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Protecting Water Resources from Pollution in the Lake Batllava

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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 catchment area of Lake Batllava. The catchment area of Lake Batllava has an area of 225km² and the active storage volume of the lake is assessed to be 34.4 Mill. m³. The current population of the Municipality of Prishtina is estimated to be around 400,000 and Lake Batllava supplies with drinking water around 64% of the 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 modelling based on a rainfall-runoff computation. The model is designed to simulate the rainfall-runoff processes of the catchment area and is applicable to a wide range of geographic areas.

Water samples are taken from three small rivers/streams which flow into the Lake Batllava: river Turiqic, river Kushevic and river Ballaban, also from the lake in different depths (5m, 10m and 15m) at different locations. Concerning the environmental impact, more than 300 interviews were conducted and questionnaires were 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 (Wetzel, 1992). 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 (Carpenter et al., 1992). 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 (Meybeck, 1995).

Water resources in Kosova are relatively small, and the rivers are seriously polluted (Avdullahi et al., 2008). Water balance studies are essentially the initial stage of a hydrological system analysis of a metropolitan area (Alcamo et al., 2007). Many hydrological models have been developed to simulate and help understand hydrological processes. The hydrological models are used as a watershed storm water management tool to provide a direction to utilize effectively and beneficially natural water resources.

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These empirical models have proven to be very useful in hydrological analysis and modelling and can be used in long-term as well as short-term hydrological analysis (Salas et al., 1980). Terrain analysis based on digital elevation models is being increasingly used in hydrology (Moore et al., 1991).

STUDY AREA

Catchment Area of Lake Batllava

The catchment area of the Lake Batllava has an area of 225km². 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, an ultra-sonic water level meter located at the outlet structure was used. Apart from the lake water levels, the drinking water abstractions from the lake are continuously measured 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 from 2002 to 2008 are listed in Table 1 and 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 shown in Figure 2.

The values were measured at the end of each month. Daily values of the water levels were also available for the period (2007-2008). 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 x10^6 m³ and 2.9 x10^6 m³.

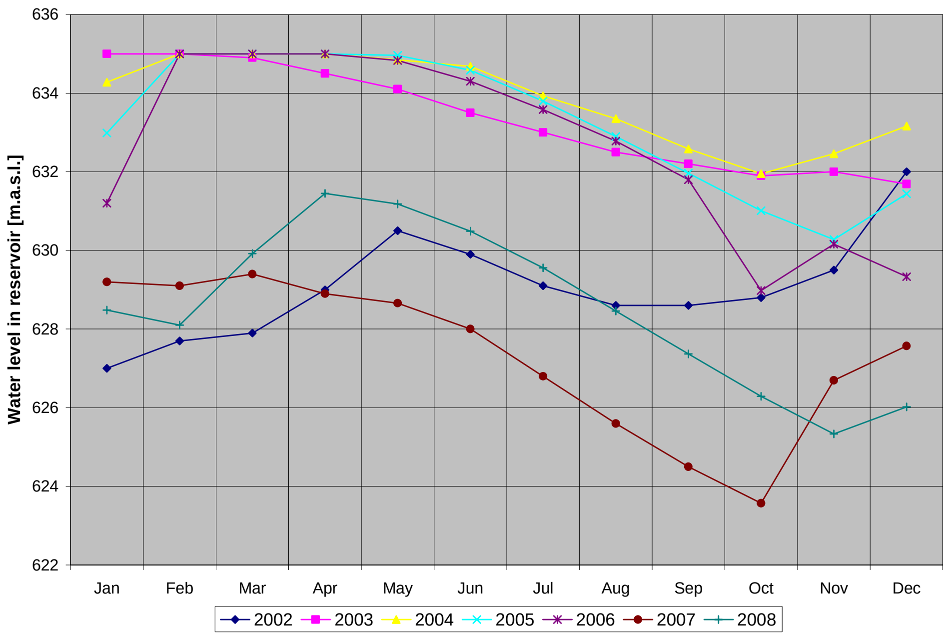

Figure 1: Monthly water level in the Lake Batllava, 2006 - 2008

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

	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**

Hydrological Modelling

The issue of resolution effects of digital elevation models on hydrological modelling parameters and peak discharge has been discussed in recent publications (Moglen and Hartman, 2001; Hill and Neary, 2005). They investigated the effect of digital elevation model. Sensitive points of existing closed sections to pressurized flow were identified and protected (Daniil et al., 2004).

Information obtained during September-October 2009 indicated 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 hydrological modelling system used is HEC-

HMS developed by the Hydrological 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 (USACE, 2003).

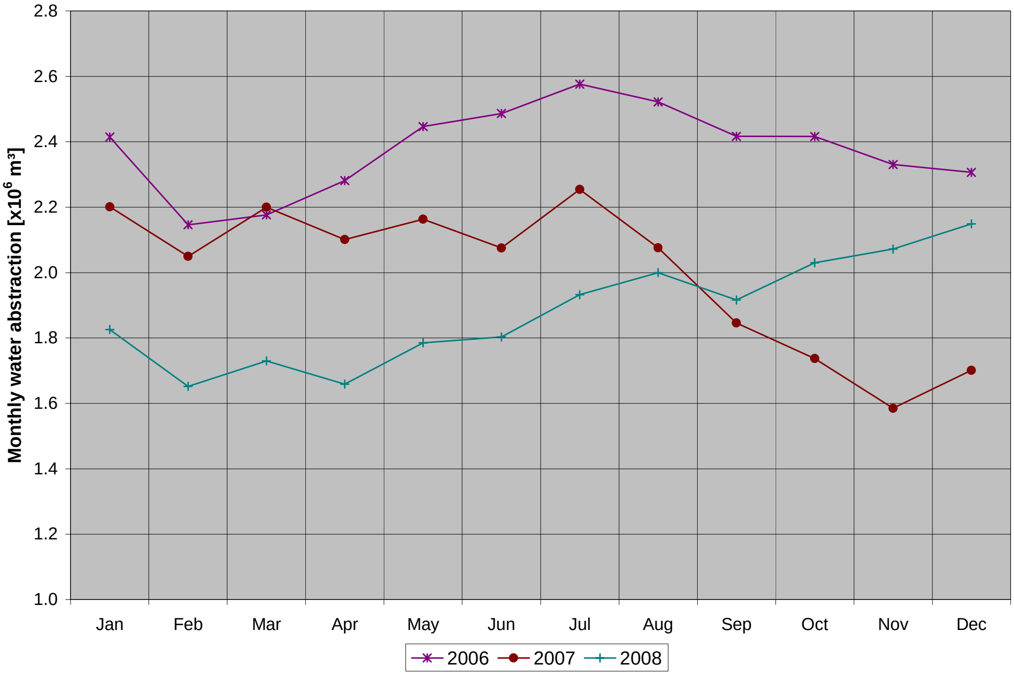

Figure 2: Monthly abstractions from Lake Batllava, 2006 - 2008

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 hydrological models and to produce flow paths of surface runoff.

The importance and responsibility of digital terrain model applications make it inevitable to provide digital terrain models with adequate quality measures (Moore et al., 1991). Practical rules of thumb are nowadays available in a more or less adequate and tested form (Krus and Pfeifer, 1998; Kraus et al., 2004). 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 10m raster size was obtained from the Kosovo Cadastral Agency. The second data source was older topographic maps in the scale of 1:25000 with contour lines in 10m intervals.

Basin Model

The basin model of the Lake Batllava was created using the additional software package HEC-Geom., which is a geo-spatial hydrological 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 hydrological 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 hydrological model of the Lake Batllava is shown in Figure 3. The catchment area is subdivided into four main sub-basins. The areas 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.

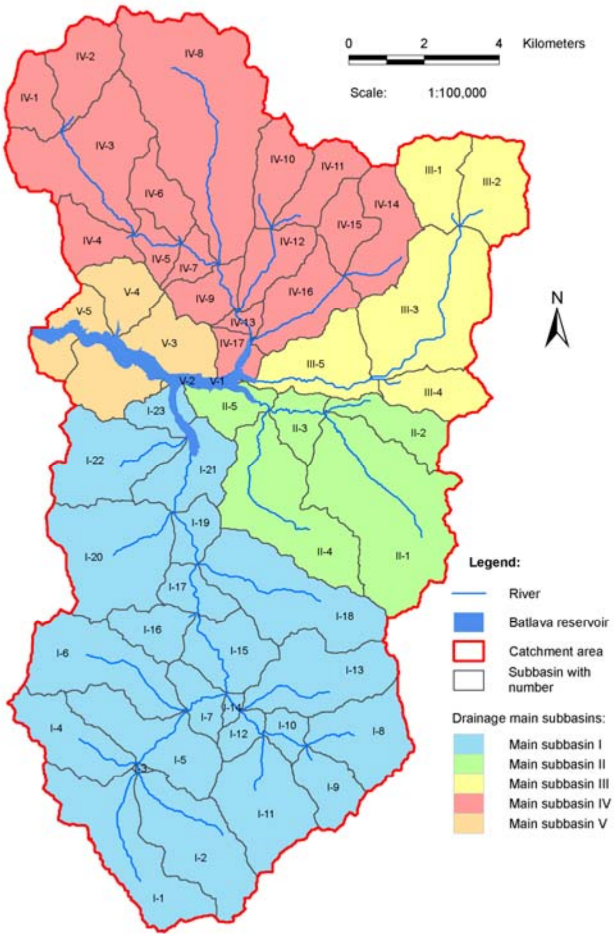

Figure 3: Sub-basins of the catchment area of Lake Batllava

Meteorological Model

Rainfall data and data on evapotranspiration were needed for the hydrological 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 Shajkovc and Llug are located outside, 4.0 and 7.5km 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 Shejkovc station was used for the hydrological modelling (Figure 4).

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

Main sub-basin I	Area [km²]
SB I-1	7.61
SB I-2	6.81
SB I-3	0.09
SB I-4	4.26
SB I-5	5.57
SB I-6	6.81
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 [km²]
SB II-1	13.15
SB II-2	2.96
SB II-3	1.98
SB II-4	8.85
SB II-5	2.37
Total MSB II	**29.3**

Main sub-basin III	Area [km²]
SB III-1	3.70
SB III-2	4.34
SB III-3	10.32
SB III-4	2.87
SB III-5	4.89
Total MSB III	**26.1**

Main sub-basin IV	Area [km²]
SB IV-1	2.47
SB IV-2	3.73
SB IV-3	8.76
SB IV-4	2.56
SB IV-5	1.41
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 [km²]
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**

COMPUTATION OF INFLOWS TO LAKE BATLLAVA

A hydrological 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 which shows a comparison between total monthly inflows to the Lake Batllava computed with the hydrological model and those 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 correlation between calculated and observed total annual inflows 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.

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 m³/month]					Monthly total inflow to the lake computed with hydrologic model [x10^6 m³/month]	Monthly total inflow to the lake obtained from water balance analysis [x10^6 m³/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

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

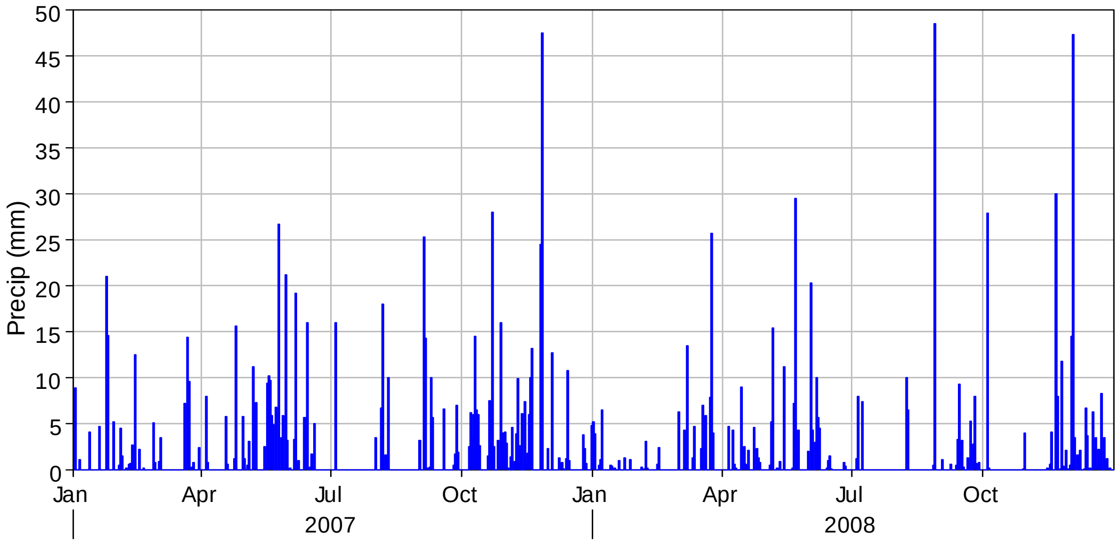

Figure 4: Daily rainfall at the rainfall station Shajkovc in the period 2007-2008

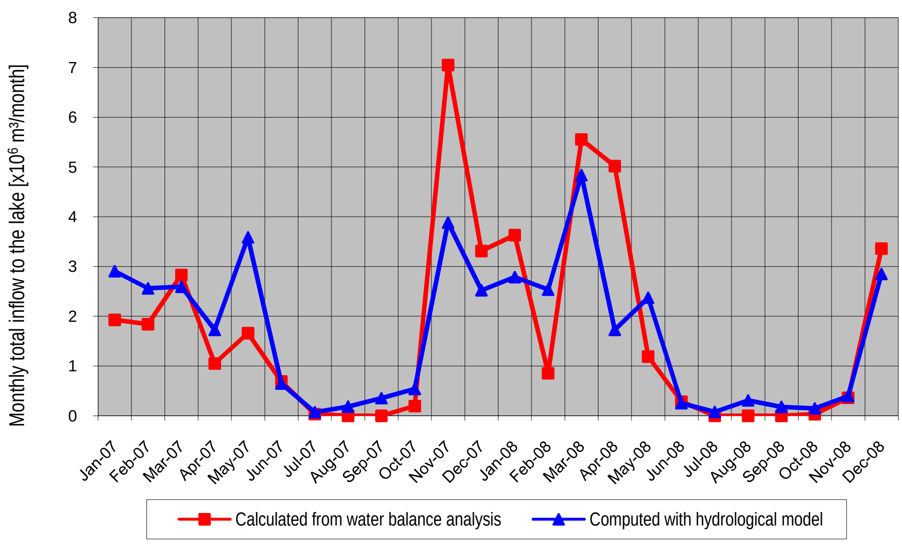

Figure 5: Monthly total inflows into the Lake Ballava, 2007 and 2008

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.

WATER QUALITY OF LAKE BATLLAVA

Chemical parameters, for which analyses were conducted, are in general in the acceptable range for raw water for water supply. Also, Lake Batllava is used as a recreation area during summer. Bacteriological analyses should be verified during the next years (Korça et al., 2002).

Three small rivers/ streams flow into 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. Water samples from the lake were taken at three different depths (5m, 10m and 15m) at different locations. Chemical parameters, for which analyses were conducted, are in general in the acceptable range for raw water for water supply (Table 5).

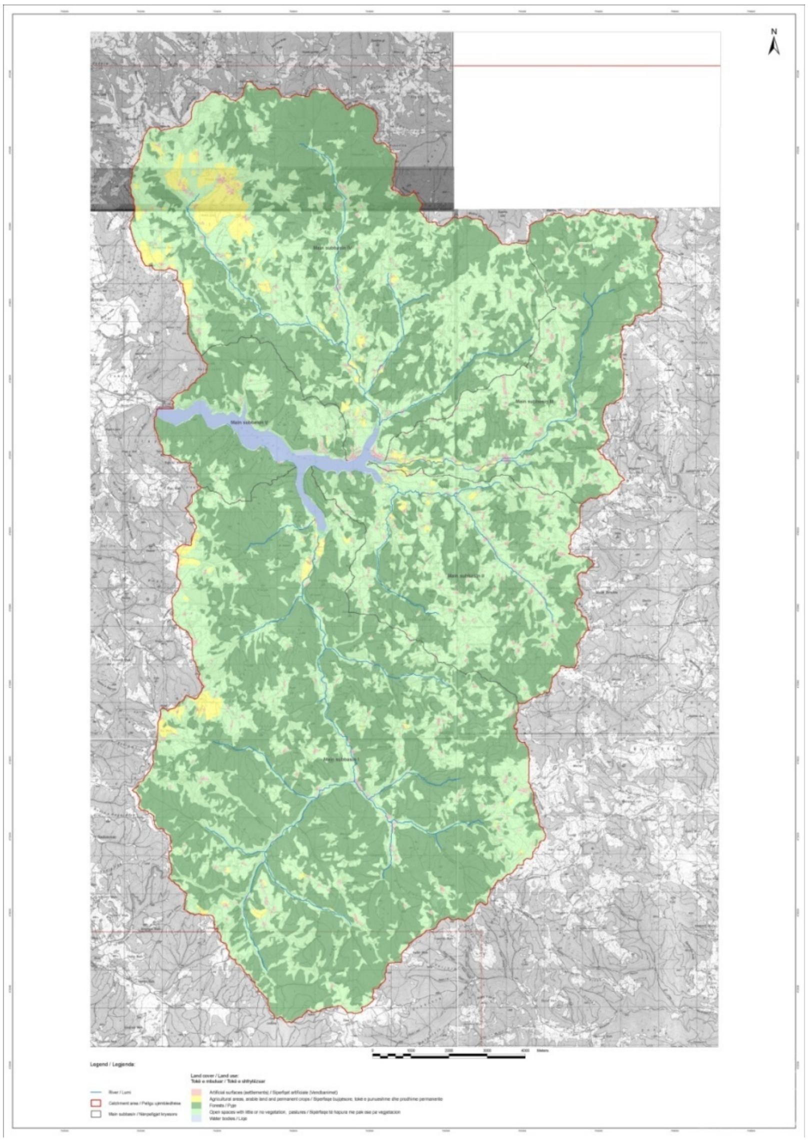

Figure 6: Land cover and land use in the catchment area of Lake Batllava

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 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 204km^2. A part of the agricultural areas concentrates 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 520ha. Settlements and roads cover 1.5% of the area; equal to around 340ha. Area covered by water courses is in the same range with 1.3%; equal to around 290ha. Overall, this can be seen as a favourable situation for the long-term sustainable use of Lake Batllava, as only around 4% of the total catchment area is 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 (Kolpin et al., 2002). 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).

Table 6. Survey of Batllava Orlan, 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 Houses/Buildings														
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
Shops/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
Restaurants/Hotels														
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

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 60% of the buildings have their private wells, and the others receive their water from a tanker truck. The concentrations of estrogens in the 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 from 2006 to 2008 is about 25 Mill. m^3/a. This value corresponds to the maximum treatment capacity of the water treatment plant Albanik of 70,000 m^3/d, or 25.5 Mill. m^3/a.

The results of the modelling show that the minimum, average and maximum total annual inflows to the lake can be expected to be around 13.5 Mill. m^3/a, 19.5 Mill m^3/a and 52.5 Mill. m^3/a (for low, average and high total annual rainfall).

The active storage volume of the Lake Batllava is assessed to be 34.4 Mill. m^3. Based on these assessments, the 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 more regularly monitored by the institution in charge for this public health issue.

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

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