DETERMINING HYDROLOGICAL CHARACTERISTICS OF A STREAM BY USING GIS METHODS

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Abstract- To protect river basins, it is necessary to know about the river and the basin. Geographical Information System (GIS) software are used to determine river basin parameters. In the study; hydrological properties of Malatya-Derme sub-basin were investigated. Derme sub-basin has contains drinking water for Malatya province, irrigation projects and hydroelectric power plants. ArcGIS software was used in the study. Hydrological properties of Derme sub-basin were determined and commented.

Keywords- Derme sub-basin, ArcGIS, Hydrological characteristics, Basin shape.

I. INTRODUCTION

Freshwater resources consist 2.7% of global water resources. Only 1% of the freshwater is in streams and lakes. Freshwater are one of the vital resources that sustain all organisms, primarily the human life. Thus, it is of utmost importance not to pollute and waste freshwater resources (Ermis 2014).

Provision of quality water is indispensable in increasing the quality of life and prevention of diseases (Oluduro and Adewoye 2007). Natural waters could contain different pollutions of different quality and quality based on the source (Drever 1988). Prevention of streams and their basins and leaving a clean and habitable environment for future generations is a social responsibility. To protect river basins, it is necessary to know about the river and the basin. Thus, meteorological, hydrological, geological and environmental characteristics of the basin should be determined and possible pollutants should be established.

Prevention of flood damage is also important up to protect streams. To determine the overflow potential of streams, initially the hydrological characteristics of the basin should be identified. Today, Geographical Information System (GIS) software are used to determine river basin parameters. Bağdatlı and Öztürk (2014) determined basin characteristics of Çorlu stream basin using GIS software and constructed the digital elevation model for that basin. Rahmati et al. (2016) compared the analytical hierarchical calculations for Iran-Yasooj river region and the results of the hydraulic model they developed with the help of GIS software. Seenath et al. (2016) compared the hydrodynamic model and GIS software to determine the increases in sea level due to the effects of climate change. Youssef et al. (2016) researched the reasons of the floods that occurred in Jeddah, Saudi Arabia in 2009 and 2011 using a GIS model. Vizireanu et al. (2016) determined that the infrastructure was damaged and epidemics were observed due to the Danube floods. They have designed flood risk plans with the help of a GIS model.

Drinking and utility water needs for Malatya province in Turkey is brought from Pınarbaşı karst source located on the left cost of Derme stream 20 km south of the urban center. Derme stream is utilized for drinking and in energy projects at the source and for irrigation at the downstream. During irrigations season, Derme stream is fed by Çat reservoir located at the neighboring basin and the stream passes through settled areas to reach irrigation land at the downstream. Protection of Derme stream and basin which are vital for Malatya province and identification of flood risks are significant for the province. Thus, it is necessary to determine hydrological characteristics of the basin. The objective of the present study is to determine certain hydrological parameters for Derme stream, located within the Malatya province drinking water resource, using GIS software.

II. MATERIAL AND METHOD

2.1 Field of Study

Derme stream is located 12 km south of Malatya, at a 2 km distance from Yeşilyurt township center and on the map sheets L40 a3 and L40 b4 of 1/25000 scale national maps. Derme stream is located in the river basin no: 21.

Derme source is the most important karst source in Malatya province with a mean flow rate of 2.6 m^3/s. It is discharged from the faulted contact of permocarboniferous aged articulate limestone with plenty of faults (Pmkl) and impermeable schists (Pms) of the same age located below the former at 1205 m altitude. It is in the form of a group of springs. The source was collected by General Directorate of Provincial Bank and supplies drinking-utility water demand of Malatya center, Battalgazi

and Yeşilyurt counties. The source is operated by Malatya municipality (Önal,1993).
People living in the area of research lives on orchard agriculture, primarily apricots and cherries. Yeşilyurt township and Gündüzbey town are main recreational spots of Malatya province with several recreational facilities.

2.2. Hydrological Characteristics

Certain hydrological characteristics of the area of study were determined using Geographical Information System (GIS) software and digital maps. Calculated parameters for Derme stream basin were basin and surrounding area, maximum, minimum and average elevation in the basin, basin vector, average slope, Main canal slope and length, distance between basin center of gravity and project cross-section, with and the length of the basin, maximum basin diameter, basin shape indices, exposure map, drainage frequency and drainage density.

III. METHOD

3.1. Geographical Information System (GIS)

GIS has several definitions, but in short, it could be described as a systems network that includes computer hardware, software and users and used to collect, store, control, processing, analysis and display of certain spatial information about the earth (Aronoff, 1991). GIS data have two characteristics: geographical (spatial, graphical) feature and attribute (non-geographical, non-graphical). GIS technologies are utilized in almost all disciplines today. Furthermore, earth science branches that utilize almost exclusively spatial data are the most important application fields of GIS. One of these leading branches is hydrology where research is a little more difficult compared to other fields. Because variables change not only spatially in hydrology, but also with time. Therefore, integration of GIS techniques with other mathematical models is necessary in hydrological GIS applications in addition to direct operations. The following are among the areas of use for GIS in the fields of water resources engineering and hydrology (Anonymous, 2013):

- River basin management,
- Erosion – sedimentation prediction, control and protection operations,
- Design and management of drinking water, wastewater and urban rainwater networks,
- Selection of dam location, plotting altitude-area-volume curves, calculation of the reservoir volume, reservoir operations,
- Water quality modeling, monitoring and management,
- Underground water monitoring and modeling,
- Flood control and prediction, constructing flood maps,
- Water resource planning and management,
- Determination of irrigable land, yield prediction, finding the channel route,
- Soil classification
- Constructing the digital altitude model for the basin,
- Determination of basin boundaries and characteristics,
- Running different hydrological models in connection with GIS software.

3.1.1. ArcGIS Software

In the study, ArcGIS 10.1 GIS software copy licensed to Inonu University Civil Engineering Department and produced by ESRI corporation was used.
ESRI ArcGIS is an integrated software product collection that could build a complete geographical information system (GIS) specific to an organization. ArcGIS technology enables the user to integrate GIS functionality and business logic in desktops, servers or mobile devices, or in special applications or web services based on a particular need.
These features of geographical information systems are significant with respect to the geographical data that is used or will be used in geographical information systems. Because, these are among the important features for studies that are conducted to relate geographical data to a particular location and create different products from the details of this geographical data (Anonymous, 2013).

IV. RESULTS

Digital Elevation Model (DEM) was constructed using digital contour lines in GIS environment. Study field basin and drainage system was determined using the ArcHYDRO tool in ArcGIS 10.1 software (Figure 1). Data obtained for the study field were transformed into usable form and transferred into the system. basin area for the study field was found as 94.69 km^2 and circumference was found as 80.1 km.

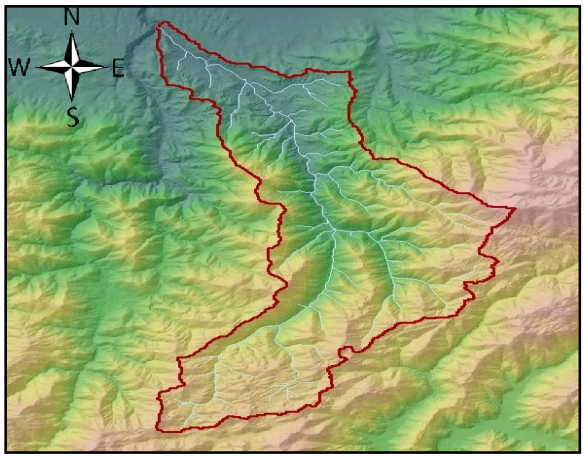


Figure 1. Basin of Derme Stream (Ermis 2014)

Drainage density is defined as the river length per unit area (Bayazıt, 1999; 2001) and calculated with Equation (1):

$$D_d = \sum L_u / A \qquad (1)$$

Drainage frequency is defined as number of tributaries per unit area:

$$D_f = \Sigma N_u / A \quad (2)$$

where D_d is drainage density, L_u is total river network length, A is basin area, D_f is drainage frequency and N_u is the number of tributaries.

Drainage network and drainage length of the Derme drainage system were determined as 101,898 km and this figure was divided by the basin area that was 94.69 km^2 gave the drainage density, which was found as 1.08.

Minimum basin altitude was 900 m and maximum basin altitude was 2493 m. Altitude map was generated using the software (Figure 2).

As could be observed on the constructed slope map, the slope varied most frequently between 20 and 45, and towards the downstream basin slope varied especially between 6-15 and 0-6 (Figure 2)

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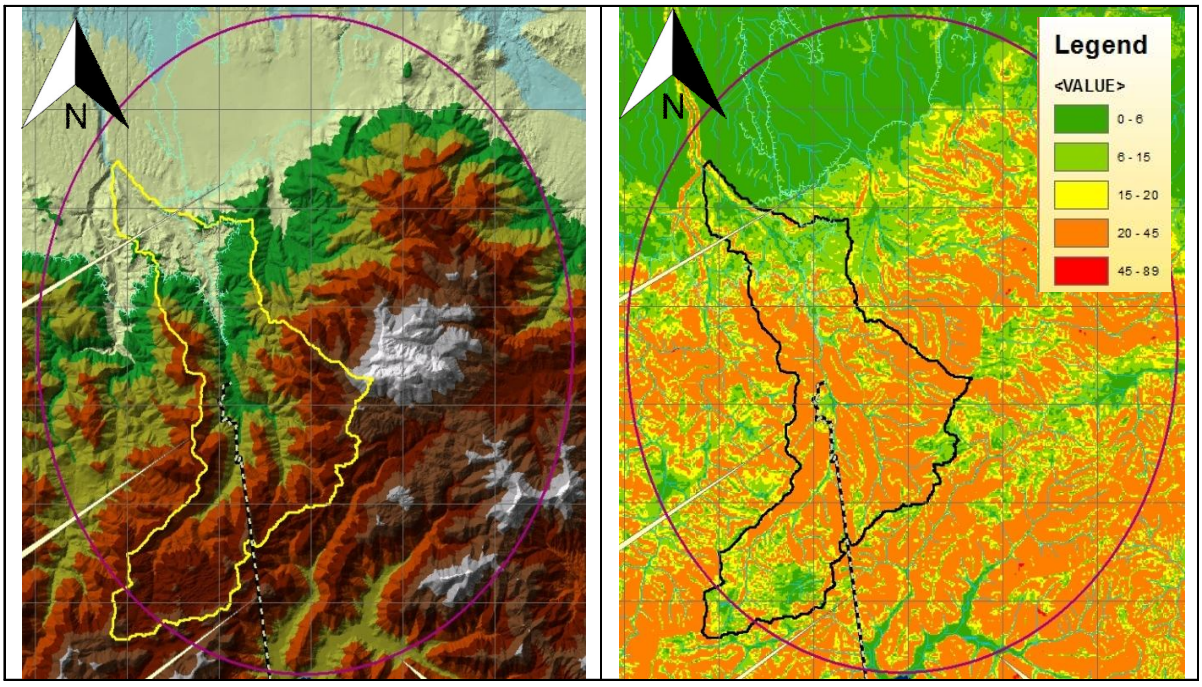


Figure 2. Elevation Map and Slope Map of Derme Stream (Ermis 2014)

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The main slope that is considered in flood calculations is the basin main waterway slope (Türkyılmaz, 1996). It is obtained by the division of the difference in altitude between the point where the main waterway commences and the basin exit point by the length of the main waterway.

Main waterway length was determined as 18,396 km. The channel main waterway between the altitudes of 1510 m and 900 m was calculated as 0.03 with the division of the altitude difference by the main waterway length.

Derme stream was divided 10 equal parts in length and slopes of each division were identified Table 1). Using the data provided in this table and Equation (3), Derme stream harmonic slope was calculated.

$$S = \left(\frac{10}{\sum \frac{1}{\sqrt{S_i}}} \right)^2 = (10/60.2124)^2 = 0.0276 \quad (3)$$

The distance between the intersection point of the vertical line drawn from the basin center of gravity to the main waterway and basin exit point was calculated as 13.85 km (L_c).

Basin length is the air line between the point found by extending the main waterway line until the basin boundary and the basin exit. Basin width (W_H) is calculated by dividing basin area by the basin length (L_H).

$$W_H = A / L_H \quad (4)$$

The length of the straight line drawn between the basin exit point and the most distant basin boundary gives the maximum diameter of the basin.Basin shape indices are calculations that demonstrate whether the basin resembles a circle or a square. These are:

$$SI_1 = L_H / W_H \quad (5)$$

$$SI_2 = A / A_d = 4\pi \frac{A}{P^2} \quad (6)$$

$$K_c = 0{,}28 \frac{P}{\sqrt{A}} \quad (7)$$

where SI_1, SI_2 are shape indices, K_c is the Gravelius index, A is the basin area, A_d is the area of the circle with an identical circumference with the basin, and P is the circumference of the basin.

Basin length was measured as 18.98 km and maximum diameter was measured as 18.99 using the basin map. Basin width and drainage frequency were calculated as 4.99 km and 0.877, respectively. Basin shape indices were calculated as SI_1 = 3.8, SI_2 = 0.185, K_c = 2.31. These index values showed that the basin was not circular or square, but more like a rectangle.

Basin Shape Coefficient (B_k) is expressed as the ratio of main waterway length squared to the drainage area.

$$B_k = U_{em}^2 / A \quad (8)$$

For the field of study, B_k value was calculated as 3.58.

It could be deducted from the exposure map that the orientation of the basin was mostly towards south and east (Figure 3).

Table 1. Derme stream harmonic slope calculation (Ermis 2014)

H_1	H_2	ΔH	l=L/10	S_i=h/L	$\sqrt{S_i}$	$1/\sqrt{S_i}$
1510	1415	95	1840	0.05	0.22	4.40
1415	1340	75	1840	0.04	0.20	4.95
1340	1280	60	1840	0.03	0.18	5.53
1280	1170	110	1840	0.05	0.24	4.08
1170	1140	30	1840	0.01	0.12	7.83
1140	1045	95	1840	0.05	0.22	4.40
1045	997	48	1840	0.02	0.16	6.19
997	958	39	1840	0.02	0.14	6.86
958	928	30	1840	0.01	0.12	7.83
928	900	28	1840	0.01	0.12	8.10
				Toplam		60.21

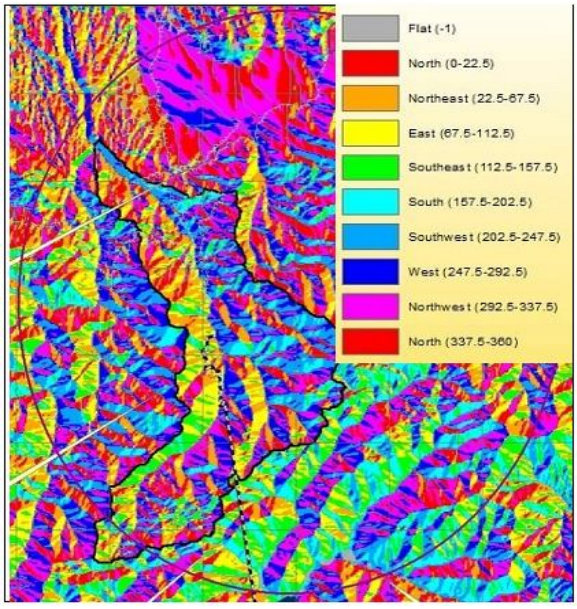


Figure 3. Exposure map of Derme Basin (Ermis 2014

CONCLUSION

- Derme stream basin area was 94.69 km^2 and circumference was 80.10 km. Total drainage length was 101.89 km and drainage density was 1.08.

- Minimum basin altitude was 900 m, maximum altitude was 2493 m. Based on the constructed slope map, the slope varied most frequently between 20 and 45, and towards the downstream basin slope varied especially between 6-15 and 0-6. Harmonic slope was 0.0276.

- Main waterway length was determined as 18.39 km. The slope of the main waterway between the altitudes of 1510 m and 900 m was 0.03. Straight distance between the basin center of gravity and the main waterway was 284 m. It could be said that the orientation of the basin is mostly southern and eastern.

- The basin is similar to a rectangle and basin shape coefficient was calculated as 3.58.

- Malatya province annual mean precipitation is 380 mm and higher altitudes of the study field receive snow during winter months. Southern and eastern orientation of the basin indicates high snowmelt during mid-spring months. Since there is low water demand for irrigation during these months, there is a high flood risk.

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