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"Historical long-distance water conveyance systems to Izmir"

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HISTORICAL LONG - DISTANCE WATER CONVEYANCE SYSTEMS TO İZMİR

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Graduate School of Natural and Applied Sciences of
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by

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İZMİR

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The first comprehensive investigation on long-distance conveyance systems to meet water needs of İzmir, a city with a history of several thousands of years, has been carried out towards the end of the 19. century by Georg Weber. In the mean time, no new investigations were carried out, neither to go into more detail, nor to identify the alignment of these systems with the help of modern maps. In this study, it is tried to determine the alignment of the historical long-distance water conveyance systems to antique İzmir (Smyrna).

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İzmir, 1999 A. KOSOVA, B.Sc. Civ. Eng.

ABSTRACT

The first comprehensive investigation on long-distance water conveyance systems to meet the water needs of İzmir, a city with a history of several thousands of years, has been carried out towards the end of the 19. century by Georg Weber, within the framework of the activities of the German Archeological Institute, and published in 1899 in the Institute's yearbook. In the mean time, no new significant investigations were carried out, neither to go into more detail, nor to identify the alignment of these systems with the help of modern maps; moreover, the area covered by the city is growing fast, so that many of the remains found a century ago, cannot be found at present at their locations. The purpose of this study is, based on the information and drawings in Weber's report, backed by field investigations on what can still be found, and with the support of modern maps, try to determine the alignment of the historical long-distance water conveyance systems to antique İzmir (Smyrna).

Principal long-distance water conveyance systems to İzmir are as follows: a) the 30 km long antique "Karapınar system", conveying the water from Karapınar springs on southern slopes of the Nif mountain, east of İzmir, and reaching the Kadifekale castle by crossing Melez creek through a 3.3 km long stone-pipe inverted siphon, with a discharge capacity in the order of 10 l/s; b) the 29 km long antique "Akpınar system", conveying the water of Akpınar springs, south of İzmir, and reaching the temple Zeus Akraios near Bayramyeri, with 62 l/s capacity; c) the antique "Buca systems", partly used through later modifications, conveying waters of Kanlıgöl-Kaynaklar area east of Buca, continuing in Melez valley at eastern slopes of Kadifekale; d) the "Osmanağa system", conveying the water of the Kozağaç springs south of İzmir; e) the ottoman "Vezir system", conveying the waters of springs near Şirinyer, southeast of İzmir; f) the "Kapancıoğlu system", conveying the waters issuing from the northern slopes of Tepecik, east of İzmir.

ÖZET

Binlerce yıllık geçmişe sahip İzmir kentinin su ihtiyacını karşılamak üzere inşa edilmiş, uzun mesafeden su getirme sistemleri konusunda kapsamlı ilk araştırma 19. yüzyıl sonlarında Alman Arkeoloji Enstitüsünün çalışmaları çerçevesinde Georg Weber tarafından yapılmış, bulguları 1899'da Enstitünün yıllığında yayınlanmıştır. Arada geçen sürede, konunun ayrıntılarına daha fazla inecek , çağdaş haritalar üzerinde bu suyollarının geçgisini tam olarak belirleyecek çalışmalar yapılmamış olduğu gibi, kentin kullanım alanının sürekli büyümesi yüz yıl kadar önce belirlenmiş kalıntıların pek çoğunun bugün artık yerinde bulunmamasına yol açmıştır. Bu çalışmada, Weber'in raporundaki bilgiler ve çizimler dikkate alınarak, hala yerinde bulunabilecek kalıntı ve izler arazide araştırılarak, çağdaş haritalardan da yararlanarak, antik İzmir'e (Smyrna) uzun mesafeden su getirmiş olan tarihi su yollarının geçgilerinin belirlenmesi amaçlanmıştır.

Bu suyollarının başlıcaları şunlardır: a) İzmir'in doğusundan, Nif dağının güney yamaçlarındaki Karapınarın sularını Kadifekale'ye ileten, Melez çayını 3.3 km uzunluktaki taşborulu ters sifonla geçen, toplam 30 km uzunluğa ve 10 l/s mertebesinde iletim debisine sahip antik "Karapınar suyolu"; b) İzmir'in güneyinden, Akpınar sularını Bayramyeri yakınındaki Zeus Akraios tapınağına kadar ileten, toplam 29 km uzunluğa ve 62 l/s iletim kapasitesine sahip antik "Akpınar suyolu"; c) İzmir'in güneydoğusundan, Buca'nın doğusundaki Kanlıgöl-Kaynaklar yöresi sularını Melez vadisine, Kadifekale'nin doğu eteklerinden dolaşarak ileten antik ve daha sonraki dönemlerde de kısmen yararlanılmış olan "Buca suyolları"; d) İzmir'in güneyinden, Kozağaç yöresi pınar sularını ileten "Osmanağa suyolu"; e) İzmir'in güneydoğusundan, Şirinyer yakınında kaynayan pınar sularını ileten Osmanlı dönemi "Vezir suyolu"; f) İzmir'in doğusundan, Tepecik'in kuzey yamaçlarından kaynayan suları ileten "Kapancıoğlu suyolu".

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CHAPTER ONE
INTRODUCTION

1.1. Purpose

Anatolia can be considered as one of the foremost open-air museums of the world with regard to ancient water works, remains of which are dating from all periods of the last four millennia. Among them, water supply systems constructed in the Aegean Region are of paramount importance.

The first comprehensive investigation on long-distance water conveyance systems to meet the water needs of İzmir, a city with a history of several thousands of years, has been carried out towards the end of the 19. century by Georg Weber, within the framework of the activities of the German Archeological Institute, and published in 1899 in the Institute's yearbook (Weber 1899); and some extra knowledge has been given some years later (Weber 1904, p.95-96).

In the mean time, no new significant investigations were carried out, neither to go into more detail, nor to identify the alignment of these systems with the help of modern maps; moreover, the area covered by the city is growing fast, so that many of the remains found a century ago, cannot be found at present at their locations.

Principal long-distance water conveyance systems to İzmir are as follows:

(a) The antique "Karapınar system", conveying the water from Karapınar springs in the upper reaches of Arapdere creek on southern slopes of the Nif Mountain, east of İzmir, and reaching

the Kadifekale castle (Mount Pagus) by crossing Melez creek through a stone-pipe inverted siphon.

(b) The antique "Akpınar system" conveying the water of Akpınar springs near Kısıkköy, south of İzmir, and reaching the temple of Zeus Akraios near Bayramyeri, where a series of ancient water mills were established.

(c) The antique "Buca systems", partly used through later modifications, conveying waters of Kanlıgöl-Kaynaklar area east of Buca, crossing Melez creek by a high aqueduct and continuing in Melez valley at eastern slopes of Kadifekale.

(d) The "Kozağaç system", conveying the water of the same named spring south of İzmir, crossing Melez creek by a high aqueduct, used probably in Ottoman times as "Osmanağa system".

(e) The Ottoman "Vezir system", conveying the waters of springs near Şirinyer, south east of İzmir, and crossing Melez creek by a high aqueduct.

(f) The "Kapancıoğlu system", probably having its origins in antiquity, conveying the waters issuing from the northern slopes of Tepecik, east of İzmir, to Halkapınar.

The purpose of this study is to evaluate the studies of Georg Weber, and to investigate the actual state of the above-mentioned systems.

1.2. Scope

The scope of this study is, based on the information and drawings in Weber's report, backed by field investigations on what can still be found, and with the support of modern maps, try to determine the alignment of the historical long-distance water conveyance systems to antique İzmir (Smyrna), within the limits of space and time associated with such a thesis.

CHAPTER TWO
EXISTING STUDIES

2.1. Studies on ancient water conveyance systems and other water works in general

Although archaeologists, historians and occasionally civil engineers prepared a limited number of publications until the second half of the 20th century on ancient water works, they attracted growing interest after the 1950's, especially with increasing contribution from civil engineers.

After Hunter Rouse and Simon Ince published the book "History of Hydraulics" in 1957, in the State University of Iowa, a course having the same name with their study has been taken into the program.

Asit Biswas has published the book entitled "History of Hydrology" in 1970, by gathering and expanding his previous papers concerning the issue.

Günther Garbrecht who investigated at the end of 1960's and during 1970's the historical water conveyance systems of Pergamon, organised seminars in France (1977), Turkey (1979), Greece (1981), Israel (1983), Egypt (1986), Italy (1988), Spain (1992) on the water conveyance systems and other hydraulic works in ancient times.

Beside several papers and articles, Garbrecht published later two books in 1985 and 1995 about ancient water works and water engineering history. The Ph.D. Thesis of Henning

Fahlbusch, with Garbrecht as advisor, is one of the most important studies on water engineering history.

Other important studies about the ancient water works is the book of Norman Smith about the history of hydro-technology (1976), papers of Niklaus Schnitter who works since 1960's about ancient water works and old dams, the book of Klaus Grewe about the long-distance water conveyance systems in Roman times (1985b), Grewe's papers in 1980's and 1990's about water tunnels, especially his most recent book (1998), and the books of the Zabern publishing company about historical long-distance water conveyance systems of ancient cities (1987,1988,1991).

In addition to this, in civil engineering periodicals like Water Power & Dam Construction, Die Wasserwirtschaft, Österreichische Wasserwirtschaft, Wasser und Boden, Wasser-Energie-Luft / Eau-énergie-air, La Houille Blanche, Water Resources Development, Schweizer Ingenieur und Architect, as well as in Scientific American with an important place in science press, and in archeological journals like Antike Welt, numerous papers on ancient water works has been written by civil engineers.

After history of hydraulics has taken place in the program of the XII. Congress of International Association of Hydraulic Research (I.A.H.R.) in 1957 in Iowa, it appeared again in 1977 in the program of the XVII. Congress in Baden-Baden through the efforts of Günther Garbrecht; and later in 1979 in the XVIII. Congress in Cagliari. In the XI. Congress of International Commission on Irrigation and Drainage (I.C.I.D.) in 1981 Grenoble and in the XVI. Congress in 1996 in Cairo, special meetings has been held about irrigation, drainage and flood control history. In 1987, a symposium held by International Association for Hydraulic Research in Rome about water for future, papers on ancient water works has been also presented.

Further papers on important water conveyance systems abroad are for Samos (Kienast 1979,1983,1984,1987b,1990), for Megara, Korinth and Athen (Camp 1979; Kienast 1987a;

Crouch 1987,1993), for Agrigento and Morgantina (Chrouch 1984,1989), for Rome (Frontinus 100 AD; Ashby 1935; Martini 1976; Pace 1983; Garbrecht 1984,1987a,1989; Panimolle 1984; Werner 1986), for Pompeji (Eschebach 1979,1987), for Bologna (Giorgetti 1985,1988), for Köln (Grewe 1983,1986b,1991a,b; Haberey 1972,1978), for Metz (Hein 1990), for Mainz (Kaphengst & Rupprecht 1988; Rupprecht 1989), for Nîmes (Fiches & Paillet 1988; Fabre, Fiches & Paillet 1991), for Lyon (Burdy 1979,1988; Grewe 1992a), for Merida (Grewe 1988b,1993), for Segovia (Grewe 1988c), for Almunear (Grewe 1988a, 1991c), for Karthago (Kottmann 1988; Rakob 1971), for Caeserea (Leveau 1988a) and for Saldae (Leveau 1988b).

All these meetings, congresses and papers show the international importance of ancient water works in the world.

Turkey can be considered as one of the foremost open-air museums of the world with regard to ancient water works, remains of which are dating from all periods of the last four millennia (Fig. 2-1).

There are remains of several water works from the second millennium BC. Hittite period in Central Anatolia (Neve 1969/ 70; Emre 1993 and Ertem 1979,1982); from the first half of the first millennium BC. Urartu period in Eastern Anatolia (Öğün1970; Garbrecht 1975-1988 and Belli 1997); from the second half of the first millennium BC. to the first half of first millennium AD. Hellenistic, Roman, Byzantine periods in Western and Southern Anatolia (Vitruvius 15 BC; Frontinus 100 AD; Dalman 1933; Eyice 1979; Fahlbusch 1981; Kienast 1981; Schnitter 1984; Crouch 1987,1993; Fahlbusch 1979,1982,1983,1987a; Garbrecht 1982b,1986; Lamprecht 1981,1988; Grewe 1985b,1998; Tölle-Kastenbein 1990 and Bildirici 1994b); from the second millennium AD. Seldjukide and Ottoman periods (Akmandor 1968; Çeçen 1986-1997; Özand 1968; Öziş 1977-1988; Öziş & Arısoy 1986-1996; Onur 1985; Schnitter 1990; Bildirici 1994a; Bildirici,M. & Bildirici,Ö. 1997) throughout Turkey (Öziş 1994b,1994,1995,1996,1998).

Figure 2.1 : Location of major historical water schemes in Turkey [Öziş 1994a]

It is anticipated that both national and international interest in the ancient water works of Turkey, some still in use, will continue to increase.

The most interesting long-distance water conveyance systems in Turkey are as follows:

a) Thrace and Western Anatolia

Hellenistic, Roman and Byzantine systems of İstanbul (Dalman 1933; Eyice 1979; Baur 1991), Pergamon (Garbrecht 1976–1987; Hecht 1975–1983; Fahlbusch 1977,1981,1987c; Garbrecht & Fahlbusch 1975,1977,1978; Garbrecht & Holtorff 1973), Foça (Önen, Özyurt & Yağcı 1979); and Ottoman systems of İstanbul (Yüngül 1957; Çeçen 1979-1997; İ.S.K.İ. 1989; Şentürk 1957; Öziş 1977-1998; Öziş & Arısoy 1986-1996).

b) Southwest Anatolia

Ephesos (Forchheimer 1923; Wilberg 1923; Alzinger 1987; Linguri, Tulgar & Şamlı 1974; Baltalı & Büyükbebeci 1977; Ersöz & Arat 1977; Öziş 1996; Atalay, Öziş, Becerik, Özdikmen 1996 a,b, 1997; Öziş, Atalay, Becerik & Özdikmen 1998; Öziş & Atalay 1999), Priene (Tanrıöver 1974; Crouch 1996), Milet (Sertöz 1974; Tuttahs 1997,1998), Iassos (Güripek & Uysal 1991), Alabanda and Gerga (Utku & Haşal 1978; Öziş, Atalay, Haşal & Utku 1979), Sultanhisar (Nysa) (Küçüksezgin & Kahraman 1978), Geyre (Aphrodisias) (Çakır, Verim & Afşar 1978), Eskihisar (Laodikeia) (Weber 1898; Yılmaz 1973; Turan & Alkan 1991), Pamukkale (Hierapolis) (Yılmaz 1973), Patara (Kocakaya & Alkaya 1993), Oenoanda (Stenton & Coulton 1986; Cantilav 1996; Baykan & Cantilav 1997), Cibyra (Cantilav 1996; Baykan & Cantilav 1997), Bubon (Cantilav 1996; Baykan & Cantilav 1997) and Balbura (Cantilav 1996; Baykan & Cantilav 1997).

c) Central and Southern Anatolia

Perge (Fahlbusch 1987e; Dağ & Terzioğlu 1991; Baykan & Dağ 1994; Büyükyıldırım 1997), Aspendos (Fahlbusch 1987d), Uzuncaburç (Diokayzerea), Uğra (Olba), Ayaş (Elaiussa Sebaste) and Kızkalesi (Korikos) (Arısoy, Öziş & Kaya 1987; Çangın & Akpınar 1994), Samsat (İzmirligil 1983) and Antakya (Antiochia) (Lassus 1977).

2.2. Studies on ancient water conveyance systems to İzmir

The first comprehensive investigation on long-distance water conveyance systems to İzmir has been carried out towards the end of the 19. Century by Georg Weber, within the framework of the activities of the German Archeological Institute's and published in the yearbooks (Weber 1899, 1904/5).

Weber expressed in his work that there were 6 historical long-distance water conveyance systems to meet the water needs of İzmir: (a) Karapınar; (b) Akpınar; (c) Kapancıoğlu; (d) Byzantine water conveyance system in Melez valley; (e) Osmanağa; (f) Vezir-su. The findings of Weber about these water conveyance systems are summarized in Chapter 3; serving as the most significant available data.

Schnitter (1984) pointed out the importance of the stone-pipe inverted siphon of the Karapınar system. Çördük investigated in detail and determined the alignment of the Karapınar water conveyance system in the context of his B.Sc. graduation project (1998). His results and the initial results of the M.Sc. thesis of the author, along with other information by Weber, are summarized in a recent congress-paper (Öziş, Özdemir, Kosova, Çördük 1999).

CHAPTER THREE

AVAILABLE DATA

3.1. Availability of Data

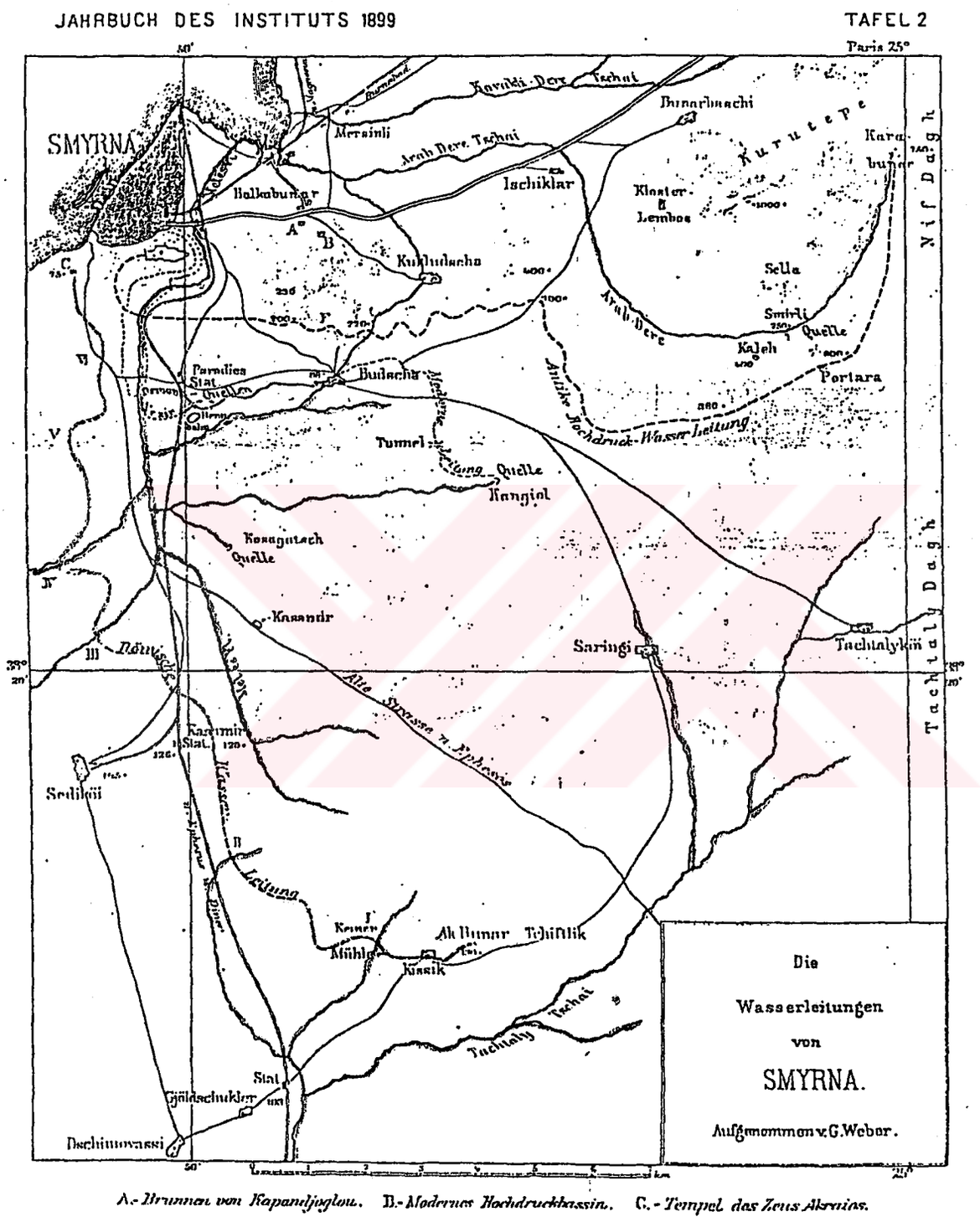
3.1.1. Historical data

The only available historical data of relevance is the main report of Georg Weber from the German Archeological Institute [Weber 1899], with some additional data in a more general one [Weber 1904]. The findings of Weber are outlined in Subchapters 3.2. and following, with page references to the main report.

3.1.2. Maps

Weber's 1899 report includes two drawings mentioned as "Tafel". "Tafel 2" (given as Fig.3-1) has a scale of about 1 : 83 330; displays the alignments of the long-distance water conveyance systems to İzmir; but shows some discrepancies with modern maps, and as will be seen later, certain consequent discrepancies with the alignments determined within the framework of this thesis.

"Tafel 3" (given as Fig.3-2) has a horizontal scale of about 1 : 14 300 (although written as 1 : 10 000) and a vertical scale of about 1 : 3 600; displays the layout and longitudinal section of the stone-pipe inverted siphon of the Karapınar system, crossing Melez-valley. The discrepancies with modern maps and findings appear of lesser



A.- Brunnen von Kapandjioglou. B.- Moderner Hochdruckbassin. C.- Tempel des Zeus Akraios.

Figure 3.1 : [Weber 1899/I; Tafel 2] The alignment of the water conveyance systems to İzmir, according to Weber

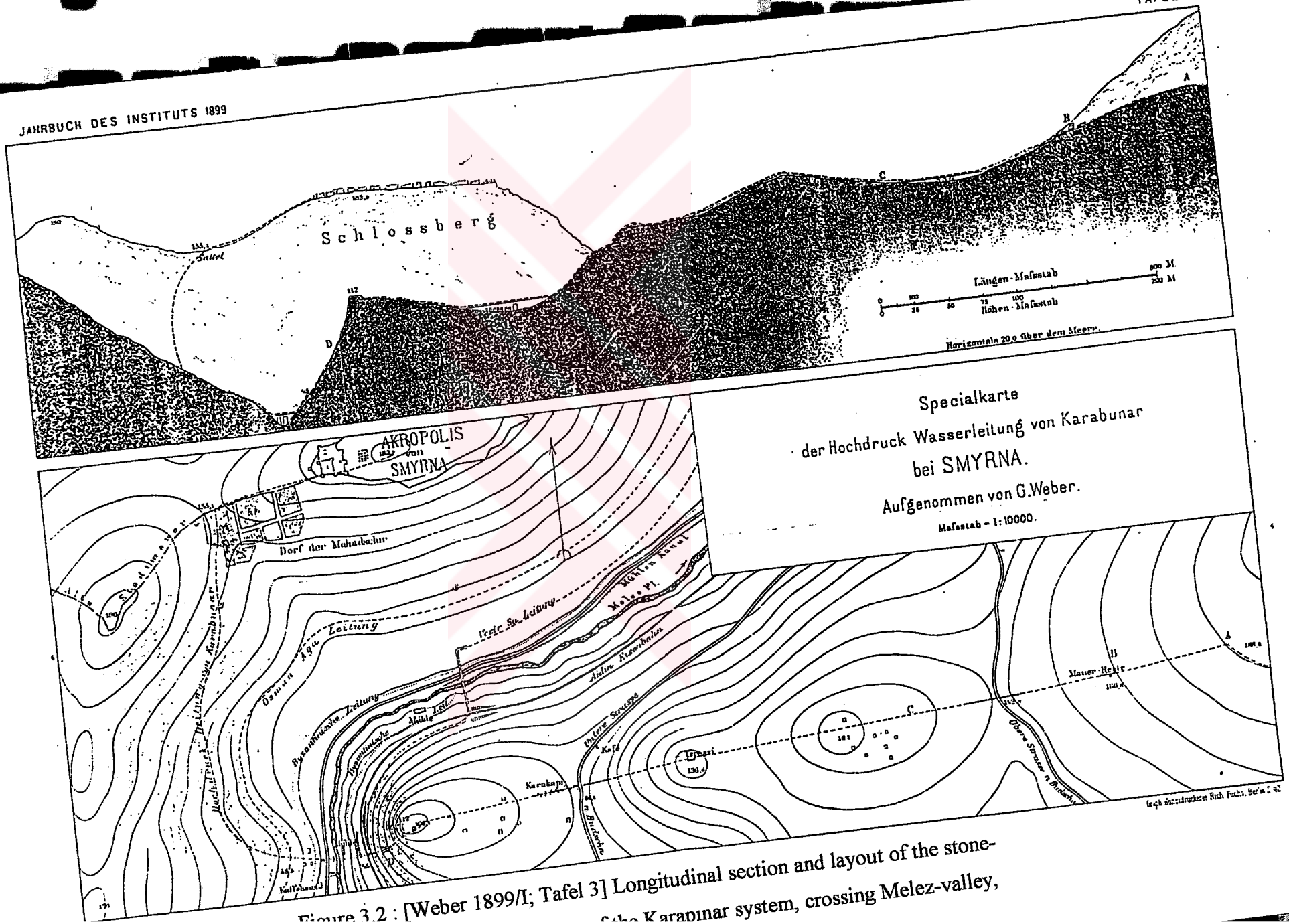


Figure 3.2 : [Weber 1899/I; Tafel 3] Longitudinal section and layout of the stone-
s the Karapinar system, crossing Melez-valley,

significance, although the actual urban development covered almost the entire alignment of the inverted siphon.

The anticipated alignments of the water conveyance systems to İzmir fall into İzmir and Manisa plates of modern 1 : 200 000 & 1 : 250 000 scale maps; in L18 of 1 : 100 000 scale map; L18-a1, L18-a2, L18-b1, L18-a4, L18-a3, L18-b4 of 1 : 25 000 scale maps; whereas the latter large scaled maps are usually classified material. There are also some city maps of İzmir, with scales in the order of 1 : 10 000 to 1 : 5 000.

3.1.3. Field investigations

Field investigations were carried out to a limited extent, due to : (a) urban developments; (b) restricted zones; (c) unfavourable weather conditions; (d) limited time allocation.

3.2. Karapınar Water Conveyance System

3.2.1. Between Kaynaklar & the Buca plain

3.2.1.1. The spring [Weber 1899; pp.6,7,22]

The only way to supply sufficient water to the acropolis (actual Kadifekale) of antique Smyrna was to bring water from outside. The best solution appeared to look for springs on the hills of the Nif mountain. According to the farmers in Melez (ancient "Melas"; in Weber's text: "St. Anna") valley, the water from Karapınar (Weber : "Karabunar"), issuing from 3 sources under large platane-trees, at an altitude of 750 m, located near the beginning of Arapdere, at the water divide between Kurutepe & Nif mountain, was conveyed to İzmir; there were some remains at the southern slopes of Kadifekale.

There is no sign of a canal near the spring. Since the loose material of the slope change the shape during each flood, the canal might have been washed out or might lay under the ground. The traces of a dike can be observed downstream of the spring, to collect the water and convey it to the canal.

Rectangular stone blocks of 2.60 m length, 0.53 m width and 0.56 m height lay around, indicating that a planned and organised work has been carried at this place. The quality of water appears to be the best around İzmir.

3.1.1.2. "Portara" region [Weber 1899; pp.21-22]

At the slope of the mountain range called "Prioni" (means: saw), there is at an altitude of 660 m, a rock-cut stretch of 8 m width and 4-5 m depth; it provides the passage from the Karapınar valley to the land in the southwest. There is no sign of the water conveyance in this cut section.

There is only a canal, 0.60 m deep and 0.50 m wide, on the left just before the cut, which can be followed for 10 m. The path climbs along the east side of the valley.

The river bed is 100 m below Portara. When the region is investigated following the river bed, it can be seen that the river bed is narrower around Portara and then widens again.

3.1.1.3. "Smirli" & Kale region [Weber 1899; pp.21-22]

Eastwards of Portara, at an altitude of 530 m, the remains of the canal is seen. It consists of rubble masonry walls without mortar outside, and plastered with cement inside. The height is about 0.30-0.40 m, the base width 0.42 m and is full of sediments (Fig.3-3).

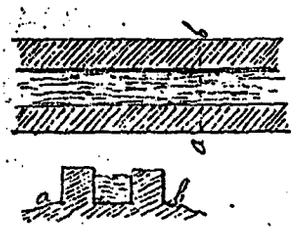


Figure 3.3 : [Weber 1899/I; Fig.32]

The canal continues at higher elevations; some parts are covered by unfinished stone blocks. A terra cotta pipe line parallel to the canal dates probably from a later by-pass activity.

The spring called "Smirli" is near Kale (means: castle) on the left bank, at an altitude of 250 m. The collected water was not conveyed to Smyrna because it is not located high enough, but rather conveyed along the Arapdere valley. The Arapdere valley has witnessed intense settlement in the past, as it can be concluded from the article of Fontrier about the Lemnos monastery (Bulletin de Correpondances Hellenistiques, XVI, p.379).

The collecting chamber of the spring, cut in the rock, is 4 m above the river bed, and discharged in the canal, which can be followed for a while. Actually, the spring issues at the foot of the rocky hillside, due probably to later earthquakes. The remains of the abutments of 2 aqueducts, bridging the narrow valleys, can be seen eastwards and westwards of the castle.

3.2.2. Between the Buca plain & the beginning of the stone pipe inverted siphon

3.2.2.1. "Petraloni" region [Weber 1899; pp.21,23]

After riding on the donkey eastwards for 2 hours on the Tahtalı road, leaving the road coming down to Tahtalı valley in southeast direction at the saddle at an altitude of 375 m, and following the water divide line in eastwards direction, after a quarter of an hour, at an altitude of 360 m, terra cotta pipes are encountered for 8 m, with top parts broken and filled with soil (Fig. 3-4).

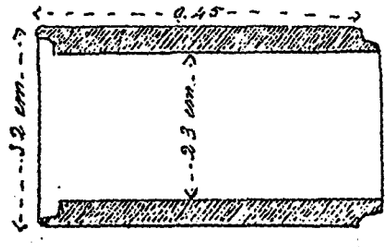


Figure 3.4 : [Weber 1899/I; Fig.31]

Although there are a lot of roads from Buca to Arapdere valley and Bornova (Weber: Burnabat), the most frequently used road is the one passing over the Petraloni. There is at an altitude of 300 m, a paved harvest place from Byzantine times, not used today; with a terra cotta pipe part of 3.5 cm wall thickness, similar to those encountered in the environment (Fig. 3-5). It is possible that the water conduit crossed here the water divide line from Arapdere valley to Buca.

Figure 3.5 : [Weber 1899/I; Fig.33]

If one leaves the beginning of Arapdere valley at an altitude of 260 m and climb the mountain, there is no traces at Kryadagara (as called by Weber) saddle at an altitude of 310 m, where the water line must have passed. However, there is a terra cotta pipe at a farm in the valley, which is said that it came from there. A farmer from Buca says that he brought the 2 terra cotta pipes used as flower pots in his garden, similar to the one in Fig. 3-6, with lengths of 0.45 m , interior diameter of 0.21 m and wall thickness of 0.06 m, and with bell-and-spigot joint ends, from his vineyards in that region.

3.2.2.2. Southern slopes of Kokluca [Weber 1899; pp.23-24]

The water conduit has to cross 8 valleys and a hill between Petraloni in the east and the wall ruin at point B in the west. These crossings were not formed with short-cutting aqueducts, but the water conduit passed deep into the valleys forming narrow bends.

The bird flight distance between Petraloni and the wall ruins at point B is 5.5 km; however, due to the bends of the alignment, the length of the water conduit may be twice as long. Because of the difference of altitude of 100 m between the two points, the pipes used should have thick walls and the conduit in this part must have been under a certain pressure.

Buca villagers used several pipes of this terra cotta pipe system in their buildings or used them as chimneys. The dimensions of a pipe in a farmer's garden are shown in Fig. 3-6.

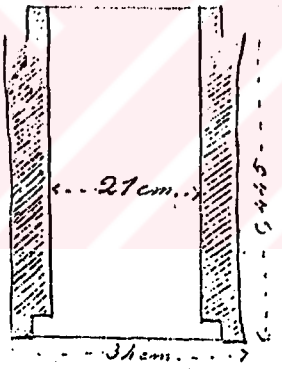


Figure 3.6 : [Weber 1899/I; Fig.34]

At point F at an altitude of 216 m, where a farmer found terra cotta pipes, the lower half of a pipe was found during an excavation. The pipe is similar to those found in their entity, with bell-and-spigot joint ends, is 0.55 m long, the wall is 0.04 m thick, and was covered with a crust of sediments.

Following almost parallel the contour lines with an aneroid northwest of Buca, a large number of broken parts of terra cotta pipes can be seen. At point E, at an altitude of 200 m, some terra cotta pipes exist in their places; with certain later renovations through pipes with thinner walls.

Between the point A at an altitude of 188.80 m and point B, there are several fragments of terra cotta pipes. The conduit might have had a change in direction upstream of point A, since such fragments were lacking in that area. Although the point A, lying 5 m higher than the highest part of Kadifekale and being the starting point of the inverted siphon, no traces of an expected surge chamber were encountered; no such chamber was found either at the conveyance system to Trapezopolis near Sarayköy, as investigated by Weber the same year.

3.2.3. Between the beginning of stone-pipe inverted siphon & the rocky hill

3.2.3.1. The beginning parts of stone-pipe inverted siphon [Weber 1899; pp. 8-13]

At point B at an altitude of 166 m, 50 m below the peak point, there are 2 parts of wall ruins. The big part is 3 m long, 4.5 m high and 2 m thick and made of rubble stone with lime mortar, outer part is roughly rectangular stone blocks, and is in horizontal layer. The mortar is extremely hard and made of rough sand. At the wall, limestone was the used material, as mostly used in that area. As seen in Fig.3-7 , this part is adjacent to the real water conveyance like a tower.

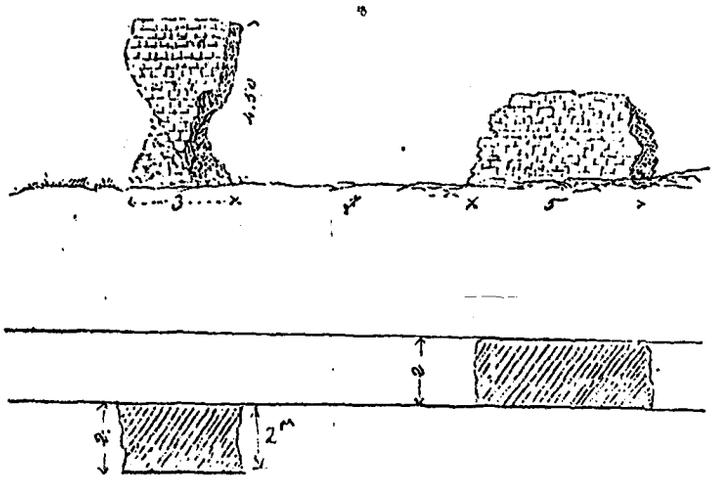


Figure 3.7 : [Weber 1899/I; Fig.1]

Until you reach the higher road, there are no signs of the wall. The wall starts from 54 m east of the road and goes on until 115 m west of the road at a height reaching 4.5 m. It might have passed through the road which is 10 m wide with 2 arch openings. There exists the ruin of the side leg of the arch in the west 5 m further, there is a third arch which is 3.7 m wide, the arch begins from the bottom and is 2 m thick. The construction technique is the same as the preceding ones. The rectangular stone blocks of the aqueduct is 0.45-0.50 m high. The stones at the bottom parts are bigger than the ones at the top parts (Fig. 3-8).

Fig. 2.

Figure 3.8 : [Weber 1899/I; Fig.2]

At the point C, a part of a stone pipe which was used at the crosswise wall of the field is seen. In addition, a lot of stone pipes used in vineyard houses at the southern slope are seen at the first house on the left; there are 2 pipes (Fig.3-9).

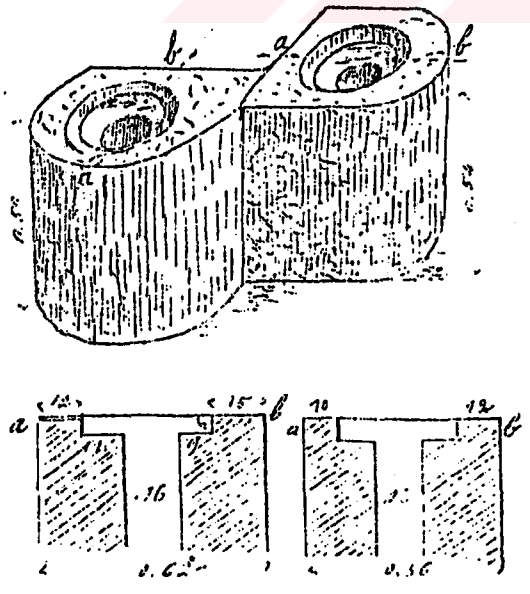


Figure 3.9 : [Weber 1899/I; Fig.3]

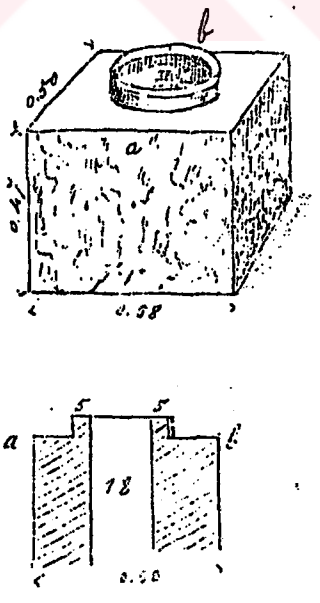


Figure 3.10:[Weber 1899/I; Fig.4]

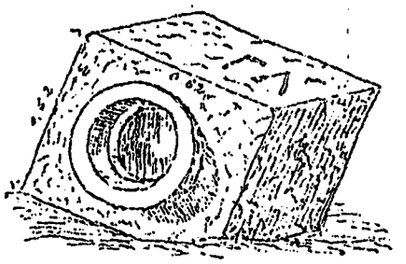
The pipes were made half round as it was usually done to stone pipes in this region. The inner diameter is 0.16 and 0.13 m, the outer edge (base) is 0.62 and 0.36 m, the length is 0.50 and 0.54 m. Wall thickness at the bell is 0.12-0.15 and 0.10-0.12 m. The pipes were made of dark coloured trachyte. The third pipe was used at the door at the bottom and has double bells. The fourth pipe is in the second house.

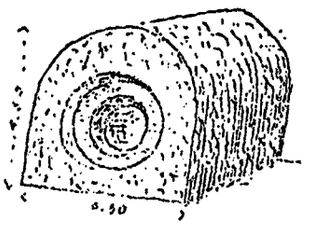
Whether there was a water tower at the peak point with an altitude of 161 m, cannot be said without excavating of the mould of rubble stone covering the site. There are several antique terra cotta pipe fragments at the field walls and at the small house on the northern side.

If one goes further to the west, nothing can be seen from the antique wall, but on the field walls, some stone pipes are observed. At the second cross wall, there is a pipe with an inner diameter of 0.24 m and width of 0.70 m. At the third cross wall, there is another stone pipe exactly at the passage level.

Near Teressi, there are two vertical and rectangular shaped stone pipes (Fig.3-10). The cross-section of the stone pipe is 0.50 * 0.58 m, the inner diameter is 0.18 m, the thickness is 0.47 m and the wall thickness of the spigot is 0.05 m.

If you go further to the west, near the wall, there are 3 stone pipes. One of them is with a cross-section of 0.52 * 0.62 m, the inner diameter is 0.16 m, the length is 0.38 m, and the letters ΓΛ, 0.10 m high and 1 cm wide, were marked on it with deep lines (Fig. 3-11). The second was made round. It is 0.52 m high, the base width is 0.50 m, the length is 0.415 m, the inner diameter is 0.15 m and both sides are with double bells (Fig. 3-12). The third is with edge width 0.56 m, length 0.53 m, the inner diameter 0.16 m. One side is with a single bell and the other side is with double bells (Fig.3-13). Further at the bottom, there is a fourth stone pipe which was used at the wall at this time.





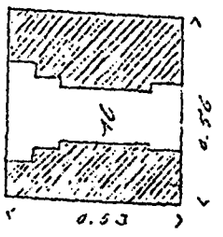
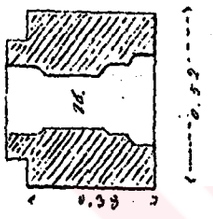


Figure 3.13:[Weber 1899/I; Fig.7]



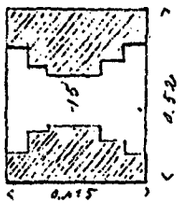


Figure 3.12:[Weber 1899/I; Fig.6]

Figure 3.11:[Weber 1899/I; Fig.5]

55 m away from Terassi, the field wall passes above the ancient water conveyance. It is possible to follow the water conveyance until the tower at an altitude of 136.6 m in the south (Fig. 3-14). In the east of the water conveyance, a room was constructed adjacent to it. Only the eastern wall of the room is in good condition, others were collapsed. The eastern wall is 6.45 m long and made of rubble stone with lime mortar. A line of rectangular stone blocks, 0.26 m high, can be seen at a height of 3.36 m from the ground at the central wall of the room. There is no sign of waterproof plaster. It can only be determined through excavations whether there are any remains in the northern part. At the northwest corner of the room, at a height of 1.36 m from the ground, a line of terra cotta pipes located across the central wall can be seen (Fig. 3-15).

Near the tower, there are 3 more broken stone pipes. 2 of them are interesting and they are with simple bell-and-spigot joint ends. On the first one was chiselled the letters ΓΛ (Fig. 3-16). On the second one was chiselled the letter H and there was a conical hole on it (Fig. 3-17). This hole looks like the elbow hole in the settling basin of Laodiceia (Jahrbuch 1898, p.8, Fig. 12).

On the west side of this hill, at the level of the alignment of the water conveyance, there are also 2 stone pipes with different diameters and without bell-and-spigot joint ends (Fig. 3-18).

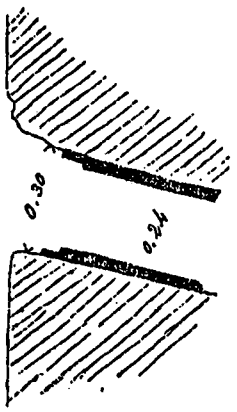


Figure 3.15:[Weber 1899/I; Fig.9]

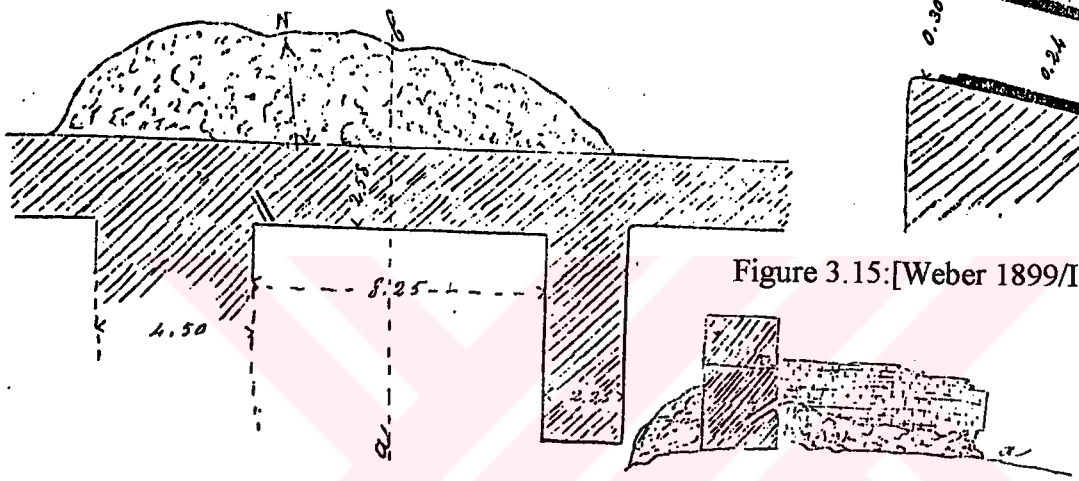


Figure 3.14:[Weber 1899/I; Fig.8]

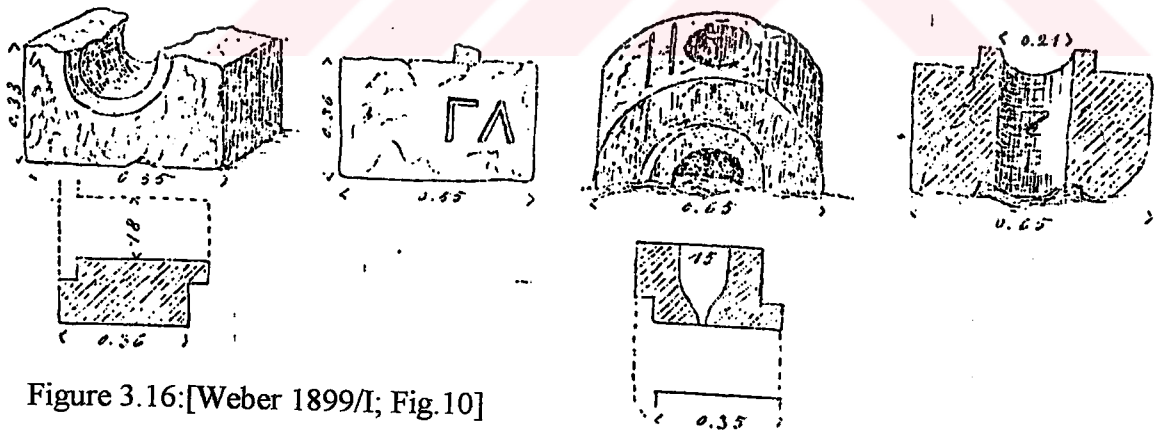


Figure 3.16:[Weber 1899/I; Fig.10]

Figure 3.17:[Weber 1899/I; Fig.11]

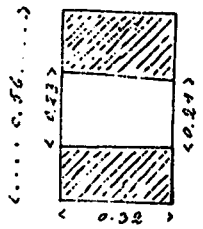


Figure 3.18:[Weber 1899/I; Fig.12]

3.2.3.2. Vicinity of " Karakapı " [Weber 1899; pp. 7,8,13,14,20,21,24,25]

The altitude of the last hill before the river Melez is 112 m and it is approximately on the same parallel with the west tower of the castle. In this region, the altitude of the river bed is 25.75 m. The water conveyance must have passed through the valley in this region. There is no more ruins of this water conveyance remaining today. In the beginning of 19th century, at the lower road to Buca, there was a high aqueduct called Karakapı (means: Black gate). The water conveyance goes towards the last hill in the west from here. These ruins seemed interesting to a lot of travellers in the history. Chandler put forward the idea that the ruins of the wall might have belonged to a " Pomoerium " (" Travels in Asia Minor ", p.79). Arundell had other comments: "On either lower road or upper road to Buca, it is passed through a hollow space in the wall. People who are still alive remember that once there was a gate on the lower road. The wall is being tracked towards a rocky place overlooking Melez. It might rather be a water conduit than a city wall." (" Discoveries in Asia Minor II ", p.404). Hamilton insisted in 1835 that this structure was absolutely not a water conduit ("Researches in Asia Minor I", p.5).

At the lower road, at a distance of 100 m, some ruins of the water conveyance, some broken parts of stone pipes and some parts of thick terra cotta pipes can be seen. In this region, the road is at an altitude of 88 m, and since this road was used more often than the other road at the top, there had to be a structure there (Fig. 3-19).

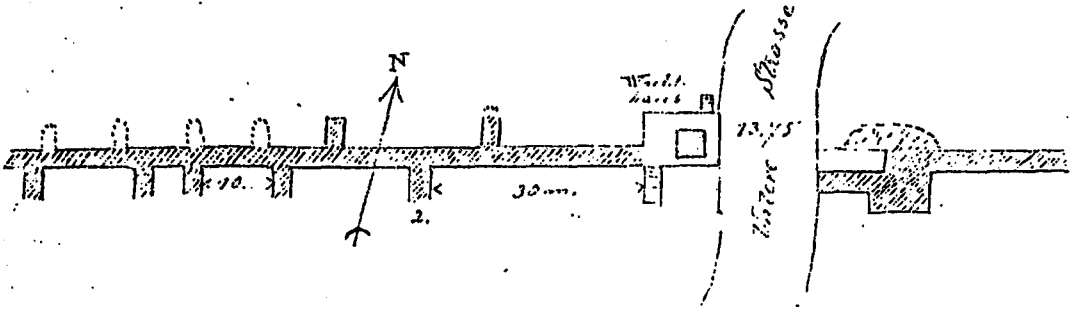


Figure 3.19:[Weber 1899/I; Fig.13]

The width of the gate can not be determined exactly today. At the east side, the wall was demolished, on the other side, it rises up to the height of 4.8 m. A modern wall which leans against this wall and the terrace at which the guard's room would be located were created. Pococke saw this gate. According to Arundell, the gate was at its place at the beginning of the century. The gate had to be too high. According to Pococke, it had one additional arch. As Pococke mentioned " There are also 4 arches nearby ", this interpretation is probably about the ruins belonging to the upper road.

There are supporting walls with thickness of 2 m along the 140 m long wall. In the south, there are 10 of them, the ones in the north were destroyed. As of the construction technique, the walls are absolutely different from the Byzantian walls of the castle.

Near the room of the guard, beside a lot of terra cotta pipes, there are also three stone pipes. One is in the south, on the west side of the street and it is cavity is full of sediments (Fig.3-20). The second is in the north, at the entrance of the guard's room and is in half buried position. It has 0.64 m side width with an inside diameter of 0.14 m and has bell-and-spigot joint ends. The third to the opposite side of the second one. It is in the low field wall. In the bell joint end of the first terra cotta pipe near the guard's room, there are broken spigot joint ends glued with lime. Lime mortar is too hard and was only produced with a special mixture. Dr. Forchheimer pointed out that the outer parts of the terra cotta pipes were also smeared with lime (Fig. 3-21).

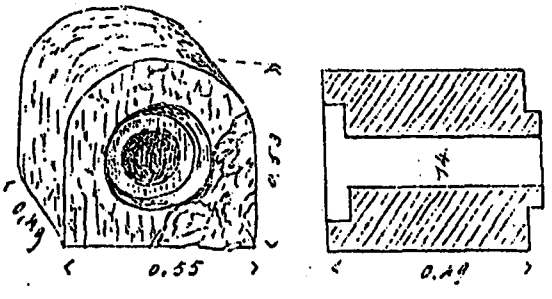


Figure 3.20:[Weber 1899/I; Fig.14]

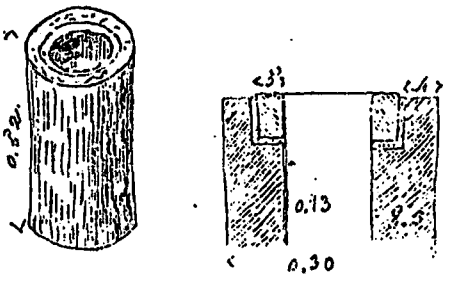


Figure 3.21:[Weber 1899/I; Fig.15]

In a tea shop on the road, there are also 2 terra cotta pipes with thinner walls and larger inner diameters. On the southern side, on the corner wall of a house is a stone pipe of which one side is with bell joint end and the other side is flat (Fig. 3-22).

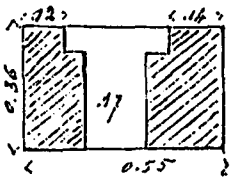


Figure 3.22:[Weber 1899/I; Fig.16]

The villagers of Buca say that they took a lot of stone pipes around Karakapı for their own use. In the village there are 11 pipes that most of them might have belonged to the water conveyance. The inner diameters are between 0.18 and 0.26 m. The bell joint ends are sometimes single and sometimes double. The spigot joint ends are broken. A pipe found near the Girl's school is cylindrical. The last 2 stone pipes were dragged near the Osmanağa aqueduct. One of them is in the big garden above the mills. The other is on the road reaching the hippodrome. It was located in the wall of Osmanağa water conveyance as it could be used as a fountain. The pipe is closed today.

There is a big stone pipe in one of the tea shops near Elias (İlyas) church. In the pipe, two lateral conduits join in the pipe with a vertical angle into one conduit (Fig. 3-23).

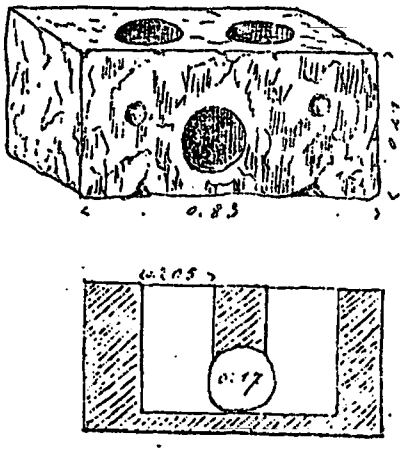


Figure 3.23:[Weber 1899/I; Fig.30]

The villagers living near the passage of the river Melez say that there are 2 water conveyances and there is a line of terra cotta pipes passing over the stone pipes.

When Pococke has seen the aqueduct at Karakapı ("Description of East II",1739, p.37), he reported that the water conveyance in the wall consisted of the stone blocks, the interior of which were carved out and were joined together; but they were located slightly higher than the ground. The wall is much higher and there is a terra cotta pipe 3 or 4 ft higher than the ground. There are a lot of broken terra cotta pipe parts around and the line of terra cotta pipes might have supplied the water from another spring.

Today, there is no sign of the stone pipe on the wall. Only there is a cavity in the wall which is on the cottage of the railway guard, through which the terra cotta pipes might have passed. Moreover, on the other side of the valley, before the houses were constructed, there was a terra cotta pipe in the wall which does not exist today.

3.2.4. The crossing of Melez valley

3.2.4.1. Downhill to Melez river from the rocky hill [Weber 1899; pp. 15-17]

Towards the west, at the gradually rising slope, the traces of the water conveyance wall disappears after 240 m from the road. The field border wall passes along the line. At the beginning parts, on the right, a green trachyte stone pipe is seen in the wall. The width is 0.58 m, the height is 0.52 m, the inner diameter is 0.165 m and it is with spigot joint end. Above, there is a terra cotta pipe in the first winter house (Fig. 3-24). A second pipe was used as a chimney on the roof. Close to the second house near the rocky hill, there is another stone pipe at an altitude of 106.10 m, with rectangular cross-section and a smaller bell-and-spigot joint end (Fig. 3-25).

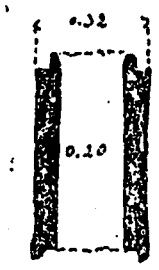


Figure 3.24:[Weber 1899/I; Fig.17]

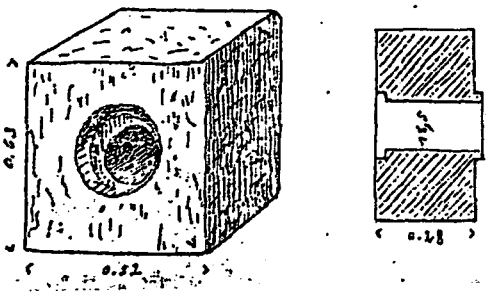


Figure 3.25:[Weber 1899/I; Fig.18]

At the descending slope, south of the garden walls, there are stone pipe parts but there is no sign of the alignment. The peak of the hill with the altitude of 112 m consists of cracked rocks; so that the alignment must have probably passed south of the hill. At point D, there is a cut with a length of 9.30 m, width of 1.45 m; the right slope depth is 4 m and it might have served to lay pipes (Fig. 3-26).

Figure 3.26:[Weber 1899/I; Fig.19]

Downhill, above the railway cut, near its side, the wall appears again; below it, the ruins of the wall extend towards the valley. The cottage of the railway guard was constructed on the

ruins of the wall. According to Ed. Purser, at this intersecting location, 7 stone pipes were found; they were then displayed along the railway before the Paradise (Şirinyer) station. These pipes are quite similar to the others. Their width is 0.52 m, length is 0.48-0.56 m, height is 0.51-0.53 m, inner diameter is 0.22 m and they have bell-and-spigot joint ends (Fig. 3-27).

The mixtures were made with white lime without sand. According to Dr. Forchheimer, this lime is very similar to the material used in Ephesus. The chemical composition of the lime is :

Calciumoxyde.....52.65 %	Siliciumhydroxyde.....0.66 %
Iron-and Aluminiumoxyde.....0.25 %	Carbondioxyde.....40.45 %
Magnesiumoxyde.....0.71 %	Water.....0.94 %
Natriumoxyde.....0.94 %	Organic matters.....3.40 %

There are the ruins of the spigot end of the terra cotta pipe on the bell end of the other one (Fig. 3-28).

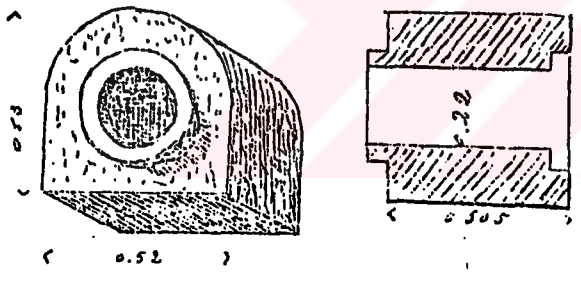


Figure 3.27:[Weber 1899/I; Fig.20]

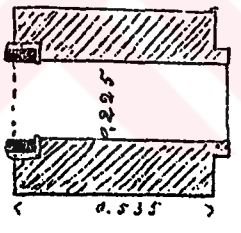


Figure 3.28:[Weber 1899/I; Fig.21]

Modern water mills and a Byzantine water conveyance have destroyed the wall between the railway and Melez. The first mill is near the pipe line, and the second one is farther downstream.

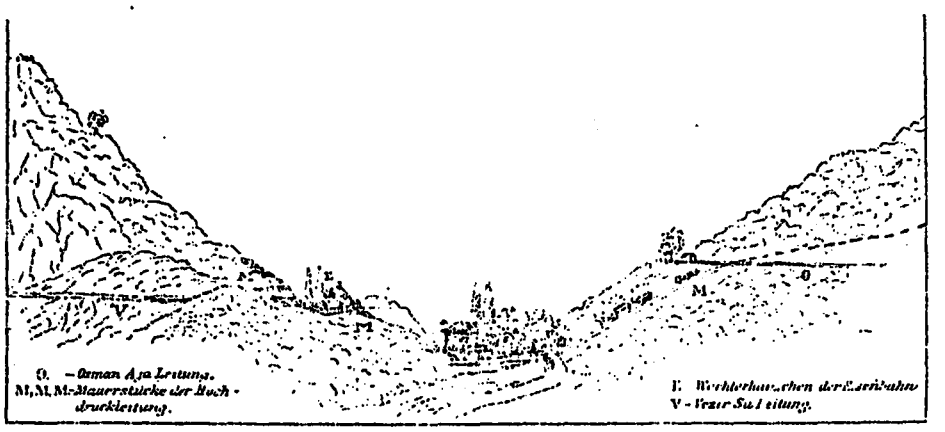


Figure 3.29:[Weber 1899/I; p.16] Northern view of the Melez valley, and the stone-pipe inverted siphon of the Karapınar system

3.2.4.2. The crossing of Melez river [Weber 1899; pp. 7,17,25]

At the crossing of Melez river, the river bed has an altitude of 25.75 m. Pococke ("Description of the East II",1739,p.36) mentioned : "The water conveyance crosses the river over high arches, actually destroyed; only some walls at the abutment and some parts of the arch over the river are existing. In addition, some stone pipes and terra cotta pipes were seen as well. The water was conveyed from a distance of an hour."

In Melez valley, the traces of an aqueduct can be seen, regularly cut stone blocks exist on the right bank (Fig. 3-30). The side supports of the modern wooden bridge are formed with the same stone blocks. There were probably 2 arches, one passing over the river and one passing over the road.

Although the pressure pipe line goes until the saddle of the castle, it is at least 130 m under water load. In a letter to Weber, Forchheimer wrote that when they investigated together the İzmir water conveyance system, he was worried about that these stone pipes could resist against 200 m water load, but after he had carried out several tests, he determined that they could resist it ("Anzeiger der Wiener Akademie der Wissenschaften", 1898, p. 38).

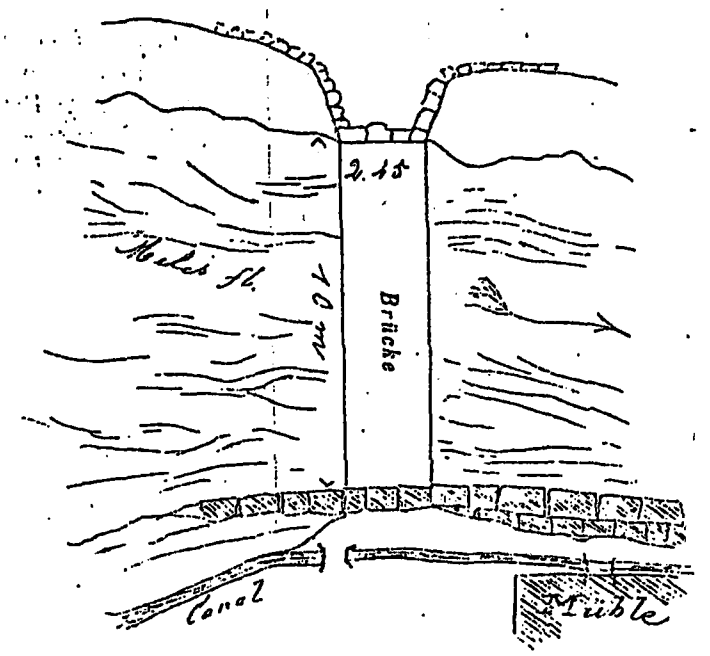


Figure 3.30:[Weber 1899/I; Fig.22]

If the trachyte blocks could resist against 200 m pressure, they will safely resist the maximal 154 m pressure of the inverted siphon, since the highest point of Kadifekale in İzmir is at elevation 183.90 m, the lowest point in Melez valley is 30m (the river bed 25 m + 5 m arch).

3.2.5. The region between Melez & Kadifekale

3.2.5.1. The southwestern slopes of the castle [Weber 1899; pp. 17,18]

After crossing Melez river, the ruins of 2 m thick walls can be seen until Osmanağa water conveyance. A farmer has built a house with a stable on the remains. At the lower road, regularly cut stone blocks can be seen on the outer parts of the wall. Inside is filled by rubble stone, in this part without lime, at higher parts with mortar.

In this region, 12 entire stone pipes can be seen. There are 3 of them in the mill's courtyard (Fig. 3-31). There are also 2 terra cotta pipes with 0.50 m length, 0.21 m inner diameter. On the wall of the tea shop's courtyard, near the road, is a fourth stone pipe. One end of the pipe is flat and the other is with bell joint end. The stone pipe is like the one in Fig. 3-22.

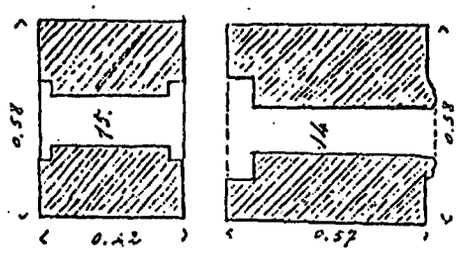


Figure 3.31:[Weber 1899/I; Fig.23]

At the slope, there are 2 stone pipes in the wall of the first house on the left. One in the door, closed with a wall today, is similar to the preceding pipe. The second one was used as a corner stone and it is more complicated (Fig. 3-32); there is a terra cotta pipe in the small side hole.

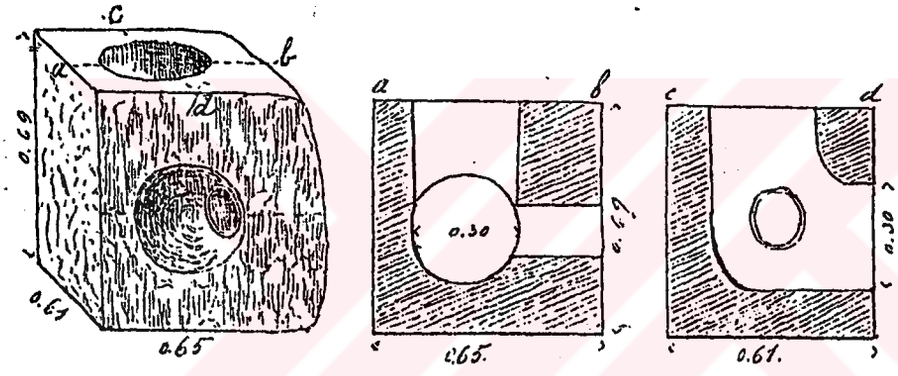


Figure 3.32:[Weber 1899/I; Fig.24]

There is a seventh stone pipe in the field wall at the upper part of the stable. The pipe has an inside diameter of 0.135 m, with wide and improper bell joint end. At a higher elevation, in the middle of the path, there is a wider, roughly cut stone pipe (Fig. 3-33).

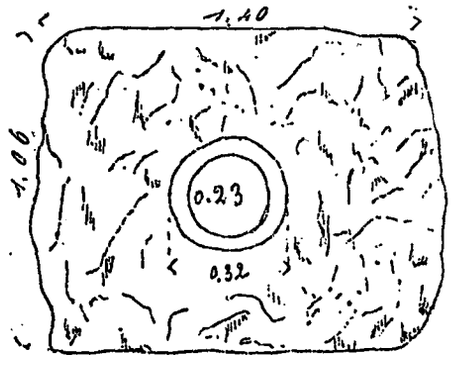


Figure 3.33:[Weber 1899/I; Fig.25]

Moreover, in the first aqueduct of the Vezir water conveyance, 4 stone pipes were also used; 3 of them were used in the opening and one was used above on the west side. There is no trace of the alignment above the Osmanağa water conveyance system, up to the saddle; in that region, the area is rocky and rugged.

3.2.5.2. Kadifekale [Weber 1899; pp. 19-21,25] [Weber 1904; pp. 95,96]

At the higher elevations, there are several stone pipes, some staying vertically in the garden of a country house, others down the immigrants district. The pipes have inside diameter of 18 cm and simple bell-and-spigot joint ends. There is another pipe half buried at the saddle (Fig. 3-34).

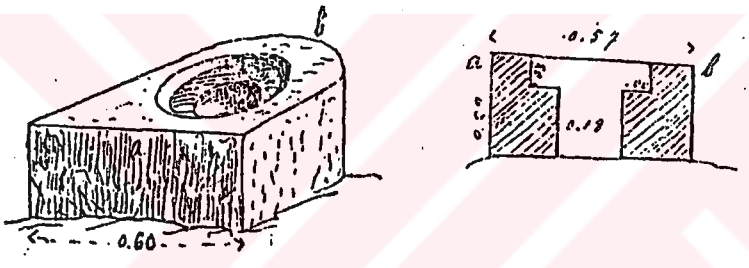


Figure 3.34:[Weber 1899/I; Fig.26]

We do not have all the information about the water conveyance system to İzmir; whether and how water was brought to the castle. According to Storari ("Guida di Smirne", p. 27), 20 years ago, there was a high wall at the saddle, on which the water conveyance was passing. There is no sign today. All the water works in the castle date from the modifications in the 13th century Byzantine time (C.I.G. IV, 8749).

There is a stone pipe inside the southeast corner of the Byzantine border wall (Fig. 3-35). The water conveyance was probably destroyed, when the wall was constructed. Some other pipe remains might have been also used in the wall.

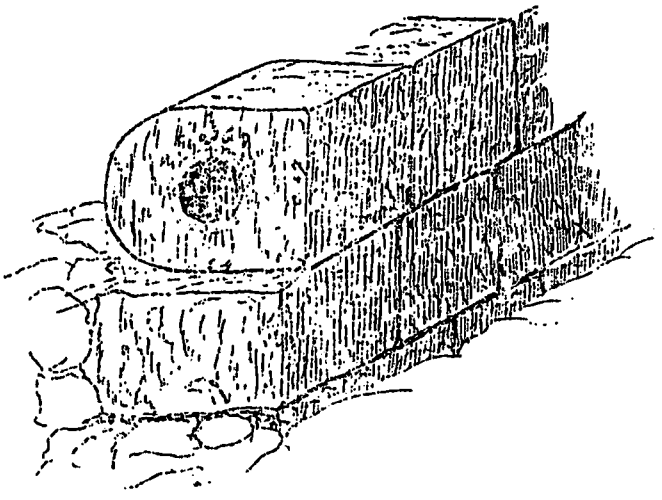


Figure 3.35:[Weber 1899/I; Fig.27]

4 stone pipes exist on the northern slope of Pagus. The first one was on the road, west of the stadium, the second one was used in the wall of a house in Apano district above the St. John church. The third one was used in a wall of Hacıbey mosque (as it is seen in Fig. 3-36, similar to that in Fig. 3-32). The fourth one was used as the top stone of a well near the theatre (Fig. 3-37). The principal inner diameter of the fourth one is 0.35 m, the lateral diameters are 0.20 and 0.15 m; it does not have bell-and-spigot joint ends; it is doubtful whether this pipe belonged to the water conveyance.

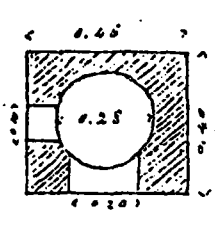


Figure 3.36:[Weber 1899/I; Fig.28]

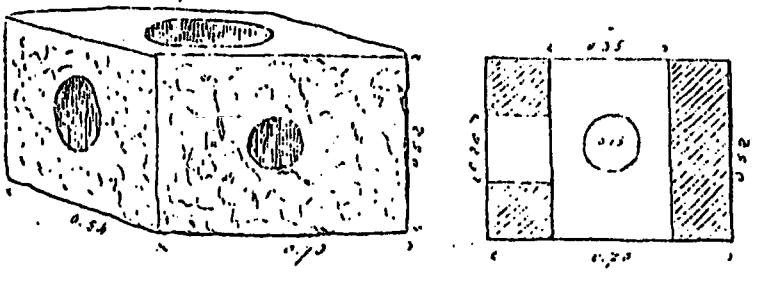


Figure 3.37:[Weber 1899/I; Fig.29]

Except for the small broken parts, as seen in Table 3-1, a total amount of 60 pipes were found. The altitudes on the special map were determined directly with level measurement instead of approximate values of aneroide. According to the instructions of Mr. Purser, an engineer working at the Aydın railway, the elevations were measured at 12 points, from the starting point A of the pressure line in the east to the end at Kadifekale.

While Weber was mentioning about the stone pipe siphon in Laodiceia in his other study about the water conveyance system of the ancient cities in Anatolia [Weber1904], he wrote about the conveyance system in İzmir too. At the saddle above the stadium, a Turk constructed a building leaning on the city wall. 5 stone pipes and 2 stone columns were found. On the round parts of a column and one pipe was seen the letters Γ Λ. He determined also that the trachyte pipes were in accordance with the pipes found and they had to belong to the same system, the stone columns were made of the same trachyte and were cut properly. They were 2.50 m high, 0.50 m wide and 0.30 m thick.

Table 3.1: The stone-pipes found by Weber [1899] [Çördük 1998] (The regions: I-Between the beginning of the stone-pipes and the hill at an altitude of 161m.; II- Between the hill and Karakapı; III- Between Karakapı and the rocky area; IV- Between the rocky area and Melez creek; V- Between Melez creek and Kadifekale; VI- Kadifekale region

Region number	Number of stone-pipes	Figure number		Stone-pipe type	Stone-pipe dimension D/L/W/H (cm)	Total numbers of stone-pipes
		Kosova 1999	Weber 1899			
I	4	3.9	3	▭	16/50/-/62	15
					13/54/-/56	
	2	3.10	4	□	18/47/50/58	
	1	3.11	5	□	16/38/52/62	
	1	3.12	6	▭	15/41.5/52/50	
	1	3.13	7	▭	16/53/56/-	
	1	-	-		-	
	1	3.16	10		18/36/55/50.6	
	1	3.17	11	▭	21/35/65/-	
	1	-	-		-	
	2	3.18	12		21.33/32/56/-	
II	1	3.20	14	▭	14/49/55/53	6
	1	-	-	▭	14/-/64/-	
	1	-	-		-	
	1	3.22	16	▭	17/36/55/-	
	1	-	-		16.5/-/58/52	
	1	3.25	18	□	18.5/52/53/106.1	
III	11	-	-		18.26/-/-/-	12
	1	3.37	29	□	35.15-20/52/70/54	
IV	7	3.27	20	▭	22/48-56/52/51-53	7
V	3	3.31	23		15/42.57/58/-	12
	2	3.22	16	▭	17/36/55/-	
	1	3.32	24	□	30/65/69/61	
	1	-	-		13.5/-/-/-	
	1	3.33	25	□	23/-/140/106	
	4	-	-		-	
VI	-	3.34	26	▭	18/29/57/60	6
	1	3.35	27	▭	16/-/47/54	
	3	3.36	28	□	28.15-20/46/40/-	
	1	3.37	29	□	35.15-20/52/70/54	
	1	3.23	30	□	17.20-50/-/85/47	
TOTAL						58

3.3. Akpınar water conveyance system

3.3.1. Spring [Weber 1899; pp. 167,168]

The Akpınar (Weber : "Ak-Bunar") spring is issuing at elevation 130 m. The water of this spring has been conveyed for 17 km with a small slope to the hill of the mills of Smyrna at 75 m elevation, where probably the temple of Zeus stood in the past. The spring is at the foot of the hill series which separate Tahtalıçayı valley and Buca plain, east of Kısık (Weber: "Kissik"). The spring was collected by a domed collection chamber with walls made of rubble stones bedded in hard cement mortar. The diameter of the dome is 1.80 m. The front part is demolished. The water was first collected in a small pond. A long wall protects from the probable flow of the water towards the valley. This pond is still being used, the water is conveyed through a 2 km long canal along the western slopes of the hills to a mill, called Kemer.

3.3.2. Değirmen (mill) aqueduct [Weber 1899; p.168]

There can be seen an aqueduct 300 m over the source of the mill. So it can be said that the canal conveying water to the mill follows the old water conveyance system. This aqueduct is 160 m long, in the middle 3 m high and 1.80 m wide, and it is only a simple wall. It is in the direction southeast to northwest, and has some openings. A 25 m part, including the main arch under which the river was flowing, does not exist today. The abutments of a 2 m wide arch still exist at the opening "a". In a structural way the aqueduct looks like the Karakapı aqueduct of the Karapınar water system. Lime mortared rubble stones between roughly cut rectangular stone blocks were used in the construction. Most of the stones were taken by the villagers. At one place inside, 3 lines of bricks can be seen. There are sediments on the north parts of the aqueduct. But there is no sign of the canal over the wall (Fig. 3-38).

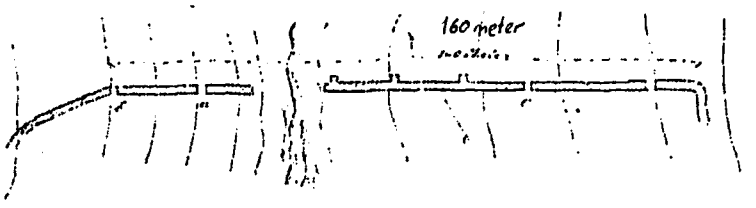


Figure 3.38:[Weber 1899/II; Fig.1]

3.3.3. Cistern (Sarnıç) aqueduct [Weber 1899; pp. 168,169]

With regard to the terra cotta pipes of 13 cm inner diameter, found on the slopes of the hill after the mill, it is possible to say that the alignment continues along the hill and passes near the Gaziemir station (Weber: "Kasamir station at Sediköi"). Remains from the system could be found near the railway at an altitude of 120 m, half an hour south from Gaziemir station. A canal crosses a tributary of Tahtalı river in south-north direction (Fig. 3-39).

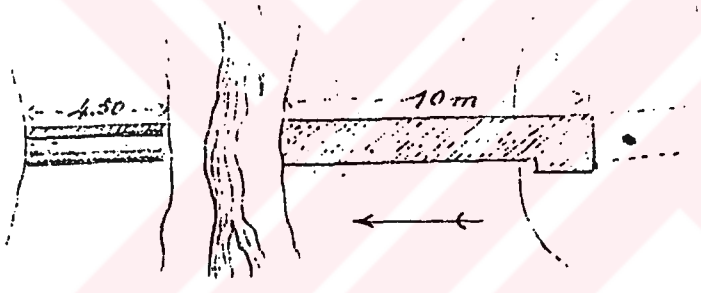


Figure 3.39:[Weber 1899/II; Fig.2]

At the south blank the wall is 10 m long; at the north blank it is 5 m long; but especially on the northern part, the dimensions of the canal can be estimated. The walls were formed with rubble stones joined by cement, and the thickness is 0.52 m. The canal bed is 0.40 m wide, it is plastered and appears to have been covered with rubble stone vault.

3.3.4. Gaziemir passage [Weber 1899; p.169]

The land on the north of the canal is 1 m higher. At this depth, the conveyance system goes underground makes a large bend around the station. The villagers of Seydiköy encountered it partly on their fields. There is no sign of any canal in the railway cut at an altitude of 110-115 m. The remains of the alignment could be lost during the leveling works.

3.3.5. Devekaşantısı aqueduct [Weber 1899; p.170]

If one turns left from the railway cut, at an altitude of 115 m, and pass the mountains full of vineyards and the Seydiköy street, there is a little valley and an aqueduct in a small valley intersecting the mountains in the southwest-northeast direction. This aqueduct is at an altitude of 110 m and is 135 m long. The thickness is 2m and it is 12 m high over the river (Fig. 3-40).

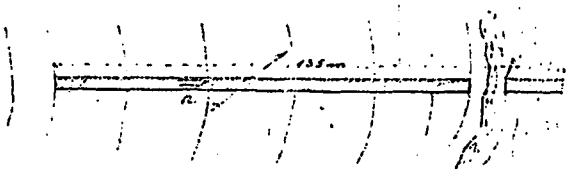


Figure 3.40:[Weber 1899/II; Fig.3]

At the site "a" a cement plastered canal of 0.80 m width can be seen. This aqueduct is very similar to the Değirmen (means: mill) aqueduct in a structural way. Where the aqueduct passes over the river, a careful and elaborate work can be observed. On the left shore with vertical slope, the signs of the wall made of large cut-stones can be seen. 4 rows of walls with heights of 0.50-0.70 m are still in their orginal location. The wall which intersects the aqueduct vertically was probably a support wall or a shore protection wall. 5 rows of walls made of properly cut-stone are still in good condition. The heights of the rows are as follows: 0.60; 0.30; 0.60; 0.39 and 0.60 m. The aqueduct over the river was ruined.

3.3.6. Uzundere aqueduct [Weber 1899; pp.170,171]

In the north direction, the mountain series intersected with a deeper second valley. At the two sides, where the peaks are very close to each other, the remains of a multi-storey aqueduct at an altitude of about 125 m can be seen (Fig. 3-41).

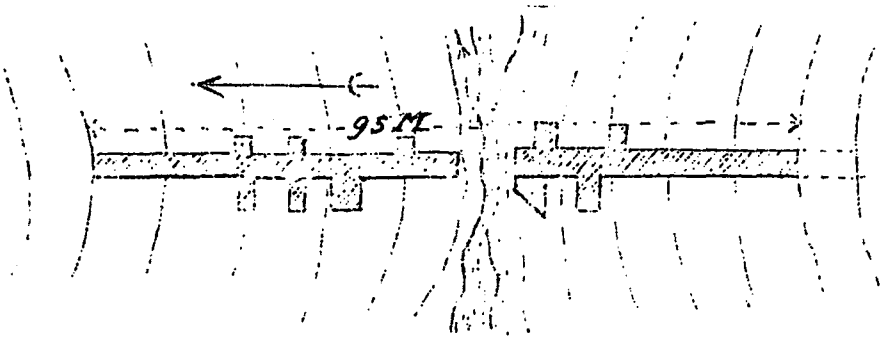


Figure 3.41:[Weber 1899/II; Fig.4]

At the right bank, 4-5 m higher as the aqueduct, there are 3 cut stones. At the west side is a support wall, made of stones without mortar, with dimensions 0.94 * 0.72 m. All the aqueducts were demolished. At both sides are support walls. From the remains of the walls at both banks, a construction made of stones and bricks can be observed. Inside the wall, there is a wall made of cement mortared rubble stone. At the south wall, there is a space for the lower aqueduct. Both sides of the aqueduct were supported with support walls. The aqueduct is in the direction of south-north and is damaged. There is no sign of the probable water canal at an altitude of about 100 m.

3.3.7. Karabağlar aqueduct [Weber 1899; p.171]

At Bozyaka (Weber :"Bos-Kaya"), at an altitude of 90 m, there are remains of an aqueduct still located over the river which is 5 m high, 70 m long and the thickness is 2.40 m. The river bed is in southwest-northeast direction. In structural way is it similar to the aqueduct seen in Fig. 3-38. Most of the rubble dressed stone were taken from the sides, only a few can be seen. The walls of the aqueduct crossing the river were damaged. Only the keystone is there. There is a second opening for the passage 20 m west of the river (Fig. 3-42).

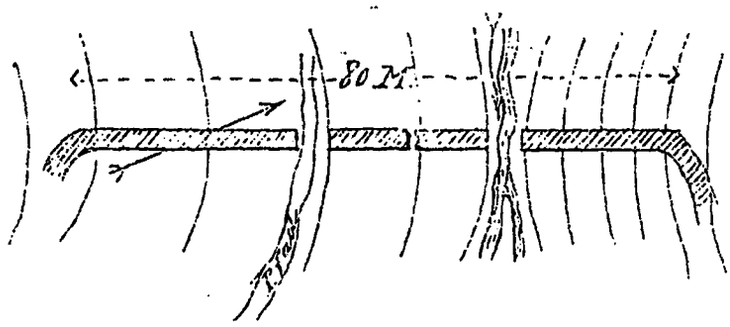


Figure 3.42:[Weber 1899/II; Fig.5]

3.3.8. Bozyaka aqueduct [Weber 1899; pp. 167,171,172]

This aqueduct is the last one on the water conveyance system. It is at an altitude of 80 m and on the 160 m wide mountain ridge, on which the way from the river Melez crosses

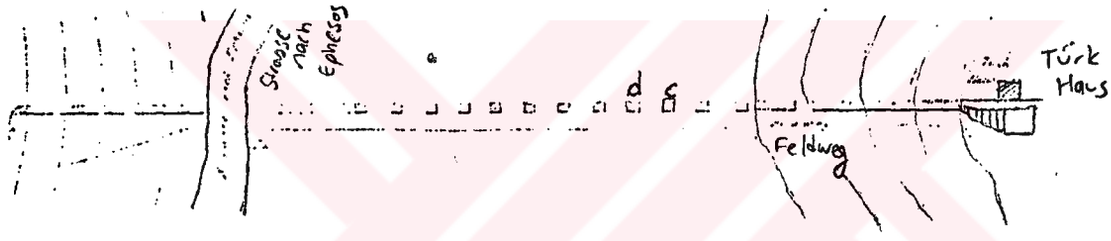


Figure 3.43:[Weber 1899/II; Fig.6]

Pococke also mentions about the aqueduct in the area called Tire kapısı (Weber : "Tireh-Kapussi"), but he mentions about the wall located on the mountain ridge as city wall ("Travels in Asia Minor", p.79). Since the walls on 2 slopes are 5-6 m high, the canal had to be at least at an altitude of 85 m. Although there is a very big damage on the aqueduct, it is still possible to see some remains to understand how it was constructed. At both ends, there are walls with 2 m thickness. At the north end, lime sediments can be observed. The aqueduct might have passed the way which is 11 m wide with a big opening. Maybe that is why this area was called Tire kapısı (means: The door of Tire). At the north end, at the bottom beside the way, there are the remains of the walls formed in 3 rows, made of big cut rectangular blocks. The thickness is 3.24 m. These can be the remains of Tire kapısı. The new road to Ephesus and the ancient road are here in the same passage. The direction of the aqueduct is south-southwest to north-northeast. The middle part of the aqueduct is in the shape of series openings. The middle tributary spaces can be seen. At two places there are one row of trachyte rubble stones

without mortar which are 0.68 m high. The middle tributary surfaces are over 2 m long and the distance between them is minimum 5 m. The width of them is probably about 2 m like the walls. According to the walls on both sides of the columns, it can be said that the columns were bounded with a low wall. It can be seen from the marble plate whose narrow side is with profiles and with dimensions of 2.22*0.65*0.30 m which were got from the excavations that during the construction, the workmanship was very careful. This marble plate might have been a roof side member. In one of the holes is a stone member with a special section which looks like a sitting place. The stone is at the middle 0.40 m wide. This stone which is 2 m near the city and which is on the street might have been used as a resting place for the pedestrians (In Alaşehir (Philadelphia), some seats with similar sections and inscriptions found along the city walls of acropolis) (Fig. 3-44).

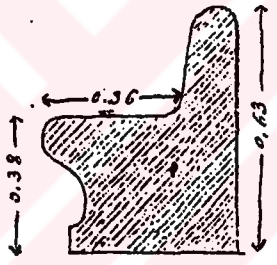


Figure 3.44:[Weber 1899/II; Fig.7]

3.3.9. The passage in the city [Weber 1899; pp.172,173]

There were found some other remains on the plateau between Değirmentepesi and the city. There is a stone wall whose only two rows exist, which is 4 m long and which was located 200 m northwest of Tire kapısı. East of the passage, at the slope after half and an hour km, further in north direction, during a new excavation, the first line of the big blocks of the support wall which leans against the slope, were found. The front side probably collapsed before. In a structural technique it is similar to the construction south of Gaziemir station. Some sediments were found here too. After that, because of the high area, the alignment has to follow along the west direction.

3.3.10. The temple of Zeus Akraios [Weber 1899; pp.167,168,173,174]

The temple of Zeus Akraios was located at Değirmentepe at an altitude of 75 m, not at the acropolis as mostly thought. The temple area is at the upper part of the old Jewish cemetery. But in this region which was left once, are not the remains of the conveyance system because the immigrants from Teselya and Turkish immigrants settle there in.

Two inscriptions belonging to the Roman time mentions about the transmission of water to the temple of Zeus Akraios (C.I. Gr. 3146, 3147). From the first inscription it is understood that the water conveyance system was constructed during Vespasian time by the Asian procouncil Traianus. (According to Waddington ("Fastres asiatiques"), M. Ulpius Traianus worked as procouncil between 78-80 AC) In the second inscription, it is mentioned that the water conveyance system was restored by Baebius Tullu. According to Prof. Dr. Otto Hirschfeld, Baebius Tullu was the council Tullu in 109 AC, as Borghesi guessed. If these two people are the same, then the Asian management status belonged to the first period of emperor Hadrian (131 AC). That means that after about 40 years, when the water conveyance system was constructed, it had to be repaired. These inscriptions probably mentions about Akpınar water conveyance system. It is reasonable that this water conveyance system was constructed in the 1. or 2. century AC, when the cities in Anatolia were very rich. So, the Akpınar water conveyance system is younger than the Karapınar water conveyance system.

3.3.11. The constructions out of the alignment [Weber 1899; pp.173,174]

There is an aqueduct belonging to the Byzantine time at a small valley which is at a few hundred feet southern than the temple of Zeus Akraios, on the left on the way climbing to Göztepe (Fig. 3-45).

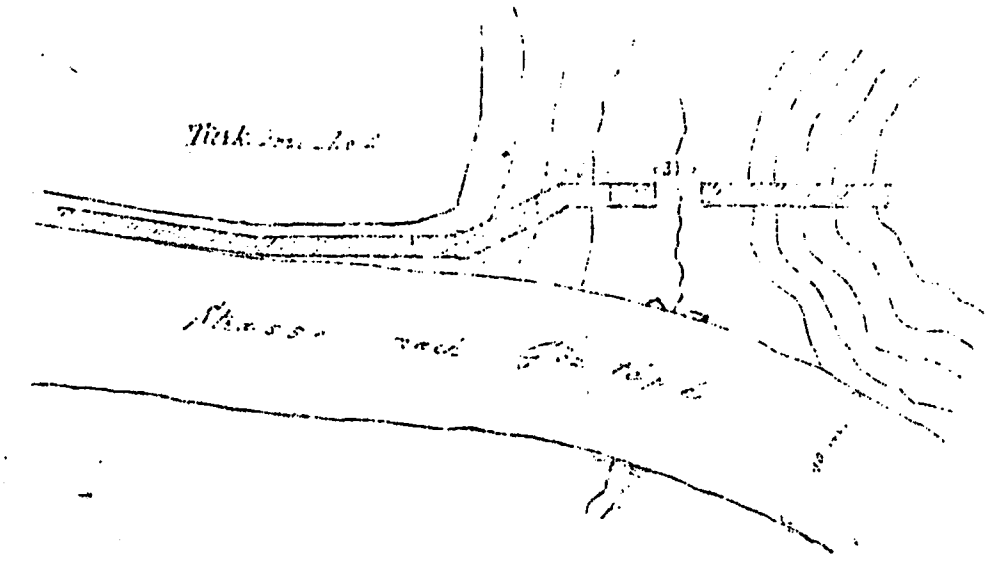


Figure 3.45:[Weber 1899/II; Fig.8]

This aqueduct is 13 m long, 1.06 m thick and 4-5 m high. It has 2 openings. One for the creek and one for the way. In the construction, not only the stone blocks, bounded with the bricks at 4 sides, but also the rubble stones brought from somewhere else were used. The archs were made of porous, yellow lime stone (Malta stone). Rows of bricks were used as well. Terra cotta pipes were at the top. There is a tower on the left, at the end of the curved passed wall with a rectangular nest on the north wall. Water probably was conveyed into a pool with a depth of 2 m and a diameter of 1 m. From there it was conveyed to the temple. The wall probably belongs to the old water system. Although the aqueduct has not been used for a long time, it is in its orginal location. Only the wall on the left of the way, was damaged.

3.4. Kapancıoğlu water conveyance system

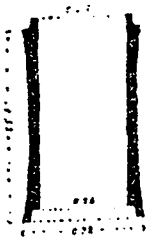
3.4.1. The spring [Weber 1899; pp.174,175]

At the south of the big street reaching Nimfio, and at the place where it turns off into the new road to Kokluca (Weber: "Kukludscha"), is a big Turkish fountain near Halkapınar (Weber: "Kalka-Bunar"). This fountain has a lot of water. The water comes from the foot of the hills above it, not from the Diana bath below it. There exists İzmir's water conveyance system today. The fountain was constructed by a rich Turk called Kapancıoğlu. From the remains it is understood that the fountain before was at a few hundred feet west and on the north of the street.

3.4.2. Alignment [Weber 1899; p.175]

The street, east of Tependschik, which is used today, goes away to the south. During the application of the new water conveyance system, it was observed that the old street was reaching Diana baths from the railway cross in a straight way. From the Caravan bridge to the garden on east of Tependschik, at the depth of 1-1.50 m, sometimes street stones made of cut rectangular blocks can be seen. They disappear where the road turns. But by coming into the same direction, these stones again arise. When the farmer whose land is on the turning point of the street, excavates the stones in his land, he found a row of beautiful terra cotta pipes (Fig.3-46). The pipes were on the north of the street stones.

Figure 3.46:[Weber 1899/II; Fig.9]



From the bell-and-spigot joint ends, it is seen that they are antique. These pipes are probably from Roman time and the part of the system supplying water from Kapancıoğlu down to the city. According to Dr. Forchheimer, Byzantinians made the pipe types simplified.

That is why these pipes only could be from Roman time (Forchheimer "Byzantinische Wasserbehälter in Constantinopel" p. 22).

Although there is no sign showing how the water passed from Caravan bridge, the old and dense sediments with which the east part bridge arch is covered, tell us something about the alignment of the system. The above parts of the bridge had changes in different times.

3.5. Byzantine water conveyance system in Melez

One of the water conveyance systems to İzmir is the Byzantine water conveyance system [Weber 1899; pp.175-177]. During the investigations of the pressure water systems at the Koravili mill, 2 terra cotta pipe rows, dated late times, were found. The two systems are at about a same elevation, they were following the river but spread to both sides of it. The one on the left bank was 4 m above the river bed and the one on the right bank was 7 m above it. Both has the same spring. It is on the right shore, on the upper part of the Osmanağa aqueduct.

Both systems crossed the river in different ways to reach the city. One of the systems crosses the river with a low bridge under the Osmanağa aqueduct. On the right bank, terra cotta pipes were seen. This bridge was demolished 4 years ago, during the construction of the new street and then a higher new bridge was constructed instead of it. The other system crosses the river at an upper part, near the Vezir aqueduct. Later, probably they were joining together and being transmitted along today's street and reaching the city at 25 m elevation.

Still the remains of the support wall with terra cotta pipes can be seen on a rock, south of the tea shop near the pressure conveyance system. In addition, in the tea shop terra cotta pipes were found too (Fig. 3-47). The remains of the other system on the right shore are around the tea shop near the church of prophet St. Elias. Many terra cotta pipes with similar sections were found in that area (Fig. 3-48).

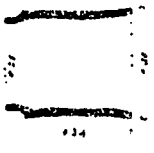


Figure 3.47:[Weber 1899/II; Fig.10]

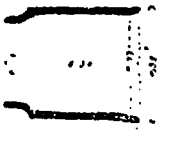


Figure 3.48:[Weber 1899/II; Fig.11]

Here the simplifications of the terra cotta pipes by the Byzantinians is obvious. Bell-and-spigot joint ends were cancelled, the diameter was increased and the back part was slightly curved. This system is still being used by the Turks. Between the pressure conveyance system and the Vezir aqueduct, a long part of the support wall of the water conveyance can be seen.

The place where the water conveyance crosses the river bed is very interesting because there is a terra cotta pipe inverted siphon. There is a circular water reservoir with a diameter of 0.75 m at the end of the horizontal support wall which is 1.66 m wide. The terra cotta pipe with 0.04 m thickness and 0.21m inside diameter is transmitted there. At the exit place, 2 terra cotta pipes with 0.16 m diameter and 0.015 m thickness transmits water down to a support wall. At the top of the wall more pipes fixed tight can be seen. The wall turns roughly at the place, where the modern irrigation canal which intersects the support wall, was located. On the left shore, there is a wide piece of wall which contains the same fixed terra cotta pipes on it is surface.

At the same place, the construction of the Vezirsu aqueduct in 1674 of course damaged the old water conveyance system. Many pipes belonging to the water conveyance system were found during the amelioration of the new street in 1898 spring and also during the construction of the small bridge 3-4 m above the river bed and 100 m east from the aqueduct. Likely, near the city, a lot of pipes were found. All found pipes were similar with the ones on Fig. 3-47 with their tips and dimensions. After the Vezirsuyu aqueduct, the conveyance systems are at the same elevation. So, probably they were conveyed water together. But the second system might have been built instead of the first system, which was out of order at this time. If so, the system on the right shore is older. After the terra cotta pipe inverted siphon had been out of order, water was conveyed from the left shore, at a higher place, passed the valley through the demolished bridge.

3.6. Osmanağa water conveyance system

Osmanağa water conveyance system [Weber 1899; pp.177-181], which conveys water to 3 aqueducts in the Melez plain is alimented from the big and the small Paradise in the Buca plain, south of the railway station. The spring at an altitude of 62 m was collected with an open, polygon shaped reservoir made by Turks. A canal whose top was covered with stone plates, conveys water to the big aqueduct through the fields and under the railway passage at a depth of 1.50 m. In the 1899 summer, the part of the system from the spring to the aqueduct was improved. The canal covered by stone plates was made bigger and located at a deeper place. During these work, an antique terra cotta pipe system was found. So, it can be said that all the system belongs to the period before Byzantine period. The pipes are 0.55 m long, the inner diameter is 0.245 m and the thickness is 0.03-0.04 m. They have bell-and-spigot joint ends as seen in Fig.3-46.

Very near to the reservoir there is a second spring. The water follows the conveyance system as an creek and was conveying to the two water mills near the aqueduct.

The conveyance system crosses the river Melez with a canal from the sides of the hills on the left shore (Fig. 3-49). The system goes around Pagos with a wide curve and reaches the city at an altitude of 55 m. There were no remains of an older construction found.

The most fascinating part of the system is the aqueduct whose plan is shown on Fig. 3-50. It is 21 m high and passes through the valley with a twice broken line. The length is 120 m and it has 2 storeys. At the top there are 14 arches.

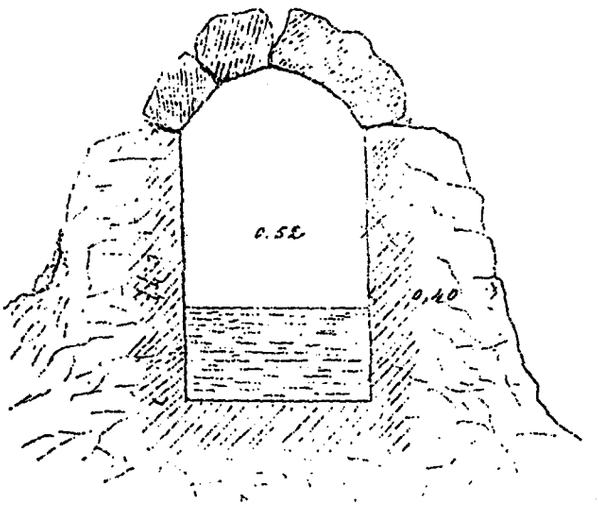


Figure 3.49:[Weber 1899/II; Fig.12]

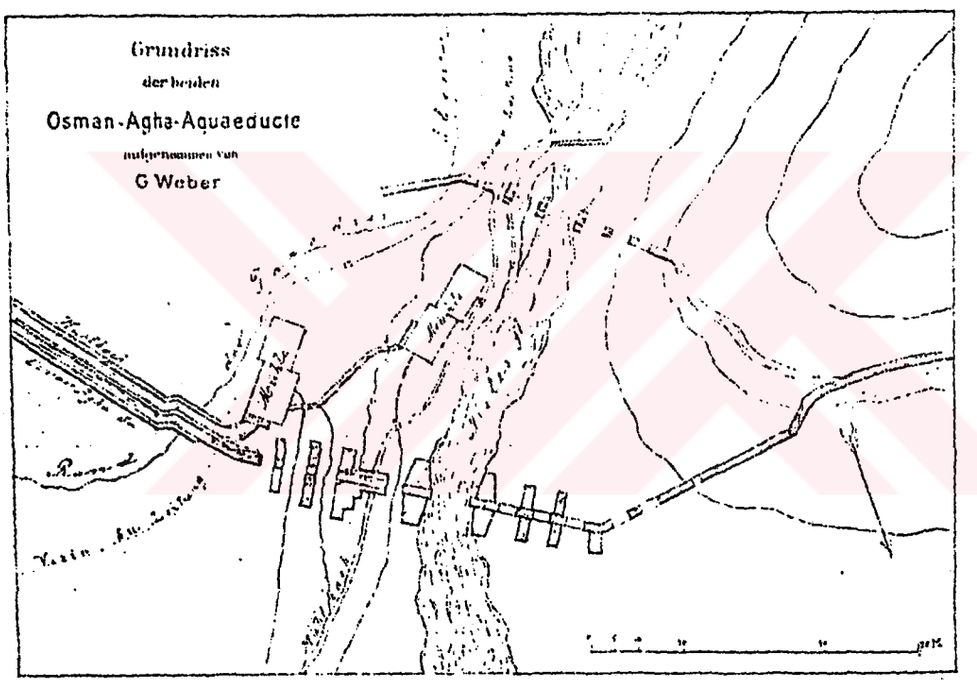


Figure 3.50:[Weber 1899/II; Fig.13]

At first the disorder of the arches are paid attention. On the right shore where the passage to the valley is free, the openings are wide. On the left side, they were located like windows. The eastern part follows as arch. The western part was constructed as a full wall with open windows. In this part the arches are pointed. Only the last 2 are not pointed. At the opposite side the arches are round. Except the last 2 arches, all arches at the top floor made of big bricks. At the first floor, the arches were made of cut rectangular blocks. The big arch which

crosses over the river, made by big rectangular stones. The other parts made by agregates bound with lime. Although there is no certain data about the date of the aqueduct, it can be said the 5th - 6th century (Fig. 3-51).

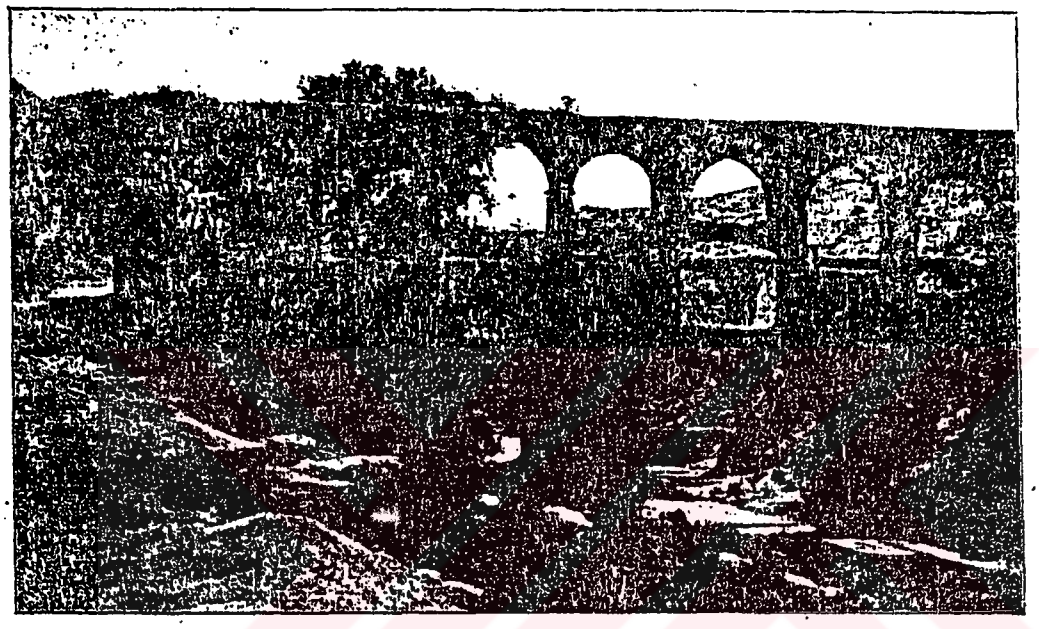


Figure 3.51:[Weber 1899/II; Fig.14]

There is an other aqueduct 50 m higher from the upstream aqueduct, at a narrower part of the valley (Fig. 3-52). It does not work today. It is about 50 m long and has 2 storeys. At the bottom it has 3, at the top it has 7 archs. Except for the one at the middle on the top floor, all arches are pointed and made of big bricks. According to the construction technique, it can be said that it was constructed during the Turks time. Although it was 2 m lower than the former aqueduct, it was conveying water to the same heights with pressure. At the top of the aqueduct were 2 tight walled terra cotta pipes with a diameter of 0.33 m. At the west end, the pipes conveyed to a canal at a height of 2.10 m. After 50 m, the canal joins with the old system.

The existence of the two aqueducts can be explained as follows: In the Middle ages, the big aqueduct was out of order because of being neglected. Since the sediments gathered, the

water could not pass through. The sediments which Chandler ("Travels in Asia Minor", also mentioned can be seen today in big masses on the southern sides of the system. V they wanted to improve the conveyance system, instead of repairing the old aqueduct, constructed an other new aqueduct at a narrower side of the valley. The construction of new aqueduct probably took place when the system, which we determined as it was from Byzantine time was still working because at the bottom of the wall, about 4 m above the rig shore of the river, a small arch was constructed which is 0.66 m wide, 1 m high, and at ground broken terra cotta pipes were found. Beside it, at a deeper place, there is an othe arch, which is bigger, and provides interval for the Mill river. It is not known how long the second aqueduct had been used. But a hydraulic engineer repaired the old aqueduct and made it usable. For this, he reconstructed the canal above it and made all the western part of the aqueduct higher. At the end, today's canal is 0.80 m higher than the old one. This raising operation can be seen from the difference wall plaiting system at the higher parts easily.

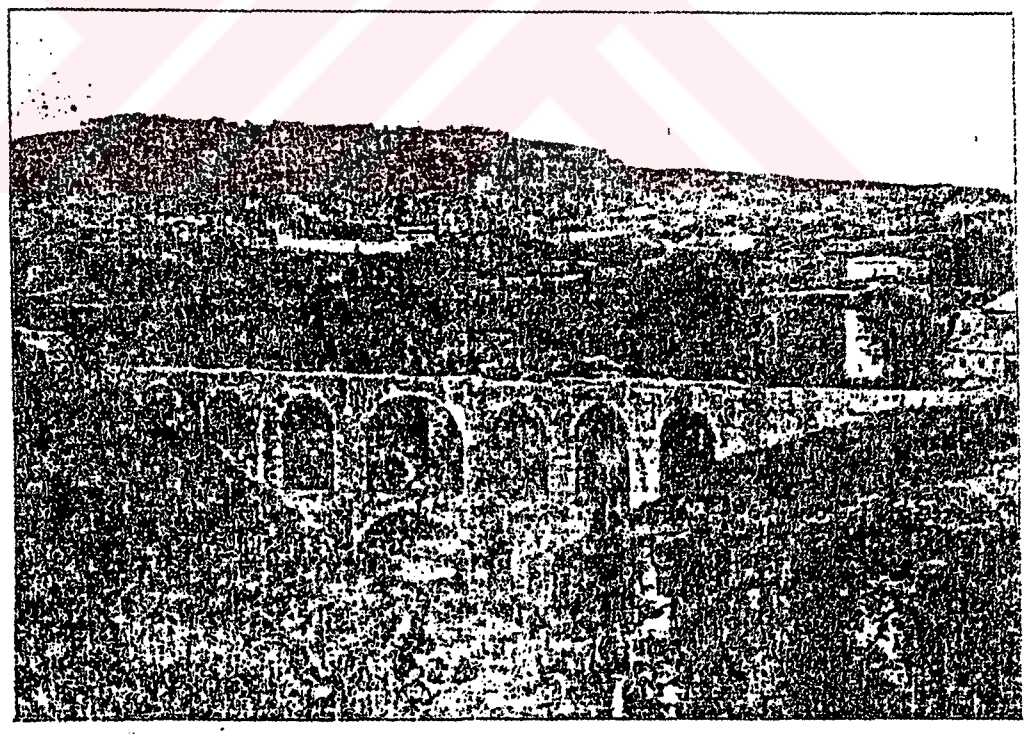


Figure 3.52:[Weber 1899/II; Fig.15]

3.7. Vezirsuyu water conveyance system

The spring area of the Vezirsuyu water conveyance system [Weber 1899; pp.181-183] is similar with the one belongs to the Osmanağa water conveyance system, but the main spring is 234 m souther. Water is collected with a reservoir which is 6 m wide, 53 m long and 3 m deep. The reservoir was divided in 4 open rooms with 3 parts. In winter water rises until the sides of the reservoir whereas in summer it is only 0.40 m height. At the southwest part, at the bottom, water is conveyed to the terra cotta pipe system from iron balustrades. Today, at a depth of 4-5 m, instead of terra cotta pipes, iron pipes were located.

The water conveyance system was located very deep, it follows mostly from underground and takes all the water from both the springs around and the old Byzantine water conveyance system. The conveyance system follows from underground and at only 3 points it comes on the ground. First, when system reaches the Meles plain, at an altitude of 52 m. Then system continues as a canal. Second, among the two Osmanağa aqueducts, where the mills are. Third, at the little Paradise area which is at the end of the system. These places today are used by the farmers as fountains. At the northern sides because of the construction of the railway, the passage had some changes. So, the conveyance system was passed around the railway partly with iron pipes. By the intersection with the high pressure pipe line it is passed the railway two times. There is a small inverted siphon at the intersection which is the below one. At the Vezir aqueduct, railway is passed with a bridge which is 5.50 m high. Then the conveyance system follows the foot of Pagos 8 m below the Osmanağa system with a covered canal and reaches the city at an elevation of 45 m. Short time ago, near the aqueduct, instead of the canal, big iron pipes were located.

The most interesting construction of the water conveyance system is the Vezir aqueduct which is 160 m long and has 2 storeys (Fig. 3-53). There are 4 arches at the bottom and 9 arches at the top. All the arches are pointed and made of big bricks.

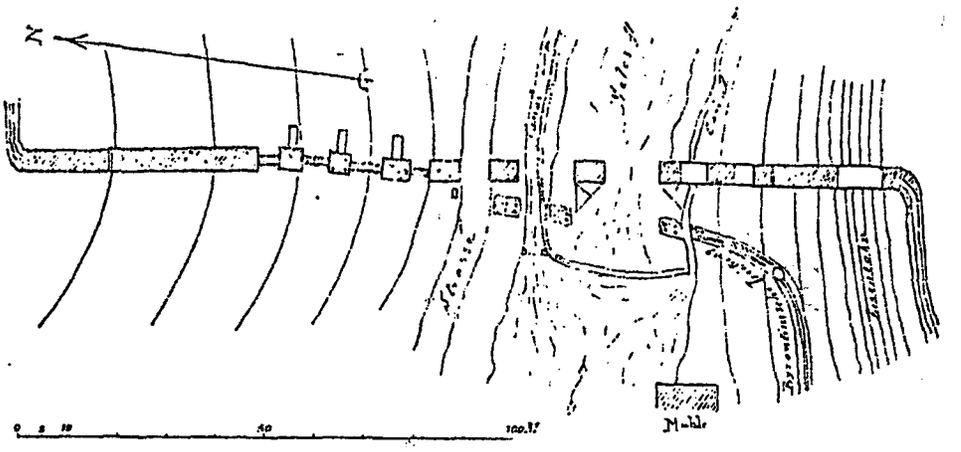


Figure 3.53:[Weber 1899/II; Fig.16]

To date the aqueduct, a lot of people made their opinions. According to Pococke was there an ancient aqueduct because of the remains of an old rusticated wall after the manner of the city walls ("Travels in Asia Minor I", p.79). According to Storari is this aqueduct made by the Genovaians ("Guida di Smirne", p.59). But Arundell & the British counsul Rycaut give a certain date. According to Arundell the aqueduct was built by Vizier Ahmet in 1674. The advantages of it are thus described by Rycault: "Ahmet erected a stately aqueduct and joined so many streams of water into one current that not only the new buildings (the Vezir Han, the Bezesten etc.) were supplied therewith, but also 73 new fountains were added to the old, besides 10 old ones which were dug and again repaired; so that whereas some houses were forced to fetch their water from far, now every family is well accommodated and every street as well supplied therewith, as most cities are, seated in the great continent of Asia." ("Asia Minor II", p.403).

In the dating of the aqueduct the fact which caused Pococke & Storari to make a mistake is the beautiful stone coverings on the column of the first floor. But the stones on the aqueduct were changed with the stones from other buildings. Most of the stones were brought down from Kadifekale, and 4 stone pipes were taken from the Karapınar water conveyance system.

CHAPTER FOUR
METHODOLOGY

4.1. General approach

It is attempted to determine the alignment of the historical long-distance water conveyance systems to İzmir, based on the information and drawings in Weber's century-old report, backed by field investigations on what can still be found and with the support of modern maps.

4.2. Evaluation of existing studies

The first, and so far only comprehensive investigation on long-distance water conveyance systems to İzmir is the main report of Georg Weber from the German Archeological Institute [Weber 1899], with some additional data in a more general one [Weber 1904]. The findings of Weber are outlined in Subchapters 3.2. and following, with page references to the main report.

Schnitter (1984) pointed out the importance of the stone-pipe inverted siphon of the Karapınar system.

Çördük investigated in detail and determined the alignment of the Karapınar water conveyance system in the context of his B.Sc. graduation project (1998). His results and the initial results of the M.Sc. thesis of the author, along with other information by Weber, are summarized in a recent congress-paper (Öziş, Özdemir, Kosova, Çördük 1999).

4.3. Investigation of maps

Weber's 1899 report includes two drawings mentioned as "Tafel". "Tafel 2" (given as Fig.3-1) has a scale of about 1 : 83 330; displays the alignments of the long-distance water conveyance systems to İzmir; but shows some discrepancies with modern maps and certain consequent discrepancies with the alignments determined within the framework of this thesis.

"Tafel 3" (given as Fig.3-2) has a horizontal scale of about 1 : 14 300 (although written as 1 : 10 000) and a vertical scale of about 1 : 3 600; displays the layout and longitudinal section of the stone-pipe inverted siphon of the Karapınar system, crossing Melez-valley. The discrepancies with modern maps and findings appear of lesser significance, although the actual urban development covered almost the entire alignment of the inverted siphon.

The anticipated alignments of the water conveyance systems to İzmir fall into İzmir and Manisa plates of modern 1 : 200 000 & 1 : 250 000 scale maps; in L18 of 1 : 100 000 scale map; L18-a1, L18-a2, L18-b1, L18-a4, L18-a3, L18-b4 of 1 : 25 000 scale maps; whereas the latter large scaled maps are usually classified material. There are also some city maps of İzmir, with scales in the order of 1 : 10 000 to 1 : 5 000.

4.4. Field investigations

Field investigations were carried out to a limited extent, due to : (a) urban developments; (b) restricted zones; (c) unfavourable weather conditions; (d) limited time allocation.

4.5. Conversations

During the field investigations in critical sections of the historical long-distance water conveyance systems to İzmir, people living in the region has been interviewed and some information has been gathered.

CHAPTER FIVE
RESULTS

5.1. Karapınar water conveyance system

5.1.1. Stone pipes

Karapınar water conveyance system has a length of 30 km, including a stone-pipe inverted siphon of 3.3 km length, crossing the Melez valley and reaching Kadifekale. The inverted siphon should have encompassed approximately 6000 stone pipes; although Weber found only 60 of them in 1899.

In the context of the present study, an entire stone pipe was found laying in an empty lot at the 809. street, near the school; the half of a pipe is on the 807. street in front of a house, another one in the foundation of a house near the road to Gürçeşme across the Police Academy. Two stone-pipes are buried in the supporting wall of the Melez creek; two halves at the right bank near the crossing point.

5.1.2. Baked clay pipes

Between the spring and the Buca plain, about an altitude of 250 m, 40 fragments of baked clay pipes were found. Again near the inverted siphon, two pipes were found but it is not certain whether they belong to the Karapınar conveyance system.

5.1.3. Alignment

The alignment of the Karapınar water conveyance system, determined by using Weber's studies, as well as field investigations and modern 1/25.000 maps, as an improved version of Çördük's 1998 layout, is given in Figure 5-1. Compared to the

Figure 5.1 : Alignment of the historical Karapınar water conveyance system to İzmir

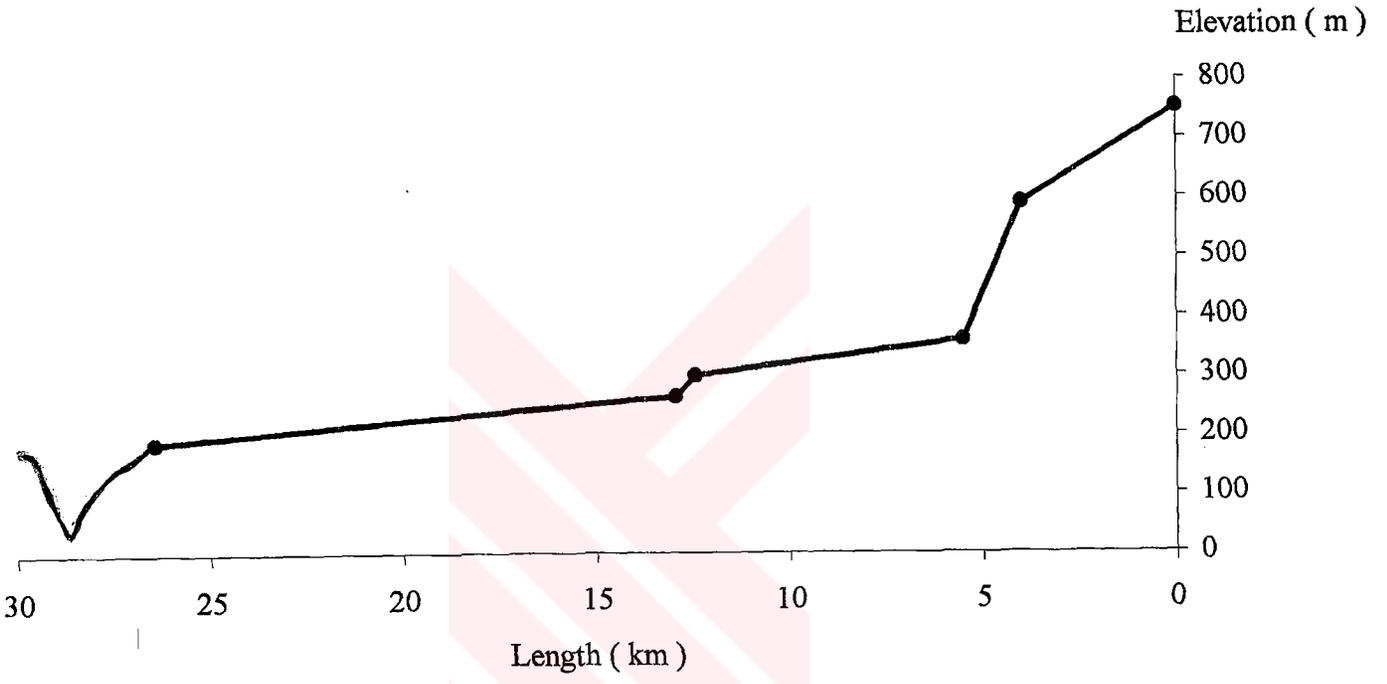


Figure 5.2: Longitudinal section of the historical Karapınar water conveyance system to Izmir

Weber's Tafel 2 map, there are several similarities; but in some cases, also significant differences.

According to this alignment, the total length of the water conveyance system is 30 km; the inverted siphon part starting from the hill at the east of the old road, north of Buca, consisting of stone pipes, is 3.3 km long.

The longitudinal section of the alignment is given in Figure 5.2. The water conveyance system begins at Karapınar spring and goes from elevation 750 m to 590 m about 4.0 km with a slope of ‰ 40, from elevation 590 m to 360 m about 1.5 km with a slope of ‰ 153, from elevation 360 m to 300 m about 6.9 km with a slope of ‰ 8.7, from elevation 300 m to 265 m about 0.53 km with a slope of ‰ 66, from elevation 265 m to 188.8 m about 13.5 km with a slope of ‰ 5.6,and from point A, at an elevation of 188.8, to Kadifekale, at an elevation of 183.9, crosses Melez river with an inverted siphon of 3.3 km length.

5.1.4. Hydraulic capacity of the conduit

The lowest slope of the conduit is 0.0056. Baked clay pipes show different diameters, but a diameter of 0.21 m may represent the water conveyance. So the hydraulic radius is 0.21/4. Assuming a roughness coefficient n=0.02, the flow velocity is computed as:

$$v= (1/0.02) (0.21/4)^{2/3} * (0.0056)^{1/2} = 0.53 \text{ m/s}$$

and consequently, the discharge capacity for flowing full:

$$Q= 0.53*\pi*0.21^2/4 = 0.018 \text{ m}^3/\text{s} = 18 \text{ l/s}$$

5.1.5. Hydraulic capacity of the inverted siphon

The elevation at the beginning of the inverted siphon is 188.8 m and the highest point in Kadifekale is 183.9 m. So the effective height difference is:

H=188.8-183.9 = 4.9 m

Length of the inverted siphon is 3.3 km so the gradient slope is;

J=4.9 / 3300 = 0.0015

The roughness of the pipe is assumed as k_s=3 mm, the representative pipe diameter as 0.17 m, so the relative roughness becomes:

r_s=3/170 = 0.018

Assuming a velocity of v'=1 m/s for the first approach, and a kinematic viscosity $\nu=1.3*10^{-6}$ m²/s, the Reynolds number is estimated as:

$R_{e'}= 1.0*0.17 / 1.3*10^{-6} = 1.3*10^5$

The corresponding friction factor λ for these r_s and R_e values is computed as 0.05

By using this value, the actual velocity is computed as:

$v''=(0.0015*0.17*2*9.81/0.05)^{½}$ =0.32 m/s

So the corresponding Reynolds number becomes:

$R_{e''}= 0.32*0.17 / 1.3*10^6 = 0.4*10^5$

And again the λ coefficient has the same value.

Thus, the capacity of the inverted siphon is estimated as:

$Q=0.32*\pi*0.17^2/4 = 0.0075$ m³/s = 7.5 l/s

5.2. Akpınar water conveyance system

5.2.1. Aqueducts

Akpınar water conveyance system has a length of 29 km and conveys the water of the Akpınar springs near Kısıkköy, south of İzmir, and reaches the temple of Zeus Akraios near Bayramyeri.

In the context of the present study, remains of an aqueduct west of Kısık, the first one in the conveyance system, were found, and the remains of another aqueduct were found crossing the Emres creek. There were also remains of the water canal walls, after the aqueduct on the Emres creek. At Uzundere, remains of an aqueduct on both abutments were found.

5.2.2. Alignment

The alignment of the Akpınar water conveyance system, determined by using Weber's studies, as well as field investigations and modern 1/25.000 maps, is given in Figure 5-3. Compared to the Weber's Tafel 2 map, there are several similarities; but in some cases, also significant differences.

According to this alignment, the total length of the water conveyance system is 29 km. The longitudinal section of the alignment is given in Figure 5.4. The water conveyance system begins at Akpınar spring and goes from elevation 130 m to 127 m about 2.0 km with a slope of ‰ 1.5, from elevation 127 m to 110 m about 9.49 km with a slope of ‰ 1.8, from elevation 110 m to 100 m about 7.16 km with a slope of ‰ 1.4, from elevation 100 m to 90 m about 5.19 km with a slope of ‰ 1.9, from elevation 90 m to 85 m about 2.11 km with a slope of ‰ 2.4, and from elevation 85 m to 75 m about 3.0 km with a slope of ‰ 3.3.

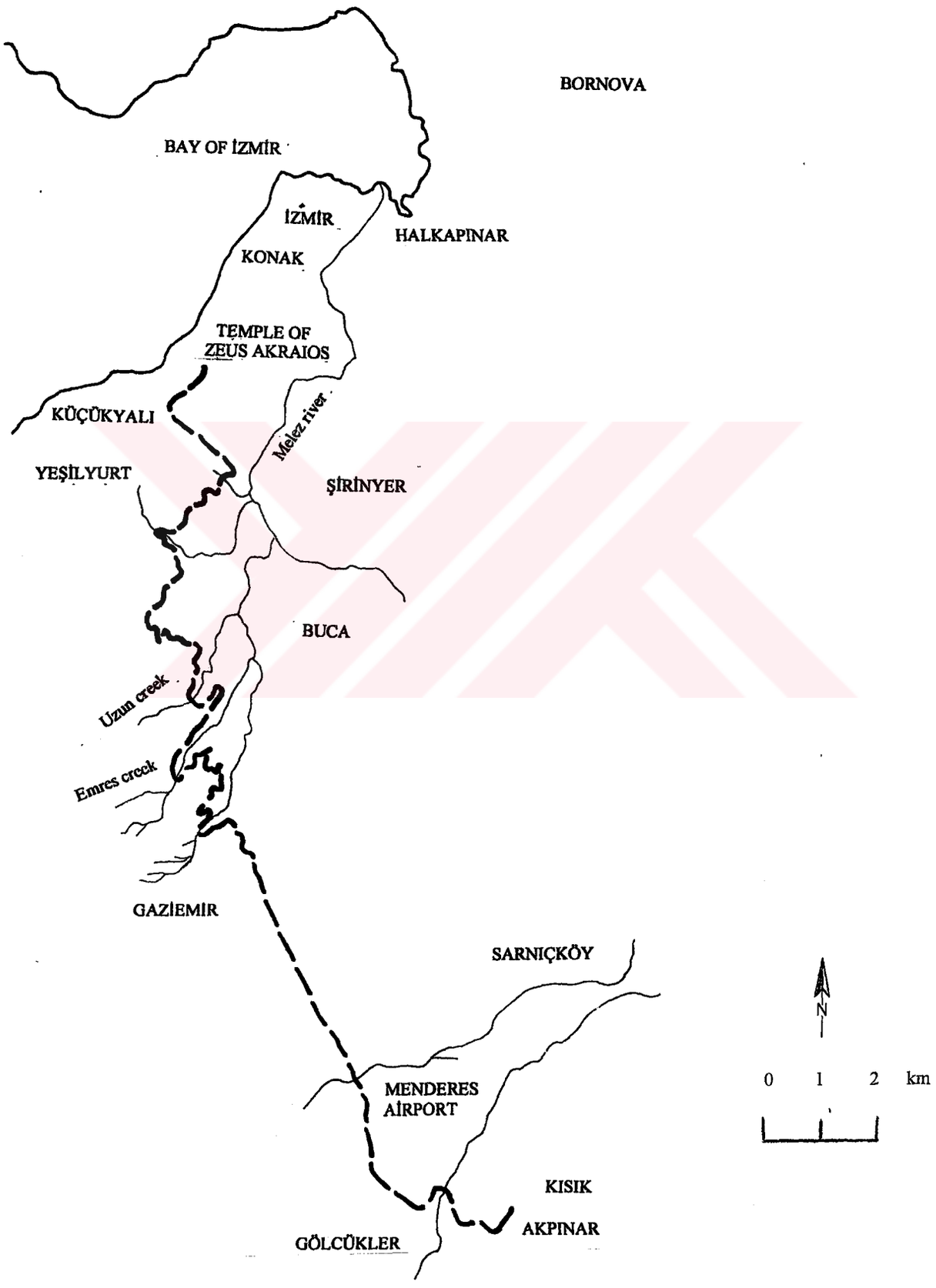


Figure 5.3 : Alignment of the historical Akpınar water conveyance system to İzmir

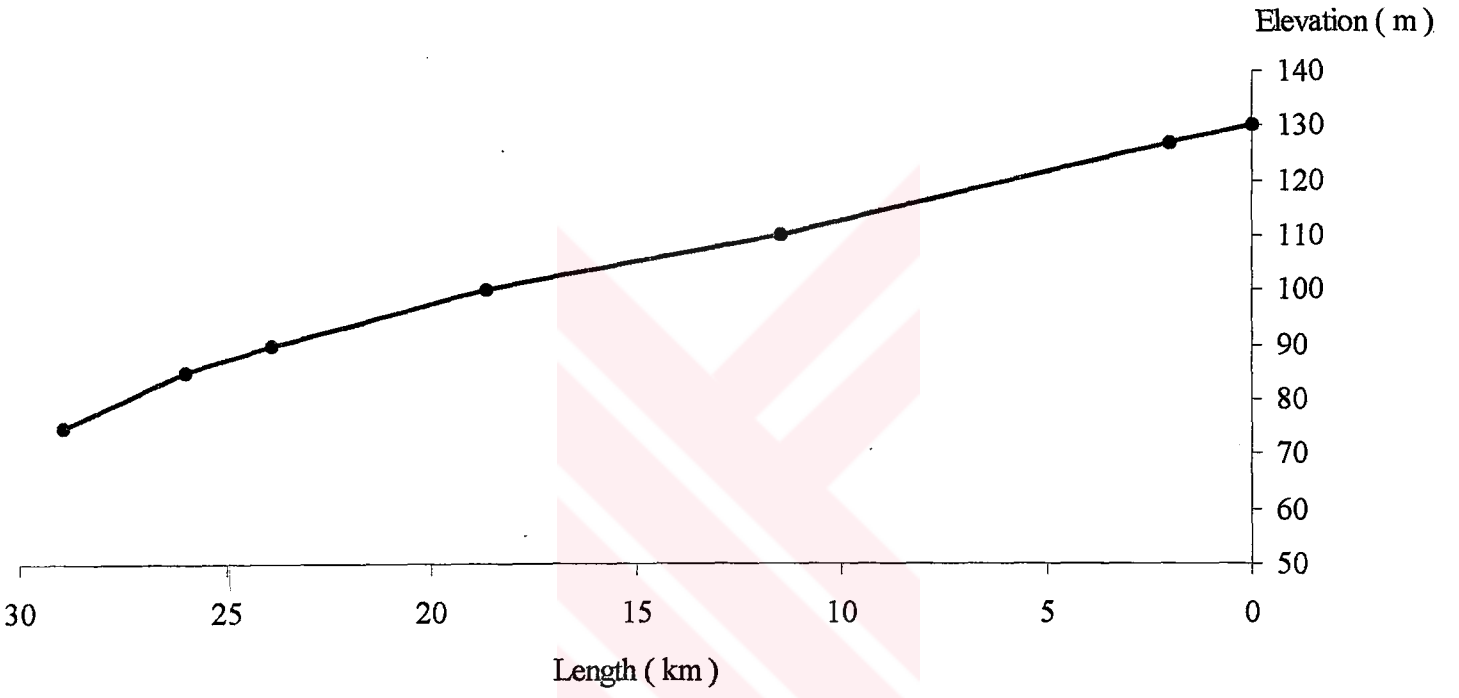


Figure 5.4: Longitudinal section of the historical Akpınar water conveyance system to Izmir

5.2.3. Hydraulic capacity of the conduit

The lowest slope of the conduit is 0.0014. The depth of water in the canal could not be determined, but by assuming a water depth in the canal as 0.4 m, and the roughness coefficient as n=0.025, the flow velocity is computed as:

$$v= (1/0.025)\ (0.4^2 / 3*0.4)^{2/3} * (0.0014)^{1/2} = 0.39 \text{ m/s}$$

and consequently, the discharge capacity for flowing full, is estimated as:

$$Q= 0.39*0.4^2 = 0.062 \text{ m}^3/\text{s} = 62 \text{ l/s}$$

5.3. Buca water conveyance systems

The Buca water conveyance systems, partly used through later modifications, convey the waters of Kanlıgöl-Kaynaklar area, east of Buca. According to Weber[1899], the water from Kanlıgöl, east of Buca, was conveyed to İzmir. Two Byzantine water conveyance systems conveyed water from the Buca area with terra cotta pipes and one of them crossed the Melez creek at the place, where the stone-pipe inverted siphon of the Karapınar water conveyance system crossed the Melez creek too. Weber mentioned that both aqueducts in Şirinyer were constructed in the Ottoman period, and the waters of Buca or Kozağaç crossed Melez creek with these aqueducts. Weber also wrote that later the Osmanağa water conveyance system used them.

The downstream aqueduct in Şirinyer, with a canal as the conduit above it, looks like to be built in Roman times.

There can be a water conveyance system, collecting the waters from Kaynaklar, south of Karapınar, and conveying it to İzmir by using this aqueduct at the Melez creek. The possible alignment of the anticipated historical Buca water conveyance systems, determined by using 1/25.000 maps and field investigations, is given in Figure 5.5, and the possible longitudinal sections of the anticipated Kanlıgöl and Kaynaklar water conveyance systems are given in Figure 5.6 and Figure 5.7.

The other aqueduct in Şirinyer can be built in the Ottoman period, and it used by both the Buca and Kozağaç or Osmanağa water conveyance systems.

Figure 5.5 : Possible alignment of the anticipated historical Buca water conveyance systems to İzmir

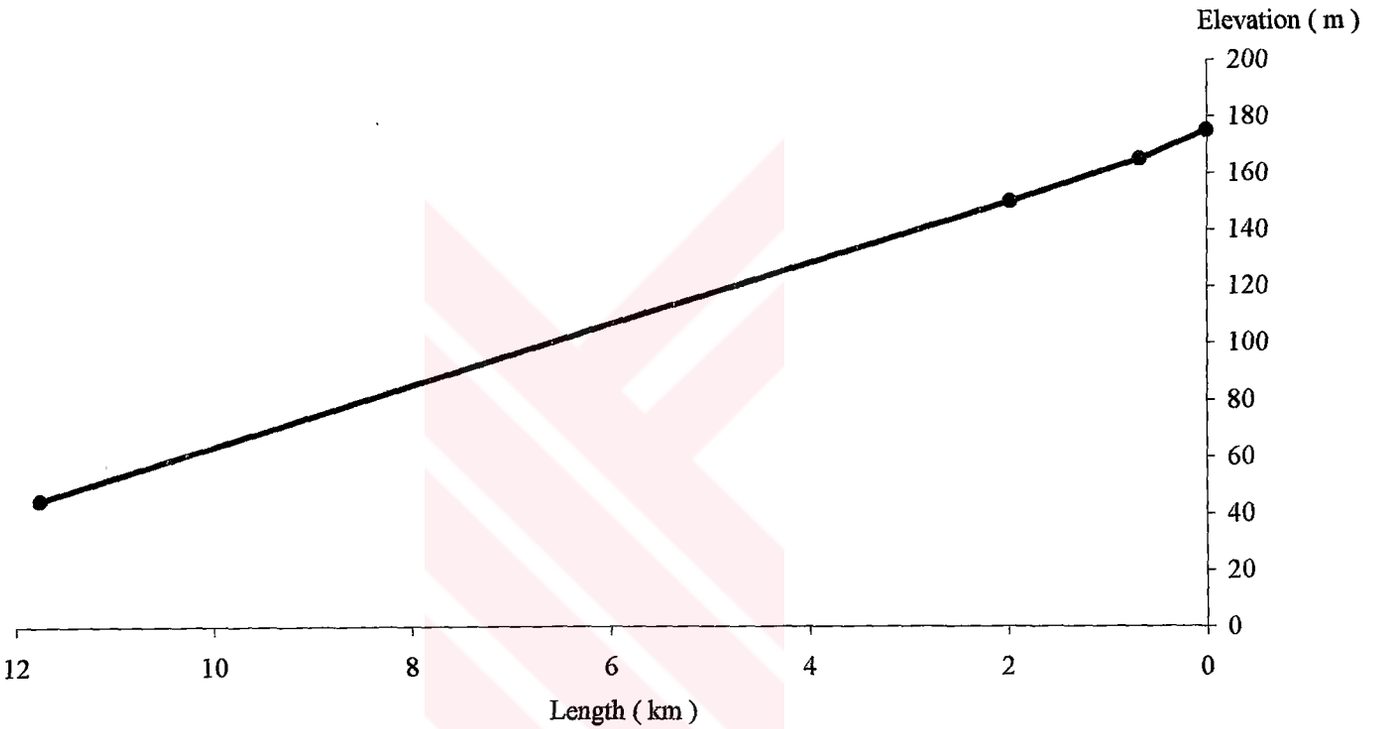


Figure 5.6: Longitudinal section of the historical Kanlıgöl water conveyance system to Izmir

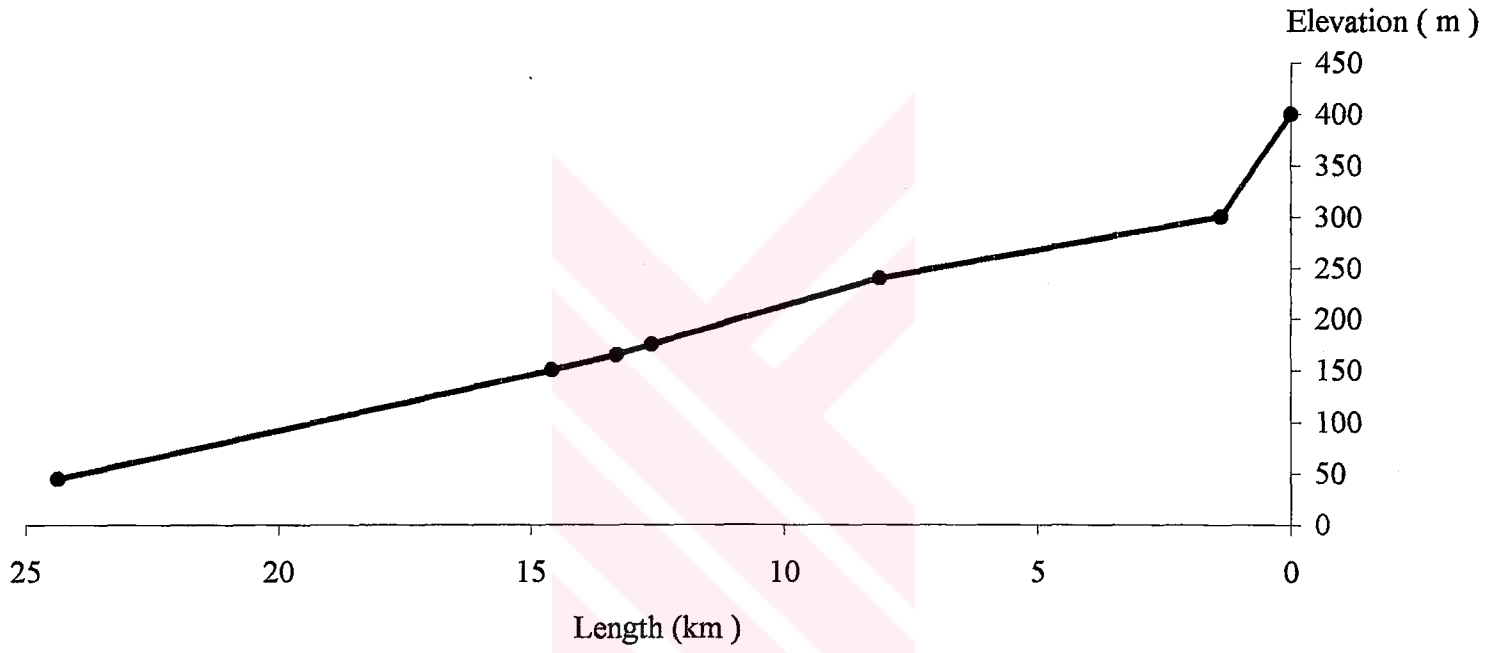


Figure 5.7: Longitudinal section of the historical Kaynaklar water conveyance system to Izmir

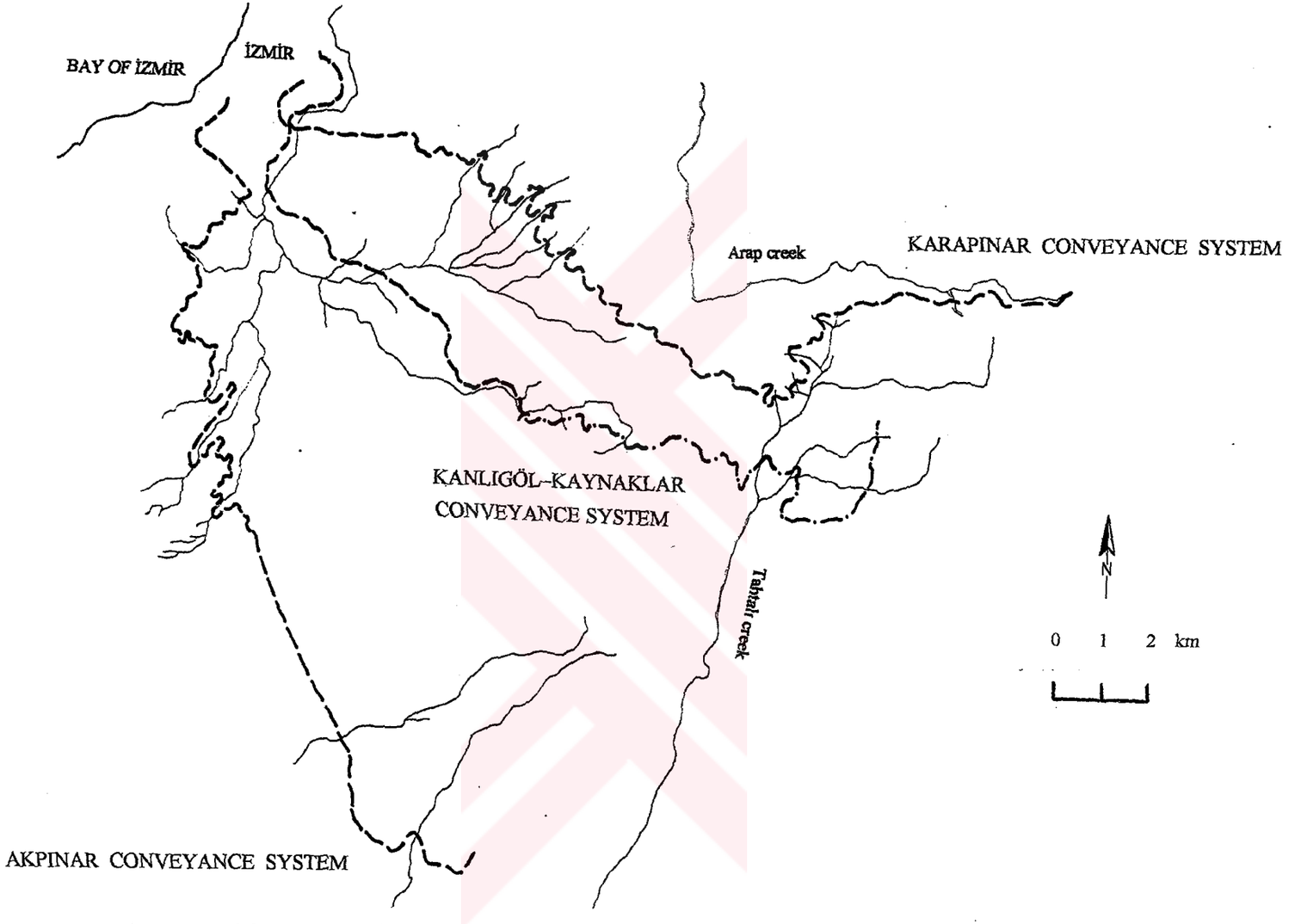


Figure 5.8 : Alignment of major historical water conveyance systems to İzmir

CHAPTER SIX
CONCLUSION

Based on the information and drawings in Weber's century-old report, backed by field investigations on what can still be found and with the support of modern maps, the alignment of the historical Karapınar and Akpınar long-distance water conveyance systems to İzmir and the possible alignment of the anticipated historical Buca water conveyance systems to İzmir is determined.

In this study, field investigations were carried out to limited extent, due to: (a) urban developments; (b) restricted zones; (c) unfavourable weather conditions; (d) limited time allocation. It is strongly recommend that these alignments of the historical water systems be controlled through future detailed field investigations; also to find out remaining elements of the conduits.

The results of this study are as follows:

The "Karapınar system", conveying the water from Karapınar springs at elevation 750 m on southern slopes of the Nif mountain, east of İzmir, and reaching the Kadifekale castle at elevation 184 m by crossing Melez creek through a 3.3 km long stone-pipe inverted siphon, is 30 km long. The lowest slope of the conduit is 0.0056, the representative pipe diameter is 0.21 m and the discharge capacity is 18 l/s. For crossing the Melez creek, the effective height difference is 4.9 m, the representative pipe diameter is 0.17 m and the capacity of the inverted siphon is computed as 7.5 m/s. Because of the different diameters and roughness of the both stone and terra cotta pipes, the capacity of the conveyance system appear to be in the order of 5-10 l/s.

The "Akpınar system", conveying the water from Akpınar springs at elevation 130 m, south of İzmir, and reaching the temple of Zeus Akraios near Bayramyeri at elevation 75 m, is 29 km long. The lowest slope of the conduit is 0.0014, and by assuming the water depth of the canal as 0.4 m like the canal width, the capacity of the system is 62 l/s.

The "Buca systems", partly used through later modifications, conveying waters of Kanlıgöl-Kaynaklar area, east of Buca and continuing in Melez valley at eastern slopes of Kadifekale, are about 12 km long from Kanlıgöl to İzmir, 25 km long from Kaynaklar over Kanlıgöl to İzmir.

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