J. Int. Environmental Application & Science, Vol. 3(5): 390-398 (2008)

Water Potential of the Gölbaşı Lakes and Their Sustainable Management[#]

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Abstract: Located at the interconnection point of the Mediterranean Region, East Anatolia Region and Southeast Anatolia Region, Gölbaşı Lakes is one of the important wetlands on the intercontinental bird migration routes. Located in the west of Gölbaşı district centre of Adıyaman province, this wetland is composed of three lakes, namely İnekli, Azaplı and Gölbaşı which have a total area of 5.97km^2. These lakes stretch along the northeast-southwest aligned long axis of the Gölbaşı depression which was formed in special conditions that developed under the control of East Anatolia Fault. The waters of the Gölbaşı Lakes, which are interconnected via the outlets, flow into the Aksu Creek. In this study, water potential of the Gölbaşı Lakes and the transfer of this potential to the following generations with sustainable management have been discussed. In this concept, the effects of the climatic, tectonic and hydrogeological features of the hydrographic basin of 210km^2 on the water potential have been set forth. Then, water balances of the lakes have been prepared. However; due to the fact that there are no adequate current measurements which put out the lakes' feeding with the surface flow, water balance has been calculated with M. Turc empirical method which gives more accurate results in Turkey's conditions. According to this, feeding and discharge of 40.167.992m^3/year have been observed in the Gölbaşı Lake; feeding and discharge of 52.748.901m^3/year have been observed in the Azaplı Lake; and feeding and discharge of 78.631.298m^3/ year have been observed in the İnekli Lake. Gölbaşı Lakes is under the threat of such factors as insensible irrigation and usage-intended water consumption which increasingly rises every year, drying activities for agricultural and residential purposes, decrease of the water sources which feed the system, and pollution. The transfer of a part of Aksu Creek's waters with gravitation from the north of the depression to the Gölbaşı Lake with a canal constitutes both the most economical and the most ecological solution for the elimination of the threats.

Key Words: Gölbaşı Depression, Gölbaşı Lakes, Hydrologic Balance, Sustainable Management.

Introduction

Water is a quintessential substance for the humans for their entire lifetime just like every living thing. For that reason, stream valleys, open coasts, floodplain areas and lake environs have been used as settlement areas by humans in the course of history. However, an opinion was embraced in time which asserted that wetlands such as especially shallow lakes, reeds and marshes are useless or even worthless places filled with pestiferous insects. The further addition of the desire to take control and exploit the nature by humans with the industrial revolution into this opinion caused the rapid destruction of wetlands. However, it started to be understood in the late 1960s that wetlands perform many functions which have vital importance. After the 1980s, the opinion asserting that wetlands must not be dried and must be protected on the contrary came forward. As for today, drying the wetlands is prohibited by laws.

The abovementioned course was also experienced in our country, and many of our wetlands which have intercontinental importance were dried. In addition to this, rapid growth of our population and the rise of the living standards with the economic development increase the per capita drinking water and utility water need. On the other hand, our clean and utilizable water sources rapidly decrease as a result of such factors as drying activities, global warming and drought. Water problems resulting

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[#] *This study has been presented at BIES'08, Giresun-Turkey*

from this condition necessitate the detection of our current water sources potential and their sustainable management.

Wetlands usually become dense in the tectonic depression areas in our country. One of these areas is the Gölbaşı Depression which developed under the control of East Anatolia Fault. Gölbaşı Lake, Azaplı Lake and İnekli Lake stretch along the northeast-southwest aligned long axis of the Gölbaşı depression. These lakes are located in the west of Gölbaşı district centre of Adıyaman, an area where Southeast Anatolia Region and Mediterranean Region intersect with each other (Figure 1).

Gölbaşı Lakes are also located in an area where East Mediterranean Flora Zone and Iran-Turan Flora Zone intersect with each other (Atalay, 1994). Gölbaşı Lakes provide significant contributions to the region's economy and country's economy with many of its functions such as regulating the water regime of the region, preventing floods, cleaning the water, fishery, inland hunting, animal grazing, agriculture, producing reeds and sedges, and recreation. In this study, the water potential of the Gölbaşı Lakes which have a vital importance in terms of water birds, which are on the intercontinental migration routes and which have wetland features will be determined and the sustainable management of this potential will be discussed.

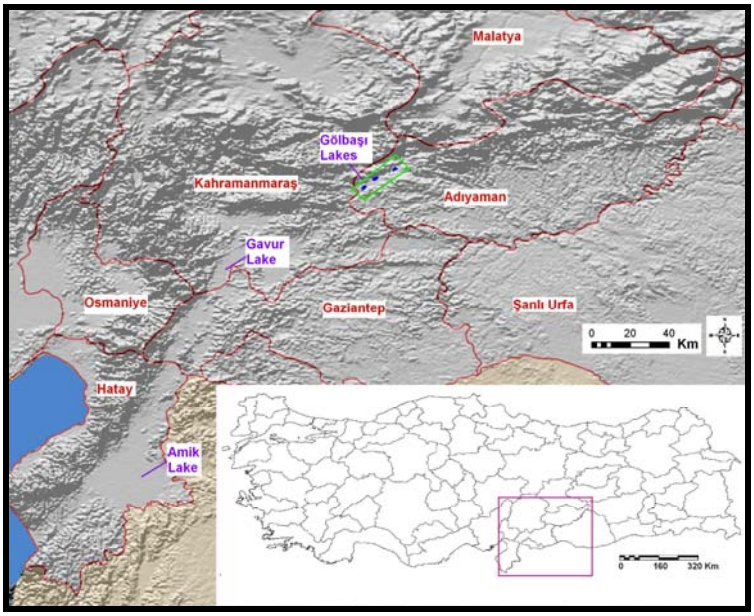

Figure 1: Location map of the Gölbaşı Lakes

Material and Method

The water potential of the Gölbaşı Lakes and its sustainable management have been set forth with the help of 1/35.000 scaled aerial photographs; data belonging to ASTER satellite; 1/25.000 scaled topography maps; geological maps, map sections and a levee maps in different scales, and reports related to them; results of the hydrological measurement conducted by XXth Regional Directorate of DSI (General Directorate of State Hydraulic Works); data from Adıyaman meteorological station which has the closest evaporation observer to Gölbaşı and the basin; literature and field works.

Feeding of the lakes is composed of surface flow (streams, sources and waters that transit from rainfall to flow), ground waters (infiltration from rainfall, extrabasinal latent underground feeding) and extrabasinal feedings, whereas the discharge of the lakes is composed of flows in the lake outlets, evaporation in the lake areas, and the infiltration waters in the lake beds. Due to the fact that there are no flow measurements which put out the lakes' feeding with the surface flow, water balance has been calculated with M. Turc empirical method which gives more accurate results in Turkey's conditions, and the value with 80% probability has been accepted as the water efficiency. In this method, Turkey has been divided into 26 precipitation basins and coefficient A of each basin has been calculated. According to this method, Gölbaşı Lakes are located in the East Mediterranean Basin Nr. 17. The coefficient of this basin has been stated as -171. In M. Turc method, the surface flow contains feeding and discharge with rainfall, streams, spring water (which feed with intrabasinal ground water),

infiltration waters, and evapotranspiration losses. When the evaporation on the lake surface and the infiltration amounts within the lake bed is subtracted from the surface flow, net water efficiency of the basin is obtained.

The level changes in the lakes have been analyzed using the results of the measurements which were conducted by XXth Regional Directorate of DSI between 1969 and 1998. Water quality has been determined by taking samples three times a year from the designated stations in each lake from three different levels, namely surface, medium and bottom.

Results and Discussions

Formation of the Gölbaşı Lakes

The basin in which the Gölbaşı Lakes are located developed in the East Anatolia Fault Zone where the Neotectonism is experienced densely; and under the direction and control of this fault. East Anatolia Fault spans from Kargapazarı region, located in the east of Karlıova which is the intersection point with North Anatolia Fault, to Türkoğlu where it meets Dead Sea Fault in northeast-southwest direction through southwest (Yalçın 1979). In this area, the fault is not in the form of a single slippage plane and it is composed of many faults which stretch parallelly and diagonally with each other in the form of a zone. These faults sometimes approach each other and sometimes move away from each other. As a result of these approaches and divergences, the depression areas and elevation areas were formed along the fault zone. One of these depression areas is the Gölbaşı Depression which is located in the section of the fault between Perveri and Aksu Creek. East Anatolia Fault spans in the northeast-southwest direction as two separate zones between Perveri and Aksu Creek. One of these zones borders the Gölbaşı Depression from the south and the other zone borders the Gölbaşı Depression from the north. The branch in the south is in the form of a single fault between Perveri and Gölbaşı and in the form of a zone which is composed of many faults parallel to each other between Gölbaşı and Aksu Creek. Both vertical strike and left lateral strike have been detected in these faults. The north block collapsed in the faults. While the faults in the north of the depression show an alignment in northeast-southwest direction, there are many northwest-southeast aligned faults which intersect them diagonally. In the northeast-southwest aligned faults, the north block rose and the south block collapsed (İmamoğlu 1993).

Gölbaşı Depression whose long axis is in northeast-southwest direction was formed between the branches of the abovementioned East Anatolia Fault as a collapsed fault slippage (İmamoğlu 1993). The north (Karyağan T. 1474 m) and the south (Büyük T. 1331 m) of the depression are surrounded with elevations. Fault formations caused the elevations surrounding the depression to earn a cascaded appearance (especially in the south of the depression). Depression base has an elevation between 873m and 900m; and Gölbaşı Lake, Azaplı Lake and İnekli Lake are aligned in its deepest sections from north to south. The width of the depression generally decreases from southwest to northeast. Its narrowest section is located between Gölbaşı Lake and Azaplı Lake (Figure 2).

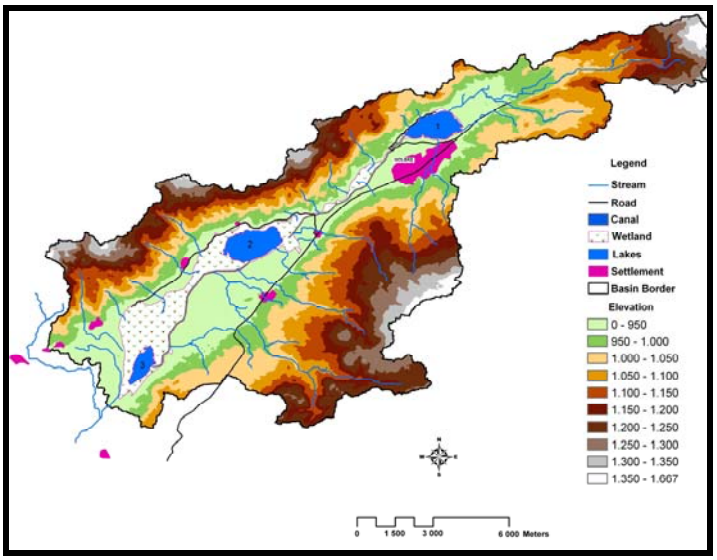

Figure 2: Gölbaşı Depression and Gölbaşı Lakes

Crashed, fragmented and shifted alluvial cones and alluvial fans are aligned as a result of the fault formations between the elevations which surround the depression base and the depression. Sometimes alluvial cones in the north and south slopes have presented such a development that it almost combined with each other in the depression base. This condition becomes effective in the depths and areas of the lakes which are located in the depression base (Selçuk Biricik 1994).

Hydrology of the Gölbaşı Lakes

In the Gölbaşı Lakes basin where the Neotectonism is experienced densely (Figure 2), units whose ages differ from Mesozoic to Quaternary become effective in the hydrologic features of the basin. The base of the basin is composed of Jura-Late Cretaceous aged allochthon ophiolites. This unit which is composed of ultrabasics, volcanics and sediments presents an irregular internal structure. This unit is rather represented with serpantinites and ultrabasics. Another Late Cretaceous aged allochthon unit which is existent in the basin is silicified limestone with a flysh characteristic, siliceous shale, clayish limestone, sandstone and piling which is composed of silicified marn levels. Allochthon units present exposure in the elevation bench which surrounds the Gölbaşı Lakes from the south and they are defined as impermeable due to their lithological structures.

The other units which are existent in the basin have autochthonous characteristic. The base of the autochthonous units is composed of piling which starts with Late Cretaceous-Early Paleocene aged marn and clayish limestones, continues with limestone-siltstone intercalation and ends with siltstone-claystone intercalation; and this piling has impermeable characteristic. Above those, there is a Late Paleocene aged unit which starts with a base conglomerate having a polygenic element and aligns in the form of sandstone, siltstone and nummulitic limestones through the upper parts. It is semi-permeable. As for Early Eocene, it is represented with a unit which starts with sandstone and conglomerate intercalation in the base and continues with marns following the conglomerates. Marn levels earned the unit an impermeable characteristic. All of the abovementioned units are observed in the elevation bench which is in the south of the depression. Middle Eocene-Late Oligocene aged units which are composed of neritic limestone and limestone present exposure in the elevation bench which is in the north of the depression, and they are permeable. Pliocene aged piling is composed of units which start with conglomerate, sandstone, claystone and mudstone intercalation in the southwest of İnekli Lake and mudstone, chalky claystone and marn intercalation in the surroundings of the highway between Balkar and Gölbaşı and continue in the form of densely chalky claystone, marn and intercalation of heavily porous limestone bands; and contains lignite coal deposits (Selçuk Biricik, 1994). Due to its lithological structure, the unit is defined as impermeable. The piling, which is composed of the intercalation of conglomerate-sandstone-mudstone-siltstone levels belonging to the Plio-Quaternary period and slope screes, presents exposure and it has semi-permeable characteristic. Old alluviums and alluvial fans which shifted with the quaternary-aged fault, and have running sand and pebble lithology cover a vast area in the south of depression especially between the depression base and the slopes surrounding the depression. In the base of the depression, there are new alluviums composed of pebble and sand levels. Moreover, screens are seen in front of the elevations and fault scarps around the depression. Quaternary units are permeable.

Gölbaşı lakes rather feed with surface waters. Rainfalls form the source of the surface waters. Climate of the Gölbaşı Lakes basin presents a transition characteristic between the Mediterranean climate and the continental climate. Thus, 48% of the rainfall occurs in winter, 31% in spring, 19% in autumn and 2% in summer. Considering that lakes rather feed with rain waters, maximum levels should be measured in winter. In the level measurements (1969-1999) conducted in lakes, maximum water levels are mostly recorded in spring. The reason for this is that the snow falling on the basin during the winter melts in spring and combines with the spring rainfalls. The minimum water levels on the lakes have not been measured in summer months when the rainfall is at minimum, but instead measured during the autumn months (Table1). In addition to the fact that in the summer period precipitation occurs at a minimum level and evaporation occurs at a maximum level, such factors as drawing irrigation water from the lakes during the summer months and the early autumn and the failure of autumn precipitation to eliminate the shortage of water in soil are effective in this issue. This change in the lake levels reflects to the areas, depths and water volumes of the lakes (Table 1).

Table 1: Depth, surface elevation and water volume of Gölbaşı Lakes

Surface Elevation	Gölbaşı	Azaplı	İnekli
*Maximum (m)**	885,23	876,76	874,34
*Minimum (m)**	883,52	874,66	871,78
*Average (m)**	884,44	875,31	873,76
*Lake Bottom (m)**	861,8	852,9	863,9
Depth based on Average Elevation (m)	22,64	22,41	9,86
Area Based on Mean Elevation (km^2)	2,45	2,83	1,2
Water Volume Based on Mean Elevation (hm^3)	32,352	33,147	6,786

* XXth Regional Directorate of DSI.

The waters of the Gölbaşı Depression flow into Aksu Creek. Gölbaşı Lake on the base of the depression is connected to Azaplı Lake with the help of an outlet, and the Azaplı Lake is connected to İnekli Lake again with an outlet. The waters of İnekli Lake, consequently the waters of the depression area are drained into Aksu Creek with an outlet (Figure 3).

Since there is no adequate flow measurement to put out Gölbaşı Lakes' feeding from the surface flow within the feeding area of 210,19km^2, this value has been attempted to be determined by M. Turc empirical method. Although the lakes are connected to one another with outlets, water balance of each lake has been separately calculated.

Gölbaşı Lake

It is located at the farthest northeast point of Gölbaşı depression (Figure 1). Its surface reception basin is 61,93km^2. The average elevation of the lake surface from the sea level is 844,44m. In line with this level, its area has been determined as 2,45 km^2, depth as 22,64m, and water volume as 32,352hm^3. (Table 1)

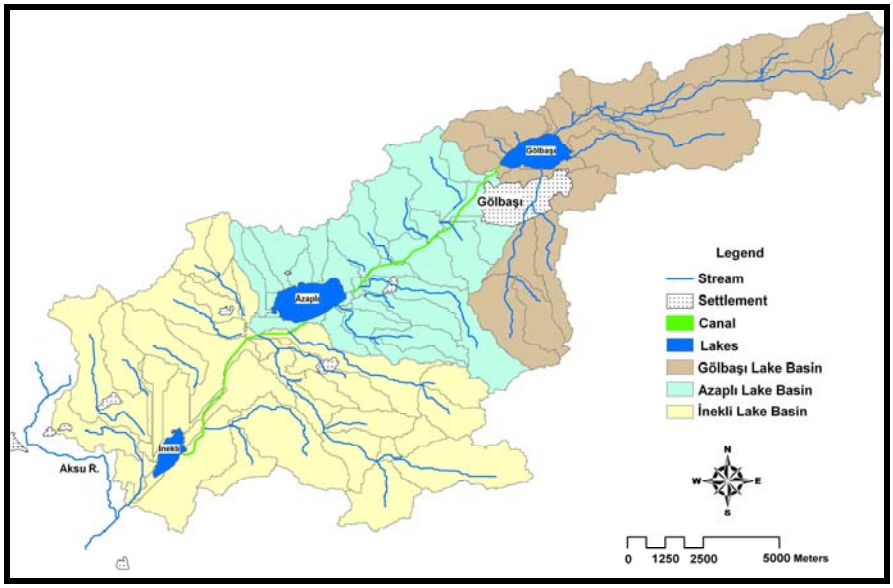

Figure 3: Gölbaşı Lakes subbasins

The lake mostly feeds from Yemişen, Kırkbayır, Nergis, Alikayası and Ağ Creeks located in the south and northeast. These rivers which feed the lake can directly reach the lake when there is adequate precipitation, yet when there is inefficient precipitation they dry up. However, these rivers lose so much water through infiltration while passing the alluvial fillings formed by them. This enables the Gölbaşı Lake to feed from the underground through infiltration. In addition to this, it also feeds from the surrounding spring waters. There is a relation between the lake level and the precipitation regime which forms the source of the rivers feeding the lake. According to measurement results, while the water level is at a minimum level in September and October, it increases to the

highest level in March. Other than this, the water level is observed to be above the average level from January to June, whereas it appeared to be below the average level from July to December.

Because flow measurement was conducted by DSİ between the years 1970-1995 in the Gölbaşı Lake outlet, primarily discharge has been observed in the calculation of water balance. In view of this, from the lake area, a water discharge of 4.456.663m^3/year occurs by means of evaporation, a water discharge of 4.902.329m^3/year from the lake base by means of infiltration and a water discharge of 30.809.000m^3/year occurs from the lake outlet. Thus, the total amount of discharge in the Gölbaşı Lake is 40.167.992 m^3/year (Table 2).

Table 2: Water balance of the Gölbaşı Lake

Gain (m^3/yıl)		**Discharge (m^3/yıl)**	
From surface runoff	22.419.026	*Evaporation from lake surface*	4.456.663
From ground water (out of basin)	17.748.966	*Infiltration to ground* *	4.902.329
		*Outlet discharge***	30.809.000
TOTAL	**40.167.992**	**TOTAL**	**40.167.992**

* Infiltration to ground value calculated by multiplying constant value (1,10) with surface evaporation rate. (Özer, 1990)
** XXth Regional Directorate of DSI

The feeding of Gölbaşı Lake through surface flow is 22.419.026m^3/year. In line with this, there is a difference of 17.748.966m^3/year between the total discharge and the feeding from surface flow. This difference constitutes the feeding of Gölbaşı Lake from extrabasinal groundwater (Table 2). The dense karstification and tectonism in the basin of the Gölbaşı Lake causes such an extrabasinal feeding.

Azaplı Lake

It is located between the Gölbaşı Lake and the İnekli Lake (Figure 3). Its surface feeding area is 53,1km^2 and in line with the average lake level its lake area has been determined as 2,83 km^2, its depth as 22,41m and water volume as 33,147hm^3 (Table 1). The base of the Azaplı Lake (852,9m) constitutes the deepest point of the depression. The dissolution of tectonism and of the limestones in the lake base has been effective in this formation (Selçuk Biricik 1994).

In addition to the rivers and sources feeding the lake, Azaplı Lake is under the effect of the water regime of Gölbaşı Lake. Hüseyin, Karacaoluk, Yılanlı and Çınargöl Creeks with flood characteristics flow into the lake from the north and south. While the average water level in Azaplı Lake is at a minimum level in August, it rises to the highest level in April. It is seen that the level averages are above the average level from December to June and below the average value from July to November.

The feeding of the lake from the surface flow occurs as 18.889.593 m^3/year. At the same time, yearly 30.809.000m^3 water discharges to the Azaplı Lake from the Gölbaşı outlet. Since there is no flow measurement in Azaplı Lake outlet, in order to determine the feeding amount from the extrabasinal ground water, İnekli Lake water balance has been utilized. When the feeding of the Azaplı Lake from the extrabasinal ground water is not taken into account, a yearly flow of 38.867.454m^3 from the lake outlet to İnekli Lake must take place. The feeding of the İnekli Lake from the Azaplı Lake outlet and extrabasinal ground waters has been calculated as 44.968.070 m^3/year. When the amount of Azaplı Lake outlet is subtracted from this figure, it is seen that the feeding from extrabasinal ground waters in two lakes is 6.100.616 m^3/year. This value has been divided into two (3.050.308 m^3/year) and accepted as the feeding amount from the extrabasinal ground waters of Azaplı and İnekli Lakes. According to this, the total feeding occurs as 52.748.901 m^3/year. In Azaplı Lake, yearly 5.157.685m^3 water discharges from the lake area via evaporation, 5.673.454m^3 water discharges from the lake base via infiltration and a water discharge of 41.917.762m^3/year occurs via the lake outlet (Table 3).

Table 3. Water balance of the Azaplı Lake

Gain (m^3/yıl)		Discharge (m^3/yıl)	
From surface runoff	18.889.593	*Evaporation from lake surface*	5.157.685
*From Gölbaşı Lake **	30.809.000	*Infiltration to ground*	5.673.454
From ground water (out of basin)	3.050.308	*Outlet discharge*	41.917.762
TOTAL	**52.748.901**	**TOTAL**	**52.748.901**

* XXth Regional Directorate of DSI

İnekli Lake

It is located in the farthest southwest of the depression (Figure 3). Its feeding area is 95,16km^2 and stands as the lake with the smallest area and the lowest depth among the Gölbaşı Lakes. In line with the average water level, the area of the lake is 1,2km^2, its depth is 9,86m and water volume is 6,786 hm^3 (Table 1).

In addition to the outlets of the Gölbaşı and Azaplı Lakes, for the feeding of İnekli Lake, small sized seasonal creeks around the lake, karstic source type sources, of which the flow rates ranges from 10 to 15lt/sec and which spring from different points in the northern skirt between Azaplı and İnekli lakes hold an important place. Other than these, on the former flow destination, the waters which infiltrate to the underground from Başpınar spring waters (approximately 50lt/sec output) which have a river bed source character and which infiltrate from the loose-textured alluvial fillings of the alluvial fans composed by the Aksu Creek feed the İnekli Lake (Selçuk Biricik, 1994).

To increase the discharge of the İnekli Lake waters into the Aksu Creek, a drainage canal were opened in 1986. The opening of this canal caused changes in the İnekli Lake and consequently in the areas and levels of the Azaplı and Gölbaşı Lakes.

In view of the results of the level measurements conducted in the lake, the average water level is at minimum in September, and reaches a maximum level in May. It has been determined that the average water level in the lake is above the average level from December to June, and below the average value from July to November.

Inekli Lake has a total feeding of 78.631.298 m^3/year including 33.663.228 m^3/year from the surface flow, 41.917.762 m^3/year from the Azaplı Lake outlet and 3.050.308 m^3/year from the extrabasinal ground waters. In İnekli Lake, a total of 78.631.298m^3/year water discharge occurs including 2.192.999m^3/year water from the lake area via evaporation, 2.412.299m^3 water from the lake base via infiltration and 74.026.000 m^3/year water via the lake outlet (Table 4).

Table 4: Water balance of the İnekli Lake

Gain (m^3/yıl)		Discharge (m^3/yıl)	
From surface runoff	33.663.228	*Evaporation from lake surface*	2.192.999
*From Azaplı Lake **	41.917.762	*Infiltration to ground*	2.412.299
From ground water (out of basin)	3.050.308	*Outlet discharge**	74.026.000
TOTAL	**78.631.298**	**TOTAL**	**78.631.298**

* XXth Regional Directorate of DSI

The abovementioned water balances of the Gölbaşı Lakes are affected in recent years by the waters pumped from the Göksu Creek outside the basin. In order to solve the water shortage problem in Kartalkaya Dam situated over the Aksu Creek, the waters of Göksu Creek are drawn with pumps with a pumping flow rate of 1,625m^3/sec and transferred to Gölbaşı Lake. In this way, 14.629.248m^3 water was discharged to Gölbaşı Lake with one pump in 2004 and 53.888.744m^3 water was discharged to Gölbaşı Lake with 3 pumps in 2007 (DSİ. XXth Regional Directorate). As all 8 pumps will begin to operate in the following years, this amount will also increase more.

The water quality of the Gölbaşı Lakes has been determined with the measurements and laboratory analyses which were conducted in autumn and summer. According to this, Gölbaşı Lakes are within the scope of lightly polluted second class waters in accordance with the "Water Pollution Control Regulation". Such type of waters cannot be used as potable water or utility water in houses

without a purification system which is required in accordance with the definition stated in the concerning regulation. However, they can be used in irrigation, recreation and fish production except salmon. Gölbaşı Lakes are in a polluted condition in terms of the total number of coliform and fecal coliform bacteria reflecting the bacteriological characteristics. The discharging of the sewage waters of the settlements around the lakes into the lakes has an effect in this pollution related to the human excrements.

Gölbaşı Lakes which are naturally connected to each other from the surface and base, the spatial development of the Gölbaşı City, the discharging of sewage water into Azaplı and İnekli lakes without establishing the purification process, the chemical fertilizers and pesticides used during the agricultural activities threaten the water quality of the lakes. In addition to these, draining operations for agricultural purposes and especially the use of river and spring waters, which feed the system, in irrigation, negatively affect the natural water regime of the lakes.

The Sustainable Management of the Water Potential of Gölbaşı Lakes

Sustaining the continuity of the wetland ecosystem of the Gölbaşı Lakes and more significantly transferring the fresh water sources to future generation in a healthy manner can be realized with the abovementioned sustainable method of water potential. To this end, in addition to the primary awareness with which the local people must be equipped, the factors that threaten the quality of the lake waters must also be eliminated. The wetland borders must be preserved with its present form, organic agriculture must be encouraged in the area and the drawing of water from the lakes for use with agricultural purposes must be performed controllably so that it does not disturb the natural balance. Aksu Creek alternative must be evaluated to achieve this. Part of the waters of Aksu Creek located at a height of 910m close to Bozlar town might be transferred to Gölbaşı Lake via a canal along the north bank of the Gölbaşı Depression by forming gravitation. Thus, the water required for agriculture is provided and the water circulation is achieved by means of supporting the feeding of the lake especially in summer, which, in return, decreases the pollution level in the lake.

Conclusion

As a result, Gölbaşı Lakes are one of the significant wetlands that managed to survive to our present-day, at the same time preserving the natural water regime to a large extent despite a human intervention. However, if necessary measures are not taken today, it is a truth that the lakes will face a risk of destruction. The elimination of this risk is possible with the use of the present water potential in a sustainable management understanding.

Acknowledgement: *This paper was summarized from the TÜBİTAK project named "Gölbaşı Lakes wetland Ecosystem Management Plan" which was prepared by us.*

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