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HYDROLOGICAL SUB-WATERSHEDS ANALYSIS OF PRESPA LAKE

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ABSTRACT

Sub-watershed analysis has become a strategic approach in assessment of the natural resources. The guiding principle of this approach is to maximize the benefits of water resources and ecosystems management. This article will present the authors experience in evaluating couple of projects within the UNDP developing program in Prespa region that deals with hydrological analysis and restoration measures.

The lake is an interesting case study as regards hydrology and hydrogeology. The lake does not have surface outflow. The waters from the lake outflow through karst underground conduits into Ohrid Lake. Since 1984 the water level declination started and it is still for about 7 m under the long-term average water level. Integrated Management Plan development initiated water balance and rainfall-runoff modeling which base is watershed and precipitation analysis. The paper discus general watershed data and the necessity of delineation based on land use and land cover data (LUC), geological and hydrogeological characteristics.

Keywords: watershed delineation, land cover, land use, hydrological analysis

PRESPA - ONE OF THE OLDEST LAKES ON EARTH

The Prespa Lake, composed of the Macro and Micro Lakes is located in the heart of the Balkan Peninsula, Figure 1. It is one of the oldest lakes on our planet, believed to be more than 5 million years old. It is an ecosystem of global significance, renowned for its ecological values and hydrological complexity.

Figure 1. Geographical location of the investigated area

Napomena Urednika. Prespansko jezero i Dojransko jezero u Republici Makedoniji su upozoravajući primeri kako se prevelikom eksploatacijom vode iz reka i jezera mogu da jako naruše ekološki odnosi. U oba slučaja su Makedoniji susedne države obavljale prevelika zahvatanja, koja se nisu mogla da pokriju iz bilansa padavina i prirodnog doticanja. Došlo je do postepenog spuštanja nivoa jezera za po nekoliko metara (u slučaju Prespanskog jezera čak za 9 metara), što je ugrozilo ne samo opstanak faune i flore koja zavisi od jezera, već su sada već ugroženi i socijalni i drugi sistemi u okruženju. Zbog toga Uredništvo smatra da je članak vrlo instruktivan, ali da otvara platformu za razmatranje problema vodnih bilansa i čitavog niza drugih vrlo osetljivih sistema i slivova. Posebno u uslovima mogućih klimatskih promena po kojima se u ovim delovima Balkanskog poluostvrva očekuju smanjenja ukupnih padavina i oticaja. Zbog toga su istraživanja Prespanskog jezera vrlo značajna, a rad ove vrste vrlo aktuelan.

Being shared by the three neighbouring countries – Macedonia, Albania and Greece – this lake system is also specific and important from a geopolitical perspective, Table 1.

Table 1. Distribution of basin area and lake surface area across state borders

	Basin area A_C		Lake surface area A_L	
	[10^3 m^2]	[%]	[10^3 m^2]	[%]
Macedonia	788.355,00	56,70	190.117,00	68,60
Greece	336.667,00	24,20	39.304,00	14,20
Albania	265.923,00	19,10	47.731,00	17,20
Total	1.390.946,00	100,00	277.153,00	100,00

Source: Maps 1:25.000 – Geokarta, Belgrade 1973; ArcView GIS–Water Master Plan – Ministry of Agriculture, Forestry and Water Economy of Macedonia

The entire ecosystem has been facing serious environmental challenges because of the combined influence of natural and anthropogenic factors.

The system has lost excessive volumes of freshwater over the past decades, as a result of the prolonged dry period, and the constant loss of water through the karstic massif of mount Galicica, into the Ohrid Lake system. The volume of Macro Prespa Lake has decreased for 1.1 km^3 since 1961, for when it was estimated at 3.8 km^3. Combined with the pressures of human activities, this has resulted in trend of deterioration of water quality, and consequently the ecological values.

Because of the complexity of the hydrological and hydrogeological features of the basin, the transboundary aspects, and the diminishing ecological values, the water resources management within the basin is an extremely challenging task.

The formulation of sound decisions regarding integrated water resources management across the state borders is critically dependent upon the understanding of the basin's hydrological features. The basin's hydrology and hydrogeology are poorly investigated, partly because of the complexity of the runoff processes and partly because of the transboundary character of the area.

This presentation elaborates an effort for studying the basin's hydrology, based on a method for delineating hydrological sub-basins/sub-watersheds, and rainfall – runoff modelling.

Figure 2. Prespa Lake Basin – a globally important ecosystem, home to more than 2,000 plant and animal species; Host of the world's largest breeding colony of the globally endangered Dalmatian pelican

METHODOLOGY APPLIED

The methodology applied in this analysis comprises of the following elements: a) hypsometric analysis, b) delineation of the Macro and Micro Prespa Lake basin using topographic maps and LANDSAT images integrated into GIS, c) definition of the subwatersheds based on their hydrological properties occurring due to different exposures, geology, slope, land cover and land use, management practices and surface outflow, and availability of meteorological and hydrological data, d) land cover analysis, and e) rainfall-runoff modelling.

RESULTS AND DISCUSSION

A-Hypsometric analysis

The Prespa Lake basin is characterised by relatively flat bottoms, high rims and sharp relief beyond the bottoms. The mountain slopes are mostly steep and reach up to 2.200 m asl. There are limited plain areas, bordering mainly the lakeshore. The hypsometric amplitude is about 1.300 m. Extreme altitudes range is 845 m asl to 2.200 m asl, Figure 3.

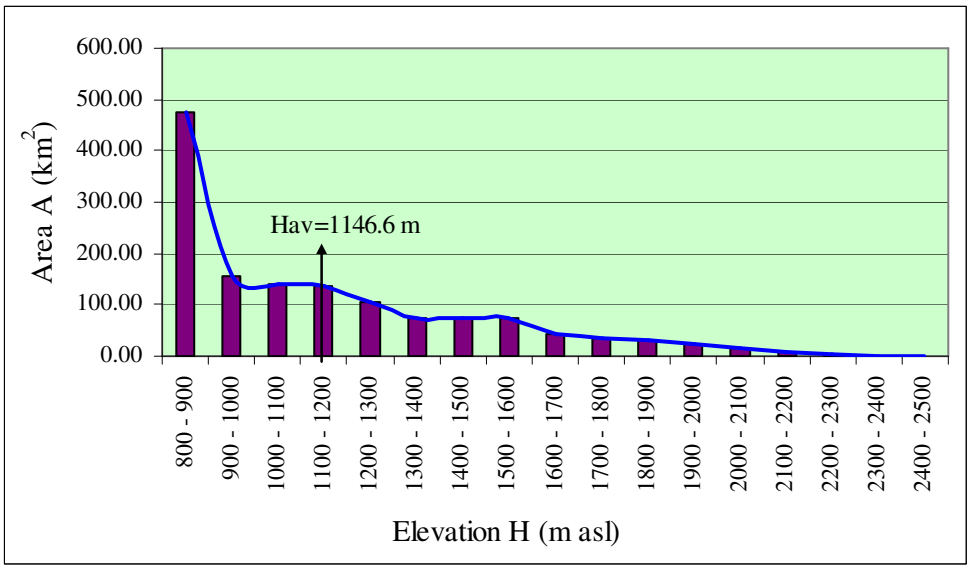

Figure 3. Hypsometric curve of the Prespa Lakes watershed

B-Delineation

The basin area of Micro and Macro Prespa Lakes was delineated by using topographic maps of scale 1:200.000, 1:50.000 and 1:25.000, and LANDSAT satellite images of August 2000, integrated into a GIS platform. The calculated basin area of Macro Prespa is 1.160 km², including the lake surface of 265 km². The total area of Micro Prespa is 224 km², including the 45 km² lake surface area.

C-Sub-watershed analysis

The Prespa Lake basin was divided into four hydrological sub-watershed units (East, South, West and North) for the purposes of rainfall-runoff modelling. The division was made based on the specifics of the hydrological properties of the sub-watersheds attributed to the different exposure, geology, slope, land cover and land use, management practices and surface outflow.

The availability of meteorological and hydrological data is also an important element contributing to the delineation process. Such an approach allows for grouping small watersheds with similar properties into larger hydrological units.

The location map with sub-watersheds model is presented in Figure 4, and the hydrographical characteristics of the sub-watersheds are presented in Table 2. The land cover of the four subwatershed units was analyzed in GIS using the Corine Land Use Classification, Popovska [2].

Table 2. Basic data on delineated sub-watersheds

Sub-watershed	Area [km²]	Perimeter [km]	Slope [°]			Elevation [m asl]		
			min	max	average	min	max	average
North	314,97	90,53	0	53,90	12,58	847,5	1.989,30	1.107,99
East	272,47	104,21	0	72,88	18,59	845,0	2.418,67	1.403,26
West	271,97	162,26	0	62,64	15,87	847,5	2.285,20	1.298,28
South	254,38	74,98	0	58,30	10,49	845,0	2.111,05	1.093,35
Total	1.113,79							

Source: KfW Feasibility Study-Transboundary Prespa Park Project, 2005

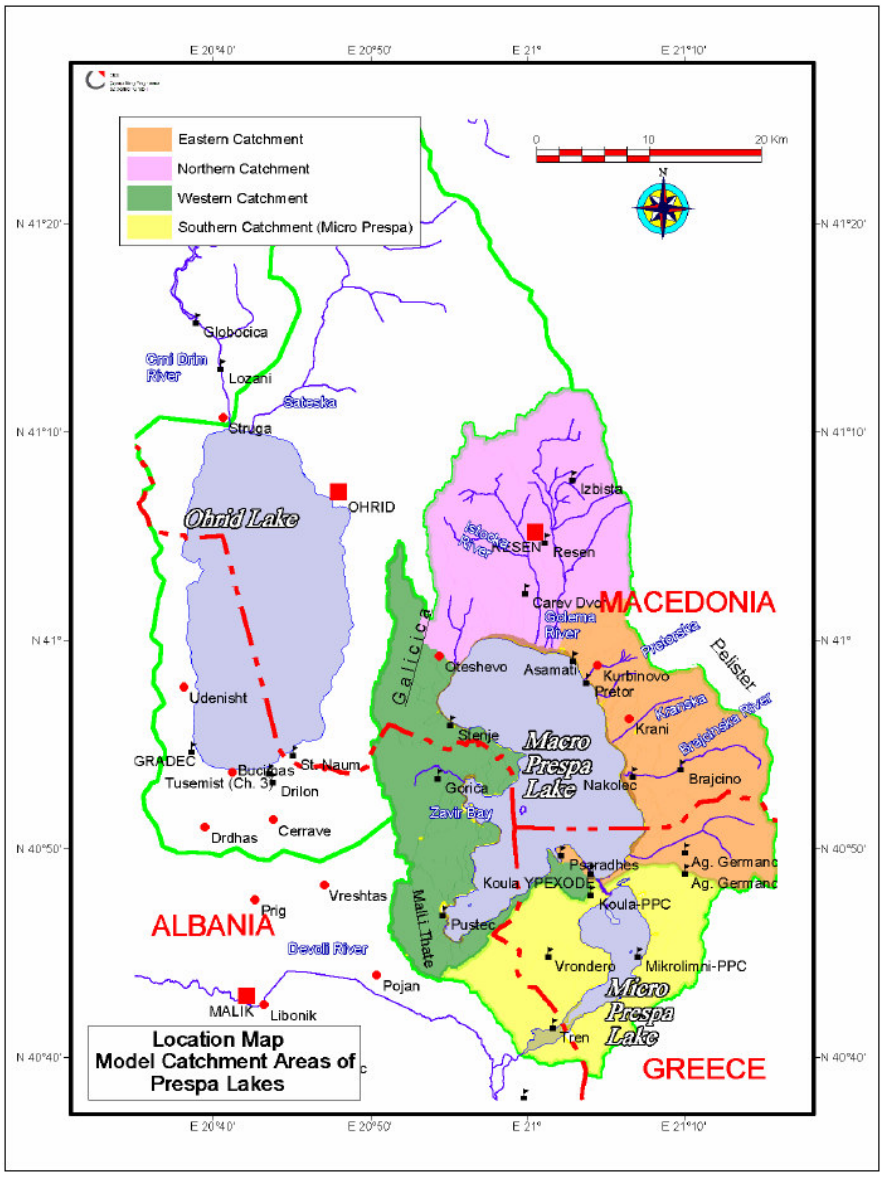

Figure 4. Location map with delineation of sub-watersheds

The basic features of the three (out of four in total) delineated sub-watersheds belonging to the Macedonian part of the basin are presented below:

East sub-watershed. Pelister Mountain Range is characterized by the Palaeozoic schist and intrusive rocks which primarily act as aquicludes. The schist and the intrusive rocks form the practically impervious base of the Mesozoic limestone and border the Prespa Lakes in the east. Irrigation water is available from the surface streams and rivers – Pretorska, Kranska and Brajcinska River. In general the groundwater yield in this sub-watershed is poor. The geologic formation of this sub-watershed explains the existence of surface water – rivers and the relatively high runoff coefficient.

North sub-watershed. The Mountains formed by Palaeozoic metamorphic rocks, mainly schist with local magmatic intrusions, reach elevations of over 1.500 m. According to the geological map of the area 'the Pliocene consists of gravel and sand whereas the Quaternary consists of moraines, glacial-fluvial formations, widespread organic-marsh sediments, river terraces, wash, piedmont and alluvial deposits'. The thickness of the young cover (Pliocene and Quaternary) reaches a thickness of more than 150 m. The thickness of Pliocene deposits increases from their outcrop and end near Kriveni at the northern end of the Resen Plain towards Macro Prespa Lake. Lithological descriptions on geological maps and explanatory notes mention gravel and sand layers in the Pliocene suggesting the presence of good aquifers. The Pliocene deposits under the Resen plain seem not to contain good aquifers. It is possible that Pliocene sediments cover significant proportion of the lake bottom.

West sub-watershed. The Mesozoic, mainly Jurassic limestone massif of the Galicica and Dry Mountains is a tectonic horst separating the Resen – Prespa depression in the east from the Korcha – Ohrid depression in the west. The limestone massif is a karst aquifer system, characterized by intensely jointed rocks with pronounced solution phenomena. This unit plays a special role because it is the only element of drainage for the Prespa Lake basin. Macro Prespa Lake water flows into the karst on the south-western Albanian part of the shore and reappears in the springs of St. Naum and Tushemiste on the Ohrid Lake shore. Paleozoic rocks are missing in the catchment area. The young deposits along the western shore of Macro Prespa Lake have poor aquifer qualities because of their low permeability and, furthermore, as they are used for domestic water supply and for garden irrigation by shaft wells. The runoff coefficient of this sub-catchment is rather poor, due to its karstic properties. For the hydrological modelling the inexistence of precipitation measurements in the higher parts of the catchment has to be considered, Popovska&Bonacci [6]. In average the existing rain gauges are at elevation 850-1020 m asl and the surrounding mountains are high 1060-2600 m asl.

For the rainfall-runoff modelling data on precipitation and river discharges are needed. Table 3 shows the existing rain gauges in Prespa region with altitudes and long-term average annual precipitation sums, and Table 4 present the characteristic discharges of the main rivers in Prespa region.

Table 3. Basic data on available rain gauges

No	Rain gauge	H [m asl]	P [mm]
1	Asamati	860	614.4
2	Brajcino	1020	686.0
3	Carev Dvor	864	605.0
4	Izbista	980	821.9
6	Nakolec	850	552.9
10	Resen	881	707.9
12	Stenje	855	872.9

Table 4. Discharges of the rivers in Prespa region

Rivers	Discharge [m^3/s]			
	Average	Average Dry Year	Normal Year	Maximum
Golema Reka	0.345	0.220	0.135	26.0
Pretorska Reka	0.150	0.115	0.075	11.0
Kranska Reka	0.265	0.180	0.120	17.0
Brajcinska Reka	0.295	0.203	0.160	21.0
Total	1.055	0.720	0.490	75.0

D-Land cover analysis

The land cover of the four sub-watershed units was analyzed in GIS using the Corine Land Use Classification, Table 5. The catchments of the Prespa Lake are composed from the high mountains area and the part of the fields in the valley. The field is accounted as all areas with the elevation lover than 900 m. About 37% of the area is covered with forests. The main rivers are: Golema, Pretorska, Kranska and Brajcinska. Golema River is the most important river in the Prespa Lake catchment. The discharge has been estimated in various documents such as Water Master Plan –Water Economy Base, (1976) and WB-FAO, (1995).

Table 5. Dominant land covers types within the four sub-watersheds

Sub-watershed	Area [km²]	Forest [km^2]	Agricultural land [km^2]
North	314,97	152 (50%)	
East	272,47	208 (76%)	55,1 (20%)
West	271,97		
South	254,38	176 (69%)	
Total	1.113,79		

The total area of the Eastern sub-watershed covered by forest is 208,8 km^2 or 76%. The agricultural area is 55,1 km^2 or 20%. In the Northern catchment area 50% or 152 km^2 is covered by forest, 30% or 90,2 km^2, and 67% or 204,7 km^2 is under natural vegetation like shrubs. Around 69% or 176 km^2 of the total area in the Southern sub-catchment are under forest and other natural areas, dominated by shrub with 40% and broad-leaved forests with 24% or 64 km^2. Permanent snow and ice cover is of about 5%.

Because of the relation between the precipitation regime and distribution and the forest cover, the alterations of the forest cover were specifically analyzed by using satellite images from 1988 and 2003, Figure 5.

A difference of the forest cover development was observed in the three countries. In the Macedonia the area under forests increased by 5%. In contrast, the forest area decreased by 5% in Greek part, and 15% in the Albanian part. This explains the occurrence of lowest average, annual and specific discharges in the Western and Southern part of the study area.

E - Rainfall- runoff modelling

The average, annual and specific discharges for the four delineated sub-watersheds, calculated based on the data acquainted by the previous analyses are shown in Table 6.

Table 6. Rainfall-runoff modelling results

Sub-watershed	Area [km²]	Average discharge [m³/s]	Annual dischsrge [MCM]	Specific discharge [l/s·km^2]
East	270,90	3,60	114,10	13,40
North	320,00	4,60	143,80	14,20
West	247,60	2,40	75,60	9,70
South	218,90	2,50	78,80	11,40

Source: KfW Feasibility Study-Transboundary Prespa Park Project, 2005

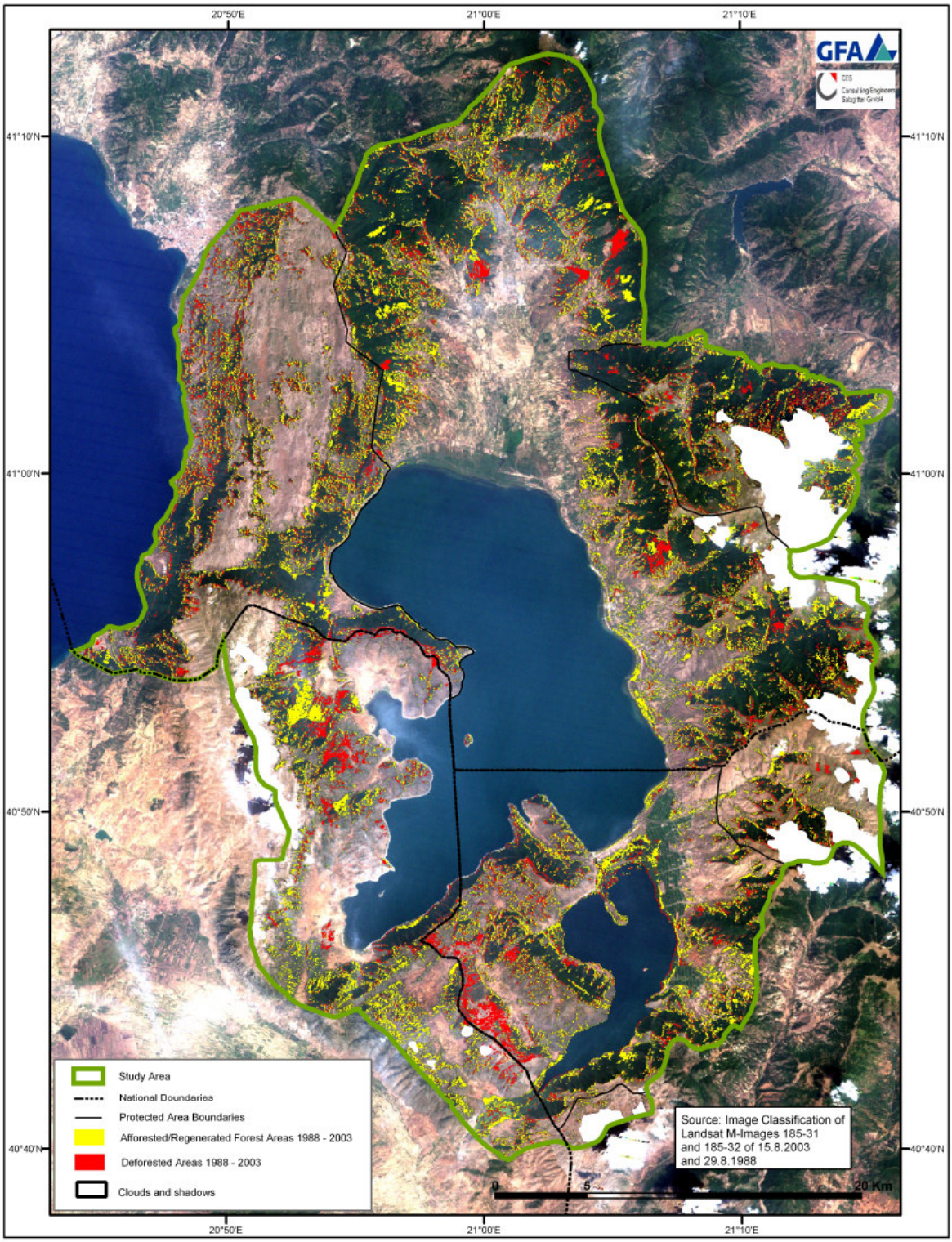

Figure 5. Forest cover change (1988 – 2003)
(Source: KfW Feasibility Study-Transboundary Prespa Park Project, 2005)

CONCLUSIONS

Water resources management in basins characterized by complex hydrological and hydrogeological features is a particularly challenging task. The study of the hydrological phenomena (including rainfall – runoff relations) is of critical importance to any decision supporting integrated approach to water resources management.

The investigations of hydrological complex systems can be facilitated by applying the sub-watershed approach. The delineation of sub-watersheds based on their hydrological properties, and availability of meteorological and hydrological data can be very helpful method for hydrological and environmental studies.

The analysis of forest cover changes of the basin can provide particularly useful information to compare the variability of the annual, average and specific discharges of delineated sub-watersheds.

The sub-watershed approach enables defining water management decisions at lower scale, within individual units, thus providing for more 'precise' response to the spatial and temporal variability of the water resources.

Besides this, the sub-watershed analysis presents a so called "cumulative analysis" that enables sub-watershed characterization information to: (a) assess impacts on watershed functions (including hydrology, water quality and habitat), (b) hypothesize on major causes and pollution sources, (c) identify indicator parameters, and (d) prioritize sub-watersheds based on various criteria.

REFERENCES

[1] Bonacci, O., (2005): Sadašnje stanje i potrebe razvoja hidrologije, Časopis VODOPRIVREDA, br. 216-218, 2005/4-6, pp. 163-171, Beograd, Srbija

[2] KfW Feasibility Study-Transboundary Prespa Park Project, GFA Terra Systems, 2005.

[3] Popovska, C., Krstić, S., (2010): Manual for river restoration, United Nations Development Program (UNDP) and Global Environmental Fund (GEF), Skopje, Macedonia (in Macedonian).

[4] Popovska, C., (2004): Climate Change and Vulnerability Assessment of the Water Resources, Journal VODOPRIVREDA, No. 209-210, 2004/3-4, pp. 219-228, Belgarde, Serbia

[5] Popovska, C., (2011): Tectonic Lakes: Climatic and Antrhropogenic Impacts, European Geosciences Union, General Assembly 2011, Vienna, Austria http://www.egu.eu/

[6] Popopvska, C., Bonacci, O., (2007): Basic data on the Hydrology of Ohrid and Prespa Lakes, Journal HYDROLOGICAL PROCESSES, 658-664 (2007), DOI: 10.1002/hyp.6252, Wiley InterScience.

[7] Prespa Lake Watershed Management Plan, UNDP/GEF Prespa project, 2011.

[8] Sekovski, D., (2010): River Corridors Restoration: Principles, Processes and Practices, Master Thesis submitted to Faculty of Civil Engineering, Skopje, Macedonia (in Macedonian).

[9] Sibinović, M., (1987): The Lakes-Prespa and Ohrid, Institut of Water Economy, Skopje, Macedonia (in Macedonian).

HIDROLOŠKA ANALIZA PODSLIVOVA PRESPANSKOG JEZERA

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Rezime

Analiza podslivova može se prihvatiti kao strateški pristup u oceni stanja prirodnih resursa. Vodeći princip u ovome je da se postignu maksimalne koristi kod upravljanja vodnih resursa i ekosistema. Ovaj rad prezentira neka iskustva autora u razvijanju nekoliko projekta u Prespanskom regionu u okviru UNDP/GEF razvojnih programa i to onaj deo koji obuhvata hidrologiju i restaruacijske mere u slivu.

Prespansko jezero je veoma interesntan problem sa hidrološkog i hidrogeološkog aspekta. Samo jezero nema površinski istek. Voda ističe u Ohridsko Jezero preko karstnog podzemlja visokih okolnih planina. Od 1984 vodostaj jezera je u opadanju, u 2000 za oko 9 m, a danas za oko 7 m ispod srednjeg višegodišnjeg vodostaja. Za potrebu integriranog plana za upravljanje sa jezerskim vodama i ekosistemima proračun vodnog bilansa bilo neohodno modeliranja padavina i isticanja. Ovaj rad prezentira samo deo tih analiza: fizičko-geografske karakteristike sliva, podela na podslivove na bazi podataka o pokrivaču i korišćenju zemljišta, geološke i hidogeološke karakteristike.

Ključne reči: podela podslivova, pokrivač zemljišta, korišćenje zemljišta, hidrološke analize

ХИДРОЛОШКА АНАЛИЗА НА ПОДСЛИВОВИ НА ПРЕСПАНСКОТО ЕЗЕРО

Цветанка ПОПОВСКА
Универзитет Св. Кирил и Методиј, Градежен факултет, Скопје, Македонија

Димитрија СЕКОВСКИ
Програма за развој на Обединетите нации, УНДП/ГЕФ Преспа проект, Ресен, Македонија

Резиме

Анализата на подсливови може да се прифати како стратешки пристап во оценатa на состојбата на природните ресурси. Водечки принцип при ова е постигнување на максимална корист во управувањето со водните ресурси и екосистемите. Овој труд презентира некои искуства на авторите во изработката на неколку проекти во Преспанскиот регион во рамките на развојните програми на УНДП и тоа оној дел кој се однесува на хидрологијата и мерките за реставрација во сливот.

Преспанското Езеро е исклучително интересен проблем од хидролошки и хидрогеолошки аспект. Езерото нема површински истек. Истекот е во Охридското Езеро преку карстното подземје на високите околни планини. Од 1984 водостојот во езерото е во тренд на опаѓање, во 2000 за околу 9 m, а денес за околу 7 m под повеќегодишниот среден водостој. За потребите на изработка на интегриран план за управување со езерските води и екосистемите, пресметување на водниот баланс врз основа на моделирање на врнежите и истекувањето беше неопходно потребно. Во трудот се презентирани само некои делови од тие анализи: физичко-географски карактеристики, поделба на подсливови со податоци за земјишниот покривач и користење на земјиштето (Corine LUC), и геолошки и хидрогеолошки карактеристики.

Клучни зборови: поделба на подсливови, земјишен покривач, користење на земјиштето, хидролошки анализи

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