GLOBALIZATION AND WATER RESOURCES MANAGEMENT:
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HISTORICAL OVERVIEW AND CURRENT TRENDS IN ISTANBUL=S WATER SUPPLY DEVELOPMENT

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ABSTRACT: Istanbul has been a major urban center since the Hellenic period. Currently, Istanbul=s population is approximately 12 million people, with an annual increase of 400,000. Daily domestic water requirements average 2.6 million m^3 in 2000, while industrial demand is also increasing. Successive empires and administrations occupying Istanbul expanded extant infrastructure to meet these demands, a trend that continues today. To meet these needs, though, Istanbul today is forced to cast a wider net, proposing diversion from lakes across the Marmara Sea and from the Black Sea region. On-going urbanization and development continues to dominate the local landscape, requiring water resources and supply systems to keep apace for both domestic and industrial use. In this paper, we examine the historical development of water sources for Istanbul, from the Roman empire to proposed plans designed to meet the urban water crisis, in relationship to Istanbul=s growing population.
KEY TERMS: surface hydrology, Turkey, urbanization, reservoir, population growth, Büyük Melen, water diversion

INTRODUCTION

Istanbul is experiencing rapid urbanization, with high migration rates from throughout Turkey moving to the city. Official estimates place Istanbul=s population in 2000 at 10.3 million (DIE, 2001). Unofficial estimates believe the number to be more accurately 12 million, with some estimates reaching 15 million. Annually, approximately 400,000 people migrate to the city (ISKI, 2000b). Given that the site of Istanbul has been an urban center since the Roman period (ISKI, 2000b), during which is started its expansion, and its location on a peninsula, Istanbul has always had to face the issue of water supply to meet its ever increasing demands. Water supply has always been a critical issue in this region, which is dominated by limestone and karst topography. Groundwater reservoirs are scarce and unreliable. Thus, the water supply is heavily dependent on surface water supplies, which requires harnessing the surface runoff and safeguarding it against pollution. In this paper, we examine the historical development of water sources for Istanbul, from the Roman empire to proposed plans designed to meet the urban water crisis, in relationship to Istanbul=s growing population.

WATER SUPPLY IN ISTANBUL

Historical Development

Early water supply efforts were largely focused, then as now, on harnessing surface water flow. Numerous springs originate in the forested regions north and west of Istanbul. The first water supply systems dating from Roman times were aqueducts running over land from Cebecikoy in the west to the city. At least two of these are known to date

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back to the time of Hadrian (117-138 AD). Three other major supply lines were built to service the needs of the city as it grew over the next 300 years. Constantine tapped the streams in the Istranca Mountains in the west of the city for a second major supply line, 242 km in length. Another supply line, build by Theodosius, collected water from the Belgrade Forests north of the city. Subsequent Byzantine emperors extended and maintained these aqueducts.

During the early Byzantine, though, emperors opted to focus more on establishing large capacity cisterns within the city rather than carry out extensive repairs to the Roman aqueducts, which required heavy maintenance in the face of wars, earthquakes, as well as natural upkeep (Ministry of Culture, 2001). Cisterns allowed storage of a large supply within the city, which had become the capital of the Roman empire in 330 AD and remained the center of the subsequent Eastern Roman empire (Byzantium). Four major cisterns were constructed, totaling approximately 868000 m^3 (ISKI, 2000b). Overall, open and covered storage capacity was approximately 1,000,000 m^3. During the Crusades and Latin conquest of Istanbul in 1204, the entire water system was destroyed. (Ministry of Culture, 2001), so that once again, the city became largely dependent on transported water.

Following the conquest of Istanbul by the Ottomans in 1453, primary importance was placed on repairing existing water ways. In addition, new water supply lines were constructed (Ministry of Culture, 2001). Throughout the Ottoman reign, the water supply system was enlarged, as water supplies fell short of increasing demands. In 1554, major reconstruction and enlargement of the Kirkcesme springs in the Belgrade Foreest, originally tapped by Valens, commenced. This also incorporated water supply from Cebecikoy. To increase the amount of water retained from surface runoff, a series of reservoirs were built on the tributaries of the Kagithane and Alibey Rivers in the Belgrade Forests during the mid 1550s (Emre, 1991). These included Buyukbent, Ayvalik Bent and Valide Dams (Figure 1). Over time, the Kirkcesme system increased its supply capacity from 1.5 x 10^6 m^3/year in the mid 1450s to 3.65 x 10^6 m^3/year by 1818 (ISKI 2000b).

The Ottoman times placed high priority on establishing public city fountains. Many were built and maintained by pious foundations, which supplied water free from a private water source allocated to individuals by the sultan., while the other major portion were state funded main lines intended to supply water to the city. Overall, it appears that the Ottoman government favored the creation of these public water sources rather than providing private homes with direct water supply (Ministry of Culture, 2001), making fountains focal community point for urban development.

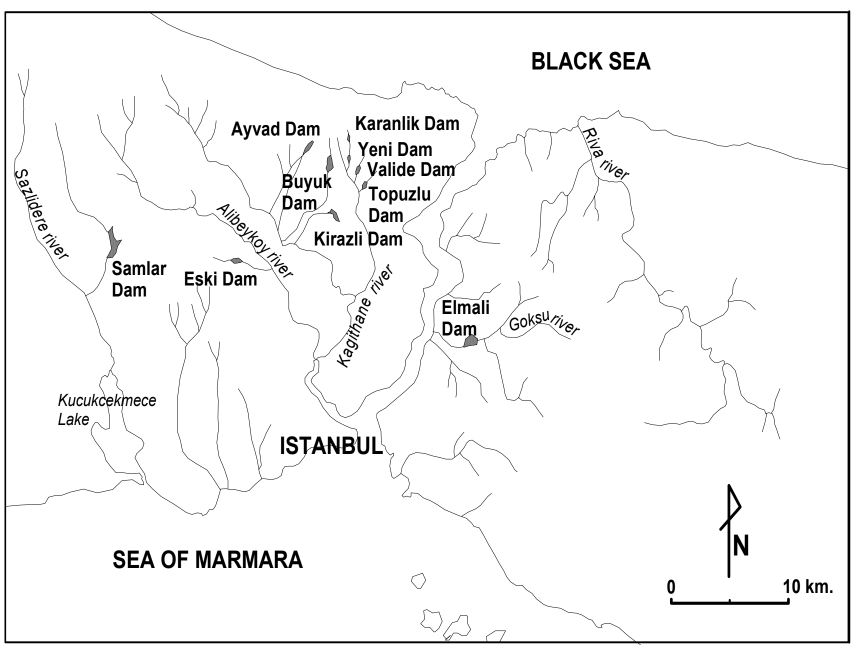

Figure 1: Location of dams created during the 1550s by the Ottomans

The supply system constructed during the Ottoman period can be divided into 4 main groups: Halkali, Kirkcesme, Üsküdar and Takism. The latter two supplied water to areas north and west of the Golden Horn, which only experienced urban expansion in the 18th and 19th centuries. Üsküdar, located on the Asian side of Istanbul, did not really become an important settlement until the middle 16th century. Local springs met the needs until then, but after that runoff from the Camlica Hills further south were collected and transported to Üsküdar (Demirci, 1997). The Hakali system, which combines 16 independent transmission lines and also dates from Roman times, also received an overhaul (Ministry of Culture, 2001). Many of the transmission lines established during the Ottoman period are still in use today as are two Roman aqueducts, the Muzulkemer and Bozdogan (Ministry of Culture, 2001). The Taksim system went into operation in 1732 and piped water using terra cotta pipes from reg2ons further north along the Bhosphorus south (Demirci, 1997). Annual capacity was approximately 0.98×10^6 m^3 (ISKI, 2000b). In 1750, Topuzlubent dam was built to increase discharge to 1.1×10^6 m^3 (ISKI, 2000b). These reservoirs served as the major city supply for the next 300 years. As the water supply increased, the government allowed water lines to be connected to private, primarily elite residences (Ministry of Culture, 2001).

In 1881, to meet ever increasing needs, a French water company was contracted to construct and maintain Lake Terkos, 25 km west of Istanbul with source water derived from the Kizildere River (Emre, 1991). The Alibeykoy system was expanded and Elmali Dam on the Asian side was constructed by the French holding company in 1893 (Samsunlu and Eroglu, 1991).

Current Water Supply

Explosive urbanization starting in the 1970s and peaking at 14% in the early 1980s forced Istanbul to once again expand and renovate its water supply system (ISKI, 2000b). In 1972, construction of one major dam, Ömerli on the Asian side, doubled the available water capacity, while construction at Alibeykoy shored up existing facilities. By the 1990s, Istanbul received its water from 6 major reservoir systems, three on the Asian side and three on the European side (Table 1). Two of these reservoirs were obtained by ranging further afield from Istanbul to existing Büyükcekmece Lake 20 km west of the city and to the Darlik in the Pontic Mountains bordering the Black Sea, 30 km east of the city (Figure 2).

In the 1989s the amount supplied to the city increased to 404×10^6 m^3/year, but this was still insufficient to meet the city's needs (Demirci, 1997). The 1990s have been marked by continual addition of new reservoirs to the city's water supply system (Table 1). By 1999, this amount increased to 910×10^6 m^3/year, although in dry seasons, the incoming water supply can be up to 20% less (Demirci, 1997), requiring a higher storage capacity to survive dry years. The Omerli-Darlik system on the Asian side are now the most important water source, supplying 51% of the water, with the Terkos-Alibeykoy system supplying an additional 31%. Water quality is controlled by a series of four conservation zones around the reservoirs which limit the activities in a buffer around the lake (Orhon, 1991; Yapici, 2001). Enforcement of these regulations concerning industrial and residential development is inadequate, especially in the face of rapid and often unplanned urbanization pressure. Seven treatment plants located on the outskirts of suburban Istanbul ensure water quality (Figure 2).

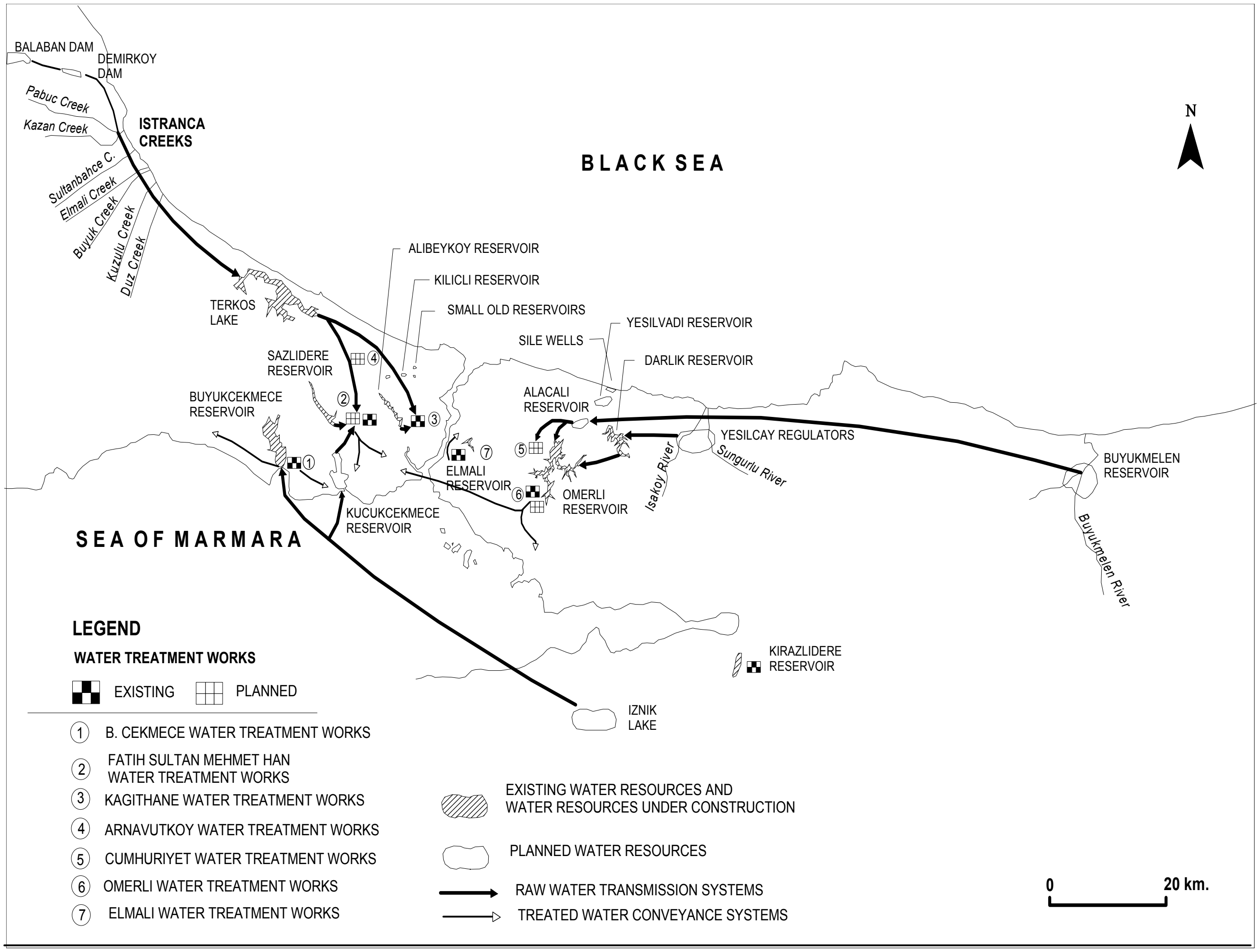

Figure 2: Map of existing and planned surface water sources for Istanbul. The seven existing water treatment plants, which serve as main distribution centers of the imported water, are also indicated (modified from ISKI, 2000a). The city of Istanbul, and its ever expanding suburbs, is located straddling the lower Bhosphorus Straits. Presently, the western edge of the city extends to Küyükcekmece and the northern edge is starting to encroach on the Alibeykoy Reservoir. The eastern edge of the city, on the Asian side, extends about 8 from the Bhosphorus Straits. Most of the territory north of the Elmali Reservoir is owned by the military and thus not subject to development or urbanization.

Table 1: Existing reservoirs of surface water resources Istanbul (ISKI, 2000b, Orhon, 1991)

Source	First year of operation	Annual capacity (10^6 m^3)
Terkos	1883	80-142
Elmali	1893-1950	12-15
Alibeyköy	1972	21-36
Ömerli	1972	164-220
Büyükcekmece	1989	45-70
Darlik	1989	72-97
Yesilvadi	1992	6-10
Cevrime Düzdere Kuzuldere Büyükdere	1995	44
Sile	1996	30
Elmalidere Sultanbahcedere	1997	131
Pabucdere	1998	60
Sazlidere	1998	50

Table 2: Planned water resources for Istanbul for (ISKI, 2000a)

Reservoir/Region	Anticipated opening	Annual capacity (10^6 m^3)
Yesilcay Regulator	2002	145
Istranca 3	2003	52
Istranca 4	2004	48
Küyükcemece	2005	30
Büyük Melen 1	2006	268
Büyük Melen 2	2012	461
Büyük Melen 3	2020	461
Göksu and Iznik	2025	500
Yesilcay Barrage	2030	190
Yesilcay/Sarkarya	2035-2040	550
Total current supply		910
Total anticipated new supply		2705

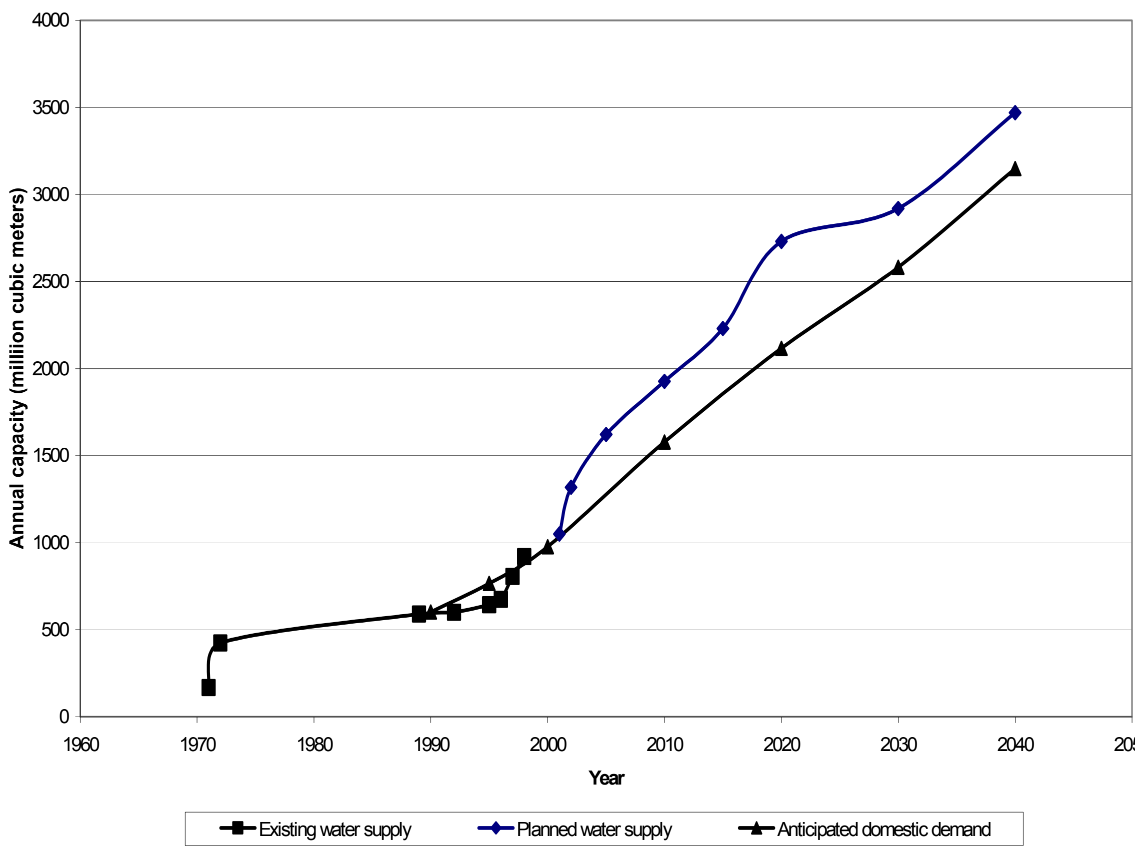

Figure 3: Chart of existing water supply resources over time, the increase in total capacity by completion of anticipated resources (ISKI, 2000a, 2000b). Using population estimates set forth by ISKI (2000a) for the worst case scenario and an average domestic use of 250L/person, anticipated domestic use is also shown.

Population Growth and Demands

Daily water need is expected to average 250 L/person (Demirci, 1997). Thus, for a population of 10.3 million (DIE, 2001), expected water demands exceed 2,575,000 m^3/day, which represents a yearly demand of almost 940 x 10^6 m^3. Obviously, the current supplies are just barely adequate, when groundwater resources and old, isolated spring systems are included. But, as the population of Istanbul keeps growing, and the industrial sector of the region develops, these demands will increase, requiring ISKI to develop ever more supplies.

To satisfy these demands, ISKI has projected a worst case scenario for population growth and established an expansion schedule for increasing surface water supply (Table 2). This schedule casts the water supply network further afield, drawing water from Iznik Lake across the Marmara Sea, as well as harvesting water from streams draining to the Black Sea over 200 km to the northwest of Istanbul (Figure 2). The Büyük Melen project, scheduled to be completed in stages, is anticipated to supply Istanbul with over 1100 x 10^6 m^3/year (DSI, 2001). Thus this project alone would produce as much water as is currently being supplied to Istanbul. The various stages for this, as well as several others, include first simply tapping existing surface flow, then the construction of a reservoir, along with continuing developments of transmission systems (DSI, 2001).

As the city continues to grow, water pollution issues are also increasing. Much of the urbanization within the city is unplanned, often in regions set aside by the government as conservation zones around reservoirs (Curi and Mandalinci, 1991). In order to protect water quality, the city has established conservation zones around the reservoirs, which through spatially delineated buffers regulate the type of land use within each zone (Timur and Eren, 1991). But, the city is expanding faster than its infrastructure and enforcement of legislative codes is often inadequate, so that sewage disposal may in the future become more vital that fresh water supply (Timur and Eren, 1991). The attempts to divert water from far outside of Istanbul=s boundaries in part may reflect this growing issue of water pollution.

Figure 3 plots the anticipated domestic water demand, along with ISKI=s anticipated growing water supply over the next 40 years. The projected increase for demand is linear, both for domestic use (r^2 =1), as well as industrial water needs (r^2=0.99), based on projected population figures (ISKI, 2000b). For the worst case scenario, population is expected to increase at 4.6% (ISKI, 2000b). Over the next forty years, domestic water use is expected to increase 5 fold in the next fifty years, while industrial water are only expected to double (ISKI, 2000b). Given the high migration rates to Istanbul of previous years and the rapid urbanization rates, the expectation of a linear increase seems unrealistic. Population rate has been increasing at a rate of 4.4% over the last 10 years in the city. Despite this, both ISKI and DSI, the government agencies in charge of water supply and reservoirs, project decreasing growth rates from now on (ISKI, 2000a). By 2010, DSI (2001) anticipates only a 2.2% growth rate, reducing to a 0.5% by 2040.

Added to the expected growth, which in itself is hampered by unrealistic expectation, is the fact that many of the population estimates for Istanbul are inadequate. The Turkish census claims to count every person present within the country by organizing a national census day on which everyone is asked to remain at home to be reached by the census takers (DIE, 2001), most recently in November 2000. Obvious problems exist with this methodology, as the physical task of counting everyone is impossible. In addition, many residents of Istanbul are recent (first or second generation) migrants to the city and when question will indicate their prior province as hometown. Thus, the official estimate for Istanbul s population is largely erroneous and accepted as such by the general public.

An example of this can be seen in the published government literature. The ISKI master plan (2000a) lists a 2000 population of 12.7 million, obviously updated from DIE's recent census, even while it calculating a worst case domestic water demand for a population of 10.7 million. At the same time, DSI (2001) which works with ISKI on water supply issues, being the agency in charge of hydraulic works, lists a 2000 population of 10.1 million, with 12.5 million only expected by 2010. Thus, agency projections are not constant in addressing demand. Also, none of these adequately address the growth rate for the industrial sector, which will likely create a larger demand than projected as Turkey continues to industrialize.

If, as general expectations hold true and the population of Istanbul is presently closer to 15 million than 10 million, the entire planning for Istanbul is severely undermined. Given that regions of Istanbul often suffer water shortages, especially during summer months, tends to support the higher population estimate. This also allows a steady sector of independent water merchants who import bottled water to maintain a foothold in the economy (Butt et al., this volume). Thus, ISKI is already at a state where its 2000 worst case scenario has been surpassed. Use may also increase beyond the average 250L/day/person, as in many industrialized cities use is up to 500 L/day/person (Shiklomanov, 2000), a trend likely to be mirrored by Istanbul as the city develops.

One possible way of safeguarding against shortfalls is ISKI (2000a) intention of reducing water loss through renewing 94% of the pipe network using ductile cast pipes in the future. Water losses in the distribution system averaged 45% in the late 1990s (Demirci, 1997). And while water conservation education measures are not yet utilized, these will likely play a large and necessary role in Istanbul's future.

CONCLUSIONS

Istanbul faces several major issues in servicing the water needs of the city in years to come. As historically, it needs to find more efficient ways to collect and transport surface water from outlying regions to the city. In addition, it needs to adequately safeguard existing resources from pollution, through controlled growth, as well as construction and maintenance of infrastructure. In a city with high population growth rates and a country attempting to rapidly industrialize, these challenges are formidable.

Istanbul's current plans for the continued water supply are predicated on conservative population growth estimates, as well as a dependence on completing planned projects on time. These projected dams only increase the expected capacity of resources, but do not guarantee delivery. In a country, where such schedules routinely fall behind, construction of the reservoirs and the required transmission lines is not certain to be accomplished in time to meet growing demands, especially since these projects are large distances away from the demand center.

Plans to reduce loss of water in distribution network is likely to be most easily accomplished, but attempts at educating the public about water conservation - another likely source of water savings - are currently non-existent. But, given the challenges, effective action will need to include these measures. Water supply, and its disposal, will become an increasingly critical issue for Istanbul. Water diversion schemes can also partially solve the problem, but engineering solutions will not be the only answer. Water prices will need to be reevaluated to incorporate a marginal water scarcity rent (Jordan, 1999). Without such pricing and education, the true value of water will not be appreciated by Istanbul's residents until too late.

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