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Assessment of Sediments into the Multi-Purpose Reservoir "Modrac"

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Abstract:- Increasingly, and often mutually conflicting requirements for the use of water resources, there is a need for more complex management methods, including the management of the volume of reservoirs. Silt filling of reservoirs is one of the most well-known problems of river hydraulics. Dams and reservoirs, created by damming river flows, cause the retention of river sediment (drag and floating sediment) that comes from the gravitating basins, or sub-basins of the reservoir's tributaries.

By analyzing the sediment transport on the tributaries, and the total amount of sediment deposited in the Modrac multi-purpose reservoir, real data are obtained on the amount of sediment introduced into the Modrac multi-pupose reservoir, the dynamics of sediment input, and the degree of pollution of this type of water body.

The Modrac multi-purpose reservoir is the only available water resource in the region of Tuzla and its surroundings. Acknowledging the fact that the useful volume of the reservoir is limited, and that over time the reservoir is filled with dragged sediment and coal dust as floating sediment, and that consumers - the population, industry and others must be provided with a water supply with a high degree of safety. Excess water needs to be used to the maximum for the purpose of electricity production, and there is a need to optimize the system, i.e. more efficient management of the water resources of the reservoir, i.e. to prove the maximum utilization of the reservoir while continuously providing all the necessary amounts of water to which the Modrac multi-purpose reservoir is connected.

I. INTRODUCTION

The Modrac multi-purpose reservoir was formed in 1964 with the construction of a dam in the Modrac strait. It is formed by the Spreča and Turija rivers with their tributaries. The total area of the basin in the profile of the dam is about 1189.00 km².

➢ *The Modrac Multi-Purpose Reservoir Solves Several Water Management and Extremely Economic Aspects:*

- Provision of technological water for the economic capacities of Tuzla and Lukavac,
- Providing the hydrobiological (water management) minimum for diluting waste water that is discharged into the Spreča River downstream of the reservoir,
- Gasification of large water waves by the retention effect of the reservoir and prevention, or significant reduction of floods in the valley of the river Spreča downstream of the reservoir,
- Increase in the flow of the river Spreča downstream of the reservoir in the summer months.
- Since the Modrac reservoir was built as a multi-purpose reservoir, with certain restrictions, the reservoir is also used for electricity production, fish farming, tourism, recreation and water sports, and more. More recently, there has been a decision to use the waters of the Modrac reservoir to supply water to the population of the cities of Tuzla, Lukavac and Živinice.

A natural process, conditioned by the erosion production of deposits in the reservoir basin. In the specific case of the Modrac multi-purpose reservoir, in addition to this natural process, there is also an anthropogenic factor of reservoir filling, related to mining activities in the wider area of the reservoir (to a much lesser extent, other polluting activities in the catchment area of the Modrac multi-purpose reservoir).

II. MODRAC MULTI-PURPOSE ACCUMULATION MANAGEMENT

Dam and reservoir management is an extremely complex process, and it takes place according to established Operation Plans, in terms of distributing the available water volume of the Modrac multi-purpose reservoir. The basic conditions that dictated the technical management solution were based on several boundary conditions:

- Available (useful) storage volume,
- Provision of a high degree of security of technological water supply to the economic capacities of Tuzla and Lukavac,
- Provision of the hydrobiological (water management) minimum,
- Maximum use of the excess amount of available water for the production of electricity at the Modrac (Operation Plan from 1998).

Fig 1 Dam and Accumulation Modrac

III. HYDROLOGICAL - HYDRAULIC ANALYSIS OF THE WATERSHED AND SEDIMENT INTO THE MODRAC MULTI-PURPOSE RESERVOIR

The Modrac multi-purpose reservoir is located in the Tuzla Canton, in northeastern Bosnia. The main tributaries of the reservoir are the Turija River and the Spreča River, and the aforementioned tributaries can be defined as the two main sub-basins in the Modrac reservoir basin.

Figure 2 shows an excerpt from www.mghydro.com that represents the catchment area of the Modrac reservoir.

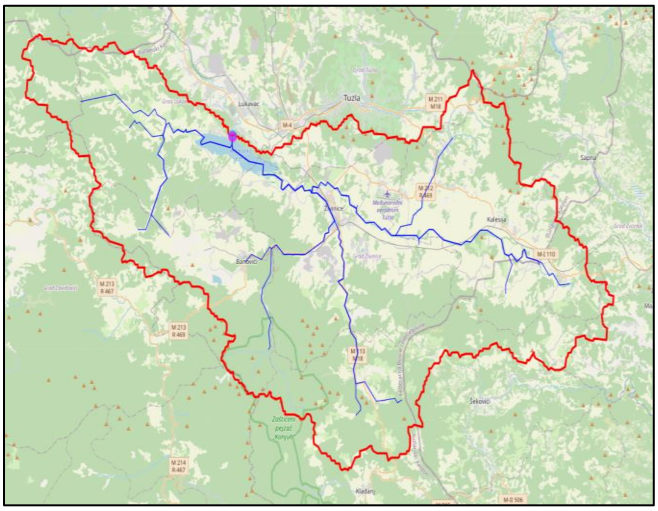

Fig 2 Catchment Area of the Modrac Multi-Purpose Reservoir

The experimental part was done in the ArcGIS software package, in which the preparation of all the foundations and input data for the calculation, the modeling of the Modrac multi-purpose reservoir basin, and the hydrological hydraulic calculation was done in ArcSWAT. In the mentioned software on the geoinformation platform (GIS) the results were obtained: the flow of the main watercourses in the watershed area of the Modrac multi-purpose reservoir, the saturation of the soil and the transport of sediments in the rivers and their transport to the Modrac multi-purpose reservoir.

- *The Main Datasets within the Hydrometeorological Datasets are Hydrological Data, such as:*

- Water Flow,
- Sediment Concentration,
- Time Data,
- Other Spatial Information Describing the Location of Hydrometeorological Stations.

The input data for the modeling of the watershed area, which will simulate the actual situation in the watershed, are: DEM model, land use and land cover, soil type, and weather data (precipitation, temperature, wind speed, solar, humidity) from weather station in this watershed area.

The hydrological cycle is based on the water mass balance. Hydrological processes and the application of the SWAT model are simulated daily for each HRU - hydrological unit, with time steps using the following soil water balance equation (Neitsch et al. 2011).

$$SW_t = SW_0 + \sum_{i=1}^{n}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (1)$$

Where is:

SW_t – final soil water content (mm)

SW_O – initial soil water content (mm)

R_{day} – amount of precipitation on day (mm)

Q_{surf} – amount of surface runoff on day (m^3/sek)

E_a – amount of evapotranspiration on day (mm)

w_{seep} – amount of percolation and bypass exiting the soil profile bottom on day (mm)

Q_{gw} – amount of return flow on day (mm)

The Penman-Monteith method of real evapotranspiration as well as potential transpiration is used for calculation. (Trajković, 2007).

Modified method CN curves with a modified rational method are used to calculate surface and peak runoff.

The universal equation of soil erosion and amount of sediments was defined by Williams in 1995:

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$$sed = 11,80 \times (Q_{surf} \times q_{peak} \times area_{hru})^{0,56} \times K_{usle} \times C_{usle} \times LS_{usle} \times CFRG \quad (2)$$

Where is:

sed – amount of sediment (t/dan)

Q_{surf} – amount of surface runoff on day (mm)

q_{peak} - pik stope površinskog oticanja (m^3/sek)

$area_{hru}$ – area of the hydrological unit HRU (ha)

K_{usle} - soil erosion factor (is taken: 0,013 t/ha)

C_{usle} - land cover factor and management

LS_{usle} – topographical factor

CFRG - coarse fragment factor

IV. RESULTS OF HYDROLOGICAL - HYDRAULIC ANALYSIS

The calculation was made for the entire observed series of 8 years (2014 – 2021), with the observation of annual precipitation and the interrelationship of the pollution load, which in this case is floating and dragged sediment in watercourses located in the Modrac multi-purpose reservoir basin. The duration of the dry period was taken as the period of hydrological minimum (May - September), while the rainy period was taken as the time of hydrological maximum (November - April). Data on precipitation and pollution load are presented in the following table (table 1).

Table 1 Data on Precipitation and Pollution Load for the Observed Series

Year	Precipitation mm	Pollution burden (sediments) t/ha
2014	1430,20	319,62
2015	870,80	47,06
2016	989,20	48,78
2017	982,90	58,40
2018	966,50	48,46
2019	896,90	41,76
2020	915,60	55,08
2021	814,00	28,89

The most relevant period is May 2014, when the hydrological maximum occurred (the highest recorded water level of the Modrac multi-purpose reservoir and precipitation ever measured). The following diagram shows the results from May 2014 and the interrelationship between precipitation and the amount of sediment that appeared in this period.

The diagram shows the values of average daily precipitation and average daily sediment transport in the catchment area of the Modrac multi-purpose reservoir, for the year 2014.

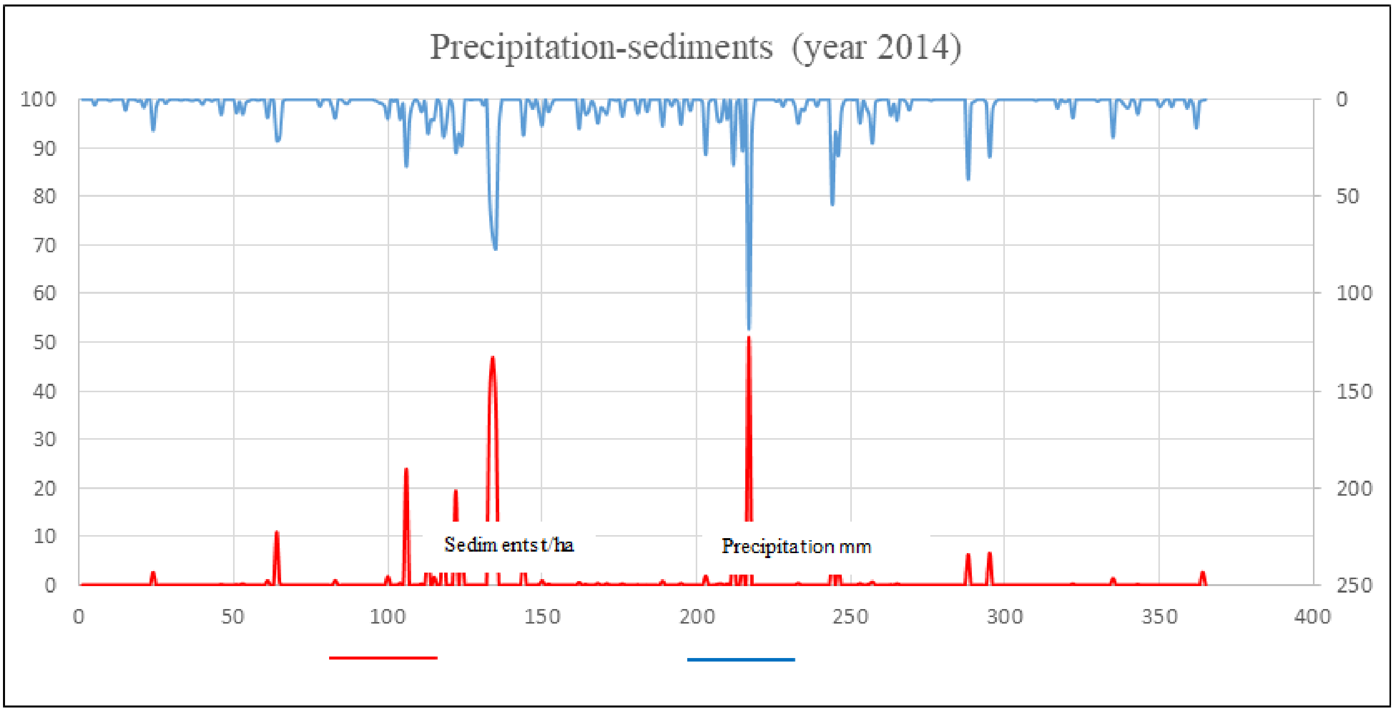

Fig 3 Diagram of Precipitation and Sediment Transport (Sediment) for the Year 2014

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The maximum amount of precipitation (average daily values) is 118.30 mm, which was recorded on August 5, 2014.

The maximum sediment transport obtained by SWAT modeling is 51.04 t/ha, on August 5, 2014.

From the precipitation-sediment diagram, it can be concluded that the calculated mean daily sediment transport follows the curve of recorded mean daily precipitation in the Modrac multi-purpose reservoir basin.

In Table 2, in the software package 3Bstat, the results of simple regression were calculated and presented for two sets, precipitation and sediments. The set of precipitation was taken as the explanatory variable X, and the set of sediment results was taken as the dependent variable Y.

Table 2 Simple Regression (Extract from 3 Bstat Software)

Analysis No: 4				
Simple regression				
Explanatory variable X = Precipitation			**Dependent variable Y = Sediments**	
Sediments = -1,334 + 0,5898 * Precipitation				
Parameter	Rating	Stand. Error Rating	t-value	*p*-value
Section	-1,334	0,82190	-1,6231	0,1158
Slope	0,5898	0,03561	16,5833	0
Coefficient of determination r^2 = 0,9076 (90,7593 %)				
Standard regression error s = (3,9463)				
Comment:				
The score is not significant at 0.05				
The slope rating is significant at a level of 0.05. The precipitation variable affects the sediment variable				

From Table 2. a regression analysis with all its elements is visible (evaluation section, slope rating, coefficient of determination R^2, standard regression error). The value of the coefficient of determination R^2 =0.9076 or 90.76% indicates that the variations of the variable Y are almost entirely explained by the regression line, indicating a strong regression relationship between the test sets.

The table also shows that: section rating is significant at the level of 0.05, and slope rating is significant at the level of 0.05, and that the precipitation variable affects the sediment variable.

➢ *There is also a Mathematical Formula:*

Sediments (t/ha) = -1,334 + 0,5898 * Precipitation (mm)

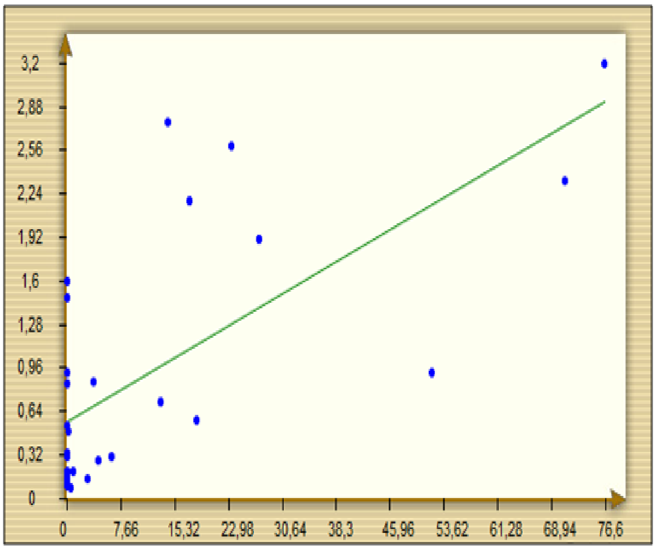

Fig 4 Regression Line Scattering Diagram Precipitation

V. CONCLUSION

In this research work, the topic is addressed: "Assessment of sediments into the Modrac multi-purpose reservoir".

Research goals were set and processed for the purposes of analysis and calculation of sediment intake estimates in Modrac multi-purpose accumulation, intake dynamics for the observed 8-year range (2014-2015 year), these measures to mitigate the intake of application in the multi-purpose accumulation of Modrac. During the work on this research, the exact data from the recording of the bottom of the reservoir and the coastal zone, which were carried out in 2012 and 2022, were taken into account.

For the relevant precipitation and other hydrometeorological data (temperature, wind speed, air humidity, solar radiation, location of the hydrometeorological station), of appropriate duration and intensity, were taken into account and analyzed through the hydrological calculation according to the SCS method and obtaining the CN curve, which were integrated in the ArcGIS/ArcSWAT software package.

According to the set goals of the research, it was necessary to determine the amount of sediment produced in the catchment area of the research polygon, all depending primarily on hydrometeorological data, the type of soil (susceptibility of the soil type to erosion) and the purpose of the surface on which the erosion process is carried out. After determining the amount of sediment that is produced at each point of the catchment area, it was necessary to perform and analyze the dynamics of sediment input into the Modrac multi-purpose reservoir.

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By reviewing the incoming hydrometeorological data taken from the Modrac rain gauge station, it was determined that 2014 was the year with the most precipitation, which amounted to P_{2014}=1430.20 mm (in May 2014, due to precipitation, the highest level of the Modrac multi-purpose reservoir was recorded, which was 203.42 mnm), and that 2021 is the year with the least amount of precipitation during the year and it amounted to P_{2021}=814.00 mm.

A correlation and regression relationship between precipitation and amount of sediment was established. The value of the coefficient of determination is R^2 =0.9076 or 90.76%, indicating that the variations of the variable Y are almost entirely explained by the regression line, which indicates a strong regressive relationship of the examined sets.

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