

Protecting Water Resources from Pollution in The Lake Batllava

Sabri AVDULLAHI¹ Islam FEJZA¹ Ahmet TMAVA¹

¹ Faculty of Geosciences and Technology, University of Prishtina, Str. Parku Industrial No NN, 40000 Mitrovic, Republic of Kosova

***Corresponding Author**

e-mail: sabriavdullahi@hotmail.com

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Abstract

In recent years, the international community has witnessed incidence of climate variability and human activities. The objective of this paper is protecting water resources from pollution in the catchments area of Lake Batllava. The catchments area of Lake Batllava has a size of 225 km² and the active storage volume of the lake is assessed to 34.4 mill. m³. The current population of Municipality of Prishtina is estimated to be around 400,000 and Lake Batllava supply with drinking water around 64% of population in this area.

Since no useful hydrological data was available for the study it was decided to obtain this information by means of hydrological modeling based on a rainfall-runoff computation. The model is designed to simulate the rainfall-runoff processes of catchments areas and is applicable to a wide range of geographic areas.

Water samples are taken from three small rivers/streams flow to the Lake Batllava: river Turiqic, river Kushevic and Ballaban, also from lake in different depths (5 m, 10 m and 15 m) at different locations. Concerning the environment impact more than 300 interviews were conducted and questionnaires filled in the period October-November for Orllan area.

Keywords: pollution, hydrological modelling, water quality, water supply, wastewater disposal

INTRODUCTION

As a readily accessible water resource, lakes house more than 95% of the liquid surface freshwater on the Earth's surface, supporting domestic, agricultural and industrial water supplies [1]. The extent of physical changes to lakes around the world has increased over the past century. Changes in surface water in response to accelerated climate and environmental changes affect the local heat balance and the evaporation rate [2]. Hence, the global distribution and changes in lakes are of key social and economic importance. It is estimated that approximately 2.1% of the terrestrial surface is covered by lakes and ponds exceeding one hectare [3].

Water resources in Kosova are relatively small, and the rivers are seriously polluted [4]. Water balance studies essentially are the initial stage of a hydrological systems analysis of a metropolitan area [5]. Many hydrological models have been developed to simulate and help us to understand hydrologic processes. The hydrological models are used as a watershed storm water management tool to provide a direction to utilize natural water resources effectively and beneficially. These empirical models have proven very useful in hydrological analysis and modelling [6] and can be used in long-term, as well as short-term hydrologic. Terrain analysis based on digital elevation models is being increasingly used in hydrology [7].

STUDY AREA

Catchment Area of Lake Batllava

The catchment area of the Lake Batllava has a size of 225 km². The ground elevations vary between 600 m.a.s.l. and 1200 m.a.s.l. The catchment area has five main sub-basins. The main sub-basins are further divided into smaller sub-basins.

Water balance analysis

For monitoring the water levels in the Lake Batllava, using ultra-sonic water level meter located at the outlet structure. Apart from the lake water levels the drinking water abstractions from the lake are measured continuously at the water treatment plant. The observed water levels in the lake can be combined with the lake storage capacity curve in order to calculate the changes of water volume in the lake. This can subsequently be combined with the measured drinking water abstractions from the lake to perform a water balance analysis of the Lake Batllava. The water levels in the lake can be related with the lake storage capacity curve in order to calculate the water volumes in the lake.

The monthly water levels in the Lake Batllava in the period 2002 to 2008 are listed in table 1 and are shown in figure 1.

Therefore, the monthly readings are used for preparing the water balance. The measured water abstractions are listed in table 2 and are shown in figure 2.

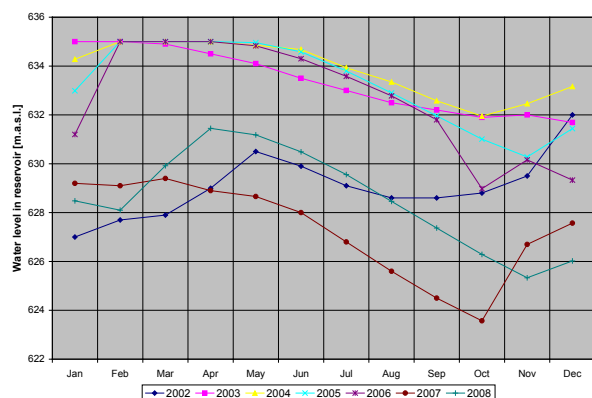


Fig.1. Monthly water level in the Lake Batllava, 2006 - 2008

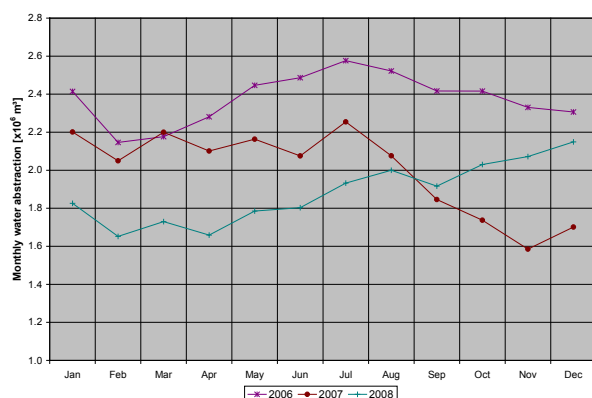


Fig.2. Monthly abstractions from Lake Batllava, 2006 - 2008

Table.1. Monthly water levels in the Lake Batllava in the period 2006 - 2008

	Monthly averaged water levels in the Lake Batllava [m.a.s.l.]						
	2002	2003	2004	2005	2006	2007	2008
Jan	627.00	635.00	634.28	632.99	631.20	629.20	628.48
Feb	627.70	635.00	635.00	635.00	635.00	629.10	628.10
Mar	627.90	634.90	635.00	635.00	635.00	629.40	629.92
Apr	629.00	634.50	635.00	635.00	635.00	628.90	631.45
May	630.50	634.10	634.85	634.96	634.83	628.66	631.18
Jun	629.90	633.50	634.68	634.58	634.30	628.00	630.49
Jul	629.10	633.00	633.93	633.80	633.58	626.80	629.56
Aug	628.60	632.50	633.35	632.90	632.78	625.60	628.46
Sep	628.60	632.20	632.58	631.96	631.80	624.50	627.37
Oct	628.80	631.90	631.95	631.01	628.98	623.57	626.29
Nov	629.50	632.00	632.46	630.28	630.16	626.70	625.33
Dec	632.00	631.69	633.16	631.44	629.33	627.57	626.02

Table.2. Monthly abstractions from Lake Batllava in the period 2006 - 2008

	Monthly water abstractions from Lake Batllava [$\times 10^6$ m ³]		
	2006	2007	2008
Jan	2.41	2.20	1.83
Feb	2.15	2.05	1.65
Mar	2.18	2.20	1.73
Apr	2.28	2.10	1.66
May	2.45	2.16	1.79
Jun	2.49	2.08	1.80
Jul	2.58	2.25	1.93
Aug	2.52	2.08	2.00
Sep	2.42	1.85	1.92
Oct	2.42	1.74	2.03
Nov	2.33	1.59	2.07
Dec	2.31	1.70	2.15
Total	28.52	23.99	22.55

The values were measured at the end of each month. Daily values of the water levels were also available for the period 2007 and 2008. The daily values were compared with the monthly values and no significant differences were detected. Therefore, the monthly readings are used for preparing the water balance. Based on the available measured data a water balance analysis was carried out for the years 2007 and 2008. In both years the annual water abstraction exceeds the total inflow to the lake by 3.6×10^6 m³ and 2.9×10^6 m³.

Hydrological Modelling

The issue of resolution effects of digital elevation models on hydrological modelling parameters and peak discharge has been discussed in recent publications [8, 9] investigate the effect of digital elevation model. Sensitive points of existing closed sections to pressurized flow should be identified and protected [10].

Information obtained during study in September-October 2009 indicates that the existing gauging stations were destroyed during the war. Since no useful hydrological data was available for the study it was decided to obtain this information by means of hydrological modelling based on a rainfall-runoff computation.

The hydrologic modelling system used, is HEC-HMS developed by the Hydrologic Engineering Centre of the US Corps of Engineers. The model is designed to simulate the rainfall-runoff processes of catchment areas and is applicable to a wide range of geographic areas [11].

Digital Terrain Model

With the advent of geographic information systems (GIS), digital terrain models have been used to delineate drainage networks and watershed boundaries, to calculate slope characteristics, to enhance distributed hydrologic models and to produce flow paths of surface runoff.

The importance and responsibility of digital terrain model applications makes it inevitable to provide digital terrain models with adequate quality measures [12]. Practical rules of thumb are nowadays available in a more or less adequate and tested form [13, 14]. The basic input information for setting up the basin model in HEC-HMS is the digital terrain model of the area of study.

In the course of the study two main sources of data were identified and found suitable for the digital terrain model. Raw data from a recent laser scanning with 10 m raster size was obtained from the Kosovo Cadastral Agency. The second data source consisted in older topographic maps in scale 1:25.000 with contour lines in 10 m intervals.

Basin Model

The basin model of the Lake Batllava was created using the additional software package HEC-Geom., which is a geo-spatial hydrologic modelling extension for ArcGIS. Basically, HEC-GeoHMS allows to process spatial information, to document watershed characteristics, to perform spatial analyses, to delineate sub-basins, and to create inputs for hydrologic models. The first step for creating the basin model is the processing the terrain data. The resulting data sets are used as spatial database for the study. The basin delineation was further processed and refined by determination of watershed characteristics and the run-off situation. The delineation of streams and sub-basins used in the hydrologic model of the Lake Batllava is shown in

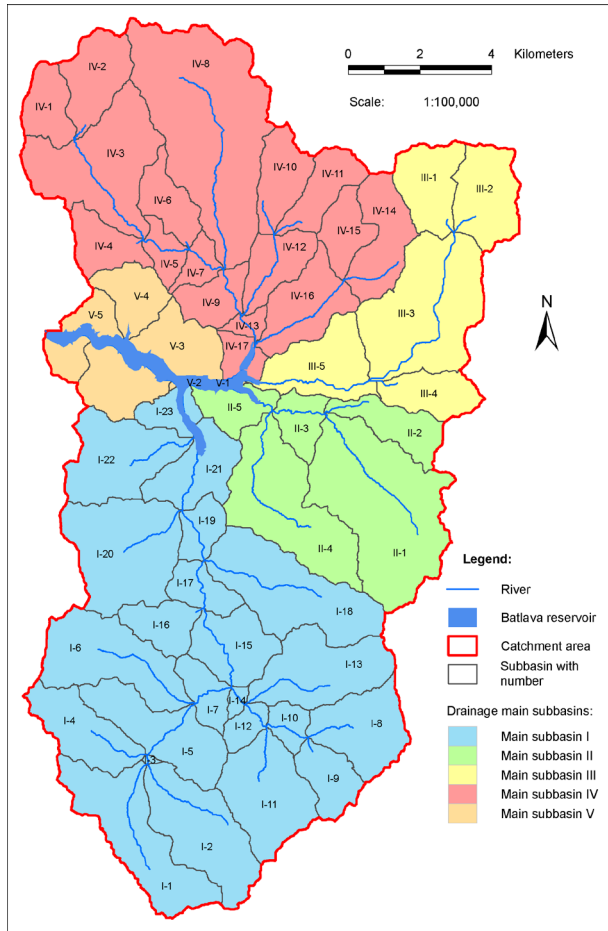


Fig.3. Sub-basins of the catchment area of the Lake Batllava

Table.3. Catchment area and sub-basins of the Lake Batllava

Main sub-basin I	Area [km ²]	Main sub-basin III	Area [km ²]
SB I-1	7.61	SB III-1	3.70
SB I-2	6.81	SB III-2	4.34
SB I-3	0.09	SB III-3	10.32
SB I-4	4.26	SB III-4	2.87
SB I-5	5.57	SB III-5	4.89
SB I-6	6.81	Total MSB III	26.1
SB I-7	1.88		
SB I-8	4.82		
SB I-9	2.54		
SB I-10	1.19		
SB I-11	6.12		
SB I-12	1.14		
SB I-13	6.09		
SB I-14	0.39		
SB I-15	3.85		
SB I-16	2.35		
SB I-17	1.97		
SB I-18	8.42		
SB I-19	1.74		
SB I-20	8.27		
SB I-21	3.87		
SB I-22	5.91		
SB I-23	1.68		
Total MSB I	93.4		
Main sub-basin II	Area [km ²]	Main sub-basin IV	Area [km ²]
SB II-1	13.15	SB IV-1	2.47
SB II-2	2.96	SB IV-2	3.73
SB II-3	1.98	SB IV-3	8.76
SB II-4	8.85	SB IV-4	2.56
SB II-5	2.37	SB IV-5	1.41
Total MSB II	29.3	SB IV-6	2.47
		SB IV-7	1.21
		SB IV-8	16.61
		SB IV-9	2.31
		SB IV-10	3.04
		SB IV-11	2.77
		SB IV-12	2.85
		SB IV-13	0.69
		SB IV-14	4.17
		SB IV-15	2.32
		SB IV-16	4.36
		SB IV-17	1.39
		Total MSB IV	63.1
Main sub-basin V	Area [km ²]		
SB V-1	0.26		
SB V-2	0.01		
SB V-3	7.51		
SB V-4	2.76		
SB V-5	2.91		
Total MSB V	13.4		

figure 3. The catchment area is subdivided into four main sub-basins. The areas of the main sub-basins and of the sub-basins are summarized in table 3.

For all sub-basins the following methods for calculating the losses (interception, infiltration, storage, evaporation), transform (runoff of excess precipitation) and base flow (sustained runoff of prior precipitation stored temporarily in the watershed) were used:

- Loss method: Deficit and constant loss
- Transform method: SCS Unit hydrograph
- Base flow method: Constant monthly base flow.

Meteorological Model

Rainfall data and data on evapotranspiration were needed for the hydrologic modelling. The data collection conducted in Prishtina revealed that little rainfall data is available from the catchment area. There are no rainfall stations in the catchment area. The rainfall stations Shajkocv and Llug are located outside, 4.0 and 7.5 km west of the Lake Batllava. Daily rainfall values of these stations could be obtained for 2007 and 2008, only. Because of its closer location to the catchment area only the data of the Shejkocv station was used for the hydrologic modelling figure 4.

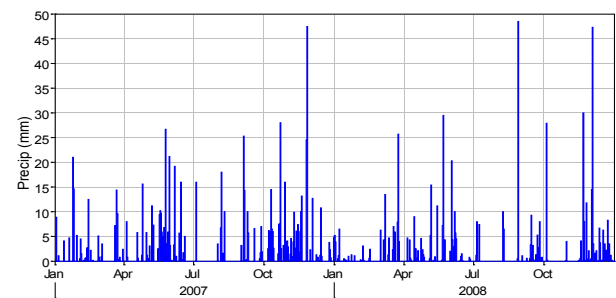


Fig.4. Daily rainfall at the rainfall station Shajkocv in the period 2007-2008

COMPUTATION OF INFLOWS TO LAKE BATLLAVA

A hydrologic model needs to be calibrated in order to compute reliable discharges. During the calibration process different model parameters are gradually varied. The computed flows are compared against the observed values and the parameter variation is continued until a good relation between model and observations is achieved. In the case of the Lake Batllava there are unfortunately no measured values of inflows to the lake. Therefore, it is not possible to calibrate the model in a conventional manner. However, there is data available of water elevations in the reservoir and of drinking water abstractions from the lake. The main parameters adjusted during the model calibration are corresponding to the loss module (initial deficit, maximum deficit and constant rate) and the values of the monthly base-flow in the sub-basins. The computed total monthly flows of each main sub-basin and the total catchment area are presented in table 4 shows a comparison between total monthly inflows to the Lake Batllava computed with the hydrological model and calculated from the water balance analysis.

The results in figure 5 show a good overall correlation between computed and observed monthly total inflows to the Lake Batllava. The seasonal variations of the reservoir inflows and the resulting runoff of the rainfall events are well described by the model. Special effort was made to obtain a good

Table 4. Computed monthly total flows from main sub-basins of Lake Batllava, 2007 and 2008

	Monthly total flow of main sub-basins computed with hydrological model [x10 ⁶ m ³ /month]					Monthly total inflow to the lake computed with hydrologic model [x10 ⁶ m ³ /month]	Monthly total inflow to the lake obtained from water balance analysis [x10 ⁶ m ³ /month]
	MSB I	MSB II	MSB III	MSB IV	MSB V		
Jan/ 2007	1.20	0.38	0.34	0.81	0.17	2.91	1.93
Feb/ 2007	1.06	0.33	0.30	0.72	0.15	2.56	1.84
Mar/ 2007	1.07	0.34	0.30	0.73	0.16	2.59	2.83
Apr/ 2007	0.72	0.22	0.20	0.48	0.11	1.73	1.05
May/ 2007	1.48	0.46	0.41	1.00	0.24	3.59	1.66
Jun/ 2007	0.25	0.07	0.06	0.16	0.10	0.65	0.69
Jul/ 2007	0.03	0.01	0.01	0.02	0.01	0.07	0.03
Aug/ 2007	0.08	0.02	0.02	0.05	0.01	0.19	0.00
Sep/ 2007	0.15	0.05	0.04	0.10	0.02	0.36	0.00
Oct/ 2007	0.23	0.07	0.06	0.15	0.03	0.54	0.20
Nov/ 2007	1.58	0.49	0.44	1.06	0.31	3.88	7.05
Dec/ 2007	1.05	0.33	0.29	0.71	0.14	2.52	3.31
Jan/ 2008	1.15	0.36	0.32	0.78	0.17	2.79	3.63
Feb/ 2008	1.05	0.33	0.29	0.71	0.15	2.54	0.85
Mar/ 2008	1.99	0.62	0.55	1.34	0.32	4.84	5.55
Apr/ 2008	0.71	0.22	0.20	0.48	0.11	1.73	5.02
May/ 2008	0.97	0.30	0.27	0.65	0.19	2.37	1.19
Jun/ 2008	0.10	0.03	0.03	0.07	0.02	0.25	0.28
Jul/ 2008	0.03	0.01	0.01	0.02	0.00	0.08	0.00
Aug/ 2008	0.13	0.04	0.03	0.08	0.02	0.31	0.00
Sep/ 2008	0.08	0.02	0.02	0.05	0.01	0.18	0.00
Oct/ 2008	0.06	0.02	0.02	0.04	0.01	0.15	0.03
Nov/ 2008	0.16	0.05	0.05	0.11	0.03	0.40	0.36
Dec/ 2008	1.18	0.37	0.33	0.80	0.16	2.85	3.36
Total 2007	8.90	2.77	2.47	5.99	1.45	21.58	20.40
Total 2008	7.63	2.38	2.12	5.15	1.19	18.48	19.69

correlation between calculated and observed total annual inflow to the reservoir. This is evidenced by the small differences of only 6% between computed and observed annual inflows to the reservoir in the years 2007 and 2008.

Relating the computed annual inflows of 2007 and 2008 to the total annual rainfall of the two years leads to the conclusion that the annual total inflow to the Lake Batllava under average rainfall conditions is around 20 Million m³.

Table 5. Water Quality of Lake Batllava

Parameter	A1	A2	A3	A4	A5	A6
Turbidity (NTU)	1.7	3.2	2.65	4.27	1.84	1.43
pH	7.62	8.61	8.64	7.62	7.74	7.67
NH ₄ -N (mg/L)	0.01	0.02	0	0.01	0	0.03
NO ₂ -N (mg/L)	0.003	0.0129	0.0077	0.0027	0.0043	0.0036
NO ₃ -N (mg/L)	1.4	0.8	2.2	1.7	1.9	1.3
Cl (mg/L)	11	13	11	11	11	11
KMnO ₄ (mg/L)	8.6	8.36	8.37	15	18.6	9.3
Fe (mg/L)	0.024	0.19	0.084	0.105	0.03	0.043
Hardness (°dH)	11.2	12	11.5	10.08	8.4	8.12
SO ₄ ²⁻ (mg/L)	29.9	65	41	40.7	39.6	38.4
PO ₄ ³⁻ (mg/L)	0.187	0.256	0.218	0.111	0.137	0.064
K (µS/cm)	342	465	438	300	296	291
Mn (mg/L)	0.069	0.014	0.008	0.016	0.003	0.173
Cu (µg/L)	1	1.1	1.9	0.5	0	0
Zn (mg/L)	-	0.05	0.009	-	-	-
Al ³⁺ (mg/L)	0.008	0.029	0.019	0.027	0.011	0.04

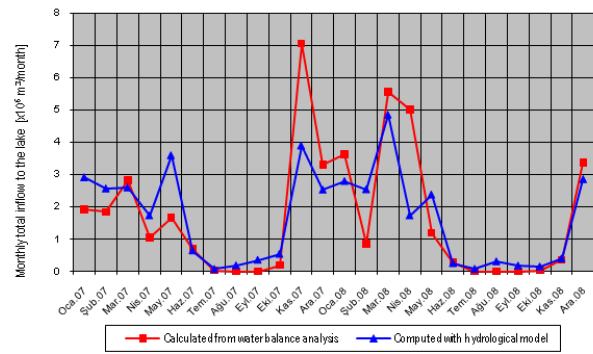


Fig.5. Monthly total inflows to the Lake Ballava 2007 and 2008

WATER QUALITY LAKE BATLLAVA

Chemical parameters, for which analyses were done, are in general in the acceptable range for raw water for water supply. Also Lake Batllava is used as recreation area during summer. Bacteriological analyses should be verified during the next years [15].

Three small rivers/ streams flow to the Lake Batllava: river Turiqic, river Kushevic, and river Ballaban. In some years water samples were taken from the streams, just few hundred meters before reaching the lake [16]. Water samples in the lake are taken from three different depths (5m, 10m and 15m) at different locations. Chemical parameters, for which analyses were done, are in general in the acceptable range for raw water for water supply (table 5).

These increased values were only found in the lake areas used for recreation, including swimming, e.g. in the Orllan area, but not close to the outlet structure, where the water is abstracted for the treatment plant. In the view of public health, a more intensive monitoring during the summer time is therefore

recommended, which eventually could lead to a limitation of the recreational activities.

Present Land Use

Forests and areas with little or no vegetation cover 95 % of the catchment area, equal to around 204 km². A part of the agricultural areas concentrate in the valleys, along the main inflowing streams. Larger areas are found in the northwest and southwest of the catchment area. In total, just 2.3 % of the catchment area is presently used for agriculture, slightly more than 520 ha. Settlements and e.g. roads cover 1.5 % of the area, equal to around 340 ha. Area covered by water courses is in the same range with 1.3 %, equal to around 290 ha. Overall this can be seen as favorable situation for the long term sustainable use of Lake Batllava, as only around 4% of the total catchment area are presently used for settlements and agriculture (figure 6).

Pollution Sources

Population concentrates in the village of Orllan, and in the valleys ending in this area. In the valleys of the sub-catchment areas single farms and groups of farm buildings are common. However, estrogens were also detected in streams in areas with intensive agriculture [17]. During the survey 300 interviews were held with owners of private houses in the Orllan area, representing approximately the total number of buildings of this category (table 6).

Lake Batllava was always used for recreation purposes and during the last years a number of new facilities were built and started. Numbers of day-visitors and related facilities, e.g. beaches and restaurants increased. There is no piped water supply in the Orllan area or elsewhere in the catchment area. More than

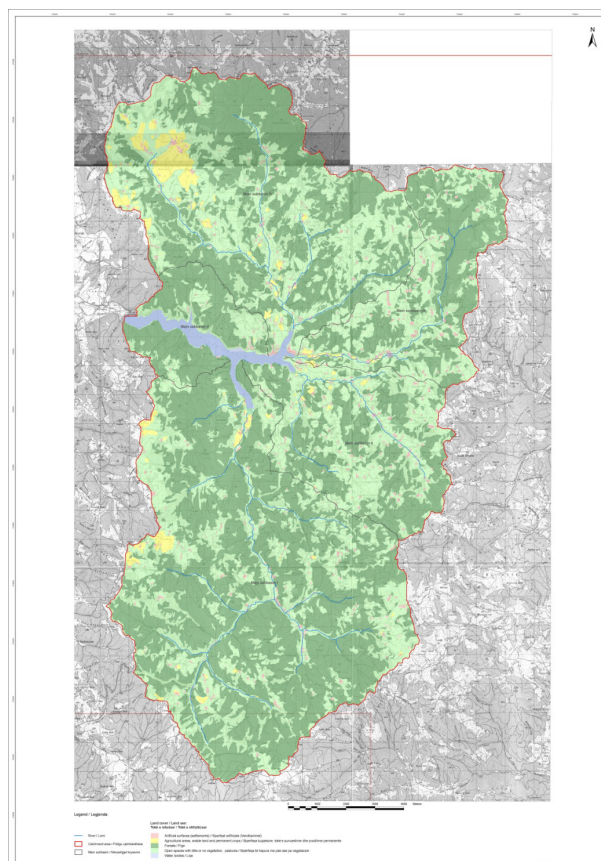


Fig.6. Land cover and land use in the catchment area of Lake Batllava

Table.6. Survey Batllava Orllan, Oct-Nov. 2009

	Building			Persons			Water supply			Wastewater Disposal		Waste Disposal		
		New	Seasonal	residents	employees	guests	public	well	water tank	septic tank	dis. Field	container	burning	nature
Private House / Building														
Total	260	48	70	1.107	0	0	0	167	73	183	55	23	2	212
Percent %	88	18	27				0	64	28	70	21	9	1	82
Shop/ Commerce														
Total	2	0	0	7	3	0	0	1	1	1	1	2	0	0
Percent %	1	0	0				0	0	0	0	0	1	0	0
Restaurant / Hotel														
Total	8	0	0	31	27	1.07	0	8	0	0	5	3	0	0
Percent %	3	0	0				0	100	0	0	63	38	0	0
Other Buildings														
Total	25	0	8	2	52	680	0	21	0	10	20	8	0	0
Percent %	8	0	0				0	62	0	29	59	24	0	0
Grand Total	295	48	78	1147	82		0	197	74	194	81	36	2	212
Percent %	100	16	26				0	67	25	66	27	12	1	72

60 % of the buildings have their private well, and the others receive their water from a tanker truck. The concentrations of estrogens in wastewater treatment plant influents and effluents were measured in several countries. Two-thirds of the buildings have septic tanks and from the remaining buildings, wastewater is discharged to the field.

DISCUSSION AND CONCLUSIONS

The annual abstraction of drinking water from the Lake Batllava in the period 2006 to 2008 is about 25 mill. m³/a. This value corresponds to the maximum treatment capacity of the water treatment plant Albanik of 70,000 m³/d, or 25.5 mill. m³/a. The results of the modelling show that the minimum, average and maximum total annual inflows to the lake can be expected with around 13.5 mill. m³/a, 19.5 mill m³/a, and 52.5 mill. m³/a, (for low, average and high total annual rainfall).

The active storage volume of the Lake Batllava is assessed to 34.4 mill. m³. Based on these assessments following conclusions are realistic:

Average annual rainfall generates an inflow of only approximately 78% of the maximum abstraction rate for the water treatment plant,

Assuming average annual inflow over a longer period and the maximum required abstraction for the water treatment plant the storage capacity would be exhausted within 5 to 6 years.

In the case of having a long period of extreme low rainfall the storage capacity would be already exhausted after 2 years.

In order to obtain more precise results detailed rainfall information is required, meaning records covering 20 and more years.

In addition, it is recommended that bacteriological contamination of the lakes during summer, close to the recreation areas, is monitored more regularly, by the institution in charge for this public health issue.

In general, buildings should have a septic tank and infiltration pit/soak away for the disposal of wastewater. Direct discharges to fields, drainage channels and water course should not be allowed any longer.

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