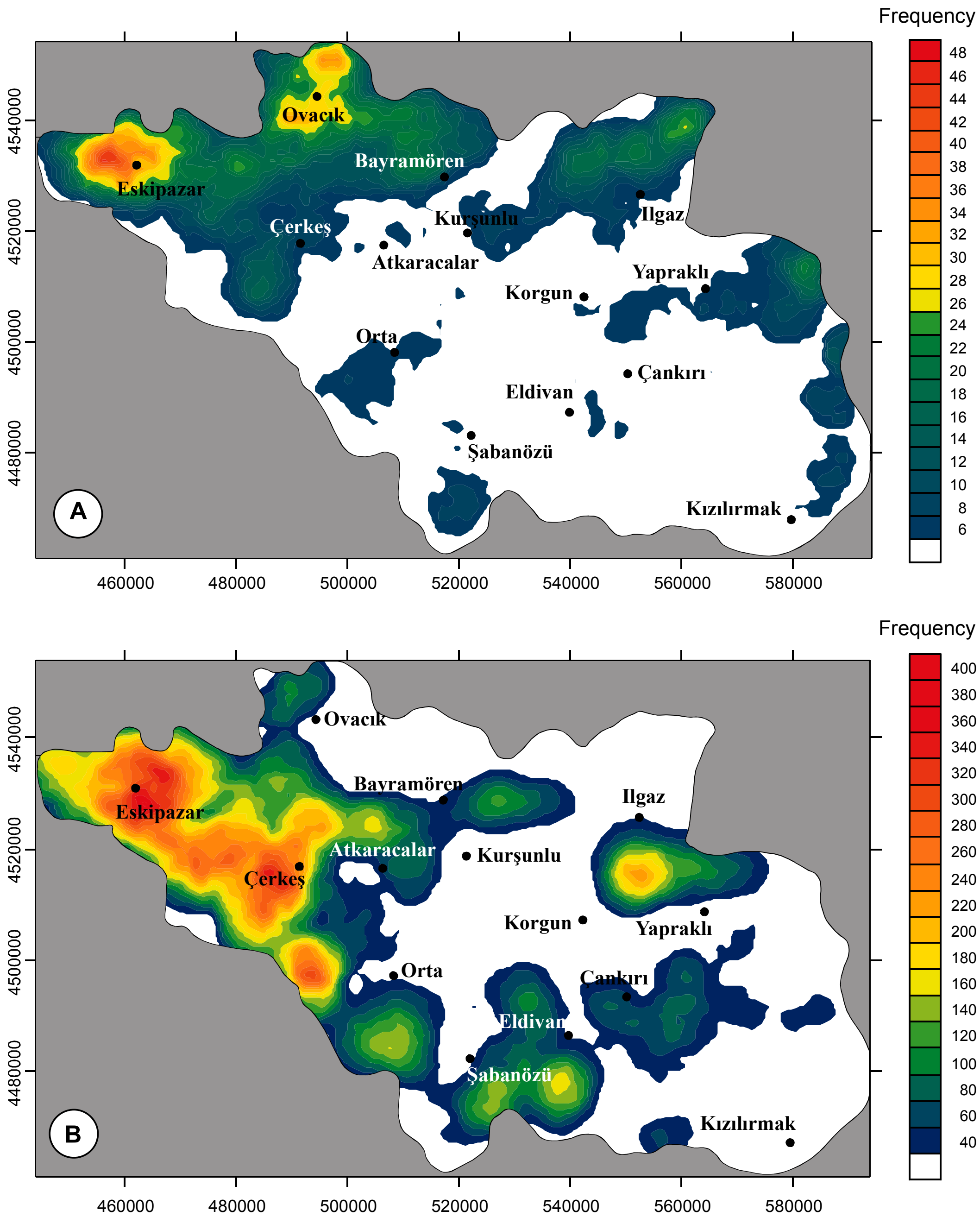


Figure 3.7: Density map of settlements (A) and water (B).

Stage 2: Two density map generated in the previous section are overlaid to compare the variation in the concentrations of water and settlement data. To overlay two maps, the two data sets are normalized to the interval 0-100 in order to standardize them. The settlement data set is multiplied by 2 and the water data set is multiplied by 0.255754 to normalize both to the interval 0 to 100 (Table 3.4). New values are subtracted from each (water-settlement) and a new map is generated from these values. The resultant map is shown in Figure 3.8.

Table 3.4: Normalization of settlement and water data set.

Settlement data	Water data
Min: 0 . . Range multiplied by: 2 . Max: 50	Min: 0 . . Range multiplied by: 0.255754 . Max:391

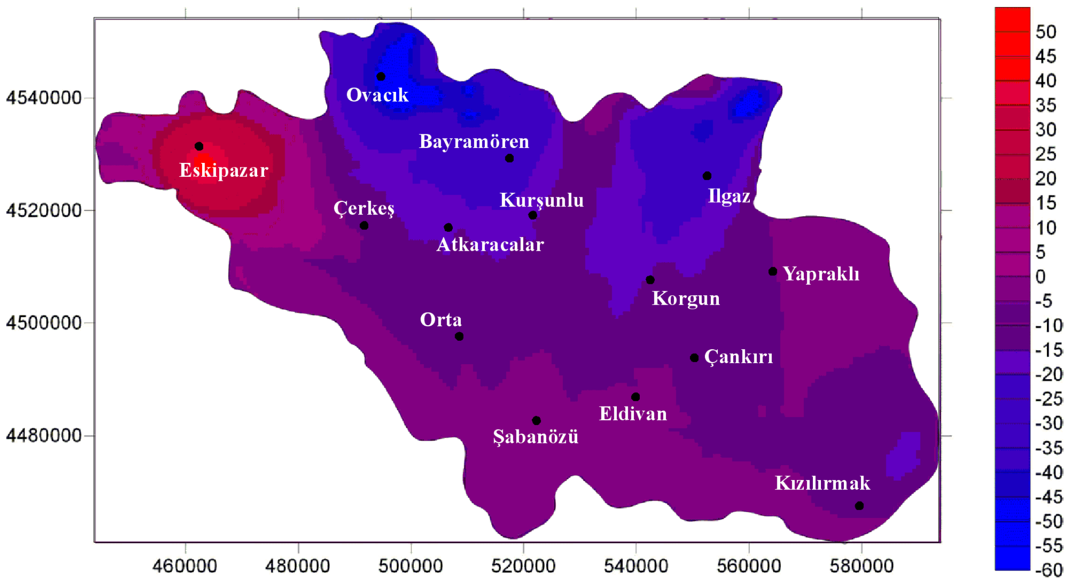


Figure 3.8: Result of the water minus settlement density maps. Positive numbers: water is more than settlement; negative numbers: water is less than settlement.

This map shows the difference between water and settlement percentages. The values range from -64.8 to +77.8. Positive values (red color) in the map indicate that the concentration of the water in this region is higher than the percentage of the settlement and vice versa. Values close to zero, on the other hand, indicate the areas where percentages of water and settlement are almost similar. This map is divided into five regions for a better understanding of the relationship between water and settlements. These regions are:

1) water >> settlement
2) water > settlement
3) water = settlement
4) water < settlement, and
5) water << settlement

Boundaries of the intervals for these regions are based on the standard deviations obtained from the data. Standard deviations of the data (in the histogram) and the resultant map of the comparison are shown in Figure 3.9. Accordingly:

- The 1^{st} standard deviation (-15 to +17) that comprise about 66 % of the data indicates the areas where water percentage is equal to settlement percentage. These areas are represented in grey color in the resultant map (Figure 3.9). More than half of the districts (Çankırı, Eldivan, Şabanözü, Orta, Yapraklı and Kızılırmak) are located within this region.

- Positive realm of the interval between 1^{st} and 2^{nd} standard deviation (+17 to +33), represented by pink color in the map, indicates the areas where amount of water is more than settlements. There is only one region in the area (around Eskipazar) for this case.
- The region greater than 2^{nd} standard deviation (> +33), represented by red color in the map, indicates the areas where amount of water is much more than settlements. This are is represented by a small circular polygon in the close vicinity of Eskipazar (Figure 3.9).
- Negative realm of the interval between 1^{st} and 2^{nd} standard deviation (-15 to -31), represented by cyan color in the map, indicates the areas where amount of water is less than settlements. These areas are indicated by two large (Bayramören-Atkaracalar area and Ilgaz-Korgun area) and a small (north of Kızılırmak) regions in the map.

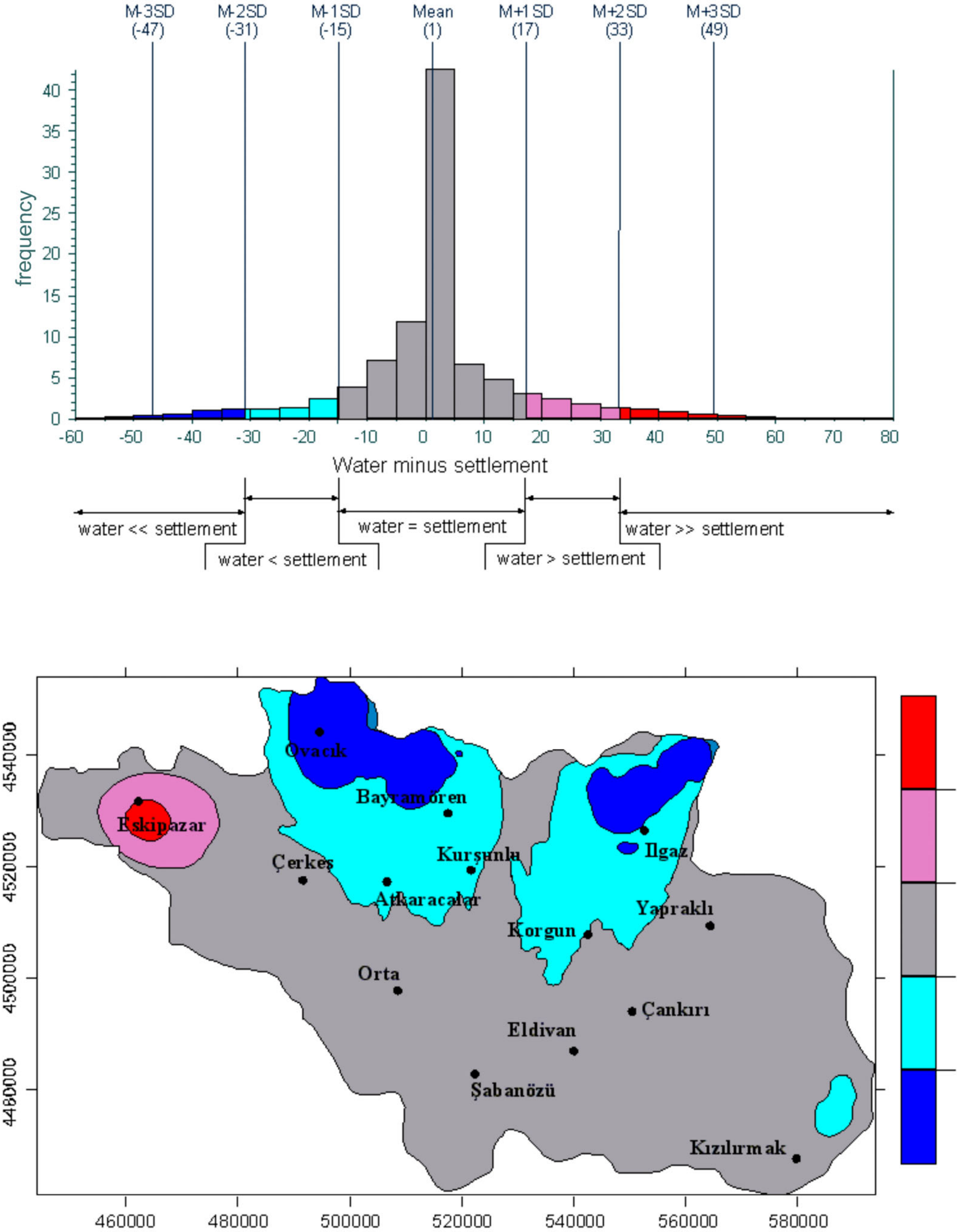


Figure 3.9: Comparison of the percentages of water and settlement in the area based on the standard deviation values. Histogram above shows the limits of the intervals; the map below is the resultant map.

- The region less than negative 2^{nd} standard deviation (< -31), represented by blue color in the map, indicates the areas where amount of water is much less than settlements. There are two such regions around Ilgaz and between Ovacık and Bayramören.

Stage 3: In the last step of this analysis the rock types in the "more water" (water > settlement) and "more settlement" (water < settlement) regions are investigated to understand the effect of the rocks in these regions. These regions (pink, red, cyan and blue in Figure 3.9) are overlaid with the rock map and the rocks are clipped out. Percentages of the rock units in these polygons are calculated by a macro program (Appendix 5) and given in Table 3.5. Observations made from these values are:

- In the "more water" areas, two rock types (olistostrome and soft clastics) with their similar percentages above 37 % are very distinctive. These rocks are followed by alluvium with a percentage of 7.5. Four rock units (carbonates, lava flows, old clastics and old volcanics) have percentages ranging from 2.1 to 5.4. Four rock types, on the other hand, namely, layered clastics, metamorphics, ophiolite and pyroclastics are not exposed in these regions.
- In the "more settlement" areas, which cover a larger area, all rocks are exposed with different percentages. Old clastics and layered clastics are the most widespread units with 24.4 % and 13.8 %, respectively. Four units have percentages a little more than 10 (alluvium, soft clastics, ophiolites and pyroclastics). Other five units have percentages less that 6.1.
- Considering the order of the abundance in each type one observation is very clear: Two maximum-percentage rock types in one category have minimum percentages in the other. These are olistostrome and soft clastics for "more water" area; layered clastics and old clastics for "more settlement" area.

Table 3.5: Percentages of the rock units exposed in "more water" and "more settlement" areas. Distribution of these areas is shown in the map in Figure 3.9. (W: water; S: Settlement)

		Alluvium	Carbonate	Lawa Flows	Layered Clastics	Old Clastics	Old Volcanics	Olistostrome	Soft Clastics	Metamorphics	Ophiolite	Pyroclastics
More water	W>S	11,5	9,5	10,2	0,0	4,2	10,7	**37,4**	**16,5**	0,0	0,0	0,0
	W>>S	3,5	0,0	0,0	0,0	0,0	0,0	**38,6**	**58,0**	0,0	0,0	0,0
	Average	7,5	4,7	5,1	0,0	2,1	5,4	**38,0**	**37,3**	0,0	0,0	0,0
	Order	3	6	5	8a	7	4	1	2	8b	8c	8d
More settlement	W<S	14,4	2,9	0,5	**26,3**	**11,8**	4,0	0,9	11,4	1,2	6,8	19,7
	W<<S	8,3	1,2	2,4	**1,3**	**36,9**	8,2	1,0	11,8	10,4	17,0	1,4
	Average	11,4	2,1	1,5	**13,8**	**24,4**	6,1	0,9	11,6	5,8	11,9	10,6
	Order	5	9	10	2	1	7	11	4	8	3	6

3.4 Overlay Analysis

The purpose of overlay analysis is to investigate the relationship between rock types, water and settlement. Rock types are represented by 11 categorical classes whereas other two by point data. To seek the relationship between all, frequencies (or %) of water and settlement data are calculated by overlaying three sets.

The procedure for this analysis is illustrated in Figure 3.10. For each polygon: 1) area of polygon, 2) number settlements, and 3) number of water data within this polygon are counted using AutoCad software and macro program written for this purpose (Appendix 6). The complete results can be seen in Appendix 7. Total number of polygons existing in the study area is 973. Analysis generated a table with 973 rows (polygons) and 7 columns. The first two columns are the area of the polygon and frequency of settlements. The rest five columns display frequencies of five types of water data (stream, spring, wet fountain, dry fountain and lake). Results of the analyses are shown in Table 3.6 and in the histograms in Figure 3.11 and 3.12. Three values in each bin of histogram correspond to, from left to right, area covered in the region for a rock type and the percentages of settlements and water data included in this rock type.

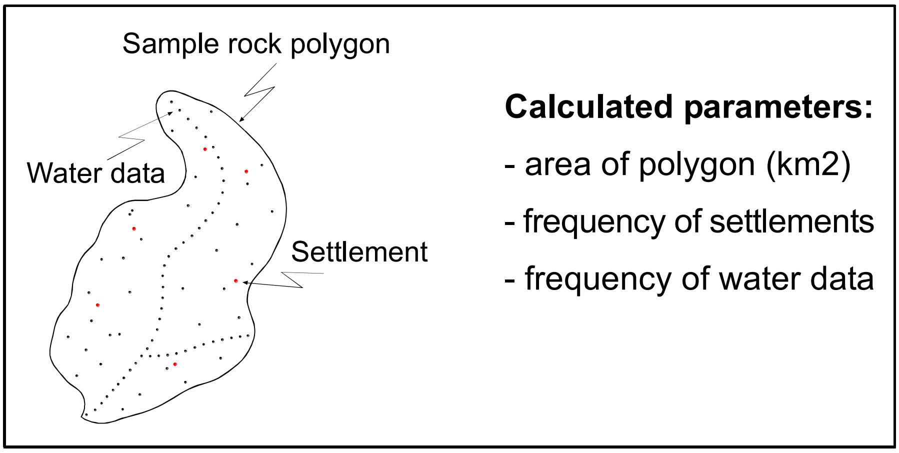


Figure 3.10: Procedure of the overlay analysis

Histograms in Figure 3.11 show the percentages of different water types, namely, a) streams, b) springs and foundations, c) lakes against different rock types. Most striking features of these histograms are:

- Streams are most commonly associated with alluvium which is an expected result (Figure 3.11-A).
- Point-like water data (springs and fountains) are not emphasized in any specific rock unit (Figure 3.11-B).
- Lakes are developed mostly within pyroclastics. The reason for this is not known. There is not reported craters developed in this unit in the area (Figure 3.11-C).

Histogram in Figure 3.12 is the summary of the relationship between rock types, settlement and all water resource. Although these results can be interpreted in different ways, the pattern of histograms in relation to each is based here to evaluate them. Accordingly five categories of the patterns are suggested that can occur theoretically (Figure 3.13). These are:

- all three are the same (one case: a)
- rock area is less than other two (three cases: b, c and d)
- rock area is more than other two (three cases: e, f and g)
- rock area is equal to one different from other (four cases: h, i, j and k)
- rock area is more than one and less than the other (two cases: l, m)

This theoretical classification (Figure 3.13) is compared with the results obtained in Figure (Figure 3.12) and following observations are made for each rock category separately:

Alluvium: The pattern of alluvium is similar to case "d". Percentage of the area covered is less than the percentage of the settlement. This indicates that alluvium is an attractive unit for the settlements. However, the percentage of the water is higher than that of the settlements suggesting that more settlements could exist in the area if only water is considered. This is maybe because most of the alluvium is exposed in flood plains which are not suitable to select a site for the settlement.

Ophiolite: The pattern of the ophiolite is similar to class "j" where area of rock is equal to percentage of settlement and both are less than water amount. Accordingly, although there is more water in the area, frequency of the settlements is not more than the surface of the rock unit.

Old clastics: Old clastics rock type has a pattern similar to class "h" in which the percentage of settlement is higher than other equal two parameters. Amount of water provided in this rock is proportional to its surface. High amount of settlement, therefore, suggest that this rock is preferred by the people for the selection of the settlement location.

Table 3.6: Table showing the frequency and percentage distribution of rock types, settlements and water.

Rock Type		Alluvium	Ophiolite	Old clastics	Pyroclastics	Layered clastics	Soft clastics	Lava flows	Metamorphics	Old volcanics	Carbonates	Olistostrome		TOTALS
Area	(km^2)	811	597	1012	1710	2000	795	380	132	372	419	304		8532
	%	9,5	7	11,9	20	23,4	9,3	4,4	1,5	4,4	4,9	3,6		100
Settlement	Freq	140	64	229	65	100	97	30	19	43	28	76		891
	%	15,7	7,2	25,7	7,3	11,2	10,9	3,4	2,1	4,8	3,1	8,5		100
Streams	Freq	5182	1677	1711	2371	1287	1304	397	458	1197	468	457		16509
	%	31,4	10,2	10,4	14,4	7,8	7,9	2,4	2,8	7,3	2,8	2,8		100
Springs	Freq	213	801	524	902	954	579	260	149	404	288	180		5254
	%	4,1	15,2	10	17,2	18,2	11	4,9	2,8	7,7	5,5	3,4		100
Wet fount.	Freq	173	82	358	202	343	260	123	19	103	117	296		2076
	%	8,3	3,9	17,2	9,7	16,5	12,5	5,9	0,9	5	5,6	14,3		100
Dry Fount.	Freq	3	6	3	3	1	2	0	0	1	2	6		27
	%	11,1	22,2	11,1	11,1	3,7	7,4	0	0	3,7	7,4	22,2		100
Lakes	Freq	0	1	2	31	4	6	0	1	0	0	0		45
	%	0	2,2	4,4	68,9	8,9	13,3	0	2,2	0	0	0		100
Point-water	Freq	389	889	885	1107	1298	841	383	168	508	407	482		7357
	%	5,3	12,1	12	15	17,6	11,4	5,2	2,3	6,9	5,5	6,6		100
All water	Freq	5571	2567	2598	3509	2589	2151	780	627	1705	875	939		23911
	%	23,3	10,7	10,9	14,7	10,8	9	3,3	2,6	7,1	3,7	3,9		100

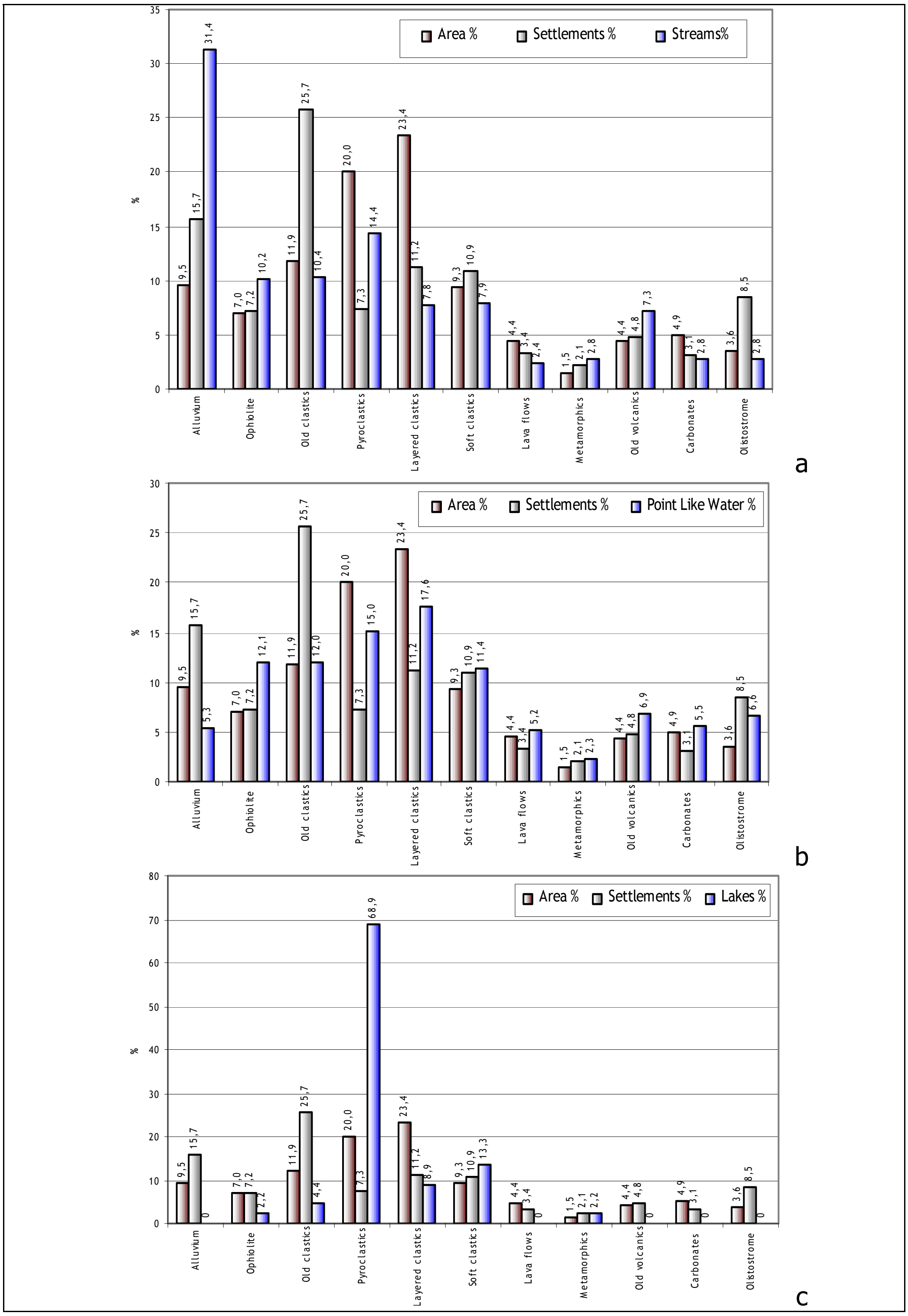


Figure 3.11: Histograms showing the relationship between rock type, area, settlements and a) Streams b) Point Like Water Resources c) Lakes. (First column in each interval is the surface area of the rock type, other two columns are percentages of settlements and water data for this rock type).

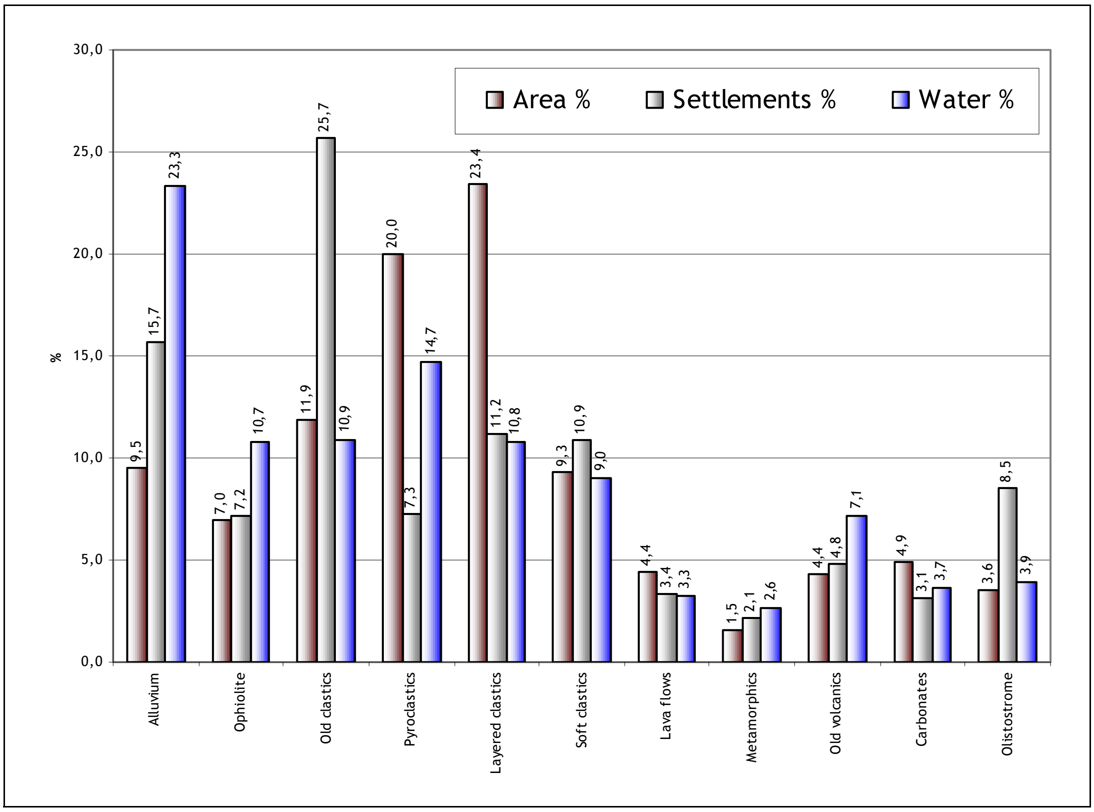


Figure 3.12: Histogram showing the relationship between three parameters in the area. (First column in each interval is the surface area of the rock type, other two columns are percentages of settlements and water data for this rock type).

Pyroclastics: In this rock type that resembles class "g" the abundance of the water is less than the area provided for this rock type and the settlement is less than both are and settlement. Therefore, this rock type is not preferred by the people.

Layered clastics: The pattern of this rock type is similar to class "e". Area covered by this rock is much higher than both settlement and water. Therefore, this unit is not attractive for settlements. However, almost equal proportions of settlement and water suggest that, this rock unit is settled where water is available.

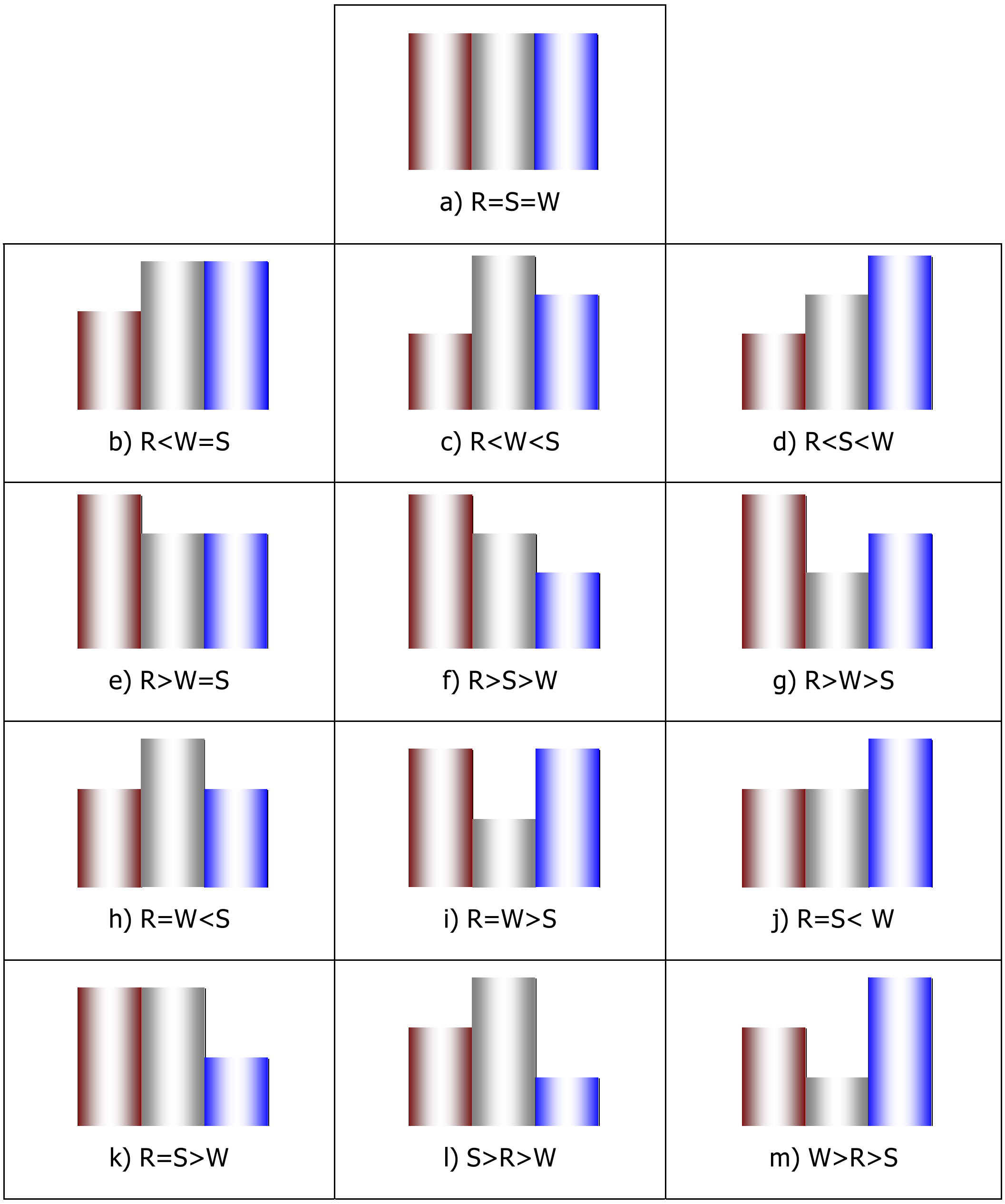


Figure 3.13: Theoretical patterns showing different combinations of abundance for rock type, settlement and water. (R: Rock type; S: Settlement: W: Water)

Soft clastics: Soft clastics have a pattern similar to "a" or "h". In both cases rock type and water have the same percentages. Considering the percentage of settlements in the bar, it can be claimed that the pattern is closer to "h". In both cases, the pattern suggests that, this rock has received more settlements than the area provided for this class, and therefore, it is preferred for the site selection of the settlements.

Lava flows: Lava flows (and other next four units) cover relatively smaller area in the region. Therefore, proportions in their histograms are represented by smaller variations (that makes the interpretation more difficult) compared to the previous rock types. The pattern of the lava flows is similar to class "e" in which the area provided for this rock type is greater than other two equal parameters. Therefore, the water in this class is less and consequently the settlement is less.

Metamorphics: Metamporphics rock type has the characteristics of class "d" and has similar properties of alluvium. Water in this class is abundant compared to its area; but frequency of settlement is between other two suggesting that this rock type could hold more settlements.

Old volcanics: The pattern of the old clastics rock type is similar to both "d" and "j" (closer to class "j") both suggesting that water amount is more than the area provided and the settlements exist. In this sense it is similar to alluvium and metamorphics.

Carbonates: Carbonates display the pattern of "g" in which frequency of settlement is less than both surface area and water resources. This suggests that carbonates are not preferred as a settlement site. Lower amount of water than area, on the other hand, can be attributed to the karstic nature of this rock type which is not tested in this study.

Olistostrome: Olistostrome is a typical example of class "h" in which frequency of settlements is more than equal percentages of area and water. In this case, it has similar properties of old clastics and soft clastics. Therefore, this olistostrome is a preferred rock type.

CHAPTER 4

DISCUSSION

Numerous studies have been carried out to investigate location of the settlements in relation to the natural environment. Some of these studies are referred to in the first chapter. There is not, however, a particular study that links the location of the settlements to the rock types exposed in the area and water resources.

In this section, various aspects of the thesis will be discussed divided into following two subheadings:

1- Data used in the study area
2- Methodology applied to seek the relationship between rocks, water resources and settlements then the results obtained

4.1 Data Used

Boundary of study area: The boundary of the study area is the boundary of the Çankırı Province. This may not be appropriate because it is not a natural boundary defined by geographical features. A better selection of the boundary should be based on the drainage divide in a region. There are several advantages in selecting an area defined by the drainage divide, for example, hierarchically weighted values could be applied to a main stream and to its tributaries. The reason to use the provincial boundary of Çankırı is that other two data sets (rocks type and settlement data) are already available for this region.

Data Source: Three data sets (rock type, settlement, and water) are used in this study. Rock type data are taken from Özdemir (2002)'s study who re-classified rock units based on the maps provided from Mineral Research and

Exploration Institute of Turkey. The map is not modified in this study and distribution of the rock units is not tested in the area because it is assumed to be correct.

Settlement data is provided in the form of a database with three columns (name, x-coordinate, y-coordinate) from the studies of Sürmeli (2003). These data similarly are not tested and accepted as correct.

Water data, on the other hand, is the only data set generated during this study. Original source of water data is 1/25.000 scale topographic maps. No any other external sources are used to verify this data set.

Accuracy of the water data: Although the work done in this study is basically a methodological approach, accuracy of the results is mostly dependent on the accuracy of the raw data. For this reason, a maximum attempt is made to collect the water data in a correct way. Following points should be mentioned about the collection of water data:

1) All possible water resource types are considered in the study; categorized in five groups and collected separately,
2) Artificial water resources are ignored in this study because they are later than settlements and have no effect on the selection of site,
3) Discharge of all water resources (particularly springs) will not be the same. It is impossible to test the discharge of the springs and streams discharge was not taken into consideration. Therefore, they are all assumed to have the same weight,
4) Hot springs in the area are not dealt separately,
5) Springs and streams are in-situ features; they represent the original location of water resource. Fountains, on the other hand, can be both in-situ or at a certain distance from the spring. This distance can not be estimated and therefore is not considered in this study.
6) Dry fountains, although rare in the area, are indications of the shift in the position of springs. Since the area is tectonically active, such shifts should

also be expected to occur in historical data. However, the data collected belong to the information available for the last decade due the dates of topographic maps used in this study.

Use of other ancillary data: Only three sets of data are used in this study considering the scope of the thesis because the purpose of the thesis is not to identify effect of all other parameters that have a role on the selection of the settlement. All other ancillary data, therefore, are considered to be constant. Among these excluded data, however, topography has a special importance and could be used in the analysis. In previous studies, for example, Özdemir (2002) and Sürmeli (2003) used topography to find "unsuitable areas" and to mask these areas in the analyses. In this study, as well, the topography could be used to mask some parts of the area. It is not in the study in order not to complicate the analysis.

4.2 Methodology and Results

The algorithm is composed of several steps. The first step is the conversion of all water data into points, and the next three steps are analyses.

Conversion of water data into points: One of the most problematic aspects of the analyses is to have the water data in different formats. Some of them are collected as points (springs and fountains), some as lines (streams) and some as polygons (lakes). All these data should be converted into one type in order to keep consistency and to be able to create a final water database (Figure 3.2).

During this step the most reasonable solution seems to be the conversion of all data into points. Converting linear stream and polygonal lake data into points practically is easy. The problem, however, is the determination of the "unit length" used in this conversion. An unsuitable length will change the weight of one of the water type in the analysis which, in turn, will generate a bias.

The distances between point-like data (springs and fountains) are based to find the unit length for the conversion. This is believed to be the best solution since the unit length is assigned using the field data. According to the distance analysis made for the point-like data mean and median values are determined as 340.9 and 231 m, respectively (Figure 3.3). The median value is used for the conversion. But, although the grid interval is 1000 m, dividing interval can be choosen arbitrarily within the range of 0-500 m. Also instead of calculating radii of the lakes manually centroid point, and for determining the shapes of the lakes fuzzy properties could be used.

Distance analysis: The purpose of this analysis is to investigate the distances between water sources and settlements. The values obtained in this analysis are not utilized in any further analysis and is used only for visual interpretation.

Accordingly the minimum, maximum, mean and median values are found to be 3, 4167, 285 and 163 m, respectively (Table 3.3; Figure 3.5). Since the settlements in this study are represented by a point located at the center of the settlements, the distances suggest that most of the nearest water sources are within the periphery of the settlements.

Density analysis: The purpose of this analysis is to investigate concentrations of the settlement and water in the area and than link these concentrations to the rock types exposed in these regions. Algorithm of this analysis is composed of three successive steps:

1- Find maximum concentrations for water and settlement and display as maps,
2- Subtract these two maps to find which parameter is dominating in which area
3- Investigate the rock types in these particular regions to decide on positively or negatively affecting rock types.

The results of these analyses are given in Figure 3.7 for the first step, in Figure 3.9 for step 2, and in Table 3.5 in for step 3.

Results of this analysis clearly indicate that certain rock types have played an important role in these areas. Interpretation of the results in Table 3.5 is illustrated in Table 4.1. Accordingly, old clastics and layered clastics are positively affecting the location of the site. These are followed by lower rankings by ophiolites, soft clastics, alluvium and pyroclastics. Negatively affecting rock types, on the other hand, are olistostrome and soft clastics followed by alluvium.

Table 4.1: Rock types "positively" or "negatively" affecting the site selection according to the density analysis. (Number in the brackets indicate the order of the rock type).

<table>
<tr><td></td><td colspan="2">Positively affecting</td></tr>
<tr><td rowspan="7">Rock types</td><td>More effect</td><td>Less effect</td></tr>
<tr><td>Old clastics
Layered clastics</td><td>Ophiolites
Soft clastics
Alluvium
Pyroclastics</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Negatively affecting</td></tr>
<tr><td>More effect</td><td>Less effect</td></tr>
<tr><td>Olistostrome
Soft clastics</td><td>Alluvium</td></tr>
</table>

This analysis does not answer the question whether the exposure of the rocks in these areas is by coincidence or not. To justify the results for this, the last analysis, overlay analysis is carried out.

Overlay analysis: This analysis investigates the relationship between water resources, rock types and settlements. The analysis is composed of two successive steps:

1) Quantify the relationship between three parameters

2) Evaluate the results using theoretical cases in relation to rock types.

Results of the first steps are given in the histograms in Figure 3.12. To evaluate these results, templates for all 13 cases are prepared and illustrated in Figure 3.13. Summary of the results are shown in Figure 4.1. Out of 13 cases only 5 classes are observed in the area:

- In the first class (case "d") settlement is more than the area but less than the water. That means, this rock type is generally preferred to settle, but extra amount of water has not a positive effect on the number of settlements. Three rock types observed in this class are alluvium and metamorphics.
- In the second class (case "e") area provided by the rock type is greater than other two equal parameters. Therefore, this rock type is generally avoided and the number of settlements is widely dependent on the water amount. Two rock types in this class are layered clastics and lava flows.
- In the third class (case "g") the settlements are less than other two parameters where area provided by this rock type is more than water available. Accordingly, extra water is not a positive factor for this case. Observed rock types in this class are pyroclastics and carbonates.
- In the fourth class (case "h") percentage of the settlements is more than that of other two equal data. Therefore, this rock type is preferred even the area and the water amount are less. Three rock types in this class are old clastics, soft clastics and olistostrome.
- In the last class (case "j") the water amount is more than other two equal data. Therefore, the percentages of the area and settlements are consistent and water does not put an extra advantage for the settlement. Ophiolite and old volcanics rock types are in this class.

If these cases are reclassified in order to comment whether the rock types are "preferred" or "avoided" for during the site selection, following two-fold classification can be suggested:

A rock type is called to be "preferred" if percentage of settlement is greater than that of both area covered by this rock and water; and similarly this case suggest that this rock type is preferred rock type is should be classified as "avoided" if its percentage is less than others. The results of the overlay analysis according to this classification are shown in Figure 4.2.

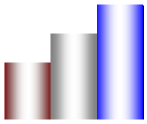
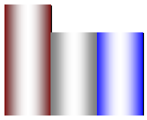
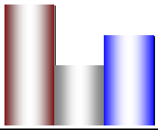
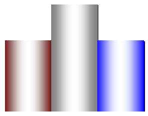
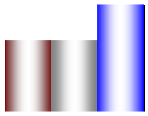
Rock Types	Matching Pattern	Explanation
- Alluvium - Metamorphics		d) R<S<W
- Layered clastics - Lava flows		e) R>W=S
- Pyroclastics - Carbonates		g) R>W>S
- Old clastics - Soft clastics - Olistostrome		h) R=W<S
- Ophiolite - Old volcanics		j) R=S< W

Figure 4.1: Summary of the results for the relationship between rock type (R), settlement (S) and water (W). Original patterns are shown in Figure 3.13.

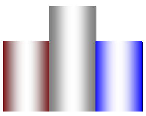
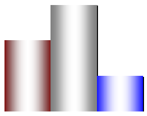
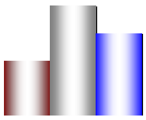
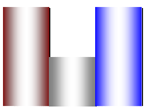
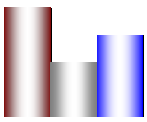
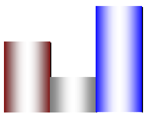
Preferred rock types		
 R=W<S	 S>R>W	 R<W<S
- Soft clastics - Olistostrome - Old clastics	(none)	(none)
Avoided rock types		
 R=W>S	 R>W>S	 W>R>S
(none)	- Pyroclastics - Carbonates	(none)

Figure 4.2: Rock types "preferred" or "avoided" according to overlay analysis. In the first row settlement percentage is higher than other two parameters and in the second row vice versa (R: rock type; S: settlement: W: water)

According to this reclassification, old clastics, soft clastics and olistostromes are designated as preferred rock types; because in these rock units the amount of water is equal to the area provided where the settlement concentration is higher than both. Therefore, people settled here even if there is relatively less water. On the other hand, carbonates and pyroclastics are designated as avoided rock types; because in this case the water concentration is very high but people do not settle here.

CHAPTER 5

CONCLUSION

The results obtained by both methods (density and overlay) are shown together in Table 5.1. The focus of these two methods is different and may not be compared to each other. Because in the first method, the rock types exposed only in two particular areas (water > settlement and settlement > water) are investigated. Some other local factors might be more important than rock type in these areas. In the second method, on the other hand, the rocks in the whole area are considered. Therefore, the results in this analysis are more reliable.

Old clastics is the only one that consistently detected by two methods. Therefore, this rock type can be interpreted as a rock type preferred by the people. The reason for this selection may be due to its easy use as construction material.

Soft clastics according to overlay analysis are preferred rock types; but density analysis assigns a negative value to this rock. From the literature it is known that these clastics are exposed in Çankırı basin where water quality is negatively affected by evaporates within the sequences. This rock, similar to old clastics, can be used as construction material. Therefore, it can be concluded that this rock is preferred when it is free of evaporates.

Table 5.1: Final remarks on effects of the rock units to the site selection according to the density and overlay analysis.

Effect on the settlement	Density Analysis	Overlay Analysis
Positive effect	Old clastics Layered clastics Ophiolites	Old clastics Soft Clastics Olistostrome
Negative effect	Olistostrome Soft clastics Alluvium	Carbonates Pyroclastics

Beside the overlay and density analysis, distance analysis stated that about 70% of the all water resources are within the distance of 0-300 m to the settlement location which can be accepted as relatively short distance. This can be interpreted as people consider the distance to water resources while selecting the location site to settle. At the same time, the fact of "people prefer pointlike water resources to the linear water resources" can be also interpreted from the distance analysis (Figure 3.5 A, B, C).

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APPENDIX-1

Table A1: Table showing the 93 geologic units and their properties

Geologic Code Of MTA	Material	Sub-material	Age	Rock Category
Q-22-K	Alluvium	Alluvium	Quaternary	Alluvium
PL-18-K	Clastic	Clastic	Pliocene	Soft clastic
PL-19-K	Clastic	Clastic	Pliocene	Soft clastic
M1M3-20-K	Clastic	Clastic	Early-Late Miocene	Layered clastic
M3-18-K	Clastic	Clastic	Late Miocene	Layered clastic
OLM1-18-K	Clastic	Clastic	MioOligocene-Early Miocene	Layered clastic
OLM2-18-K	Clastic	Clastic	Oligocene-Middle Miocene	Layered clastic
OLM-18-K	Clastic	Clastic	Oligocene-Miocene	Layered clastic
M3-12-K	Evaporite	Evaporite	Late Miocene	Layered clastic
M3-19-K	Clastic	Clastic	Late Miocene	Layered clastic
M2-20-K	Clastic	Clastic	Middle Miocene	Layered clastic
M2-1 9-K	Clastic	Clastic	Middle Miocene	Layered clastic
M2M3-18-K	Clastic	Clastic	Middle-Late Miocene	Layered clastic
M2-3-K	Clastic	Shale	Middle Miocene	Layered clastic
E1E2-18-KS	Clastic	Clastic	Early-Middle Miocene	Old clastic
OD1-20-S	Clastic	Clastic	Ordovician-Early Devonian	Old clastic
KAKG-19-Y	Clastic	Clastic	Berriasian-Senomanian	Old clastic
KFPN-20-YS	Clastic	Flysh	Albian-Paleocene	Old clastic
E2-18-K	Clastic	Clastic	Middle Eocene	Old clastic
E1E2-18-K	Clastic	Clastic	Early-Middle Eocene	Old clastic
PN-1 8-S	Clastic	Clastic	Paleocene	Old clastic
EB-1-S	Clastic	Clastic	Lutesian	Old clastic
E3OL-18-K	Clastic	Clastic	Late Eocene-Oligocene	Old clastic
PN2EB-19-YS	Clastic	Clastic	Late Paleocene-Lutesian	Old clastic
EB-18-S	Clastic	Clastic	Lutesian	Old clastic
KM-20-S	Clastic	Flysh	Maastrictian	Old clastic
KGKH-19-Y	Clastic	Clastic	Senomanian-Turonian	Old clastic
JLKA-20-SY	Clastic	Clastic	Portlandian-Beriasian	Old clastic
JLK2S-20-S	Clastic	Flysh	Portlandian-Senonian	Old clastic
EB-18-K	Clastic	Clastic	Lutesian	Old clastic
E-18-S	Clastic	Clastic	Eocene	Old clastic
E1E2-1-SK	Clastic	Clastic	Early-middle Eocene	Old clastic
KLKM-20-S	Clastic	Flysh	Kampanian-Maastrichtian	Old clastic
KGKL-1 9-Y	Clastic	Clastic	Senomanian-Kampanian	Old clastic
KGKH-20-Y	Clastic	Flysh	Senomanian-Turonian	Old clastic
ES-3-S	Clastic	Shale	Ipresiyan	Old clastic

Table A1 continued: Table showing the 93 geologic units and their properties

Geologic Code Of MTA	Material	Sub-material	Age	Rock Category
J3K1N-20-SY	Clastic	Flysh	Malm-Neocomian	Old clastic
EB-18-KS	Clastic	Clastic	Lutesian	Old clastic
E3OL1-18-S	Clastic	Clastic	Late Eocene-Early Oligocene	Old clastic
M1PDP2-K	Volcanic	Rhyolite-dacite-tuff	Early Miocene	Pyroclastic
M3P1P2A-K	Volcanic	Agglomerate-tuff-andesite	Late Miocene	Pyroclastic
M2M3BAP2-K	Volcanic	Basalt-andesite-tuff	Middle Miocene-Late Miocene	Pyroclastic
M1M2P-K	Volcanic	Pyroclastic	Early Miocene-Middle Miocene	Pyroclastic
M1AP2P2-K	Volcanic	Andesite-tuff-agglomerate	Early Miocene	Pyroclastic
M3-10-K	Volcanic	Clastic	Late Miocene	Pyroclastic
M2ADP-K	Volcanic	Andesite-dacite-tuff	Middle Miocene-Late Miocene	Pyroclastic
M1P-K	Volcanic	Pyroclastic	Early Miocene	Pyroclastic
M2M3PAB-K	Volcanic	Pyroclastic-andesite-basalt	Middle Miocene-Late Miocene	Pyroclastic
Y1J2Q-PN	Volcanic	Granodiorite	Paleocene	Lava
Y1J2Q-J2	Volcanic	Granite	Late Cretaceous	Lava
PL1B-K	Volcanic	Basalt	Early Pliocene	Lava
M3-AB-K	Volcanic	Andesite-basalt	Late Miocene	Lava
M1DP-K	Volcanic	Dacite-rhyolite	Early Miocene	Lava
PLB-K	Volcanic	Basalt	Pliocene	Lava
M3B-K	Volcanic	Basalt	Late Miocene	Lava
M2M3BA-K	Volcanic	Basalt-andesite	Middle Miocene-Late Miocene	Lava
MAB-K	Volcanic	Basalt-andesite	Miocene	Lava
M2M3ABD-K	Volcanic	Basalt-andesite-dacite	Middle Miocene-Late Miocene	Lava
K2-1 0-Y	Volcanic	Clastic	Late Cretaceous	Old volcanic
K2-1 0-SY	Volcanic	Clastic	Late Cretaceous	Old volcanic
KLPN-10-S	Volcanic	Clastic	Kampanian-Paleocene	Old volcanic
KM-10-SY	Volcanic	Clastic	Maastrichtian	Old volcanic
JKABP2-Y	Volcanic	Andesite-basalt-tuff	Jurassic-Cretaceous	Old volcanic
KGKH-10-Y	Volcanic	Clastic	Senomanian-Turonian	Old volcanic
E1ADP1-SK	Volcanic	Andesite-dacite-agglomerate	Early Eocene	Old volcanic
E1E2-8-S	Limestone	X	Early Eocene - Middle Eocene	Carbonate
J3K1-8-S	Limestone	X	Late Jurassic-Early Cretaceous	Carbonate
D2C1-8-S	Limestone	X	Middle Devonian-Early Carbonifereous	Carbonate
KME1-7-SY	Limestone	X	Maastrictian-Early Eocene	Carbonate
JHKS-17-Y	Limestone	Chert	Kallovian-Apsian	Carbonate
T2T3-8-S	Limestone	X	Middle Triassic-Late Triassic	Carbonate
Q-29-K	Travertine	Travertine	Quaternary	Carbonate
KMPN-8-SY	Limestone	X	Maastrictian-Paleocene	Carbonate
M3-8-K	Limestone	X	Late Miocene	Carbonate
KGKH-7-Y	Limestone	X	Senomanian-Turonian	Carbonate
KMPN-8-S	Limestone	X	Late Cretaceous -Paleocene	Carbonate

Table A1 continued: Table showing the 93 geologic units and their properties

Geologic Code Of MTA	Material	Sub-material	Age	Rock Category
M-8-K	Limestone	X	Miocene	Carbonate
M2M3-7-K	Limestone	X	Middle Miocene-Late Miocene	Carbonate
KMPN-8-S	Limestone	X	Maastrictian-Paleocene	Carbonate
PEYM	Metam.	Metagranitoid	Precambrian	Metamorphics
T2T3OLM	Metam.	Meta-Olistostrome	Middle Triassic-Late Triassic	Metamorphics
TDM	Metam.	Meta-Clastic	Triassic	Metamorphics
TJ1S	Metam.	Schist	Trassic-Early Jurassic	Metamorphics
T3J1SF	Metam.	Phyllite	Late Triassic-Liassic	Metamorphics
J10LM	Metam.	Meta-Olistostrome	Liassic	Metamorphics
T3J1MR	Metam.	Marble	Late Triassic-Liassic	Metamorphics
T3SK	Metam.	Schist-Calcshist	Late Triassic-Liassic	Metamorphics
K2E1-15-SY	Olistostrome	Olistostrome	Late Cretaceous-Early Eocene	Olistostrome
P-15-Y	Olistostrome	Olistostrome	Permian	Olistostrome
MMZ-K	melange	Ophiolite	Creatceous	Ophiolite
VMZ-JK	melange	Chert-basalt-shale-ophiolite	Jurassic-Cretaceous	Ophiolite
MMZ-KKKL	melange	Ophiolite	Santonian-Kampanian	Ophiolite
WMZ-JK	melange	Gabbro-Ophiolite	Jurassic-Cretaceous	Ophiolite

APPENDIX-2

BASIC program to calculate water distances

```
REM
REM This program finds the nearest distances between point-like water resources
REM
REM wx: x-coordinate of water; wy: y-coordinate of water
REM distan: nearest distance
CLS
DIM wx(7357), wy(7357), distan(7357)
OPEN "7357.txt" FOR INPUT AS #1
  FOR i = 1 TO 7357: INPUT #1, wx(i), wy(i): NEXT
  CLOSE #1
OPEN "dist-sp.txt" FOR OUTPUT AS #3
FOR i = 1 TO 7357
   min = 999999999
   PRINT i
  FOR j = 1 TO 7357
  IF i = j THEN GOTO 10
   distx = ABS(wx(i) - wx(j))
   disty = ABS(wy(i) - wy(j))
   sqx = (distx * distx)
   sqy = (disty * disty)
   dist = SQR(sqx + sqy)
   IF (dist < min) THEN min = dist
10  NEXT j
   distan(i) = min
   NEXT
   FOR i = 1 TO 7357
   PRINT #3, USING "########"; i; distan(i)
NEXT i
   CLOSE #3
END
```

APPENDIX-3

BASIC program to calculate water-settlement distances

```
REM This program finds the nearest water resource to the settlement
REM sx: x-coordinate of settlement:  sy: y-coordinate of settlement
REM wx: x-coordinate of water:                  wy: y-coordinate of water
REM typeof: type of water resource (e.g. 1: stream, 2: spring,)
REM distan: distance to nearest water resource
REM sayi: number of input data for water resource
DIM sx(891), sy(891), wx(10000), wy(10000), typeof(891), distan(891)
INPUT sayi
REM get input data
        OPEN "xy-set.txt" FOR INPUT AS #1
                FOR i = 1 TO 891
                INPUT #1, sx(i), sy(i), typeof(i)
                NEXT
        CLOSE #1
        OPEN "xy-spr.txt" FOR INPUT AS #2
                FOR i = 1 TO sayi
                INPUT #2, wx(i), wy(i)
                NEXT
        CLOSE #2
REM calculate disstances
        OPEN "dis-spr.txt" FOR OUTPUT AS #3
                FOR i = 1 TO 891
                 min = 999999999
                        FOR j = 1 TO sayi
                         distx = ABS(sx(i) - wx(j))
                         disty = ABS(sy(i) - wy(j))
                        sqx = (distx * distx)
                        sqy = (disty * disty)
                        dist = SQR(sqx + sqy)
                        IF (dist < min) THEN min = dist: type=typeof(j)
                        NEXT j
                        distan(i) = min
                        typeof(i) = type
                NEXT i
REM print results
                FOR i = 1 TO 891
                PRINT #3, USING "########"; i; distan(i); typeof(i)
                NEXT i
                CLOSE #3
END
```

APPENDIX-4

BASIC program to find densities of settlement and water

```
REM This program finds density of settlements and water resources
REM
REM Note: Program should be run twice one for settlements, one for water data
REM File names and variables should be modified accordingly
REM This example is for settlements
REM
REM
DIM x(891), y(891)
REM get input data
        OPEN "xy-set.txt" FOR INPUT AS #1
        FOR i = 1 TO 891
        INPUT #1, x(i), y(i)
        NEXT
        CLOSE #1
OPEN "se-grid.txt" FOR OUTPUT AS #2
REM Calculate and print grid values
   FOR i = 444000 TO 594000 STEP 1000    : REM STEP is grid interval
   FOR j = 4461000 TO 4554000 STEP 2500          : REM STEP is search radius
        total = 0
                FOR k = 1 TO 891
                distx = ABS(x(k) - i)
                disty = ABS(y(k) - j)
                d1 = distx * distx
                d2 = disty * disty
                d = SQR(ABS(d1 + d2))
                IF d < 5000 THEN toplam = toplam + 1
                NEXT k
                PRINT #2, USING "########"; i; j; total
   NEXT j
                PRINT i
   NEXT i
   CLOSE #2
   STOP
   END
```

APPENDIX-5

Macro Program for calculating rock polygons

This program calculates the areas of each rock type polygon in cluster polygons.

```
Sub AreaSub()
Dim exce As Excel.Application, wbk As Workbook, she As Worksheet
Dim elem As AcadLWPolyline, Layername As String
Dim groupCode As Variant, dataCode As Variant, cors() As Double
Dim curves(0 To 1) As AcadEntity
        Dim ssetObj As AcadSelectionSet, Springobj As AcadSelectionSet, Fountainobj As AcadSelectionSet, Setleobj As AcadSelectionSet, Streamobj As AcadSelectionSet
        Dim gpCode(0) As Integer
        Dim dataValue(0) As Variant
Set exce = GetObject(, "Excel.Application"): Set wbk = exce.ActiveWorkbook: Set she = wbk.ActiveSheet
Set d = ThisDrawing
'Laye ("Dummy")
mas = 2
If d.SelectionSets.Count > 0 Then
For h = 0 To d.SelectionSets.Count – 1
d.SelectionSets(0).Delete
Next
End If
        Set ssetObj = d.SelectionSets.Add("SSET0")
        Set Springobj = d.SelectionSets.Add("SSET1")


For Each z In d.Layers
```

```
If InStr(1, LCase(z.Name), "bölge") > 0 Then
        gpCode(0) = 8:    dataValue(0) = z.Name
        groupCode = gpCode:    dataCode = dataValue
        ssetObj.Select acSelectionSetAll, , , groupCode, dataCode
For Each elem In ssetObj
Set curves(0) = elem
cor = elem.Coordinates
ReDim cors(((UBound(cor) + 1) / 2 * 3) - 1)j = 0
For I = 0 To UBound(cor) Step 2
cors(j) = cor(I): cors(j + 1) = cor(I + 1)
j = j + 3
Next
elem.Closed = True
'dataValue(0) = "Alluvium": dataCode = dataValue
Springobj.SelectByPolygon acSelectionSetCrossingPolygon, cors
Dim o As AcadEntity
no = 1
For Each o In Springobj
Set curves(1) = o
If o.ObjectID <> elem.ObjectID Then
alan1 = o.Area
regionobj = ThisDrawing.ModelSpace.AddRegion(curves)
If UBound(regionobj) = 1 Then
regionobj(0).Boolean acSubtraction, regionobj(1)
Else
MsgBox "hata"
End If
alan2 = regionobj(0).Area
fark = alan1 - alan2

DoEvents
```

```
regionobj(0).Erase
With she
        Cells(mas, 1) = elem.Layer
        Cells(mas, 2) = o.Layer
        Cells(mas, 3) = fark
        Cells(mas, 1).Select
End With
mas = mas + 1: no = no + 1
End If
Next
Springobj.Erase
d.SelectionSets("SSET1").Clear
DoEvents
Next
End If
d.SelectionSets("SSET0").Clear: DoEvents
Next
Set exce = Nothing: Set wbk = Nothing: Set she = Nothing
MsgBox "Tamam"
End Sub
```

APPENDIX-6

Macro Program for overlay analysis

This program;

Assigns a new layer for each rock unit polygon
Measures the area of each polygon
Counts number of settlement points for each layer
Counts number of spring points for each layer
Counts number of wet fountain points for each layer
Counts number of dry fountain points for each layer
Counts number of lake points for each layer
Counts number of stream points for each layer
Writes the results in an excel sheet

```
Sub Overlay Analysis ()

Dim exce As Excel.Application, wbk As Workbook, she As Worksheet

Dim elem As AcadLWPolyline

Dim groupCode As Variant, dataCode As Variant, cors() As Double

    Dim ssetObj As AcadSelectionSet, Springobj As AcadSelectionSet,
Fountainobj As AcadSelectionSet, Setleobj As AcadSelectionSet, Streamobj As
AcadSelectionSet

    Dim gpCode(0) As Integer

    Dim dataValue(0) As Variant

Set exce = GetObject(, "Excel.Application"): Set wbk = exce.ActiveWorkbook:
Set she = wbk.ActiveSheet

Set d = ThisDrawing

'Layer ("Dummy")

mas = 2

If d.SelectionSets.Count > 0 Then

For h = 0 To d.SelectionSets.Count – 1

d.SelectionSets(0).Delete

Next


End If
```

```
        Set ssetObj = d.SelectionSets.Add("SSET0")
        Set Springobj = d.SelectionSets.Add("SSET1")
        Set Fountainobj = d.SelectionSets.Add("SSET2")
        Set Setleobj = d.SelectionSets.Add("SSET3")
        Set Streamobj = d.SelectionSets.Add("SSET4")
For Each z In d.Layers
If z.Name <> "0" And z.Name <> "Spring" And z.Name <> "WetFountain" And
z.Name <> "Settlement" And z.Name <> "Stream" Then
        gpCode(0) = 8:    dataValue(0) = z.Name
        groupCode = gpCode:    dataCode = dataValue
        ssetObj.Select acSelectionSetAll, , , groupCode, dataCode
no = 1
For Each elem In ssetObj
cor = elem.Coordinates
ReDim cors(((UBound(cor) + 1) / 2 * 3) - 1)
j = 0
For I = 0 To UBound(cor) Step 2
cors(j) = cor(I): cors(j + 1) = cor(I + 1)
j = j + 3
Next
Layername = z.Name & " " & Format(no, "000")
Laye (Layername)
elem.Layer = Layername
elem.Closed = True
Alan = Round(elem.Area, 3): perim = Round(elem.Length, 3)
dataValue(0) = "Spring": dataCode = dataValue
Springobj.SelectByPolygon acSelectionSetWindowPolygon, cors, groupCode,
dataCodedataValue(0) = "Settlement": dataCode = dataValue
Setleobj.SelectByPolygon acSelectionSetWindowPolygon, cors, groupCode,
dataCode
dataValue(0) = "WetFountain": dataCode = dataValue
```

```
Fountainobj.SelectByPolygon acSelectionSetCrossingPolygon, cors, groupCode, dataCode

dataValue(0) = "Stream": dataCode = dataValue

Streamobj.SelectByPolygon acSelectionSetCrossingPolygon, cors, groupCode, dataCode

'If fountainobj.Count > 0 Then

'fountainle = stre2(elem, fountainobj)

'End If

With she

        Cells(mas, 2) = Layername
        Cells(mas, 3) = Alan
        Cells(mas, 4) = perim
        Cells(mas, 5) = Setleobj.Count
        Cells(mas, 6) = Springobj.Count
        Cells(mas, 7) = Fountainobj.Count
        Cells(mas, 8) = Streamobj.Count
        Cells(mas, 2).Select
End With

mas = mas + 1: no = no + 1

Setleobj.Erase: Springobj.Erase: Fountainobj.Erase: Streamobj.Erase

d.SelectionSets("SSET1").Clear: d.SelectionSets("SSET2").Clear: d.SelectionSets("SSET3").Clear: d.SelectionSets("SSET4").Clear

DoEvents

Next

End If

d.SelectionSets("SSET0").Clear: DoEvents

Next

Set exce = Nothing: Set wbk = Nothing: Set she = Nothing

MsgBox "Tamam"

End Sub
```

APPENDIX-7

Table A2: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Alluvium 001	120.001,6	0	0	0	0	0	0
Alluvium 002	673.700,1	0	7	0	0	0	0
Alluvium 003	58.432,1	0	1	0	0	0	0
Alluvium 004	365.660,1	0	2	0	0	0	0
Alluvium 005	119.119,8	0	0	0	0	0	0
Alluvium 006	293.417,8	0	0	0	0	0	0
Alluvium 007	830.948,0	1	0	2	0	0	11
Alluvium 008	176,1	0	0	0	0	0	0
Alluvium 009	39.886,0	0	0	0	0	0	0
Alluvium 010	4.946.867,7	0	0	0	0	0	104
Alluvium 011	635.718,6	2	0	3	0	0	0
Alluvium 012	8.424.955,8	0	1	0	0	0	0
Alluvium 013	405.438,5	0	1	0	0	0	3
Alluvium 014	240.874,7	0	0	0	0	0	6
Alluvium 015	2.028,9	0	0	0	0	0	0
Alluvium 016	114.660,3	0	0	0	0	0	2
Alluvium 017	65.637,2	0	0	0	0	0	5
Alluvium 018	1.576.975,7	2	1	2	0	0	13
Alluvium 019	832.623,3	0	0	0	0	0	22
Alluvium 020	2.925,8	0	0	0	0	0	0
Alluvium 021	1.065.466,3	0	0	1	0	0	32
Alluvium 022	35.919,3	0	0	0	0	0	0
Alluvium 023	1.070.918,5	0	0	2	0	0	0
Alluvium 024	974.214,5	0	2	1	0	0	2
Alluvium 025	75.870,6	0	0	1	0	0	0
Alluvium 026	408.619,6	0	1	0	0	0	10
Alluvium 027	11.946,3	0	0	0	0	0	0
Alluvium 028	273.516,3	0	1	0	0	0	0
Alluvium 029	471.322,2	0	0	1	0	0	0
Alluvium 030	2.681.936,8	0	1	2	0	0	25
Alluvium 031	235.901,3	0	0	1	0	0	0
Alluvium 032	461.694,3	0	0	0	0	0	0
Alluvium 033	22.020.972,5	21	2	17	0	0	324
Alluvium 034	1.068.813,2	1	1	1	0	0	23
Alluvium 035	1.658.723,8	1	0	5	0	0	45
Alluvium 036	981.595,6	0	1	0	0	0	2
Alluvium 037	4.979.600,2	1	0	0	0	0	0
Alluvium 038	445.648,4	0	0	0	0	0	0
Alluvium 039	336.144,4	0	1	0	0	0	15
Alluvium 040	719.502,5	0	1	0	0	0	41

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Alluvium 041	14.745,9	0	0	0	0	0	0
Alluvium 042	4.100.218,0	7	0	0	0	0	36
Alluvium 043	276.463,9	0	0	0	0	0	0
Alluvium 044	127.583,2	1	0	0	0	0	0
Alluvium 045	892.016,4	1	0	1	0	0	5
Alluvium 046	129.354,3	0	0	0	0	0	0
Alluvium 047	479.942,3	1	2	1	0	0	0
Alluvium 048	4.415.741,3	0	3	0	0	0	30
Alluvium 049	1.940.989,5	0	0	0	0	0	0
Alluvium 050	516.398,0	0	0	0	0	0	2
Alluvium 051	3.217.565,3	0	0	0	0	0	0
Alluvium 052	457.495,7	1	1	2	0	0	0
Alluvium 053	66.525,8	0	0	0	0	0	0
Alluvium 054	144.901,5	0	0	0	0	0	0
Alluvium 055	504.857,3	0	0	0	0	0	16
Alluvium 056	2.163.241,3	0	0	0	0	0	0
Alluvium 057	382.526,7	0	0	0	0	0	0
Alluvium 058	837.442,7	0	0	0	0	0	0
Alluvium 059	326.700,6	0	0	0	0	0	0
Alluvium 060	37.886,7	0	0	0	0	0	0
Alluvium 061	1.349.967,5	0	0	0	0	0	0
Alluvium 062	957.838,1	0	0	0	0	0	0
Alluvium 063	4.080.851,3	0	1	0	0	0	0
Alluvium 064	775.168,5	0	1	0	0	0	15
Alluvium 065	189.846,3	0	0	0	0	0	0
Alluvium 066	97.464,3	0	0	0	0	0	0
Alluvium 067	1.481,4	0	0	0	0	0	0
Alluvium 068	9.558,7	0	0	0	0	0	0
Alluvium 069	996.523,9	1	0	0	0	0	0
Alluvium 070	917.832,9	0	1	1	0	0	0
Alluvium 071	1.049.414,5	0	0	2	0	0	0
Alluvium 072	180.988,0	0	0	0	0	0	0
Alluvium 073	874.609,6	0	0	0	0	0	0
Alluvium 074	21.852.010,2	3	4	5	0	0	252
Alluvium 075	805.921,4	0	0	0	0	0	2
Alluvium 076	14.966.033,7	0	28	3	0	0	85
Alluvium 077	164.226,7	0	0	0	0	0	1
Alluvium 078	756,5	0	0	0	0	0	0
Alluvium 079	3.222,5	0	0	0	0	0	0
Alluvium 080	90.423.049,2	25	17	8	0	0	687
Alluvium 081	422.966,5	0	0	0	0	0	0
Alluvium 082	1.146.820,3	0	2	0	0	0	0
Alluvium 083	10.437.805,4	1	2	6	0	0	74
Alluvium 084	1.935.133,1	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Alluvium 085	9.174.136,9	5	1	6	0	0	165
Alluvium 086	1.586.468,9	0	0	1	0	0	32
Alluvium 087	50.762.740,2	14	19	19	0	0	421
Alluvium 088	84.610.840,6	17	59	22	2	0	1052
Alluvium 089	425.425.550,3	32	48	56	1	0	1581
Alluvium 090	4.589.441,9	2	0	1	0	0	41
Ophiolite 001	39.262,0	0	0	0	0	0	0
Ophiolite 002	186.657,1	0	0	0	0	0	0
Ophiolite 003	3.104.035,8	0	19	0	0	0	0
Ophiolite 004	1.076.638,6	0	0	0	0	0	1
Ophiolite 005	7.378.407,8	2	18	0	0	0	71
Ophiolite 006	1.612,6	0	0	0	0	0	0
Ophiolite 007	187.151,9	0	0	0	0	0	0
Ophiolite 008	10.117.941,1	3	16	0	0	0	25
Ophiolite 009	3.600.932,3	0	0	0	0	0	33
Ophiolite 010	770.402,5	0	1	0	0	0	0
Ophiolite 011	139.981,1	0	0	0	0	0	0
Ophiolite 012	203.925,3	0	0	0	0	0	0
Ophiolite 013	94.116,1	0	0	0	0	0	0
Ophiolite 014	318.305,0	0	0	0	0	0	0
Ophiolite 015	2.886.107,5	0	5	0	0	0	30
Ophiolite 016	97.603,0	0	0	0	0	0	0
Ophiolite 017	84.617,6	0	0	0	0	0	0
Ophiolite 018	56.581,3	0	0	0	0	0	0
Ophiolite 019	404.183,3	0	2	0	0	0	3
Ophiolite 020	43.745,4	0	0	0	0	0	0
Ophiolite 021	125.231,4	0	0	1	0	0	0
Ophiolite 022	2.528,1	0	0	0	0	0	0
Ophiolite 023	113.613,8	0	0	0	0	0	0
Ophiolite 024	1.177.024,0	0	0	1	0	0	2
Ophiolite 025	556.903,1	0	0	0	0	0	0
Ophiolite 026	1.806.074,7	0	3	0	0	0	10
Ophiolite 027	1.048.480,5	0	0	1	0	0	0
Ophiolite 028	454.914,5	0	1	0	0	0	5
Ophiolite 029	217.720,8	0	0	0	0	0	0
Ophiolite 030	94.113,1	0	0	0	0	0	0
Ophiolite 031	114.898,2	0	1	0	0	0	0
Ophiolite 032	413.547,6	0	0	0	0	0	0
Ophiolite 033	485.891,5	0	0	0	0	0	0
Ophiolite 034	505.143,0	1	0	1	0	0	4
Ophiolite 035	275.146,1	0	0	0	0	0	0
Ophiolite 036	3.529.511,8	1	1	2	0	0	0
Ophiolite 037	1.907.184,8	0	1	0	0	0	5
Ophiolite 038	382.534,4	0	1	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Ophiolite 039	415.595,1	0	0	0	0	0	0
Ophiolite 040	267.109,1	0	0	0	0	0	0
Ophiolite 041	192.921,1	0	0	0	0	0	0
Ophiolite 042	1.914.923,4	0	1	0	0	0	0
Ophiolite 043	2.710.714,3	0	0	1	0	0	11
Ophiolite 044	716.213,1	1	0	1	0	0	0
Ophiolite 045	25.511.576,2	1	38	3	0	0	27
Ophiolite 046	635.103,6	0	1	1	0	0	0
Ophiolite 047	249.517,9	0	1	0	0	0	0
Ophiolite 048	550.509,7	0	0	0	0	0	0
Ophiolite 049	724.838,9	0	0	0	0	0	0
Ophiolite 050	200,3	0	0	0	0	0	0
Ophiolite 051	149.426,9	0	0	0	0	0	0
Ophiolite 052	525.843,3	0	0	0	0	0	0
Ophiolite 053	3.785.240,5	2	5	1	0	0	1
Ophiolite 054	107.155,3	0	0	0	0	0	0
Ophiolite 055	839.405,1	0	2	0	0	0	0
Ophiolite 056	448.563,7	0	0	0	0	0	0
Ophiolite 057	45.504.774,2	9	85	12	1	0	194
Ophiolite 058	188.464.602,1	6	211	21	0	0	456
Ophiolite 059	711.764,0	0	0	0	0	0	0
Ophiolite 060	1.172.682,9	0	1	0	0	0	0
Ophiolite 061	3.965.901,3	1	1	3	0	0	17
Ophiolite 062	152.936.632,9	33	108	23	2	1	253
Ophiolite 063	1.528.828,5	0	2	0	0	0	8
Ophiolite 064	118.765.507,6	4	276	10	3	0	521
Old Clastics 001	18.896.293,6	10	15	3	0	0	57
Old Clastics 002	1.771.483,8	0	3	0	0	0	1
Old Clastics 003	43.602.211,4	2	2	2	0	0	25
Old Clastics 004	313.700,2	0	0	0	0	0	0
Old Clastics 005	470.723,8	0	0	0	0	0	3
Old Clastics 006	2.684.766,2	1	2	1	0	0	0
Old Clastics 007	1.082.805,5	0	0	0	0	0	2
Old Clastics 008	39.078,7	0	0	0	0	0	0
Old Clastics 009	2.096.435,1	0	2	0	0	0	7
Old Clastics 010	226.894,1	0	0	0	0	0	2
Old Clastics 011	133.426,1	0	0	0	0	0	0
Old Clastics 012	1.057.212,6	0	1	0	0	0	6
Old Clastics 013	848.642,6	0	1	0	0	0	1
Old Clastics 014	18.140.184,3	2	0	0	0	0	2
Old Clastics 015	10.053.074,6	3	0	0	0	0	0
Old Clastics 016	67.357.759,2	14	41	4	0	0	62
Old Clastics 017	100.334,9	0	0	0	0	0	0
Old Clastics 018	206.453,0	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m²)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Old Clastics 019	6.186.558,7	1	10	2	0	0	28
Old Clastics 020	36.211.266,7	8	3	0	0	0	30
Old Clastics 021	24.123.446,8	1	11	0	0	0	68
Old Clastics 022	2.019.472,9	0	3	1	0	0	16
Old Clastics 023	302.625,1	0	0	0	0	0	1
Old Clastics 024	87.998,3	0	0	0	0	0	0
Old Clastics 025	729.398,0	0	0	0	0	0	2
Old Clastics 026	139.875,8	0	0	0	0	0	0
Old Clastics 027	3.359.406,7	0	0	0	0	0	0
Old Clastics 028	48.275,0	0	0	0	0	0	0
Old Clastics 029	67.112.507,1	1	56	4	0	1	109
Old Clastics 030	19.083.757,6	2	8	1	0	0	63
Old Clastics 031	719.133,5	1	0	0	0	0	0
Old Clastics 032	16.596.939,0	9	8	3	0	1	58
Old Clastics 033	91.278,8	0	0	0	0	0	0
Old Clastics 034	5.117,2	0	0	0	0	0	0
Old Clastics 035	48.542,6	0	0	0	0	0	0
Old Clastics 036	487.727,2	0	0	0	0	0	0
Old Clastics 037	37.087.399,3	2	41	0	0	0	167
Old Clastics 038	150.559,2	0	0	1	0	0	0
Old Clastics 039	130.630,0	0	0	0	0	0	0
Old Clastics 040	116.541,8	0	0	0	0	0	0
Old Clastics 041	3.970.253,4	0	1	0	0	0	0
Old Clastics 042	716.602,9	0	0	0	0	0	0
Old Clastics 043	2.636.892,7	0	0	1	0	0	0
Old Clastics 044	13.781.160,7	4	12	8	0	0	36
Old Clastics 045	475.794,4	0	0	0	0	0	0
Old Clastics 046	30.432.035,0	6	11	26	0	0	33
Old Clastics 047	3.737.526,7	3	0	6	0	0	1
Old Clastics 048	58.201,7	0	0	0	0	0	0
Old Clastics 049	90.271,4	0	0	0	0	0	0
Old Clastics 050	715.513,5	0	0	0	0	0	2
Old Clastics 051	5.845.768,1	3	6	4	0	0	7
Old Clastics 052	181.145,3	0	0	0	0	0	0
Old Clastics 053	400.543,7	0	0	0	0	0	0
Old Clastics 054	1.029.694,0	0	0	0	0	0	0
Old Clastics 055	1.738.076,9	1	0	4	0	0	0
Old Clastics 056	444.741,8	1	0	0	0	0	1
Old Clastics 057	643.737,2	0	3	0	0	0	2
Old Clastics 058	790.574,2	0	1	0	0	0	1
Old Clastics 059	359.808,0	1	0	0	0	0	0
Old Clastics 060	17.736.012,8	6	7	16	0	0	28
Old Clastics 061	3.259.847,2	2	0	5	1	0	3
Old Clastics 062	12.803.122,0	4	1	15	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Old Clastics 063	5.806.400,1	1	0	5	0	0	9
Old Clastics 064	675.941,0	0	0	0	0	0	0
Old Clastics 065	3.317.418,7	0	0	0	0	0	13
Old Clastics 066	5.892,5	0	0	0	0	0	0
Old Clastics 067	284.492,5	0	0	0	0	0	6
Old Clastics 068	1.146.476,6	0	4	0	0	0	2
Old Clastics 069	617.260,3	0	0	0	1	0	2
Old Clastics 070	1.788.382,5	0	0	0	0	0	0
Old Clastics 071	2.251.157,8	0	7	0	0	0	2
Old Clastics 072	72.844,4	0	0	0	0	0	0
Old Clastics 073	23.606,7	0	0	0	0	0	0
Old Clastics 074	3.311.992,6	1	3	0	0	0	2
Old Clastics 075	611.586,3	0	1	0	0	0	0
Old Clastics 076	2.777.133,5	0	0	0	0	0	9
Old Clastics 077	6.515.296,8	0	2	0	0	0	30
Old Clastics 078	525.873,7	0	1	0	0	0	7
Old Clastics 079	1.422.195,4	1	13	3	0	0	13
Old Clastics 080	2.903.592,9	0	14	0	0	0	40
Old Clastics 081	285.494,5	0	0	0	0	0	0
Old Clastics 082	33.803,6	0	0	0	0	0	0
Old Clastics 083	4,1	0	0	0	0	0	0
Old Clastics 084	300.207,7	1	0	0	0	0	0
Old Clastics 085	361.805,1	0	0	0	0	0	0
Old Clastics 086	31.717.178,0	2	13	13	0	0	78
Old Clastics 087	16.006,2	0	0	0	0	0	0
Old Clastics 088	1.928.626,0	0	0	0	0	0	0
Old Clastics 089	297.785,5	0	0	0	0	0	2
Old Clastics 090	85.416.812,1	14	32	27	0	0	137
Old Clastics 091	429.011,9	0	0	3	0	0	2
Old Clastics 092	620.601,8	1	0	0	0	0	2
Old Clastics 093	29.000,4	0	0	0	0	0	0
Old Clastics 094	3.155.146,5	0	8	0	0	0	26
Old Clastics 095	5.539.905,8	1	2	1	0	0	0
Old Clastics 096	441.226,5	0	2	0	0	0	7
Old Clastics 097	352.217,3	0	0	0	0	0	3
Old Clastics 098	5.424.460,3	2	0	3	0	0	0
Old Clastics 099	233.734,0	0	0	0	0	0	0
Old Clastics 100	206.844,5	0	0	0	0	0	0
Old Clastics 101	842.756,0	0	0	0	0	0	0
Old Clastics 102	1.795.047,7	0	0	0	0	0	6
Old Clastics 103	1.015.059,8	0	2	0	0	0	6
Old Clastics 104	1.017.611,0	1	1	4	0	0	2
Old Clastics 105	462.307,9	0	0	0	0	0	0
Old Clastics 106	270.486,5	0	1	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Old Clastics 107	5.283.158,8	1	0	0	0	0	5
Old Clastics 108	109.162,9	0	0	0	0	0	0
Old Clastics 109	271.635,0	0	0	0	0	0	0
Old Clastics 110	18.532.639,4	13	9	18	0	0	36
Old Clastics 111	865.754,2	1	1	1	0	0	0
Old Clastics 112	7.187.351,6	1	3	3	0	0	3
Old Clastics 113	813.736,0	0	0	0	0	0	9
Old Clastics 114	18.349.993,1	3	39	4	0	0	16
Old Clastics 115	122.751.576,8	36	47	74	0	0	82
Old Clastics 116	53.934.529,3	33	24	40	0	0	113
Old Clastics 117	34.433.849,8	16	1	24	0	0	7
Old Clastics 118	8.963.483,5	2	2	8	1	0	28
Old Clastics 119	319.107,8	0	0	1	0	0	0
Old Clastics 120	17.816.377,3	7	16	7	0	0	52
Old Clastics 121	3.390.686,0	1	0	5	0	0	0
Old Clastics 122	17.187.849,1	0	5	4	0	0	5
Old Clastics 123	2.339.223,3	0	1	0	0	0	18
Old Clastics 124	1.211.155,5	0	1	0	0	0	5
Old Clastics 125	218.664,9	0	0	0	0	0	0
Old Clastics 126	182.372,0	1	0	0	0	0	0
Old Clastics 127	11.475.712,7	0	13	1	0	0	51
Old Clastics 128	24.570.617,9	1	7	2	0	0	51
Pyro Clastics 001	4.439.690,5	1	3	1	0	0	4
Pyro Clastics 002	1.191.549.866,1	44	652	119	3	26	1667
Pyro Clastics 003	10.368.277,2	1	1	5	0	0	0
Pyro Clastics 004	75.718,7	0	0	0	0	0	3
Pyro Clastics 005	158.848,6	0	0	0	0	0	1
Pyro Clastics 006	93.486,2	0	0	0	0	0	0
Pyro Clastics 007	2.204.420,5	1	5	0	0	0	5
Pyro Clastics 008	3.017.229,2	0	6	0	0	0	5
Pyro Clastics 009	2.578.506,6	0	0	0	0	0	0
Pyro Clastics 010	67.033,3	0	0	0	0	0	0
Pyro Clastics 011	142.359,9	0	0	0	0	0	0
Pyro Clastics 012	60.349,0	0	0	0	0	0	0
Pyro Clastics 013	273.434,2	0	0	0	0	0	2
Pyro Clastics 014	72.200,0	0	0	0	0	0	1
Pyro Clastics 015	201.786,5	0	0	0	0	0	0
Pyro Clastics 016	247.194,8	0	0	1	0	0	0
Pyro Clastics 017	824.663,2	0	0	0	0	0	5
Pyro Clastics 018	9.457.879,3	0	6	2	0	0	28
Pyro Clastics 019	185.719,7	0	0	0	0	0	0
Pyro Clastics 020	9.826.226,5	1	0	0	0	0	8
Pyro Clastics 021	439.812,6	0	1	1	0	0	0
Pyro Clastics 022	36.310,8	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Pyro Clastics 023	184.478,2	0	0	0	0	0	0
Pyro Clastics 024	403.701,7	0	0	0	0	0	0
Pyro Clastics 025	2.027.497,5	0	0	1	0	0	5
Pyro Clastics 026	1.760.558,5	0	0	0	0	0	0
Pyro Clastics 027	3.118.674,0	0	0	1	0	0	10
Pyro Clastics 028	458.516,2	0	0	0	0	0	7
Pyro Clastics 029	1.665.910,2	0	1	0	0	0	1
Pyro Clastics 030	13.663.711,7	0	6	4	0	0	14
Pyro Clastics 031	4.521.133,4	0	2	0	0	0	13
Pyro Clastics 032	2.294.265,8	0	0	0	0	0	10
Pyro Clastics 033	986.414,1	0	0	0	0	0	9
Pyro Clastics 034	733.067,4	0	0	0	0	0	0
Pyro Clastics 035	577.227,1	0	0	0	0	0	0
Pyro Clastics 036	359.368,4	0	0	0	0	0	0
Pyro Clastics 037	264.620,3	0	0	0	0	0	0
Pyro Clastics 038	26.935.157,3	2	15	2	0	0	8
Pyro Clastics 039	149.604,0	0	0	0	0	0	0
Pyro Clastics 040	3.026.704,4	0	0	0	0	0	2
Pyro Clastics 041	145.136,1	0	0	0	0	0	1
Pyro Clastics 042	886.740,2	0	0	0	0	0	0
Pyro Clastics 043	148.167,8	0	0	0	0	0	0
Pyro Clastics 044	328.600,7	0	0	0	0	0	0
Pyro Clastics 045	1.305.387,0	0	0	0	0	0	1
Pyro Clastics 046	231.345,6	0	0	0	0	0	0
Pyro Clastics 047	76.022,5	0	0	0	0	0	0
Pyro Clastics 048	458.759,7	0	0	0	0	0	0
Pyro Clastics 049	437.773,8	0	0	0	0	0	0
Pyro Clastics 050	287.077,5	0	0	0	0	0	0
Pyro Clastics 051	810.490,7	0	0	0	0	0	0
Pyro Clastics 052	352.894,2	0	0	0	0	0	0
Pyro Clastics 053	335.373,2	0	0	0	0	0	0
Pyro Clastics 054	814.110,2	0	0	0	0	0	0
Pyro Clastics 055	173.969,6	0	0	0	0	0	0
Pyro Clastics 056	899.514,2	0	0	0	0	0	0
Pyro Clastics 057	1.014.095,4	0	0	0	0	0	0
Pyro Clastics 058	1.001.712,0	0	0	0	0	0	0
Pyro Clastics 059	2.216.040,8	0	0	0	0	0	0
Pyro Clastics 060	758.818,2	0	0	0	0	0	0
Pyro Clastics 061	3.429.195,0	0	0	0	0	0	0
Pyro Clastics 062	203.524,4	0	0	0	0	0	0
Pyro Clastics 063	7.005.491,7	0	0	0	0	0	0
Pyro Clastics 064	10.740.814,2	0	0	0	0	0	0
Pyro Clastics 065	971.545,2	0	1	0	0	0	0
Pyro Clastics 066	472.012,2	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Pyro Clastics 067	747.470,8	0	0	0	0	0	0
Pyro Clastics 068	899.163,4	0	0	0	0	0	0
Pyro Clastics 069	3.054.136,3	0	0	0	0	0	0
Pyro Clastics 070	445.390,2	0	0	0	0	0	0
Pyro Clastics 071	1.984.137,4	0	0	0	0	0	0
Pyro Clastics 072	539.541,4	0	0	0	0	0	0
Pyro Clastics 073	334.857,6	0	0	0	0	0	0
Pyro Clastics 074	79.430,9	0	0	0	0	0	0
Pyro Clastics 075	374.907,6	0	0	0	0	0	0
Pyro Clastics 076	1.110.324,8	1	5	3	0	0	0
Pyro Clastics 077	810.863,6	0	3	0	0	0	1
Pyro Clastics 078	292.883,7	0	0	0	0	0	0
Pyro Clastics 079	10.718.893,0	0	0	0	0	0	0
Pyro Clastics 080	489.397,4	0	0	0	0	0	0
Pyro Clastics 081	286.933,5	0	0	0	0	0	0
Pyro Clastics 082	2.542.875,8	0	0	0	0	0	0
Pyro Clastics 083	80.270,7	0	0	0	0	0	0
Pyro Clastics 084	1.352.853,9	0	0	0	0	0	0
Pyro Clastics 085	836.195,7	0	0	0	0	0	0
Pyro Clastics 086	324.588,8	0	0	0	0	0	0
Pyro Clastics 087	92.614,5	0	0	0	0	0	0
Pyro Clastics 088	246.229,7	0	0	0	0	0	0
Pyro Clastics 089	139.015.265,0	5	31	9	0	1	251
Pyro Clastics 090	8.961.600,6	0	0	2	0	0	27
Pyro Clastics 091	226.698,3	0	0	1	0	0	0
Pyro Clastics 092	823.719,4	0	0	1	0	0	0
Pyro Clastics 093	1.961.434,3	0	0	0	0	0	0
Pyro Clastics 094	211.975,0	0	0	0	0	0	0
Pyro Clastics 095	979.848,3	0	6	0	0	0	3
Pyro Clastics 096	199.586,7	0	0	0	0	0	0
Pyro Clastics 097	169.232,9	0	0	0	0	0	0
Pyro Clastics 098	71.240,3	0	0	0	0	0	0
Pyro Clastics 099	5.449.497,2	0	3	7	0	0	0
Pyro Clastics 100	27.041.390,8	3	67	20	0	0	17
Pyro Clastics 101	627.444,6	0	1	0	0	0	0
Pyro Clastics 102	24.154,4	0	0	0	0	0	0
Pyro Clastics 103	256.965,5	0	0	0	0	0	0
Pyro Clastics 104	193.946,6	1	0	0	0	0	0
Pyro Clastics 105	1.151.318,6	0	0	1	0	0	2
Pyro Clastics 106	142.280,0	0	0	0	0	0	0
Pyro Clastics 107	1.078.137,8	0	2	0	0	0	0
Pyro Clastics 108	405.909,1	0	0	0	0	0	0
Pyro Clastics 109	17.040.551,7	1	7	1	0	0	48
Pyro Clastics 110	341.861,1	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Pyro Clastics 111	619.485,3	0	0	0	0	0	2
Pyro Clastics 112	247.080,8	0	0	0	0	0	3
Pyro Clastics 113	638.262,6	1	0	1	0	0	0
Pyro Clastics 114	1.389.975,3	0	0	0	0	0	0
Pyro Clastics 115	457.308,1	0	0	0	0	0	0
Pyro Clastics 116	65.294,9	0	0	0	0	0	0
Pyro Clastics 117	82.726,5	0	1	0	0	0	0
Pyro Clastics 118	259.681,0	0	0	0	0	0	0
Pyro Clastics 119	107.358,0	0	0	0	0	0	0
Pyro Clastics 120	397.128,9	0	0	0	0	0	5
Pyro Clastics 121	214.710,2	0	0	0	0	0	4
Pyro Clastics 122	3.805.327,5	0	0	0	0	0	0
Pyro Clastics 123	79.414,3	0	0	0	0	0	0
Pyro Clastics 124	67.964,5	0	1	0	0	0	0
Pyro Clastics 125	68.957,3	0	0	0	0	0	0
Pyro Clastics 126	104.601,1	0	0	0	0	0	0
Pyro Clastics 127	262.186,4	0	0	0	0	0	0
Pyro Clastics 128	222.190,3	0	0	0	0	0	0
Pyro Clastics 129	2.371.213,4	0	1	1	0	0	0
Pyro Clastics 130	147.958,5	0	0	0	0	0	0
Pyro Clastics 131	1.710.165,0	0	0	0	0	0	4
Pyro Clastics 132	3.203.993,9	0	0	0	0	0	0
Pyro Clastics 133	43.977.907,7	0	36	3	0	0	90
Pyro Clastics 134	1.027.727,4	0	1	1	0	0	0
Pyro Clastics 135	10.933.413,3	0	4	3	0	0	8
Pyro Clastics 136	816.308,7	0	0	0	0	0	3
Pyro Clastics 137	238.192,5	0	0	0	0	0	0
Pyro Clastics 138	6.191.093,3	1	0	3	0	4	3
Pyro Clastics 139	6.591.740,0	0	3	0	0	0	13
Pyro Clastics 140	487.825,9	0	0	0	0	0	6
Pyro Clastics 141	27.214.564,8	0	4	0	0	0	18
Pyro Clastics 142	27.031.511,7	2	27	8	0	0	53
Layered Clastics 001	460.750,5	0	0	0	0	0	0
Layered Clastics 002	42.485.011,6	3	75	12	0	0	59
Layered Clastics 003	1.657.172,6	0	4	0	0	0	0
Layered Clastics 004	1.386.933,2	1	1	0	0	0	6
Layered Clastics 005	888.645,0	0	0	0	0	0	0
Layered Clastics 006	126.658,1	0	0	0	0	0	0
Layered Clastics 007	108.086,7	0	0	0	0	0	0
Layered Clastics 008	801.321,6	0	0	0	0	0	0
Layered Clastics 009	171.243,5	0	0	0	0	0	0
Layered Clastics 010	573.822,4	0	0	0	0	0	0
Layered Clastics 011	19.864.174,5	0	18	2	0	0	0
Layered Clastics 012	18.620.361,9	0	5	0	0	0	3

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Layered Clastics 013	16.716.913,4	2	3	1	0	0	3
Layered Clastics 014	362.118,0	0	0	0	0	0	0
Layered Clastics 015	275.769,2	0	0	0	0	0	7
Layered Clastics 016	43.666,4	0	0	0	0	0	0
Layered Clastics 017	2.472.933,0	0	0	2	0	0	0
Layered Clastics 018	122.975,5	0	0	0	0	0	1
Layered Clastics 019	2.348.995,4	0	0	3	0	0	5
Layered Clastics 020	334.344,6	0	0	0	0	0	3
Layered Clastics 021	8.915.895,1	1	3	10	0	0	9
Layered Clastics 022	481.863,3	0	0	0	0	0	0
Layered Clastics 023	118.793,0	0	0	0	0	0	0
Layered Clastics 024	54.445,9	0	0	0	0	0	0
Layered Clastics 025	266.341,3	0	0	0	0	0	0
Layered Clastics 026	51.202,4	0	0	0	0	0	0
Layered Clastics 027	4.876.231,8	0	0	0	0	0	0
Layered Clastics 028	9.924.185,3	1	0	3	0	0	4
Layered Clastics 029	15.896,0	0	0	0	0	0	0
Layered Clastics 030	159.754,4	0	0	0	0	0	0
Layered Clastics 031	3.535.901,3	0	1	0	0	0	0
Layered Clastics 032	778.506,8	0	0	0	0	0	0
Layered Clastics 033	674.259,1	0	0	0	0	0	7
Layered Clastics 034	30.111,9	0	0	0	0	0	0
Layered Clastics 035	88.302,5	0	0	0	0	0	0
Layered Clastics 036	191.394,4	0	0	0	0	0	0
Layered Clastics 037	589.453,5	0	0	0	0	0	0
Layered Clastics 038	502.419,5	0	0	0	0	0	0
Layered Clastics 039	665.221,0	0	0	0	0	0	0
Layered Clastics 040	1.048.647,6	0	2	0	0	0	0
Layered Clastics 041	2.144.494,2	0	0	1	0	0	0
Layered Clastics 042	1.861.643,1	1	0	0	0	0	0
Layered Clastics 043	4.600.094,2	0	0	3	0	0	1
Layered Clastics 044	1.245.807,2	0	0	0	0	0	0
Layered Clastics 045	4.651.971,3	0	3	0	0	0	0
Layered Clastics 046	833.748,4	0	0	0	0	0	2
Layered Clastics 047	14.547.256,4	1	18	0	0	0	23
Layered Clastics 048	174.750,0	0	0	0	0	0	0
Layered Clastics 049	28.993.321,9	1	38	2	0	0	75
Layered Clastics 050	1.269.666,6	1	0	0	0	0	3
Layered Clastics 051	38.782.618,9	1	8	7	0	0	6
Layered Clastics 052	3.607.636,8	0	0	0	0	0	2
Layered Clastics 053	333.640,0	0	0	0	0	0	2
Layered Clastics 054	16.479.542,3	7	4	1	0	0	15
Layered Clastics 055	4.984.344,1	1	11	1	0	0	3
Layered Clastics 056	41.752.980,3	2	21	2	1	0	73

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Layered Clastics 057	413.110,6	0	0	0	0	0	0
Layered Clastics 058	9.522.035,9	1	2	0	0	0	2
Layered Clastics 059	1.358.924,6	0	0	1	0	0	0
Layered Clastics 060	94.539,0	0	0	0	0	0	0
Layered Clastics 061	6.588.079,4	1	1	0	0	0	28
Layered Clastics 062	288.550,1	0	0	0	0	0	0
Layered Clastics 063	63.485,9	0	0	0	0	0	0
Layered Clastics 064	189.232,6	0	0	0	0	0	0
Layered Clastics 065	647.410,0	0	1	0	0	0	5
Layered Clastics 066	772.805,7	0	5	1	0	0	9
Layered Clastics 067	164.269,9	0	0	0	0	0	0
Layered Clastics 068	192.501,4	0	0	0	0	0	0
Layered Clastics 069	40.560,7	0	0	0	0	0	0
Layered Clastics 070	321.190,6	0	0	0	0	0	1
Layered Clastics 071	5.225.631,7	0	6	5	0	0	8
Layered Clastics 072	464.898,8	0	0	0	0	0	0
Layered Clastics 073	266.924,7	0	0	1	0	0	0
Layered Clastics 074	457.374,0	0	0	0	0	0	0
Layered Clastics 075	196.344,1	0	0	0	0	0	0
Layered Clastics 076	867.401,1	0	0	1	0	0	0
Layered Clastics 077	552.184,7	0	0	0	0	0	0
Layered Clastics 078	71.191.467,4	5	3	3	0	0	0
Layered Clastics 079	60.560,4	0	0	0	0	0	0
Layered Clastics 080	5.140.825,1	0	1	2	0	0	0
Layered Clastics 081	414.813,4	0	0	0	0	0	0
Layered Clastics 082	65.831,4	0	0	0	0	0	0
Layered Clastics 083	527.279,8	0	0	0	0	0	0
Layered Clastics 084	906.525,8	0	0	0	0	0	0
Layered Clastics 085	3.934.576,8	0	0	0	0	0	0
Layered Clastics 086	2.400.597,4	0	0	0	0	0	0
Layered Clastics 087	220.113.877,5	3	93	13	0	0	8
Layered Clastics 088	3.259.743,6	0	2	2	0	0	5
Layered Clastics 089	29.289.487,8	1	20	1	0	0	0
Layered Clastics 090	10.553.366,7	1	0	1	0	0	0
Layered Clastics 091	2.368.007,7	0	9	1	0	0	0
Layered Clastics 092	574.027,3	0	0	0	0	0	0
Layered Clastics 093	81.602.938,4	5	4	4	0	0	27
Layered Clastics 094	2.866.275,7	0	6	1	0	0	0
Layered Clastics 095	459.307,3	0	0	0	0	0	0
Layered Clastics 096	19.039.313,3	0	14	0	0	0	0
Layered Clastics 097	1.127.696,9	0	0	1	0	0	0
Layered Clastics 098	38.802,9	0	0	0	0	0	0
Layered Clastics 099	107.889,8	0	0	0	0	0	0
Layered Clastics 100	236.229,1	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Layered Clastics 101	13.251.294,3	0	13	0	0	0	2
Layered Clastics 102	86.412,6	0	1	0	0	0	0
Layered Clastics 103	8.325.457,3	1	2	0	0	0	0
Layered Clastics 104	230.323,9	1	0	1	0	0	0
Layered Clastics 105	2.396.072,1	0	0	0	0	0	0
Layered Clastics 106	706.135,9	0	0	0	0	0	0
Layered Clastics 107	10.321.268,8	0	12	2	0	0	0
Layered Clastics 108	2.548.219,0	0	4	0	0	0	0
Layered Clastics 109	767.083,7	0	0	0	0	0	0
Layered Clastics 110	33.797,6	0	0	0	0	0	0
Layered Clastics 111	84.047,5	0	0	0	0	0	0
Layered Clastics 112	49.480,8	0	0	0	0	0	0
Layered Clastics 113	2.858.901,8	0	1	0	0	0	0
Layered Clastics 114	88.432,3	0	0	0	0	0	0
Layered Clastics 115	283.457,9	0	0	0	0	0	0
Layered Clastics 116	434.476,9	0	0	0	0	0	0
Layered Clastics 117	166.564,1	0	0	0	0	0	0
Layered Clastics 118	1.679.661,5	0	0	0	0	0	0
Layered Clastics 119	1.789.166,1	0	2	1	0	0	15
Layered Clastics 120	888.689,8	0	3	0	0	0	0
Layered Clastics 121	5.859.966,6	0	6	2	0	0	3
Layered Clastics 122	4.765.163,3	0	3	0	0	0	0
Layered Clastics 123	3.330.251,4	0	3	1	0	0	2
Layered Clastics 124	6.442.671,1	0	6	0	0	0	0
Layered Clastics 125	206.539.699,5	9	82	56	0	0	128
Layered Clastics 126	7.971.911,3	0	0	2	0	0	0
Layered Clastics 127	32.592.583,1	0	36	7	0	0	5
Layered Clastics 128	234.749.718,2	8	51	34	0	0	202
Layered Clastics 129	28.152.985,0	3	5	1	0	0	75
Layered Clastics 130	629.239.564,4	38	342	148	0	4	450
Soft Clastics 001	16.420.408,0	3	0	1	0	0	43
Soft Clastics 002	1.023.796,2	0	0	0	0	0	0
Soft Clastics 003	12.892.744,3	5	0	6	0	0	19
Soft Clastics 004	2.744.179,7	0	1	0	0	0	0
Soft Clastics 005	1.020.554,8	0	0	0	0	0	0
Soft Clastics 006	577.929,8	0	0	0	0	0	0
Soft Clastics 007	1.033.689,0	0	3	0	0	0	2
Soft Clastics 008	305.170,3	0	0	1	0	0	0
Soft Clastics 009	2.861.684,1	0	8	1	0	0	4
Soft Clastics 010	290.123,3	0	0	0	0	0	0
Soft Clastics 011	31.870.526,1	15	14	43	0	0	54
Soft Clastics 012	1.266.951,4	1	0	5	0	0	0
Soft Clastics 013	581.123,6	0	0	0	0	0	5
Soft Clastics 014	92.944,1	0	0	0	0	0	1

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Soft Clastics 015	358.387,2	0	0	0	0	0	0
Soft Clastics 016	81.621,5	0	0	0	0	0	0
Soft Clastics 017	1.289.931,4	0	4	1	0	0	2
Soft Clastics 018	10.329.267,5	4	7	14	0	0	16
Soft Clastics 019	63.345,2	0	0	0	0	0	0
Soft Clastics 020	300.304,3	0	0	0	0	0	2
Soft Clastics 021	480.482,2	0	0	1	0	0	0
Soft Clastics 022	314.581,0	0	0	0	0	0	0
Soft Clastics 023	582.101,2	0	0	0	0	0	0
Soft Clastics 024	132.336,9	0	0	0	0	0	0
Soft Clastics 025	263.321,1	0	0	0	0	0	4
Soft Clastics 026	49.445,8	0	0	0	0	0	0
Soft Clastics 027	46.162.250,6	16	52	63	1	0	109
Soft Clastics 028	16.037.094,2	1	22	1	0	0	32
Soft Clastics 029	22.225.923,3	3	1	2	0	0	0
Soft Clastics 030	3.601.114,1	0	0	0	0	0	0
Soft Clastics 031	135.848,7	0	0	0	0	0	0
Soft Clastics 032	4.737.111,3	0	0	2	0	0	0
Soft Clastics 033	109.245,9	0	0	0	0	0	0
Soft Clastics 034	6.006.369,2	0	6	0	0	0	2
Soft Clastics 035	1.183.879,0	0	0	0	0	0	0
Soft Clastics 036	32.282.173,8	4	7	3	1	0	47
Soft Clastics 037	53.268.945,5	6	9	8	0	1	94
Soft Clastics 038	7.845.087,8	1	3	0	0	0	27
Soft Clastics 039	550.067,3	0	0	0	0	0	0
Soft Clastics 040	5.656.484,1	0	0	0	0	0	0
Soft Clastics 041	837.415,4	0	0	0	0	0	0
Soft Clastics 042	222.061,1	0	0	0	0	0	0
Soft Clastics 043	300.858,7	0	0	0	0	0	0
Soft Clastics 044	79.331,7	0	0	0	0	0	0
Soft Clastics 045	900.188,1	0	0	0	0	0	0
Soft Clastics 046	510.652,7	0	0	0	0	0	0
Soft Clastics 047	83.650,4	0	0	0	0	0	0
Soft Clastics 048	3.254.543,5	0	3	1	0	0	0
Soft Clastics 049	313.215,8	0	0	0	0	0	0
Soft Clastics 050	121.249,0	0	0	0	0	0	0
Soft Clastics 051	983.410,8	0	0	0	0	0	6
Soft Clastics 052	3.192.236,8	0	1	1	0	0	0
Soft Clastics 053	231.035,3	0	0	0	0	0	0
Soft Clastics 054	210.524,9	0	0	0	0	0	0
Soft Clastics 055	525.537,4	0	0	0	0	0	0
Soft Clastics 056	2.031.799,2	0	1	0	0	0	1
Soft Clastics 057	749.278,4	0	0	0	0	0	0
Soft Clastics 058	13.318.661,8	0	2	2	0	0	12

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Soft Clastics 059	9.723.893,3	3	16	4	0	0	12
Soft Clastics 060	10.103.235,9	1	2	6	0	0	40
Soft Clastics 061	298.256,1	0	1	0	0	0	0
Soft Clastics 062	469.654,7	0	0	0	0	0	0
Soft Clastics 063	501.178,2	0	4	1	0	0	0
Soft Clastics 064	290.615,7	0	0	0	0	0	0
Soft Clastics 065	21.955.146,9	1	25	9	0	0	37
Soft Clastics 066	347.454,7	0	0	0	0	0	0
Soft Clastics 067	1.096.305,9	0	0	0	0	0	14
Soft Clastics 068	1.158.127,4	0	0	1	0	1	2
Soft Clastics 069	8.853.072,9	0	11	4	0	0	35
Soft Clastics 070	32.225.140,0	3	14	18	0	0	9
Soft Clastics 071	40.361,5	0	0	1	0	0	0
Soft Clastics 072	19.845.979,0	2	5	2	0	0	8
Soft Clastics 073	5.295.146,6	2	2	0	0	0	6
Soft Clastics 074	714.558,1	0	0	0	0	0	0
Soft Clastics 075	715.178,1	0	0	0	0	0	0
Soft Clastics 076	30.718.346,9	3	6	4	0	0	48
Soft Clastics 077	22.320.111,1	3	6	6	0	0	67
Soft Clastics 078	29.076.049,4	3	14	7	0	0	0
Soft Clastics 079	23.917.521,4	1	3	2	0	0	7
Soft Clastics 080	260.881.861,6	16	326	39	0	4	537
Lava Flows 001	478.485,8	0	0	0	0	0	0
Lava Flows 002	340.560,0	0	0	0	0	0	0
Lava Flows 003	72.753,1	0	0	0	0	0	0
Lava Flows 004	42.448,0	0	0	0	0	0	0
Lava Flows 005	129.548,9	0	0	0	0	0	0
Lava Flows 006	570.113,2	0	0	0	0	0	1
Lava Flows 007	9.366.486,5	0	29	0	0	0	1
Lava Flows 008	207.557,9	0	0	1	0	0	0
Lava Flows 009	2.661.811,3	0	0	0	0	0	0
Lava Flows 010	360.716,0	0	0	0	0	0	0
Lava Flows 011	800.581,7	0	0	0	0	0	0
Lava Flows 012	5.703.741,7	2	9	1	0	0	32
Lava Flows 013	196.481,7	0	0	0	0	0	0
Lava Flows 014	83.531,8	0	0	0	0	0	0
Lava Flows 015	12.260.959,4	3	5	11	0	0	26
Lava Flows 016	1.222.291,0	1	0	1	0	0	0
Lava Flows 017	13.576.122,0	3	3	15	0	0	7
Lava Flows 018	23.737.369,9	5	15	25	0	0	27
Lava Flows 019	115.046,5	0	0	0	0	0	0
Lava Flows 020	267.120,1	0	1	0	0	0	0
Lava Flows 021	602.734,7	0	0	0	0	0	1
Lava Flows 022	135.153,4	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Lava Flows 023	318.287,7	0	0	0	0	0	0
Lava Flows 024	159.033,1	0	0	0	0	0	0
Lava Flows 025	847.927,9	0	0	0	0	0	0
Lava Flows 026	164.607,7	0	0	0	0	0	0
Lava Flows 027	543.907,1	0	0	0	0	0	0
Lava Flows 028	156.781,9	0	0	0	0	0	0
Lava Flows 029	781.872,5	0	0	0	0	0	0
Lava Flows 030	149.224,0	0	0	0	0	0	0
Lava Flows 031	99.844,9	0	0	0	0	0	0
Lava Flows 032	143.905,9	0	0	0	0	0	2
Lava Flows 033	17.231.738,1	1	6	3	0	0	11
Lava Flows 034	29.407.927,4	1	7	4	0	0	0
Lava Flows 035	380.665,5	0	0	0	0	0	0
Lava Flows 036	334.799,6	0	0	0	0	0	0
Lava Flows 037	800.257,7	0	3	0	0	0	0
Lava Flows 038	55.297,9	0	0	0	0	0	0
Lava Flows 039	703.216,4	0	0	0	0	0	0
Lava Flows 040	60.581,8	0	0	0	0	0	0
Lava Flows 041	258.365,9	0	0	0	0	0	0
Lava Flows 042	1.284.634,4	0	0	1	0	0	0
Lava Flows 043	252.137,1	0	0	0	0	0	0
Lava Flows 044	944.326,1	0	0	0	0	0	2
Lava Flows 045	521.986,2	0	0	0	0	0	0
Lava Flows 046	140.403,5	0	0	0	0	0	0
Lava Flows 047	102.180,5	0	0	0	0	0	0
Lava Flows 048	680.575,1	0	0	0	0	0	0
Lava Flows 049	148.687,1	0	0	0	0	0	0
Lava Flows 050	191.435,8	0	0	0	0	0	0
Lava Flows 051	801.309,5	1	0	0	0	0	0
Lava Flows 052	39.408,6	0	0	0	0	0	0
Lava Flows 053	336.075,0	0	0	0	0	0	0
Lava Flows 054	44.568,9	0	0	0	0	0	0
Lava Flows 055	1.049.808,9	0	0	0	0	0	0
Lava Flows 056	21.354,6	0	0	0	0	0	0
Lava Flows 057	40.374.297,2	1	28	4	0	0	100
Lava Flows 058	199.191,0	0	0	0	0	0	0
Lava Flows 059	42.816,3	0	0	0	0	0	1
Lava Flows 060	474.175,7	0	0	0	0	0	2
Lava Flows 061	196.203,9	0	0	0	0	0	0
Lava Flows 062	249.618,0	0	0	0	0	0	0
Lava Flows 063	451.943,8	1	0	1	0	0	0
Lava Flows 064	306.975,9	0	0	0	0	0	0
Lava Flows 065	162.194,8	0	0	0	0	0	0
Lava Flows 066	626.933,9	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Lava Flows 067	135.736,9	0	0	0	0	0	0
Lava Flows 068	11.267.191,7	2	8	6	0	0	2
Lava Flows 069	856.335,7	0	5	0	0	0	0
Lava Flows 070	165.444,8	0	0	0	0	0	0
Lava Flows 071	1.290.507,2	0	0	0	0	0	0
Lava Flows 072	57.008,1	0	0	0	0	0	0
Lava Flows 073	679.443,2	0	1	1	0	0	0
Lava Flows 074	246.203,6	0	0	0	0	0	0
Lava Flows 075	24.071,1	0	0	0	0	0	0
Lava Flows 076	359.714,7	0	0	0	0	0	0
Lava Flows 077	92.369,5	0	0	0	0	0	0
Lava Flows 078	59.860,5	0	0	0	0	0	0
Lava Flows 079	1.099.806,5	0	1	2	0	0	0
Lava Flows 080	6.740.839,1	1	5	2	0	0	0
Lava Flows 081	106.124,0	0	0	0	0	0	0
Lava Flows 082	1.064.510,0	0	0	0	0	0	0
Lava Flows 083	9.410.218,9	1	27	0	0	0	19
Lava Flows 084	952.575,2	0	0	0	0	0	0
Lava Flows 085	55.837,0	0	0	0	0	0	0
Lava Flows 086	44.065,6	0	0	0	0	0	0
Lava Flows 087	209.367,5	0	0	0	0	0	0
Lava Flows 088	180.870,5	0	0	0	0	0	0
Lava Flows 089	2.992.851,4	0	0	0	0	0	0
Lava Flows 090	992.738,8	0	4	0	0	0	0
Lava Flows 091	2.046.651,8	0	0	0	0	0	0
Lava Flows 092	305.086,6	0	0	0	0	0	0
Lava Flows 093	779.395,1	0	0	1	0	0	0
Lava Flows 094	185.326,0	0	0	0	0	0	0
Lava Flows 095	4.158.236,5	0	0	0	0	0	3
Lava Flows 096	78.536,6	0	0	0	0	0	0
Lava Flows 097	21.639.940,9	1	19	15	0	0	42
Lava Flows 098	18.482.103,2	2	12	6	0	0	0
Lava Flows 099	841.873,6	0	3	0	0	0	4
Lava Flows 100	44.057,0	0	0	0	0	0	0
Lava Flows 101	65.686,8	0	0	0	0	0	0
Lava Flows 102	23.896,1	0	0	0	0	0	0
Lava Flows 103	345.335,1	0	0	0	0	0	0
Lava Flows 104	3.904.467,5	0	0	1	0	0	0
Lava Flows 105	74.005,0	0	0	0	0	0	0
Lava Flows 106	1.119.535,5	0	0	0	0	0	0
Lava Flows 107	446.641,0	0	0	0	0	0	0
Lava Flows 108	12.653,5	0	0	0	0	0	0
Lava Flows 109	124.434,1	0	1	0	0	0	0
Lava Flows 110	6.675.743,7	0	4	1	0	0	2

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Lava Flows 111	1.078.131,2	0	0	1	0	0	0
Lava Flows 112	60.353,5	0	0	0	0	0	0
Lava Flows 113	651.421,3	0	0	0	0	0	0
Lava Flows 114	833.066,5	0	0	0	0	0	0
Lava Flows 115	650.771,9	0	0	2	0	0	0
Lava Flows 116	726.884,2	0	3	0	0	0	0
Lava Flows 117	14.378,9	0	0	0	0	0	0
Lava Flows 118	47.024,7	0	0	0	0	0	0
Lava Flows 119	1.132.989,0	0	0	0	0	0	0
Lava Flows 120	890.531,6	0	0	0	0	0	0
Lava Flows 121	89.483,1	0	0	0	0	0	0
Lava Flows 122	44.940,7	0	0	0	0	0	0
Lava Flows 123	978.687,0	0	0	0	0	0	0
Lava Flows 124	82.835,0	0	0	0	0	0	0
Lava Flows 125	486.265,7	0	0	0	0	0	0
Lava Flows 126	102.499,9	0	0	0	0	0	0
Lava Flows 127	50,4	0	0	0	0	0	0
Lava Flows 128	127.803,7	0	0	0	0	0	0
Lava Flows 129	7.346.487,8	0	12	0	0	0	4
Lava Flows 130	151.316,6	0	0	0	0	0	0
Lava Flows 131	57.577,1	0	0	0	0	0	0
Lava Flows 132	179.016,6	0	0	0	0	0	0
Lava Flows 133	168.680,0	0	0	0	0	0	0
Lava Flows 134	87.211,2	0	0	0	0	0	0
Lava Flows 135	892.891,2	0	0	0	0	0	0
Lava Flows 136	108.024,7	0	0	0	0	0	0
Lava Flows 137	3.203.394,9	1	1	0	0	0	0
Lava Flows 138	7.516.024,9	0	5	6	0	0	0
Lava Flows 139	11.709.492,5	1	15	3	0	0	33
Lava Flows 140	17.903.556,0	1	1	1	0	0	0
Lava Flows 141	11.220.912,7	1	8	4	0	0	9
Lava Flows 142	1.954.609,1	0	0	0	0	0	0
Lava Flows 143	253.264,0	0	0	0	0	0	0
Lava Flows 144	33.192.918,7	0	19	4	0	0	66
Metamorphics 001	7.434.279,3	0	19	0	0	0	51
Metamorphics 002	88.328,0	0	0	0	0	0	2
Metamorphics 003	21.467.294,0	6	26	2	0	0	65
Metamorphics 004	96.928,8	0	0	0	0	0	0
Metamorphics 005	140.762,5	1	0	0	0	0	0
Metamorphics 006	192.041,1	0	0	0	0	0	5
Metamorphics 007	157.281,0	0	0	0	0	0	1
Metamorphics 008	14.974.423,9	2	2	0	0	0	30
Metamorphics 009	156.026,6	0	0	0	0	0	1
Metamorphics 010	320.823,1	0	1	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Metamorphics 011	152.062,1	0	0	0	0	0	0
Metamorphics 012	215.054,1	0	0	0	0	0	0
Metamorphics 013	5.261.896,8	0	3	0	0	0	36
Metamorphics 014	39.294,9	0	0	0	0	0	0
Metamorphics 015	18.858,1	0	0	0	0	0	0
Metamorphics 016	14.470,6	0	0	0	0	0	0
Metamorphics 017	25.094,1	0	0	0	0	0	0
Metamorphics 018	15.779,1	0	0	0	0	0	0
Metamorphics 019	26.056,0	0	0	0	0	0	0
Metamorphics 020	277.584,6	1	1	0	0	0	4
Metamorphics 021	14.764,8	0	0	0	0	0	1
Metamorphics 022	4.046.035,5	5	19	3	0	0	22
Metamorphics 023	7.208.182,0	2	5	0	0	0	13
Metamorphics 024	109.137,0	0	0	0	0	0	0
Metamorphics 025	929.641,8	0	1	0	0	0	11
Metamorphics 026	86.390,3	0	1	0	0	0	0
Metamorphics 027	50.572,9	0	0	0	0	0	1
Metamorphics 028	208.478,1	0	0	0	0	0	0
Metamorphics 029	779.234,1	0	0	0	0	0	12
Metamorphics 030	6.503.776,1	0	17	0	0	0	41
Metamorphics 031	577.766,9	0	3	0	0	0	0
Metamorphics 032	62.243,2	0	0	0	0	0	0
Metamorphics 033	730.928,1	0	2	0	0	0	0
Metamorphics 034	149.839,6	0	0	0	0	0	0
Metamorphics 035	1.211.404,9	0	0	0	0	0	0
Metamorphics 036	4.768.026,9	0	0	0	0	0	15
Metamorphics 037	250.815,2	0	0	0	0	0	0
Metamorphics 038	27.208.878,6	1	17	8	0	0	95
Metamorphics 039	586.009,1	0	1	0	0	0	1
Metamorphics 040	790.644,8	0	0	0	0	0	0
Metamorphics 041	633.904,8	0	0	0	0	0	0
Metamorphics 042	1.357.662,0	0	0	1	0	0	7
Metamorphics 043	5.953.624,5	0	10	1	0	0	21
Metamorphics 044	1.850.253,5	0	0	0	0	0	1
Metamorphics 045	92.719,4	0	0	0	0	0	0
Metamorphics 046	1.014.191,9	0	2	0	0	0	0
Metamorphics 047	11.003.463,9	1	9	4	0	0	0
Metamorphics 048	2.239.996,2	0	10	0	0	1	22
Metamorphics 049	361.594,9	0	0	0	0	0	0
Old Volcanics 001	462.811,8	0	0	0	0	0	5
Old Volcanics 002	259.330,3	0	0	0	0	0	3
Old Volcanics 003	5.194.707,4	0	3	0	0	0	6
Old Volcanics 004	180.111,4	0	0	0	0	0	0
Old Volcanics 005	19.232.586,4	3	7	1	0	0	49

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Old Volcanics 006	637.138,3	0	0	0	0	0	0
Old Volcanics 007	495.725,2	0	0	0	0	0	7
Old Volcanics 008	567.490,4	0	1	0	0	0	0
Old Volcanics 009	381.492,0	0	5	0	0	0	1
Old Volcanics 010	10.382.598,2	0	0	0	0	0	37
Old Volcanics 011	53.413,3	0	0	0	0	0	0
Old Volcanics 012	356.888,7	0	0	0	0	0	0
Old Volcanics 013	327.855,5	0	0	1	0	0	0
Old Volcanics 014	169.956,9	0	0	0	0	0	0
Old Volcanics 015	2.012.146,1	0	0	0	0	0	20
Old Volcanics 016	947.378,2	0	1	0	0	0	1
Old Volcanics 017	37.379.101,9	4	72	6	0	0	68
Old Volcanics 018	77,7	0	0	0	0	0	0
Old Volcanics 019	1.759,1	0	0	0	0	0	0
Old Volcanics 020	1.167,2	0	0	0	0	0	0
Old Volcanics 021	402.293,6	0	0	0	0	0	1
Old Volcanics 022	198.558,0	0	0	0	0	0	0
Old Volcanics 023	1.419.172,8	0	0	0	0	0	1
Old Volcanics 024	224.369,0	0	0	0	1	0	0
Old Volcanics 025	129.552,5	1	0	0	0	0	0
Old Volcanics 026	242.919,3	0	0	0	0	0	0
Old Volcanics 027	731.943,3	0	0	0	0	0	0
Old Volcanics 028	2.751.481,5	0	1	0	0	0	0
Old Volcanics 029	518.318,7	1	0	2	0	0	0
Old Volcanics 030	142.208,0	0	0	0	0	0	0
Old Volcanics 031	171.128,4	0	0	0	0	0	0
Old Volcanics 032	382.603,3	0	0	0	0	0	0
Old Volcanics 033	40.351.945,7	13	15	41	0	0	43
Old Volcanics 034	1.023.967,7	0	1	1	0	0	0
Old Volcanics 035	60.169.762,2	1	92	4	0	0	344
Old Volcanics 036	17.135.154,9	3	5	0	0	0	122
Old Volcanics 037	1.887.675,3	1	0	0	0	0	26
Old Volcanics 038	90.224,2	0	0	0	0	0	0
Old Volcanics 039	131.107,0	0	0	0	0	0	0
Old Volcanics 040	974.850,5	0	1	0	0	0	1
Old Volcanics 041	332.593,3	0	0	0	0	0	0
Old Volcanics 042	342.065,9	0	0	0	0	0	0
Old Volcanics 043	469.908,2	0	0	0	0	0	0
Old Volcanics 044	133.809,1	0	0	0	0	0	4
Old Volcanics 045	90.872,5	0	0	0	0	0	0
Old Volcanics 046	159.338,3	0	0	0	0	0	1
Old Volcanics 047	483.071,6	0	0	0	0	0	0
Old Volcanics 048	37.694.640,2	1	44	7	0	0	76
Old Volcanics 049	268.727,6	0	0	0	0	0	1

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Old Volcanics 050	2.871.525,9	0	4	0	0	0	0
Old Volcanics 051	2.995.708,5	0	2	0	0	0	2
Old Volcanics 052	425.474,7	0	0	0	0	0	0
Old Volcanics 053	342.295,7	0	0	0	0	0	0
Old Volcanics 054	2.870.534,6	0	0	2	0	0	0
Old Volcanics 055	9.491.513,6	1	1	1	0	0	0
Old Volcanics 056	1.096.432,9	0	0	0	0	0	0
Old Volcanics 057	222.444,4	0	0	0	0	0	0
Old Volcanics 058	682.866,2	0	0	0	0	0	0
Old Volcanics 059	1.330.078,2	0	0	2	0	0	0
Old Volcanics 060	114.893,8	0	0	0	0	0	0
Old Volcanics 061	2.243.777,6	1	3	1	0	0	1
Old Volcanics 062	37.858.350,5	0	88	3	0	0	271
Old Volcanics 063	23.658.200,8	5	51	19	0	0	73
Old Volcanics 064	29.365.569,5	4	5	3	0	0	26
Old Volcanics 065	507.665,6	0	0	0	0	0	0
Old Volcanics 066	7.843.810,5	4	2	9	0	0	7
Old Volcanics 067	114.139,4	0	0	0	0	0	0
Carbonates 001	73.742,1	0	0	0	0	0	0
Carbonates 002	15.913.815,9	0	29	0	0	0	59
Carbonates 003	1.408,4	0	0	0	0	0	0
Carbonates 004	791.263,4	0	0	0	0	0	0
Carbonates 005	137.780,3	0	0	0	0	0	1
Carbonates 006	1.270.766,1	0	0	3	0	0	0
Carbonates 007	688.248,5	0	0	0	0	0	0
Carbonates 008	284.915,9	0	0	0	0	0	0
Carbonates 009	2.725.832,0	0	0	0	0	0	0
Carbonates 010	5.534.601,3	1	1	2	0	0	8
Carbonates 011	145.579,8	0	0	0	0	0	0
Carbonates 012	2.346.621,9	2	0	6	0	0	7
Carbonates 013	893.564,7	0	0	0	0	0	0
Carbonates 014	37.385.319,5	4	14	20	0	0	80
Carbonates 015	17.513.027,8	1	7	15	0	0	2
Carbonates 016	567.270,3	0	0	0	0	0	3
Carbonates 017	5.708.619,7	1	3	3	0	0	3
Carbonates 018	11.707.918,8	0	0	0	0	0	0
Carbonates 019	4.306.815,4	0	0	0	0	0	0
Carbonates 020	1.388.826,1	0	0	0	0	0	0
Carbonates 021	153.864,4	0	0	0	0	0	0
Carbonates 022	4.022.498,2	1	1	0	0	0	0
Carbonates 023	652.988,1	0	0	0	0	0	0
Carbonates 024	5.837.167,4	0	3	0	0	0	0
Carbonates 025	1.448.842,2	0	6	0	0	0	10
Carbonates 026	80.706,5	0	0	0	0	0	0

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Carbonates 027	693.092,2	0	0	0	0	0	0
Carbonates 028	55.511,7	0	0	0	0	0	0
Carbonates 029	7.658.173,0	3	3	4	0	0	9
Carbonates 030	14.735.593,1	1	1	0	0	0	45
Carbonates 031	30.044,7	0	0	0	0	0	0
Carbonates 032	129.540,2	0	0	0	0	0	0
Carbonates 033	50.722,0	0	0	0	0	0	0
Carbonates 034	41.456,8	0	0	0	0	0	0
Carbonates 035	112.638,2	0	0	0	0	0	0
Carbonates 036	78.477.071,7	3	28	10	0	0	0
Carbonates 037	203.573,7	0	0	0	0	0	0
Carbonates 038	74.557,1	0	0	0	0	0	0
Carbonates 039	7.790.577,2	0	29	3	0	0	13
Carbonates 040	64.159,9	0	0	0	0	0	0
Carbonates 041	3.284.742,0	0	4	5	0	0	0
Carbonates 042	2.537.436,9	0	2	0	0	0	11
Carbonates 043	721.060,4	0	0	0	0	0	0
Carbonates 044	69.392,6	0	0	0	0	0	0
Carbonates 045	45.013,7	0	0	0	0	0	0
Carbonates 046	130.271,1	0	0	0	0	0	0
Carbonates 047	281.383,4	0	0	0	0	0	0
Carbonates 048	317.462,3	0	0	0	0	0	0
Carbonates 049	48.855.231,2	3	60	11	0	0	45
Carbonates 050	127.458,1	0	0	0	0	0	0
Carbonates 051	322.892,2	0	0	0	0	0	0
Carbonates 052	193.650,3	0	0	0	0	0	0
Carbonates 053	28.818.203,8	3	31	8	0	0	10
Carbonates 054	101.445.532,8	5	66	27	2	0	162
Olistostrome 001	15.242.787,4	5	19	21	2	0	37
Olistostrome 002	119.629.467,3	30	68	112	1	0	207
Olistostrome 003	160.597,1	1	0	2	0	0	0
Olistostrome 004	92.579,8	0	0	0	0	0	0
Olistostrome 005	138.755.213,2	36	80	139	1	0	184
Olistostrome 006	80.537,2	0	0	0	0	0	0
Olistostrome 007	797.391,1	1	0	0	1	0	0
Olistostrome 008	461.011,4	0	0	0	0	0	3
Olistostrome 009	947.386,6	0	0	0	0	0	0
Olistostrome 010	1.033.981,3	0	0	0	0	0	0
Olistostrome 011	881.825,2	0	0	0	0	0	0
Olistostrome 012	547.768,1	0	0	0	0	0	0
Olistostrome 013	135.568,0	0	0	0	0	0	0
Olistostrome 014	223.565,6	0	0	0	0	0	0
Olistostrome 015	100.535,5	0	0	0	0	0	0
Olistostrome 016	12.662.855,7	0	8	9	1	0	20

Table A2 continued: Table showing the results of overlay analysis

Rock Polygons	Area (m^2)	Settlement	Spring	Wet Fountain	Dry Fountain	Lakes	Stream
Olistostrome 017	55.327,4	0	0	0	0	0	0
Olistostrome 018	189.586,5	0	0	0	0	0	0
Olistostrome 019	43.449,0	0	0	0	0	0	0
Olistostrome 020	97.330,3	0	0	0	0	0	0
Olistostrome 021	171.728,9	0	0	0	0	0	0
Olistostrome 022	61.345,3	0	0	0	0	0	0
Olistostrome 023	445.242,9	0	0	0	0	0	0
Olistostrome 024	870.660,2	1	0	1	0	0	6
Olistostrome 025	9.849.272,9	2	5	12	0	0	0