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THE LAND USE IN THE WATER RESERVOIRS AREAS OF ISTANBUL

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Abstract

This study considers the land use in the water reservoirs areas supplying Istanbul in freshwater. A literature review was pursued, gathering information on Büyükçekmece, Terkos, Elmalı, Ömerli, Küçükçekmece (not used as a drinking water source), Darlık, Alibeyköy and Melen watersheds. Then, field observations were performed in the Büyükçekmece lake. The types of land use focused in this study are the residential areas, industries, transportation ways and agricultural areas.

This review highlights that almost all the reservoirs supplying Istanbul witness rapid urbanization leading to residential settlements, industries and agricultural fields widespread in the protection zones of the reservoirs.

Introduction

The land use is defined by the OECD as “based on the functional dimension of land for different human purposes or economic activities. Typical categories for land use are dwellings, industrial use, transport, recreational use or nature protection areas”. The land use development has major impact on the environment among them the degradation of the ecosystem and water resources (US EPA; 2001). The water supply of the megacity Istanbul is mainly supported by surface waters, the majority lying in the provincial boundaries, with the exception of Melen located in the Düzce province. These reservoirs are endangered by the urbanization. Indeed, the protection zones set up by ISKI are threatened. The ISKI regulation states that permanent settlement and industrial activities are forbidden in the absolute and short protection zones. Starting from the medium-range protection zone, ISKI permits a very low density of single houses¹.

Several factors influencing the degradation of the water bodies were identified by Geymen et al. (2011) like highways; illegal settlements; the second Bosphorus bridge; the municipalities established in the watershed’s boundaries; the industrial activities; complex jurisdictional authorities and the weakness of ISKI’s by-laws.

Transportation ways bring pollution like polycyclic aromatic hydrocarbons, mineral oil and heavy metals, damaging the water quality. This is all the more worrying that several highways cut the watersheds of Istanbul (Demirel et al.; 2008). Furthermore, road construction has impact on the modification of hydrology (US EPA; 2001).

The construction of the E-5 motorway and the 1st Bosphorus bridge determined the urban expansion of Istanbul (Tekeli et al.; 2009). The processus of expansion also affected the agricultural lands which were replaced by urban lands (Tekeli et al.; 2009). Urbanization is also a significant factor leading to forests degradation and land use/cover change (Yu et al.; 2010 quoted in Sivrikaya et al.; 2011). The forests of Istanbul became damaged because of the urban sprawl (Tekeli et al.; 2009).

Stated that the more the impervious surfaces increase, the more the pollutant loads in the watershed rise (US EPA; 2001), the land use in the Istanbul water bodies areas is a question that need to be addressed. Several articles refer to the land use around the water reservoirs supplying Istanbul in freshwater. Although mostly of the data comes from 2006 and before, they provide a useful overview on which this study is based on.

The objectives of this study are: (i) to hold a literature review about the land use situation of the reservoirs supplying Istanbul in freshwater and (ii) to present field observations carried out in Büyükçekmece lake.

¹ ISKI new regulation (2006):

From 0 to 300m: absolute protection zone

300-1000m: short range protection zone

1000-2000m: medium range protection zone

2000m – water basin borders : long range protection zone

Literature review

1. *Büyükçekmece*

Maktav and Sunar (2010) focused on the urban land-use changes in Büyükçekmece district. The district underwent a rapid urbanization during the last decades, mostly due to the huge amount of migration since 1970's. The authors estimated the land use changes from 1984 to 1998: the total settlement area increased by 19.7%, the stone quarry area by 1.3 % and the industry area by 1.5 %. During the same period, the field areas decreased by 26.4 % and the forest area by 0.7 %. Kavaklı, Kıraç, Esenyurt and Hoşdere are the sub-districts where the most important changes occurred. The authors emphasized that in these sub-districts, while the settlement areas increased, the agricultural fields declined. Mimarsinan also witnessed a large scale change from 1984 to 1998. The TEM serving the district is one of the key points in the understanding of the rapid urbanization of the area.

According to the maps drew up by DSI²(cf. Appendix 7), Ahmediye is located in the absolute protection zone, Mimarsinan is situated in the short range and Tepecik in the medium range protection zone.

Guyer and Ilhan (2011), studied the land use and water quality of Büyükçekmece watershed between December 2007 and June 2008. They investigated land uses according to the protection zones and in the surroundings of the main streams feeding the lake. They found 16 facilities in the absolute protection zone; 23 in the short protection zone; 13 in the medium protection zone and 77 in the long range protection zone (cf. Appendix 1). Moreover, the authors identified the livestock and farms' distribution in the protection zones. They notice 4 personal farms in the absolute protection zone and dairy, chicken and dog farms located in the short protection zones (cf. Appendix 2). In addition, settlements are established in the absolute and short protection zones (cf. Appendix 3). The water quality is endangered because of non treated wastewaters coming from the villages near the streams. Thus, high level of nitrogen and phosphorus occurs because of domestic discharges.

According to the authors, the distribution of the land uses in the watershed is as following: 65 % of agricultural lands, 19 % of forests and meadows, 10 % of settlements, livestock, farms and limited industrial activities. Livestock and farms are responsible of high level of fecal coliform in streams. Nevertheless, Guyer et Ilhan (2011) argue that the flow rates of the streams are so low that it's not significant for the global water quality of the lake. Finally, the water quality class of the lake is second class but approaches class three. Among other things, this is the consequence of livestock, agricultural and residential areas. Thus, the authors warn about the function of drinking water supply of Büyükçekmece which won't be ensured shortly.

2. *Terkos*

The contribution of Terkos reservoir in the water supply of Istanbul is around 25 %. The TEM connects Terkos lake to the city (Coskun et al.; 2006). It was estimated that 16 % of the population of the area live in Balaban and Durusu located in the absolute protection zone (Coskun et al.; 2006), whereas 73 % live in the long-range protection zone. Ormanli, Hisarbeyli and Celepköy are located in the short protection zone (cf. Appendix 7).

Moreover, deforestation occurred in the surrounding of Tayakadin stream because of urbanization.

From 1992 to 2000, the study shows the increase in pollution load around the Karliyan stream as a consequence of the urbanization. Agricultural fields are extended around the reservoir and cover 17% of the region, while forests and meadows mean for 77 % and represent the first nitrogen source, following by domestic and agriculture (use of pesticides). Furthermore, Coskun et al. (2006) identified animal breeding industries,

² Maps were given by DSI, the 15-04-2013. The data are dated from 2006.

non-metallic mining and quarries in the region. Nevertheless, according to them, urban industries don't discharge their effluents in the lake.

3. *Elmalı*

Musaoglu et al. (2005) studied the area of the Beykoz province belonging to the Elmalı watershed. Among the 540 ha of Beykoz located within the watershed boundaries, 157 ha are established in the absolute, short and medium range protection zone. The urbanization effects led to a twofold increase of urban areas in these zones, between 1984 and 2001. Thus, instead of complying with the ISKI legislation of 30 cap/ha, the population density reached 39.42 cap/ha. Moreover, the authors estimated the land-use distribution between 1984 and 2001. It appeared that deforestation occurred mostly during the 1992-2001 period, resulting in the substitution of forest areas by residential areas. The forest areas lying in the watershed declined by one-half during this time, whereas urban areas increased from 16 % to 27 %. Similarly, Balik Sanli et al. (2008) highlighted this phenomenon in Çavuşbaşı region. On the maps given by DSI (cf. Appendix 6), one can notice easily the location of Çavuşbaşı in the absolute protection zone.

Furthermore, Musaoglu et al. (2005) recorded that agricultural lands increased from 20 % to 32 % and the barren land from 3.5 to 8 %, showing the rise of urbanization. Moreover, the authors argued that many settlements were built illegally, leading to domestic wastewater effluents reaching the reservoir through infiltration or surface runoff. In 1994, the reservoir belonged to the class 3 in terms of water quality, which means polluted water status. Thus, advanced treatments are essential for the use as a drinking water. In addition, the TEM cuts through the protection zones of the reservoir and adds traffic pollutants (Musaoglu et al. 2005; Kucukmehmetoglu, Geymen, 2009).

4. *Ömerli*

Ömerli reservoir provides 40 % of the water demand of Istanbul. In so doing, it represents the largest share in the water supply contribution of the city. Nevertheless, the water quality is seriously damaged by a high annual rate of population increase and unplanned developments (Coskun et al. 2009). Between 1990 and 1997, the growth population rate was 101 % (Tezer et al., 2012). Among them, Sultanbeyli, Sancaktepe and Samandıra districts are located around the Ömerli lake (Kucukmehmetoglu, Geymen, 2009; Tanik et al. 2000; Dubovyk et al. 2011). The north-eastern part of the Sancaktepe district belongs to the watershed and includes informal settlements located near the border of the lake (Dubovyck et al. 2011). According to Tanik et al. (2000), the population raised to 35.67 % in the southwest part of the catchment between 1985 and 1990. Moreover, among the 26 settlements areas identified, 65 % are located in the long-range protection zone, 12 % are in the short-range and 8 % in the absolute range. Nevertheless, these last percentages of settlements lying in the absolute and short protection zones cause a harmful impact on the water quality of the reservoir (Coskun et al., 2009). Besides, it has been recorded that the most important pollutant sources emanate from domestic points. Maps drew up by DSI inform that Esenceli, Kurt Dogmus and Emirli are located in the absolute protection zone. Ballica, Kurna, Pasaköy and Kooullu are in the medium range protection zone (cf. Appendix 6).

Regarding the land use distribution of the watershed area, it is divided up as following: 51 % of forests; 35 % of meadows and agriculture and 10 % of settlements (Coskun et al., 2009).

In addition, Tanik et al. (2000) registered 260 industrial plants in the watershed area, included animal breeding and metal industries. According to Tezer et al. (2012), the agricultural areas decreased significantly by up to 82 % whereas built up areas increased by 169 % between 1990 and 2010. Finally, motorways cut the protection zones and amplify the pollution in the area (Tanik et al. 2000; Coskun et al. 2008).

In the last ten years, Sultanbeyli district witnessed an increase of the population by 2000 % (WWF and the World Bank, 2003). Sultanbeyli district altered the natural resources of the area. Indeed, it was established in a forest area, which above all, includes one of the main transportation ways of Istanbul (Geymen, 2011). Moreover,

Geymen (2011) and Demirel et al. (2008) argue that the construction of transportation network foster the increase in urbanization near the transportation ways. Indeed, industrial zones and settlements stemmed are built up in the water basins (Geymen, 2011). The author warns that the planned third bridge may lead to urbanization in the watershed areas and deforestation.

5. *Küçükçekmece*

The district of Küçükçekmece underwent a high rate of migration and consequently unplanned urbanization widened in the region. In 1992, the urban areas went up to 729 ha, and spread to 3630 ha in 2006 (Coskun et al.; 2008).

The purpose of the study of Demirci et al. (2006) was to link the water quality of the Küçükçekmece lake with the land use in the area. The authors argued that unplanned urbanization and domestic and industrial discharges related figure among the major polluting factors. Indeed, industrial and residential wastewaters are discharged in the lagoon (Ümit Taner et al., 2010; Demirci et al., 2006).

Many industries in Hadımköy and İkitelli discharged their effluents in the Ekşinoz and Nakkaşdere streams feeding the lake. Moreover, other industrial areas were established in the north western part of the region and exacerbate the amount of pollution. These industries include textiles, metallurgy, chemistry, wood and leather (Demirci et al.; 2006). Textile, metal, petrol and plastics firms are the most significant industries in the area, especially in Hadımköy, Kayabaşı and Firüzköy located nearby the lake and its streams (Ümit Taner; 2007).

Taner et al. (2010), monitored the water quality of the lagoon between 2005 and 2008. The authors argue that the lagoon reached the eutrophic stage, because of the land use changes. Nevertheless, the water quality is variable as a consequence of application of pesticides depending on the season.

In 2004, the land distribution was as following: 42 % of agricultural land; 24 % of residential areas; 4 % of industries; 0.4 % of mining; 1 % of motorway (TEM), whereas natural areas represented 23 % (Demirci et al.; 2006).

6. *Darlık*

The paper of Alparslan et al. (2010) outlines the situation in Darlık watershed. According to the study, urban areas represented 0.39 % of the total watershed in 2006. The urban areas cover 1.23 ha in the absolute protection zone; 4.78 ha in the short protection zone; 3.68 ha in the medium zone and 70.81 ha in the long range zone. Despite the low level of urban areas, domestic wastewaters discharged effluent into the rivers feeding the lake, leading to the slightly polluted water quality status (Alparslan et al.; 2010).

7. *Alibeyköy*

Gaziosmanpaşa and Sultangazi are two districts located in the Alibeyköy reservoir area and witnessed a rapid population growth (Geymen, 2011). According to the maps from DSI, Bogazkoy and İmrahor are located in the absolute protection zone (cf. Appendix 7).

8. *Melen*

The Melen project, built up out of the borders of the province, is a partnership between İSKİ and DSI (Gurel et al., 2010). İkiel et al. (2012) revealed that significant land cover changes occurred between 1987 and 2010 (cf. Appendix 4). The forest areas underwent a dramatic decrease of 33.5 % in the period and were replaced by agricultural areas. Similarly, industrial and commercial areas increased significantly by 161 % whereas inland wetlands dropped by 62 %.

Sivrikaya et al. (2011) focused on the forest degradation of Cumaova region in Düzce province. The results show that from 1987 to 2008, the average annual deforestation rate of Cumaova region reached 31.6 ha per year which corresponds to a 5 % decrease in the period. The two main highways E5 and D-100 cross the watershed.

The map from DSI gives information concerning the settlements around the lake. One can notice that numerous of them are located in the short and medium range protection zones (cf. Appendix 8).

Moreover, Pehlivanoglu Mantaş et al., (2007) mapped the industries established in the Düzce province (cf. Appendix 5). The province includes one organized industrial district. Textile, machinery, metal and forests products are the most significant industrial sectors which account for 27 % and 21 % respectively. Nevertheless, in terms of wastewater flow rates, the textile sector is the more notable with 66 % of discharges, following by the food sector with 11 %. Moreover, there are 245 individual industrial facilities also belonging to the food, textile and forests products sectors. The industries belonging to the food sector are yeast, dairy, catering, tobacco, slaughterhouse and beverage. The food sector registers high pollution loads but the domestic wastewaters are responsible for half of the total pollution (Pehlivanoglu Mantaş et al., 2007; Karakaya, 2010). A pharmaceutical industry is located in the watershed also, as well as plywood and fibreboard facilities. As 22 million people are foreseen in the city in 2023, plans consider directing the industrial investments in the Düzce province (Geymen, 2011).

Concerning the domestic effluents, only one domestic wastewater treatment plant exists, which is inadequate to the amount of discharges. Thus, a part of the flow rate is bypassed toward Küçük Melen River without being treated (Pehlivanoglu Mantaş et al., 2007).

Karakaya et al. (2009) assert that the streams feeding the Melen reservoir, namely Big Melen and Aksu, are polluted because of municipal discharges and agricultural runoff.

According to Gurel et al. (2011), the land use distribution of 2006 in the watershed is as following: the biggest share is the forest area with 51.9 %, meadows and pastures succeeding with 25.7 %, whereas agricultural areas and settlements represent 17.6 % and 2.1 % respectively. Settlements and agricultural areas are widespread all around the streams feeding the lake. Water quality parameters as ammonium, BOD₅, faecal streptococcus, manganese and phenol are estimated as a level requiring advanced treatment (Erturk et al., 2010, cited in Gurel et al., 2011). Moreover, the ammonia load is high as a consequence of both point nitrogen and non-point nitrogen sources.

9. Impacts of land use on forests of the reservoir areas

In the watersheds studied above, forest areas are endangered by urbanization. However, they have a key role in maintaining the quality of waters. Bekiroglu and Eker (2011) report that illegal settlements located in watershed areas reached 200 000 in 2007. These illegal settlements destroyed the forest area which reduced significantly.

According to Atmis et al. (2007), the urban population growth exacerbates the damages on forests areas of Istanbul. The mining activities are not negligible in terms of land use within the forest zones as they represent 4 % of this area in the European side. Moreover, 91.7 % of mines are seated in the forests.

The forest areas are also allotted for educational facilities, mostly universities. Even if this share is relatively weak, this kind of facilities draw more settlements in. Although built-up areas located in the forests are regulated, 5% were granted to commercial and settlements purposes (Atmis et al., 2007). In 1995, 51 % of Istanbul was covered by forest areas and the amount dropped to 41 % in 2005 (Geymen, 2011).

Moreover, the forest areas are also impaired because of the construction of pipelines. The Istanca project led to 1 400 ha of forests destroyed, which in turn, impacted the water quality of Terkos lake (WWF and the World Bank, 2003).

10. General overview

According to Baykal et al. (2000) cited in Beler Baykal et Erdem, the land uses in the Ömerli, Terkos, Büyükçekmece, Darlık, Alibeyköy and Elmalı watersheds are divided up as following:

- Ömerli: 51 % of forests; 35 % of agriculture and meadow; 10 % of settlements and industries; 4 % of lake; on a total area of 621 km²;
- Terkos: 77 % of forests; 17 % of agriculture and meadow; 1 % of settlement and industry; 5 % of lake; on a total area of 619 km²;

- Büyükçekmece: 20 % of forests; 63 % of agriculture and meadow; 12 % of settlement and industry; 5 % of lake; on a total area of 621 km²;
- Darlık: 72 % of forests; 25 % of agriculture and meadow; 1 % of settlement and industry; 3 % of lake; on a total area of 199 km²;
- Alibeyköy: 68 % of forests; 19 % of agriculture and meadow; 3 % of settlement and industry; 2 % of lake; on a total area of 160 km²;
- Elmalı: 42 % of forests; 31 % of agriculture and meadow; 26 % of settlement and industry; 5 % of lake; on a total area of 81 km²;

In a more recent study based on 2005 Landsat data, Geymen (2011) pointed out that the first three water resources with the higher level of settlements are Ömerli, Elmalı and Küçükçekmece. According to the same authors, Elmalı witnesses the higher population density with 6519 person per km², following by Ömerli, Alibeyköy, Büyükçekmece, Sazlıdere, Terkos and Darlık. Although Ömerli includes more industrial facilities (503 in 2002), Alibeyköy is the more industrialized watershed because of its smaller area.

The main motorways (TEM and E-5) cut through four watersheds which are Büyükçekmece, Alibeyköy, Ömerli and Elmalı. As a consequence, these watersheds are the most populated and industrialized ones.

Büyükçekmece field observations

Simple field observations were performed in the Büyükçekmece lake. Firstly, we went to the ISKI treatment plant³. The Büyükçekmece municipality and İstanbul metropolitan municipality are responsible for the zoning, planning and public works. Nevertheless, ISKI is in charge of the area from 0 to 1000 m surrounding the lake, and consequently, has the right to remove the illegal settlements. But, if settlements were established before the implementation of the protection zones, stemming from any local municipality zoning projects, ISKI's role is shrunk to a simple report.

Concerning the rivers feeding the lake, ISKI checks every month the quality of these rivers. If pollution is detected, ISKI warns the industries which have the obligation to run a treatment plant. If pollution still occurs, the municipality has the right to suspend all activities. Nevertheless, all land use allow by the municipality can remain, even if they are located in the protection zones⁴.

By the observations performed on the field, one can notice that the absolute and short range protection zones are witnessing various types of land use: residential areas, agricultural lands, industry and main roads. For example, the Ahmediye Köy is a low population density village located in the short range protection zone (Fig. 4). The official name of the street may inform that the municipality allowed this settlement, despite of its location in the short protection zone (Fig. 5). Moreover, people freely organize picnic on the bank of the lake. Finally, one of the most striking human impacts is the main road O-3 (E80) cutting through the lake (Fig 6) and the D564 passes the absolute and short range protection zone.

³ See detailed treatment steps in appendix 9.

⁴ Information obtained from the personnel of ISKI treatment plant, Büyükçekmece.



Figure 1: cement industry in the medium range protection zones



Figure 2: settlements in the absolute/short protection zones



Figures 3: agricultural lands in the absolute/short range protection zones



Figure 4: Ahmediye Köy in the absolute/ short protection zone



Figure 5: official street of Ahmediye Köy

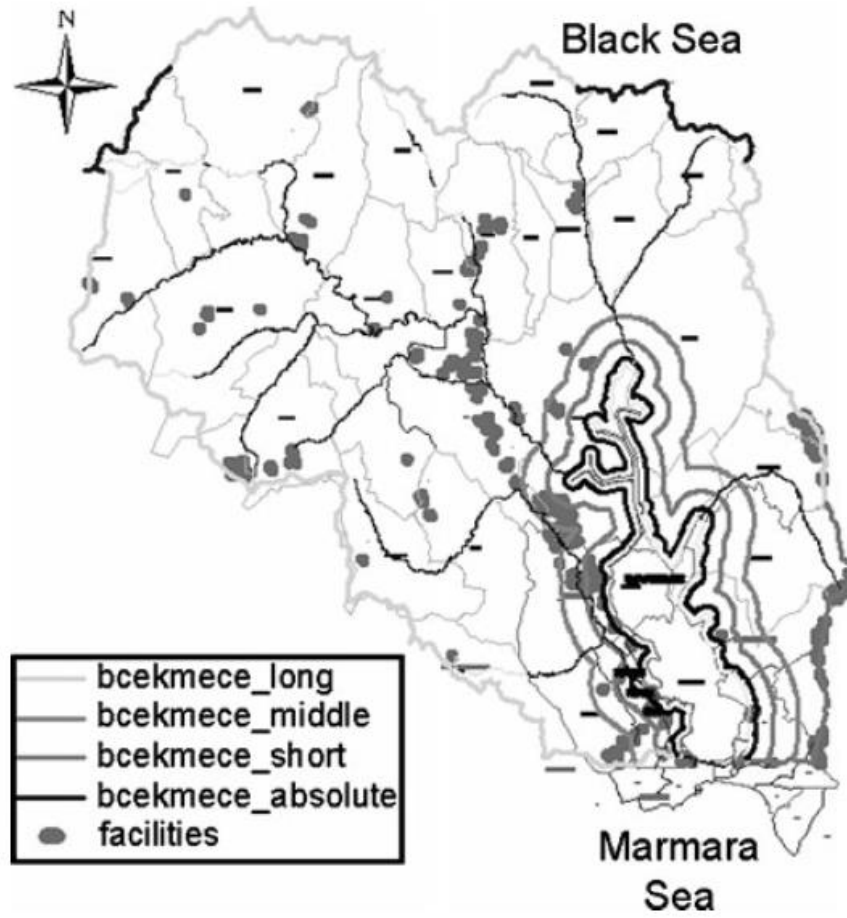


Figure 6: O-3 (E80) road cuts through the lake

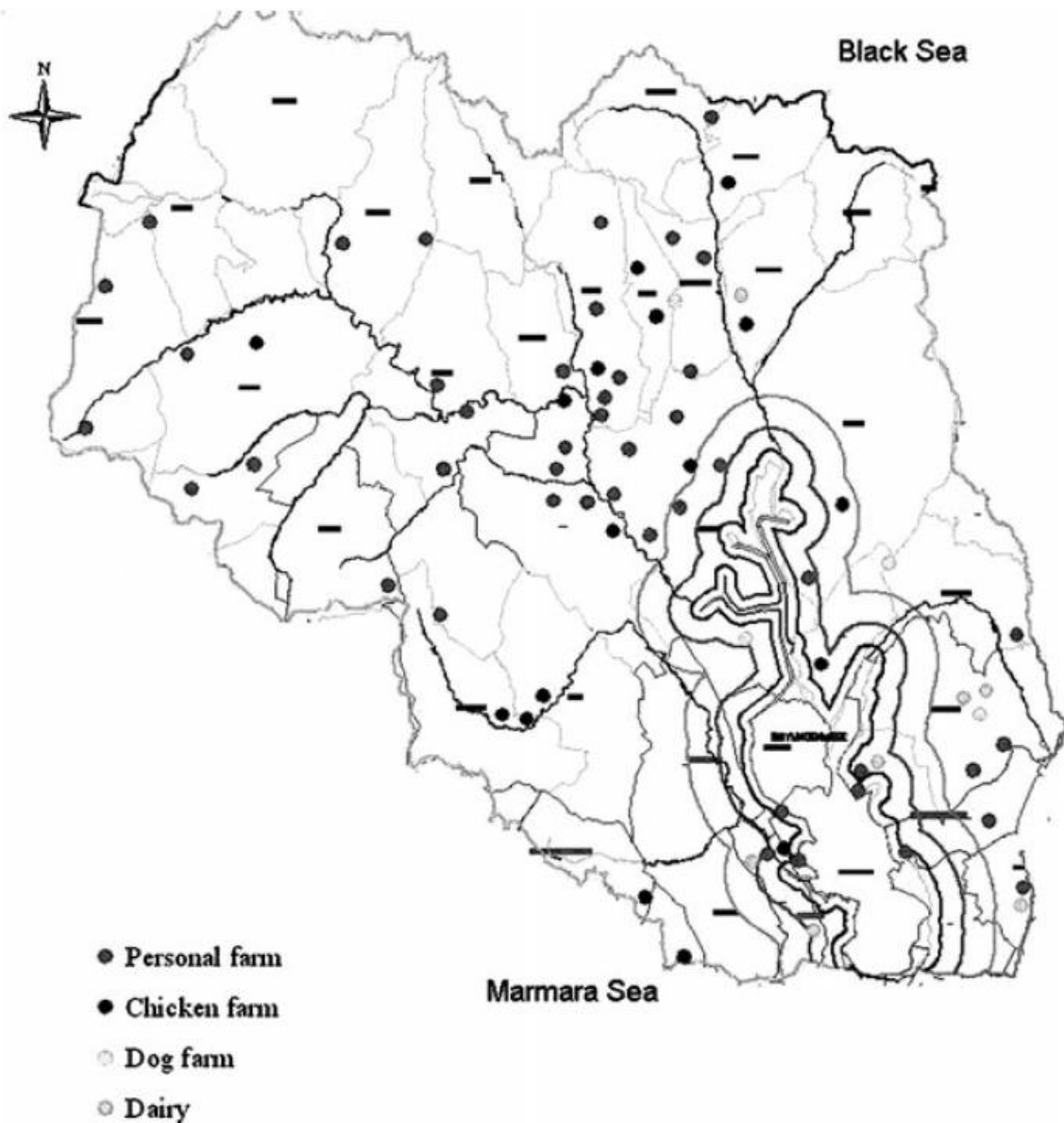
Conclusion

The literature review and the field observations revealed that urban land uses in the water supply reservoir areas of Istanbul are threatening the watersheds. Büyükçekmece, Küçükçekmece, Terkos, Elmalı, Ömerli, Darlık, Alibeyköy and Melen

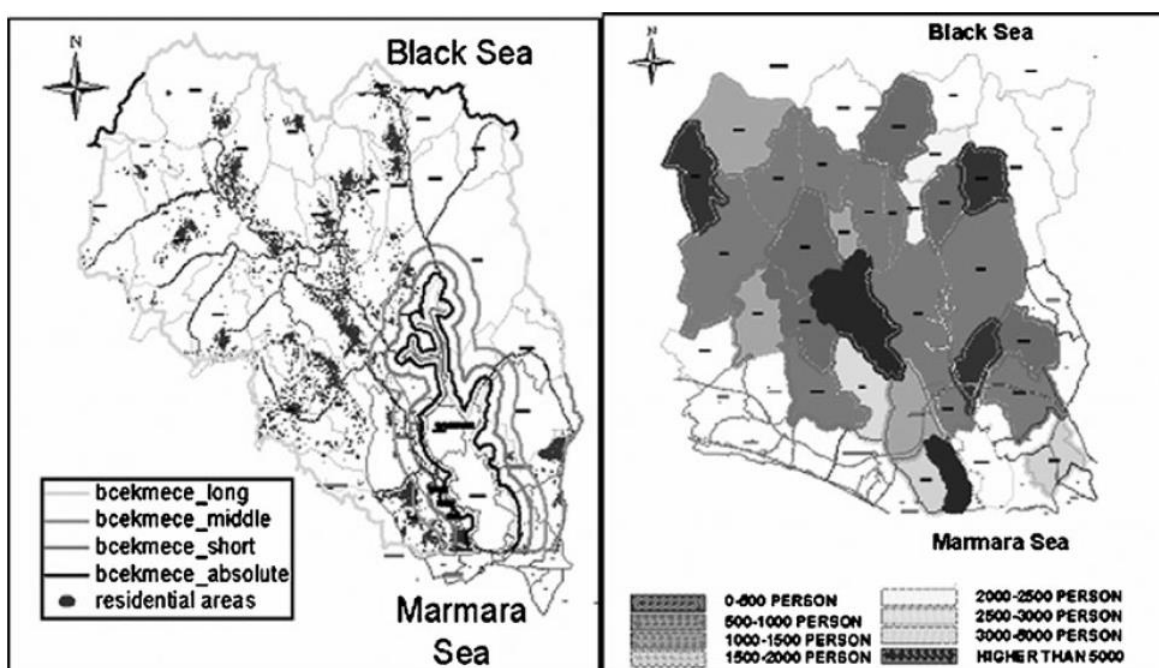
are witnessing residential areas, industries, highways and agricultural lands in the protection zones where these land uses are not allowed according to the ISKI regulation of 2006. Büyükçekmece, Elmalı, Ömerli, and Alibeyköy watersheds are the most populated and industrialized ones (Geymen, 2011; Beler Baykal et al., 2000). The water quality is endangered, as well as the ecosystem sustainability of the watersheds.



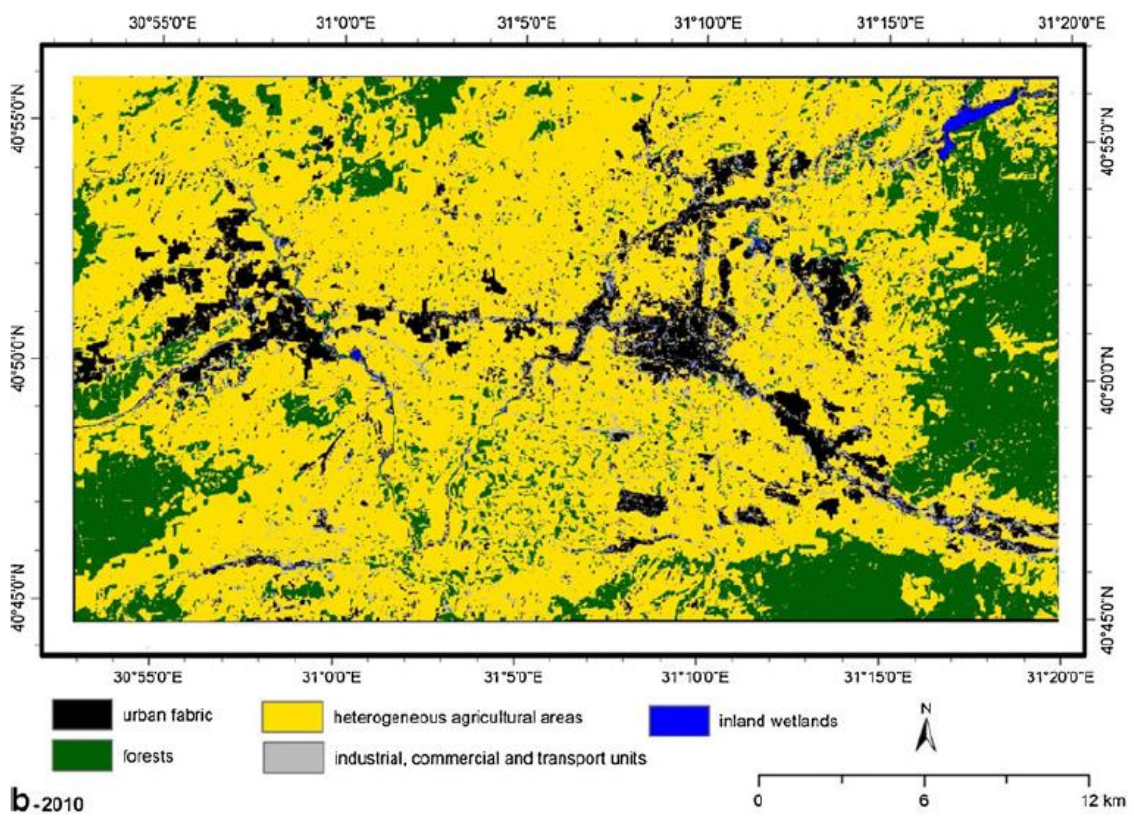
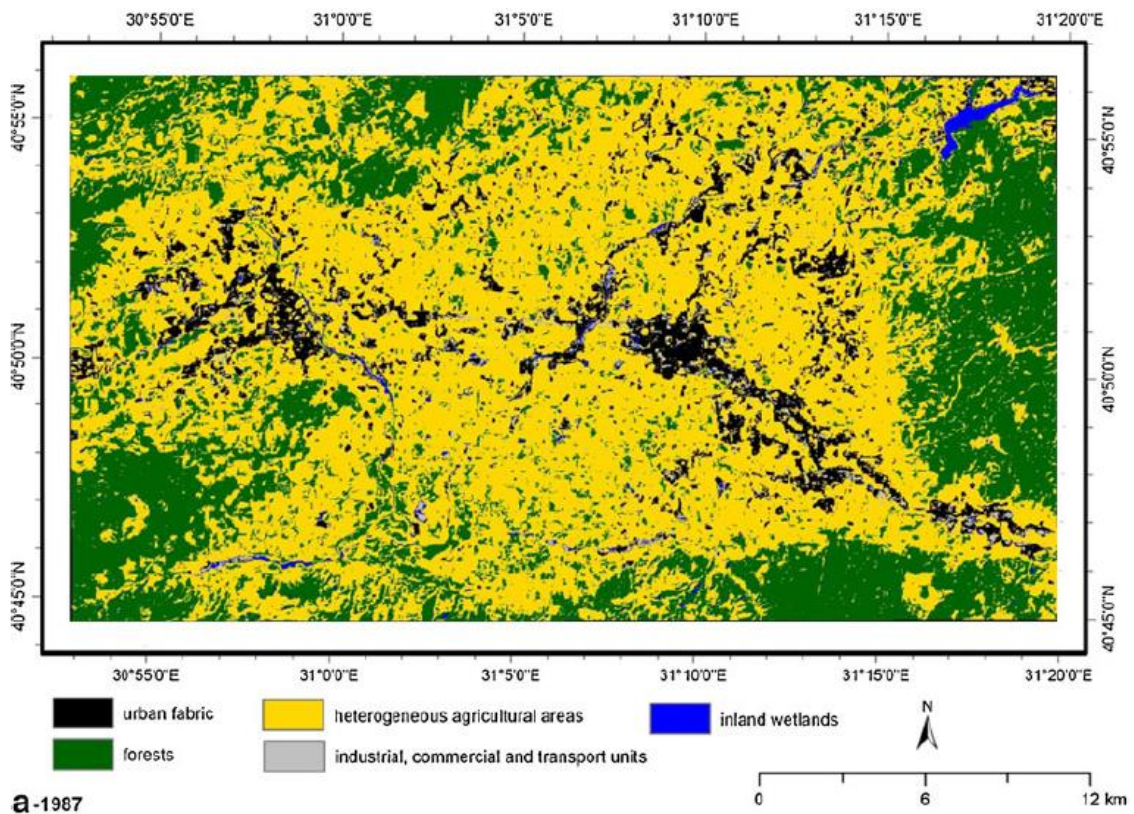
Appendix 1: distribution of facilities in Buyukcekmece watershed (number of facilities in absolute-range protection zone, 16; short-range protection zone, 23; middle-range protection zone, 13; long-range protection zone, 77). Guyer and Ilhan (2011).



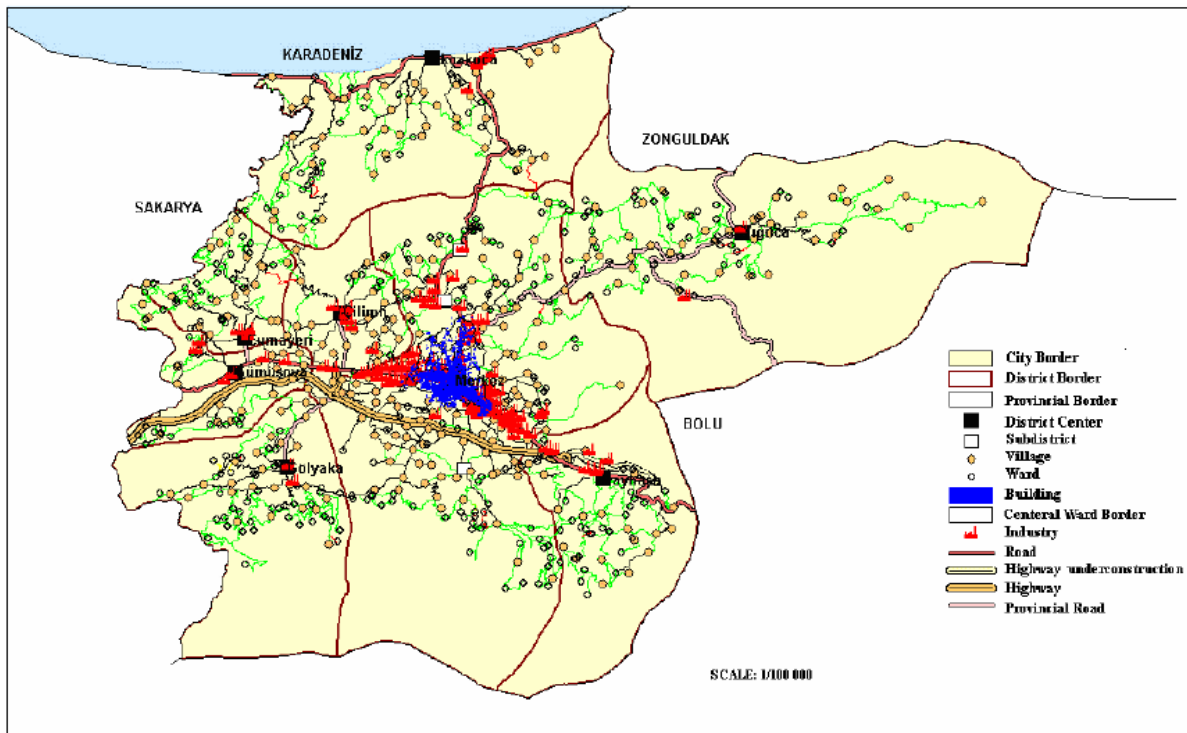
Appendix 2: Distribution of livestock, personal-chick farms in Büyükçekmece watershed. Guyer and Ilhan (2011)



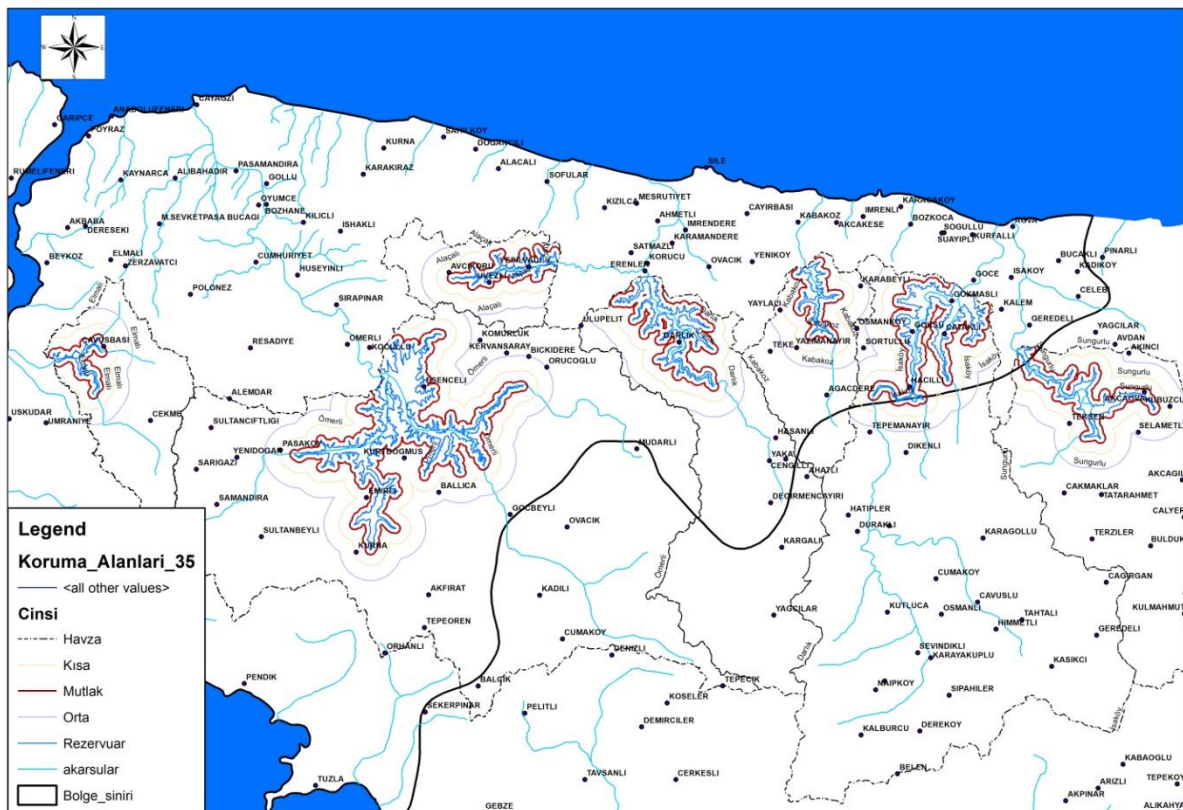
Appendix 3: a Settlement, b compactness of population in Buyukcekmece watershed. Guyer and Ilhan (2011).



Appendix 4: Land cover classification maps for each time step (1987- 2010) according to the CORINE land cover nomenclature. Ikiel et al. (2012).



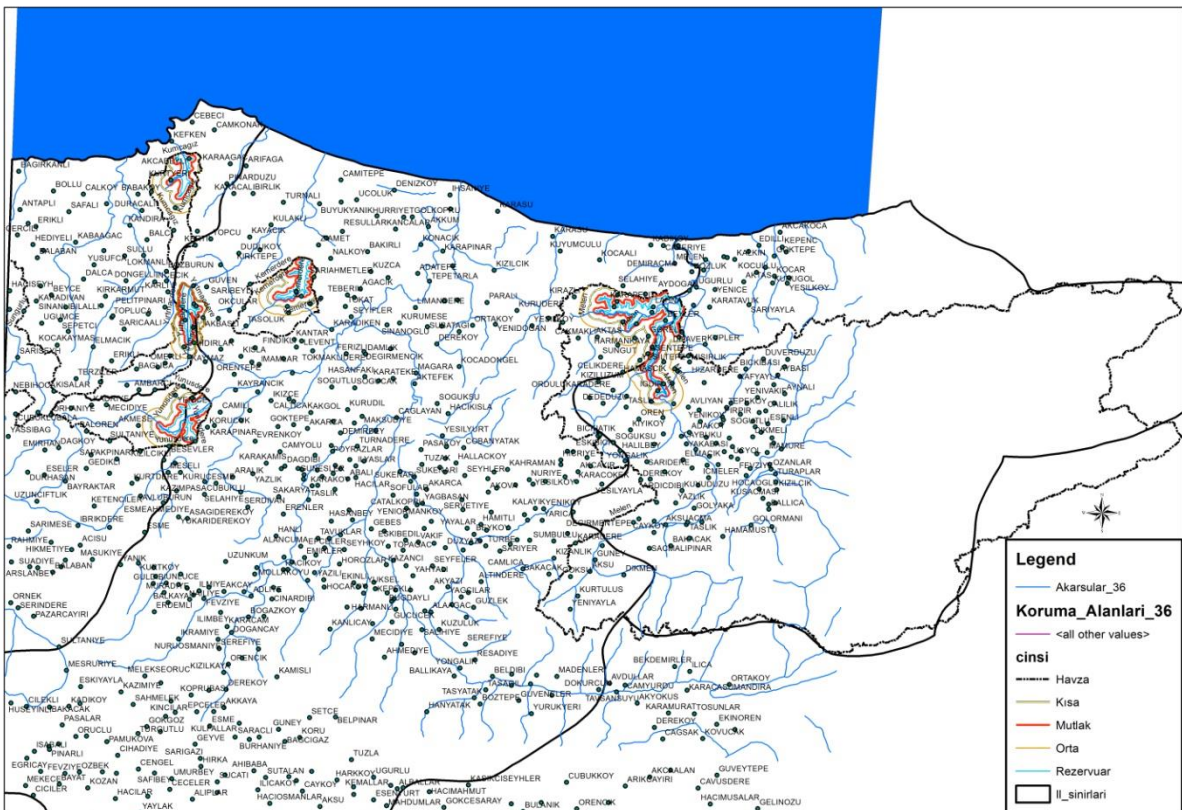
Appendix 5: Locations of the industries in Düzce Province. Pehlivanoglu Mantas et al. (2007).



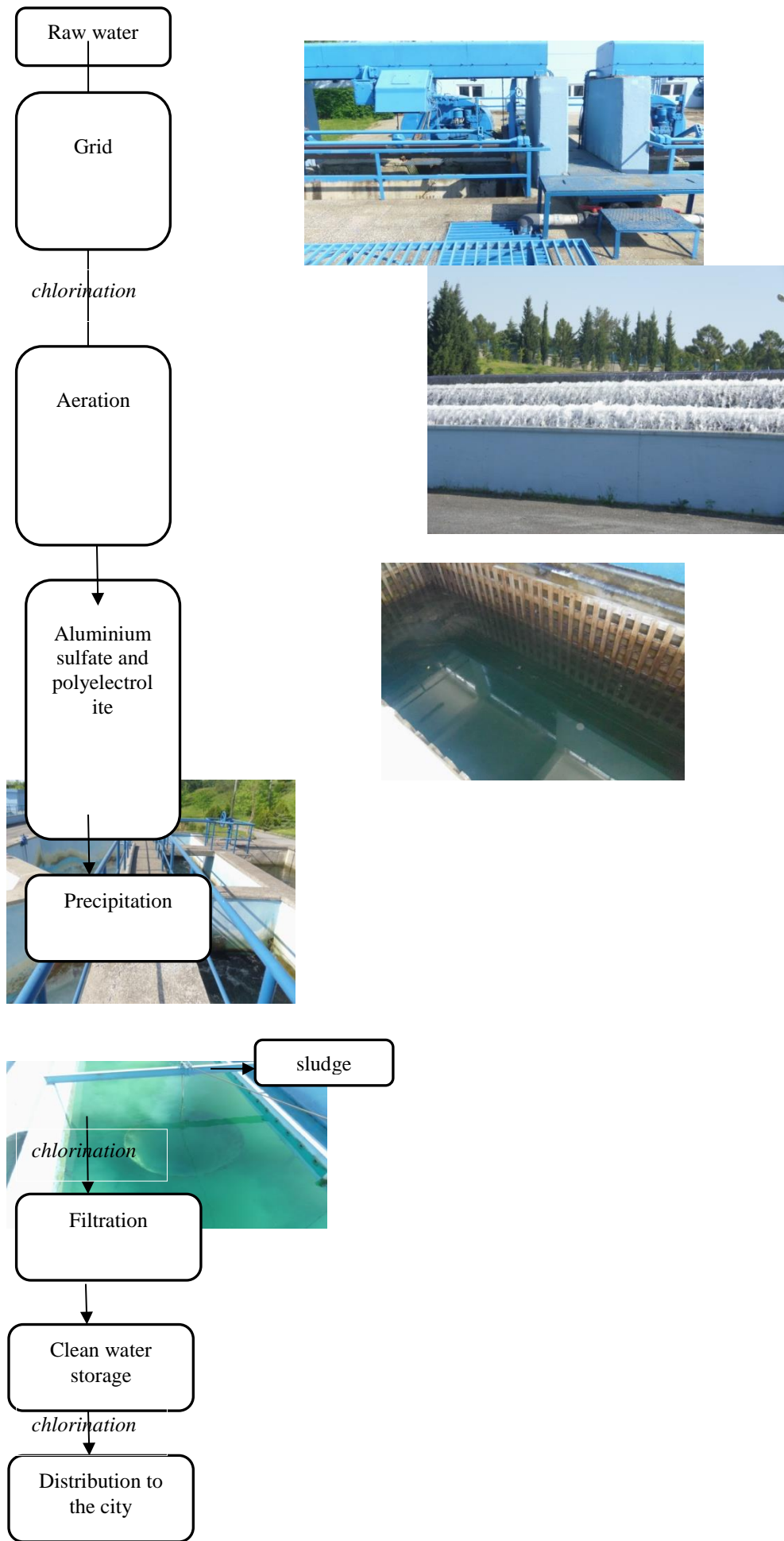
Appendix 6: Elmalı and Ömerli reservoirs. Map from DSI (data dated from 2006).



Appendix 7: Terkos, Büyükçekmece, Küçükçekmece and Alibeyköy reservoirs. Map from DSI (data dated from 2006).



Appendix 8: Melen reservoir. Map from DSI (data dated from 2006).



Appendix 9: ISKI water treatment steps, Büyükçekmece treatment plant

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