KATLANOVO MARSH

DOI: https://doi.org/10.18509/GBP22075m
UDC: 556.56:556.1.04(497.711)

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ABSTRACT

Katlanovo Marsh is a main wetland hydrological object in the Skopje Plain, Macedonia. According to this classification, Katlanovo Marsh belongs to type of "Tp". The scope of the paper is to make a hydrological research one of the significant wetland objects in Macedonia, Katlanovo Marsh. Much smaller, but also important hydrological object is a permanent small lake, Katlanovo Pond, covering area of 5.130 m2, and have a water volume of 11.286 m3. The performed analysis created new morphometric and hydrometric results about the Katlanovo marsh and the pond, elsewise. Additionally, the hydrological basic regime is analyze also, using the nearby piezometric station Petrovec. In order to complete the hydrological work, the implementation of the Penmann-Monteaux equation helped to calculate the evapotranspiration, a Rational Method to calculate the runoff inflow and after that, with the simple water balance equation usage, which helped to estimate water budget of the Katlanovo Pond.

Keywords: wetlands, marshes, mapping, physiography, hydrology, Macedonia.

INTRODUCTION

Location

The country water belongs predominantly to the Aegean Basin with 22319 km2 and to Adriatic Basin with 3350 km2. The main river basin with its tributaries Lepenec, Pchinja, Bregalnica, Treska and Crna River has a drainage area in Macedonia of 20535 km2 is Vardar, with length of 388 km (301 km in Macedonia), which streams directly in Aegean Sea at Termaikos Golf near city of Thessaloniki in Greece. The second basin belongs to Strumica River with length of 114 km, 81 km in Macedonia (right tributary of river Struma in Bulgaria). The main river in Adriatic Basin is Crni Drim with two large lakes Oh¬rid and Prespa (connected with underground inflow in Ohrid Lake) and largest Crni Drim's tributary from the north, river Radika [20]. According to the relief structure, Macedonia has many plains, which before 1950 were covered by large wetlands. Today the area cover by the wetlands decreased significantly, which caused many changes in the country ecosystem.

Katlanovo Marsh is a main wetland hydrological object in the Skopje Plain, Macedonia. It is located in the lowest, southeastern part of the plain, between the river Vardar on the west and the Pchinja River on the east, with the coordinates N and E and elevation of 224 m a.s.l. Near this natural feature, on the north side, is the main country motorway (E75) and on the west is flat irrigated part of the Skopje Plain.

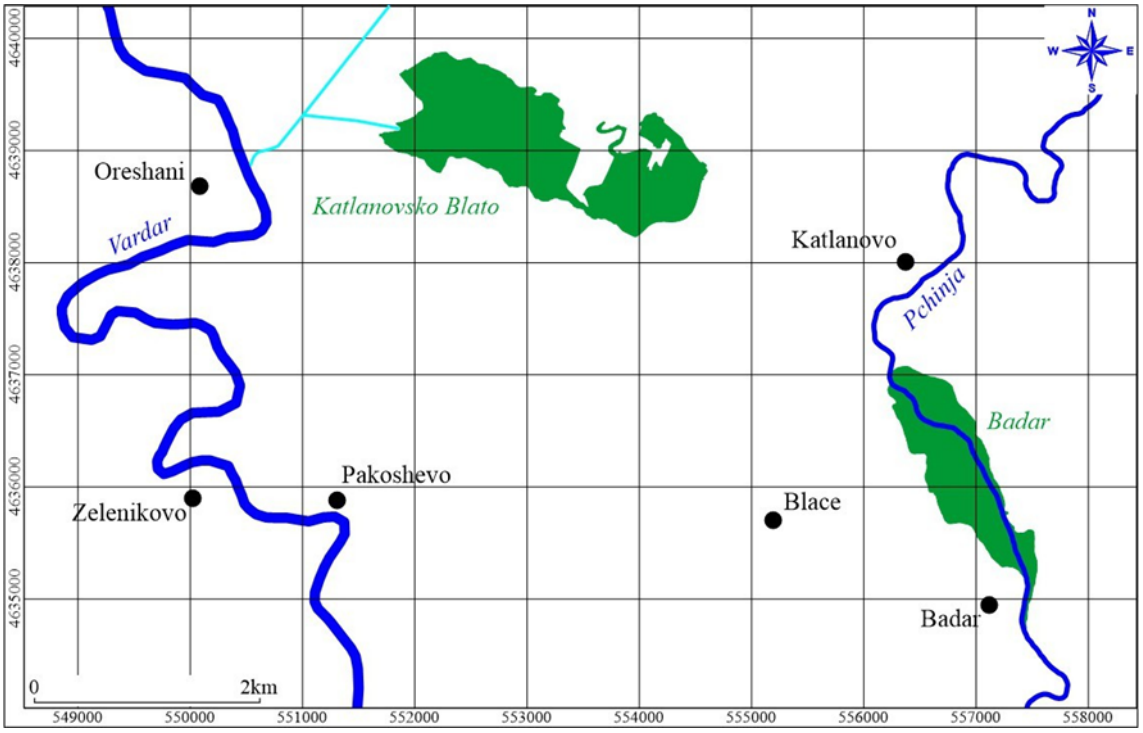

Figure 1. Location of the marshes Katlanovo and Badar

Climate characteristics

Skopje valley's climate touches the warm air that circulates from the Aegean Sea, especially in the summer period, and as such constitutes a distinct thermal valley area in which climate affects the temperature regime with very hot summer temperatures and an intensive evapotranspiration process, which strongly affects the permanently flooded Katlanovo March. The wind rose shows predominantly North and Northeast direction, which allows transport of very cold air masses in the winter and absolute minimum air temperature lower than -20°C. From the other point of view the Skopje valley is surrounded by high mountains, which maintain direct Influence of Mediterranean climate from the southeast, while from the north and north west penetrate free movement of continental air, which in winter resulting especially with low temperatures and a marsh water frosting. Additionally the largest problem of this part of the Skopje Plain is air pollution which is strongly concentrated in this lowest area of the plain. Annual quantity of rainfalls in the period from 1991-2010 year on average is 489.6 mm.

According to the annual rainfall values we can make a difference in between changed continental precipitation regime with maximum rainfall in November by 52 mm and December by 53 mm and May 54 mm and a minimum rainfall we have in months August 28 mm and February 34 mm. The average annual precipitation sum is 540 mm. The Vardar Valley in the Macedonia lies on the border of two large vegetation-geographical areas: Mediterranean and Euro Siberian [25], which causes the interference of the influences of the mild Mediterranean and sharp continental climate.

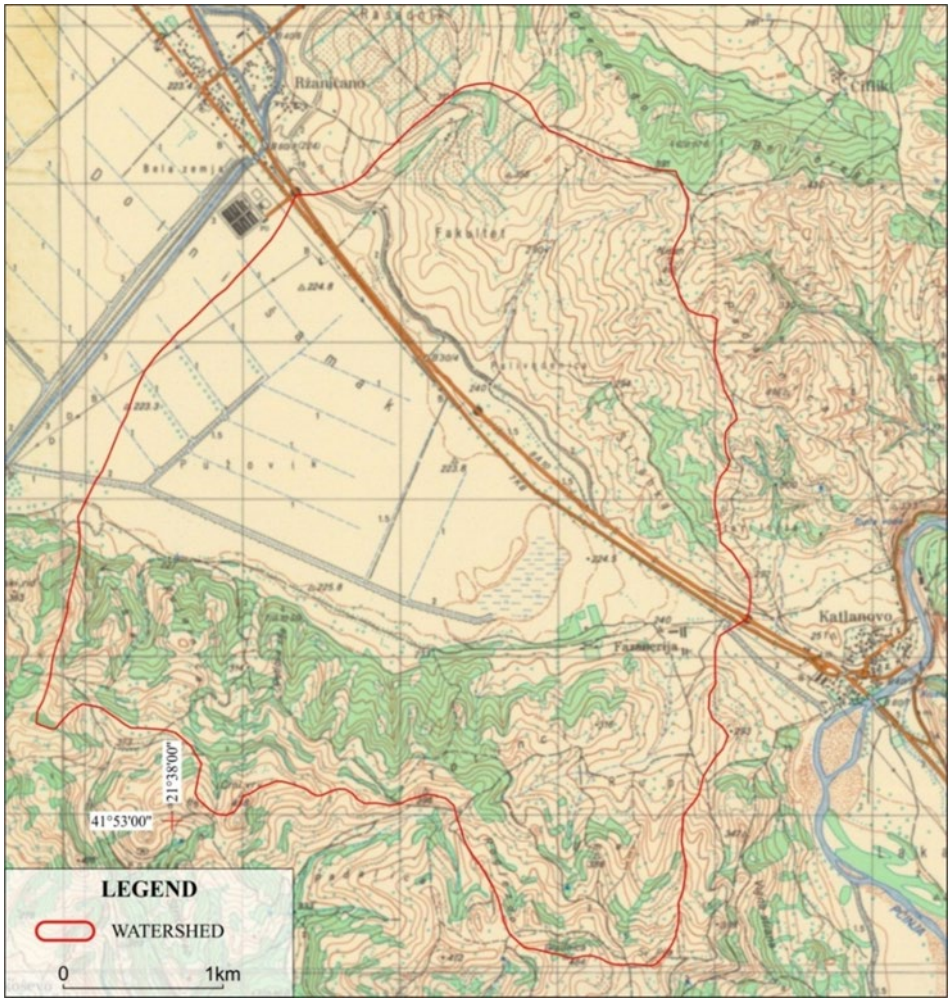

Figure 2. Topographic location of the basin of the Katlanovo Marsh in the south-east part of the Skopje Valley

This watershed segment belongs to the Aegean Basin, through the main water course Vardar. Skopje Valley is under significant Mediterranean and moderate continental climatic influence, with cold winters and hot summer season. The precipitation maximum occurs in the spring and precipitation minimum in the summer.

The result of these two influences is existence of a particular local climate highly modified by the features of the valley. The average annual precipitation in Skopje valley is 540 mm, so this valley may be characterized as one of the drier regions in Macedonia, with approximately 100 mm precipitation per year below the country average.

However, due to the high altitude difference of the tectonically highly developed relief with different exposure and inclination, the high mountains and deep depressions, the Vardar basin finds great differences from the nival conditions of the high mountains to the semi-arid areas of the lowest parts of the depressions around Vardar in the middle course. On the highest mountains, the snow cover is kept up to half a year, from the end of November to the beginning of June, while in the southernmost regions of Gevgelija, the occurrence of weak and short-term snowfall occurs once a few years. The Mediterranean climate along the valley of Vardar is present to Demir Kapija and in the north its changed influence is felt to the edge of the Skopje valley and the valleys of its tributaries. All this conditions in the Vardar basin to have four climatic regions: a

Mediterranean climate region, mixed Mediterranean and continental climate regions, continental climate regions and mountain climates.

Landscape

Tectonically, the working area belong to Vardar geotectonic zone, which was generally flooded during the Pliocene period. Besides, the numerous mountains in the country, there is no larger mountain around the study area, but Skopje Plain and two significant gorges, Baderska on Pchinja and Taorska Gorge on river Vardar. The Katlanovo Marsh was formed from the former historical Skopje Lake, which was a part of the historical Aegean Lake [3]. Elsewise, the pilot site landscape is a composition between flat cultivated plain, surrounded by several lower hills, and a massive human objects as motorway, Gas Station, Pheasantry and international Skopje Airport on several km.

On the south of the marsh basin there are to lower peaks Taninci (396 m) and Crni Vrv (458 m), and in the foothill the main Pheasantry which make a natural south border of the marsh. On the east, there is a flatter pass in relief, which is a natural watershed and divides the river Pchinja and River Vardar waters with abovementioned gauges. Beside this small pass, where the motorway pass there is the Pchinja riverbed in just 4 km distance from the Katlanovo Marsh.

Elsewise the previous study determine that the whole site covered 125 ha, located on Skopska Kotlina Basin, near rivers Vardar and Pcinja, and the village Katlanovo. Since 1960 water has been extracted and many of 95% of area is drainage. Present situation: only 5% of locality have fragments of wetlands characteristic [17].

Figure 3. Landscape of the Katlanovo Marsh (Photo: Markoski Bl., 2019)

The main marsh has still natural boundary, but it is predominantly bordered with huge anthropogenic objects. The frame of the marsh water aquatorium is oval, with a length direction NE-SW and the wide direction NW-SE. The total area of the under the protection is 70 ha. The marsh is the last final form of the extinction/disappearance of the former Skopje Pliocene Lake, formed by Aegean Lake [3]. It began with the elevation of the Vardar riverbed with a layer that deposited the water that flowed from Vardar from the north side. Between Lake and Vardar there used to exist the riverbed of the river Michkichka. Through it during the high water level Vardar poured into the Katlanovo Pond and then it increased its surface, flooding this part of the field until village Idrizovo. That is why this part of Skopje is known as Blatia (Marshland area). Elsewise, the lake from its normal surface area of 4,24 km2 increased to an area of 10 km2. However, after 1930 significant land reclamation was undertaken and the shamak was dried, and the surface of the lake significantly decreased

These works were extended in the second half of the last century, with the lake being brought to pre-drying. Its surface abruptly decrease after the huge country irrigation works were completed in 1950s. The research in administrative scope belongs to the Petrovec Municipality in the rural settings of Rzhanichino and Katlanovo villages.
The vegetation period starts in May and ends in November. The soil is mostly alluvial dominated by clay, with high content of organic substances. In the lower part of Skopsko Pole field, the soil is fertile and of high agricultural value. The groundwater level in the south-east part is artificially kept below the surface of the terrain by a drainage network and it is discharged into the Vardar before Taor gorge. The drainage network was constructed in the 1950s to drain most of the Katlanovo marsh.

RAMSAR CLASSIFICATION OF KATLANOVO MARSH

For wetland classification it is necessary to present the wetland classification according to the Ramsar Convention for the Inland and "Man-made" wetlands [4]. According to this classification, Katlanovo Marsh belongs to type of "Tp". Additionally with previous studies, the pilot study area contains euglena inorganic soils [5], which is complementary with the Katlanovo Marsh typology. The marine wetlands classification is not in the frame of research for Macedonia and therefore the bold was chosen selected class complementary with Katlanovo Marsh:

I Inland Wetlands

- L. Permanent inland deltas.
- M. Permanent rivers/streams/creeks; includes waterfalls.
- N. Seasonal/intermittent/irregular rivers/streams/creeks.
- O. Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.
- P. Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.
- Q. Permanent saline/brackish/alkaline lakes.
- R. Seasonal/intermittent saline/brackish/alkaline lakes and flats.*
- Sp. Permanent saline/brackish/alkaline marshes/pools.
- Ss. Seasonal/intermittent saline/brackish/alkaline marshes/ pools.*
- Tp. Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
- Ts. Seasonal/intermittent freshwater marshes/pools on inorganic soil; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.*
- U. Non-forested peatlands; includes shrub or open bogs, swamps, fens.
- Va. Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.
- Vt. Tundra wetlands; includes tundra pools, temporary waters from snowmelt.
- W. Shrub-dominated wetlands; Shrub swamps, shrub-dominated freshwater marsh, shrub carr, alder thicket; on inorganic soils.*
- Xf. Freshwater, tree-dominated wetlands; includes freshwater swamp forest, seasonally flooded forest, wooded swamps; on inorganic soils.*
- Xp. Forested peatlands; peatswamp forest.*
- Y. Freshwater springs; oases.
- Zg. Geothermal wetlands.
- Zk. Subterranean karst and cave hydrological systems.

* As appropriate, includes: floodplain wetlands such as seasonally inundated grassland (including natural wet meadows), shrublands, woodlands or forest.

II Artificial wetlands

- Aquaculture (e.g. fish/shrimp) ponds.
- Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
- Irrigated land; includes irrigation channels and rice fields.
- Seasonally flooded agricultural land**
- Salt exploitation sites; salt pans, salines, etc.
- Water storage areas; reservoirs/barrages/dams/impoundments; (generally over 8 ha).
- Excavations; gravel/brick/clay pits; borrow pits, mining pools.
- Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
- Canals and drainage channels, ditches.

** To include intensively managed or grazed wet meadow or pasture.

POPULATION BASICS

The Skopje Plain is densely populated. The central part is occupied by city of Skopje - the major administrative and industrial center in Macedonia, with a total population of 506926 [21]. Along with the city of Skopje, the basin comprises the municipalities of Želino, Sopište, Čučer-Sandevo, Studeničani, Zelenikovo, Ilinden, Aračinovo and Petrovec – municipalities with an approximate population of 80000 citizens. More than 80% of the settlements and villages situated in the area are adjacent to rivers and streams. These data indicate the severity of the anthropogenic pressure upon the river Vardar and its tributaries.

PROTECTED AREAS WITHIN THE PILOT SITE
(name, subject and purpose of conservation)

The Katlanovo Marsh is protected according to the "Law of natural rarities protection" in 1965 on an area of 70 ha, and is a significant station of migratory birds in the autumn of Northern Europe, but also rich in ichthyofauna. According to the qualitative assessment of Nastov refers to the concern, i.e. the threat to the ecosystem, species and habitat diversity of the locality. In accordance with the international ones criteria [4] are allocated 10 ecosystem types: blunt, extraordinary, channel, low grass (pastoral), high fever (secondary overgrown with shamak and reeds), belts with shrub and woody species, arable land (fields), artificial meadows, forested complexes and a fish farm. Evaluation data is displayed in a tabular way. Based on the results obtained from the evaluation concluded that with a very high degree of concern/endangered are two ecosystem types: blatant and ancestral type. The medium intensity of the threat is four types of ecosystems: high grasses secondary overgrown areas, low grassland (pastoral), shrubbery and woody belts and a network with drainage channels. The remaining ecosystem types are distinguished by low level of endangerment, and the expert assessments that are applied in natural ecosystem types are not relevant [17].

In the end of the 1980s researchers proposed measures for wetland restoration with average marsh pond's depth of 2-3 m, which could be a serious natural fish farm for carp fish. The other significant studies propose that the revitalization of the Katlanovo Marsh in the much smaller area, as it is today will be very significant not only for scientific research, but for the ichtiophauna existence and fish spawning, which is obtained with a connection with river Vardar thru the Rzhanichino Channel [18].

In accordance with the Decree for classification of watercourses, lakes, accumulations and groundwater [19], the quality of water in the river Vardar after the Pchinja inflow is

from the second category with BOD = 7,5 mg with projection to 2025 to reach 1,5 mg [5].

Figure 4. Areal of Katlanovo Marsh

Biodiversity of Katlanovo Marsh

Katlanovo marsh ("Katlanovo Blato") represents the last remaining part i.e. the termination phase, of the Katlanovo Lake that once spread over a large area in the northern part of Macedonia. Katlanovo marsh is situated in the Skopje valley and is part of the northern watershed of the largest river in Macedonia – Vardar. Today the marsh occupies area of 70 ha, surrounded by arable fields, small marshes and humid meadows.

Katlanovo Marsh is an important locality for Macedonia due to its natural, biodiversity and scientific values, and also because of its esthetic, cultural characteristics and economic potential [15]. Hence, the marsh has been an important topic of scientific interest in the past three decades.

Katlanovo Marsh encompasses ten ecosystem types, including: Marshes/wetlands, Coastal formations, Artificial water channel networks, Low grasslands, High grasslands, Shrub and tree belts, Arable fields, Forest complexes and Fishery pond.

According to the qualitative ecosystem analysis [17], the marshes/wetland and the coastal formations, characterized by the following dominant plant associations *Cyperetum longi-caricetosum acutiformis* [16] and *Caricetum-Martinum-Nymphacetum,* as well as *Cladium mariscum, Oenanthe aquatica/silaifolia, Roripa amphibian, Potamogeton crispus, Salvinia natans* and *Juncus tenuis*, respectively, are the most critically endangered ecosystems. Other vulnerable ecosystems include the artificial water channel network and the coastal tree belt. They are dominated by *Scirus lacustris*, *Phragmites australis*, *Juncus tenuis* as well as *Salix alba*, *Populus alba*, *Tamarix parviflora* and *Alnus glutinosa*, respectively.

The main threats that endanger these ecosystems are anthropogenic activities such as water abstraction, water pollution, landscape degradation and transformation, cutting and

burning of trees and shrubs, drying of the wetland, degradation of the water channels and climate change.
The marsh/wetland encompasses four different habitats, which according to the EUNIS classification are categorized as:

- *Phragmites australis* (Common reed) beds normally without freestanding water (EUNIS code D5.11)
- *Typha* (Reedmace) beds normally without freestanding water (EUNIS code D5.13)
- Swamps and marshes dominated by *Juncus effusus* (Soft rush) or other large *Juncus* spp. (EUNIS code D5.3)
- Helleno-Moesian riverine and humid *Trifolium* (clover) meadows (EUNIS code E3.31) [6].
- This habitat is listed under endangered natural habitats in accordance with the Bern Convention on the Conservation of European Wildlife and Natural Habitats.

Katlanovo marsh has rich diatom biodiversity (74 identified species) and includes uncommon species. *Sellaphora bacilloides, Stauroneis palustris* and *Caloneis macedonicus*. Other common diatoms and epiphytic species include: *Nitzschia linearis*, *Surirella splendida*, *Caloneis amphisbaena*, *Mastogloia smithii*, *Cymatopleura solea, Diatoma vulgaris, Rhoicosphenia lacustris, Cocconeis pediculus, Gomphonema olivaceum, Gomphonema parvulum* and *Planothidium frequentissimum* [11].
The plant diversity is represented by roughly 100 species, among which most important are: *Utricularia vulgaris, Salvinia natans, Butomus umbellatus, Schoenoplectus matitimus, Iris pseudocorus, Rumex hydrolapatrum, Carex accutiformis, Carex distans, Carex hirta, Carex divisa, Eleocharis palustris, Juncus tenuis, Oenanthe silaifolia, Oenathe aquatica, Stachys palustris, Orchis lati ora, Scutelaria hastifolia, Equisetum palustre, Phalaris arundemersus, Typha angustifolia, Hydrocharis morsus-ranae, Spirodela polyrhiza.* The larger region of the Katlanovo Marsh hosts the rare and endemic species *Gastrocotyle macedonica* (previously known as *Anchusa macedonica*) [14].

Invertebrate biodiversity

Katlanovo Marsh is characterized by high faunal diversity [17]. *Odonata* (damsels and dragonflies) represent an important, highly abundant and versatile group of invertebrates at Katlanovo Marsh. They are represented by 24 known species: *Sympecma fusca*, *Sympetrum sanguineum*, *S. depressiusculum*, *Anax imperator*, *Calopteryx virgo*, *Calopteryx splendens, Lestes barbarous, Lestes virens, Platycnemis pennipes, Erythromma viridulum, Enallagma cyathigerum, Ischnura elegans, Onychogomphus forcipatus, Orthetrum cancellatum, Orthetrum albistylum, Orthetrum brunneum, Orthetrum coerulescens, Crocothemis erythraea, Sympetrum meridionale, Aeshna isosceles, Onychogomphus forcipatus, Ischnura elegans and Lestes barbarus*. Katlanovo marsh host 52% of all *Odonata* species collected in the whole territory of Macedonia [8, 9].

Vertebra diversity

Fish diversity

Vertebrates are the best-studied group of organisms inhabiting Katlanovo Marsh. Fish populations were previously represented by ten species, e.g. *Cyprinus carpio*, *Rutilus rutilus*, *Scardinius erytrophtalmus*, *Cobitis taenia*, *Perca uviatilis*, *Barbus barbus*, *Barbus peloponensis*, *Gobio gobio*. However today, only four species are found living in the drainage channels and the abandoned fishpond [18].

Herpetofauna biodiversity

Reptiles and amphibian dwelling in Katlanovo Marsh are represented by eight species typical for wetlands. These include: newts *Lissotriton vulgaris* (previously *Triturus vulgaris*), frogs *Pelophylax ridibundus* (previously *Rana ridibunda*), *Pelobates syriacus balcanicus*, *Hyla arborea*, snakes *Natrix tessellate*, *Natrix natrix* and turtles *Emys orbicularis*, *Clemys caspica* (or *Mauremys caspica*) [17].

Avifauna diversity

Birds are the most numerous group of vertebrates at Katlanovo Marsh. More than 70 bird species are using this locality for nesting, hunting, wintering or migration. Aquatic birds and those that are typically found in wetlands are the most numerous in Katlanovo Marsh, and these include: *Spatula clypeata*, *Spatula querquedula*, *Anser anser*, *Mergus albellus*, *Charadrius marinellus*, *Gallinula chloropus*, *Phalacrocorax pygmaeus (Microcarbo)*, *Phalacrocorax carbo*, *Podiceps cristatus*, *Tachybaptus rucollis*, *Aythya nyroca*, *Egretta alba*, *Egretta garzetta*, *Larus ridibundus*, *Alcedo atthis*, *Anas platyrhynchos*, *Rallus aquaticus*, *Podiceps nigricollis*, *Botaurus stellaris*, *Himantopus himantopus*, *Panurus biarmicus* and *Ciconia ciconia*, *Ixobrichus minutus*, *Nycticorax nycticorax, Ardea purpurea*, *Circus aeruginosus, Cuculus canorusi, Troglodytes troglodytes, Cettia cetti*, *Locustella luscinioides*, *Acrocephalus schoenobaenus*, *Acrocephalus palustris*, *Acrocephalus scirpaceus*, *Acrocephalus arundinaceus, Sylvia communis*, *Remiz pendulinusi* and *Emberiza schoeniclus*, *Recurvirostra avosetta*, *Eudromias morinellus*, *Sternula albifrons* [24].

Mammal diversity

Due to the drainage of Katlanovo Marsh, today only 23 mammal species (out of previously known 30 species) are found at this locality [17].

Biodiversity of humid meadows habitats

The vegetation of the humid meadows is largely represented by the following species: **clovers** (*Trifolium resupinatum*, *T. balansae*, *T. nigrescens*, *T. filiforme*, *T. patens*, *T. repens*, *T. pretense*), perennial grasses (*Cynosurus cristatus*, *Anthoxanthum odoratum*, *Agrostis alba*, *Alopecurus utriculatus*, *A. pratensis*, *Bromus racemosus*), **sedges** (*Carex hirta*, *C. vulpina*, *C. distans*, *C. divisa*) as well as **herbaceous plants** *Lychnis flos-cuculi*, *Ranunculus acris*, *R. velutinus*, and *Cirsium canum* and *Inula britannica*.

Similar to the marsh habitats, the humid meadows are populated by diverse and abundant butterfly species (Lepidoptera), and hence habitats represent a hot spot for these types of organisms. Among the most common butterfly species are: *Lycaena virgauraea*, *Parnassius mnemosyne*, *Thymelicus sylvestris*, *Issoria lathonia*, *Pieris brassicae*, *Maniola jurtina* etc. Other abundant invertebrate group is Odonata (damsels and dragonflies), which is dominated by the *Calathus*, *Brachinus*, *Amara* and *Harpalus* genera.

RESULTS AND DISCUSSIONS

Hydrological characteristics

As a hydrological separated object, Katlanovo Marsh is natural and clearly defined wetland area, located in the lowest part of Skopje Plain. Today because of the past human activities, this wetland is strongly connected with the largest river in the country, Vardar.

It is not only a hydrological significant relation, but also very important for hydrobiology. The main hydrological analyzed issues are the morphometry of the marsh and also the morphometry of the small pond in the central part of the wetland:

Katlanovo Marsh morphometry

Katlanovo Marsh Lake coordinates:

x: 553115,242; y: 4639053,115
φ: 41°54'06"; λ: 21°38'25"

Altitude:

z: 221m

Length (L) is the shortest distance between the two most distant points on the marsh border.

L=2935m

Width (W) is the measured distance of a line from shore to shore at right angles to the length.

W = 1059 m

Area (A) is the surface area of the marsh.

A = 198,5 ha

Shoreline (*L'*), is the length of the shore line (km).

L'=12,188 km

Katlanovo Pond morphometric characteristics

According to the many limnology studies the main pond/lake morphometric elements are: total length (L), total wide (W), average wide (Wa), total wetland surface (A) total surface of wetland aquatorium (Aw), Maximum Depth (Zmax), Average depth (Za) and the total lake volume-V [10].

Katlanovo Pond coordinates:

x: 554243,630; y: 4638602,665;
φ: 41°53'51"; λ: 21°39'14"

Altitude:

z: 218m

Length (L) is the shortest distance between the two most distant points on the pond shore.

L = 141,3 m

Width (W) is the length of a line from shore to shore at right angles to the length.

W = 52,4 m

Area (A) is the surface area of the pond.

A = 0,513 ha

Average width (W_a) is the scale between the pond area and its length.

$$W_a = 36,3\ m$$

Shoreline (L'), is the length of the shore line (km).

$$L' = 0,459\ km$$

Pond volume

$$V=5130\ m^2*2,2m=11286\ m^3$$

Mean depth (Z_{ave}) is the volume divided by the area.

$$Z_{ave} = V/A$$
$$Z_{ave}=2,2m$$

Lake catchment area (Ac)

$$16043\ km^2\ or\ 1.604,3\ ha.$$

Watershed length (W_l)

$$17557\ km$$

Development of shoreline [7] is the ratio of the shoreline length (L') to the circumference of a circle with area equal to the area of the lake (A). That is, the lake shape is compared with an idealized shape (circle). That is:

$$DL = L'/(2\sqrt{\pi A})$$

$$DL=1,81$$

The closer this ratio is to 1, the more circular the lake. A large ratio, larger than 1.5 indicates the shoreline is more crenulated and reflects the potential for development of littoral communities (plants) and usually of high biological productivity or massive relief structures (rapid changes from sand beach to vertical cliffs. In the above result, the pond shape is very well developed and allows the development of rich coastal vegetation, which is normal for a shallow marsh pond.

Katlanovo Pond hydrology

The small Katlanovo marsh lake belongs to the group of shallow lakes, created in the plain, as a result of fluvial processes and high underground water. According to the wetland hydrologic methodology [23], marsh hydrological condition depends on three hydrologic variables that are useful for characterizing wetland hydrologic behavior, the water level, hydro-pattern, and residence time. Each of these wetland descriptors are described in greater detail in subsequent sections. What follows here is a brief introduction of these concepts

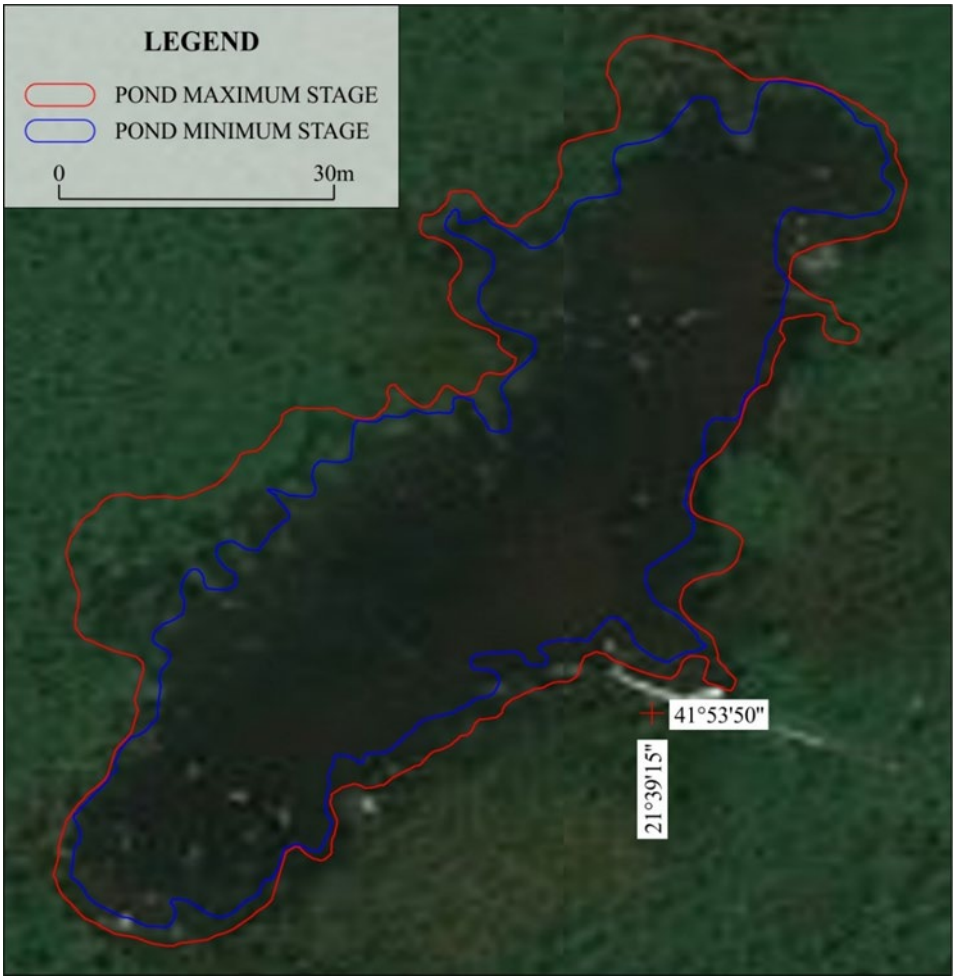

Figure 5. Areal of permanently humid zone and zone under permanent water in the Katlanovo Marsh

The water circulation in the Katlanovo Marsh is also artificial, because of the Rzhanicino channel, which outflows the marsh water for the "Skopsko Pole water irrigation system". The channel structure starts in the south western part of the Katlanovo Marsh and outflows in the East-northeast direction. This hydrological object has no water level monitoring.

One hydrologic descriptor is the general elevation of wetland water levels relative to the soil surface. The water level can, therefore, be used as an indicator of the vegetation types likely to occur in each of these zones.

A second descriptor of wetland hydrology is the temporal variability of water levels. The timing, duration, and distribution of wetland water levels are, together, commonly referred to as the wetland hydro-pattern, which incorporates the duration and frequency of water level perturbations.

The basic information about the Katlanovo Marsh in situation without of lake stage measurement is comparing the groundwater regime by using the nearest piezometric station in Petrovec village. The gauge elevation is 227,3 m a.s.l. This altitude is almost complementary with Katlanovo Marsh altitude 224 m a.s.l.

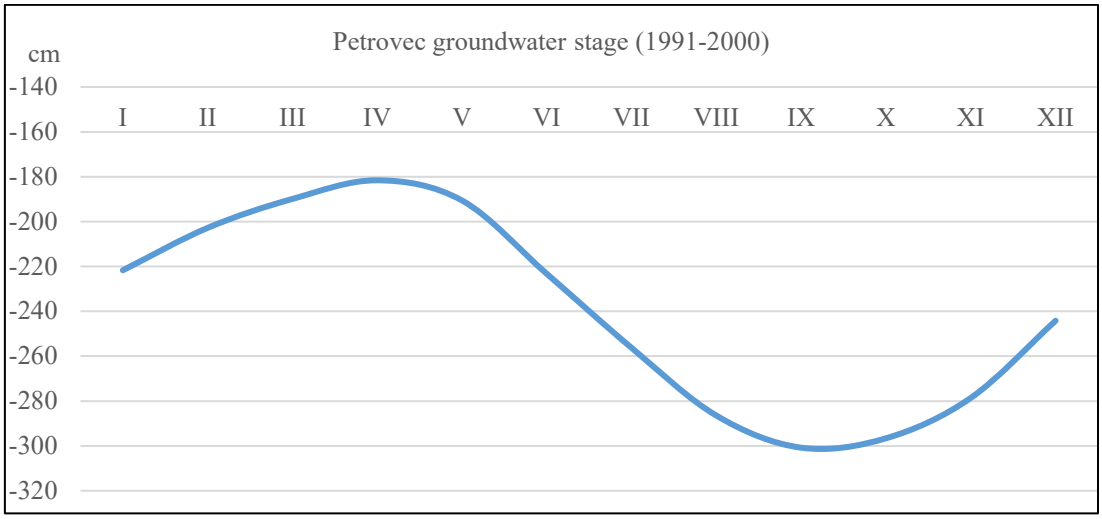

Figure 6. Multiannual monthly groundwater regime at Piezometer Petrovec
Source: National Hydrometeorological Service, Skopje, Macedonia

The Katlanovo Marsh groundwater recharge is crucial during the whole year. It is higher in the spring season, while there decreasing recharge in the dry summer period, particularly in August and September, when the groundwater stage is approximately -3 m, but even then there is a strong connection with marsh lake, which maximum depth is below the absolute groundwater stage minimum. The main groundwater role in permanent existing of the Katlanovo Marsh is in the March, April and May, when the aquifers are charging with precipitation water, but also from the snowmelt process in the surrounding hilly area. Elsewise, the groundwater recharge of the marsh is less intensive in autumn, and even after November it is increased again.

Katlanovo Pond annual water balance depends from the precipitation (P) on the pond aquatorium (A), groundwater recharge (GR) which is predominant factor in the pond existence and the surrounding catchment runoff which is a marginal factor, taking in consideration that the evapotranspiration value (895 mm/year) is significantly larger than the precipitation rate (540 mm/year). The evapotranspiration (〖ET〗_0) was calculated according to the Penmann-Monteauh equation in official United Nations FAO calculator [1, 23].

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where:

ET_o	reference evapotranspiration [mm day-1],
R_n	net radiation at the crop surface [MJ m-2 day-1],
G	soil heat flux density [MJ m-2 day-1],
T	mean daily air temperature at 2 m height [°C],
u_2	wind speed at 2 m height [m s-1],
e_s	saturation vapour pressure [kPa],
e_a	actual vapour pressure [kPa],
e_s-e_a	saturation vapour pressure deficit [kPa],
Δ	slope vapour pressure curve [kPa °C-1],
γ	psychrometric constant [kPa °C-1].

Besides in the study area there is no surface gauge, the Runoff (mm) as a significant input hydrological element was determined by the Rational Method, which is connected with dimensionless coefficient (CN) relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavement, steep gradient), and lower for permeable, well vegetated areas (forest, flat land) [12, 22]:

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

$$R = Q \times An$$

P	daily precipitation
An	net catchment area (A-Aa)
S	maximum retention potential
S	(1000/CN) - 10
l	related to soil and cover conditions of the watershed through the CN
l	determined by rainfall-runoff plots

Taking in consideration the specific anthropogenic influence on the pond, the water balance for the Katlanovo Pond is:

$$P + G_R + R(I) - O - ET_0 - \Delta S = 0$$

where:
The present study of the Katlanovo Pond water-balance contains the main water balance elements as: precipitation (P), evapotranspiration (ET_0), inflow runoff R(I), groundwater recharge (Gr), outflow (O) and change of the pond water storage ΔS. The equation of all these values should result with 0.

Table 1. Katlanovo Pond water balance (m^3/year)

Water Balance element		m^3/year	%	Inflow/Outflow %
Inflow	P	2770	20	100%
	R(I)	3223	24	
	Gr	7593	56	
Outflow	ET	4590	34	100%
	O	6330	46	
	ΔS (storage)	2666	20	

From the above table and graph, there are six crucial elements, making complete water balance hydrological pattern. The main human influence in pond water loses is presented with the outflow, which result with the multiple decreasing of the Katlanovo Marsh, but particularly the Katlanovo Pond.

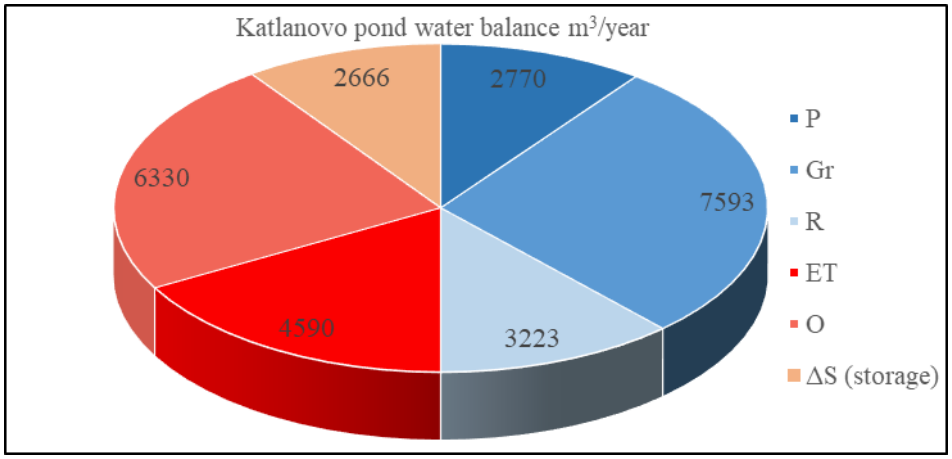

Figure 7. Water balance chart of the Katlanovo Pond

Other similar studies show several possible mistakes occurred with connection of the uncertainty of the parameters estimation in the pond water balance analysis [13]. According to the Brown [2], the total summer precipitation evaporates even in the high geographical latitudes, so the groundwater recharge is crucial for permanent existence of the wetland ponds. The same situation occurred in our analyzed case.

CONCLUSION

Katlanovo Marsh is previously natural, human modified hydrological object in the eastern part of the Skopje basin. The interaction with high underground waters is crutial for its existence. Only a small, a micro hydrological object from the Katlanovo Marsh is Katlanovo Pond. From the total marsh area of 198,5 ha (1985000 m2), only 5130 m2 is pond area. The total pond volume is 11286 m3.The annual water balance depends from the precipitation (P) on the pond aquatorium (A), groundwater recharge (GR) which is predominant factor in the pond existence and the surrounding catchment runoff which is a marginal factor, taking in consideration that the evapotranspiration value (895 mm/year) is significantly larger than the precipitation rate (540 mm/year). The precipitation participates in the suficite with 20% (2770 m3), inflow runoff from the Katlanovo Marsh basin contribution is 24% (3223 m3), and the most significant is groundwater recharge element with 56% (7593 m3) of total inflow. The artificial changes are evident with the built Rzhanichino canal, which made it a main deficite element with a contribution of 46% (6330 m3), highly above the evapotranspiration, ET=34% (4590 m3), and the storage contributes with 20% (2666 m3).

Taking in consideration its Ramsar status, it is very significant for the country environment to protect this last evidence of the ancient Katlanovo Marsh, which was existing in the past. The same situation with remains of the ancient marshes are also located in Pelagonia, Strumica Basin and Ohrid–Struga Plain in Macedonia.

Acknowledgements

This study was funded by INTERREG Balkan - Mediterranean program. Project title: Improving the conservation effectiveness of wetland – WETMAINAREAS. 2019

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