DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ASSESSMENT OF POLLUTION LOADS BY USING GIS BASED MASS BALANCE APPROACHES

by
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June, 2023
İZMİR

ASSESSMENT OF POLLUTION LOADS BY USING GIS BASED MASS BALANCE APPROACHES

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University in Partial Fulfillment of the Requirements for Master of Science in Geographic Information Systems

by

Okan TURHAN

June, 2023

İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"ASSESSMENT OF POLLUTION LOADS BY USING GIS BASED MASS BALANCE APPROACHES"** completed by **OKAN TURHAN** under supervision of **PROF.DR. OKAN FISTIKOĞLU** and we certify that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ASSESSMENT OF POLLUTION LOADS BY USING GIS BASED MASS BALANCE APPROACHES

ABSTRACT

Water is essential to our existence, providing life, civilization, struggle, and vigor to our bodies. Oceans and oceans contain around 97% of the world's water, yet they are unfit for drinking, cultivation, or industry. As a result, every country conducts basin-wide evaluations of potable water inside its boundaries.

These assessments consider surface waters, artificial and natural lakes, and groundwater, focusing on quantity and quality. To estimate future water usage, quantity studies analyze purposes and amounts of water utilized. Quality studies investigate point and diffuse pollutants that could contaminate streams.

It is possible to determine to what extent point pollutants contaminate the waterways, various techniques have been developed to determine how much dispersed pollutants contaminate the waters. As a result of these approaches, regions of diffuse contamination can only be identified at the sub-basin level, and it is not possible to offer suggestions for taking precautions in this regard.

This study provides the potential to expose particularly diffuse pollution quantitatively and geographically utilizing Geographic Information Systems. It exposes the pathways and pollution quantities of point and diffuse pollutants by linking spatial pollutant components with basin topography. For this purpose, Güzelhisar Basin is chosen as the application area.

As a consequence, the geographical distribution of point and diffuse pollution loads in the basin could be quantitatively presented in this study. In this approach, it allows for the presentation of a geographical method of steps to restore the water to excellent condition in terms of the pollutants that contaminate the water.

Keywords: Geographic Information Systems, spatial analysis, pollution

KİRLİLİK YÜKLERİNİN CBS TABANLI KÜTLE DENGESİ YAKLAŞIMLARIYLA İRDELENMESİ

ÖZ

Su, varlığımızın temel taşı, tarih boyunca medeniyetlerin çevresinde kalkındığı, uğruna savaşlar verilen, vücudumuz için ise olmazsa olmaz, yaşamımızın kaynağıdır. Dünya üzerindeki su oranlarına baktığımız zaman suyun yaklaşık %97'sini okyanuslar ve denizler oluşturmaktadır. Fakat bu sular, içme suyu, tarım ve sanayi gibi amaçlarla kullanılamamaktadır. Bu yüzden tüm dünya devletleri, kendi sınırları içerisindeki kullanılabilir sular üzerinde havza bazında miktar ve kalite çalışmaları yürütmektedir.

Suyun miktar ve kalite çalışmalarında genellikle, yerüstü suyu olan nehirler, yapay göller, doğal göller ve yer altı suları dikkate alınmaktadır. Miktar çalışmalarında suların hangi amaçla ve ne kadar miktarda kullanıldığı tespit edilerek gelecek projeksiyonları hazırlanmaktadır. Kalite çalışmalarında ise bu suları kirletebilecek noktasal ve yayılı kirletici unsurlar üzerinde çalışılmaktadır. Noktasal kirletici unsurların suları ne kadar kirlettiği belirlenebilmekte, yayılı kirletici unsurların suları ne kadar kirlettiği konusunda çeşitli yaklaşımlar geliştirilmektedir. Bu yaklaşımlar sonucunda yayılı kirlilik gösteren alanlar ancak alt havza bazlı olarak belirlenebilmekte olup, tedbir önerilememektedir.

Bu çalışma, Coğrafi Bilgi Sistemleri kullanılarak mekânsal analizler ile özellikle yayılı kirlilikleri sayısal ve mekânsal olarak ortaya koyma imkânı sunmaktadır. Alansal kirletici unsurlar ve havza topoğrafyası ilişkilendirilerek, noktasal ve yayılı kirleticilerin izledikleri yolu ve kirlilik miktarlarını ortaya çıkartmaktadır. Bu çalışma kapsamında "Güzelhisar Havzası" çalışılmıştır.

Sonuç olarak bu çalışma, havzadaki noktasal ve yayılı kirlilik yüklerinin alansal dağılımını sayısal olarak sunabilmektedir. Bu sayede suları kirleten kirletici unsurlar ile ilgili, suyu iyi duruma getirmek için mekânsal olarak tedbirler programı sunma imkânı tanımaktadır.

Anahtar kelimeler: Coğrafi Bilgi Sistemleri, mekânsal analiz, kirlilik

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ABBREVIATIONS

EU	: European Union
GIS	: Geographic Information Systems
TN	: Total nitrogen
TP	: Total phosphorus
SS	: Suspended solid
COD	: Chemical Oxygen Demand
TÜİK	: Turkish statistical institute (Türkiye istatistik kurumu)
CORINE	: Coordination of information on the environment
DEM	: Digital elevation model
SÇD	: Water framework directive (Su Çerçeve Direktifi)
SYGM	: General directorate of water management (Su Yönetimi Genel Müdürlüğü)
ÇYGM	: Republic of Turkey Ministry of Environment, Urbanization and Climate Change (Çevre Yönetimi Genel Müdürlüğü)
DSİ	: State Hydraulic Works (Devlet Su İşleri)
TÜBİTAK	: The Scientific and Technological Research Council of Turkey (Türkiye Bilimsel ve Teknolojik Araştırma Kurumu)
UHYS	: National Basin Management Strategy (Ulusal Havza Yönetim Stratejisi)
ESRI	: Environmental Systems Research Institute, Inc.
ASTER	: Advanced Spaceborne Thermal Emission and Reflection Radiometer

SILC : Sensor Information Laboratory Corporation

NASA : National Aeronautics and Space Administration

METI : Ministry of Economy, Trade and Industry

UNESCO : United Nations Educational, Scientific and Cultural Organization

UNCED : United Nations Conference on Environment and Development

WWTP : Waste water treatment plant

CHAPTER ONE
INTRODUCTION

Water is crucial for the survival of living beings. It sustains all biological life forms, from the tiniest microorganisms to the largest living organisms, as well as all human activities. Water covers 70% of our planet and is a significant component of our bodies. However, approximately 0.3% of the Earth's water resources are usable and potable. Water found in oceans and inland seas is unsuitable for drinking, irrigation, and industrial use due to its high salinity. Only 2.5% of the world's water is freshwater, and 87% of this is found in glaciers, soil, the atmosphere, and groundwater (JMO, 2023).

Due to the fact that the usable percentage of water on earth is so limited, international organizations have started to take precautions in the early 70's. For this purpose, first global environmental conference was the United Nations Conference on the Human Environment, held in Stockholm from June 5 to 16, 1972. The second significant conference was the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro from June 3 to 14, 1992. These conferences have produced important policy and legal instruments related to water management and the planning of water resources. However, the declarations made by countries represent significant achievements in their own right. These laws, adopted at twenty-year intervals, represent the modern era of international environmental law (Handl, 2012).

The scarcity of available water on Earth makes the quality of available water equally important. Therefore, in 2008, UNESCO conducted urban water series studies that revealed the interactions between urbanization and the water cycle (Marsalek, J. et al., 2008).

The rational and sustainable use of water resources can be achieved through coordination and integration of spatial and inter-sectoral planning and decision-making processes. Two main issues emerge in the management of water resources: one is to protect water resources, and the other is to manage the use of water resources in a sustainable manner (Aksungur, N., & Firidin, Ş., 2008).

In addition, the increasing world population and water demand have led to more widespread and serious struggles and conflicts in economic, political, and environmental issues. Water resources face many serious problems in terms of quantity, quality, and all other sectoral uses (Sevindi, 2005).

In recent years, the issue of water has become increasingly prominent on the international agenda. The reasons for water attracting the growing interest of the global public include population growth, the water needs resulting from rapid urbanization and industrialization, and climate change. There is a possibility that water scarcity may turn into a water crisis in some regions, including the Middle East, within the next 20-25 years. Therefore, it is widely accepted that this irreplaceable natural resource will be one of the strategic resources of the 21st century (Istanbulluoglu, H., & Kır, T., 2011).

The issue of water is being addressed within the framework of the environmental chapter in the EU accession negotiations, which began in 2005. The EU Water Framework Directive (WFD), which is considered the main document of EU water legislation, aims to prevent the pollution of surface, coastal, and groundwater. The WFD imposes the obligation of cooperation among EU countries in river basin management and calls for coordination with non-EU countries. In the Turkey Accession Partnership Document adopted by the Council of the EU, Turkey is requested to cooperate on transboundary waters within the framework of the WFD and international agreements to which the EU is a party. Turkey has noted that it is not a party to some of these agreements that are not specifically focused on water and that the issue of becoming a party to these agreements will be considered with EU membership (İstanbulluoğlu, H., & Kır, T., 2011).

Although it is stated in current international law that "every country has the right to use the waterways within its borders freely and to act independently", including transboundary waters and water systems, it can be said that comprehensive international water law is still in the process of formation (İstanbulluoğlu, H., & Kır, T., 2011). Turkey is among the countries that may face water scarcity in the future. Considering our country's water potential, agreements to be made on water will be binding and therefore have great importance. Therefore, compliance with EU

legislation is not just a technical issue, but also a matter that needs to be evaluated from a hydro-political perspective, taking into account the country's water potential.

The global average of daily urban water consumption per capita is 150 liters, while in industrialized countries it is 265 liters, and in our country, it is 111 liters. The proportion of people who have access to water in industrialized countries is 99%, while in Turkey it is around 85%. It is stated that the total usable surface and groundwater potential in our country is 112 billion m^3. There are 26 water basins in Turkey, and the distribution of water among the basins is not equal. Therefore, numerous structural and non-structural measures and assessment methods are needed for the planning, management, and conservation of water resources in our country. (İstanbulluoğlu, H., & Kır, T., 2011).

Water resources are crucial in planning and managing them. It is not possible to create a sound management plan without data.

From a technical standpoint, the data used in water management planning can be in the form of point, linear, or areal features. Spatially relating these features with one another is only possible within a geographic information system (GIS), which is currently the most practical tool for accomplishing this task.

Geographic information systems (GIS) offer us opportunities to evaluate spatial data. These tools enable us to collect, compile, visualize, analyze, and obtain results from data in a digital environment. By defining the study area spatially in GIS tools, data from that area can be displayed spatially. Furthermore, fast analyses between data can be carried out, allowing us to reach managerial outcomes and interpretations beyond mere visualization.

Within the scope of the thesis, the Güzelhisar Basin was compiled in a GIS environment to create a scaled data model of the basin in a virtual world. Spatial analyses were performed using other necessary data for determining water pollution, and studies were conducted to evaluate and interpret this data spatially within the context of the thesis.

1.1 Literature Review

Despite the increasing need for water due to rapid population growth, the scarcity of suitable resources and the problems experienced due to excessive use and pollution occurring in parallel with the ever-increasing industrial and agricultural activities have increased the importance of water resources management, especially on a basin wide. In Article 9 of the Law No. 4856 on the Republic of Turkey Ministry of Environment, Urbanization and Climate Change was assigned the task of "making protection and utilization plans for water resources and carrying out necessary studies to ensure the integrated management of continental water resources and soil resources on a basin basis". In addition, Article 5 of the Regulation on Water Pollution Control, which entered into force after being published in the Official Gazette dated 2004 and numbered 25687, states that -Basin Protection Action Plans are made and/or commissioned by the Ministry of Environment and Forestry by taking the opinions of the General Directorate of State Hydraulic Works and relevant organizations‖ (TÜBİTAK, 2010).

Basin management concepts must be examined and planned at the basin scale for the sustainable use of water resources. Various research is being conducted in this regard throughout the world and in European Union (EU) member nations. Turkey has also increased its research within the framework of the EU Water Framework Directive in recent years. The scope of basin management serving for natural resource management in Turkey, methods and principles of basin management plans, information about studies conducted in Turkey, and the importance of basin scale in water resources management were all emphasized in this study (Öztürk S. et al., 2014).

The study region is located in The North Aegean part of the Turkey’s basins. The State Hydraulic Works completed the most current geological research relevant to the Güzelhisar sub-basin within this basin. Environmental planning, hydrology, land categorization, identification of existing and proposed infrastructure, environmental evaluation and water quality, flood and sediment control, and hydrogeology studies of the North Aegean basin were all conducted as part of this research (DSİ, 2016).

Measures and precautions to be taken in the North Aegean Basin in the short, medium, and long term have been determined within the scope of the Pollution Prevention Action Plan in order to prevent pollution in the basin and control point and diffuse source pollution in order to improve water quality in order to protect human and environmental health and ensure the sustainability of economic activities. The water quality of the North Aegean Basin is expected to improve from Class IV to Class III if the actions are implemented in the near term, and to Class II if the measures are implemented in the medium term (SYGM, 2016b).

The aim of the National Basin Management Strategy (NBMS) (2014-2023) is to provide guidance for medium and long-term decisions and investment programs related to the protection, development, and sustainable use of our country's water basins and their natural resources, and to provide a common roadmap for efforts to meet the ecological, economic, social, and cultural needs and expectations of our society related to the benefits and services of the basins at a sufficient and sustainable level. The main priority of the NBMS is to stop the ongoing process of natural resource and environmental degradation in our country's water catchment basins, to maintain and improve the productivity and quality of soil, groundwater and surface water resources, to ensure the conservation and improvement of fauna and flora in the basin, to maximize the basin services provided to users in a way that does not harm the ecosystem integrity of the basin, and to contribute to raising the welfare level of the low-income rural population living in the basin. In this context, the "River Basin Management Plan" is prepared as a document that shows how the ecological, quantitative, chemical, and special protection area objectives intended for any river basin will be achieved within the envisaged timeframes (SYGM, 2019).

Yüce (1997) examined the rivers flowing into the İzmit Bay and focused specifically on the eastern end, which is considered the most risky area in terms of pollution load. The study found that domestic sources were the main contributor to the accumulation of nitrogen and phosphorus loads in the bay, and the installation of wastewater treatment facilities by industrial establishments significantly reduced industrial pollutants.

Küçükballı (2003) collected samples from fifteen measurement stations in the Nilüfer River Basin over a period of one year as part of their master's thesis. All data obtained was digitized using GIS, and the basin was divided into four sub-basins, with pollution loads determined for each sub-basin.

In Baştürk's (2006) master's thesis, pollution loads of the Sakarya River were determined using GIS. The study investigated the impact of industrial facilities located along the river on its pollution. Industrial facilities and discharge values were digitized to calculate pollution impacts at different points along the river.

Sayan (2019) conducted a master's thesis study in the Güzelhisar basin, where soil, plant, and water samples were collected from specific locations within the basin at certain intervals. The heavy metal, boron, and nitrate content of these samples were determined to investigate the pollution status of the basin.

Numerous studies are still being conducted worldwide on water quality and its improvement. One of these studies is the work of Uddin et al. (2021). In their study, they compared the indices of different surface water quality models, aiming to further develop these models.

1.2 Purpose and Scope

In Turkey, 26 strategic hydrological basins have been identified. Currently, numerous methodologies are being developed for basin-wide water management and prevention of water pollution. State Hydraulic Works (DSI) and General Directorate of Water Management (SYGM), which are the main water institutions in Turkey, produce and implement basin-based projects. In these studies, the current situation of surface and groundwater in terms of quantity and quality is determined. Scenario modeling is conducted by establishing a relationship between pollutants and sources, and a program of measures is prepared to improve the risky areas. As a result of these studies, it is determined which measures and when the waters will reach a good state in terms of quantity and quality.

The North Aegean Basin's Güzelhisar Basin was chosen as the study region for the purposes of this thesis. Within the parameters of the study, the point and diffuse

pollution loads of the Güzelhisar Basin, the southernmost of the 19 river branches of the North Aegean Basin draining into the Aegean Sea, were determined. Data generated by various pollution loads, including TN (Total Nitrogen), TP (Total Phosphorus), COD (Chemical Oxygen Demand), and SS (Suspended Solids), were geographically assembled. To track the migration of contaminants in the river ecosystem, geographical data on natural flow and wastewater flow was also obtained. In order to make the studies on taking action in spatially important locations easier to conduct, all data were translated into a format that could be examined in a GIS system.

CHAPTER TWO
METHODOLOGY

With the advancement of technology, geographical analyses are now essential in the battle against water pollution. It is feasible to take economically sound actions to enhance the water quality in the basin by doing a spatial study of water pollution. It is anticipated that the techniques covered by this thesis will particularly lessen the effect of diffuse pollutants on water contamination. The flowchart outlining the fundamental working procedures is shown in Figure 2.1.

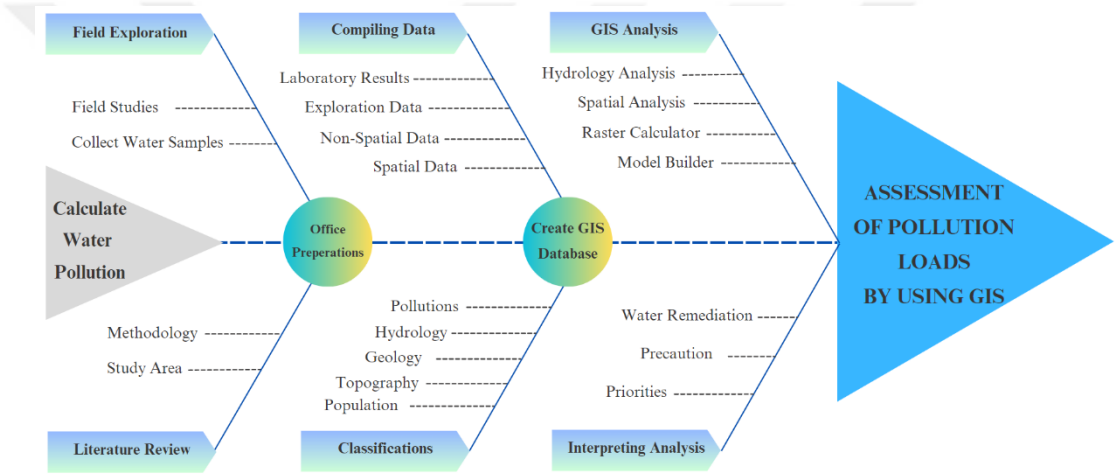


Figure 2.1 Flowchart of methodology

A literature review is the foundation of the study technique. Before beginning work in the Güzelhisar basin, a survey of the literature on previous research in the region and works that could be comparable to the current approach was done.

The purpose of field investigations is to investigate water pollution sources and water systems, to evaluate the interaction between water and geological structure and other characteristics, and to collect water samples.

An office work plan was constructed using the data acquired and compiled in the field and academic settings, with the goal of producing a GIS database. Water contamination can thus be discovered by geographical analysis.

Field investigations were used to identify the components that may poison the water in the basin, and their locations were documented. This data was converted in point and geographical terms to the GIS environment. Furthermore, all data were categorized to avoid the confusion caused by employing too much data during the approach.

Following the creation of the GIS database, the analytical output data necessary to expose water contamination geographically was developed utilizing this database. The elevation raster data was used to perform hydrological calculations, and the drainage network, river tributaries, sub-basins, and many other analytical outputs were developed. These data were used to execute mathematical operations on the loads and wastewater flows produced annually by polluting sources, and graphics were created to show the spatial distribution and amount of pollution.

As a consequence of using this approach for different pollution parameters, it is possible to observe how much pollution load originates from particular pollution source and how these pollutants are carried or distributed with water for each pollution parameter. As a result, economic measures to enhance water quality will be easier to implement.

In Digital Geographic Information System-based software, raw elevation data collected by satellite is shown as raster elevation data. The cell size in this raster data denotes a specific area. The value of a cell with a cell size of 100x100 units, for example, corresponds to the value of an area of 10000 units. The elevation data in this study is organized so that each pixel corresponds to 1 ha of land area.

The direction of water may be identified using a series of computations that can only be performed using elevation data. The relationship of the heights may be used to identify these basins where the water will travel from where the water falls, how intensively it will move, and where the water falls. We can accomplish this with any GIS application.

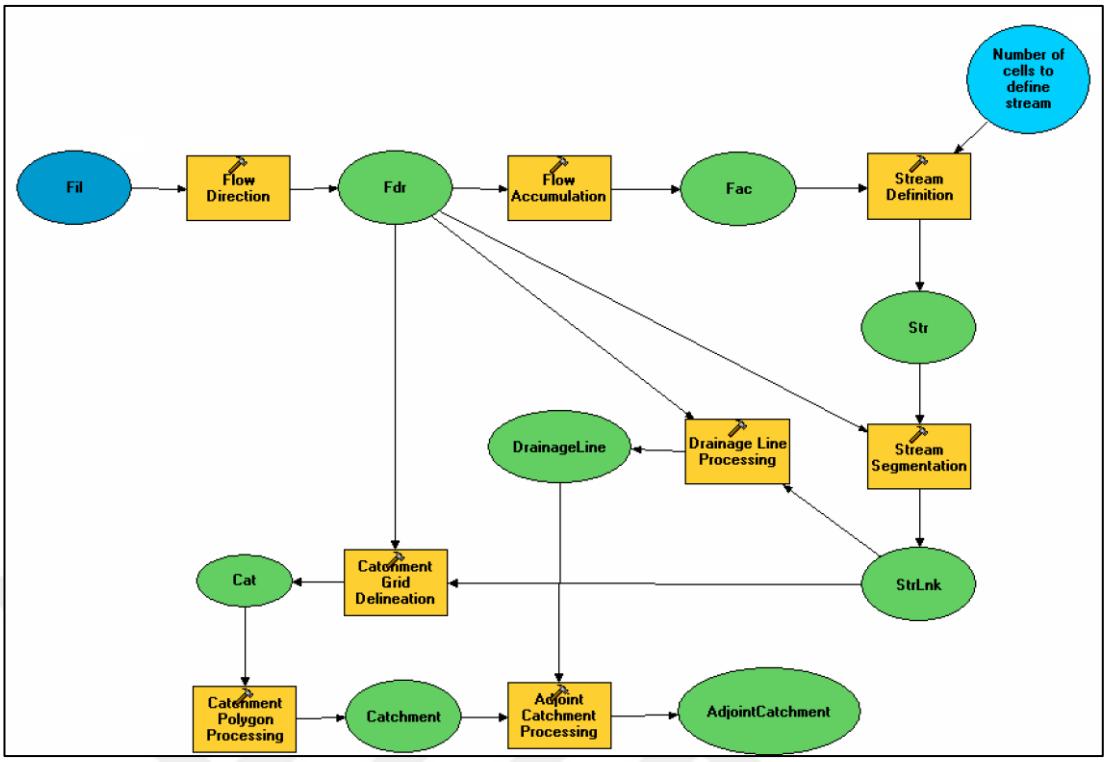


Figure 2.2 Raster elevation data pretreatment process order in model builder

2.1 Fill Sinks

Sinks (and peaks) are frequently mistakes caused by data resolution or rounding of heights to the closest integer number.

Sinks should be filled to ensure correct basin and stream delineation. A derived drainage network may be discontinuous if the sinks are not filled.

The Fill tool uses the equivalents of several tools to detect and fill sinks, including Focal Flow, Flow Direction, Sink, Watershed, and Zonal Fill. The tool fills all drains within the chosen z limit iteratively. As sinks are filled, additional ones may form at the boundaries of the filled zones, which are then removed in the next iteration.

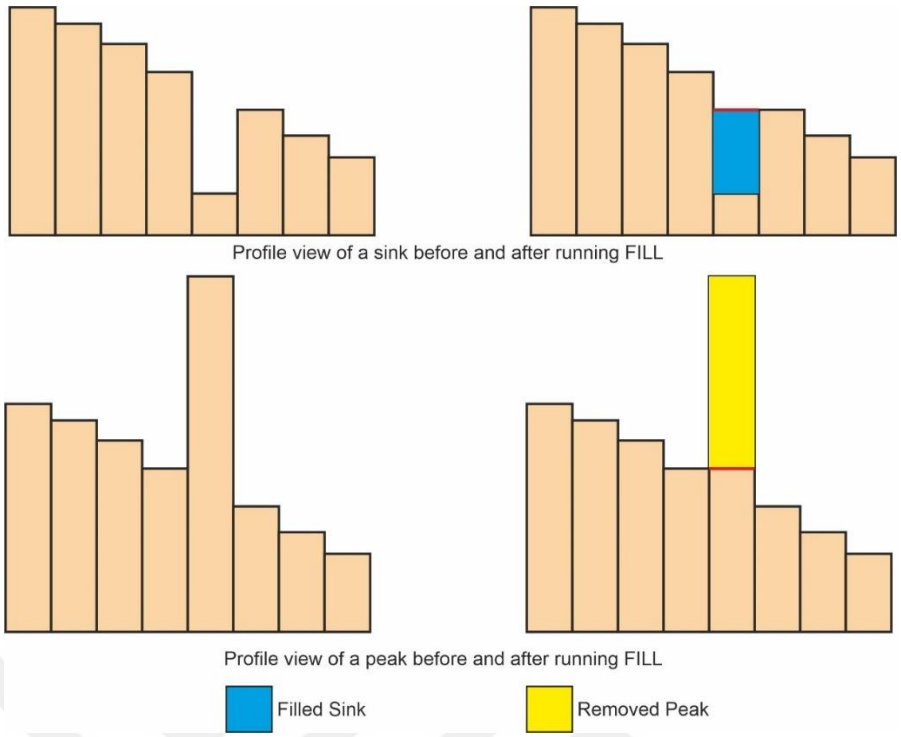


Figure 2.3 Profile view of a sink and peak before and after running fill tool (ESRI, 2020)

2.2 Flow Direction

The ability to discern the direction of flow from each cell in the raster is one of the keys to obtaining hydrologic properties of a surface. This is accomplished using the Flow Direction tool (ESRI, 2020).

This tool takes a surface as input and outputs a raster indicating the flow direction out of each cell. If the Output drop raster option is enabled, an output raster displaying a% ratio of the largest change in elevation from each cell along the direction of flow to the route length between cell centers is created. If you select the Force all edge cells to flow outward option, all cells at the surface raster's edge will flow outward (ESRI, 2020).

There are eight legitimate output routes associated with the eight neighboring cells into which flow might flow. This method is known as an eight-direction (D8) flow model (Figure 2.4), and it is based on Jenson and Domingue's (1988) methodology (ESRI, 2020).

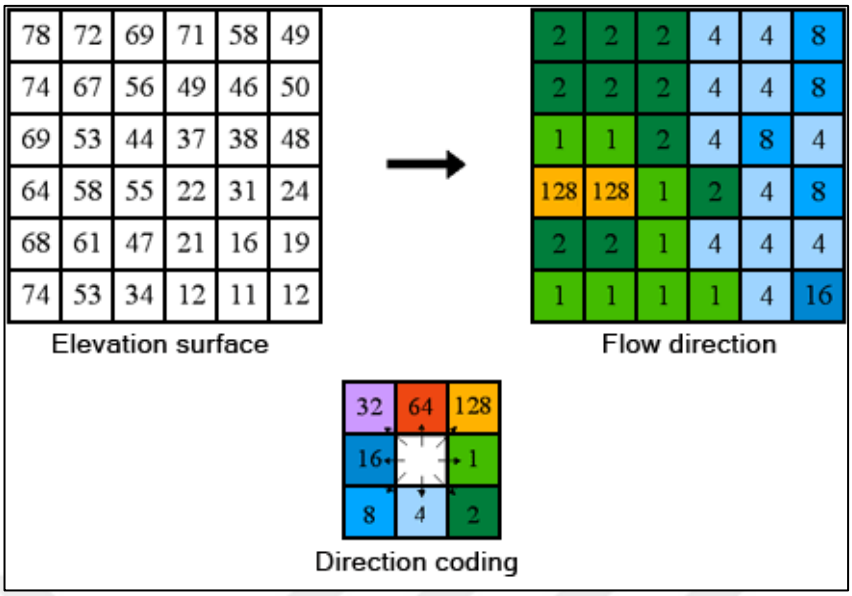


Figure 2.4 The coding of the direction of flow (ESRI, 2020).

2.3 Flow Accumulation

The Flow Accumulation tool calculates accumulated flow as the total weight of all cells flowing into each downslope cell in the output raster. If no weight raster is supplied, each cell is assigned a weight of one, and the number of cells flowing into each cell is represented by the value of cells in the output raster (ESRI, 2020).

In the Figure 2.5 depicts the direction of passage from each cell, while the top right depicts the number of cells that flow into each cell.

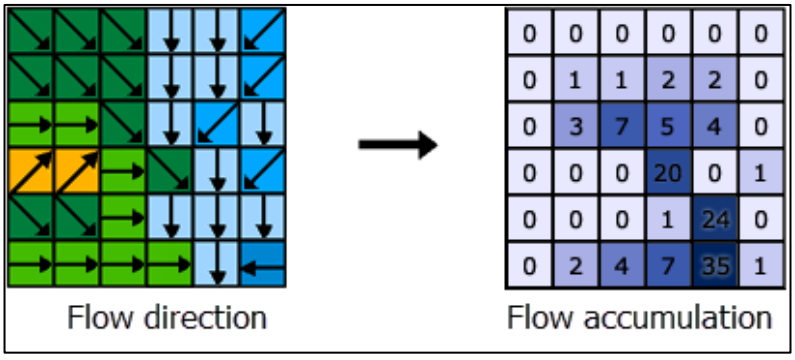


Figure 2.5 Determining the accumulation of flow (ESRI, 2020).

The flow accumulation tool is a significant component of this thesis. This tool is commonly used in the planning of drainage networks. This technique was especially used in this experiment to accumulate pollution loads. This application provides the spatial load data of point and diffuse pollutants, as well as their distribution amounts and basin places.

2.4 Stream Link

Assigns distinct values to raster linear network intersections. Links are the sections of a stream channel that connect two successive junctions, a junction and the outflow, or a junction and the drainage division. In hydrology, these stream segments are known as reaches. A junction is linked to a pour point and helps define a watershed or drainage sub-basin border (ESRI, 2020).

Links are stream channel portions that link two subsequent junctions, such as a junction and the outflow or a junction and the drainage division (Figure 2.6).

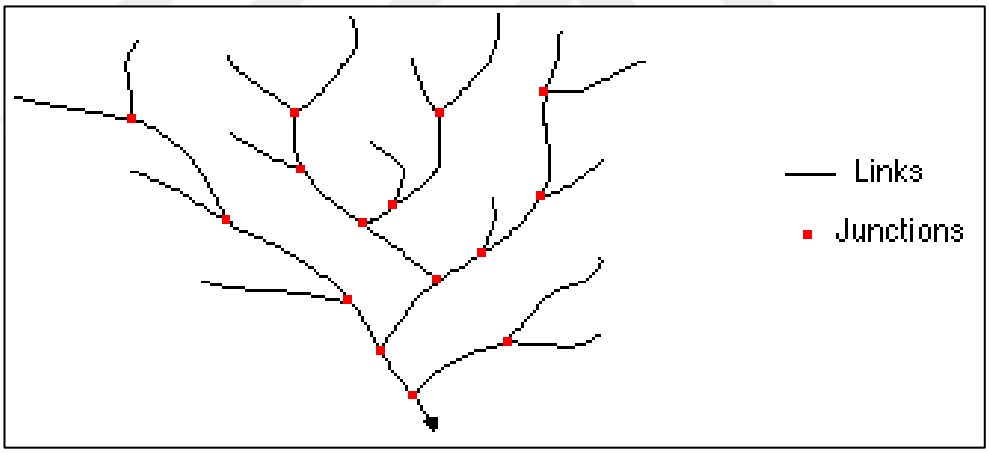


Figure 2.6 Illustration of the links in a stream channel (ESRI, 2020).

2.5 Stream Order

Stream ordering is the process of assigning a numerical order to links in a stream network. This arrangement serves as a technique for identifying and categorizing stream types based on the number of tributaries. Some stream features can be derived from their order alone (ESRI, 2020).

Overland circulation of water, for example, dominates first-order streams; there is no concentrated flow upstream. As a result, they are more sensitive to non-point source pollution problems and can benefit from large riparian buffers more than other watershed zones (ESRI, 2020).

You can assign orders using one of two approaches in the Stream Order tool. Strahler (1957) and Shreve (1966) proposed these approaches (Figure 2.7).

2.5.1 Strahler

Strahler's stream ordering approach, developed in 1952. When streams of the same order collide, the order of the streams rises. The intersection of a first-order and second-order connection does not result in the formation of a third-order link. This is the standard (ESRI, 2020).

2.5.2 Shreve

Shreve's magnitude-based stream ordering approach, developed in 1966. The magnitude (order) of all linkages with no tributaries is one. Downslope, magnitudes are cumulative. When two links overlaps, the magnitudes of the intersecting connections are summed and attributed to the downslope link (ESRI, 2020).

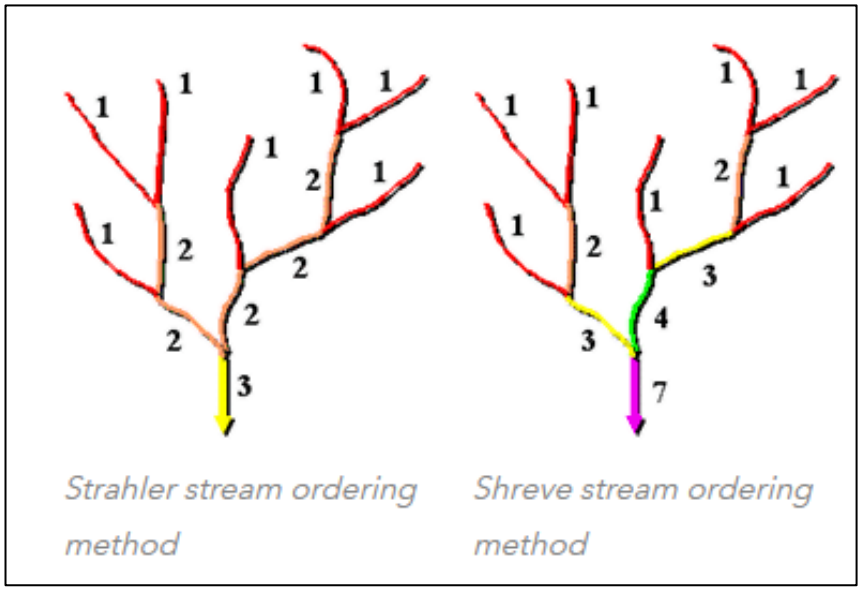


Figure 2.7 Stream order methods (ESRI, 2020).

2.6 Watershed

A watershed is an upslope region that provides water to a shared exit as concentrated drainage. It might be a component of a larger watershed or comprise smaller watersheds known as sub basins (Figure 2.8). Drainage divides are the borders between watersheds. The exit, also known as the pour point, is the point on the surface where water pours out of a space. It is the lowest point along a watershed's limit (ESRI, 2020).

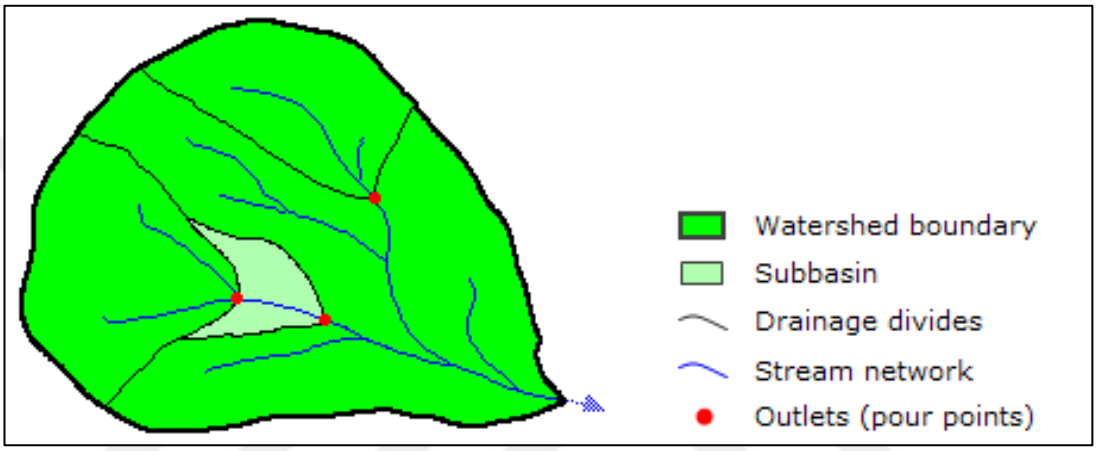


Figure 2.8 Watershed components (ESRI, 2020).

2.7 Pollution Sources Analysis Methods

Within the scope of the thesis, four point pollutant elements and one non-point pollutant element were analyzed. These are all vector datasets. These vector data were transformed into 100x100m size pixels of raster data for use in the study (Figure 2.9). In the conversion of vector to raster data, DEM data was used as a reference. All translated raster data pixels match the DEM data precisely.

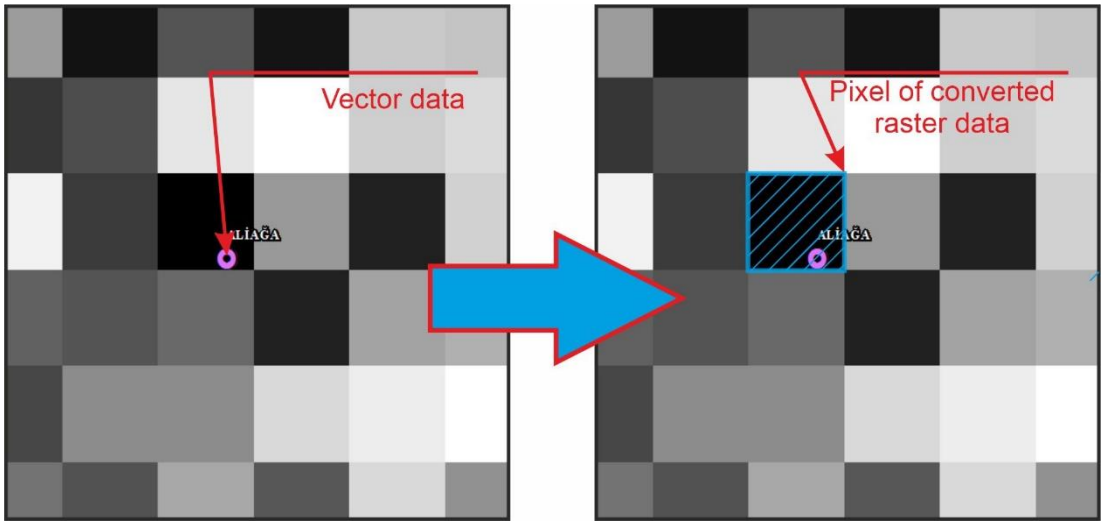


Figure 2.9 Conversion of point pollution vector data to raster data

Each vector data has an attribute table. With this attribute table, vector data can contain multiple data in columns for each row of data. Raster data, on the other hand, usually contains only one data information per pixel. Therefore, 4 different pollution parameter information columns representing a pollution element in the vector data layer represents 4 raster data conversions for this approach. For example, an urban wastewater treatment plant contains 4 different pollution parameters in its attribute information in a single layer vector data. This information is available in 4 different columns and for each row of data. Therefore, a different raster data is generated for each pollution parameter (Figure 2.10).

Assuming that there are 4 different types of point pollution sources, 16 pollution raster layers are generated for all of them.

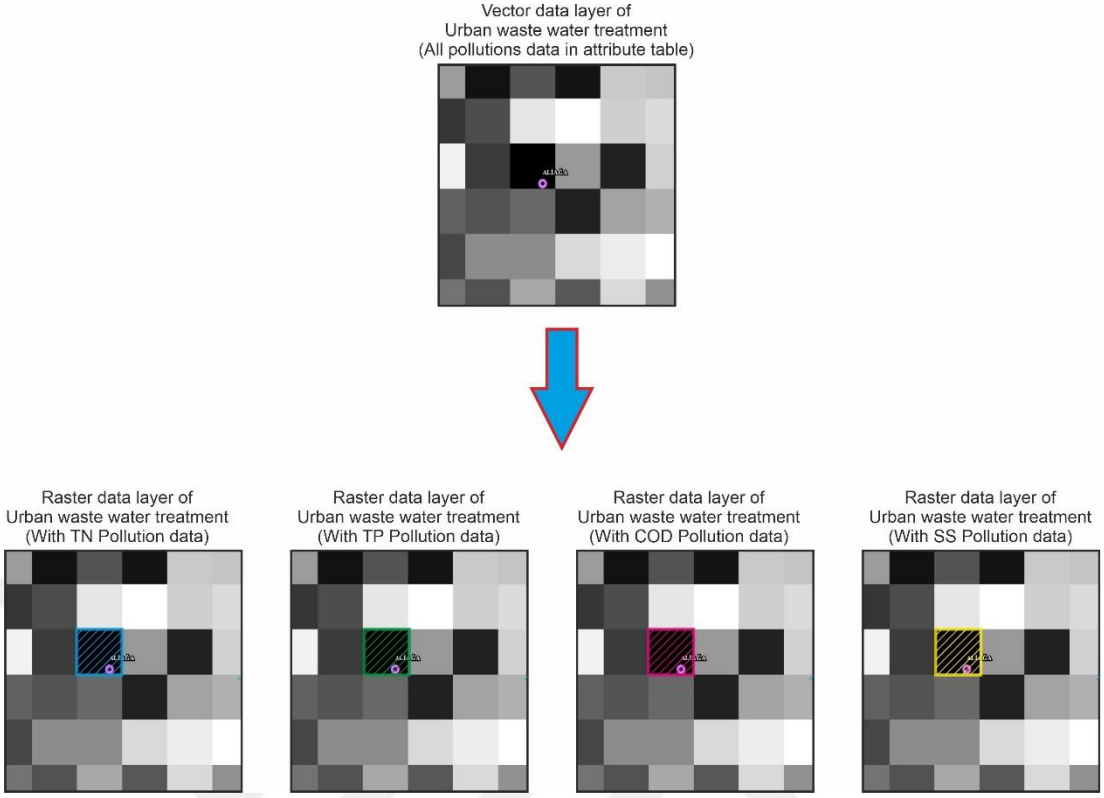


Figure 2.10 Conversion of vector data to all pollution types raster data

For the spatial land use data, there are 19 different types of land use for this basin. These 19 different areas are considered to emit only TN and TP pollution. Therefore, 38 different pollution raster layers were generated on behalf of 19 different vectoral area layers (Figure 2.11).

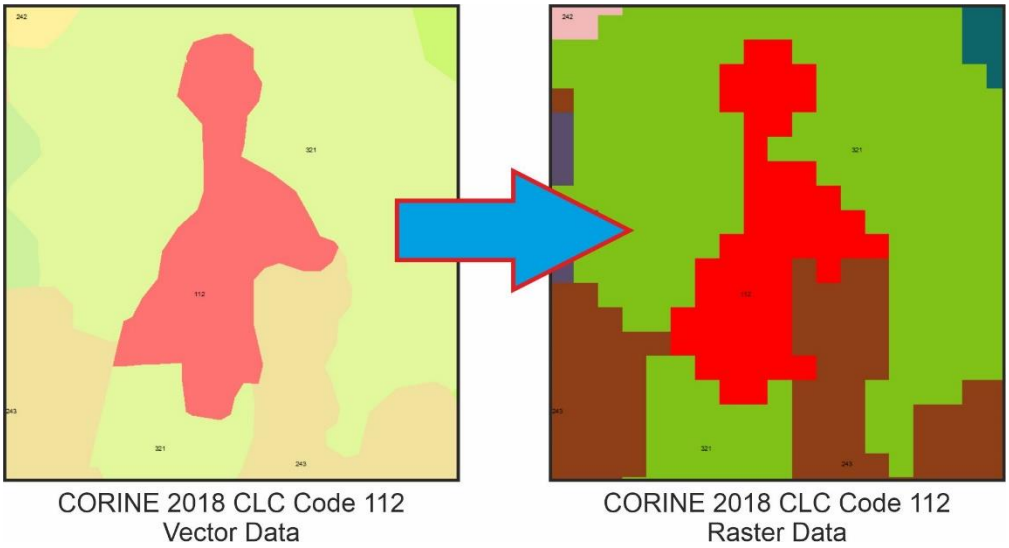


Figure 2.11 Conversion of non-point pollution vector data to all pollution types raster data

The raster data showing these pollution values are calculated by using the weighted flow accumulation method to calculate the spread depending on the topographical structure of the basin. By associating the values found at the pollution points with the flow directions raster data, it is calculated which pollution is moving towards which location of the basin in which amount.

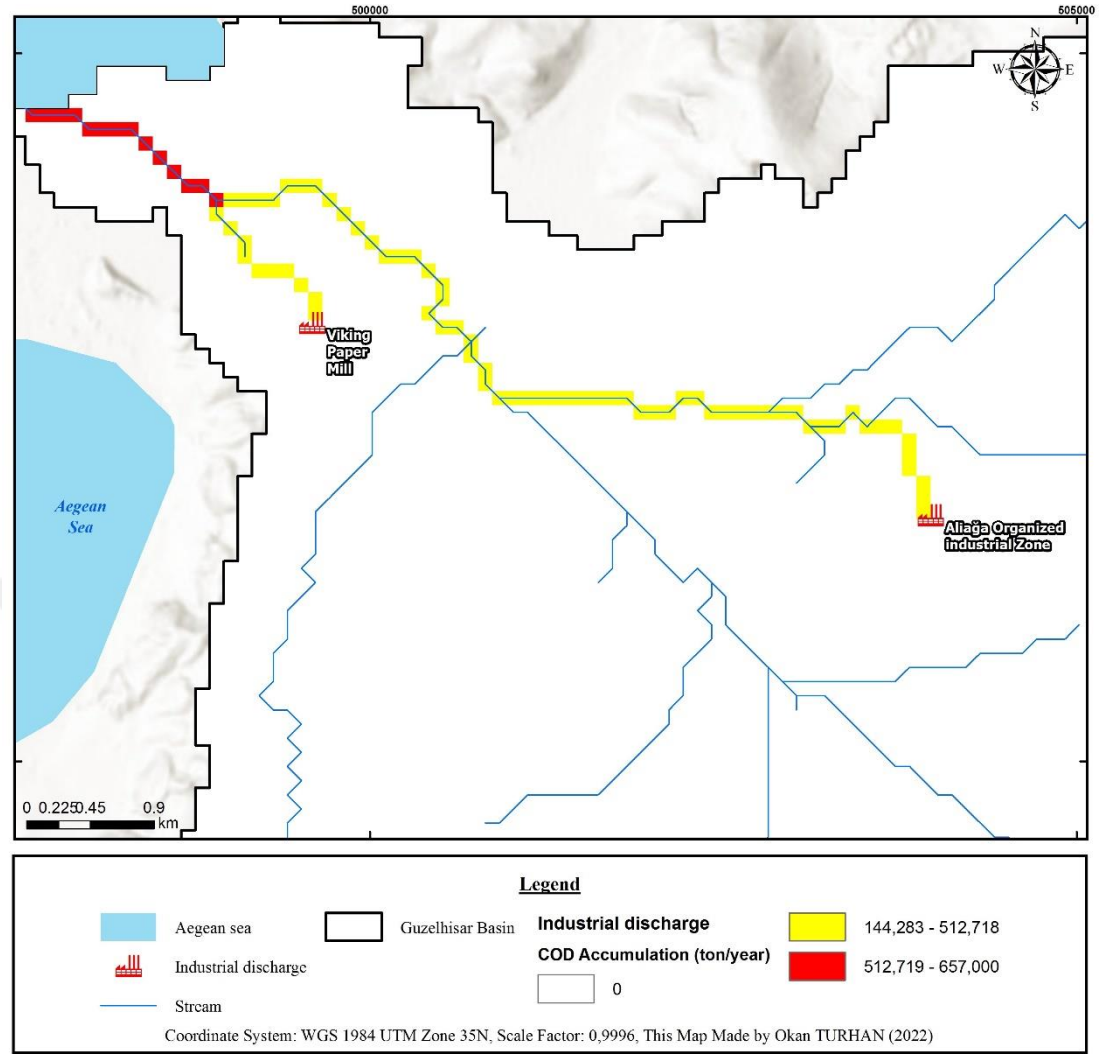


Figure 2.12 Calculated COD pollutions of industrial discharge with weighted flow accumulation

After all pollutant raster layers are rasterized with the weighted flow accumulation method, it remains to sum these raster pixel values with the same pollution parameter. For example, when 4 point and 1 non-point TN pollutant raster layers are summed with the "raster calculator" method, raster data showing the total TN load distribution values in the basin is produced. This process was performed separately for 4 different pollutant parameters and TN, TP, SS and COD pollution distribution results of the basin were obtained.

CHAPTER THREE
APPLICATION AND DATA

3.1 Selecting the Study Area

In many aspects, the Aegean Region is one of Turkey's wealthiest areas. The region's population accounts for around 15% of Turkey's total. Because the location is selected for settlement, its industry has grown at the same rate. The advancement of industrialization implies that all of Turkey benefits from this advancement. Water contamination caused by development in this region would have an impact on the entire country. In this regard, it is critical to investigate water contamination in this region's industrial sectors.

From an urban and industrial standpoint, the Aegean Region is a significant plot region for water contamination investigations.

According to global research, climate change will cause serious concerns in the future. The Aegean Region is one of the regions that will be influenced by climate change in the future. The quality improvement projects that will be undertaken in this region will serve as a model for all future projects.

Considering these geographically critical features, the Aegean region was chosen for spatial scale studies on water pollution subject.

The Aegean Region includes extensive river systems, including the Bakırçay, Gediz, Küçük, and Büyük Menderes. Surface water systems are commonly used by wastewater treatment facilities and industrialization.

The Güzelhisar basin has rivers that flow into the Aegean Sea. Because of the region's high population, industrialization, and the presence of urban wastewater treatment plants, it is a significant basin in geographic studies of water pollution. This basin was chosen as the research region for these reasons.

3.2 Location of Study Area

The Güzelhisar basin is a study area in Turkey that encompasses the northern portion of İzmir Province and the western half of Manisa Province. The basin includes Aliağa, Menemen, Kınık, and Bergama in İzmir, as well as Yunusemre in Manisa Figure 3.1).

Güzelhisar Basin in Turkey is located inside the sub-basin in the south of the North Aegean Basin, according to the hydrological borders. The basin has a total size of 631.09 km^2. According to the Turkey 1/25000 scale partitioned map index, it falls inside K17-b3, K18-a1, K18-a2, K18-a3, K18-a4, K18-b1, K18-b2, K18-b3, K18-b4, K18-c1, K18-d1, K18-d2. The basin was examined using the UTM WGS 84 N35 Cartesian projection, and it is located within the area bordered by the coordinates 4311513.32 in the north, 4281313.32 in the south, 497465.47 in the west, and 537265.47 in the east.

Güzelhisar Stream, the major stream in the Güzelhisar basin, is 40.61 kilometers long. The Güzelhisar Stream flows into the Aegean Sea. The Güzelhisar Dam, built on the Güzelhisar Stream, is the basin's most major surface water supply (Figure 3.2).

This thesis was completed by performing computer based spatial analysis of the data collected from the research region.

Data is one of the most significant aspects of GIS studies. The data used in this analysis were gathered as part of the North Aegean Basin River Basin Management Plan project. Field experiments data were used to collect data over a two-year period, during rainy and dry times. The current state of the data gathered from past field research was examined, and the geographical data were updated.

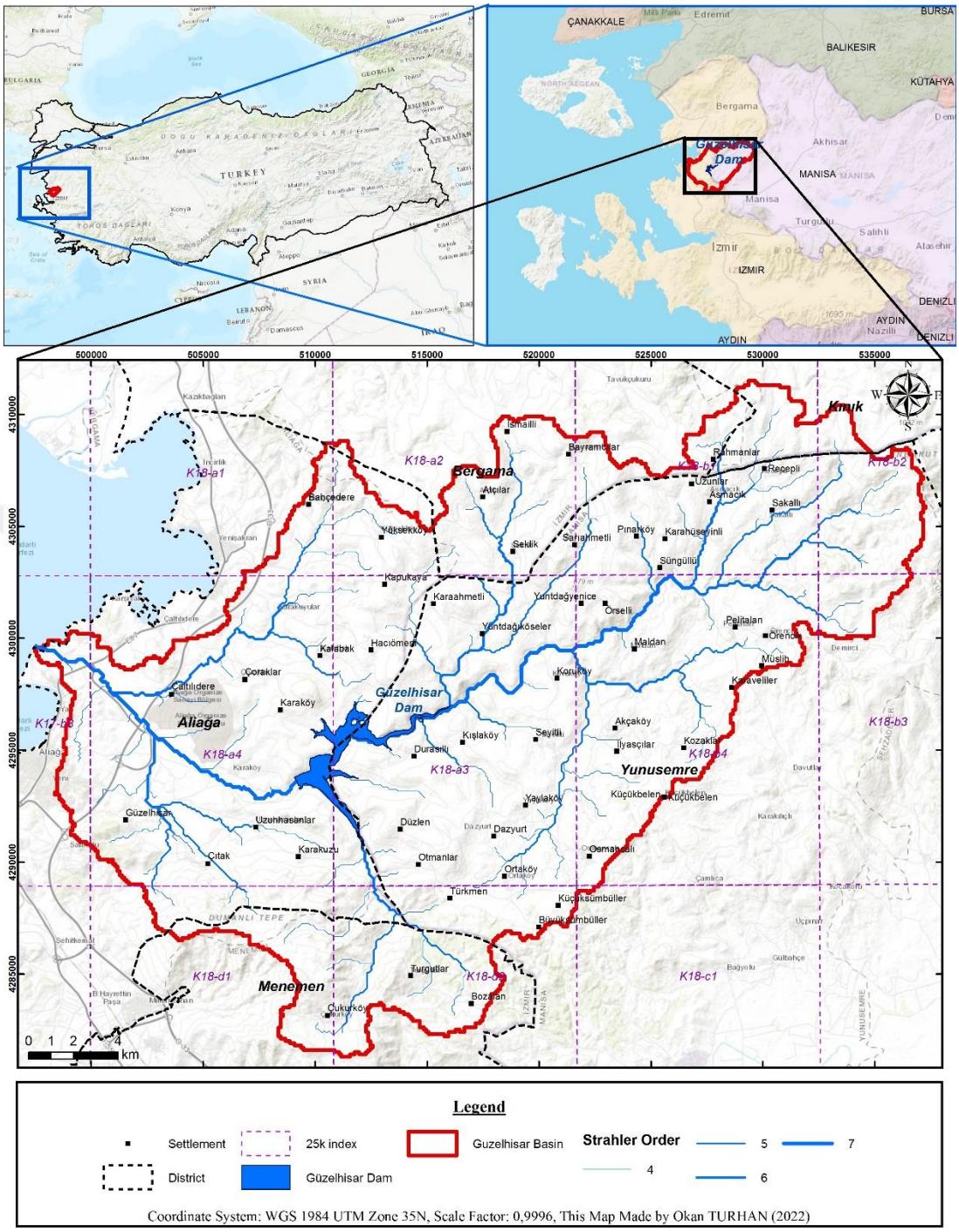


Figure 3.1 Güzelhisar basin location map

One of the most important uses of GIS technology nowadays is the capacity to employ geographic information science and systems to solve issues and implement various solutions. Geographic information system software includes several capabilities and benefits, such as mapping, assessing, modeling, visualizing, and

analyzing geographical data with diverse tools. This study looks at analyses and strategies that make use of geographic information system technology.

Sources of point contamination in the basin can be listed as urban and industrial wastewater treatment plants, septic tanks, direct discharge and other similar pollution factors in a case where the dispersive contamination sources such as agriculture, livestock, pesticides and solid waste landfills are present, the critically important region to take action cannot be delimited easily as the affected area will be wider. Therefore, the basins are divided into smaller sub-basins defined as underground and surface water bodies. Even with these sub-basins, areal measurements remain in an uncertain zone. For this reason, the goal of this thesis is to reveal the pollutant loads of dispersive contaminants more precisely in spatial terms with the GIS based study.

3.3 Field Exploration and Collecting Data

The field investigations were done as part of the North Aegean Basin River Basin Management Plan project, which was created by the General Directorate of Water Management, one of Turkey's primary water organizations, in accordance with the European Union Water Framework Directive. Field investigations were conducted to locate, monitor, and sample water resources as well as to ascertain all current contaminant sources. Furthermore, on-site flow measurements indicated the basin's water quantity status, and laboratory examination of water samples obtained on a regular basis throughout dry and rainy seasons revealed the basin's quality state.

The elevation data of the basin was gathered as part of the scope of the research. The Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) Version 3 (ASTGTM) data is the most accurate digital elevation model (30m/pixel) that covers the whole planet. It was created in 2019 at the Sensor Information Laboratory Corporation (SILC) facilities in Tokyo as part of a collaboration between Japan's Ministry of Economy, Trade, and Industry (METI) and the National Aeronautics and Space Administration (NASA) of the United States.

The human aspect, which serves as the foundation of the investigations, also shows as significant data. The Turkish Statistical Institute (TUIK, 2021) database was used

to acquire population statistics for this investigation. The data set covers population statistics from 2013 through 2021.

3.4 Classification of Collected Data

3.4.1 Population

Within the Güzelhisar basin, there are 55 villages (Figure 3.2). The basin population is 27237 persons as of 2021. In the basin's north, the most heavily inhabited settlement is Bahçedere. In 2021, the population of Bahçedere will be 11043 people. In 2021, the population of Pelitalan, the second most densely inhabited hamlet, is 1021. In 2021, the population of all other villages is fewer than 1000 persons. The population of 27 communities does not exceed 200 individuals (Figure 3.3, Table 3.1).

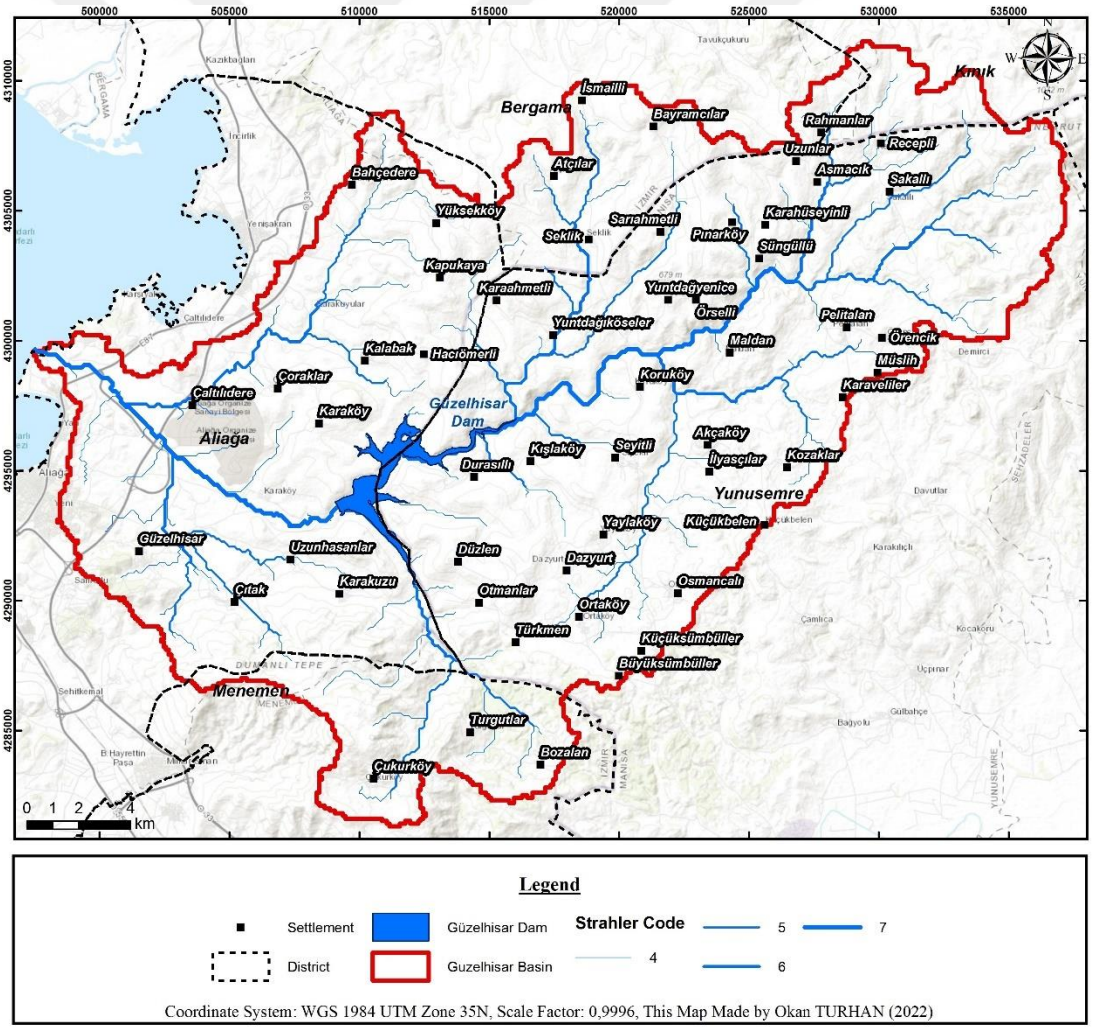


Figure 3.2 Güzelhisar basin settlement map

Table 3.1 Güzelhisar basin population table

Province	District	Settlement	Population (TUIK)								
			2013	2014	2015	2016	2017	2018	2019	2020	2021
İzmir	Aliağa	Çıtak	630	605	581	570	538	555	557	548	524
		Karakuzu	694	652	636	609	609	599	593	600	590
		Uzunhasanlar	315	315	288	287	271	283	273	276	271
		Güzelhisar	632	658	886	1,139	959	702	648	598	604
		Karaköy	231	224	210	203	205	198	182	183	216
		Bahçedere	6,945	7,252	7,685	8,111	9,315	8,923	9,068	10,237	11,043
		Kapukaya	211	201	199	192	187	183	179	178	173
		Yüksekköy	178	170	160	158	152	153	171	172	166
		Hacıömerli	795	1,030	752	769	759	780	779	810	830
		Kalabak	409	409	409	417	413	406	402	401	416
		Çoraklar	65	62	57	55	50	51	47	51	49
		Çaltılıdere	659	621	650	655	661	641	651	672	693
	Bergama	Seklik	342	336	328	328	323	319	315	312	312
		Atçılar	75	73	73	70	76	77	77	71	69
		Rahmanlar	146	144	134	131	118	123	119	120	118
		Bayramcılar	207	199	194	192	186	182	170	165	157
		İsmailli	288	218	209	215	201	197	191	189	191
	Menemen	Çukurköy	826	817	748	753	751	745	732	730	712
		Bozalan	310	304	309	305	298	294	288	285	275
		Turgutlar	86	89	77	57	43	47	49	44	43
Manisa	Yunus Emre	Karaveliler	-	665	654	627	604	582	572	559	545
		Küçükbelen	174	176	160	164	158	162	155	148	143
		Küçükbelen	174	176	160	164	158	162	155	148	143
		Büyüksümbüller	79	70	70	61	61	76	89	90	94
		Küçüksümbüller	75	73	69	69	69	61	61	63	65
		Türkmen	176	174	165	160	158	174	164	162	154
		Ortaköy	210	203	209	200	193	200	201	192	198
		Otmanlar	173	163	157	150	146	139	140	134	134
		Osmancalı	490	477	467	451	435	403	404	400	410
		Dazyurt	313	312	303	293	282	276	285	275	254
		Düzlen	481	471	453	450	443	443	425	414	408
		Yaylaköy	179	183	170	178	166	212	207	217	201
		Durasıllı	265	249	236	235	238	234	229	232	217
		İlyasçılar	158	147	134	135	130	140	134	121	118
		Kozaklar	66	64	59	60	61	62	59	57	58
		Kışlaköy	126	127	126	122	120	118	115	119	117
		Seyitli	-	-	610	604	597	586	571	568	545
		Akçaköy	201	199	202	198	199	199	208	193	186
		Koruköy	134	138	131	127	126	134	135	129	126
		Müslih	181	181	177	178	169	172	169	173	172
		Maldan	847	835	811	797	785	775	759	743	731
		Örencik	418	434	435	447	447	439	460	456	463
		Yuntdağıköseler	233	244	237	237	242	231	227	221	225
		Pelitalan	1,081	1,072	1,080	1,063	1,057	1,041	1,039	1,048	1,021
		Karaahmetli	162	159	154	154	153	144	134	134	137
		Yuntdağyenice	541	533	530	531	527	507	506	500	478
		Örselli	237	231	224	217	212	209	212	195	189
		Süngüllü	268	264	237	225	220	233	217	211	211
		Sarıahmetli	185	177	172	176	173	173	172	170	150
		Karahüseyinli	32	29	27	26	30	30	28	28	28
		Pınarköy	911	932	889	904	892	881	889	889	880
		Sakallı	217	204	200	196	190	190	185	182	172
		Asmacık	265	271	266	254	245	254	246	247	238
		Uzunlar	205	199	186	177	179	169	163	158	155
		Recepli	525	530	489	480	474	462	447	426	419
	Total		**23,826**	**24,741**	**25,234**	**25,726**	**26,454**	**25,731**	**25,653**	**26,644**	**27,237**

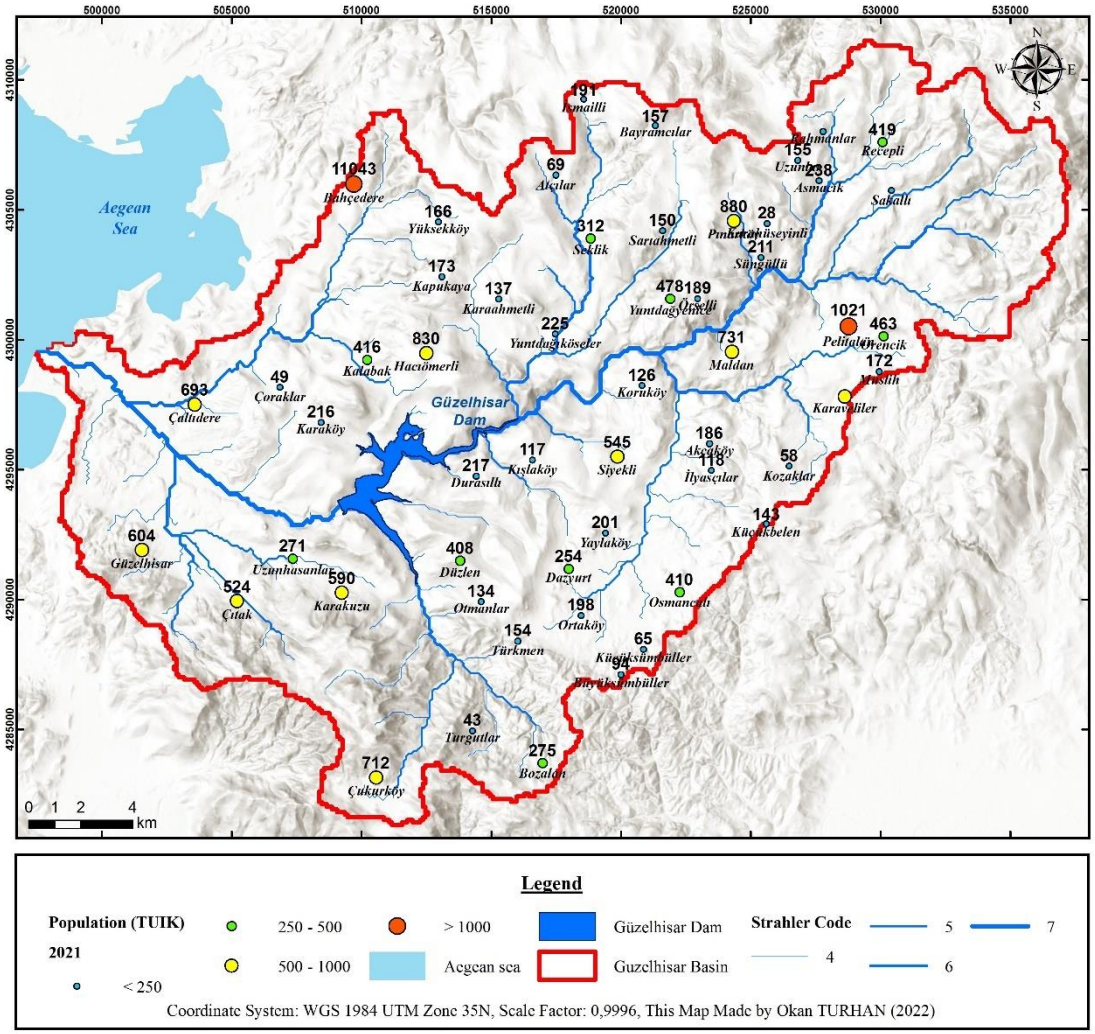


Figure 3.3 Güzelhisar basin population map

3.4.2 Topography

The Güzelhisar Basin is a basin that flows into the Aegean Sea. As a result, the basin's minimum elevation is sea level. The basin's highest point is 1069 meters (Sarmaşık Tepe). The basin's highest points are towards the northeast and southwest. The highest hills in the basin are Somak Tepe (1013 m) in the northeast and Sarmaşık Tepe (1069 m) in the southwest. Figure 3.4 depicts the basin's elevation image, while Figure 3.5 depicts the basin's satellite image.

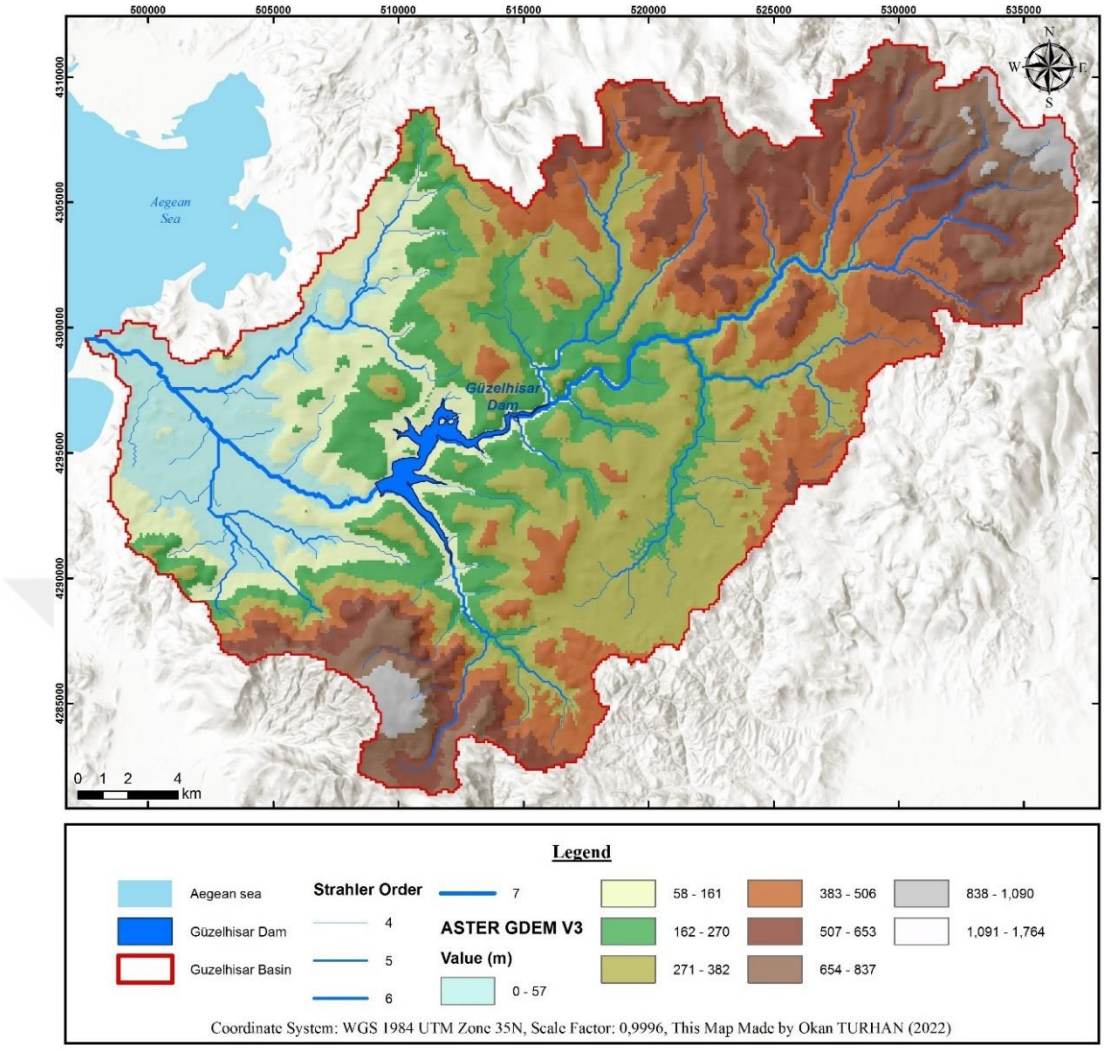


Figure 3.4 Güzelhisar basin elevation map

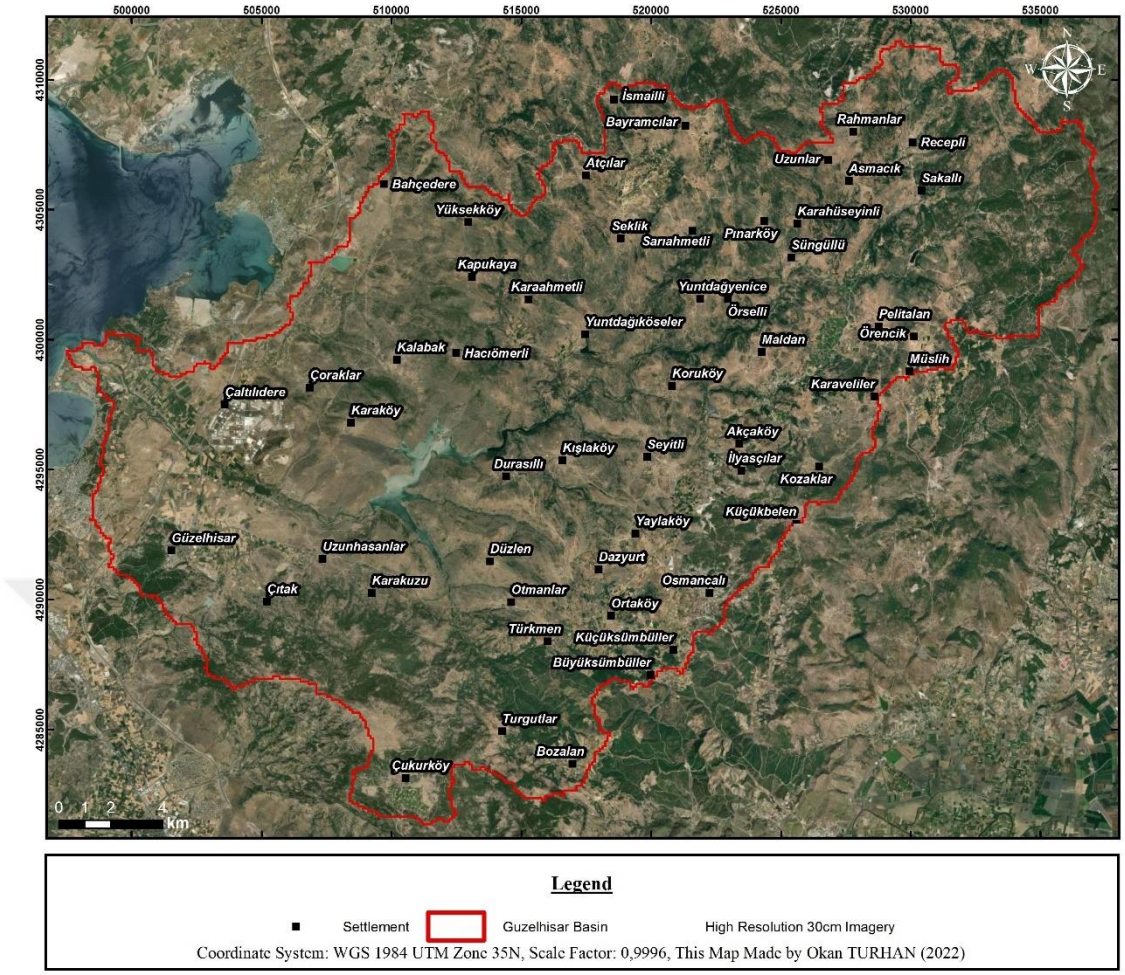


Figure 3.5 Güzelhisar basin satellite view

The elevation data collected throughout the investigation was evaluated, and several maps were created. The aspect map (Figure 3.6) is one of these. The basin's typical slope direction is west-southwest.

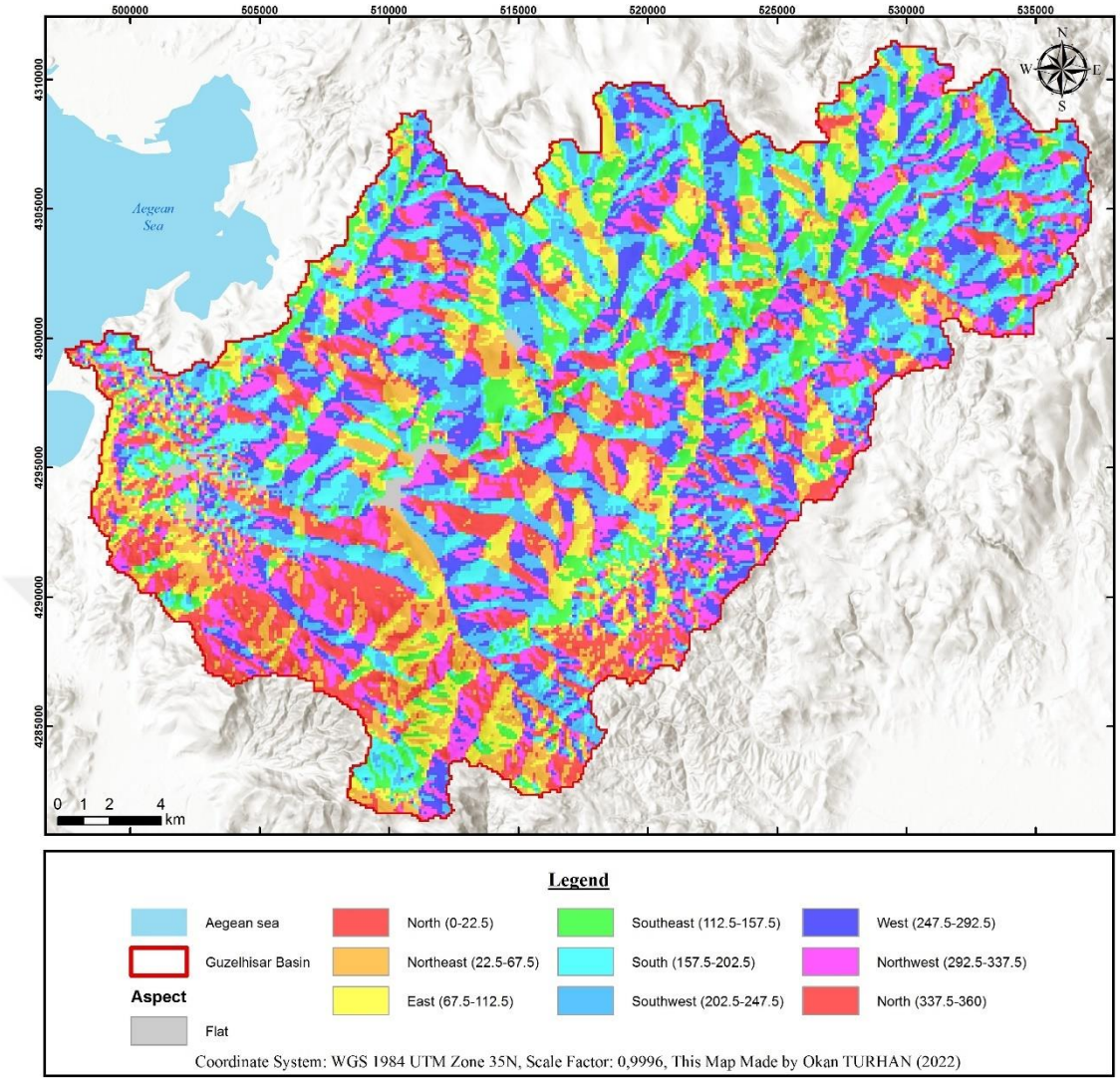


Figure 3.6 Güzelhisar basin aspect map

Hydrological analysis was done with the elevation data in addition to morphological evaluations. The flow direction map in Figure 3.7, for example, depicts the direction in which rain falling on the surface tends to flow. These instructions also tell us about the course that contaminants may take together with the flowing water.

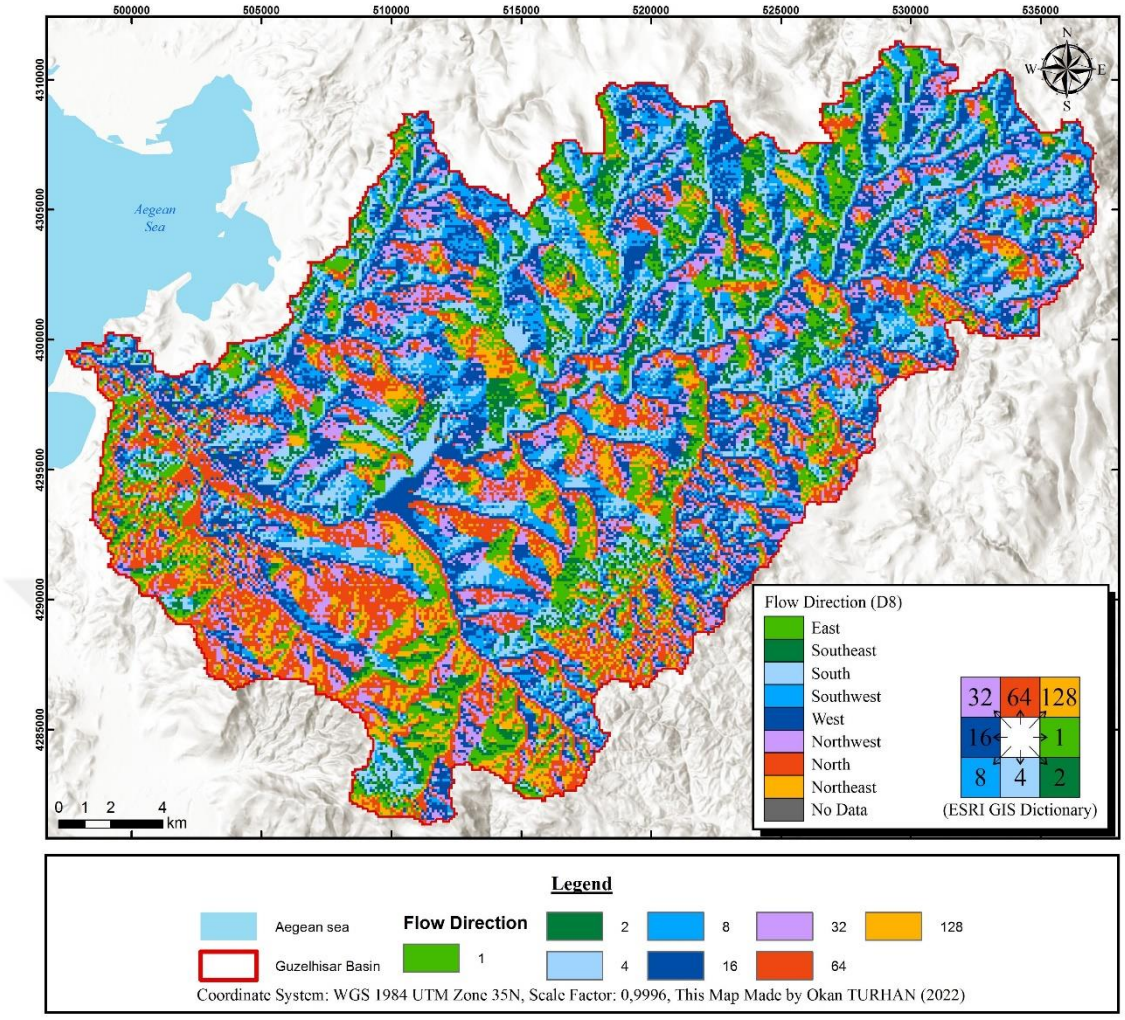


Figure 3.7 Güzelhisar basin flow direction map

3.4.3 Geology

3.4.3.1 General Geology

The sedimentary and volcanic rocks that make up the Güzelhisar basin. Table 3.2 displays the basin's units and areas.

The overall geology of the basin was scanned using MTA maps. Figure 3.8 depicts the broad geological map of the research region.

In terms of area density, the volcanic rocks in the research region are andesite, tuff, basalt, and rhyolite. Andesites are found across the 168 km2 basin, with the Tuff unit concentrating mostly on the southern and southeastern slopes. Tuff unit has an area of 98 km2. The basin's volcanic rocks account for half of its total area.

Table 3.2 Lithology of Güzelhisar basin

Label	Age	Lithology	Area (km^2)
Qal	Quaternary	Alluvium	40.34
Qtr	Quaternary	Travertine	1.97
Tmau	Upper Miocene	Pebblestone - Sandstone - Mudstone	0.34
Sk	Upper Miocene	Quartz Vein	0.02
Tma3	Upper Miocene	Limestone	2.62
Tmkb	Upper Miocene	Basalt	1.12
Tmdr	Middle - Upper Miocene	Agglomerate	9.08
Tmda	Middle - Upper Miocene	Tuff	38.86
Tmö	Middle - Upper Miocene	Rhyolite	10.78
Tmhl	Middle - Upper Miocene	Rhyodacite	3.01
Tmdb	Middle - Upper Miocene	Basalt - Andesite	6.6
Tmdç	Middle - Upper Miocene	Andesite	168.07
Tmh4	Middle Miocene	Agglomerate	3.49
Tmf	Middle Miocene	Tuff	50.78
Tma1	Middle Miocene	Pebblestone - Sandstone - Mudstone	0.86
Tmh3	Middle Miocene	Basalt	13.76
Tma	Miocene	Silicified Rock	0.38
Tmv	Lower - Middle Miocene	Agglomerate	240.88
Tmsy	Lower Miocene	Alluvial Fan	1.37
Tms	Lower Miocene	Basalt	8.78
Tmad	Lower Miocene	Dacite	0.48
Tmsz	Lower Miocene	Sandstone - Mudstone - Limestone	14.45
Toay	Upper Oligocene	Tuff	8.42
Mkb	Upper Cretaceous - Lower Paleocene	Sandstone - Mudstone - Limestone	2.13
Kb	Cretaceous	Limestone	1.1
Mkb	Cretaceous	Melange	0.19

Agglomerate is the most extensively known sedimentary rock type in the basin. This unit, which is particularly concentrated in the Güzelhisar Dam lake area, accounts for 40% of the basin's total size of 253 km^2 (Figure 3.9).

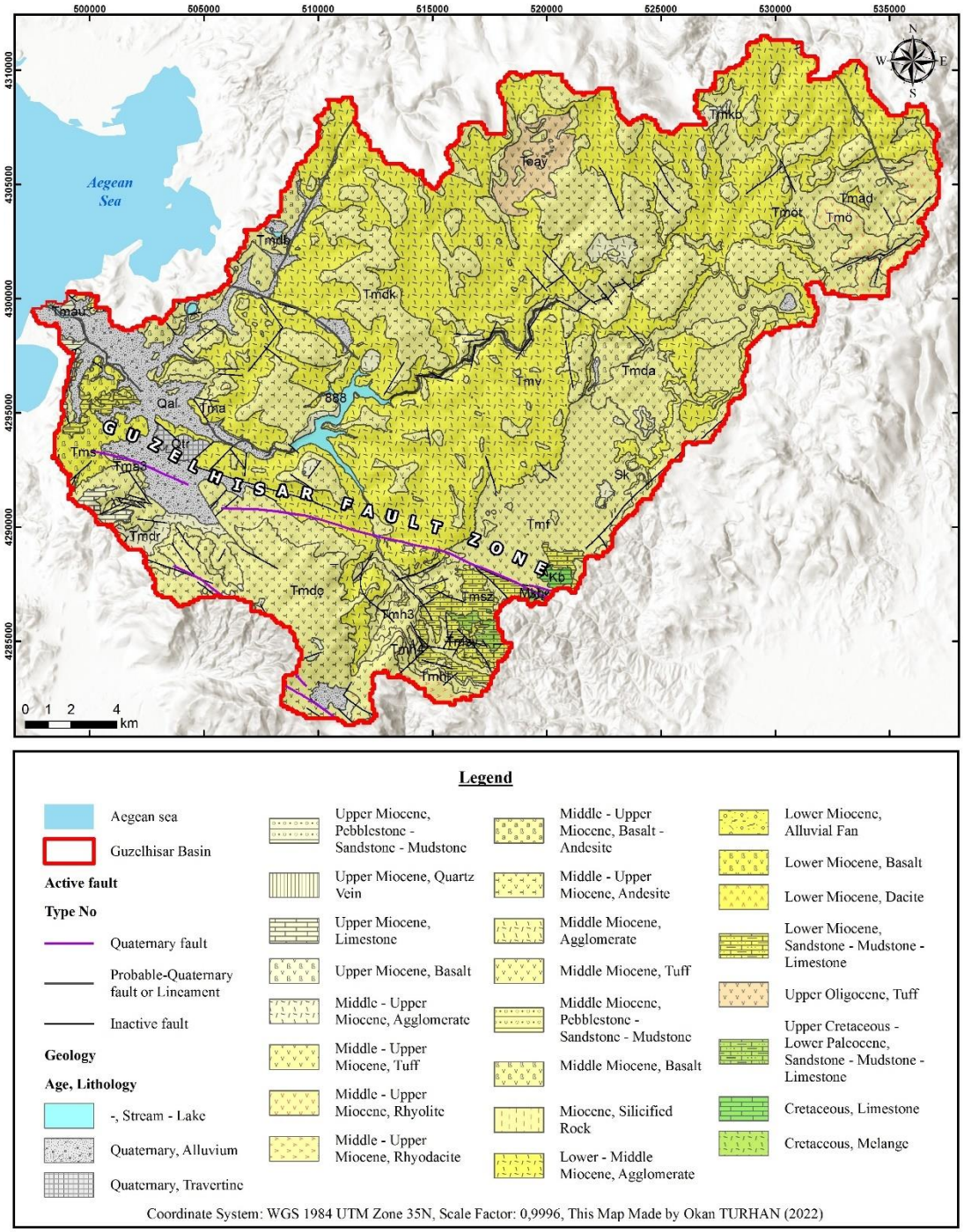


Figure 3.8 Güzelhisar basin lithology map

Alluvium is found in stream beds and occupies 6% of the basin, covering an area of around 40 km^2.



Figure 3.9 The view of the formations in which the agglomerates spread to the west of the Güzelhisar Dam (Eroğlu, 2011)

The stratigraphy of the Miocene strata surrounding Menemen-Foça-Aliağa in the northwestern part of Izmir is exceedingly intricate. These units are composed of fluvial and lacustrine facies terrestrial units, as well as highly extensive volcanism interbedded with these units. It has been determined that the volcanism is divided into two distinct phases, the first of which is intermediate in nature and the second of which is silicic in nature. Volcanites composed of transitional lava, agglomerates, and tuffs with Neogene sediments produce volcanic complexes visible as elevations in the terrain. These stratovolcano complexes are represented by Yamanlar Mountain in Izmir's northwestern section and Dumanlıdağ in the Menemen region. The highest section of the Upper Miocene-Early Pliocene package in Cumaovası and Foça area is made up of rhyolitic volcanism products formed by acidic eruptions and is characterized morphologically by lava domes and plugs (Bülbül and Yücel, 2009).

The Upper Cretaceous Izmir flieze is the oldest unit in the research region. The melange is epiclastic, with a regular succession of turbidite and olistostromal stages including enormous foreign limestone blocks. Although it does not outcrop near the Güzelhisar field, it has been claimed that these units were cut approximately 900-1000 m in Samurlu drillings. The oldest rock unit outcropping in the field is represented by

Middle Miocene dated volcanic rocks varying in character from rhyolite to andesite with diverse settlement dynamics and represented by distinct products. These units are commonly seen in and around the research region as basaltic lava, pyroxene andesitic lava, block and ash flows, pyroclastic flows, and debris deposits. Based on the volcanites in the Dikili area, these units are known as Islamlar volcanites (Figure 3.11). The other rock unit in the study area is the Aliaa Formation, which is Middle Miocene-Lower Pliocene (?) in age and is composed of clayey limestone, limestone, chert limestone, clay, marl, and siltstone with occasional pyroclastic interbedding (Bülbül and Yücel, 2009).

3.4.3.2 Structural Geology

The structure of the Güzelhisar region is very tectonically broken. The most significant fault in the region is known as the Güzelhisar Fault (Figure 3.10). This fault runs for around 25 kilometers. The fault runs mostly north-southwest. From the north, it morphologically confines the Dumanlıdağ rise, a Miocene-aged stratovolcano. The fault is dominated by strike-slip morphology and is made up mostly of main body and tail parts at both ends. The tail segment, which is approximately 5 km long at the northwest end, connects Güzelhisar hamlet with the Aliaa district headquarters. The fault cuts Miocene-aged volcano-sedimentaries in this area. It represents a contact between volcano-sedimentary deposits and Quaternary sediments in the Güzelhisar village region. Aside from this fault, numerous others in the N80D, D-B, and N-S directions have been discovered in the vicinity (Bülbül and Yücel, 2009).



Figure 3.10 The view from the area where the Güzelhisar fault passes, in the north of Karakuzu settlement (Eroğlu, 2011)

MTA discovered 394 passive faults totaling 180 km in length and 15 active faults totaling 75.7 km in the basin. The majority of these active faults are found in the basin's south, with east-west expansion (Emre et al., 2011).

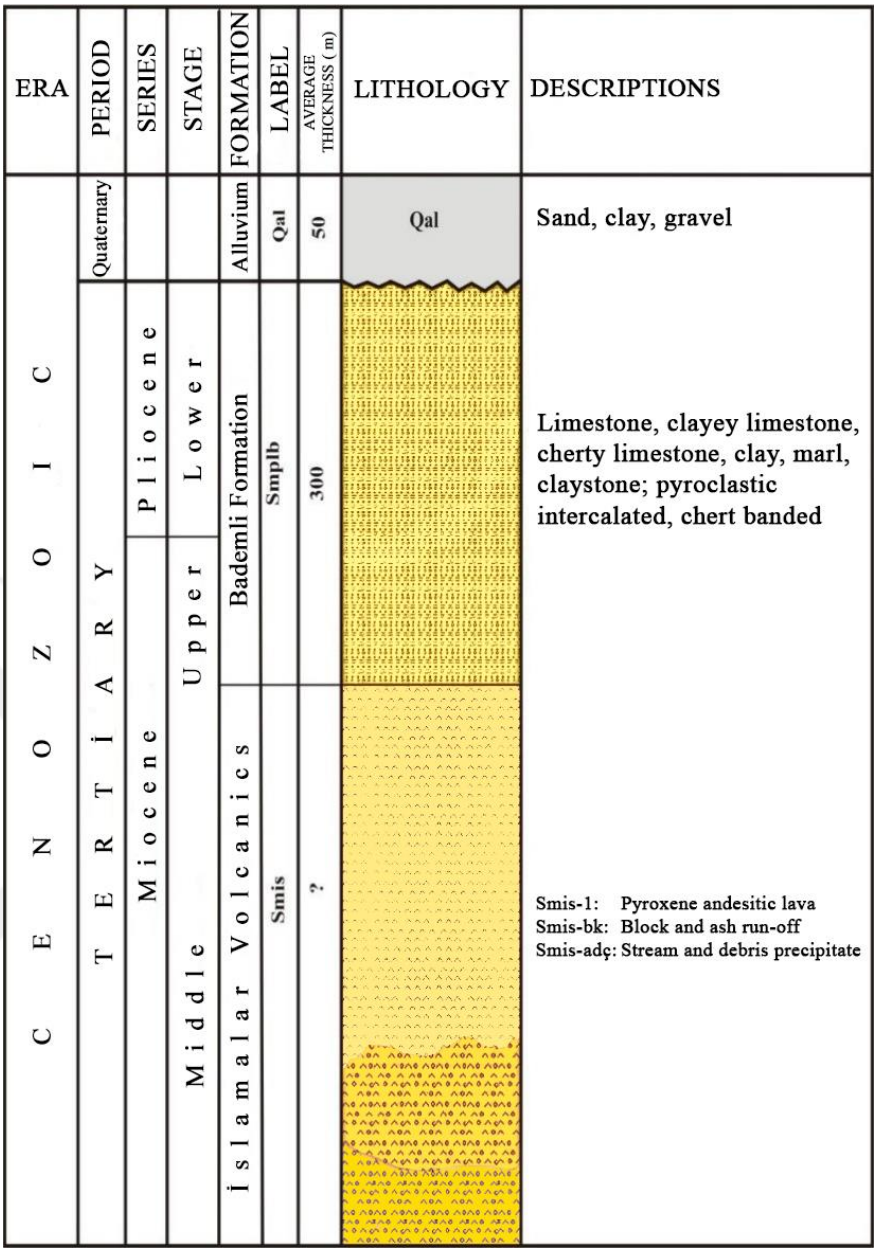


Figure 3.11 Generalized stratigraphic section of Güzelhisar basin (Bülbül and Yücel, 2009 modified from)

3.4.4 Hydrology

3.4.4.1 Streams and Lakes

At the basin, the river network of the basin flows from northeast to southwest. The primary tributary of Güzelhisar Stream, which creates the basin, is 40.62 km long in total.

Güzelhisar Dam (Figure 3.12) is the basin's most important water storage. Güzelhisar Dam has a stream named Koca Creek, and Güzelhisar Stream has a tributary called Güzelhisar Stream. The following are some technical details about the Güzelhisar Dam.

Table 3.3 Güzelhisar basin technical specifications

Feature	Value
Main Dam Type	Earth Zoned Rock Fill Dam
Maximum Flood Reservoir Area	455.81 km^2
Average Amount of Precipitation Per Year	110M m^3
Flood Discharge Per Year	90M m^3
Maximum Height Above Spillway	86 m
Maximum Height Above Foundation	89 m
Minimum Tailwater Level	12.5 m
Dam Crest Elevation	98.5 m
Minimum Operation Reservoir Level	63 m
Normal Operation Reservoir Level	107 m
Maximum Operation Reservoir Level	107 m
Minimum Operation Reservoir Capacity	12M m^3
Normal Operation Reservoir Capacity	155M m^3



Figure 3.12 The view of Güzelhisar Dam (Personal Archive, 2019)

The Strahler technique was used to generate river network data for the investigation. The Strahler system works by combining streams of the same order. There is no other stream that flows into a first order stream. As a result, it was discovered that streams of varying orders in the basin converged to produce the 7th order Güzelhisar Stream (Figure 3.13).

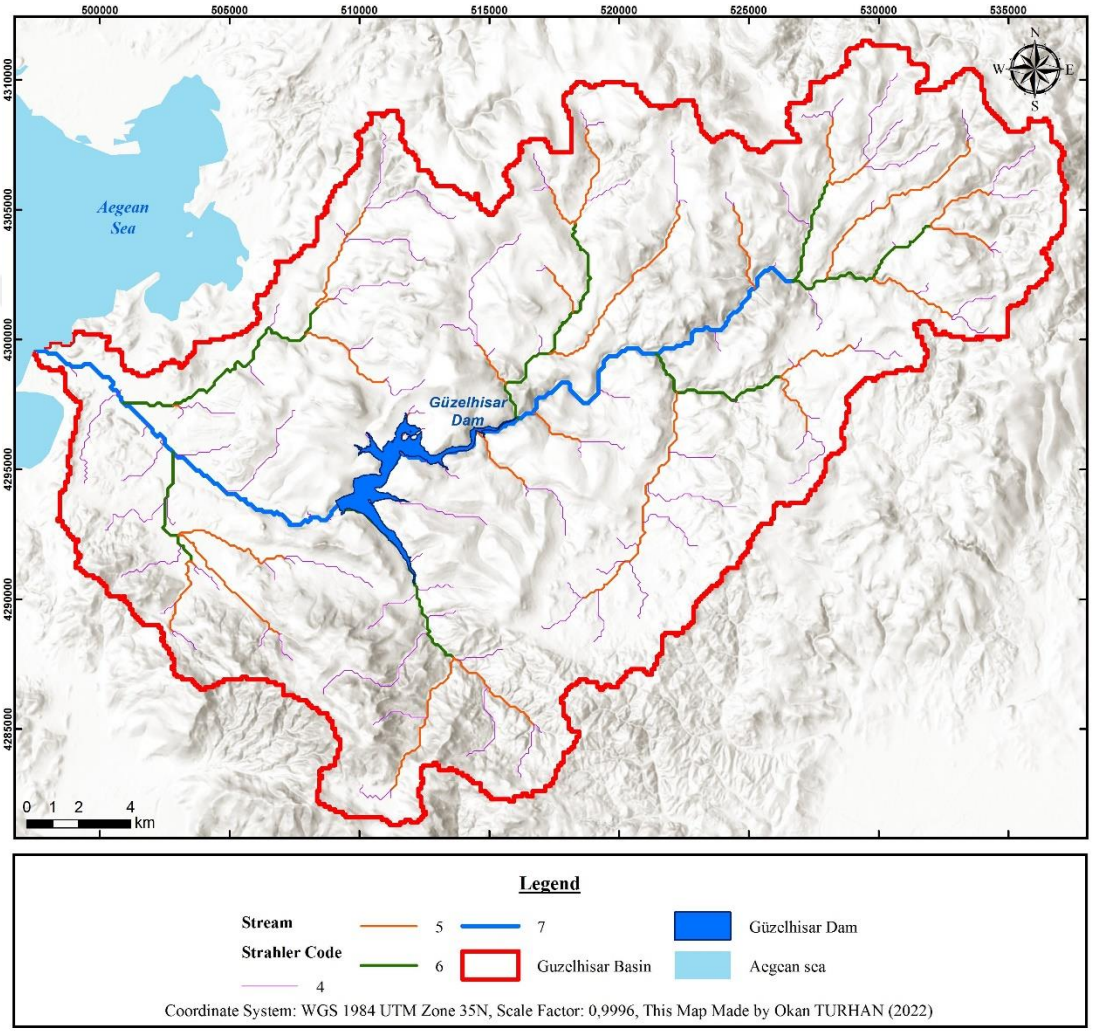


Figure 3.13 Güzelhisar basin Strahler map

3.4.4.2 Basins and Watersheds

The Ministry of Agriculture and Forestry in Turkey has built surface and groundwater bodies in basins around the nation. Although numerous approaches are used to estimate groundwater bodies, surface water bodies are determined by their drainage regions. According to this study, the Güzelhisar basin is made up of three

surface water bodies. These three surface water bodies flow into the Aegean Sea (EGE12), which is regarded as one coastal water body. Two of these bodies of water are rivers, while the other is a lake. Surface water bodies are provided in the Güzelhisar basin. The upstream area of Güzelhisar Dam's lake area is designated as KEN033, the lake area basin as KEG010, and the remaining river tributary drainage basin as KEN034. The letter "KE" refers for North Aegean, while the letters "N" and "G" represent for "river" and "lake" respectively. Furthermore, because this project was developed in line with European Union harmonization standards, Turkey-specific "TR" codes were assigned (Table 3.4).

Table 3.4 Güzelhisar basin surface water bodies codes

TR Code	Local Code	Name	Area (km^2)
TR04010529	KEN033	Karadere Stream	330.35
TR04010530	KEN034	Güzelhisar River	176.06
TR04020485	KEG010	Güzelhisar Dam	123.99
TR00042591	EGE12	Aegean Sea	469.25

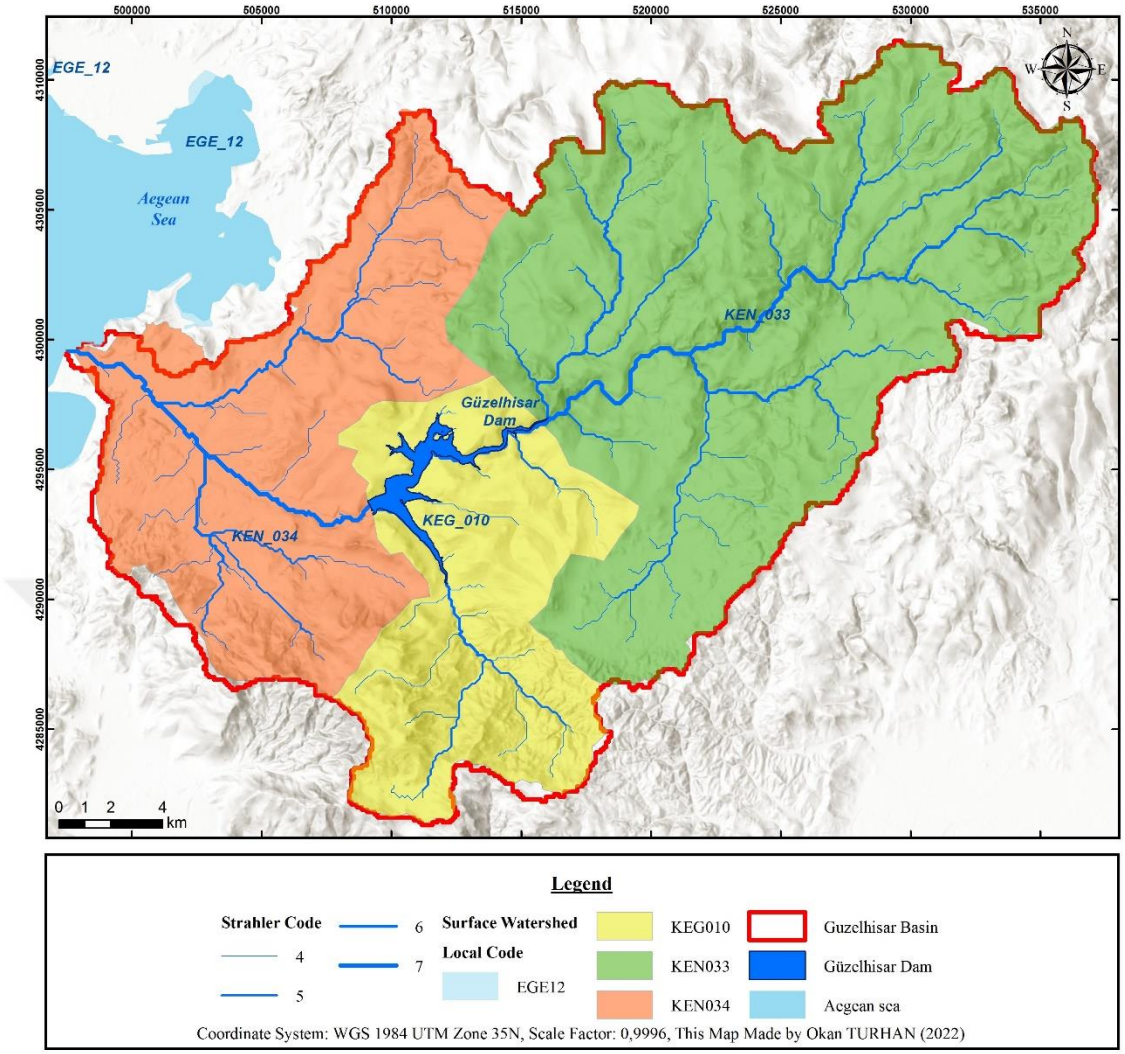


Figure 3.14 Güzelhisar basin surface watersheds

A program of water pollution prevention measures has also been devised as part of the North Aegean Basin River Basin Management Plan Project. To provide the scenarios of the measures program with future forecasts, modeling studies were conducted. Existing surface water bodies were separated into more precise drainage zones for use in these modeling experiments. Figure 3.15 depicts these sub basins.

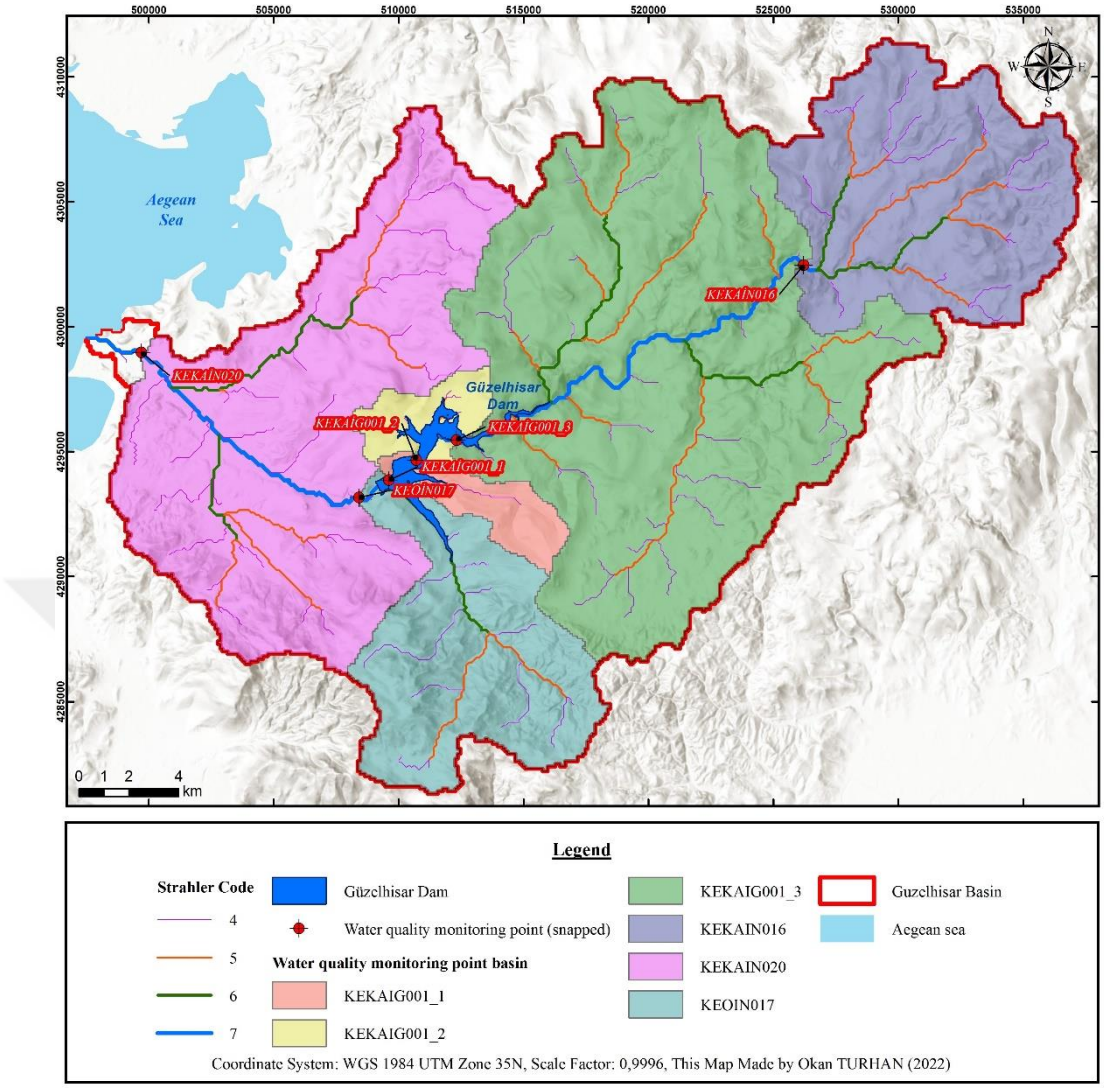


Figure 3.15 Güzelhisar basin water quality monitoring points and model watersheds

The primary objective for developing model water bodies is to compare the pollution source connection with parameter data at the water quality monitoring point stations. As a result, the existing drainage regions were split more precisely according to a certain logic. Figure 3.16 depicts a method for dividing the current surface water bodies. This diagram is based on the existing river water body's starting and finishing places, as well as any connecting points. By removing the crossings of these locations in the drainage regions generated, detailed drainage areas of the area were created and tagged. A surface water body in the basin is illustrated, along with the drainage regions generated as a result of the divide.

The basin partitioning approach can be used at various scales depending on the situation. Although Turkey is split into 26 primary basins, these basins contain numerous sub basins, surface and groundwater bodies. The administrative manageability of the basins is intended based on these divisions at various sizes.

For pollutant load distributions, a geographical technique is used in this work. As a result, the Güzelhisar basin was divided based on the drainage network acquired at the location of the field water samples. Thus, sample measurement results and calculated spatial pollution loads may be compared.

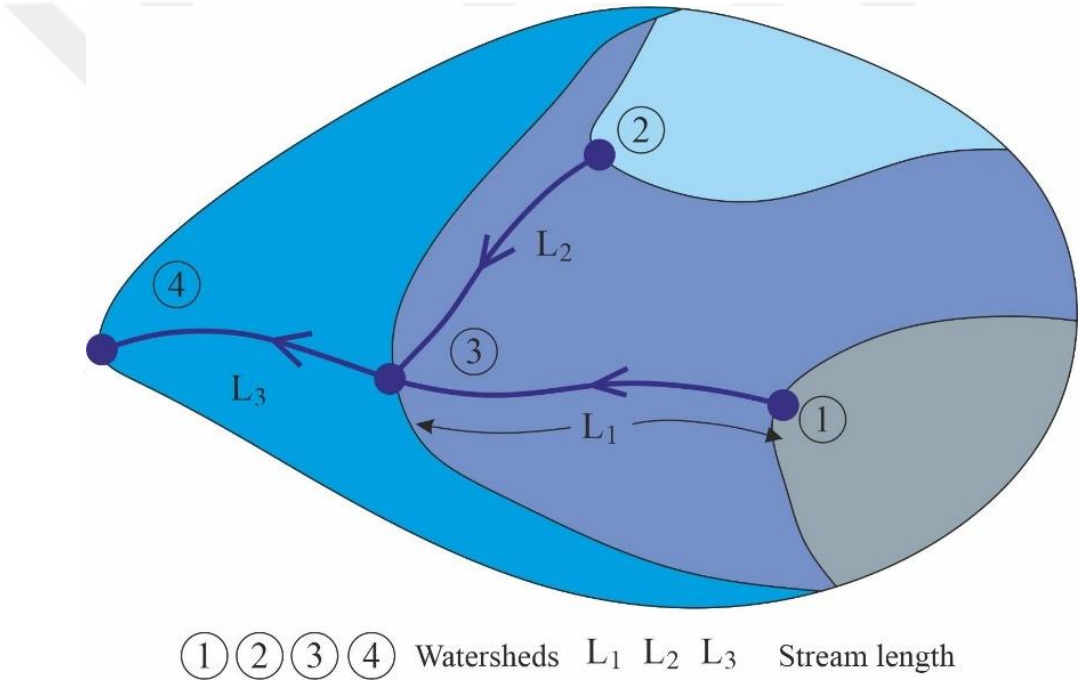


Figure 3.16 Creation schema that for model watersheds

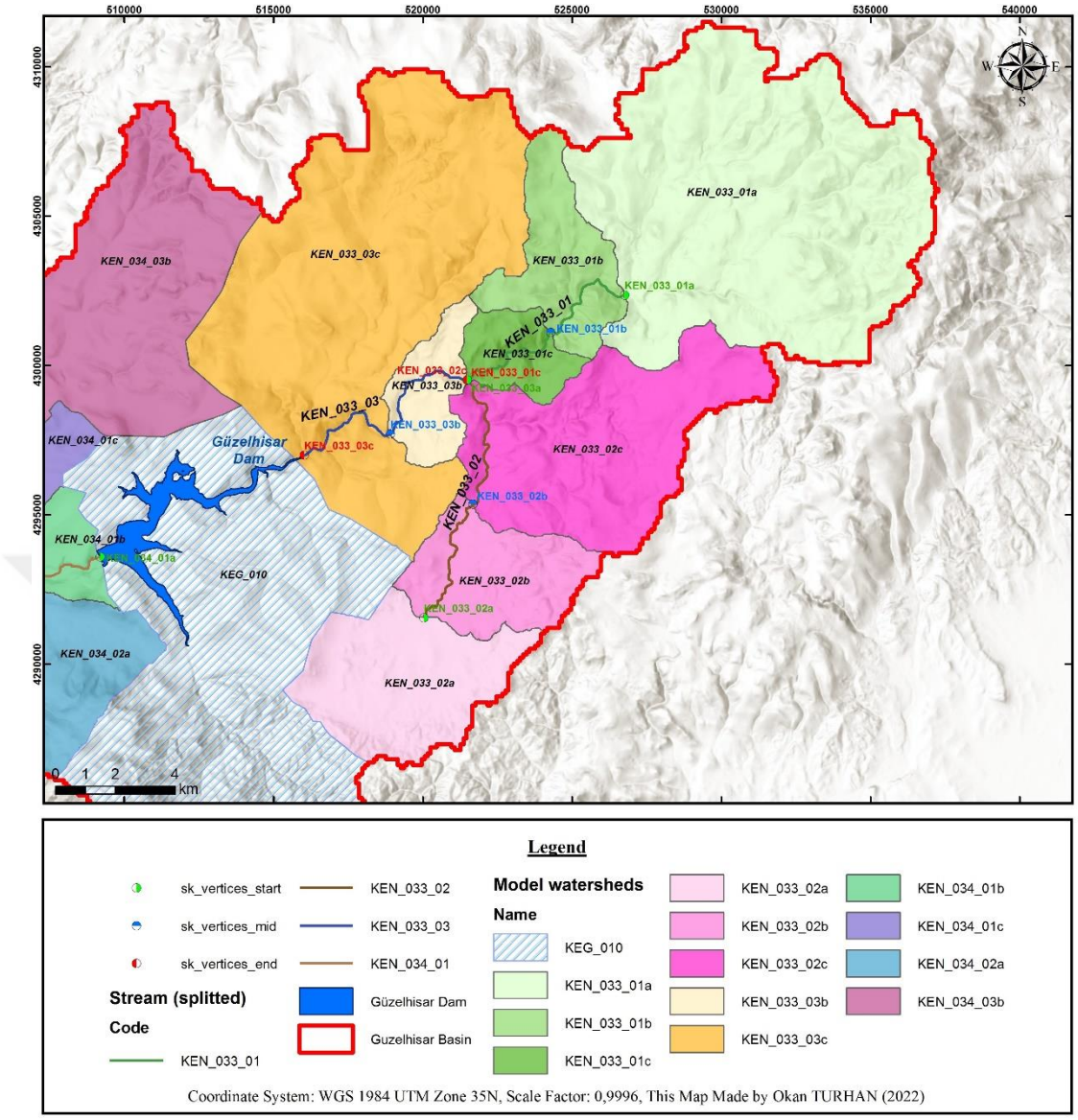


Figure 3.17 Example of model watersheds

3.4.5 Water Quality Monitoring Locations

A total of six samplings were conducted in the basin as part of the North Aegean Basin River Basin Management Plan, one on the upstream of the dam, three in the lake, one from the river in the downstream area of the dam, and one from the point where the Güzelhisar basin drains into the sea (Figure 3.18).Within the scope of the experiment, these samples were collected and analyzed at 6-month intervals over two years. Because the sample locations would be used to generate model sub-basins, the

position of the sample acquired with the "snap point" approach was zoomed to the nearest point of the stream network created by the Strahler method (Figure 3.19).

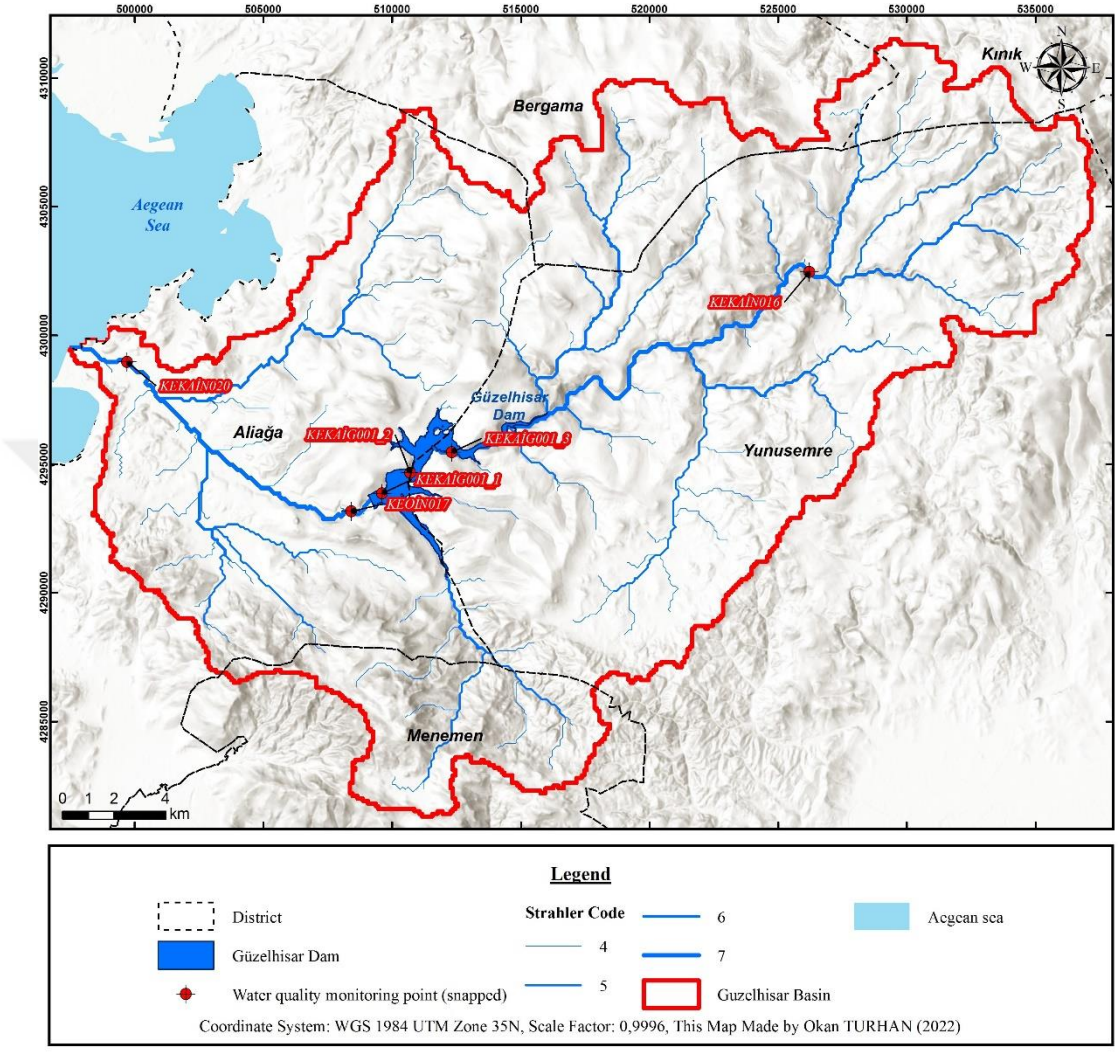


Figure 3.18 Güzelhisar basin map of water quality monitoring points

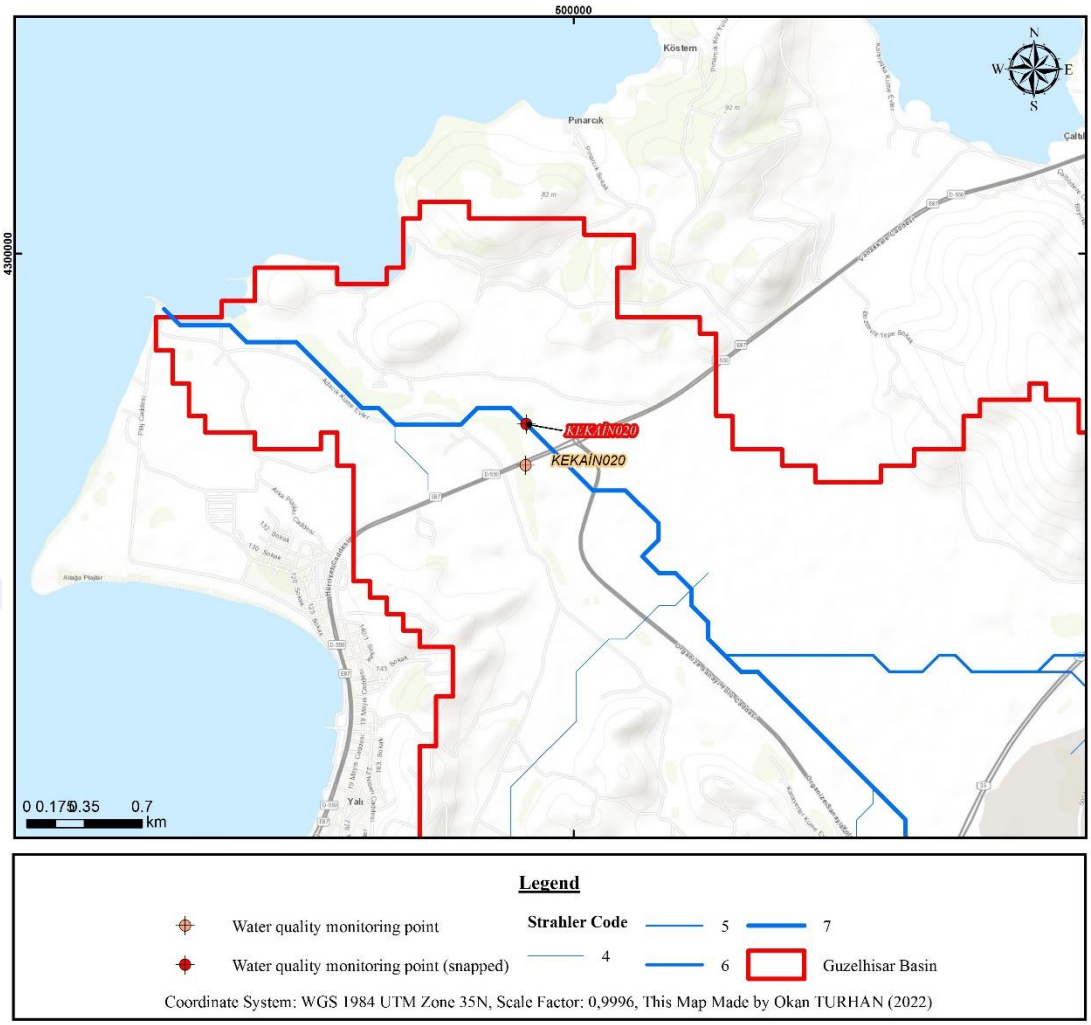


Figure 3.19 Güzelhisar basin analysis of snap

3.4.6 Pollution Sources

Pollution sources are the primary cause of poor water quality in the basin. The pollutant and source connection in the field is critical in water quality research. As a result, the analysis environment includes all constituents that may be contaminants in the research region. Pollution loads are categorized into two kinds to aid these studies: point and diffuse.

3.4.6.1 Point Pollution Sources

Pollutant sources that enter the water at a single point are referred to as point sources of pollution. Each basin has various pollution sources based on its geographical features. Point pollution sources in the Güzelhisar basin identified;

- Urban waste water treatment plant,
- Urban direct discharge,
- Septic tanks,
- Industrial waste water treatment plants,
- Organized industrial zones,
- Individual industrial plants.

The distribution of point pollutant sources in Güzelhisar basin is given in Figure 3.20.

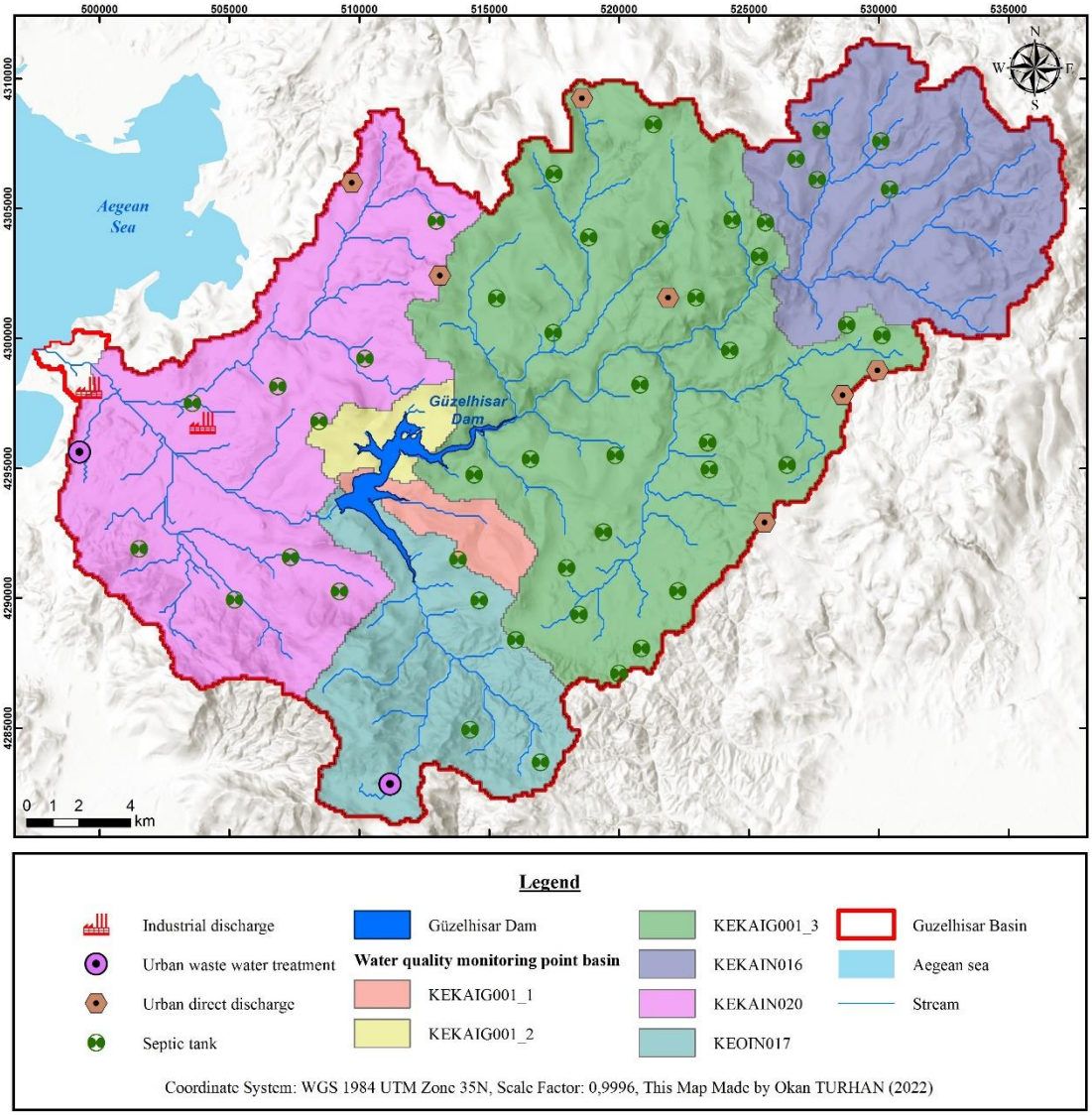


Figure 3.20 Güzelhisar basin map of point pollution sources

3.4.6.2 Non-Point Pollution Sources

Non-point pollution sources are pollutant sources that can pollute water throughout a geographic area. Without any other component in terms of the criteria it includes, the geology of the region might contaminate water. One of the most significant sources of areal contamination is geogenic water pollution. Furthermore, industries such as agriculture, livestock and mining might be cited as examples of local pollution sources.

In this study, we looked at the many pollution sources that are known to have an impact on the water in the Güzelhisar basin;

- Land Use CORINE, 2018),
- Agricultural areas,
- Mining sites,
- Solid waste landfills.

CORINE data, often known as land use data, is a dataset obtained by studying satellite photography that covers Europe. This information essentially depicts the texture of the locations. This data displays the spatial quality of all regions in Europe using three distinct features. The most basic data indicates five fundamental levels. These are the layers;

- Water Bodies
- Agricultural Areas
- Artificial Surfaces
- Agriculture Areas
- Forest and semi-natural areas.

Of course, addressing water consumption and contamination in these five fundamental elements is difficult. As a result, precise labels of the third order were employed. According to CORINE (2018) data, the Güzelhisar basin has 19 distinct land uses in 3rd order detail (Table 3.5). It is conceivable to address water use in that area in this manner. Figure 3.21 depicts the land use distribution in the Güzelhisar basin.

Table 3.5 CORINE Land use data classification in Güzelhisar Basin (Copernicus, 2018)

CLC Code	Label	Label 2	Label 3	Area (ha)
112	Artificial surfaces	Urban fabric	Discontinuous urban fabric	764.14
121		Industrial, commercial and transport units	Industrial or commercial units	610.73
131		Mine, dump and construction sites	Mineral extraction sites	143.69
133			Construction sites	135.04
211	Agricultural areas	Arable land	Non-irrigated arable land	1,502.35
212			Permanently irrigated land	771.95
223		Permanent crops	Olive groves	390.91
231		Pastures	Pastures	1,673.12
242		Heterogeneous agricultural areas	Complex cultivation patterns	5,691.71
243			Land principally occupied by agriculture, with significant areas of natural vegetation	5,650.10
311	Forest and semi natural areas	Forests	Broad-leaved forest	1,404.14
312			Coniferous forest	3,346.69
313			Mixed forest	731.8
321		Scrub and/or herbaceous vegetation associations	Natural grasslands	16,007.99
323			Sclerophyllous vegetation	13,151.14
324			Transitional woodland-shrub	10,253.57
333		Open spaces with little or no vegetation	Sparsely vegetated areas	275.06
421	Wetlands	Maritime wetlands	Salt marshes	26.38
512	Water bodies	Inland waters	Water bodies	611.56

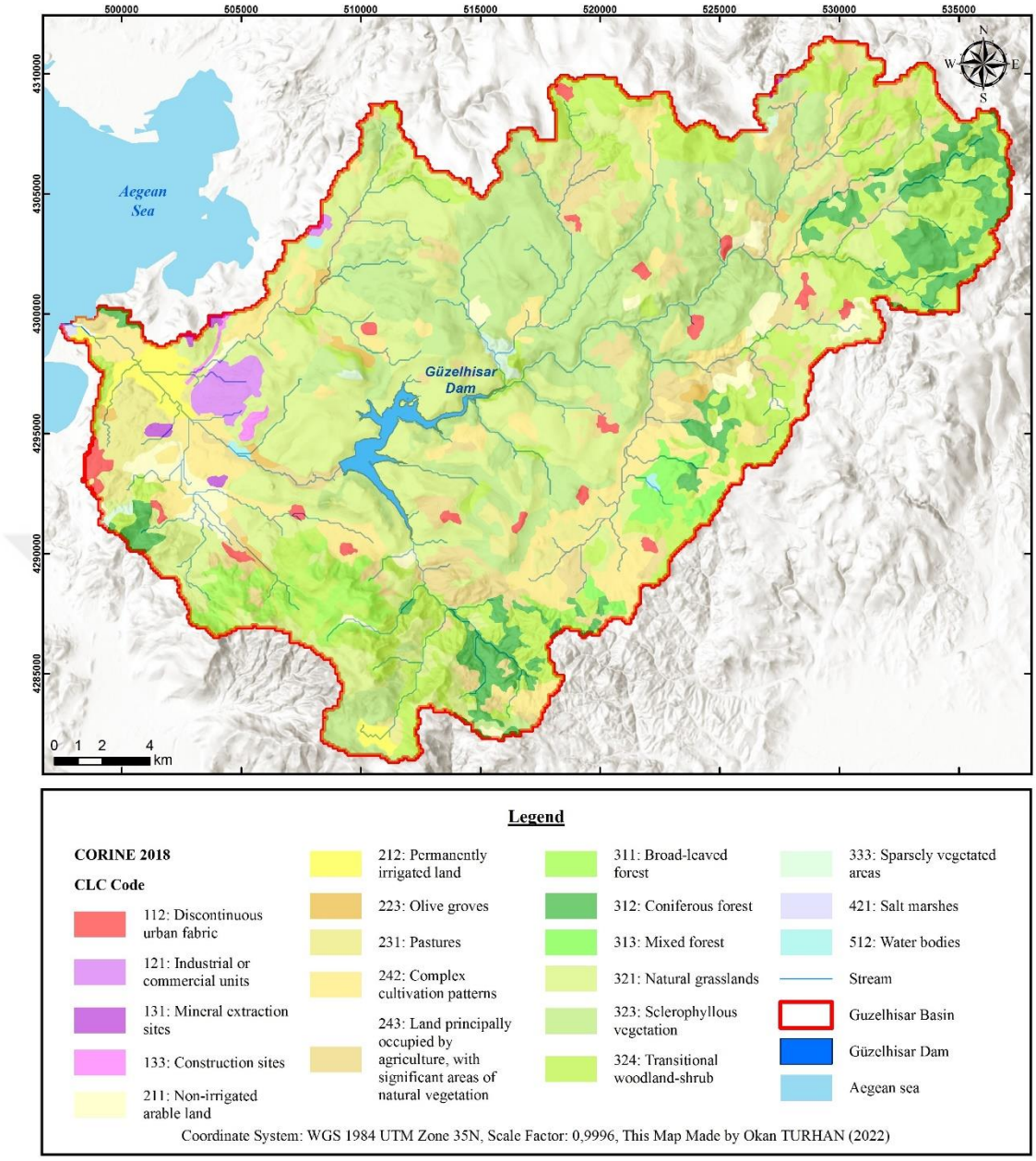


Figure 3.21 Güzelhisar basin map of CORINE (2018) data (Copernicus, 2018)

Agricultural fields are another source of dispersed pollution. Because of the crops produced on them, agricultural regions are subjected to a variety of pesticides. These pesticides pollute the basin's surface and groundwater owing to rainfall, percolation, and other factors.

Mining sites in the vicinity are another source of pollution. Pollutants are created geographically in the underground and above ground, depending on the kind of mine, during the separation and other operations.

Solid waste dumps are another source of diffuse pollution in the basin because it is a densely populated residential region. Storage is done in defined spaces on a regular or irregular basis. Leachates that may form as a result of rainfall in the area may mix contaminants with surface and groundwater.

Figure 3.22 depicts agricultural lands, mining sites, and solid waste storage locations in the basin.

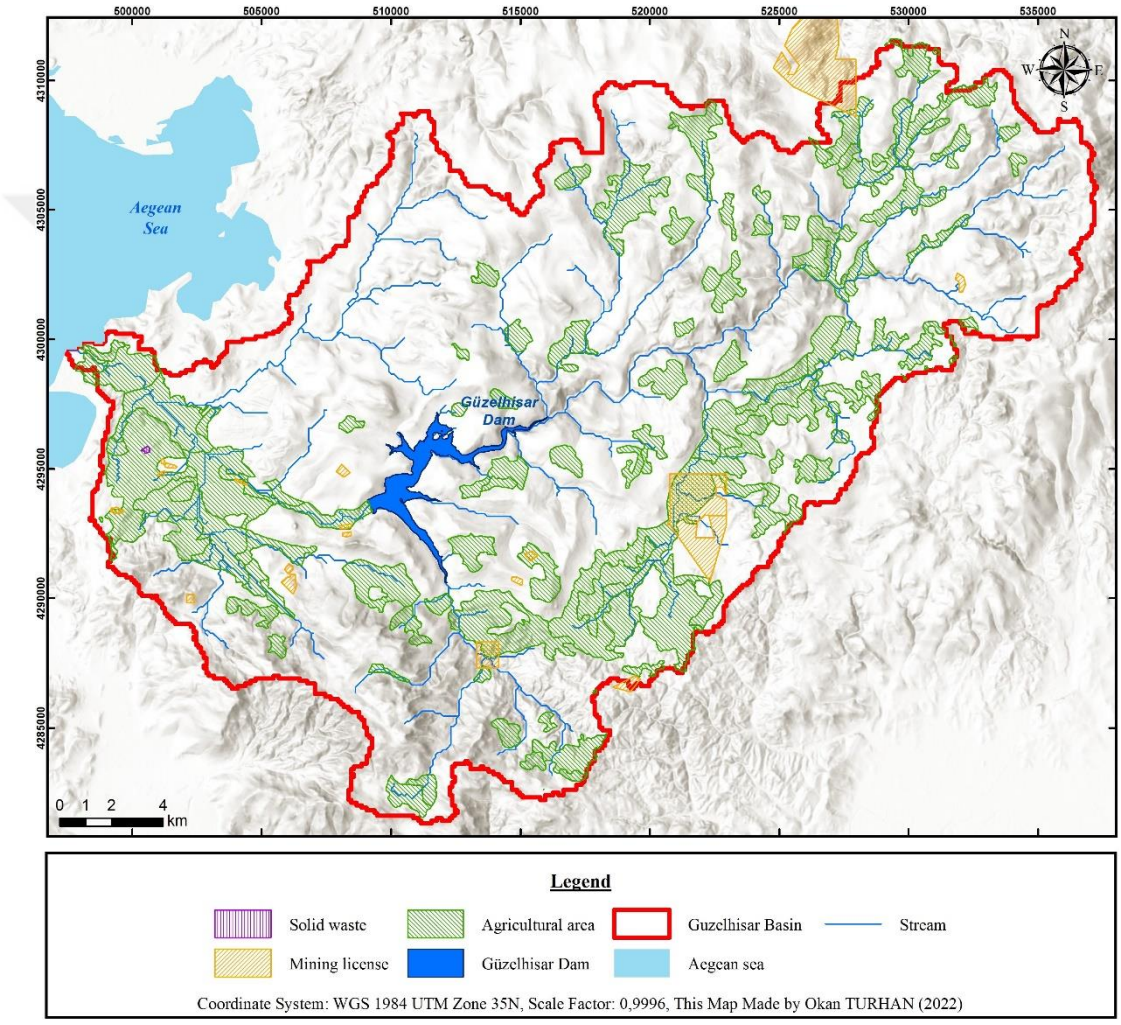


Figure 3.22 Güzelhisar basin map of other non-point pollution sources

3.5 Spatial Analysis of Point and Non-Point Pollution Sources

In this study, GIS-based pollution-weighted raster accumulation analysis (Pollution-Weighted Flow Accumulation), TN (Total Nitrogen), TP (Total Phosphorus), COD (Chemical Oxygen Demand), and SS (Suspended Solids) data will be utilized to identify pollutant levels as well as the location of pollutants and pollution pathways.

The basin's point and diffuse pollutant sites and spatial distributions were converted to raster format. Loads were allocated to contaminants using unit load assumptions throughout this conversion. To include these values, pollution rasters were constructed for each pollutant in the relevant unit.

3.5.1 Urban Waste Water Treatments

In the research region, two urban wastewater treatment plants were found (TURAAT, 2017). These include the Çukurköy Urban wastewater treatment plant in the basin's south and the Aliaa Urban wastewater treatment plant in the basin's west (Figure 3.23).

In a few steps, the approach to the quantities of pollutants emitted by urban wastewater treatment facilities may be explained. Population data is the initial stage in quantity calculations. Urban wastewater treatment plants have a limited population capacity. While the Çukurköy wastewater treatment plant has a population capacity of 751, the Aliaa wastewater treatment plant has a capacity of 66,845 persons (TURAAT, 2017).

Because wastewater flow cannot be monitored at these facilities, numbers for wastewater flow were estimated. This method is known as the unit wastewater flow rate per capita. Furthermore, daily pollution levels per capita were estimated. Table 3.6 shows the unit flow and unit load values connected to this value based on population density.

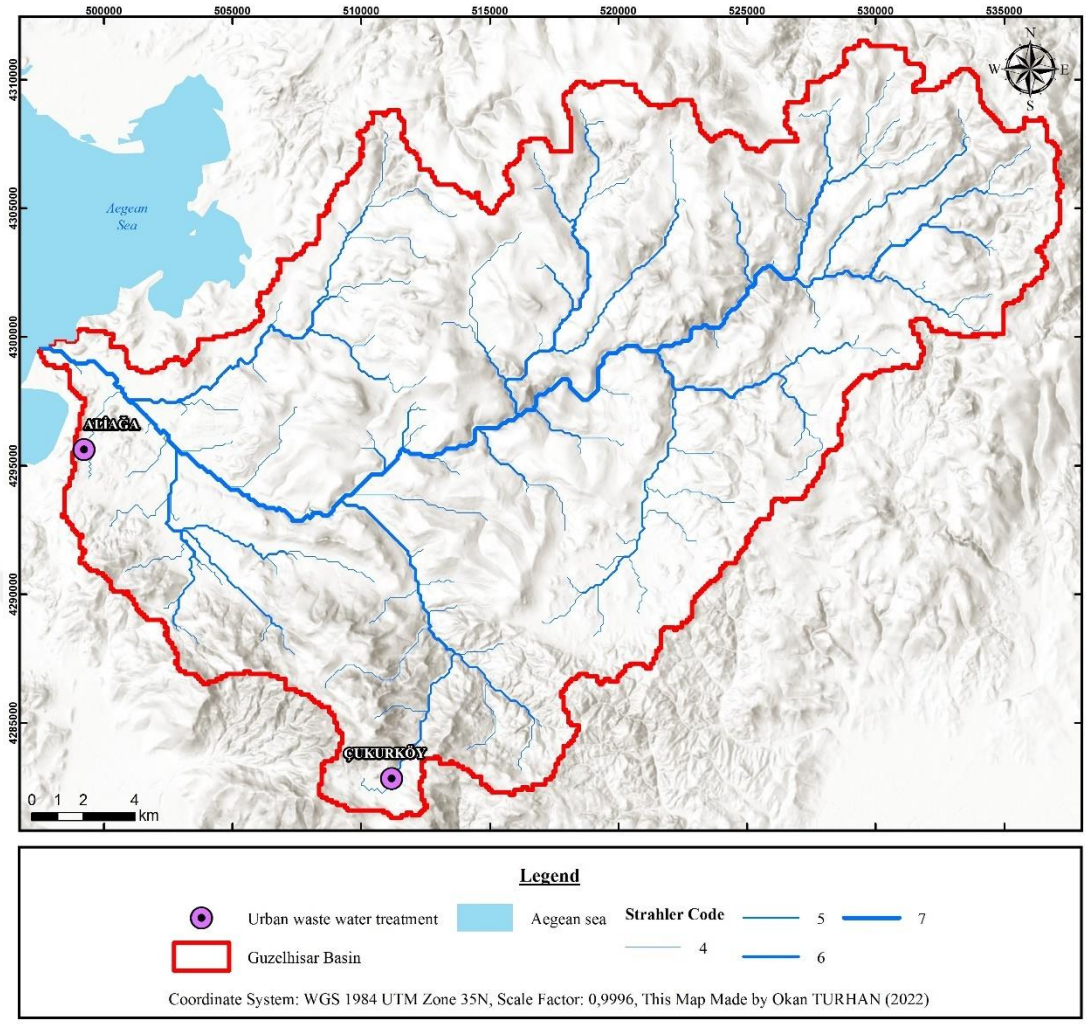


Figure 3.23 Urban Waste water treatments of Güzelhisar basin

Table 3.6 Urban waste water treatment plant unit waste waterflow evaluation scale

Population	Unit Flow (lt/person/day)	Unit TN Load (gr/person/day)	Unit TP Load (gr/person/day)	Unit COD Load (gr/person/day)	Unit SS Load (gr/person/day)
<2000	105	5	0.9	55	35
2000-10000	120	5	0.9	55	35
10000-50000	135	6	1	75	45
50000-100000	150	7	1.1	90	50
>100000	150	7	1.1	90	50

The number of tons of pollutant load generated per year was computed using the assumption of how much pollutant load (mg/L) urban wastewater treatment facilities may create per day with their daily wastewater flow rates. Annual loads were computed using this assumption by multiplying the unit load by the flow rate and determining the load from the wastewater treatment facilities (Table 3.7).

Table 3.7 Urban waste water treatment plant load calculation

Urban Wastewater Treatment	Aliağa WWTP	Çukurköy WWTP
Population	66,845	751
Unit Waste Water Flow (lt/person/day)	150	105
Unit TN Load (mg/L)	7	5
Unit TP Load (mg/L)	1.1	0.9
Unit COD Load (mg/L)	90	55
Unit SS Load (mg/L)	50	35
Waste Water Flow (lt/day)	3,659,764	28,782
Calculated TN Load Per Year (ton/year)	51.24	1.1
Calculated TP Load Per Year (ton/year)	8.05	0.16
Calculated COD Load Per Year (ton/year)	439.17	6.78
Calculated SS Load Per Year (ton/year)	121.99	0.96

In a GIS context, the computed pollutant levels were allocated to the sites of wastewater treatment plants. Figure 3.24 depicts the distribution of the sample WWTP TN pollutant load throughout the basin as determined by "Flow Accumulation" study. In addition to this map, pollutant raster data for TP, ACM, and COD were generated.

All of these phases are broken down into numerous tools that may be executed in a single command with the model builder, with the goal of providing quick integration to the field or data changes in the studies. Figure 3.25 depicts the model for municipal wastewater treatment facilities.

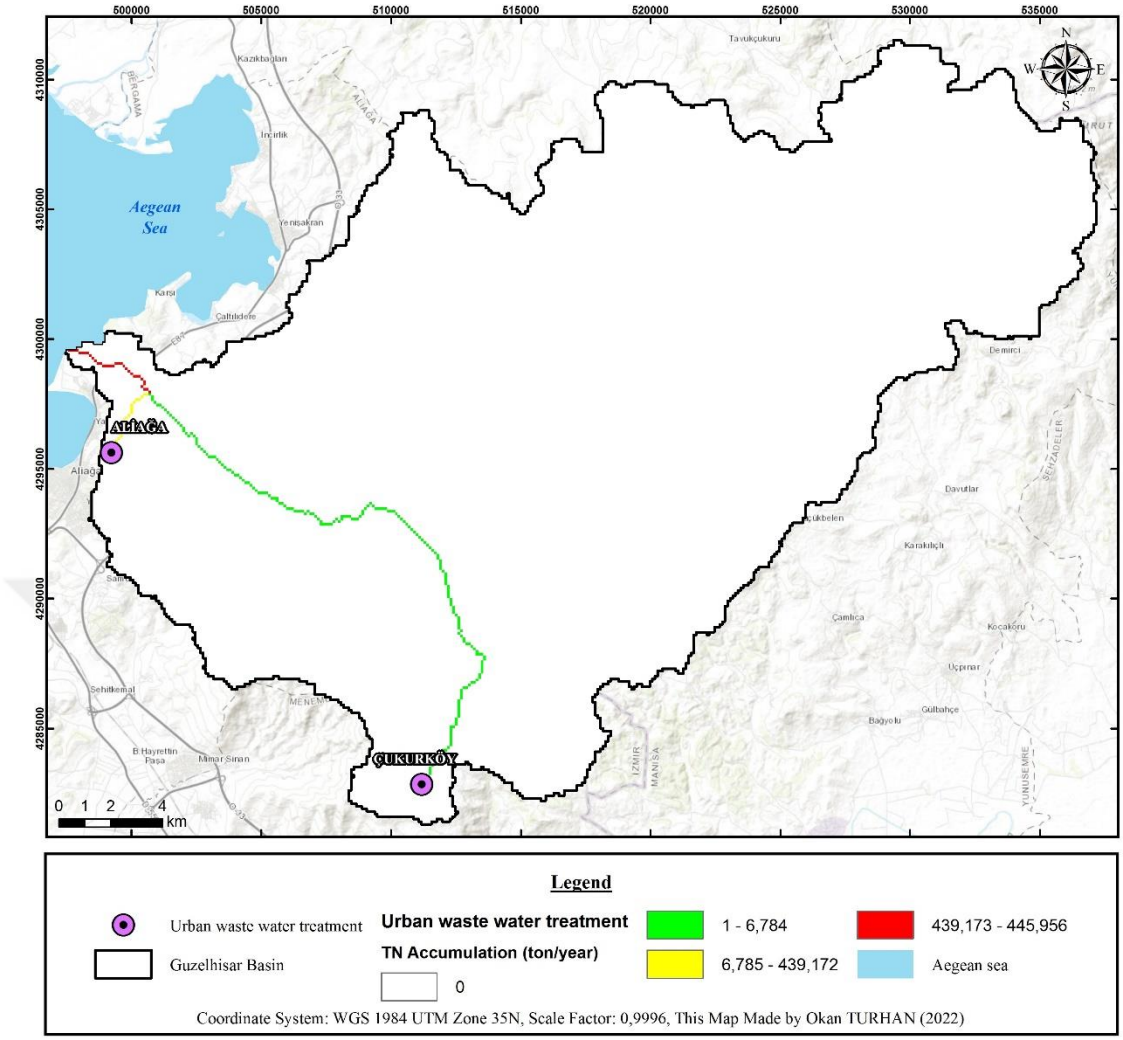


Figure 3.24 Urban waste water treatment TN pollutions of Güzelhisar basin

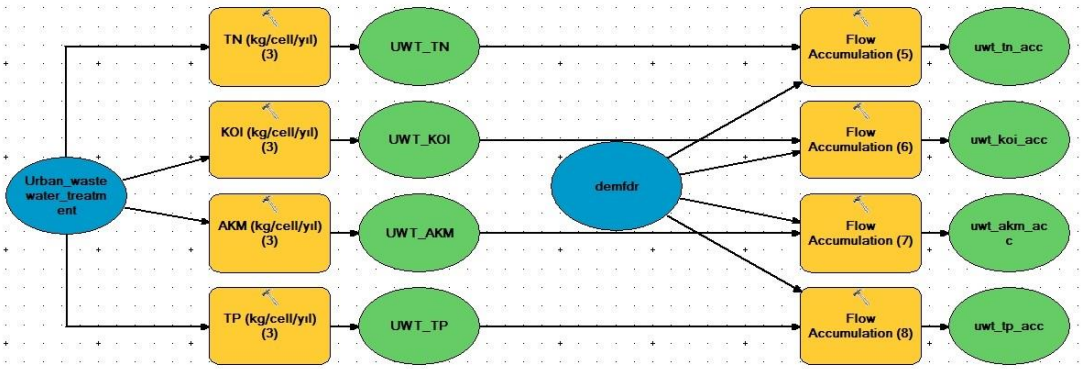


Figure 3.25 Model builder schema of urban waste water treatment pollutions

3.5.2 Urban Direct Discharges

In the studied region, there are seven direct discharges. These direct discharges are caused by settlements in the Güzelhisar Stream feeding zones (Figure 3.26). The average height of these discharges is 400 meters.

The pollutant load technique was used for both urban direct discharges and urban wastewater treatment facilities. The population discharged was multiplied by the unit pollution loads, and yearly pollution was estimated by matching this number to wastewater flows (Table 3.6).

Because wastewater flow rate in direct discharges could not be quantified, wastewater amount per capita was estimated (Table 3.8).

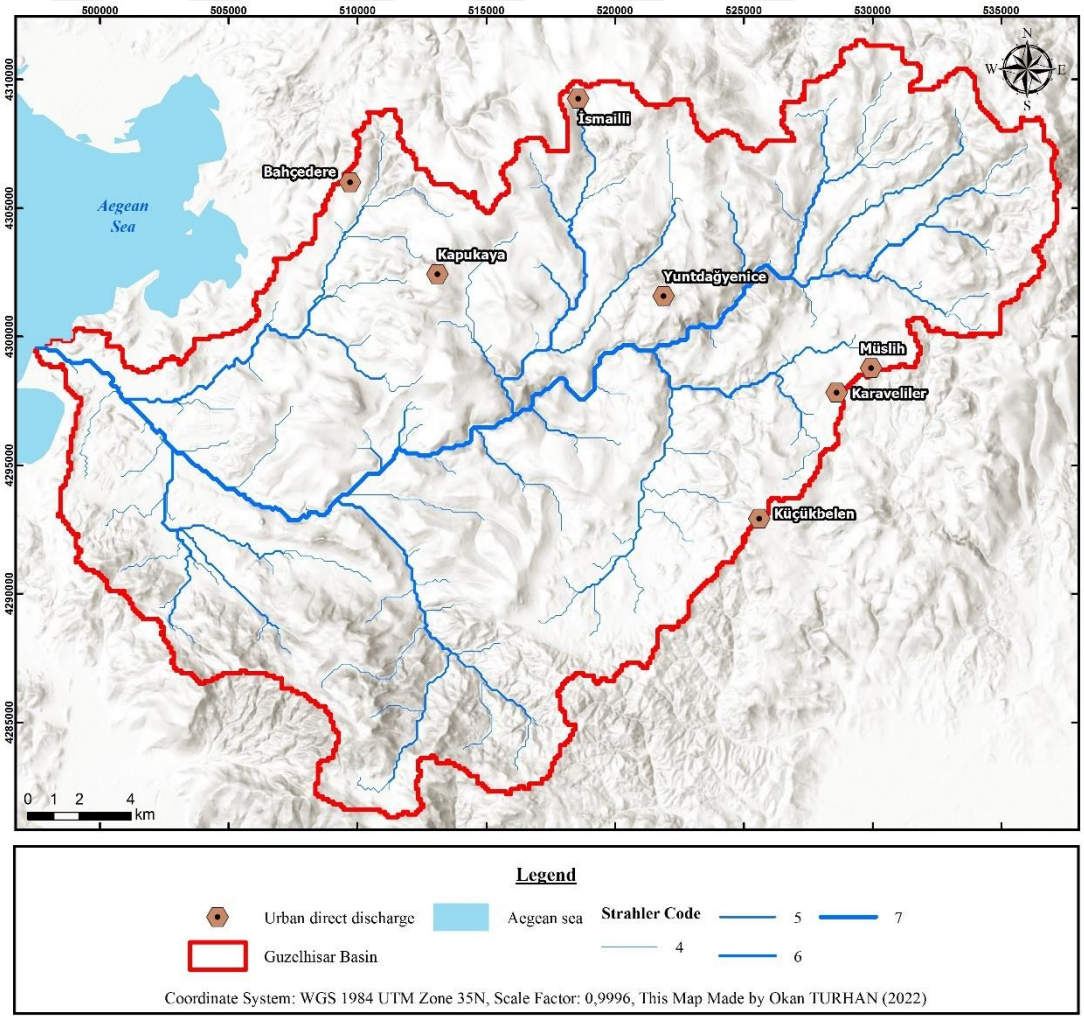


Figure 3.26 Urban direct discharges of Güzelhisar basin

Table 3.8 Urban direct discharges plant load calculation

Urban Direct Discharge	**Bahçedere**	**Yuntdağyenice**	**İsmailli**	**Kapukaya**	**Müslih**	**Küçükbelen**	**Karaveliler**
Population	9315	527	201	187	169	158	146
Unit Waste Water Flow (lt/person/day)	120	105	105	105	105	105	105
Unit TN Loads (mg/lt)	5	5	5	5	5	5	5
Unit TP Loads (mg/lt)	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Unit COD Loads (mg/lt)	55	55	55	55	55	55	55
Unit SS Loads (mg/lt)	35	35	35	35	35	35	35
Waste water Flow (lt/day)	407,997	20,197	7,703	7,167	6,477	6,055	5,595
Calculated Loads TN Loads (ton/ year)	17	0.96	0.37	0.34	0.31	0.29	0.27
Calculated Loads TP Loads (ton/ year)	3.06	0.17	0.07	0.06	0.06	0.05	0.05
Calculated Loads COD Loads (ton/ year)	187	10.58	4.04	3.75	3.39	3.17	2.93
Calculated Loads SS Loads (ton/year)	119	6.73	2.57	2.39	2.16	2.02	1.87

In a GIS context, these pollutant levels were attributed to urban direct discharge sites. The sample Urban Direct Discharge with the distribution of COD pollution load in the basin is provided by the "Flow Accumulation" study. In addition to this map, pollution raster data for TN, TP, and SS were prepared.

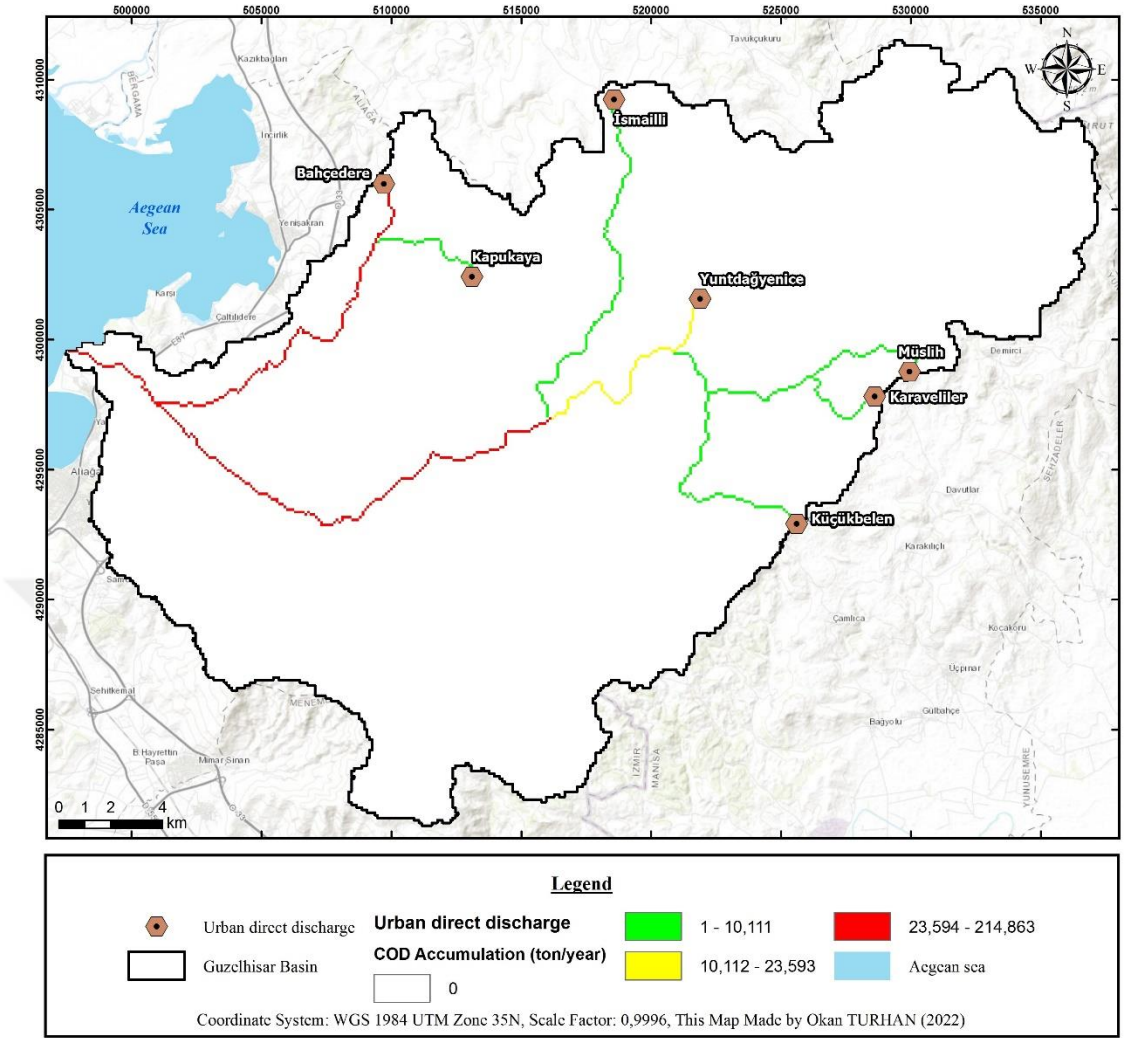


Figure 3.27 Urban direct discharge COD pollutions of Güzelhisar basin

All of these phases are broken down into numerous tools that may be executed in a single command with the model builder, with the goal of providing quick integration to the field or data changes in the studies. Figure 3.28 depicts the urban direct discharge model.

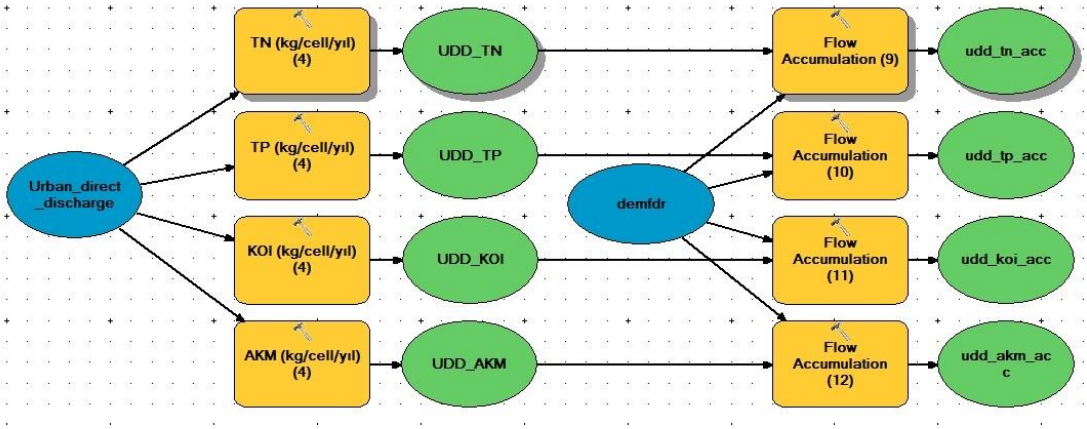


Figure 3.28 Model builder schema of urban direct discharge pollutions

3.5.3 Industrial Discharges

Industrial pollutant sources in the Güzelhisar basin have been identified as Aliağa Organized Industrial Zone and Viking Paper Mill. These industrial facilities are located downstream of the Güzelhisar Dam, quite close to the sea outflow (Figure 3.29).

Industrial discharges' daily wastewater flow rates can be monitored. All industrial establishments must have usage and waste water meters. It was determined how many tons of pollution load these facilities will create per year based on the assumption of how much pollutant load they can generate each day. Annual loads were computed using this assumption by multiplying unit load by flow rate and determining the load from wastewater treatment plants (Table 3.9).

In a GIS context, the computed pollutant levels were allocated to industrial discharge sites. Figure 3.30 depicts the distribution of the sample industrial COD pollution load throughout the basin as determined by "Flow Accumulation" study. In addition to this map, pollution raster data for TN, TP, and SS were prepared.

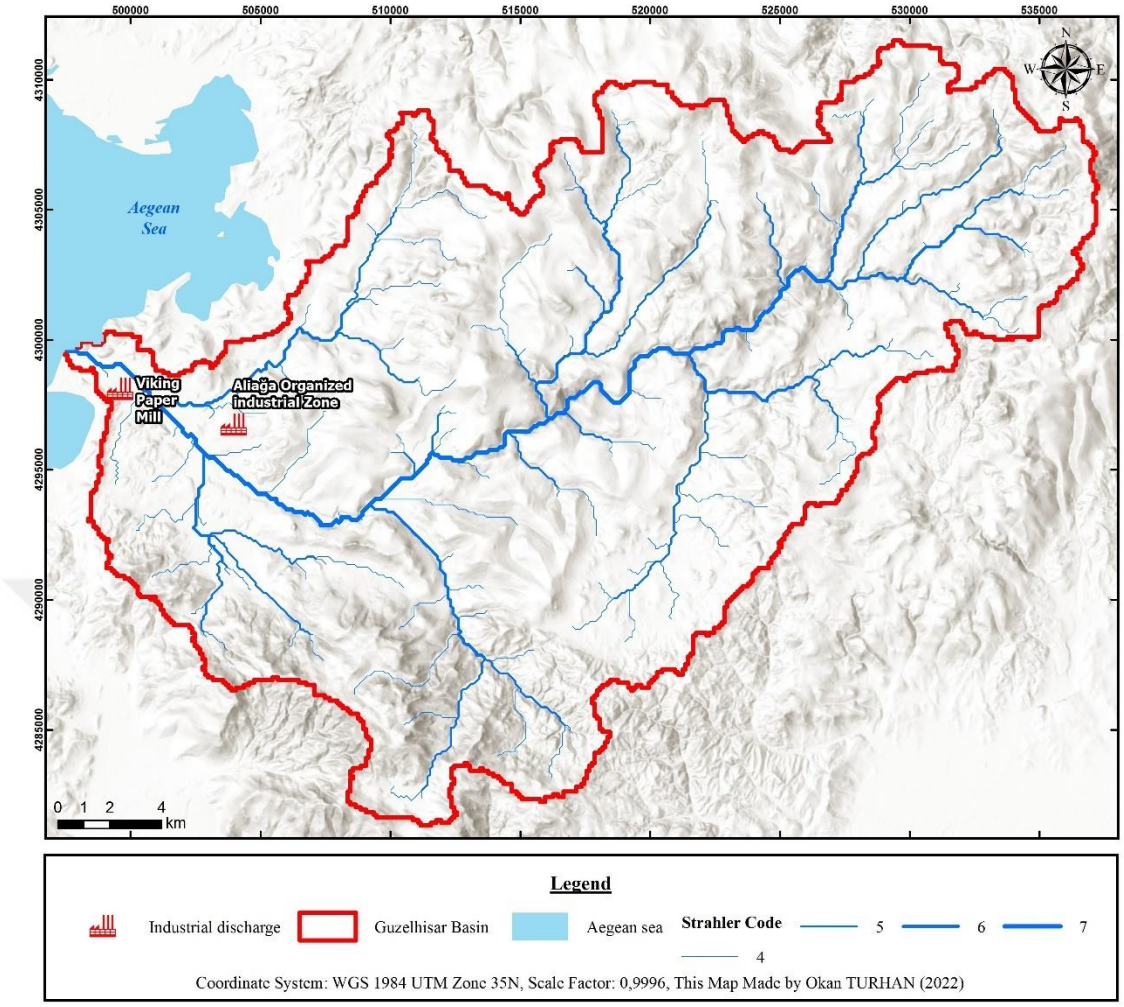


Figure 3.29 Industrial discharges of Güzelhisar basin

Table 3.9 Industrial discharge loads calculation

END (Industrial discharge)	Viking Paper Mill	Aliağa Organized Industrial Zone
Unit TN Loads (mg/lt)	0	20
Unit TP Loads (mg/lt)	0	2
Unit COD Loads (mg/lt)	100	400
Unit SS Loads (mg/lt)	0	200
Waste Water Flow (lt/day)	4,000	3,500
Calculated TN Loads (ton/year)	0	25.55
Calculated TP Loads (ton/year)	0	2.56
Calculated COD Loads (ton/year)	146	511
Calculated SS Loads (ton/year)	0	255.5

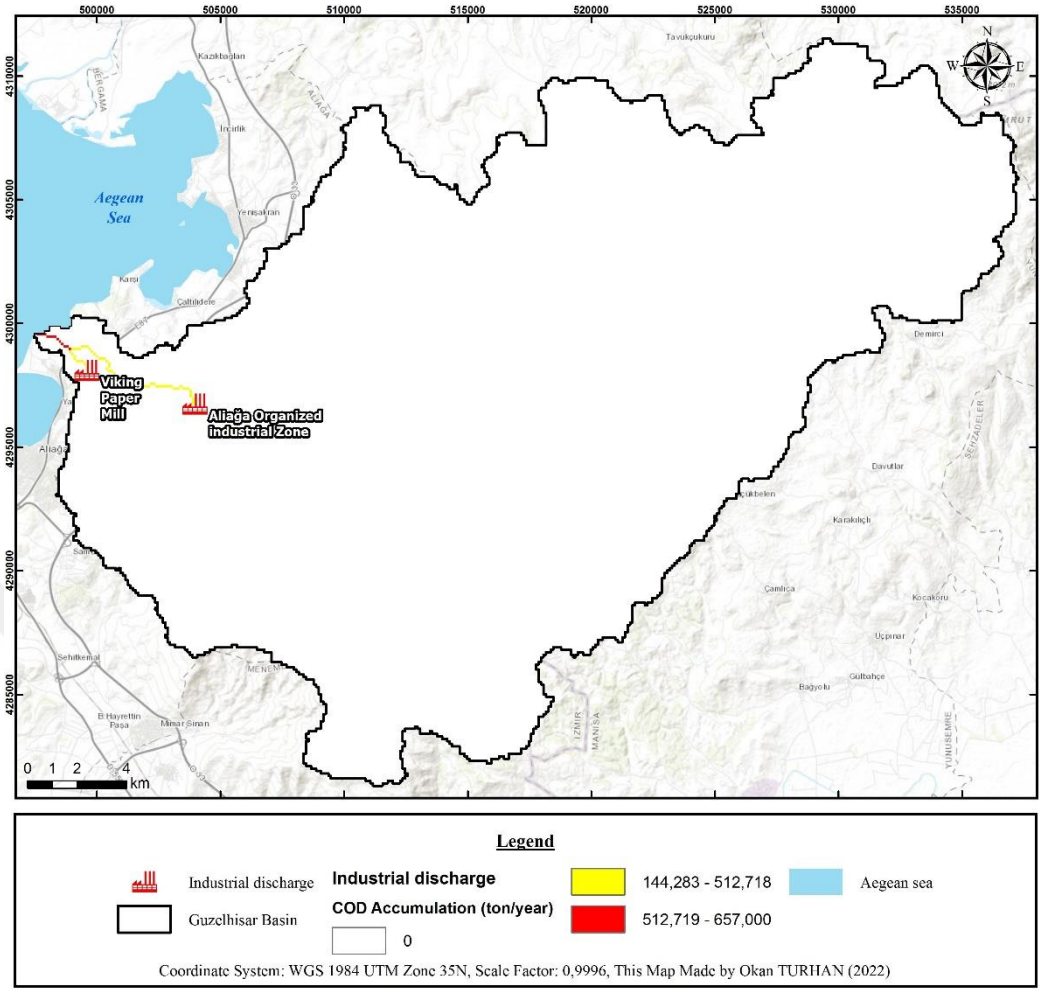


Figure 3.30 Urban direct discharge COD pollutions of Güzelhisar basin

All of these phases are broken down into numerous tools that may be executed in a single command with the model builder, with the goal of providing quick integration to the field or data changes in the studies. Figure 3.31 depicts the industrial discharge model.

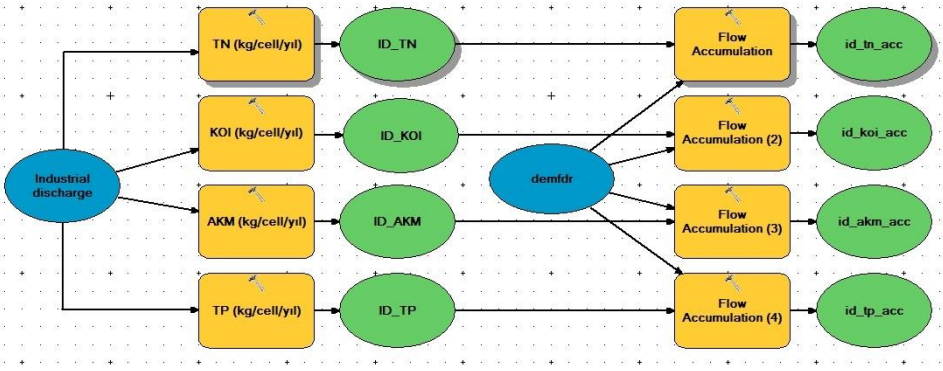


Figure 3.31 Model builder schema of industrial discharge pollutions

3.5.4 Septic Tanks

As can be seen in the figure below, there are 45 cesspools in locations with no urban wastewater treatment facility and no direct outflow (Figure 3.32).

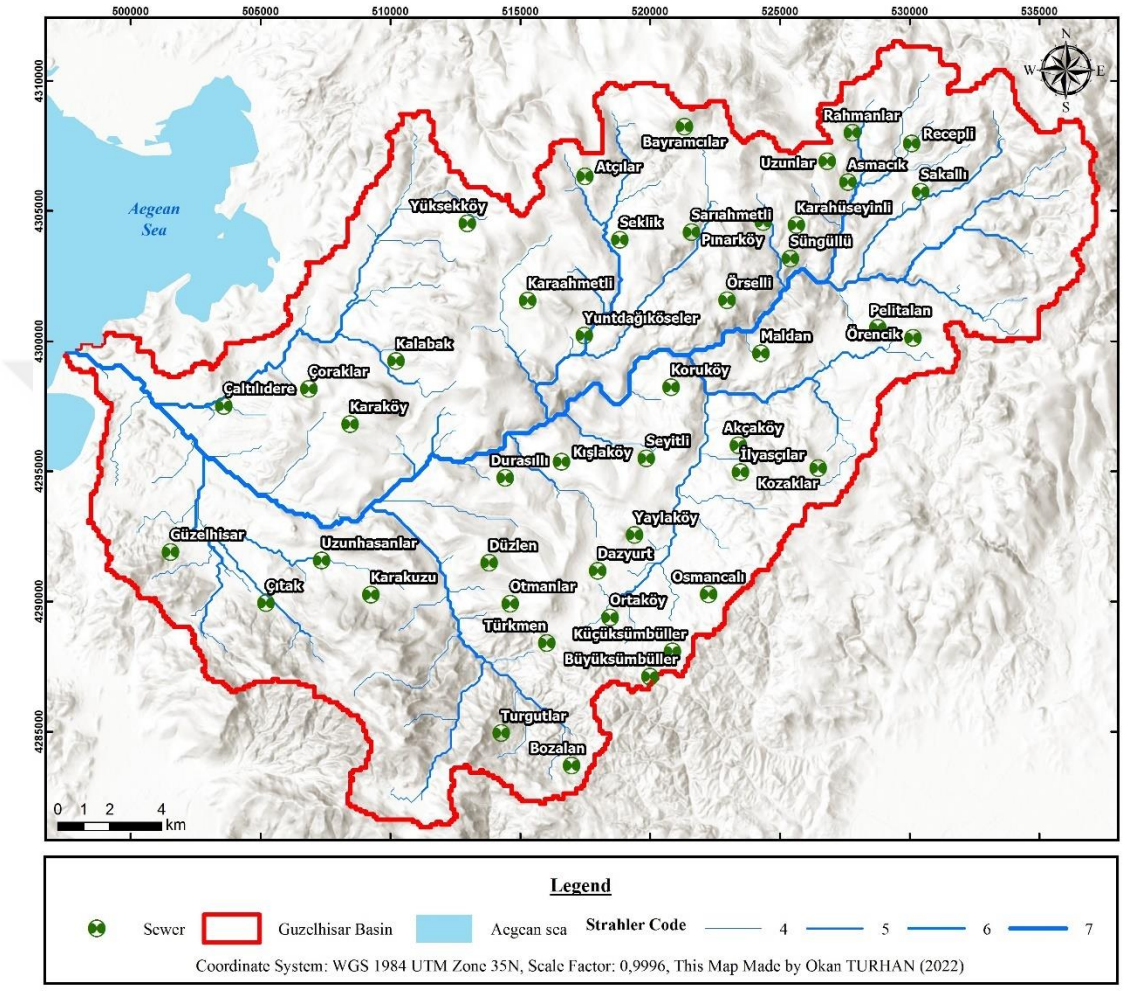


Figure 3.32 Septic tanks of Güzelhisar basin

The population technique was used to compute the pollutant load estimates of septic tanks. Table 3.10 contains these calculations.

Table 3.10 Septic tanks unit loads load calculation

Septic Tanks	Population	Unit Waste Water Flow (lt/person/day)	Unit TN Loads (gr/person/day)	Unit TP Loads (gr/person/day)	Unit COD Loads (gr/person/day)	Unit SS Loads (gr/person/day)
Turgutlar	43	105	5	0.9	55	35
Türkmen	158	105	5	0.9	55	35
Durasıllı	238	105	5	0.9	55	35
Düzlen	443	105	5	0.9	55	35
Kışlaköy	120	105	5	0.9	55	35
Bozalan	298	105	5	0.9	55	35
Otmanlar	146	105	5	0.9	55	35
Seyitli	597	105	5	0.9	55	35
Süngüllü	220	105	5	0.9	55	35
Uzunlar	179	105	5	0.9	55	35
Yaylaköy	166	105	5	0.9	55	35
Yuntdağıköseler	242	105	5	0.9	55	35
Örselli	212	105	5	0.9	55	35
İlyasçılar	130	105	5	0.9	55	35
Pelitalan	1,057	105	5	0.9	55	35
Örencik	447	105	5	0.9	55	35
Rahmanlar	118	105	5	0.9	55	35
Seklik	323	105	5	0.9	55	35
Akçaköy	199	105	5	0.9	55	35
Asmacık	245	105	5	0.9	55	35
Büyüksümbüller	61	105	5	0.9	55	35
Dazyurt	282	105	5	0.9	55	35
Karaahmetli	153	105	5	0.9	55	35
Karahüseyinli	30	105	5	0.9	55	35
Koruköy	126	105	5	0.9	55	35
Kozaklar	61	105	5	0.9	55	35
Küçüksümbüller	69	105	5	0.9	55	35
Maldan	785	105	5	0.9	55	35
Ortaköy	193	105	5	0.9	55	35
Osmancalı	435	105	5	0.9	55	35
Pınarköy	148	105	5	0.9	55	35
Recepli	474	105	5	0.9	55	35
Sakallı	190	105	5	0.9	55	35
Sarıahmetli	173	105	5	0.9	55	35
Atçılar	76	105	5	0.9	55	35
Bayramcılar	186	105	5	0.9	55	35
Kalabak	413	105	5	0.9	55	35
Çoraklar	50	105	5	0.9	55	35
Çaltılıdere	661	105	5	0.9	55	35
Karaköy	205	105	5	0.9	55	35
Güzelhisar	959	105	5	0.9	55	35
Uzunhasanlar	271	105	5	0.9	55	35
Çıtak	538	105	5	0.9	55	35
Karakuzu	609	105	5	0.9	55	35
Yüksekköy	152	105	5	0.9	55	35

Table 3.11 Septic tanks load calculation

Septic Tanks	Unit Waste Water Flow (lt/person/day)	Calculated TN Loads (ton/year)	Calculated TP Loads (ton/year)	Calculated COD Loads (ton/year)	Calculated SS Loads (ton/year)
Turgutlar	105	0.06	0.01	0.43	0.11
Türkmen	105	0.23	0.04	1.59	0.40
Durasıllı	105	0.35	0.05	2.39	0.61
Düzlen	105	0.65	0.10	4.45	1.13
Kışlaköy	105	0.18	0.03	1.20	0.31
Bozalan	105	0.44	0.07	2.99	0.76
Otmanlar	105	0.21	0.03	1.47	0.37
Seyitli	105	0.87	0.14	5.99	1.53
Süngüllü	105	0.32	0.05	2.21	0.56
Uzunlar	105	0.26	0.04	1.80	0.46
Yaylaköy	105	0.24	0.04	1.67	0.42
Yuntdağıköseler	105	0.35	0.06	2.43	0.62
Örselli	105	0.31	0.05	2.13	0.54
İlyasçılar	105	0.19	0.03	1.30	0.33
Pelitalan	105	1.54	0.24	10.61	2.70
Örencik	105	0.65	0.10	4.49	1.14
Rahmanlar	105	0.17	0.03	1.18	0.30
Seklik	105	0.47	0.07	3.24	0.83
Akçaköy	105	0.29	0.05	2.00	0.51
Asmacık	105	0.36	0.06	2.46	0.63
Büyüksümbüller	105	0.09	0.01	0.61	0.16
Dazyurt	105	0.41	0.06	2.83	0.72
Karaahmetli	105	0.22	0.04	1.54	0.39
Karahüseyinli	105	0.04	0.01	0.30	0.08
Koruköy	105	0.18	0.03	1.26	0.32
Kozaklar	105	0.09	0.01	0.61	0.16
Küçüksümbüller	105	0.10	0.02	0.69	0.18
Maldan	105	1.15	0.18	7.88	2.01
Ortaköy	105	0.28	0.04	1.94	0.49
Osmancalı	105	0.64	0.10	4.37	1.11
Pınarköy	105	0.22	0.03	1.49	0.38
Recepli	105	0.69	0.11	4.76	1.21
Sakallı	105	0.28	0.04	1.91	0.49
Sarıahmetli	105	0.25	0.04	1.74	0.44
Atçılar	105	0.11	0.02	0.76	0.19
Bayramcılar	105	0.27	0.04	1.87	0.48
Kalabak	105	0.60	0.09	4.15	1.06
Çoraklar	105	0.07	0.01	0.50	0.13
Çaltılıdere	105	0.97	0.15	6.63	1.69
Karaköy	105	0.30	0.05	2.06	0.52
Güzelhisar	105	1.40	0.22	9.63	2.45
Uzunhasanlar	105	0.40	0.06	2.72	0.69
Çıtak	105	0.79	0.12	5.40	1.37
Karakuzu	105	0.89	0.14	6.11	1.56
Yüksekköy	105	0.22	0.03	1.53	0.39

In a GIS context, the computed pollutant levels were allocated to septic tanks. Figure 3.33 depicts the "Flow Accumulation" study of the distribution of the sample septic tanks TN pollutant load in the basin. In addition to this map, pollutant raster data for TP, SS, and COD were generated.

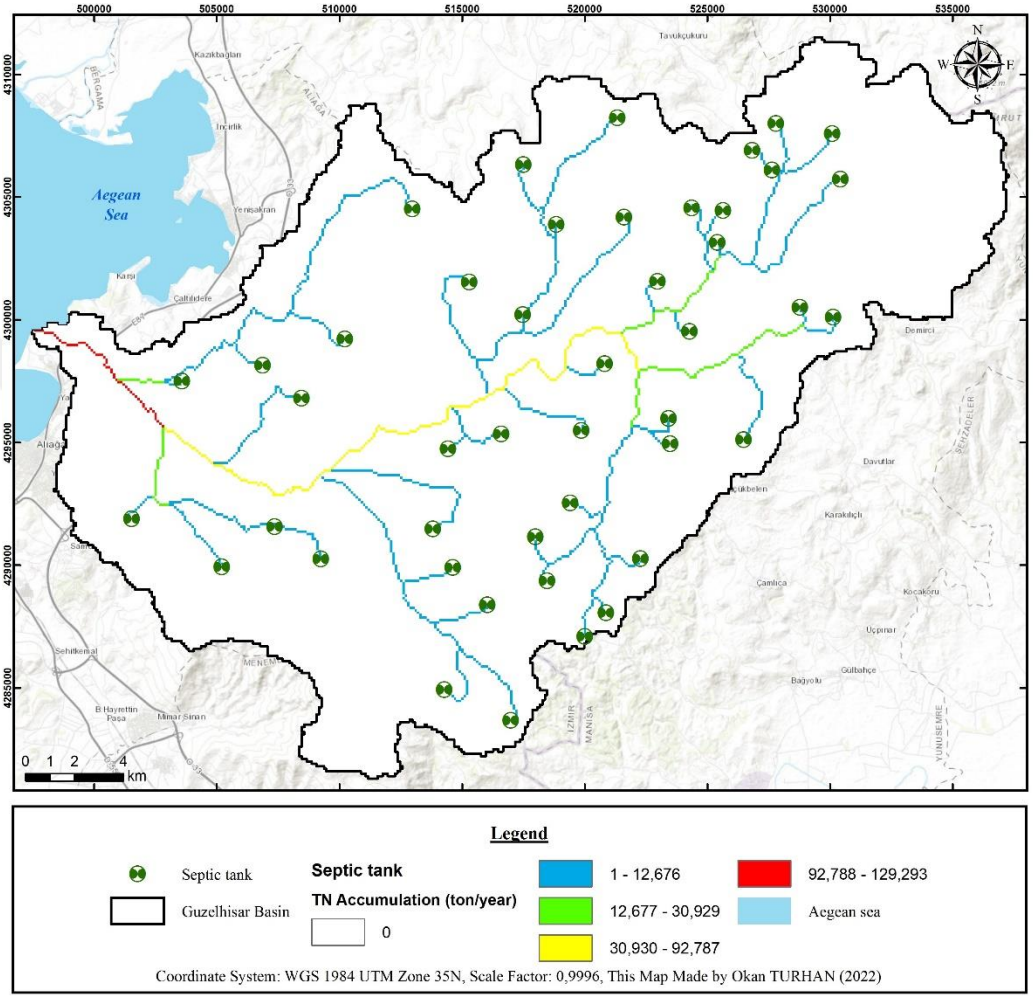


Figure 3.33 Septic tanks TN pollutions of Güzelhisar Basin

All of these phases are broken down into numerous tools that may be executed in a single command with the model builder, with the goal of providing quick integration to the field or data changes in the studies. Figure 3.34 depicts the cesspool model.

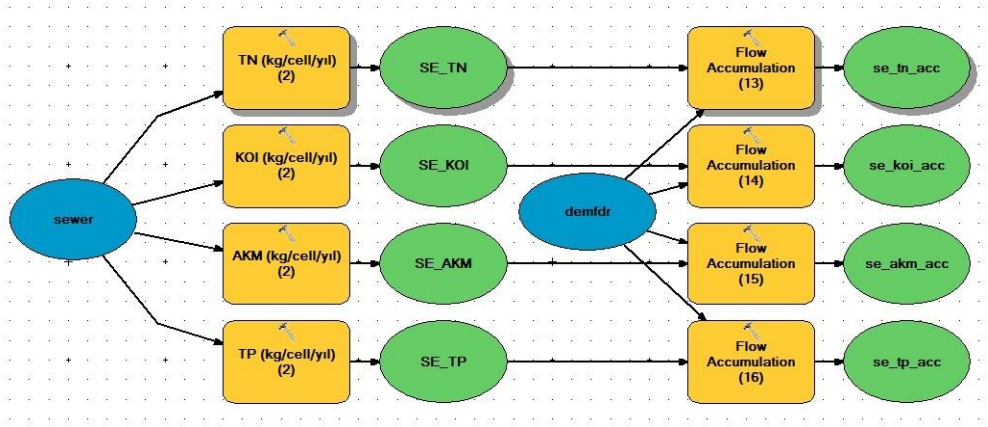


Figure 3.34 Model builder schema of septic tanks pollutions

3.5.5 Land Use Cover

The Güzelhisar basin has 19 different forms of land use (Copernicus, 2018). According to their kind, these places are expected to generate a given quantity of unit pollution. In land usage, it is believed that only TN and TP contamination occurs. Table 3.12 shows these unit loads.

The raster data produced in the research region has a pixel size of 100x100m. This demonstrates that each pixel on the land plane corresponds to a 1ha region. The areal load values were determined by multiplying the above-mentioned unit loads by the number of pixels in the land use pollutant raster data with each individual label. Figure 3.35 depicts the TN distribution map of the area coded 112 as an example of the distribution of these values. TN and TP load raster data for 19 distinct codes were created using the land use data.

Table 3.12 CORINE land use pollution loads (Copernicus, 2018)

Land Use Label 3	Main Load Class	Unit TN Loads (kg/ha/year)	Unit TP Loads (kg/ha/year)
111	Urban Area	3	0.5
112	Urban Area	3	0.5
121	Urban Area	3	0.5
124	Urban Area	3	0.5
131	Urban Area	3	0.5
132	Urban Area	3	0.5
133	Urban Area	3	0.5
141	Urban Area	3	0.5
142	Urban Area	3	0.5
231	Pasture and Grassland	5	0.1
243	Rural Area	9.5	0.9
311	Forest Area	2	0.05
312	Forest Area	2	0.05
313	Forest Area	2	0.05
321	Pasture and Grassland	5	0.1
323	Pasture and Grassland	5	0.1
324	Pasture and Grassland	5	0.1
331	Pasture and Grassland	5	0.1
333	Pasture and Grassland	5	0.1

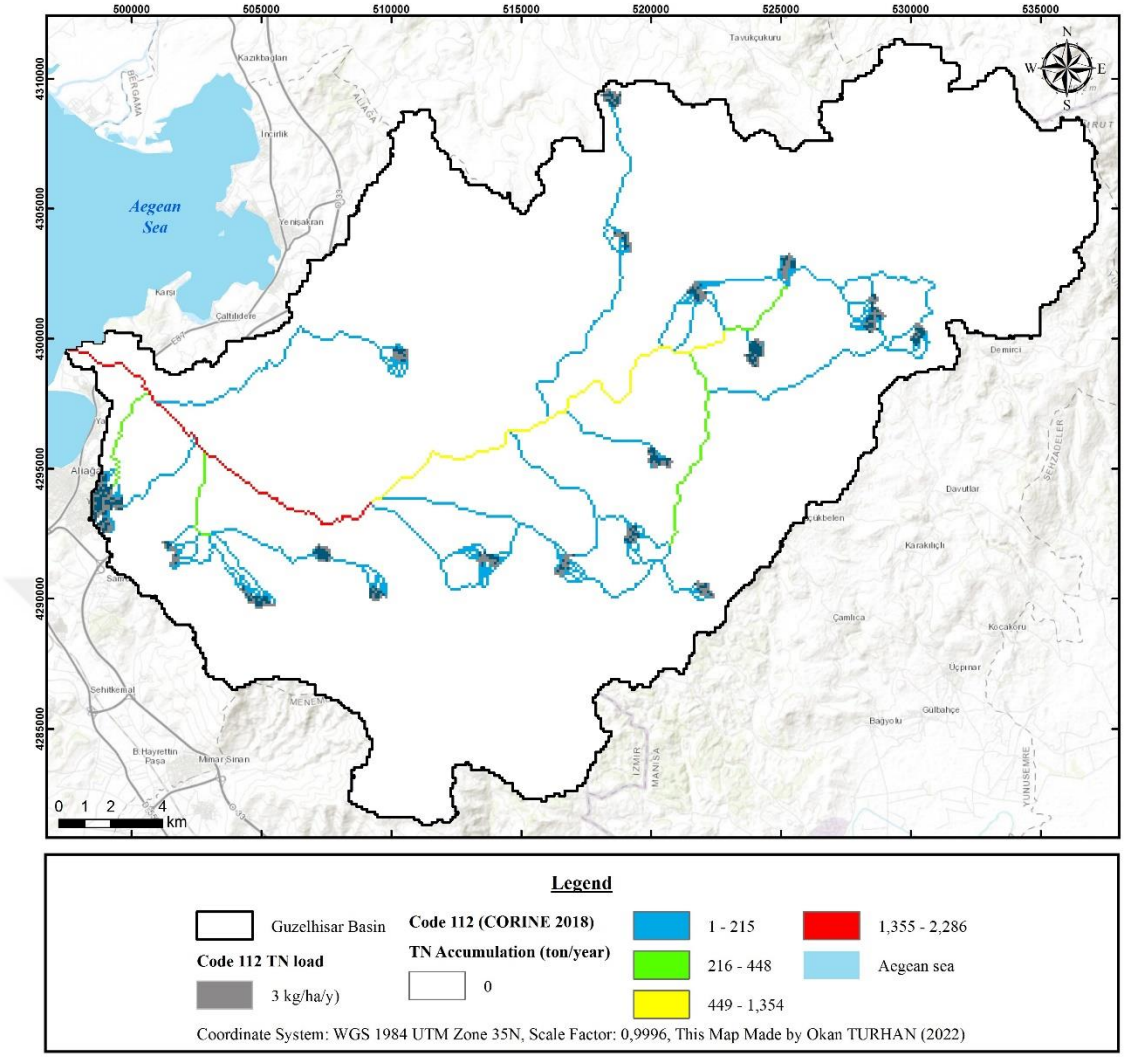


Figure 3.35 Example for land use 112 code TN pollutions of Güzelhisar basin

All of these phases are broken down into numerous tools that may be executed in a single command with the model builder, with the goal of providing quick integration to the field or data changes in the studies. Figure 3.37 depicts a land-use model.

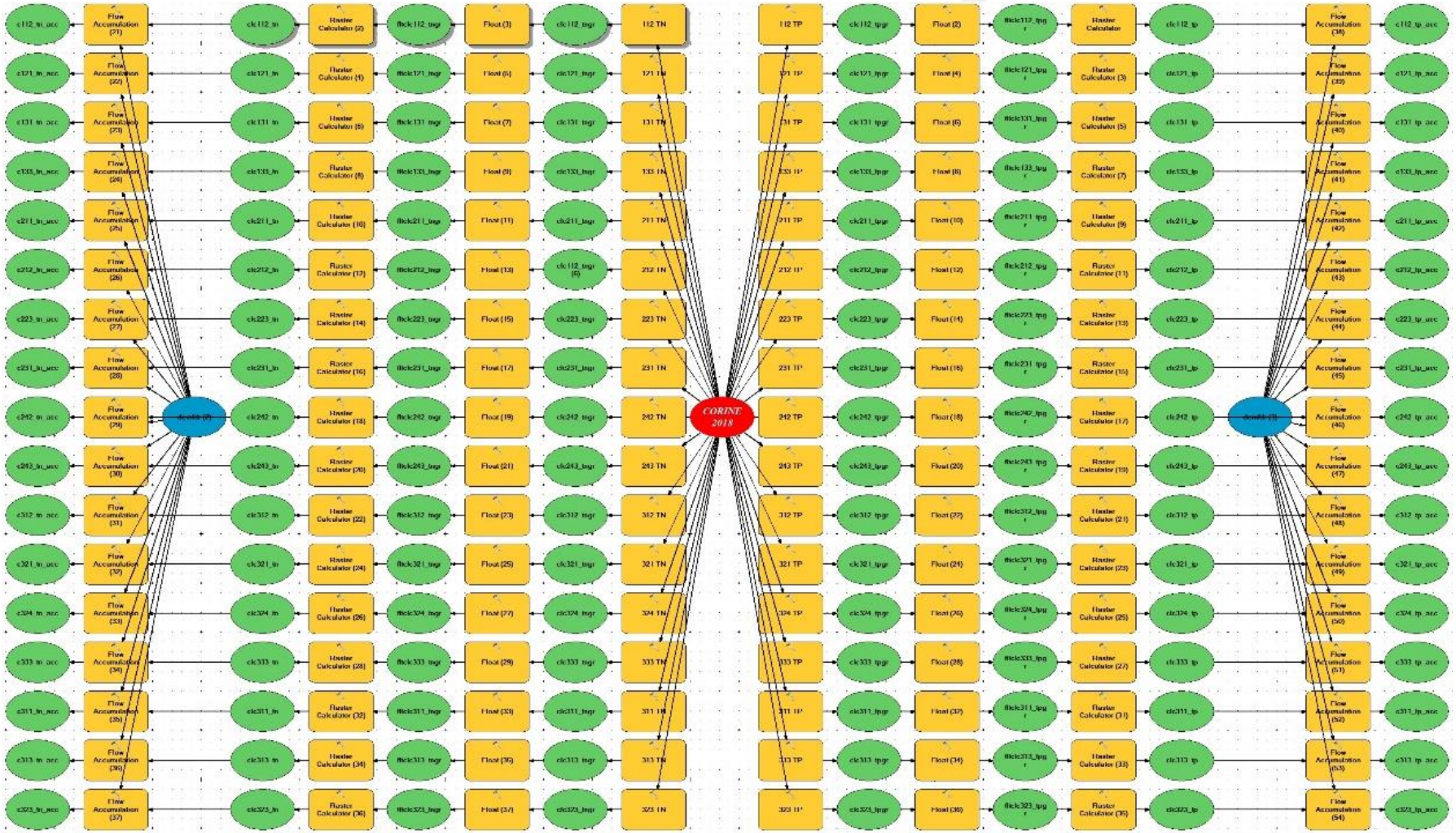


Figure 3.36 Model Builder Schema of Land Use Pollutions

Total land use load data was generated once all land use pollution load data was generated. The entire TN and TP load data was derived by adding all layers individually using a "raster calculator." An example land use is shown, along with the total TN and TP load levels and distribution.

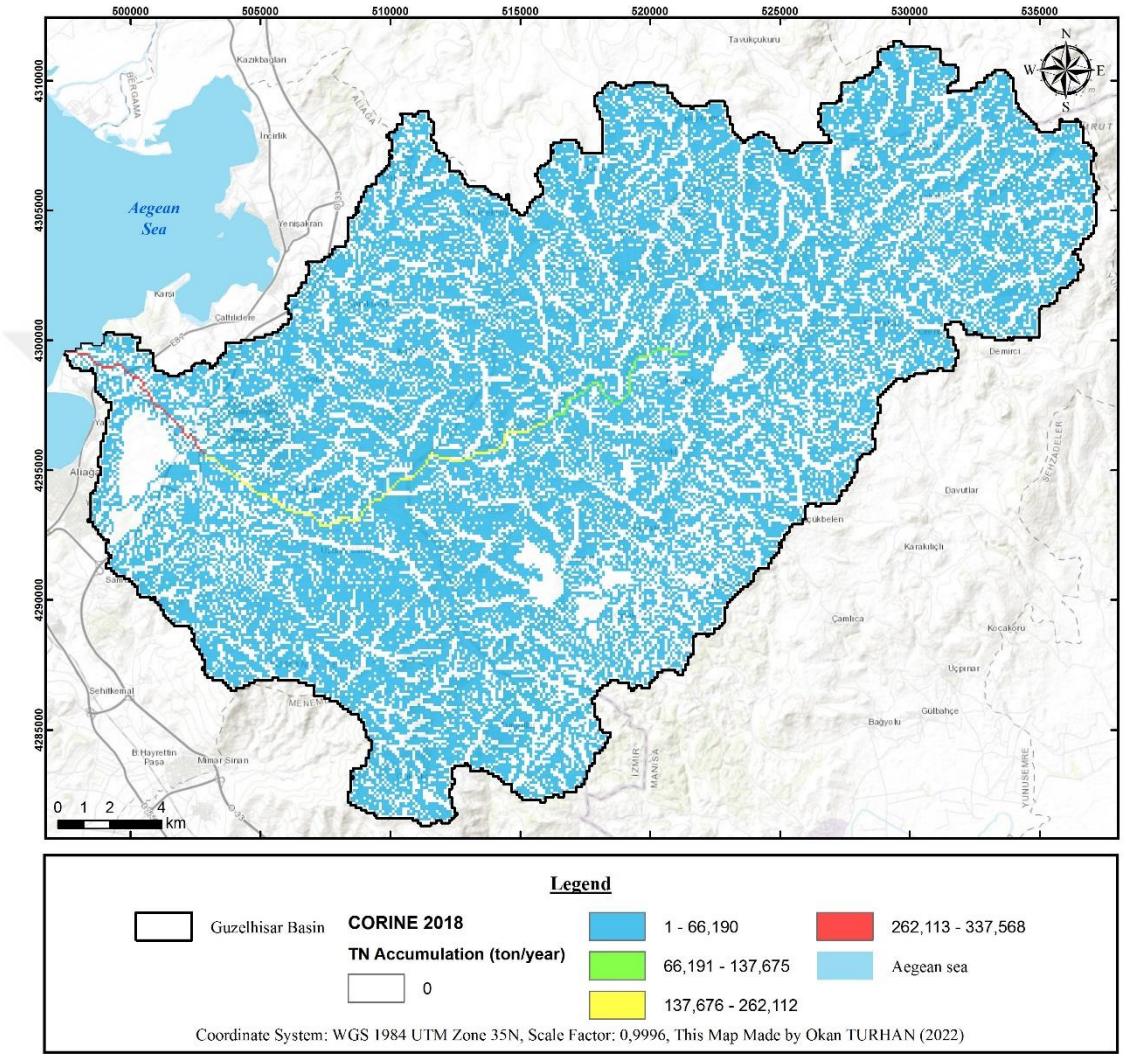


Figure 3.37 Land Use Cover Total TN pollution of Güzelhisar Basin

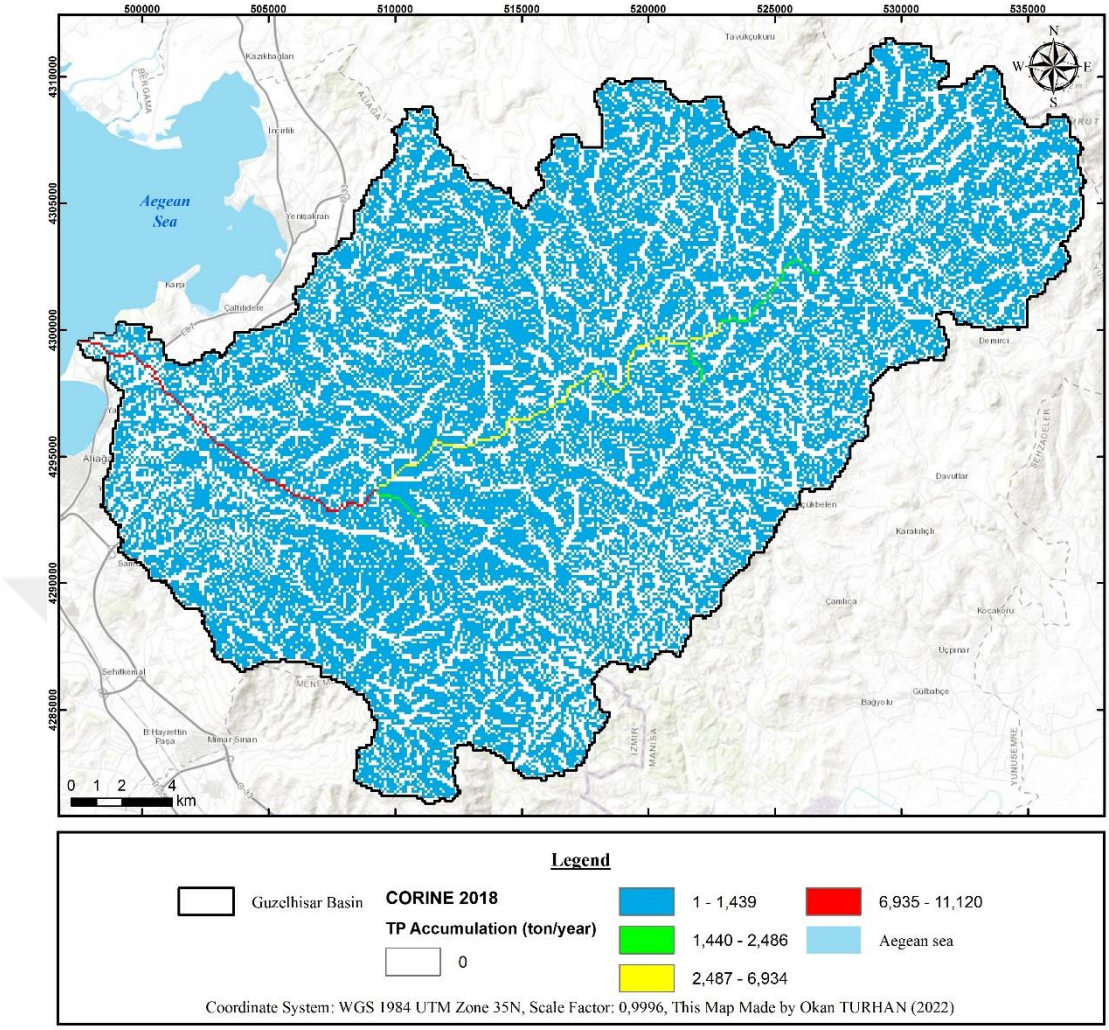


Figure 3.38 Land Use Cover Total TP pollution of Güzelhisar Basin

CHAPTER FOUR
RESULTS

4.1 Distribution of Total Loads Over the Güzelhisar Basin

The totals of TN, TP, SS, and COD pollution parameters in Güzelhisar Basin were mapped based on point and diffuse pollutant sources (Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4).

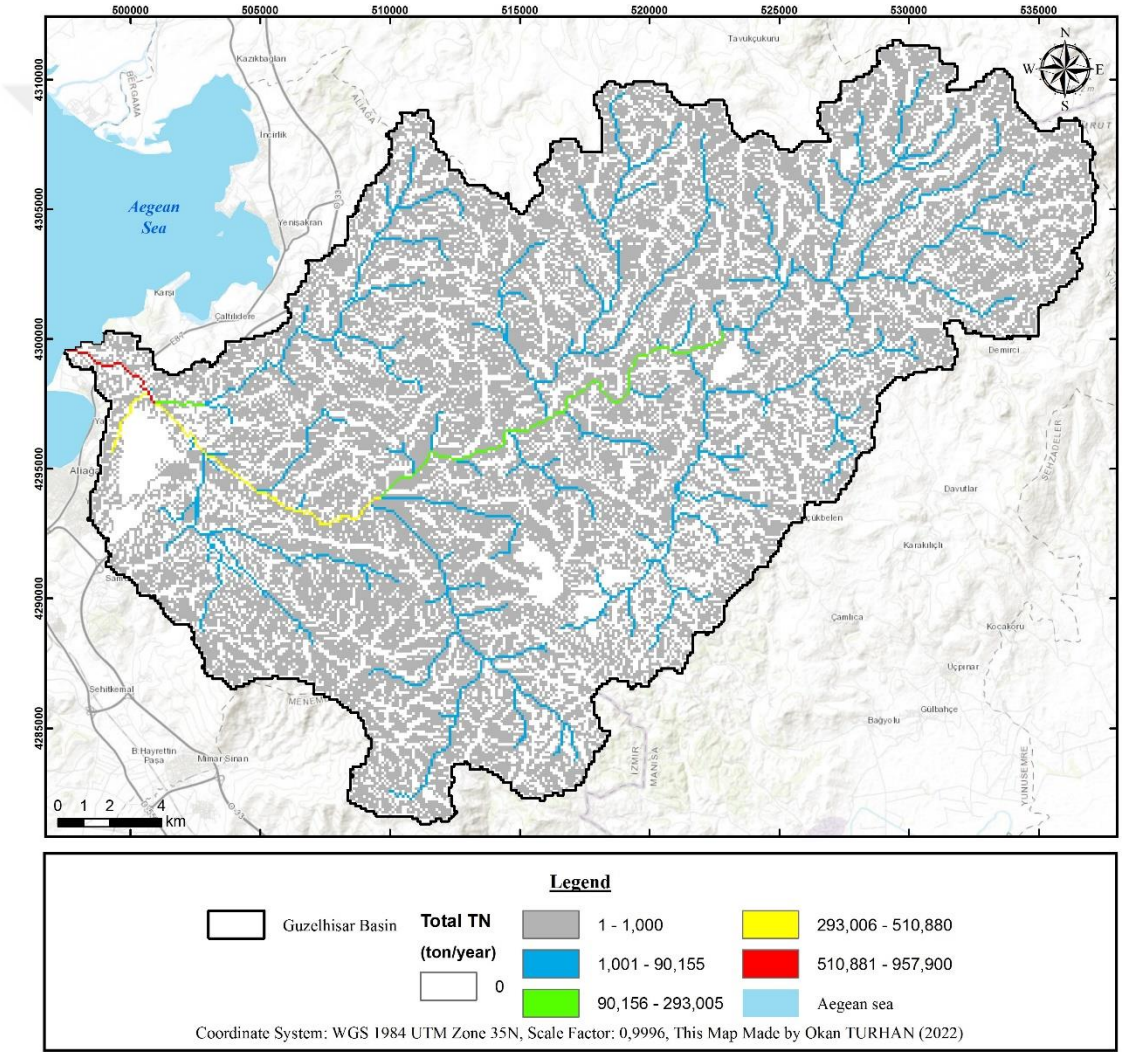


Figure 4.1 Total TN pollution of Güzelhisar Basin

It has been discovered that land use and structured industrial zones are the primary causes of TN burdens in the Güzelhisar sub-basin. The Güzelhisar sub-basin, classified

KEN_034, has the highest level of TN contamination since its rivers are nearest to the sea. This is because the structured industrial zone is located in this sub-basin. Furthermore, because the population density in this location is considerable, the TN load from the municipal wastewater treatment facility is also substantial. Urban direct discharges from the densely populated Bahçedere settlement in the basin's north enhance TN contamination in the Güzelhisar sub-basin labeled KEN_034. Urban direct discharges in the Karadere River sub-basin KEN_033 are also among the variables that raise the TN pollution load on the basin's water resources.

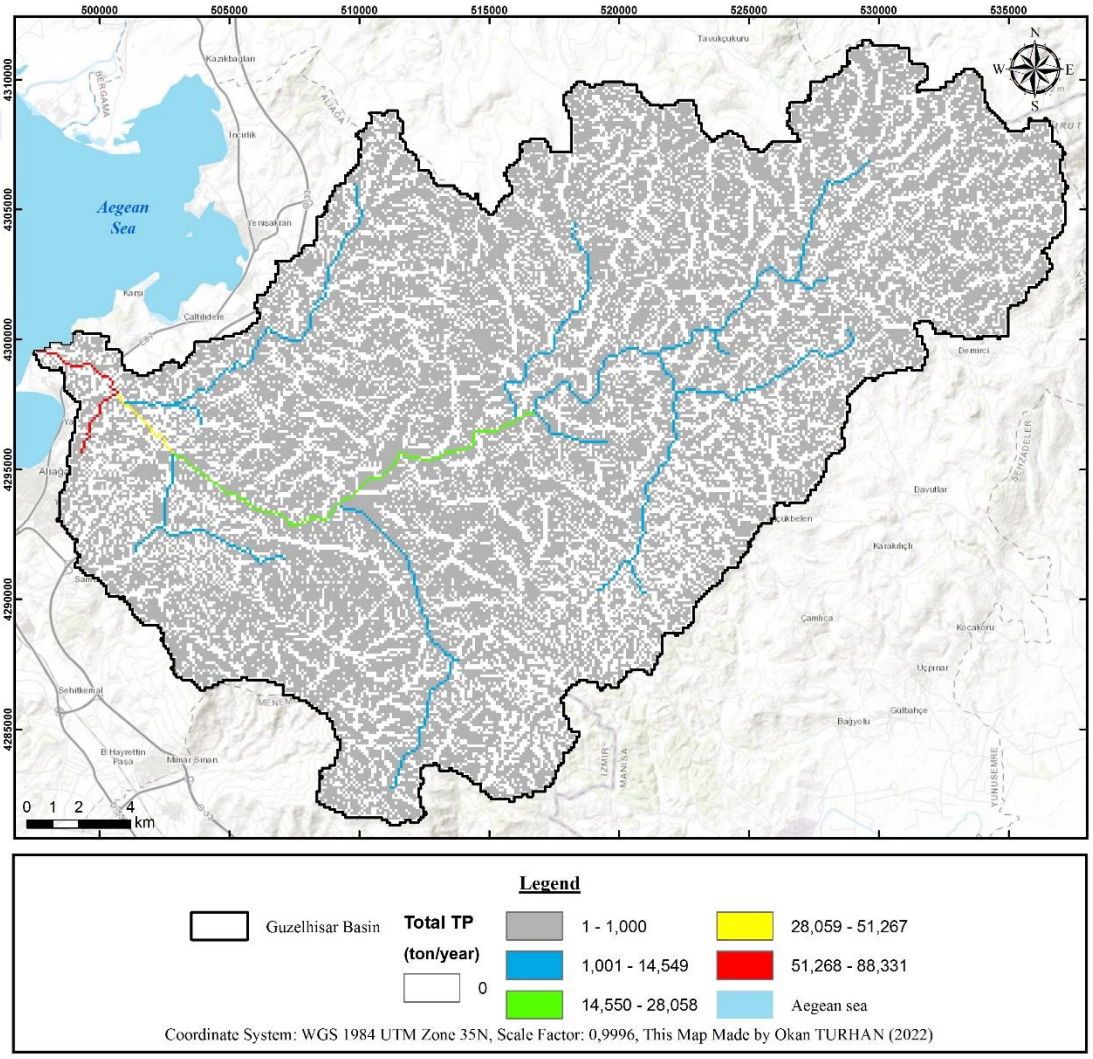


Figure 4.2 Total TP pollution of Güzelhisar Basin

When the TP load, another pollution element, is analyzed, it is discovered that the primary pollutant source is the municipal wastewater treatment facility, which is

located near the outflow to the sea. The organized industrial site zone in this region, as stated in the pollutant sources in the TN load, plays an essential role in growing TP pollution in water resources.

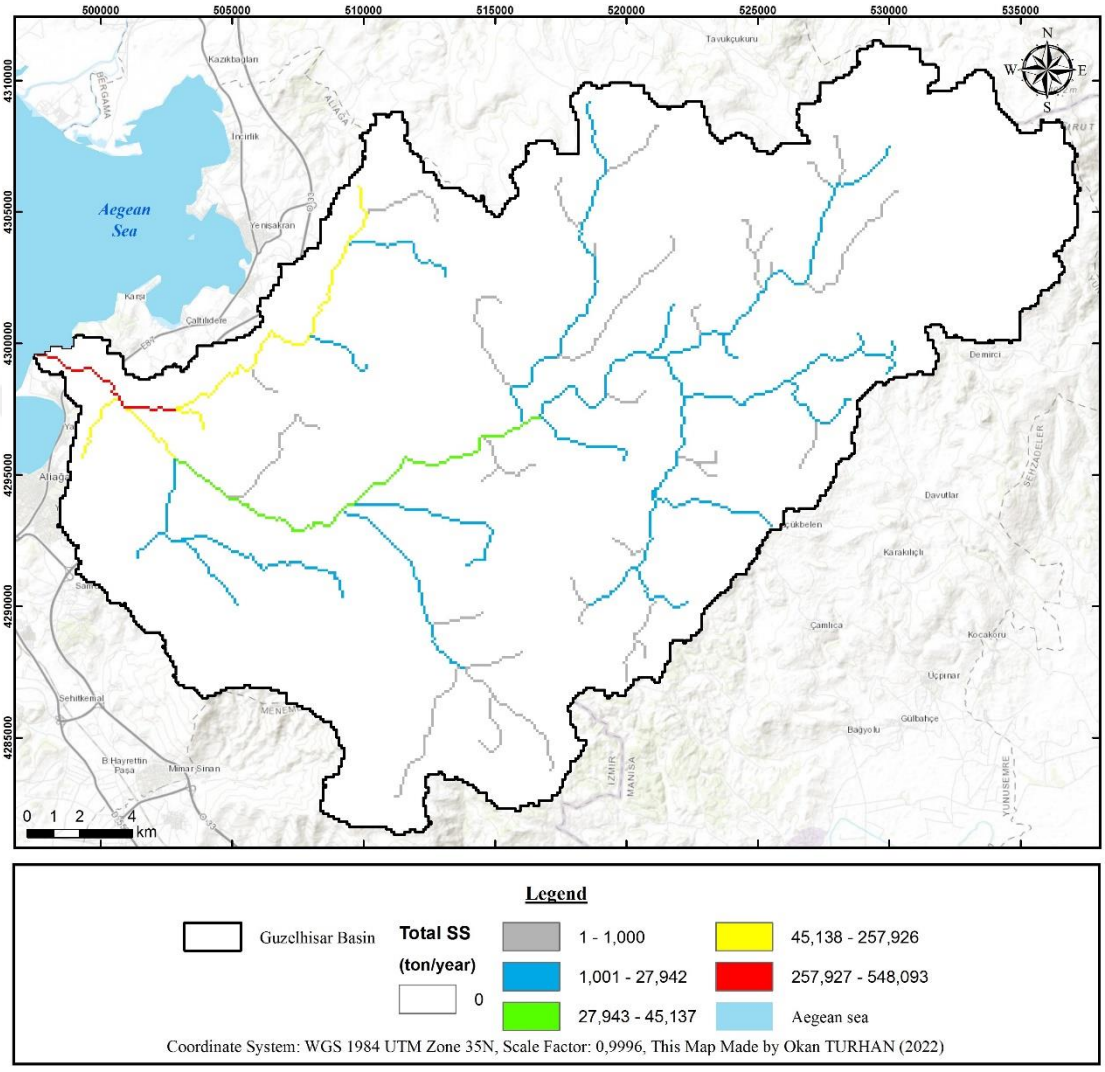


Figure 4.3 Total SS pollution of Güzelhisar Basin

It was assumed that there was no land use pollution for SS and COD parameters, and that these pollutant parameters were mostly consisted of urban and industrial pollutant sources.

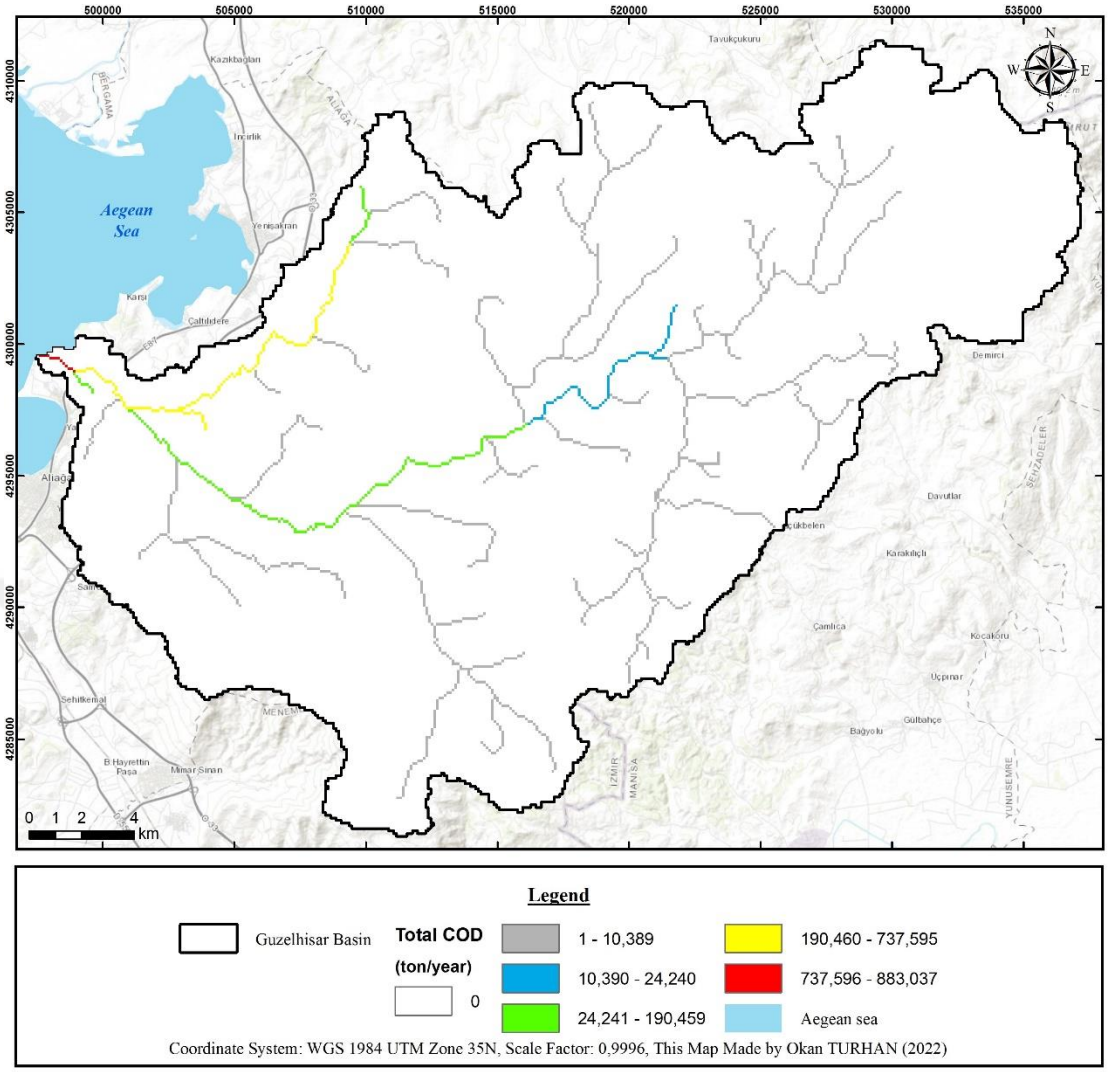


Figure 4.4 Total COD pollution of Güzelhisar Basin

CHAPTER FIVE
CONCLUSION

The goal of this master's thesis, "Assessment of pollution loads by using GIS-based mass balance approaches," was to expose the pollution loads in the Güzelhisar Basin using GIS methods.

The study's scope included determining point and diffuse pollution loads in Güzelhisar Basin, the southernmost of the North Aegean Basin's 19 river tributaries draining into the Aegean Sea. These pollutant loads yielded TN (Total Nitrogen), TP (Total Phosphorus), COD (Chemical Oxygen Demand), and SS (Suspended Solids) data, which were geographically assembled. In order to study the migration of contaminants in the river environment, natural flow and wastewater flow data were spatially gathered. All data was translated into a format that could be studied in a GIS context, with the goal of making research on taking measures in geographically crucial regions easier.

The studies undertaken in the Güzelhisar basin in the literature, as well as pollution analyses completed using GIS methodologies, were investigated.

Pollutant sources unique to the study region were discovered. Pollutant sources are classed as either point or diffuse. Urban wastewater treatment plants, urban direct discharges, cesspools, industrial wastewater treatment plants, structured industrial zones, and individual industrial facilities are examples of point pollutant sources. CORINE land use data (Copernicus, 2018), agricultural regions, mining sites, and solid waste dumps are all sources of diffuse pollution.

After the data compilation, all data were uploaded to the GIS environment. Analyses to be performed on these data were determined, and an analytic strategy was developed. Pollution maps for the basin were created using these approaches.

GIS-based pollution-weighted raster accumulation analysis (Pollution-Weighted Flow Accumulation) was utilized in this work to identify pollutant levels as well as the location of pollutants and pollution pathways.

Pollution-Weighted Flow Accumulation (Pollution-Weighted Flow Accumulation) was utilized to construct a pollutant-specific technique for each pollution source, with unit load assumptions. All polluting sources were independently mapped, and pollution load raster data was created for usage in various situations. This raster data was created with a pixel size of 100x100 m, representing an area of 1 hectare in detail.

For all contaminants, Pollution-Weighted analysis was used. The values of this raster data at the locations where water samples were collected were evaluated and compared. Furthermore, the areal total loads in the model studies in the North Aegean Basin River Basin Management Plan Project were compared to the values in the remaining parts of the raster data in that region. However, owing to the differing assumptions used, this comparison could not be established.

All of the assessments were conducted while ignoring the Güzelhisar dam reservoir region. When the entire river network is fluid, the pollutant distribution may be predicted to be as indicated in the analysis. Furthermore, this location-based analysis approach may be enhanced by devising a methodology for stationary water bodies and dry streams.

By adding soil and geology data in the analysis, it is possible to demonstrate that certain pollution spillovers penetrate groundwater.

As a consequence of the investigation, it is clear that acquiring data based on measurements is critical in terms of data supply, which serves as the study's foundation. It is demonstrated, particularly by measuring the volume of urban and industrial wastewater, that analysis may be performed using an actual data set rather than estimate methodologies. Pollution dispersal in these places can be disclosed more precisely by establishing measuring methods connected to geographical pollutant sources.

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