AN OVERVIEW OF THE PALIĆ LUDAŠ LAKE SYSTEM

Mirjana Horvat [1]
Zoltan Horvat [2]

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Summary: *This paper presents an overview of the Palić Ludaš lake system, which is located in northern Bačka near the town of Subotica in Serbia. The main water bodies on this domain are Lake Palić, Lake Omladinsko and Lake Ludaš. Lake Palić is divided into a series of Sectors and Lagoons. The most important channel in this system is the Palić-Ludaš channel, that connects Lake Palić and Lake Omladinsko with Lake Ludaš. This paper gives a description of this lake system, taking into account all the major hydraulic structures. Also, an outline and preliminary analysis is given of all the available measured data on the domain. These measurements consist of surface water discharge into Lake Palić, precipitation, temperature and wind speed, as well as water quality parameters such as* BOD_5*, COD, total phosphorous, suspended solids and total nitrogen.*

Keywords: *hydraulic data, water quality data, Palić Ludaš lake system, hydraulic structures*

1. INTRODUCTION

The development of a sound monitoring system for a selected domain requires a certain amount of preparatory work. Relying on a thorough examination of the selected lake system, one can propose a water resources management policy that would allow future decision makers to acquire a better insight of the considered system, hence it's more efficient governance.

This paper focuses on the preliminary works carried out on the Palic Ludas lake system, in order to allow a better insight into the current situation, and consequently a more competent measurement campaign. The most important water bodies on this domain are Lake Palić (total surface area of cca. 590*ha*), Lake Omladinsko (total surface area of cca. 13ha) and Lake Ludaš (total surface area of cca. 358ha). Lake Palić is divided into four Sectors, while the firs Sector itself is divided into three Lagoons. The most important channel in this system is the 4.5*km* long Palić-Ludaš channel, that connects the first two lakes with Lake Ludaš.

[1] doc.dr Mirjana Horvat, dipl.inž. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, tel: +381 24 554 300, e-mail: isicm@gf.uns.ac.rs
[2] doc.dr Zoltan Horvat, dipl.inž. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, tel: +381 24 554 300, e-mail: horvatz@gf.uns.ac.rs

2. THE PALIĆ LUDAŠ LAKE SYSTEM

The firs step in the preliminary work is collecting the existing information regarding the area of interest. In this case, these included old design projects for hydraulic structures, research different authors conducted on the area of the lake system over the years, as well as preliminary field survey in order to acquire in situ information about the researched area. The presented map (Fig. 1) contains the basic information concerning the researched lake system.

Figure 1. The Palić Ludaš lake system

The main inflow of surface water into Lake Palić is the outlet of the Waste Water Treatment Plant Subotica (WWTP Subotica). The treated wastewater enters the first Lagoon through the outlet of the WWTP Subotica, marked on Fig. 2 as structure 1. From here, the water can flow through structure 2 into the second Lagoon. Structure 3 is a culvert that allows water from the second Lagoon to flow two ways optionally, to the third Lagoon or tho the second Sector. The connection of the second and third Sectors is also provided through a culvert, marked as structure 4. Following is Sector 3 from which water enters the fourth and last Sector of Lake Palić via structure 5 that consists of a gate and a weir (Fig. 2 on the right).

Figure 2. Lake Palić and it's Sectors

Finally, the water leaves Lake Palić through a circular underground culvert (pipe) that connects Lake Palić (Sector 4) with Lake Omladinsko (structure 6 on Fig. 3). The outflow from Lake Omladinsko is accommodated by a broad crested weir, after which the water flows through a pipe (structure 7 on Fig. 3), and enters the channel connecting Lake Omladinsko with the Lake Ludaš (the Palić-Ludaš channel). The inflow into Ludaš is marked as point 8 on Fig. 3. Ultimately, the water exits Lake Ludaš over a weir (structure 9, Fig. 3). The point marked 10 on Fig. 3 represent the inflow of a the Kireš channel to Lake Ludaš.

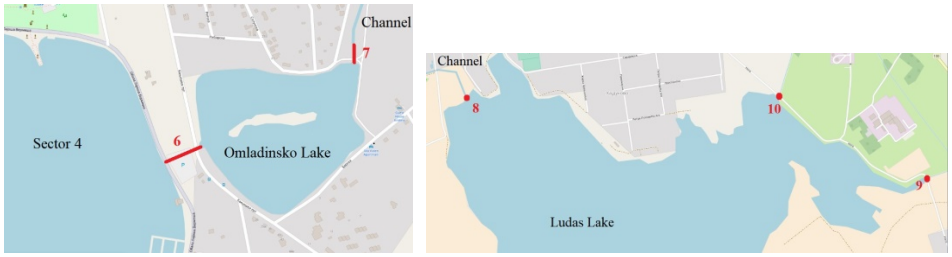

Figure 3. Lake Omladinsko and Lake Ludaš

3. AVAILABLE DATA

In order to prepare a comprehensive model, a series of measurements regarding hydraulic and water quality parameters are necessary. The first step is collecting the already existing measurements. As a part of the management process of the WWTP Subotica, the Public Utility Company "Waterworks & Sewerage" Subotica conducts daily measurements of the following parameters that were of interest for the purpose of this research: biological oxygen demand (BOD_5), chemical oxygen demand (COD), total nitrogen, total phosphorous and suspended solids and the total outflow (discharge of water into Lagoon 1).

The hydrograph of outflow from the sewage treatment plant into Lagoon 1 is given on Fig. 4 for the time period between 1st of October 2016 to 31st of December 2017. Although with some variation during this time period, it can be stated that the sewage treatment plant releases the discharge around $0.4 m^3/s$ into Lagoon 1 of Lake Palić.

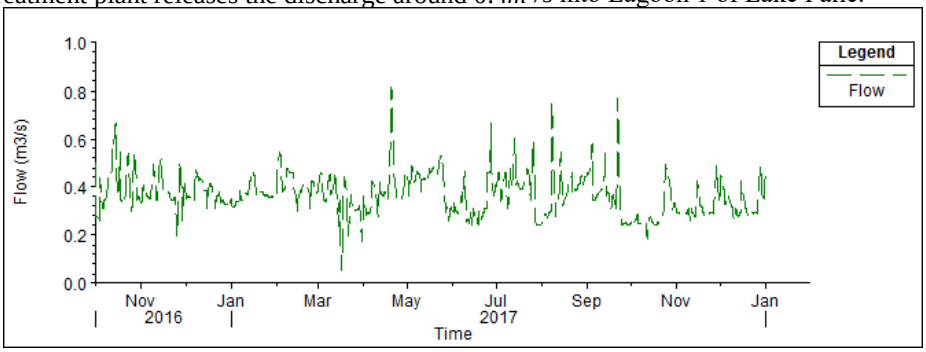

Figure 4. Hydrograph from the sewage treatment plant

The data concerning precipitation relies on measured values for the considered period, and is given on Fig. 5. Evaporation from the free water surface of the lakes on the system was computed using measured temperatures and wind speeds in the researched area. Since the evaporation is not directly measured, one should keep in mind that these computed values can deviate from real ones. The values of evaporation are presented on Fig. 5.

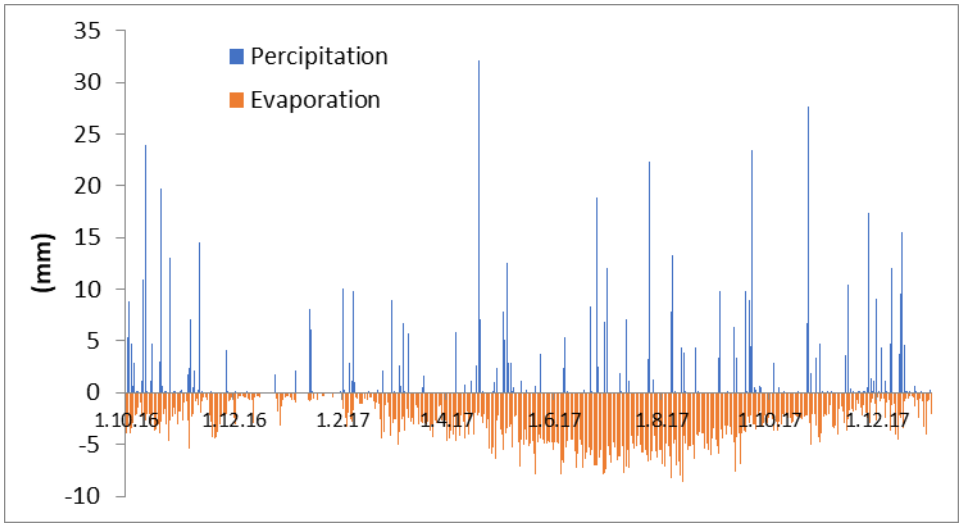

Figure 5. Measured precipitation and computed evaporation

With respect to hydraulic structures on the system, Lagoon 1 and Lagoon 2 are connected with a box culvert. Lagoon 2, Lagoon 3 and Sector 2 are mutually connected with a "Y" shaped box culvert (width 1*m*, bed elevation 101.7*m*). Sector 2 and Sector 3 are connected with a box culvert (width 1*m*, bed elevation 101.7*m*). The water leaves Sector 3 into Sector 4 via a structurer that consist of a gate (width 1*m*, bed elevation 101.5*m*) and a weir (width 6*m*, crest elevation 102.7*m*). Sector 4 and Lake Omladinsko are connected with a pipe culvert that is fully submerged (length 109*m*, diameter 1.2*m*). Water flows form Lake Omladinsko into the Palić-Ludaš channel through a broad crested weir (width 9*m*, crest elevation 101.45*m*) and a subsequent pipe (length 50*m*, diameter 1.2*m*). The most important hydraulic structure on the Palić-Ludaš channel is a broad crested (width 1.4*m*, crest elevation 98.14*m*) weir preceding a 1.41*m* drop in bed elevation. The water leaves Lake Ludaš over a weir.

Additionally, the City of Subotica regularly publishes measurements conducted by the Public health Institute in Subotica. These measurements are done in all four Sectors of Lake Palić, as follows: along the first (L1), second (L2) and third levee (L3), in the middle of the fourth Sector (MS4) and at the Lake Palić's outflow (OS4). Data is also gathered in the Palić-Ludaš channel (Ch), and in Lake Ludaš itself (on the north part of the lake near the inflow (NLudas), in the middle (MLudas) and on the south of the lake (SLudas)). These measurements are carried out once a month and include the following

parameters that are of interest for this research: BOD_5, COD (using two different methods), total phosphorous, suspended solids and total nitrogen.
Figures 6, 7, 8, 9, 10 and 11 represent the water quality measurements for the year 2017, at previously discussed locations for total nitrogen, total phosphorous, suspended solids, BOD_5, $COD_{C_2Kr_2O_7}$ and COD_{KMnO_4}, respectively.

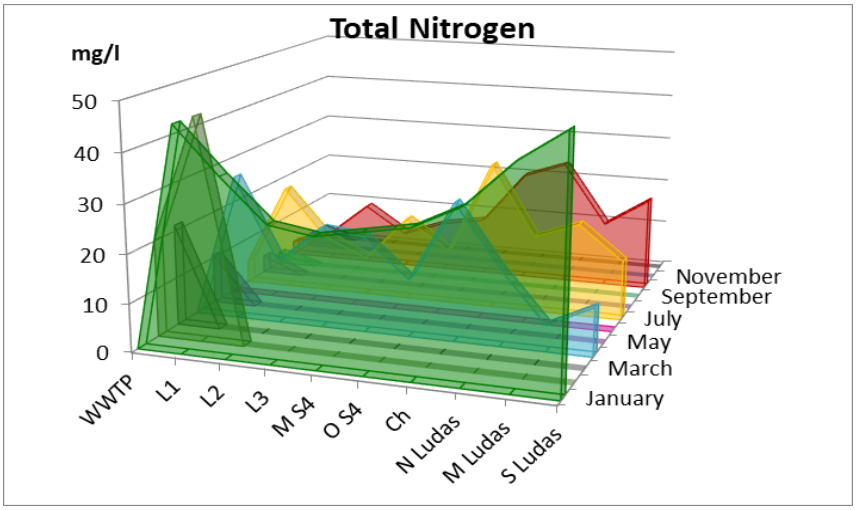

Figure 6. Total Nitrogen concentration in 2017

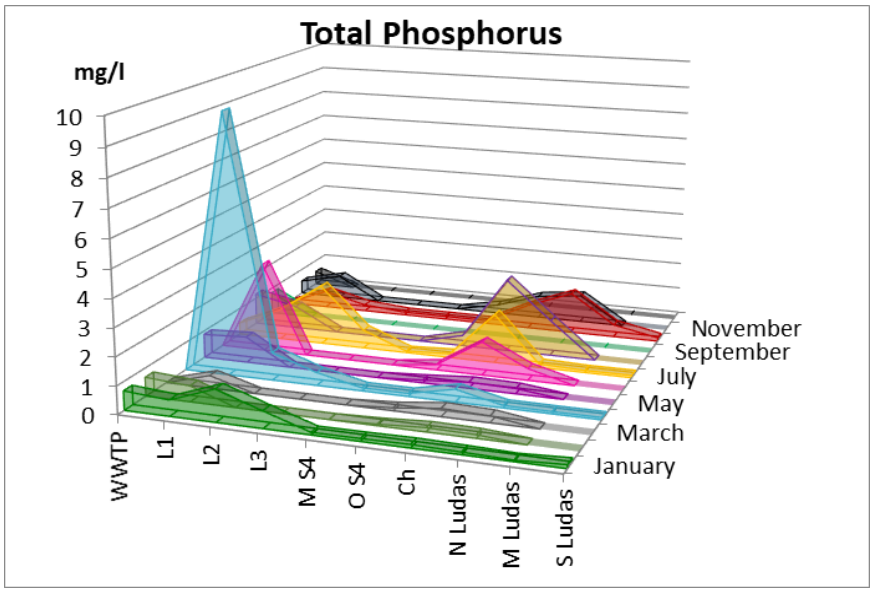

Figure 7. Total Phosphorus concentration in 2017

Although, a few tendencies can be identified on these charts (e.g. in January there was a high concentration of total nitrogen in the whole system) there can be no conclusions regarding the water quality changes in the system during the year.

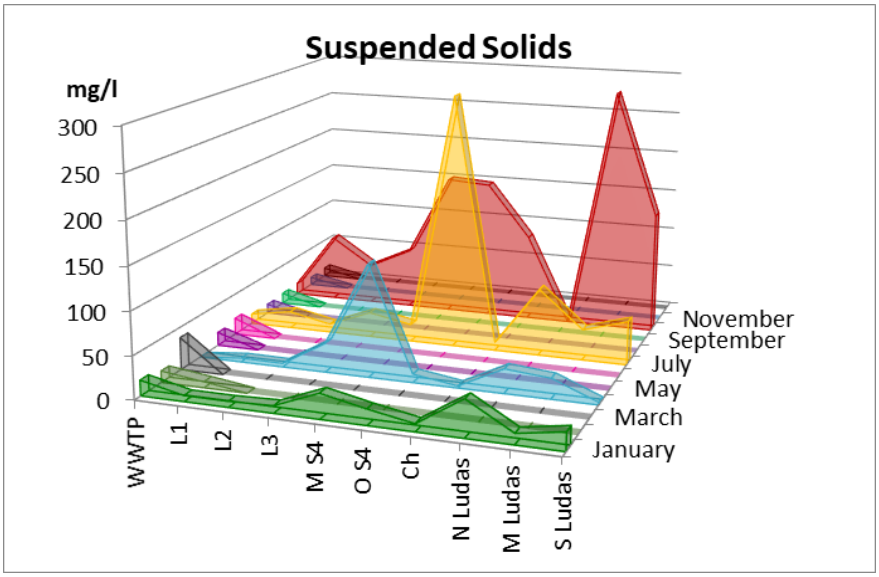

Figure 8. Suspended solid concentration in 2017

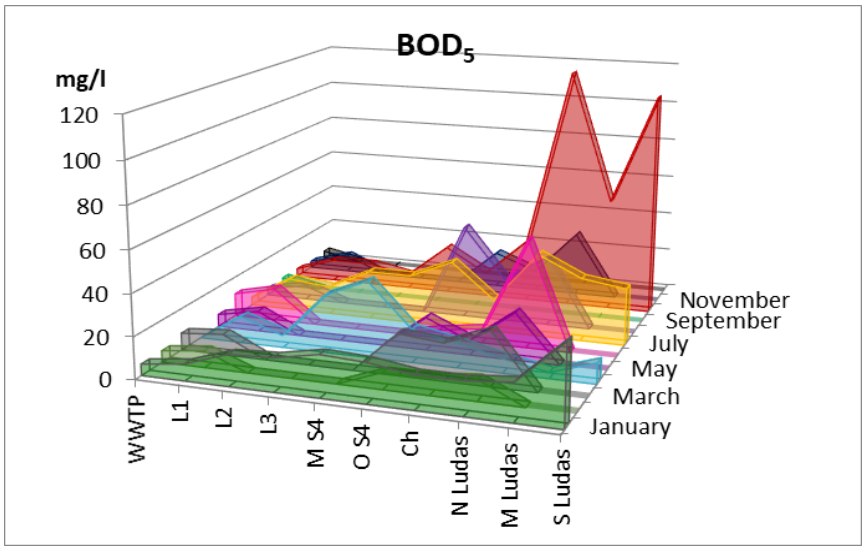

Figure 9. BOD_5 concentration in 2017

One of the reasons for this is that complete measurements are available only for January, April, July and October . The rest of the year measurements of some of the parameters were completely omitted, while others were measured on some parts of the system. Consequently, it isn't possible to draw a reliable conclusion. For example, from Fig. 6 it could be concluded that the total nitrogen decreases throughout the system starting from January through the year, but the missing measurements are considerable and could givea wrong impression.

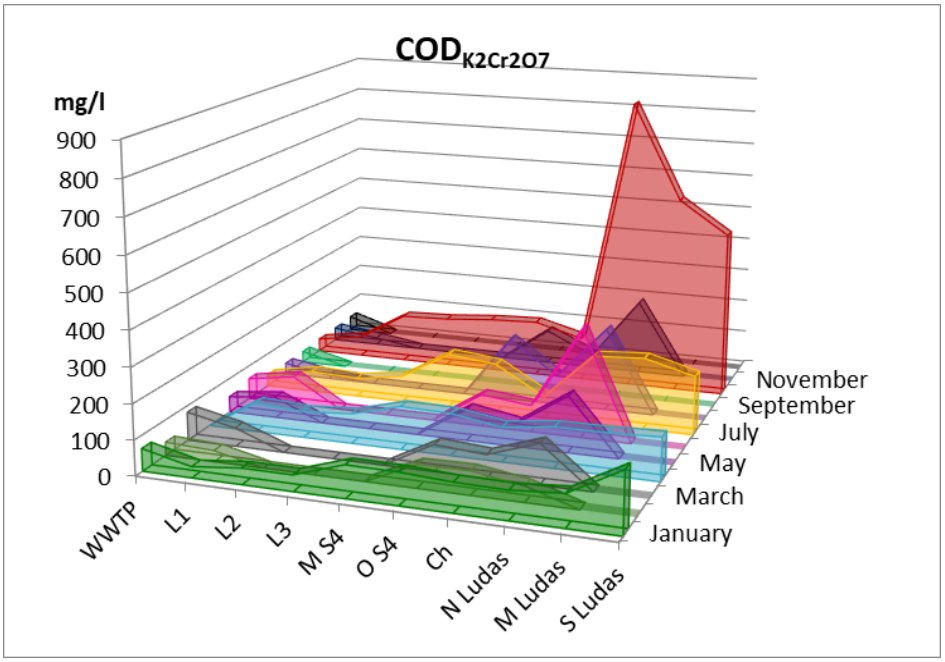

Figure 10. $COD_{C_2Kr_2O_7}$ concentration in 2017

Also, there seems to be a tendency of increasing BOD_5 and COD towards the outflow of the system. This could suggest a possible contaminant source in the system, that should also be investigated.

A more complete set of measurements would make possible conclusions regarding the water quality such as: Is there an annual tendency? Does the WWTP Subotica affect the system and in what way? How fast does the system react to the water that comes in from the WWTP? How do the groundwater and precipitation influence the water quality?

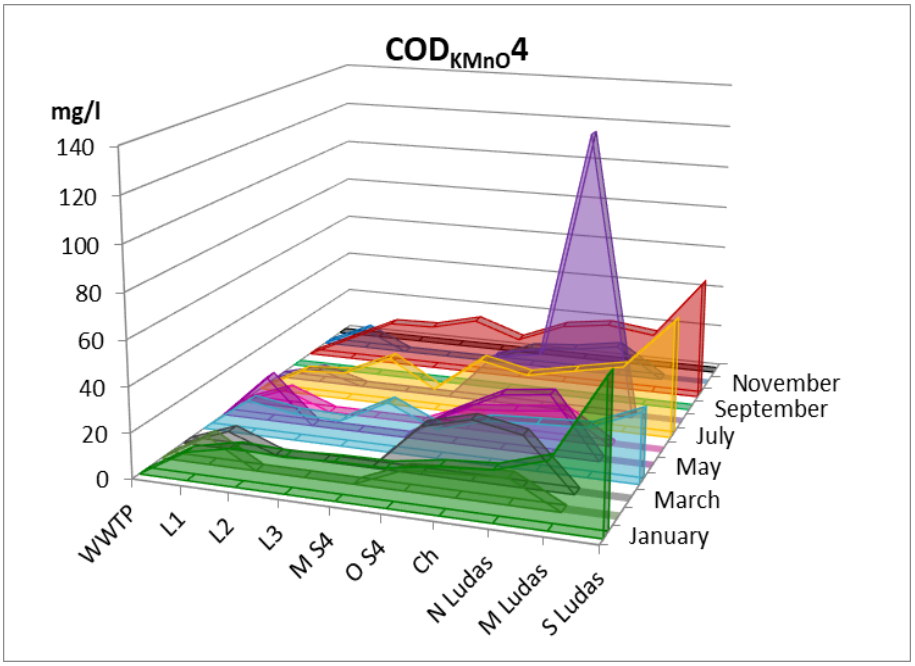

Figure 11. COD_{KMnO_4} concentration in 2017

4. CONCLUSION

The Palić-Ludaš lake system consists of a fairly complex chain of water bodies and channels. In order to attain a useful tool for this system's management, a water quantity (water budget) and water quality model should be established. In order to achieve this, the current discharge, precipitation, temperature and wind speed measurements are quite satisfactory. However, the hydraulic measurements should be complemented with groundwater elevation measurements in appropriate locations. Water quality measurements should by carried out with greater frequency, at least in the beginning stages of the water quality model development. Since the exact location where the measurements are conducted in the Palić Ludaš channel isn't known, it is impossible to tell the reason of the increasing values of BOD_5 and COD. Hence, measurements should be carried out in multiple points along the channel in order to identify the cause of this occurrence. Later, these water quality measurements can be more sporadic and can serve the purpose of validating the model.

Acknowledgements

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ПРЕГЛЕД СИСТЕМА ЈЕЗЕРА ПАЛИЋ ЛУДАШ

Резиме: *Овај рад представља преглед система језера Палић Лудаш, који се налази на северу Бачке надомак Суботице у Србији. Најбитнија водна тела у овом подручију су језера Палић, Лудаш и Омладинско језеро. Језеро Палић је подељено у низ сектора и лагуна. Најзначајнији канал у овом систему је канал Палић-Лудаш, који повезује језера Палић и Омладинско са језером Лудаш. Рад даје опис овог система језера, узимајући у обзир све релевантне хидротехничке објекте. Такође је дата прелиминарна анализа доступних мерених података на домену од интереа. Ова мерења се састоје од протицаја површинске воде у Палић, висине падавина, температуре и брзине ветра, као и параметара квалитета воде као што су* $БПК_5$*, ХПК, укупан фосфор, укупан азот и суспендоване материје.*

Кључне речи: *хидраулички подаци, подаци квалитета воде, систем језера Палић Лудаш, хидротехнички објекти*