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Water Resources of Turkey: Potential, Planning, Development and Management

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ABSTRACT *Turkey is a country with considerable water resources in a region where scarcity of water makes it a strategic item. In the second half of the 20th century important efforts have been made in the planning and development of these resources. However, less than one-half of the potential has so far been developed. The rapid growth of population and the expansion of irrigated agriculture and industry are stressing the water resources both quantitatively and qualitatively. The completion of the South-eastern Anatolia Project (GAP) and several other projects requires a considerable part of Turkey's financial and technical resources to be devoted to water resources development.*

Introduction

Turkey, with a surface area of 780 000 km^2 and a population over 63 million, is a country with considerable water resources in a region where a sufficient amount of water has never been available, and water is expected to be the key to war and peace in the near future.

In Turkey important attempts have been made in the second half of the 20th century to develop the country's water resources. Rapid growth of population plus an increase in the standard of living and accompanying industrialization have raised the water demand considerably and are stressing the quantity and quality aspects of the country's water resources. To meet this demand, Turkey has been constructing dams, hydropower plants and irrigation projects throughout the country.

The areal distribution of water does not fit that of the population and industry, thus making the inter-basin transfer of water and energy necessary. Development of the water resources must be planned not on a regional basis but as a whole in an integrated manner.

Despite the serious efforts in this area, a great deal remains to be done. At present less than one-half of the potential has been developed. Irrigation projects provide water for about 50% of the economically irrigable land. Nearly 40% of the flood control projects have been realized. Although more than 35% of the electric power is generated by hydro, less than 30% of the hydropower potential has been developed. The Southeastern Anatolia Project (GAP) will make important contributions to both irrigation and electricity generation. The need for cooperation with neighbouring countries in the development of international river basins increases the difficulty of the management of these resources.

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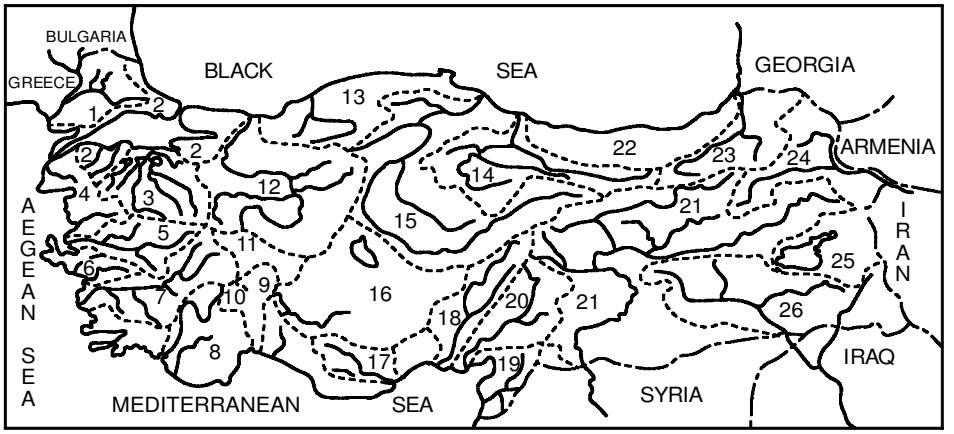

Figure 1. Drainage basins of Turkey (numbers as in Table 1 and Figure 2).

Water and Energy Potential

The annual average precipitation in Turkey is estimated at 643 mm, corresponding to a volume of 500 km^3. The average runoff coefficient is 0.37, and the annual runoff is 186 km^3 (2400 m^3/ha). Subtracting from this figure the estimated water rights of neighbouring countries, minimum streamflow requirements for pollution control, aquatic life and navigation, and topographic and geologic constraints, the annual consumable water potential is computed as 95 km^3. An extractable groundwater potential of 12 km^3 should be added to this, bringing the total annual consumable potential to 107 km^3.

The annual per capita water potential is at present 1700 m^3 but expected to be reduced to 1000 m^3 in the year 2020. Thus Turkey cannot be considered a 'water-rich' country, and its per capita potential is nearly the same as that of its neighbours such as Iraq (2000 m^3/yr) and Syria (1400 m^3/yr).

Precipitation differs considerably both from year to year and among the river basins. The annual depth of precipitation is as high as 250 cm in the Eastern Black Sea region, and as low as 30 cm in some parts of Central Anatolia. Most of the country's water potential lies in the south-east (28%) and the Black Sea region (8%). Turkey's water resources can be considered in 26 drainage basins (Figure 1). Table 1 gives the water potential by drainage basins. The most important rivers are the Fırat River (Euphrates) and Dicle River (Tigris), both of which are transboundary rivers originating in Turkey and discharging into the Persian (Arabian) Gulf. The Meriç, Çoruh, Aras, Arapçay and Asi Rivers are the other transboundary rivers. Some 22% of the boundaries between Turkey and the neighbouring countries are along international rivers.

Twenty-eight million ha of the land in Turkey is considered arable, 21.5 million ha is pasture and meadow, and 23 million ha is woodland. The irrigable land totals 26 million ha, and of this 8.5 million ha is considered economically irrigable, 0.6 million ha by groundwater.

Turkey has considerable hydropower potential, among the highest in Europe. The feasible hydroelectric energy potential is estimated at 125 000 GWh/yr, and the installed capacity potential at 35 000 MW. A large part of this potential will have to be developed by means of small hydropower plants. Figure 2 and

Table 1. Water potential of Turkey by drainage basins

Drainage basin	Average runoff (km^3/yr)	Percentage of potential	Annual average yield ($l/s\text{-}km^2$)	Runoff coefficient
1. Meriç-Ergene	1.33	0.7	3.6	0.16
2. Marmara Sea	8.33	4.5	11.0	0.41
3. Susurluk	5.43	2.9	7.2	0.33
4. Northern Aegean	2.09	1.1	7.4	0.30
5. Gediz	1.95	1.1	3.6	0.16
6. K. Menderes	1.19	0.6	2.9	0.13
7. B. Menderes	3.03	1.6	3.9	0.18
8. Western Mediterranean	8.93	4.8	12.4	0.43
9. Antalya	11.06	5.9	24.2	0.63
10. Lake Burdur	0.50	0.3	1.8	0.11
11. Akarçay	0.49	0.3	1.9	0.13
12. Sakarya	6.40	3.4	3.6	0.19
13. Western Black Sea	9.93	5.3	10.6	0.42
14. Yeşilırmak	5.80	3.1	5.1	0.28
15. Kızılırmak	6.48	3.5	2.6	0.18
16. Konya (closed)	4.52	2.4	2.5	0.14
17. Eastern Mediterranean	11.07	6.0	15.6	0.83
18. Seyhan	8.01	4.3	12.3	0.55
19. Asi	1.17	0.6	3.4	0.18
20. Ceyhan	7.18	3.9	10.7	0.43
21. Fırat	31.61	17.0	8.3	0.43
22. Eastern Black Sea	14.90	8.0	19.5	0.43
23. Çoruh	6.30	3.4	10.1	0.61
24. Aras	4.63	2.5	5.3	0.44
25. Lake Van (closed)	2.39	1.3	5.0	0.26
26. Dicle	21.33	11.5	13.1	0.54
Total	186.05	100.0		

Table 2 show the planned irrigation area and hydropower potential by drainage basins.

Planning, Development and Management

Historical Perspective

In Turkey remains of historical hydraulic structures are found in various parts of the country, dating from the eras of the Hittites, Urartus, Greeks and Romans. Later, Seljuk and Ottoman Turks constructed fountains, cisterns, irrigation ditches and diversion dams. Most important of these are seven dams near Istanbul built in the 17th to 19th centuries to supply water to the city. However, important water resources development attempts started with the foundation of the Turkish Republic in 1923.

State Agencies for Water Resources Management

In 1925 regional offices for water resources were established under the Ministry of Public Works. Preliminary studies on river basin planning were started in 1932. The first state agency responsible for streamflow measurement, hydro-

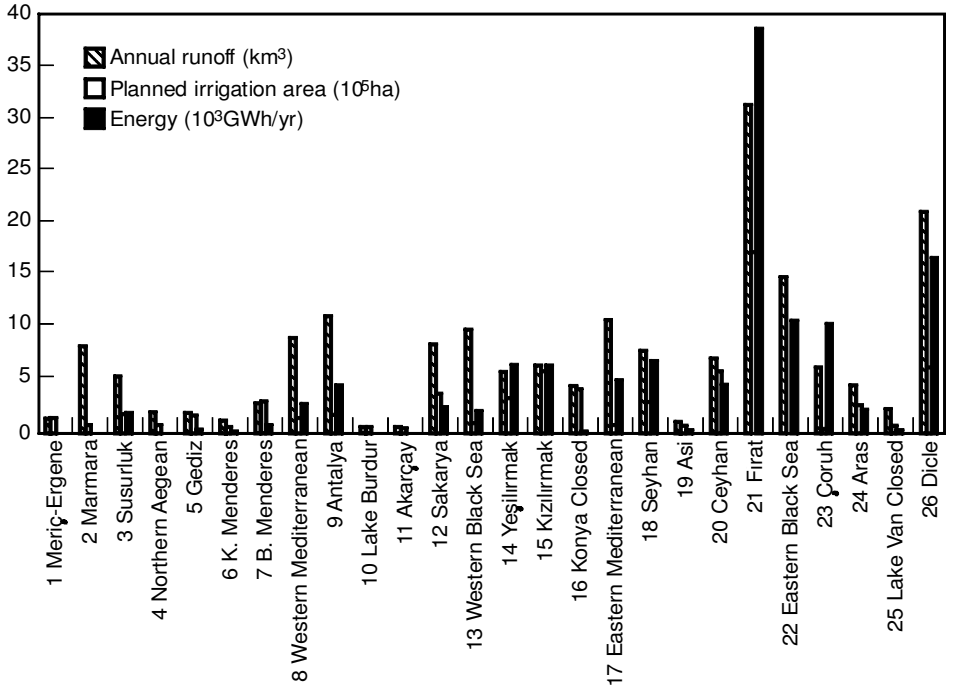

Figure 2. Annual runoff, planned irrigation area and hydropower potential of drainage basins.

power planning and design, EIE (Electrical Investigation Administration), was founded in 1935.

The first dam built in the 20th century was Çubuk I dam (1936), which supplied water to the capital city of Ankara. Some irrigation and river regulation projects were realized at that time. However, important developments in water resources could be made only after the Second World War. Sarıyar and Seyhan dams were the first major hydraulic structures realized in the country, with financial contributions from the private sector.

In 1953 the major state agency in this area was founded. DSİ (State Water Works), modelled after the Bureau of Reclamation in the USA, is responsible for the planning, design, construction and operation of nationwide hydraulic structures. It is charged with "multiple utilization of ground and surface water and prevention of soil erosion and flood damages, building protective structures against floods, draining swamps, building irrigation and drainage systems, constructing hydroelectric power plants, supplying water for settlements over 100 000 population, and improving navigable rivers" (TBMM, 1995).

Today DSİ is an enormous organization with a total of 25 000 employees. More than 5000 of these are engineers and technical personnel. Its General Directorate and divisional offices are in Ankara. It has 25 regional offices throughout the country. In each office there are sections for mapping, hydrometric measurement, land management, classification and drainage, groundwater, planning and construction for major and minor water projects.

In 1963 the Ministry of Energy and Natural Resources was established and DSİ was affiliated to it. Other state agencies dealing with water resources are

Table 2. Planned irrigation area and hydropower potential by drainage basins

Drainage basin	Planned irrigation area (10^6 ha)	Annual hydropower potential (10^3 GWh)
1. Meriç-Ergene	0.15	—
2. Marmara Sea	0.08	—
3. Susurluk	0.18	1.90
4. Northern Aegean	0.09	0.04
5. Gediz	0.19	0.42
6. K. Menderes	0.03	0.14
7. B. Menderes	0.31	0.85
8. Western Mediterranean	0.13	2.50
9. Antalya	0.16	4.41
10. Lake Burdur	0.04	—
11. Akarçay	0.03	—
12. Sakarya	0.37	2.36
13. Western Black Sea	0.10	2.11
14. Yeşilırmak	0.34	6.47
15. Kızılırmak	0.50	6.51
16. Konya (closed)	0.43	0.10
17. Eastern Mediterranean	0.09	5.18
18. Seyhan	0.31	7.12
19. Asi	0.10	0.12
20. Ceyhan	0.59	4.63
21. Fırat	1.74	38.94
22. Eastern Black Sea	—	10.93
23. Çoruh	0.03	10.61
24. Aras	0.27	2.29
25. Lake Van (closed)	0.09	0.26
26. Dicle	0.65	16.88
Total	7.00	124.57

Topraksu, responsible for constructing irrigation farm structures and minor irrigation projects, Iller Bank, constructing water supply and sewerage systems, and TEK (Turkish Electrical Authority, 1970), planning and operating electrical energy systems.

Hydrometric Measurements

The main agency for hydrometric measurement is EIE. This agency performs water-level and discharge measurements in streams and lakes, snow-cover measurements in basins, suspended load, water quality parameters and ice-cover measurements in streams. The first measurements were started in 1936. The nationwide observation network was established in 1962. In Turkey there are 107 main streams with catchment areas over 1500 km^2. In 1993 the agency was operating 289 hydrometric stations, about half of which were equipped with automatic level recorders. DSİ also operates more than 1200 hydrometric stations, mainly on minor streams, for specific projects. Since the earliest measurements were started only 60 years ago, most of the records are not of sufficient length. The number of gauging stations on minor streams is not adequate. Measured data are being published every year by EIE and DSİ. Computerization of the data has been started recently.

Present Situation

Turkey has completed a large number of water resources development projects and many more are in the construction or planning stages. Today the nation has the technological and management knowledge and experience necessary for the successful accomplishment of these projects.

Some of the recent major projects, such as Atatürk Dam and H. Ugurlu Dam, were built mainly by Turkish companies and know-how. Turkish engineering companies have successfully bid for and realized development projects in the region.

The main difficulty is in providing the necessary funding. International organizations such as the World Bank are not willing to provide money, especially for projects on transboundary rivers, owing to conflicts with other riparian countries.

Water resources projects completed so far have made it possible to consume 27.5 km^3/yr of the surface water, and 6 km^3/yr of the groundwater. Thus total consumption is now about 31% of the potential.

Irrigation

Turkey is agriculturally self-sufficient but it can continue this position only if the irrigation projects can be brought to fruition in time. Turkey also hopes to sell agricultural surpluses to the neighbouring countries, thus balancing its import–export account.

At present 4.5 million ha of land are being irrigated, 3 million ha by the projects operated by the state agencies. This is nearly one-half of the economically irrigable land area estimated at 8.5 million ha. Most of the irrigation is by gravity flow and only 5% by pumping. Salinity and water quality problems are encountered in some places, and better drainage is required. Efficiency of most irrigation projects is rather low. In the future DSI plans to increase the irrigated land to 7.1 million ha.

Hydropower

In 1995, the installed capacity of hydropower plants was 9900 MW (46% of total electricity generating capacity); 32 000 GWh of energy was generated by hydropower (38% of total electrical energy). Hydropower plants can generate 36 400 GWh annually, which corresponds to 29% of the feasible hydroelectric energy potential of the country estimated at 125 000 GWh. Thus the present hydropower capacity can be increased by 3.5 times, but this requires the construction of about 400 new plants. The hydropower plants under construction will generate 10 300 GWh/yr, bringing the total up to 46 700 GWh/yr. It is planned to increase this figure to 39 000 GWh/yr in the year 2000, 68 000 GWh/yr in 2005, and 77 000 GWh/yr in 2010, but it seems improbable that these targets will be met. On the other hand, Turkey's electrical energy demand is estimated to increase by 8% annually to 130 000 GWh/yr in 2000, and 270 000 GWh/yr in 2010.

Turkey is spending large amounts of foreign currency to import oil each year for electrical energy. The substitution of hydropower for thermal energy will help to reduce the foreign trade deficit. Most of the large-scale hydropower

Table 3. Turkey's largest hydropower plants

Dam	Year	River	Installed power (MW)	Energy (GWh/yr)
Atatürk	1995	Fırat	2400	8900
Karakaya	1987	Fırat	1800	7354
Keban	1975	Fırat	1330	6000
Altinkaya	1988	Kızılırmak	700	1632
Oymapınar	1984	Manavgat	540	1620
H. Ugurlu	1982	Yeşilırmak	500	1217
Sır	1991	Ceyhan	283	725
Köklüce	1988	Yeşilırmak	90	588
Aslantaş	1984	Ceyhan	138	569
Gökçekaya	1973	Sakarya	278	562
Gezende	1990	Ermenek	159	528
Menzelet	1989	Ceyhan	124	515

projects have been realized (see Table 3). The remaining schemes are mostly small hydropower plants, nearly 400 in number. Obviously, the electrical energy demand, which has been increasing at a rate of 10% in recent years, cannot be met only by hydropower. But it is important to increase hydroelectric capacity as rapidly as possible to reduce imports. Otherwise, the energy deficit that has just begun to be sensed will become more serious.

Flood Control

In Turkey floods occur mainly in the spring season due to snowmelt and heavy rainfall. Flash floods may be seen in summer months. The destruction of the vegetative cover and settlements in the valleys increases flood damages. It is estimated that flood control will be needed for 725 000 ha of land. In 1993 flood protection was provided for 270 000 ha.

Dams

DSİ estimates that nearly 700 dams have to be built to regulate the flow in Turkish streams. At present the number of dams completed numbers about 170. The major dams are shown in Table 4. The largest dams are on Fırat River. Atatürk Dam is the eighth largest in the world by structural volume (84.5 hm^3) and Keban Dam is the third largest by height (207 m) among the composite dams of the world.

Water Transfer

Most of Turkey's water resources are in the south-east and the Eastern Black Sea region, whereas the demand is highest in western and central Turkey. Therefore the transfer of water between river basins will be required in the future. The waters of Fırat, Dicle, Eastern Black Sea, Eastern Mediterranean, Antalya and Western Black Sea drainage basins can be transferred to meet the deficits in the west and middle parts of the country.

No major water transfer projects have yet been realized. It is planned to

Table 4. Major dams of Turkey

Dam	Year	River	Type	Height (m)	Reservoir capacity ($10^9 m^3$)	Purpose
Atatürk	1995	Fırat	r	169	48.7	EI
Keban	1975	Fırat	g + r	207	30.6	E
Karakaya	1987	Fırat	a	173	9.6	E
Hirfanlı	1959	Kızılırmak	r	83	6.0	E
Altinkaya	1988	Kızılırmak	r	195	5.8	E
Menzelet	1989	Ceyhan	r	150	2.0	EI
Sarıyar	1956	Sakarya	g	108	1.9	E
Kılıçkaya	1990	Kelkit	r	140	1.4	E
Demirköprü	1960	Gediz	e	77	1.3	EIF
Seyhan	1956	Seyhan	e	77	1.2	EIF
Aslantaş	1984	Ceyhan	e	95	1.2	EIF
Çamlıdere	1985	Bayındır	r	106	1.2	W
Karacaören	1989	Aksu	e	95	1.2	EIF
Adıgüzel	1990	B. Menderes	r	145	1.2	EIF
H. Ugurlu	1982	Yeşilırmak	r	175	1.1	E
Gökçekaya	1972	Sakarya	a	158	0.9	E
Oymapınar	1984	Manavgat	a	185	0.3	E

Symbols: Type: a = arch; e = earthfill; g = gravity; r = rockfill.
Purpose: E = energy; F = flood control; I = irrigation; W = water supply.

supply water for the city of Istanbul from the Melen basin in the Western Black Sea region. Some 1200 MCM/yr of water will be transmitted a distance of 180 km. The cost of the project that will be completed in the year 2030 is estimated at US$2.5 billion.

Southeastern Anatolia Project (GAP)

GAP is the largest regional development project in Turkey, and also one of the major projects in the world. It consists of dams, hydropower plants and irrigation schemes in the lower Fırat and Dicle basins, and accompanying growth of agriculture, transportation, industry, telecommunications, health and education sectors and services in the region. It covers nearly 10% of the total area of Turkey and 8% of the national total population in an underdeveloped region where per capita gross product is about one-half of the national average.

A total of 22 dams and 19 hydropower plants are to be constructed as components of GAP; 27 350 GWh/yr will be produced (22% of the country's hydropower potential), with an installed capacity of 7500 MW and 1 700 000 ha will be irrigated (19% of Turkey's economically irrigable land). Flow regulation and flood control will also be provided downstream.

The completion of this project requires a considerable part of Turkey's financial and technical resources to be devoted to it. It is expected that GAP will be completed in its entirety in the first quarter of the 21st century. At present only three dams and two hydropower plants have been constructed, from which 16 250 GWh/yr of energy can be produced, and 37 000 ha of land can be irrigated (1995 figures).

The realization of GAP is causing intense tension between Turkey and the other riparian countries, Syria and Iraq. In the presence of economic, ethnic and

religious conflicts in the region, it is unlikely that a rational solution for the problem can be found soon.

International Projects

There are various projects to transfer the excess water from Turkey to other countries in the region. 'The Peace pipeline' project, proposed by the late President Turgut Özal in 1987, would carry water from the Seyhan and Ceyhan Rivers as far south as Saudi Arabia (3.5 MCM/day) and from the Dicle River to the United Arab Emirates (2.5 MCM/day) at a cost of about $20 billion, one-third of the cost of desalinized water. A shorter pipeline could transmit 0.6 MCM/day of water to Jordan. This project was never realized, owing to political and economic difficulties. It is not clear, either, whether the Seyhan and Ceyhan River basins will have surplus water in the future. Another project, about to be completed, will export 0.5 MCM/day of water from Manavgat River. International negotiations are in progress for its marketing.

Plans for the Future

The Five-Year Development Plan for the period 1996–2000, approved by parliament in 1995, emphasizes the issues to be considered in water resources planning in the future.

No extensive policy exists for the national planning and management of water and land resources in Turkey. Data collection and evaluation studies should be intensified. Available financial resources are not sufficient to reach the targets in time. Public institutions in charge of the projects are not coordinated.

Providing water for settlements without adequate supplies will take priority. Long-term water supply for cities should be considered. It is planned to provide 7800 MCM annually as water supply for the settlements. The build–operate–transfer (BOT) model will be encouraged for water supply and water treatment systems. Conceptual, physical and financial participation by the beneficiaries will be realized in the planning, construction and management of infrastructure development in order to reduce the burden on the state. A Water Law will be prepared to achieve institutional reorganization for the rational planning, management and protection of surface and groundwater resources. Pricing of water supplies and sewerage will be reconsidered. Environmental effect evaluation projects will be prepared and applied concurrently with the development projects.

Participation of the farmers must be achieved in the irrigation schemes. Their education is essential in order to increase efficiency. Savings in water and drainage can be made through appropriate pricing policies and controlled irrigation. Land classification studies and planning for land use should be renewed. Agricultural development must be balanced, sustainable and in harmony with the environment. The irrigation schemes that are being operated by DSİ should be transferred to the users.

Although primary energy consumption has increased by 5%, and electrical energy production by 11% annually in the past 40 years, per capita energy consumption is substantially below the average for the developed countries. Annual electrical energy consumption is slightly over 1300 kWh per capita and

is expected to increase to 1800 kWh per capita in the year 2000. About one-half of the primary energy is dependent on imported sources.

Investments in the energy sector should be continued so that no deficits occur in the future. This can be achieved only through participation by the private sector. It has not been possible to operate the BOT model owing to problems of energy purchase and pricing. This model is not suitable for multipurpose and transboundary projects. The realization of hydropower schemes is sometimes hindered by environmental considerations. Private sector enterprises must be planned for optimal use on the basin scale.

A systems approach should be adopted in future efforts to achieve sustainable growth of the water and related land resources in Turkey.

Acknowledgement

Data on Turkey's water and energy potential and water resources development are taken from various publications of DSI and EIE.

Reference

TBMM (1995) Seventh five-year development plan, *T. C. Resmi Gazette*, No. 22354 (in Turkish).