# FLOODPLAIN DELINEATION IN MUGLA-DALAMAN PLAIN USING GIS BASED RIVER ANALYSIS SYSTEM

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## ABSTRACT

Floodplains are important land features that are highly discriminated from the neighboring uplands in terms of their hydrological and geomorphologic processes. The important step in floodplain studies is the determination of lateral floodplain extent and its variability in the plain.

DSI had used traditional methods for the studies of floodplain, in the past years. Traditional method does not satisfy the needs of the real flood plain analysis. Because they do not consider the real topography in the longitudinal cross-section, change of the velocity, the contraction and expansion in the river bed. Use of the new technology is a must for determining floodplains.

In this study, an application of HEC-RAS and HEC-GeoRAS model is applied in Mugla-Dalaman Plain. Due to its economic and touristic potential, Dalaman plain is very important. DSI had studied this area before and delineated the floodplain with traditional methods. In the recent years, some touristic hotels were constructed in the plain which are mostly in floodplain. The houses and lands of the local people prices are decreasing because of being in the flood plain. For the determination of floodplain, first, HEC-RAS simulations were performed to generate water surface profiles throughout the system. Floodplain zones for the design storms were reproduced in three dimensions with HEC-GeoRAS by overlaying the integrated terrain model for the region with the corresponding water surface TIN. As a result it was seen that the floodplain extend that was found by GIS based methods gives considerable better results than by traditional methods.

***Keywords***: Dalaman plain, floodplain delineation, GIS, HEC-RAS , HEC-GeoRAS

## INTRODUCTION

Due to its conditions related to geographical location, geology and topography, Turkey often undergoes adverse affects of natural disasters. Flooding is the second important natural hazard after the earthquakes, with 22 floods and 19 deaths per year on average.

Floods in Turkey generally occur due to heavy rainfall on the costal areas of the northern, southern and western parts of Anatolia or on account of a sudden increase in air temperature, resulting in snow melt in the eastern and mountainous part of southeastern Anatolia. In the northern and central parts of the country both factors may be prevailed depending on the time of the year. As in most developing countries, in Turkey, there is one more an important factor which has to be considered during flood assessment. These are known as the factors reducing the flood plain capacity, artificially decreasing the available safe wetted area, and increasing the devastating effect of the floods; and the ones of the unauthorized use of the flood plains by the construction of local barriers and settlements, as in the case of the Izmir flood disaster in 1995, of the construction of inappropriate bridges, culverts, and creating new agricultural plots. This is very common application, however, especially in fertile river flood plains.

DSI studies on flood protection and mitigating hazards of flooding have been carried on generally as ‘with project’ activities including structural precautions in frame of duties and responsibilities mentioned in DSI Law. Besides, these include several studies on each process of flooding based on the determinations defined in flood water law and natural disasters legislation.

Building protective structures against flood waters and torrents, and management of these structures have been given to DSI by its Establishment Law. DSI prepares ‘with project’ activities including structural elements aimed at flood protection and mitigating hazards of flooding . Besides, DSI prepares multi-purpose storage structures for flood protection and control in the whole river basin or need for other water development requirements. Furthermore, DSI provides river basin improvement projects for flood protection in a certain restricted part of a basin because of urgency.

According to related provisions of Flood Waters Law, areas which have high flood risk in different parts of our country have been announced as forbidden areas for any kind of urbanization. Within this frame work, 32 Government Decrees which have been determined since 1943 were compiled by DSI and published as a book with the name “ Decrees Related to Flood Protection, Exsiccation and Natural Disasters”.

In the process of preparation of development plans for the municipalities, State Hydraulic Works (DSI) is the main governmental organization that is responsible for identifying the floodplain. Investigations for flood risk of planning areas are conducted in order to be used as data for prepatory period of planning. These investigations are realized considering the demands come from municipalities or other related public agencies. They are also done for the circumstances that if the position of settlement and urbanization is dependent of an upper scale municipal plan or of wider extent regional plans. The results of these investigations are presented to related organizations and institutions that demand.

Generally DSI uses a discharge of 500 year return period for the floodplain delineation in case of a dense settlement and urbanization in downstream. By using the traditional methods, identifying the real flood risk is not so easy. Because real dynamism of the river basin can not be shown due to limitations in the traditional methods.

In the latest years there is an increasing trend for helping and supporting environmental planning decisions with simulation models because of the development of regulatory and planning tools. For example River basin development plans have a close link between the definition of physical phenomena such as floods and the characteristics of land planning limitations. Generally geomorphologic analyses are used in the definition of river floodplain, but definition of a risk or definition of a flooding of an area for a return period needs to use hydraulic and hydrologic models.

Estimation of flood inundation and its risk is increasingly a major task in relevant national and local government bodies in world-wide. When river flow depth is reached in a flood event, water ceases to be contained solely in the main river channel and water spreads onto adjacent floodplains. This consists a 1D hydraulic routing procedure for channel flow, 2D or 3D over floodplain to enable simulation of flood water depth and hence inundation extent. These make the flood prediction a very complex process in both spatial and temporal contexts. Traditional engineering methods are are not easy to apply, and visual representation of the plan for a catchment is very simple.

These problems can be partially overcome by the integration of a hydraulic modeling tool such as HEC-RAS with GIS. Thus the outputs from model can be used in GIS along with other spatial data for analysis and visualization. Incorporating HEC-RAS’s capabilities with a GIS allow for analysis of the full impacts on flood extents, flood depths. Flood damage assessment from a cost/benefit analysis can also be linked to an optimization module with a graphical user interface(GUI). At all stages of the integrated process model results can be presented to decision-makers in a clear and easily understandable formats.

## STUDY AREA

The study area is the Dalaman Plain, which is located in Lower Dalaman river basin. The lower Dalaman river basin is situated at the southwest of Turkey within the Dalaman river basin (Fig1). The catchment area of the lower Dalaman river basin is about 5250 km$^2$. Dalaman river rises near Güntutan mountain and takes the name of Horzum at the beginning. The main tributaries of the Dalaman river are Cavdır, Aksu, Kocacay streams on the upper basin and Husniye, Kilcan, Gokcay and Cehennem streams on lower basin. The major lakes of the project are Sogut and Golhisar lakes on the upper basin. The mean annual natural flow of the river at the Akkopru dam location is estimated as 1773 million m$^3$ for the period of 1938-1980.

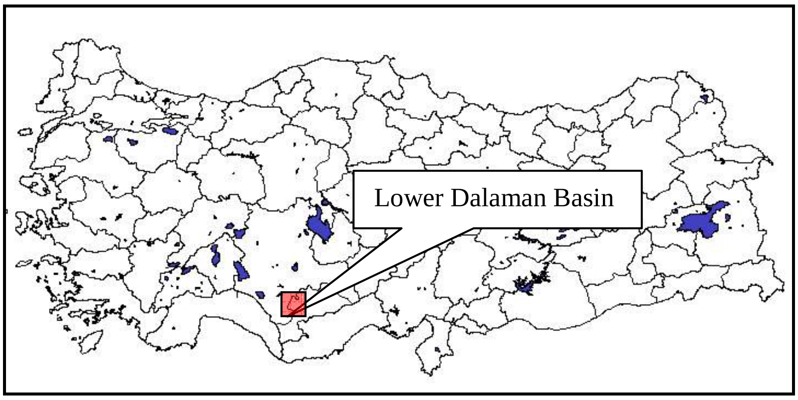

Figure1 Location of Project site

## AIM OF THE STUDY

Dalaman plain has been used for agricultural purposes for years. But due to latest touristic and business trends in the area makes the area attractive as a settlement place. Construction of touristic hotels in the plain increases the value of the land. In the latest years, there is a big trend for settlement in the floodplain. Due to the limitation of the floodplain which was identified earlier by DSI, people living in those areas have being difficulties to get municipal permission. This was resulted in illegal settlement through the area.  The big problem is that touristic hotels constructed in the plain which are mostly in floodplain. Also Dalaman airport which is the center of transportation for the nearby areas is in the plain. The idea of this study is to identify flood risk on the Dalaman plain and define the possible flood water level by applying latest hydrologic / hydraulic modeling tools (HEC-RAS and HEC-GeoRAS) and GIS software.

## HEC-RAS MODELLING

The model package “River Analysis System” (RAS) by the US Army Corps of Engineers – Hydrologic Engineering Center (HEC) includes:

- ♦ - a steady flow model
- ♦ - an unsteady flow model
- ♦ - the consideration of a wide range of hydraulic structures
- ♦ - facilities for hydraulic design such as computation of localized scour at the piles of a bridge Because of the capability of defining wide range of physical processes it has proven very helpful in supporting all phases of flood management.

In flood simulations with HEC-RAS following input data are required:

- ♦ • channel geometry;
- ♦ • boundary conditions;
- ♦ • tributary inflows if any; and
- ♦ • Manning roughness coefficient.

The output data is the water level for each cross-section which was found after flood routing.

## HEC-RAS AND GIS INTEGRATION

HEC-GeoRAS has been specifically designed to aid engineers with limited GIS experience in the development and display of hydraulic data for HEC-RAS. Knowledge of ArcGIS is advantageous, but not necessary to use GeoRAS. However, users must have enough experience modeling with HEC-RAS and river hydraulic to properly create and interpret GIS data sets.

HEC-GeoRAS is an extension for use with ArcGIS that provides the users with a set of tools, procedures and utilities for the preparation of GIS data for import into Hydraulic Engineer Center’s River Analysis System (HEC-RAS) and generation of GIS data from HEC-RAS output. This extension was developed though a Cooperative Research and Development Agreements between the Hydraulic Engineer Center (HEC) and the Environmental System Research Institute, Inc (ESRI). Users must have experience modeling with HEC-RAS and river hydraulics to properly create and interpret GIS data sets.

GeoRAS provides the user with environments to manage; create and edit; process; and visualize data sets. Each environment is intended to lead the user through procedures in a clear and logical order.

Geometric data for use in performing river analysis can be developed from a TIN of the land surface and four line coverages. The four line coverages are the Main

Channel Invert Coverage, Cross Section Cut Line Coverage, Main Channel Banks Coverage, and Flow Paths Coverage.

HEC-GeoRAS allows users to create required geometric data from an existing digital terrain model (DTM) and complementary data sets to run HEC-RAS Model. This extension creates an import file (RAS GIS Import File) containing river, reach and station identifiers, cross-sectional cut lines, cross-sectional surface lines, cross sectional bank stations, downstream reach lengths for the left overbank, main channel, and right overbank and cross-sectional roughness coefficient.

HEC-RAS is capable of modeling subcritical, supercritical, or mixed flow regimes. Hydraulic calculations are performed at each cross section to compute water surface elevation, critical depth, energy grade elevation, and velocities.

A hydraulic model of a river system depends on the development of geometric data that accurately depicts the land surface to be modeled. GIS provides the tools for storing and manipulating a three-dimensional representation of the land surface as a DTM, and more specifically to HEC-GeoRAS, as a TIN.

Provided a TIN of the channel and adjacent floodplain area, linear data sets (line) can be created based on terrain features, and used to develop the required HEC-RAS data components by using ArcGIS, 3D Analyst and HEC-GeoRAS.

## APPLICATION OF THE MODEL

In the modeling with HEC-RAS , Manning roughness coefficient (n) is one of the most input important parameter. Roughness coefficients are an indication of the relative channel roughness. Channel roughness is considered for calculating frictional energy loss between cross sections. Considering the features of this river reach, the Manning roughness coefficient for main channel and flood plain is taken as 0.023 and 0.028 respectively.. The “n” values are found from the calibration the flood event which was happened in 1998. Since the geometry, surface and river bed is nearly same in the river, same “n” values are used for each cross-section. The resistance parameter which is known to vary with water level, decreasing with increasing water level by decreasing the effective relative roughness, and then increasing again as the flow spills overbank, since floodplain roughness is usually higher than the channel roughness (Chow, 1959). So floodplain “n” value is taken as bigger than the river bed. Several simulations were done and tracks of previous big floods are used for the calibration.

The other main input for HEC-RAS model is the river cross section. In this study, the contour map of the study areas were digitized from 1:25000 scale topographic maps and 1:5000 scale maps. Also, other features such as rivers, sea and settlements and their information were digitized from those maps. By using ArcGIS and 3D Analyst software, Triangulated Irregular Network (TIN) surface model were created from contour maps. As will be explained in following sections, cross section data was derived for each reach from TIN. But in order to increase the accuracy, cross section survey was also done at different river reach ranging between 300 m to 900 m which sometimes extent up to 3 km each side of the river bank (Figure 2). About 56 cross-section data is taken and integrated with the data derived from TIN for the modeling. Normally 56 cross-section is not enough for modeling such a river plain but, due to the constraints in the river bed (obstacles, houses, trees and among others), only 56 cross sections can be taken. To reduce the big transformation effect from one reach to another, cross section data is converted to as 25 meter intervals. This also reduces the formation of critical points in the longitudinal cross-section because of the smoothened passing from one reach to another.

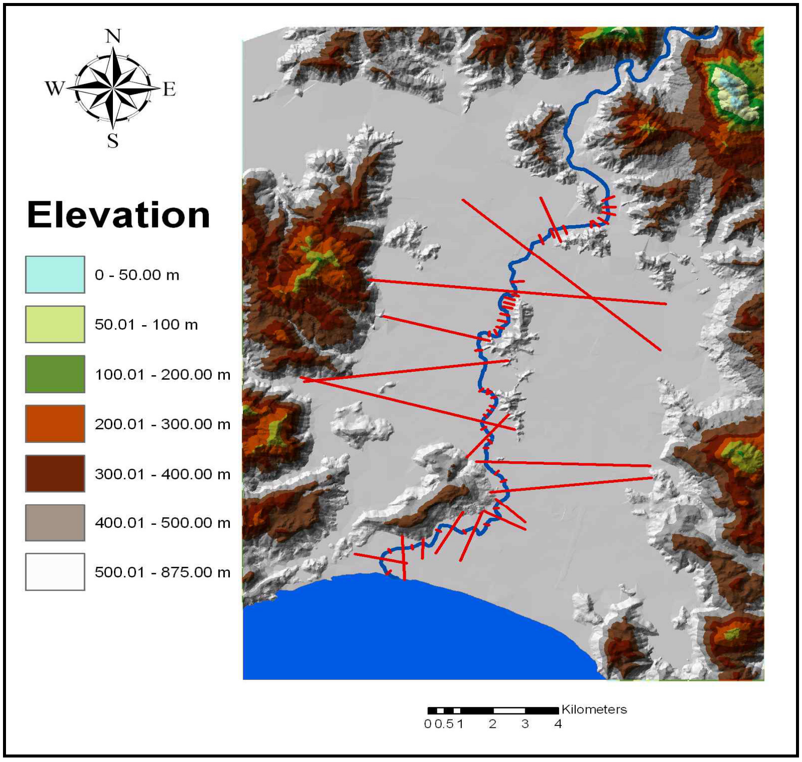

Figure 2: Plan view and the locations of the cross-sections

Another input parameter is the inflow value from the upstream. Several studies were done to find the inflow in the upper reach. As mentioned above the upstream is restricted with Akkopru Dam. The dam has a gated spillway. There is no other tributary to the main river after the dam, so the outflow from the Dam spillway after flood routing is used for the inflow of the hydraulic modeling. In the feasibility study which was done in 1983 a return period of 100 years was used in the analysis by traditional way considering the situation of the plain at that time. But due to recent urbanization, touristic and economic potential of the plain 500 years return period is selected and used in this study.

Boundary conditions are the main inputs in order to make the model to produce accurate results. The downstream of the river is discharging to the sea, so the downstream end boundary condition for the river is given as sea water level. The upstream boundary condition is given as the slope of the river bed where there is no other known value. The simulations were run in both sub-critical and super-critical flow scenarios. After an analysis of the results, it was seen that a sub-critical run is most acceptable where boundary conditions agrees better.

The geometric data was imported into HEC-RAS for model completion and simulation. Data imported into HEC-RAS included the stream network and cross-sectional geometry. Station-elevation data, bank stations, downstream reach lengths, Manning's *n* values, and levee information were imported for each cross section.

Modification of cross-section and bank stations was accomplished using the graphical cross section editor in HEC-RAS. Flow data and boundary conditions were also input in HEC-RAS before simulating.

The resulting longitudinal cross-section of the river is shown in figure 3. As it can be seen from the figure, due to the contraction or expansion in the cross-sections, some critical energy is formed. These can be overcome by adjusting the river bed or adding enough cross section to eliminate rough trespassing.

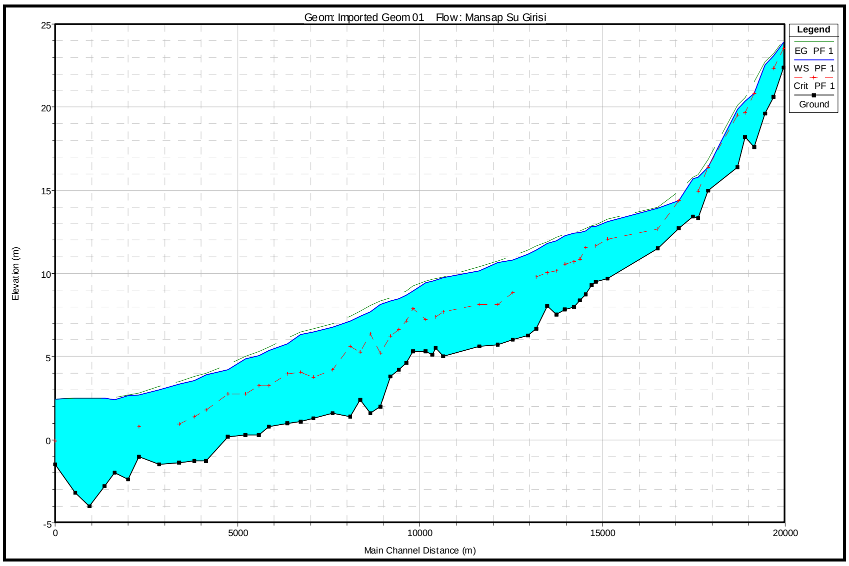

Figure 3: Longitudinal Cross Section of the river

After running various simulations in HEC-RAS, water surface profile results are exported to the GIS.

## FLOODPLAIN DELINEATION

Inundation data sets are created from water surface elevation data at each cross-section location in concert with a bounding polygon. The bounding polygon limits the area inundated by water due to such features as levees, bridges and islands, represented in the hydraulic model.

Results exported from HEC-RAS were imported into the GIS using GeoRAS. Data exported from HEC-RAS included water surface elevations at each cross section, velocity information at distributed points along each cross section, and bounding polygon information. The bounding polygon information defined the extent of each cross section as modeled in HEC-RAS for the given flow. Floodplain delineation and velocity data were developed which adhered to the bounding criterion.

Floodplain delineation for each scenario was performed resulting in an inundation depth grid and floodplain polygon (Fig. 4). The polygon can be used as boundary region and the inundation depth can be used for the determination of the real flood risk.

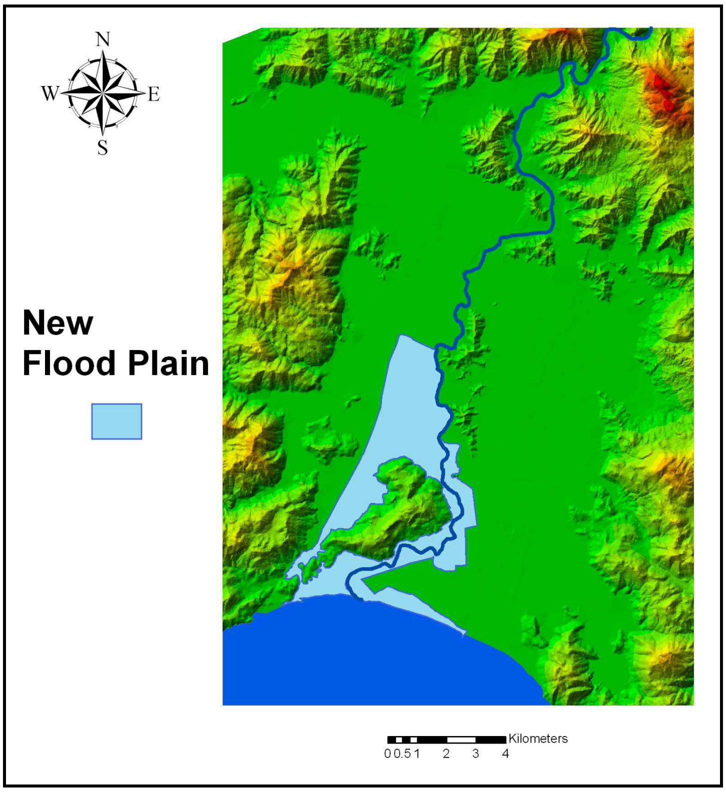

Figure 4 : New Flood Plain found after modeling

## CONCLUSION

In this study, a coupled application of HEC-RAS and HEC-GeoRAS is used to delineate the flood plain and identify the flood risk in Dalaman Plain. HEC-RAS is used for hydraulic modeling and HEC-GeoRAS is used for GIS integration of the results of HEC-RAS.

The HEC-GeoRAS is used successfully to illustrate flooding and to delineate floodplains. A floodplain for any simulated storm event can be visualized by utilizing flood elevations obtained from the model and topography.

The old flood plain and the new flood plain which is found by modeling with HEC-RAS and HEC-GeoRAS is shown in Figure 5. It can be seen from the figure that the use of new model in delineation of the flood plain reduce the flood plain about 60% which also supports the use of new models in flood plain delineation.

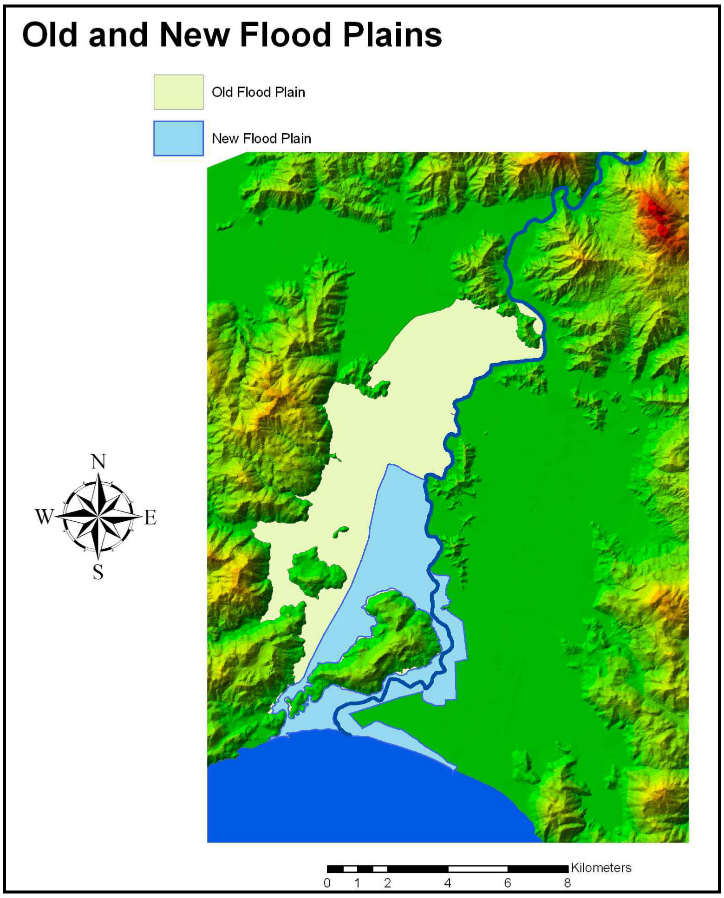

Figure 5: Old and New Flood Plains in Dalaman Plain

The river discharges to the Mediterranean Sea, but none of the possible sea level rise is included in the study. So this study should be developed by including the sea level rise due to inverse wind effect and high sediment load during floods.

Models are tools that can be easily used as decision support tools, but the human factor in the models should not be neglected. Also the user of the model should know the uncertainty and errors that can come from the collected data and must use the model with these errors and uncertainty (Keskin, 2006). The accuracy of the hydraulic model is the most important thing to the success of delineating floodplains. The HEC-GeoRAS simply visualize flood inundation results from the model. Therefore, if model accuracy is compromised, the floodplain delineation should be questionable.

The accuracy of the topographic information is very critical to identify of delineating floodplains in 3 Dimension. In this study, the 1/5000 and 1/25000 scale maps are used which may not be refined enough for some other types of studies. Stream modeling is typically conducted to higher degree of precision. The extent of the floodplain can be very sensitive to small changes in the Digital Terrain Model.

The results of the study indicate that integration of HEC-RAS with HEC-GeoRAS provides an effective environment for both flood risk analysis and mapping. The results showed that traditional methods for delineating flood plain should be replaced with new technological models.

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