DEVELOPING A COMPUTATIONAL FRAMEWORK FOR ESTIMATING INFLOWS TO A COASTAL LAGOON FROM ITS BASIN

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Abstract

This study aims to develop a methodology for generating the upstream boundary conditions to run hydrodynamic and water quality models for Dalyan Lagoon, declared as a Special Protection Area, located in the southwest part of Turkey. The outflow from Koycegiz Lake to Dalyan Lagoon is the upstream boundary condition, which is necessary to construct input data sets for preliminary modeling studies. For Dalyan Lagoon, Koycegiz Lake at the north and the Mediterranean Sea at the south constitute the two boundary conditions. There are several streams feeding Koycegiz Lake intermittently, however, the outflow from the lake is continuous because of its large volume and high hydraulic detention time in comparison with other system components. Watershed and sub-watershed boundaries are delineated and the stream networks for the sub-watersheds have been visualized with Watershed Modeling System (WMS 6.1). Following the estimation of run-off hydrographs, one-dimensional hydrodynamic models were used to estimate flow hydrographs at the discharge points to Koycegiz Lake. Then simple hydrologic routing algorithms together with water budget analyses were used to obtain the unsteady outflows that constitute the upstream boundary condition, from Koycegiz Lake to Dalyan Lagoon. The methodology used here can be applied to similar systems for preliminary modeling studies.

Introduction

Direct or indirect impacts of human activities on coastal ecosystems, started to cause severe environmental problems, therefore, the effect of such changes on these sensitive and economically important environments has become a major concern. Mathematical modeling is a significant tool in environmental issues such as water quality management and ecosystem restoration of coastal zones. Models allow rapid evaluation of various causes and effects. The principal advantage is that they make the analyses of various future scenarios possible at present time.

Modeling is a complicated task that requires expertise and data on the real system. Boundary conditions mainly comprise the most important part of the input data set for both hydrodynamic and water quality models.

The aim of this study is to develop a methodology for generating the upstream boundary conditions in order to run hydrodynamic and water quality models for Dalyan Lagoon, Turkey.

Description of the watershed and the methodology used for developing the computational framework

The watershed of Koycegiz Lake/Dalyan Lagoon, with an approximate surface area of 1200 km^2, is situated at the southwest of Turkey, where the Lake joins the Lagoon and the Lagoon joins the Mediterranean Sea. The watershed is composed of two drainage systems, one being the drainage area of Koycegiz Lake (1070 km^2), and the other is the drainage area of Dalyan Lagoon (130 km^2) (1). Part of the area has been declared as a Special Protection Area and is one of the sensitive and vulnerable coastal regions of the country in terms of endangered and endemic species. *Caretta-caretta* sea turtles utilize the area as their nesting and breeding sites. The watershed hosts a population of almost 45000 capita mainly dealing with agriculture, tourism and fishery, besides there is no significant industrial activity in the region. The location of the watershed in Turkey is presented on the map in Figure 1, which was produced by 3D digital elevation model.

The first task of the study was the delineation of the watershed and sub-watershed boundaries, and extraction of stream channel network. There are many procedures for this task as cited by (2). The 8-direction pour point model has been selected as an appropriate watershed modeling method for this case. This method is described by Saunders and Maindment (3) and Beneman et al. (4) in more detail. Watershed Modeling System 6.1 (WMS), which was used to delineate the watershed and sub-watershed boundaries and extract the stream network partly, contains special algorithms such as the 8-direction pour point model. WMS was also used to produce Digital Elevation Model (DEM) for the entire watershed. The missing parts of the watershed, which could not be obtained digitally, were delineated manually and digitized by Ustun (5). The results of the first task are given in Figure 2.

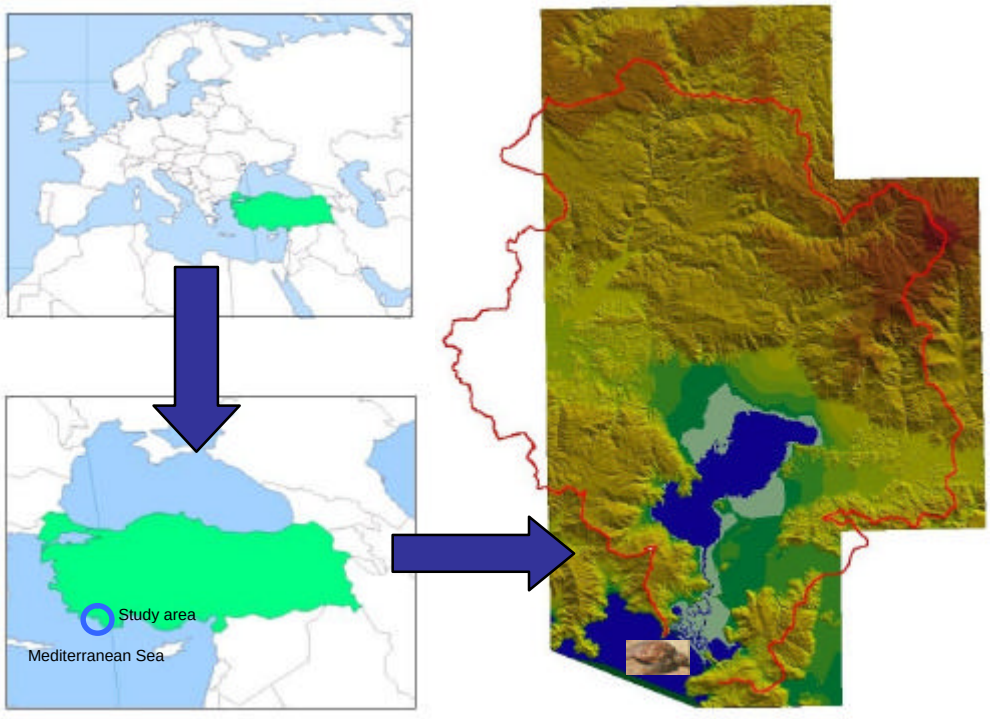

Figure 1 Location of the watershed in Turkey and its 3D plan view

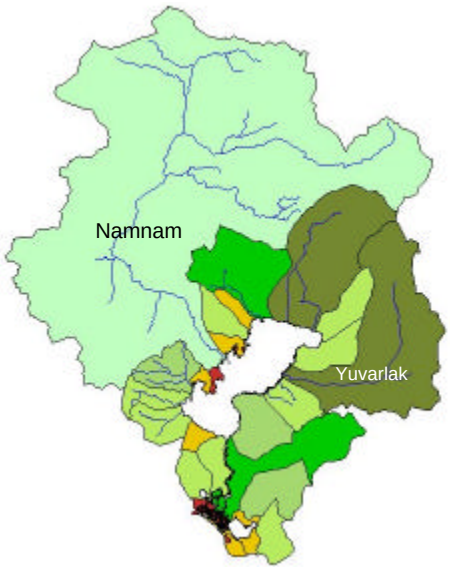

Figure 2 Boundaries of sub-basins

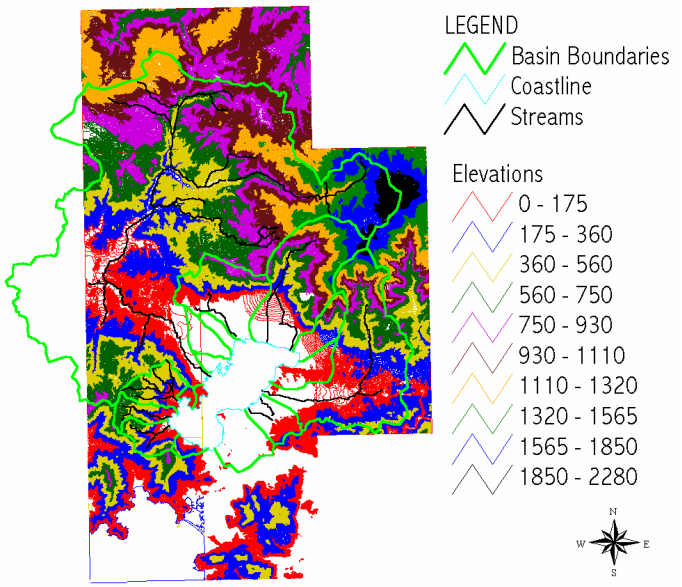

Figure 3 Elevation map obtained from GIS analyses used for hydrological calculation of Sub-basins

The Namnam Creek and Yuvarlakcay Creek are the two most important streams, which carry most of the flow and nutrient loads to Koycegiz Lake. The amount of water transported to the streams was estimated using simple software developed for this study. The software uses the kinematic wave model for calculating overland flow. Long term precipitation data together with stream gauge data was used to obtain the runoff coefficient which was calculated as 0.7. Other geomorphologic parameters such as characteristic lengths and slopes were calculated using the ArcView 3.1 GIS software package. The GIS output is illustrated in Figure 3. With the help of the overland flow calculations approximately 85% of the flow is found to be transported via Namnam and Yuvarlakcay Creeks. The daily flow data of Namnam Creek and Yuvarlakcay Creek were gathered from the State Hydraulic Works (DSI) (6) and from the Institute of Electrical Affairs (EIE) (7) respectively. A simple one-dimensional numerical hydrodynamic modeling software, which uses the dynamic wave model (full Saint Venant equations) was developed to calculate flow routing effects in the stream networks. The complex stream networks were divided into branches, which were treated separately by the modeling software. Full Saint Venant equations and/or stream branching are also used in more complex stream hydrodynamics modeling software such as BRANCH (8), CE-QUAL-RIV1 (9), FEQ (10) and FourPt (11). The lag time in the stream networks were found to be less than one day in many cases. The temporal resolution of meteorological and stream flow data were one day. Therefore, application of one dimensional hydrodynamic model for stream networks became a numerical experiment, which resulted that flow routing by overland flow is more pronounced than flow routing by the stream network.

A simplified version of the Muskingum algorithm, together with water budget analyses containing stream inflows, precipitation, evaporation and water level variations, were used to obtain the unsteady outflows from the precipitation data obtained from the State Meteorological Service for Koycegiz Meteorological Station that covers a time interval of 50 years. Flow data of two streams were obtained from DSI and EIE. Water surface elevation data for Koycegiz Lake were obtained from DSI. All data used in the analyses were daily averaged values.

The outflow hydrograph generated in this study constitutes the upstream boundary condition of Dalyan Lagoon, and will be useful to conduct preliminary hydrodynamic and water quality modeling studies for the complex lagoon network system downstream of Koycegiz Lake.

Results

The calculated outflow hydrograph is given in Figure 4. According to this figure, large fluctuations and seasonal variations might be expected at the upstream boundary of Dalyan Lagoon. These conditions were also reported in various studies. High flows of 50-90 m^3/s and low flows of a few m^3/s can be observed during a hydrologic year. However, under extreme conditions the water surface elevation could increase by 100 cm and this elevation difference may cause peak flows of several hundreds of cubic meters per seconds, which flood the entire Dalyan Lagoon basin and the wetlands.

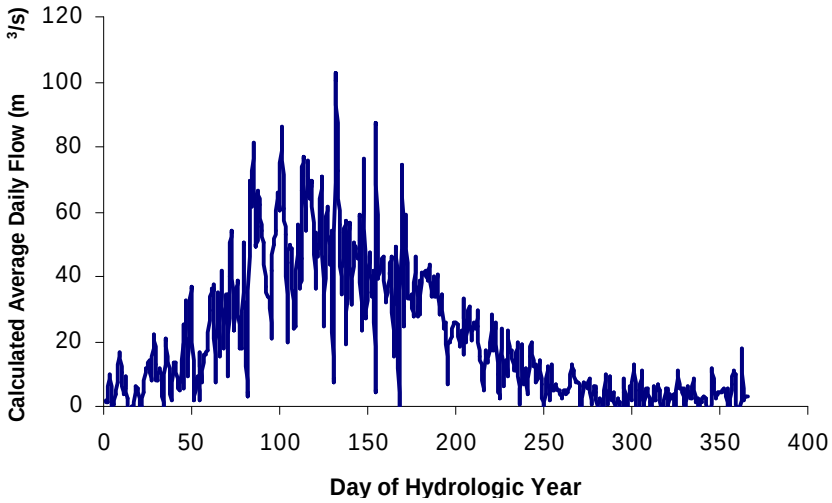

Figure 4 Outflow hydrograph of Koycegiz Lake

Conclusions

In this study outflow hydrograph for Koycegiz Lake was generated as the starting point of an ongoing water quality modeling study. However, to obtain a date specific boundary conditions, more detailed watershed modeling studies should be conducted with full model calibration and verification. More accurate water budget calculations may be done if groundwater influences can also be modeled.

Acknowledgements

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