Modeling of Morphou (Güzelyurt) Flood and Remedial Measures†

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ABSTRACT

Flash floods are known to result in excessive damage and loss of lives due to lack of early warning systems. In this study, characteristics of a flash flood occurred in the Morphou region in Northern Cyprus on 18th of January, 2010 are studied and some remedial measures are proposed. Hydrologic and hydraulic modeling of this flood event has been developed for decision-making concerning type and degree of implementation of these measures. Since there is no stream flow gauging station along the creeks in the investigated area, the synthetic unit hydrograph is developed by using the US Soil Conservation Service method to obtain design flood hydrographs. Two remedial alternatives are eventually tested. Based on cost analyses, the one that concerns building a detention basin for storing water and a lateral channel for diverting extra flow from Zodia Creek to Potami Creek, is found to be feasible. In addition, flow carrying capacities of the creeks are improved.

***Keywords:** Flood, detention basin, diversion channel, remedial measure, Morphou*

1. INTRODUCTION

In recent years, short and sudden rainfall events, which cause flash flooding, have become more frequent. This kind of a flood is one of the most important natural hazards in the world. It can cause damage to various types of facilities and cause loss of lives. Effects of a flash flood can be pronounced by very intense rain falling on saturated or impermeable surface resulting in a high-volume surface runoff. In 2007-2008, the driest winter season on record was observed in Cyprus. However, in 2009-2010, there were heavy rainfalls which led to flooding during the winter season.

On January 18, 2010, a 16 hour-long non-stop heavy rainfall in the Morphou region of Northern Cyprus, caused a flash flood. The amount of daily total rainfall was the highest in recorded history (1978-2009). The highest total daily rainfall is 75 mm in Zümrütköy (Gadagopya), a nearby meteorological station in the flooded area up to 2010, but it was recorded as 160 mm on the day of the flood.

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The observed amount of rainfall of all regions and the amount of rainfall on January 18, 2010 (d_{At}) can be seen in Table 1 in which d_A and d_{max} denote the annual average and maximum precipitation depth, respectively. The village of Zodia and the town of Morphou were affected badly by this flash flooding that has never been observed in the recorded history. This flood caused considerable damage in the order of 2.8 million US dollars in Morphou and its close proximity.

Table 1 Precipitation data for Meteorological stations located in Morphou region

Station	Period	d_A (mm)	d_{max} (date) (mm)	d_{At} (mm)
Çamlıbel (Mirtu)	1978-2009	432	108 (05-12-2001)	169
Kozanköy (Lapitos)	1985-2009	497	150 (05-12-2001)	182
Kalkanlı (Gabudi)	2001-2009	320	74 (10-12-2002)	114
Güzelyurt (Morphou)	1978-2009	281	87 (19-08-2001)	101
Bostancı (Zodia)	2000-2009	378	127 (19-08-2001)	150
Zümrütköy (Gadagopya)	1978-2009	272	75 (01-11-1986)	160

The objective of this study is to develop a feasible solution for flood protection for the Morphou region. Hydrologic modeling is essential for the establishment of flood mitigation systems. The boundaries of the basin are obtained using Arc-GIS [1]. Various relevant hydrologic and geomorphologic parameters are then obtained for determining the flood hydrographs. Furthermore, hydraulic modeling is performed by using HEC-RAS program [2] to obtain water surface profiles of the creeks in the study area such that the extension of the flooded areas can be obtained. These computations are also used for checking the adequacy of the creeks and appurtenant structures like bridges and culverts. Finally, solutions for protection from flood are proposed. Scouring depths at bridges are computed and applicable armoring type scour countermeasures are designed. Some protective measures for Morphou region against flooding events are proposed. The first solution involves building a detention basin on Zodia Creek and a diversion channel between this basin and Potami Creek. The second solution is building a diversion channel between Zodia Creek and Morphou Dam.

2. DESCRIPTION OF THE INVESTIGATED AREA

With a semi-dry climate, the island of Cyprus is located in the Eastern Mediterranean Sea. The studied area covers the land close to the Morphou region located at the west coast of Northern Cyprus (Figure 1). There are a number of subbasins in the Morphou region but only two of them that were severely exposed to the January 2010 flood are considered in this study. Figure 2 shows the locations of the Zodia and Potami Creek basins. Extreme flows of a number of western creeks of the Morphou region are diverted to Morphou Dam

by means of a channel so that stored water can be used for recharging the Morphou aquifer. There are orange orchards, wheat and barley fields, and urban areas in the Zodia Creek basin, whereas the upstream part of Potami Creek basin is mountainous area and its downstream consists of citrous orchards, wheat and barley fields. There are only a few buildings in the downstream of Potami basin. Zodia Creek is composed of five branches. These branches are combined at the entrance of Zodia village (Figure 2).

Figure 1 Cyprus Island and the location of the town of Morphou (Google Earth, 2011)

There are no stream gauging stations in the aforementioned basins. That is why a synthetic unit hydrograph needs to be developed and the geomorphologic characteristics of the basins should be determined. For this purpose, the software Arc-Hydro, which is an application of Arc-GIS software program, is used [1]. The digital elevation model of the region is created from 1/25000 scaled contour maps of the region. Arc-Hydro D8 algorithm is operated for forming the basins of both creeks with their network pattern. To catch a good agreement between the map and the findings of the Arc-Hydro, some adjustments are made in the Arc-Hydro medium. Basins of both creeks, generated by ArcGIS software program are depicted on Google Earth map as shown in Figure 2. After generating the boundaries of the basin, the basin properties are calculated. The necessary data to be used in the derivation of SCS unit hydrographs for six-hour duration (UH_6) are presented in Table 2 in which A is the basin area, t_p is the time to peak, Q_p is the peak discharge, t_r is the duration of excess rainfall, t_l is the basin lag, t_b is the base time, L is the main stream length, S is the potential maximum retention, and S_h is the bed slope of the main stream. Besides that, CN is the curve number and it is obtained with reference to local conditions, such as soil type, surface cover, and antecedent moisture condition [3].

Figure 2 The study area (Google Earth, 2012)

The downstream reaches of these basins have almost zero slopes where the river cross-sections cover a very wide surface width. With highly pervious soil characteristics, flow feeds the groundwater partially and the rest of the flow that is not infiltrated is stored locally on the ground surface. That is why the outlets of these basins do not reach directly to the Mediterranean Sea on the surface.

Table 2 Parameters for obtaining the synthetic unit hydrograph for creeks

Parameter	Zodia Creek Basin	Potami Creek Basin
CN	76.48	77.34
L (km)	14	17.6
S (cm)	7.82	7.44
S_h (%)	1.4	1.5
t_L (hours)	6.38	7.23
t_p (hours)	9.38	10.23
A (km^2)	33.50	30.00
Q_p (m^3/s)	7.43	7.73
t_r (hours)	6	6

Cross-sections of the Zodia Creek and Potami Creek are measured precisely using the Global Navigation Satellite System (GNSS) and Total Stations by the authors of the paper.

The total study reach is divided into 38 cross-sections for the Zodia Creek and 37 cross-sections for the Potami Creek. Zodia Creek has seven bridges and seven culverts from the entrance of the village of Zodia and exit of the town of Morphou. Of these seven culverts three of them are circular and four of them are rectangular in cross-section. Besides that, there is one bridge and one culvert on Potami Creek near Zodia village.

3. HYDROLOGIC ANALYSES

SCS unit hydrograph method is employed by using the rainfall data and the characteristics of the basin. As the closest meteorological station, Gadagopya (Zümrütköy) rainfall data with sufficient length is used for the rainfall frequency analysis. This station has daily data from the year 1978 to the present. Maximum daily rainfall data per year are chosen for the frequency analysis. Figure 3 shows that, 160 mm rainfall is the heaviest rainfall on the recorded data from 1978 to 2010. The rainfall depth values corresponding to 50, 100, 200, and 500 years of return period are obtained through a frequency analysis using HEC-SSP [4] program as 117, 150, 191, and 261 mm, respectively. Using the Chi-Square test under 95% confidence level, Log-Pearson Type 3 distribution is selected as the best distribution for the annual series of peak rainfall depths.
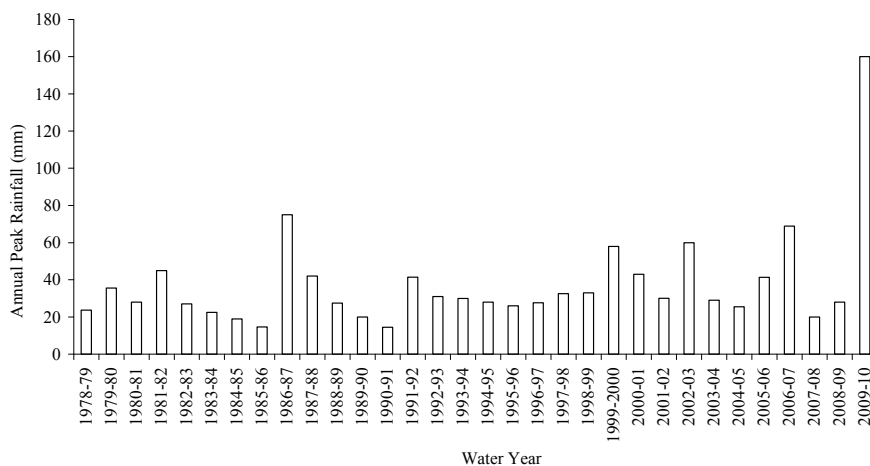

Figure 3 The maximum annual rainfall values for the Zümrütköy station

Gadagopya (Zümrütköy) station has a non-recording pluviometer, therefore the representative hyetograph of rainfall of the basin is required. This could be possible using the hourly rainfall data of meteorological station(s) in and around the region. Since only the Morphou station has a recording gage and the study area is small enough, it is assumed that Morphou station data can be used as representative information for the basin. The hourly rainfall data of Morphou station in the winter period of 2000 to 2010 are used to obtain the percent distribution of daily rainfall. Only the rainfall depth values greater than 10 mm were taken into consideration. After analyzing these data, 59 rainfall events were found to be greater than 10 mm in 24 hour periods. The average rainfall duration of these storms is

18 hours with an average rainfall depth of 19 mm. However, during the flood day, 100.7 mm precipitation was observed at the Morphou station. It is assumed that the representative hyetograph of the basins consists of four equal parts having each a six-hour period. Using the available data, the rainfall pattern of the Morphou region is obtained as shown in Figure 4. It is assumed that, the 160 mm rainfall was distributed following the same rainfall distribution pattern as the Morphou station. Figure 5 shows the modified hyetograph of Morphou station with respect to Gadagopya (Zümrütköy) observation on the flood day. This hyetograph is accepted as the design hyetograph and the corresponding flood hydrographs are accepted to be the design hydrographs to be used for designing their mitigation facilities.
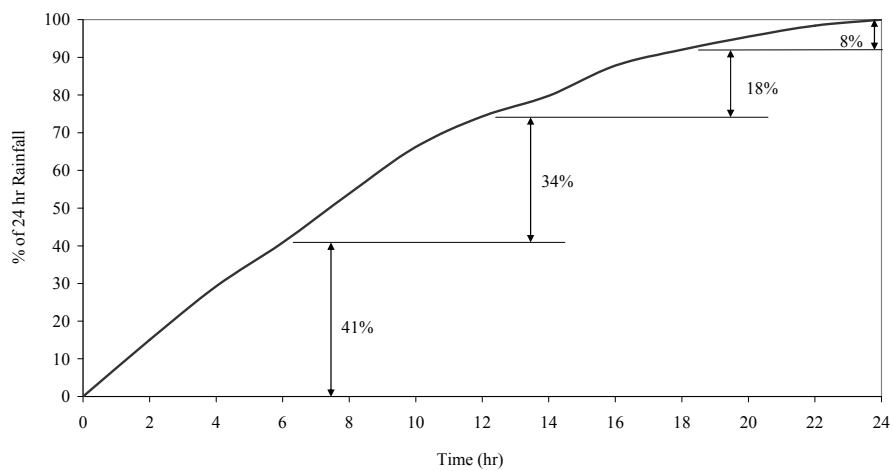

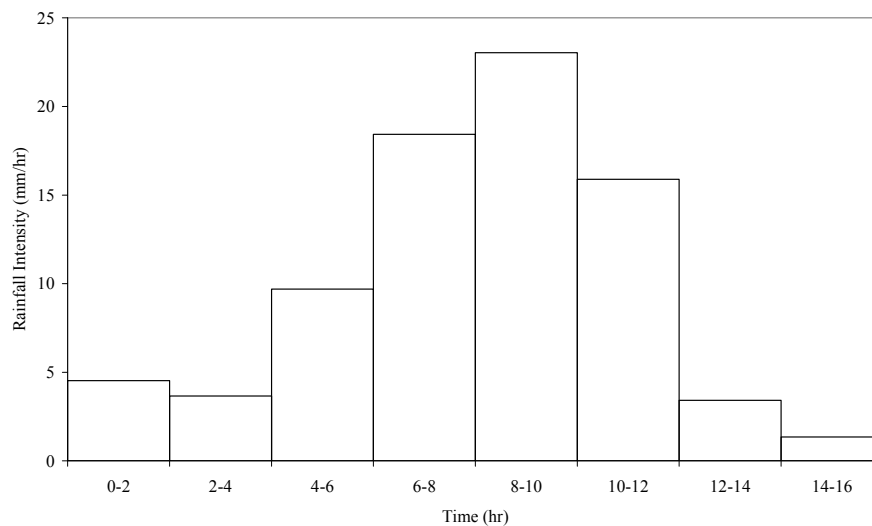*Figure 4 Percent distribution of daily rainfall of Morphou station*

Figure 5 Design hyetograph of Morphou station

Unit hydrographs having six-hour durations (UH_6) for Zodia and Potami Creek basins are generated by the SCS method (USDA, 1972) as shown in Figure 6. Direct runoff hydrographs are then obtained for these basins using the convolution principle. As seen in Figure 6, the peak discharges of the design flood hydrographs are 90.3 m³/s for Potami Creek and 104.6 m³/s for Zodia Creek. Based on a previous study conducted by Akıntuğ et al. [5], the return period of the design flood hydrograph is estimated to be approximately 300 years. Therefore, design of flood mitigation facilities using this design information is considered as conservative regarding the characteristics of the study area.
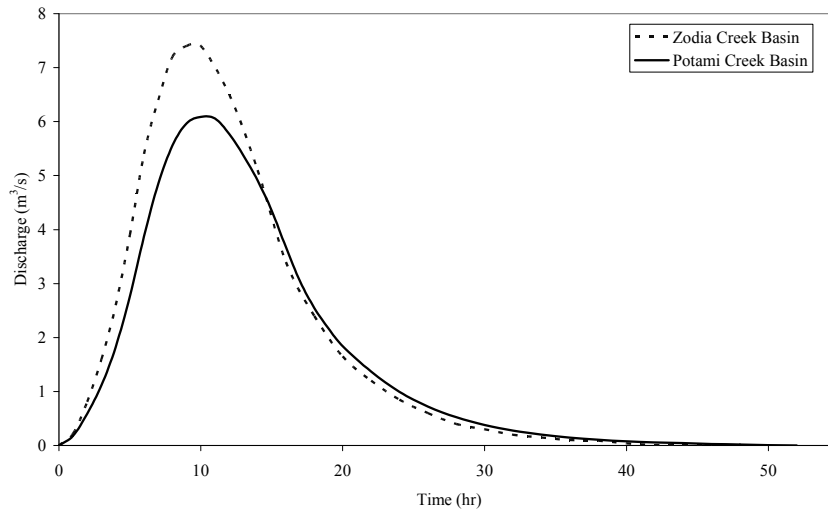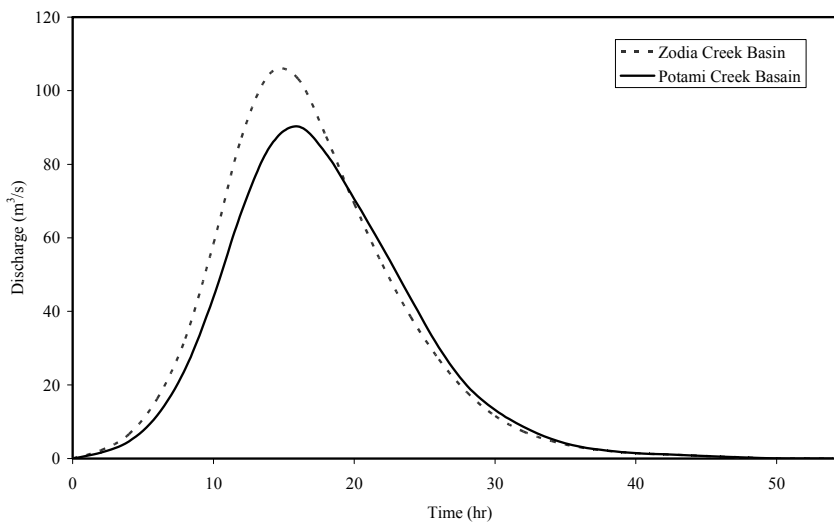

Figure 6 UH$_6$ of the basins

Figure 7 Design flood hydrographs of the basins

4. HYDRAULIC ANALYSES

Hydraulic analyses are required for deciding the degree of protective works and flood management practices. Water surface profiles are determined for the Zodia and Potami Creeks using HEC–RAS program, Version 4.0 [2]. In this study, steady flow water surface profile computations are used. Necessary input data, such as geometric characteristics of the cross-sections of the creeks, bed material characteristics, details of the existing bridges and culverts, and Manning's roughness coefficient values are determined for these creeks. Topographic, geometric, and soil characteristics of the creeks are studied in detail. Soil samples taken at nine different sections are analyzed. The overall roughness coefficient to account for these effects is accepted to be 0.056. After all sections, bridges, and culverts are simulated, the peak discharges of the computed hydrographs are inserted into HEC-RAS for determining flood inundation maps of the creeks according to the design flood.

Bank-full capacities of the Potami Creek and Zodia Creek are calculated according to two options. The first one is determining the capacities of the creeks without any changes in the conditions of the creeks and hydraulic structures. The second option is modifying the existing structures like culverts and bridges for increasing capacities of the creeks. Based on the first option, Zodia and Potami Creeks are observed to transmit up to 5 m^3/s and 25 m^3/s, respectively, without overtopping the channel sides. If the creeks are cleaned from impurities and channel widening and deepening are applied, Manning's roughness coefficient is accepted to decrease to a value of 0.033. Besides that, some culverts having smaller capacities must be replaced with new ones of higher capacity. With this modification, the capacities of Zodia Creek and Potami Creek will increase to 11 m^3/s and 180 m^3/s, respectively.

Scouring at bridges is computed using the Colorado State University equation [6] which is a standard equation of HEC-18 software. Eight soil samples are taken around bridges piers and analyzed for local particle size distribution. The values of median sediment size (D_{50}), size of grain for 95% finer (D_{95}), and the maximum scour depth (d_s) of bridges are shown in Table 3. A quite big scour depth is obtained at Section 11 on Zodia Creek as 2.38 m because of severe hydraulic conditions. Among various types of scour countermeasures around bridge piers, riprap is the most commonly applied measure throughout the world because of ease in application and economy [7]. The median stone diameter D_{r50} needs to be determined for the design of rock riprap to be placed around the pier. In this study, Isbach equation, which is commonly used for determining the riprap size in American practice is used [8].

The flow conditions around Bridge No 7 are relatively tranquil, therefore no bed protection is required for that bridge. However, 1.42 m-diameter of riprap size is obtained at Bridge No 4 and 5. Since this size is not practical to apply, partially grouted riprap placement may be considered. For partially grouted riprap application, Class 2 gradation according to [9] standard classification can be used. Therefore, D_{r50} value can be taken between 0.22 m and 0.27 m. The thickness of the partially grouted riprap layer can be taken as $3D_{r50}$. Gradation details for riprap classes can be found in [9].

Table 3 Scour data for bridges on Zodia Creek

Bridge No	D_{50} (mm)	D_{95} (mm)	d_s (m)
1	8.5	28.2	0.83
2	8.2	28.0	0.90
3	7.8	28.0	0.90
4	7.0	27.6	0.95
5	6.3	26.0	0.95
6	6.0	25.8	2.38
7	2.8	20.4	0.42

5. REMEDIAL MEASURES

Two remedial measures are proposed for flood protection in proximity of the Morphou-Zodia region. These measures are mainly categorized as storing a considerable flood volume at the upstream portions of these settlements by means of a flood detention basin on Zodia Creek and diverting a certain fraction of flows of Zodia Creek to the neighbouring Potami Creek by means of a diversion channel. The second measure is the diversion of a certain portion of flows of Zodia Creek to the Morphou Dam. These measures are described below together with the corresponding analyses and their results in a comparative manner. For decision-making, cost analyses are performed for these alternatives.

Alternative 1

Construction of a flood detention basin at a suitable location is considered as an effective measure as it can accommodate considerable flood water volume behind its reservoir. Hence reduced flow rates can safely be transmitted to the downstream reaches. A detention basin is normally composed of a small embankment having an uncontrolled bottom outlet. A riser pipe is connected to the bottom outlet in order to facilitate formation of a dead volume. During low flows, river flow takes place through the bottom outlet without storing water in the reservoir. Considering the possibility of high flows, an overflow spillway can also be supplemented [11]. In this study, a reservoir routing procedure dealing with a numerical solution is used. Temporal variation of reservoir surface elevation, h, measured from the axis of the bottom outlet is determined from the following equation [11]:

$$\frac{dh}{dt} = \frac{I(t) - Q(h)}{A(h)} \tag{1}$$

where t is the time, I(t) is the inflow, Q(h) is the outflow, and A(h) is the area-elevation relationship of the reservoir. When I(t), Q(h), and A(h) are expressed mathematically, the temporal variation of h can be obtained in iterative manner using a numerical solution, such as Euler or Runge-Kutta solutions [11]. This study is initiated by searching a suitable location for such a reservoir having adequate storage ability. Based on site investigations,

two choices are found to be suitable for the reservoir locations. The area-elevation data of the reservoirs are measured in the field. The following polynomials having correlation coefficients of 0.998 are fitted to Zodia Creek Detention Basin (Equation 2) and Potami Creek Detention Basin (Equation 3):

$$A\ (h) = 9.2257h^4 - 100.92h^3 + 856.29h^2 - 20.904h \tag{2}$$

$$A\ (h) = 5.1753h^3 + 308.66h^2 - 634.67h \tag{3}$$

A one-meter diameter bottom outlet and riser pipe is considered with the riser entrance height of 2 m. A homogeneous embankment having a height of 9 m, a crest thickness of 3 m, and a base width of 53 m is assigned according to the guidelines presented in [11]. The side slopes corresponds to 1V:2.8H, where V and H denote the vertical and horizontal values of the side inclinations, respectively. These values are reasonable for a homogeneous embankment [11]. The energy equation is used for calculating the outflow discharge. The following loss coefficients are taken for steel pipe with reference to [12] as 0.2, 0.2, and 1.0 for the entrance, bend, and exit, respectively. The friction factor is taken as 0.02. Frictional headloss is computed using the Darcy-Weisbach equation. Taking the datum as the centreline of the bottom outlet and assuming negligibly small velocity at the reservoir side, the energy equation is simplified as the following outflow relation as a function of h [13]:

$$Q(h) = 1.859\sqrt{h} \tag{4}$$

The form of inflow hydrograph recommended by Horn [14] is found to represent the local inflow hydrographs with relatively good agreement. So it can be used in the routing process. This hydrograph is obtained by fitting the dimensionless unit hydrograph of US Soil Conservation Service in the general form of a Pearson type 3 probability density function as

$$I(t) = I_p \left(\frac{t}{t_p} \right)^{3.5} \exp\left(-3.5 \left(\frac{t}{t_p} - 1 \right) \right) \tag{5}$$

where I_p is the peak discharge and t_p is the peak time. Using the information given before, the I_p and t_p values are taken as 104.6 m³/s and 14 hours for the Zodia Creek and 90.3 m³/s and 14 hours for the Potami Creek. With this alternative a diversion channel is proposed to divert a certain portion of flows of Zodia Creek to Potami Creek. Therefore, building flood detention basins on both Zodia Creek and Potami Creek is considered. With this configuration, flow is to be diverted to Potami Creek where it is to be stored in a detention basin on the Potami Creek. In this option, no spillway is proposed for the Zodia Detention Basin as it is desired to divert the majority of the flood waters to Potami Creek Detention Basin. A 600 m long lined trapezoidal channel having a height of 1.9 m and bottom width of 3.5 m can be built between both detention basins. The bed elevation at the beginning of the channel is desired to be 94 m at the edge of the reservoir on Zodia Creek, which finally joins Potami Creek at an elevation of 86 m. Flood routing computations are performed for both creeks. The minimum topographic elevations of the reservoir sites for Zodia Creek

and Potami Creek are 88 m and 82 m, respectively. When water level reaches 94 m elevation at Zodia Creek reservoir, water starts to flow from Zodia Creek Detention Basin to Potami Creek by means of the diversion channel. The operation period of the diversion channel is between 4.25 hr after the design flood enters the Zodia Detention Basin and 42.33 hr (See Figure 8). Therefore, inflow to the village of Zodia decreases as a result of operation of the diversion channel during this period as shown in Figure 9.
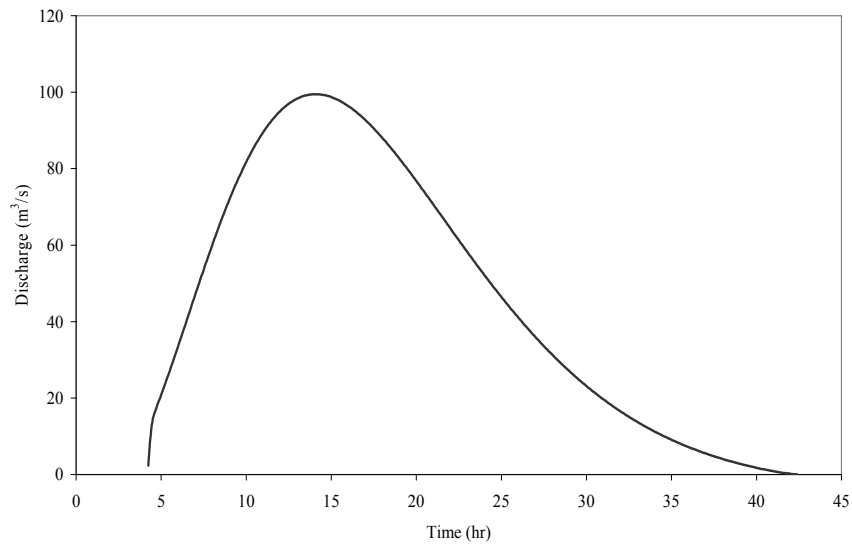

Figure 8 Flow transmission through the diversion channel in Alternative 1
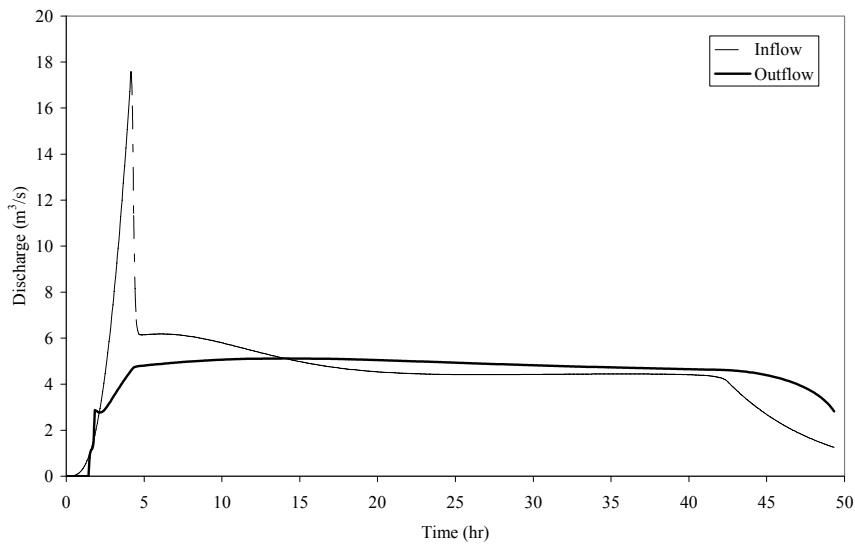

Figure 9 Inflow-outflow relation for Zodia Creek Detention Basin

After flood routing calculations of Potami Creek, stage hydrograph and inflow-outflow hydrographs of Potami Creek are generated. The maximum water depth in the Zodia Creek Detention Basin is 13.91 m and maximum inflow is 183.80 m³/s, which includes inflow coming from Zodia Creek Detention Basin. The outflow increases rapidly after 5.3 hours because considerable flow is transmitted to the Potami Creek Detention Basin by the aforementioned diversion channel. Therefore, almost negligibly small flood accommodation is achieved by the Zodia Creek Detention Basin. The option of building a detention basin on Potami Creek is then eliminated. Based on the flood routing calculations of Zodia Creek Detention Basin, the maximum depth of water is 7.4 m at 13.08 hours. Inflows decrease rapidly because of diversion to Potami Creek at 4.25 hours. Moreover, the maximum outflow is obtained as 5 m³/s for Zodia Creek and this discharge can safely be transmitted to the downstream. As can be seen from Figure 9, considerable attenuation is achieved in this basin. Hence it is recommended to build a flood detention basin on Zodia Creek only. The flood inundation map of Potami Creek is generated for the maximum discharge of 183.75 m³/s with the help of Google Earth (See Figure 10).

Figure 10 Flood inundation map corresponding to Alternative 1

The Potami Creek begins to disappear where it gets closer to Lefke-Morphou diversion channel. As stated before, water is partially absorbed and the remaining amount is stored on the soil surface just at the close upstream of the Lefke-Morphou diversion channel as shown in Figure 10. The upper elevation of the edge of diversion channel is 45.28 m and maximum water elevation during this flood is 44.74 m at this side. Therefore, the diversion channel is not overtopped during the passage of the design flood from the Potami Creek. The investment cost of this alternative considering costs of the diversion channel between

Zodia and Potami Creeks and detention basin on Zodia Creek is computed as 579,000 US dollars [13].

Alternative 2

Zodia Creek is considerably close to the Morphou Dam. Therefore, the design flow of 104.6 m^3/s is considered to be transferred directly to the Morphou Dam via a new lined channel. After field investigations, a channel, 5 km long with a bed slope of 0.0056, is observed to be built between the Zodia Creek and the Morphou Dam in the direction of decreasing elevation from 88 m to 60 m. Manning's roughness coefficient of the channel can be taken as 0.015. Considering the channel capacity, the width and height of the channel is 4 m and 3 m, respectively. Along the direction of the channel, there are two roads. Therefore, two small bridges are proposed to be constructed. The cost of this alternative, excluding the cost of bridges, is found as approximately 7,138,000 US dollars [13]. As a result, the first alternative is accepted to be effective and economical.

CONCLUSIONS

This study deals with flood management practices in Morphou region of Northern Cyprus. Rainfall frequency calculations are performed for hydrological modeling. Percentage distribution of daily rainfall of Morphou station is derived from the available rainfall data to obtain the representative rainfall hyetograph. The properties of the basins are obtained by using ARC-GIS software. SCS unit hydrographs are developed for obtaining the design flood hydrographs of the basins. Water surface profile computations are executed by using HEC-RAS software to obtain flood inundation maps of the basins. Flow carrying capacities of the creeks are observed and channel improvements concerning deepening and widening are proposed to decrease Manning's roughness coefficient. The dimensions of some of the existing bridges and culverts are modified to increase the flow transmission ability of the creeks. Partially grouted riprap is proposed to be placed around bridge piers as a suitable scour countermeasure. Construction of a flood detention basin on Zodia Creek with a supplementary diversion channel is proposed as an effective remedial measure.

Symbols

A   : Basin area

CN   : Curve number

d_A : Annual average precipitation depth

d_{max} : Annual maximum precipitation depth

D_{50} : Median Sediment Size

D_{95} : Size of grain for which 95% is finer

d_s : Depth of scour

I(t)	: Inflow
I_p	: Peak discharge
L	: The main stream length
S_h	: The bed slope of the main stream
t	: Time
t_b	: Base time
t_l	: Basin lag
t_p	: Time to peak
t_r	: Duration of rainfall excess
t_p	: Time to peak
UH	: Unit Hydrograph
Q	: Discharge
Q(t)	: Outflow

Acknowledgments

References

[1] ESRI. ArcMap Users Manual Version 9.3, ESRI Inc., 2008.

[2] USACE. HEC-RAS Users Manual Version 4.1, Davis, CA, ABD, 2010.

[3] USDA. Soil Conservation Service, National Engineering Handbook, Washington D.C., 1972.

[4] USACE, HEC-SSP Users Manual Version 4.1, Davis, CA, ABD, 2009.

[5] Akıntuğ, B. Yanmaz, A. M. Akyürek, Z., ve Sürer, S. Modelling of Zodia-Morphou Flood and Determination of Flood Risk Areas in Morphou Region. Scientific Research Project (FEN-15) Report. METU Northern Cyprus Campus, 2011.

[6] Richardson, E. V., and Davis, S. R. Evaluating Scour at Bridges, Fourth edition. FHWA Report No. FHWA NHI 01-001. Virginia: Federal Highway Administration, 2001.

[7] Yanmaz, A. M. Köprü Hidroliği, METU Press, Ankara, 2002.

[8] Lagasse, P. F., Zevenberg, L. W., Schall, J. D., ve Clopper, P. E. Bridge Scour and Stream Instability Countermeasures – Experience, Selection, and Design Guidelines, Hydraulic Engineering Circular (HEC) No. 23, Second Edition. FHWA Report No. FHWA NHI 01-003. Washington, D. C.: Federal Highway Administration, 2001.

[9] Lagasse, P. F., Clopper, P. E. Zevenberg, L. W., ve Girard L. G. Countermeasures to Protect Bridge Piers from Scour, NCHRP Report 593, Transportation Research Board, Washington, D. C., 2007.

[10] Yanmaz, A.M., ve Çam, E. Bridge Scour Countermeasure Design: A Case Study, 10. International Congress on Advances in Civil Engineering, Proceedings, Vol 1, 2012.

[11] Yanmaz, A. M. Applied Water Resources Engineering, METU Press, Ankara, 2006.

[12] Munson, R. B., Young, F. D., ve Okiishi, H. T. Fundamentals of Fluid Mechanics. ABD, John Wiley and Sons, 2006.

[13] Şahin, E. A Study on Flood Management Practices for Güzelyurt*,* MSc Thesis, Department of Civil Engineering, METU, Ankara, 2012.

[14] Horn, D. R. Graphic Estimation of Peak Flow Reduction in Reservoirs, J. Hydraulic Division, ASCE, 113(11) pp. 1441-1450, 1987.