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Analysis of drinking water infrastructure systems with GIS

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Abstract

The aim of this study is to make heat maps in order to determine the pipeline fault areas with the geographical information system by using the location and detail information of the drinking water pipeline faults repaired by the Mersin Water and Sewerage Administration. The study area is covering Akdeniz, Mezitli, Toroslar and Yenişehir, where are the four central districts of Mersin. The coordinates of pipeline fault points were collected by GNSS. The points were analyzed with heatmap. Preventing future pipeline faults on these areas is very important. The study is going to help to prepare the advanced investment plans of the institution that invests in drinking water, and to ensure that the public institution uses these investments correctly and appropriately.

1. Introduction

80 countries with 40% of the world's population are already suffering from water shortages. The rapid increase in the population, on the other hand, the fact that the known water resources are stable, the water resources are not filled enough because the rain and snow are less. Water resources are also decreasing and the need for water is increasing day by day. 98% of this water is in the oceans and inland seas, but because it is salty, it is not suitable for use as drinking water, irrigation and industrial use. Only 2.5% of the world's water is fresh water. 87% of this is found in glaciers, soil, atmosphere, groundwater and is unusable [1-3].

Drinking water and sanitation services, which are considered as a public service throughout the world, are evolving in a direction that includes private sector participation, especially with the 1990s. The public aspect of water services ignoring the profit motive and the private sector starting to provide water services, water will become a commodity that can only be consumed by those who can pay the price. There are a number of efforts against this trend. The most recent of these efforts is the recognition of water as a human right by the United Nations Committee on Economic, Social and Cultural Rights in its General Comment No. 15 in 2002. This right, which has been expressed at international conferences in previous years, aims to guarantee that every person has access to a certain amount of water. However, the right to water, which is not included in an international treaty to be binding in terms of international law, is developing as a fragile concept of international law. This study examines the content and scope of the right to water, as well as the obstacles to the realization of this right [4].

"Turkey's Water Potential The average annual precipitation in our country is 643 mm, which corresponds to an average of 501 billion m³ of water. 274 billion m³ of precipitation returns to the atmosphere through evaporation from tea, rivers, lakes and seas and plants. 158 billion m³ of the water falling to the soil with precipitation is carried to the sea or lakes by many large and small rivers. The remaining 69 billion m³ constitutes 108 groundwater. 28 billion m³ of the underground water formed is re-joined into the surface waters in the form of spring water (springs). In

addition, an average of 7 billion m³ of water annually comes to our country from neighbouring countries with rivers such as Meriç and Asi. The gross water potential of our country (158+28+7=193) consists of 158 billion m³ of surface waters formed by precipitation and 28 billion m³ of water that reaches the surface again as spring water from underground waters, and 7 billion m³ of waters coming from neighbouring countries by rivers. When the 41 billion m³ (69-28=41) water that goes underground and joins the groundwater is added, the renewable gross water potential of our country reaches 234 billion m³ (193+41)" [5].

Infrastructure information systems, which are one of the components of Urban Information Systems, and their usage areas increases day-by-day. The usage of infrastructure information systems in a small-scale settlement is included. Atabey district of Isparta province was chosen as the study area. For this purpose, maps (Plans, data) of the drinking water network system, which is one of the infrastructure network systems of Atabey district, were obtained and these were digitized through the ArcView 9.0 Geographical Information System program [6].

In literature, there are many studies on the topics such as water management, water resources, drinking water, etc. In addition, traceability and sustainability of the system, pressure management, hydraulic behaviour of drinking water lines, and leak-leak detection is analysed with hydraulic modelling [7]. Hydraulic Modelling was performed with drinking water network using online monitoring (SCADA) in Antalya [8]. It was improved a decision support system, which optimizes the maintenance of water distribution network problem by differential evolution algorithm [9]. The use of Technical Performance Indexes was explored with the pressure-driven simulation model [10]. A multiobjective model was applied for water quality and trading-off pumping cost for operation of water distribution systems [11].

Research subject; the aim is to locate the existing the pipeline faults in the field with GNSS devices and to establish the relationship between the pipeline faults and which streets and to determine the infrastructure needs of the dense regions with GIS applications.

Mersin Water and Sewerage Administration reported the drinking water malfunctions occurring in the field in 2017 and 2020 by the repair teams formed within its body, and each the pipeline fault was taken from the field by GNSS measuring devices by the mapping unit within the institution.

A total of 1800 the pipeline fault points were taken from the streets and avenues for four districts of Mersin, and all of them were stored in Netcad.

2. Material and Method

2.1. The Study Area: Mersin Central Districts

Mersin province consists of 13 districts and the highest population is found in Akdeniz, Mezitli, Toroslar, and Yenişehir districts. The drinking water need of the population living in these districts is provided from the Berdan Dam located in Tarsus. Drinking water coming from the Berdan dam to Mersin with the pumping stations reaches the warehouses with the existing infrastructure systems and then to the households with the help of network lines. Mersin Water and Sewerage Administration (MESKI) is responsible for maintaining this system and providing the necessary drinking water and sewerage services. While doing this, it is necessary to eliminate the pipeline faults that occur in the existing network line and make an investment.

As the study area, Akdeniz, Toroslar, Yenişehir and Mezitli central districts of Mersin province with the highest population were selected. It is showed the pipeline fault points of drinking water in the study area (Figure 1).

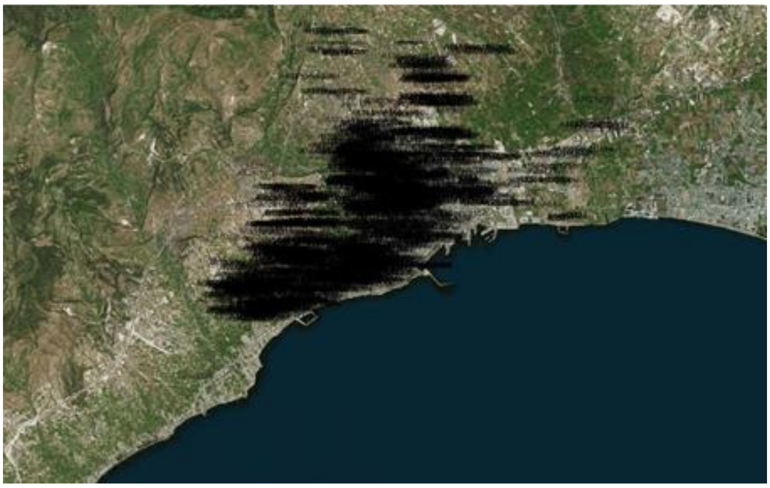

Figure 1. The points in the study area

These 1800 pipeline fault points selected in total correspond to the roads with a sensitivity of less than 1 meter horizontally and generally located in the city and specified in the zoning plans. All of the pipeline faults were physically collected from the field by GNSS device. The images of some pipeline fault were presented (Figure 2).

Figure 2. General situation of the pipeline faults

2.2. Mersin Central District Analysis with Heatmap Method

The points are stored on the Netcad program and it was chosen for the related database setup structure. The database was chosen as Microsoft Access database. The most important data to ensure relevant analysis is to determine the areas surrounding the points. These areas are district borders, neighborhood borders, roads and the pipeline fault points should know each other.

Heatmaps are a popular graphical way to summarize data, observe relationships among several statistical variables (the columns in a heatmap), and organize the observations from numerous participants (the rows in a heatmap) – all in one single graph. Heatmaps and related graphs can be defined the 19th century [12-13]. The underlying idea for heatmaps is that the data are split into different intervals that are assigned to a color.

3. Application

3.1. Editing the Database

First of all, the database was established with the Netcad Program, and then the database was transferred to ArcGIS in order to make the necessary examinations, and heat maps were produced.

Objects to the database were created by transferring CAD data to tables. Coordinate system of CAD data is determined as WGS84 (EPSG:4326) so that it can be easily understood in programs such as ArcGIS or QGIS and necessary coordinate transformations are made. The data of the Existing Roads has been downloaded from the Open-Source Map (OSM) [14] as SHP file for whole Turkey. Objects to the database were created by transferring CAD data to tables. Coordinate system of CAD data was determined as WGS84 (EPSG:4326) so that it can be easily understood in programs such as ArcGIS or QGIS, and necessary coordinate transformations were made. District boundaries and district boundaries of districts were selected as CAD data from 1/1000 application development plans, and then necessary coordinate transformations were made. Objects to the database were created by transferring CAD data to tables (Figure 3).

3.2. Editing Geographical Data

The roads converted to CAD were first cut according to the District Boundaries, then again using the same district borders, the table's named roads were filled in the database by using the "get information from the area inside" command in the OVERLAY operation under the Tools Menu of NetCAD.

Since all points of Mersin Water and Sewerage Administration for the years 2017 - 2020 are purchased in the NetCAD environment, you can enter the table in the Pipeline Fault Points database, where the main analysis will be made in the District Neighborhood and Roads, under the Tools Menu of NetCAD, in the process named OVERLAY, with the help of the "get information from the area inside" command. Then, the District - Neighborhood table was filled with the help of the database manager and the relationship 1-N relationship. The relation with the roads is provided with the BUMPER Command under the Tools Menu of Netcad.

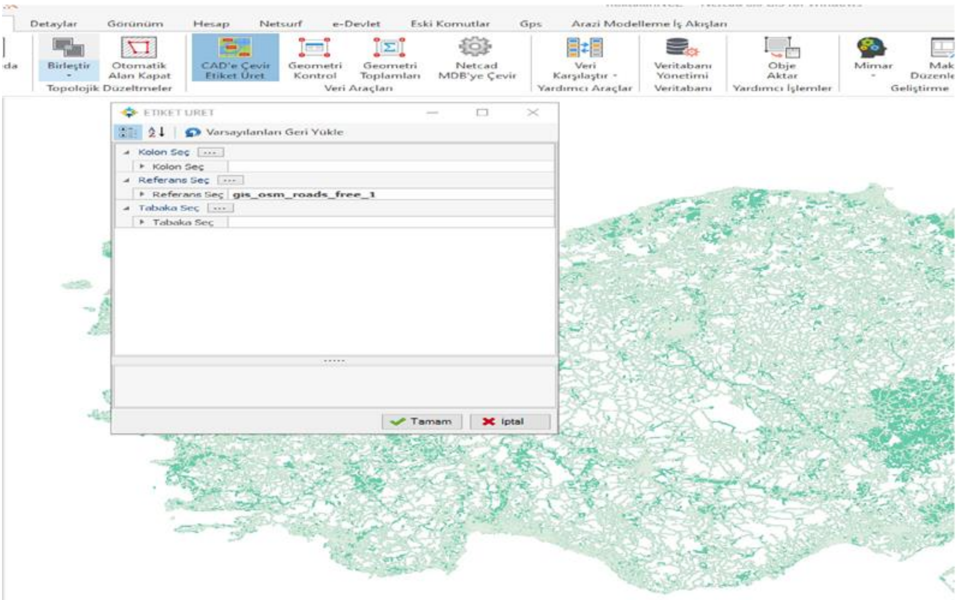

Figure 3. Transfer of Turkey OSM Roadmap

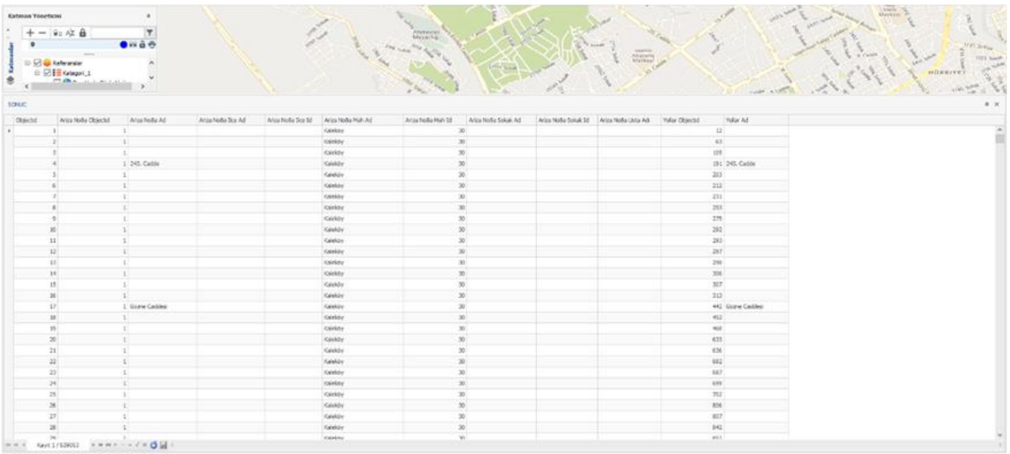

Figure 4. The points attributes in database

In following, the titles of the points attributes in database were gives. These were regulated together with their data in Figure 4.

- Number
- Date
- ULAKBEL No (MESKI the Pipeline Fault Code)
- Depth
- Pipe Diameter
- Pipe Type
- Repairman Name
- Location

3.3. Heatmap Analysis

Although Netcad includes database and GIS parts, NETIGMA module is needed for certain analyses. Analyses such as heat map (HEATMAP) are made. In Netcad Tables, simple queries such as filtering the pipeline fault points on Akbelen Blv or fetch the pipeline faults in Yenişehir District are made only with the current filter method. In order to make use of the Heat Map to understand in which regions the pipeline faults are concentrated, the pipeline fault points were converted to SHP files with the help of Netcad and a heat map was created with the help of ArcGIS.

The SHP file is opened with ArcMap and added as data to the Layers section. In order to make the map understandable, the Basemap will be added to determine the regions. A heatmap will also be created with the help of spatial analyst tool – density – point density (Figure 5).

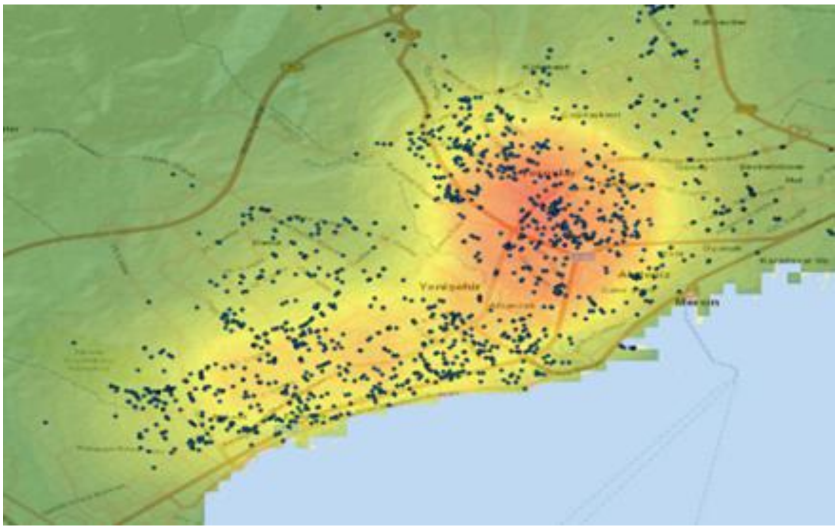

Figure 5. The pipeline faults heat map in Mersin

As can be seen in the heat map, it is seen that most of the pipeline faults are concentrated in Akdeniz and Toroslar districts, which are the former settlements of Mersin.

4. Conclusion

According to the results of the heat map, millions of m^3 of water is wasted in these periods when water shortages are at the door. Infrastructures, especially Osmaniye and Çavuşlu Districts of Toroslar District It turns out that drinking water renewal processes should be carried out in the İhsaniye and Nusratiye neighbourhoods of the Akdeniz District. During the collection phase of water breakdown points;

- Continuity of protection and operation by the public
- Effective use of drinking water facilities focused on citizen service
- Ensuring that repair tenders are made to the most troubled areas of the city.

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Author contributions

Hasan Galip Yeşil: Investigation, Methodology, Editing, Application**, Fatma Bünyan Ünel:** Conceptualization, Reviewed and Edited.

Conflicts of interest

The authors declare no conflicts of interest.

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