SAFM

Studien zu Spätantike und Frühmittelalter 8

Infrastruktur und Distribution zwischen Antike und Mittelalter

Tagungsbeiträge der Arbeitsgemeinschaft Spätantike und Frühmittelalter 8

Herausgegeben von

Christian Later, Michaela Helmbrecht

und Ursina Jecklin-Tischhauser

Verlag Dr. Kovač

Inhalt

Vinka Bubić

The Construction of Diocletian's Aqueduct in Late Antiquity and its Landscaping Today

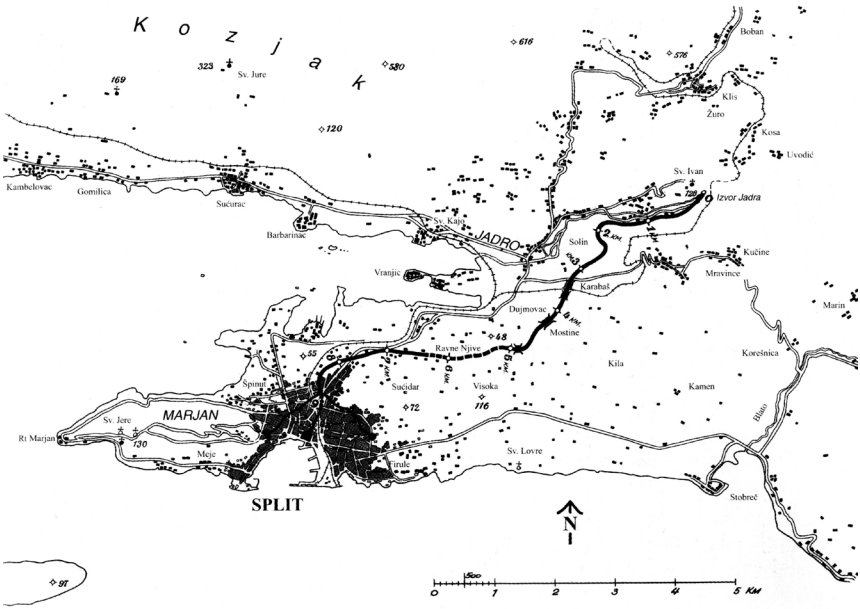
Schlagwörter: Diokletiansaquädukt, Bilice, Rekonstruktion, Spätantike
Keywords: Diocletian's aqueduct, Bilice, reconstruction, late Antiquity

A brief history of research

At the beginning of the 4th century Emperor Diocletian built his famous palace 6 km south-west of Salona (today Solin), the capital of the Roman province of Dalmatia. Simultaneously with the palace the Emperor built an aqueduct (Fig. 1). Two centuries later the Western Roman Empire came to an end, but Diocletian's Palace and the aqueduct have survived thanks to Roman architectural skills. Even today new details of their construction are revealed.

The aqueduct did not raise particular interest among scholars until the mid-19th century, when the architect and conservator Vicko Andrić began to survey its remains[1]. In 1910, registering Roman ruins in Split, the architect George Niemann edited a folio-format monograph involving the aqueduct[2]. Complementary to this, professor of ancient history Jacques Zeiller and architect, archaeologist and town planner Ernst Hébrard published a book about the palace in Split[3]. In 1927 the conservator and archaeologist Frane Bulić and art historian Ljubo Karaman also made a remark about the aqueduct[4], but the most comprehensive study of the aqueduct was published in 1972. This study includes a description of the aqueduct route from the source of the Jadro rivulet to the distribution basin (*castellum divisorium*) near the palace, as well as architectural observations of columns, arches and un-

1 D. Kečkemet, Vicko Andrić arhitekt i konzervator (1793–1866) (Split 1993) 21.
2 G. Niemann, Der Palast Diokletians in Spalato (Wien 1910).
3 E. Hébrard/J. Zeiller, Le palais de Diocletien a Spalato (Paris 1912).
4 F. Bulić/Lj. Karaman, Palača cara Dioklecijana u Splitu (Zagreb 1927).



1 Aqueduct route. – After BELAMARIĆ 1999 (note 6).

derground tunnels[5]. Further discoveries were made in 1999 on the route of the highway Split – Klis (Fig. 9). Archaeologists discovered a previously unknown section with eleven columns and arches that supported the channel of the aqueduct. As a result of this significant discovery, complex infrastructure and conservation work has been carried out and published as

5 N. KATANIĆ/M. GOJKOVIĆ, Građa za proučavanje starih kamenih mostova i akvedukata u Hrvatskoj (Beograd 1972).

preliminary reports[6]. More recent papers dealing with Diocletian's aqueduct refer to its route and to the sewage system in the palace[7].

From the source to the palace

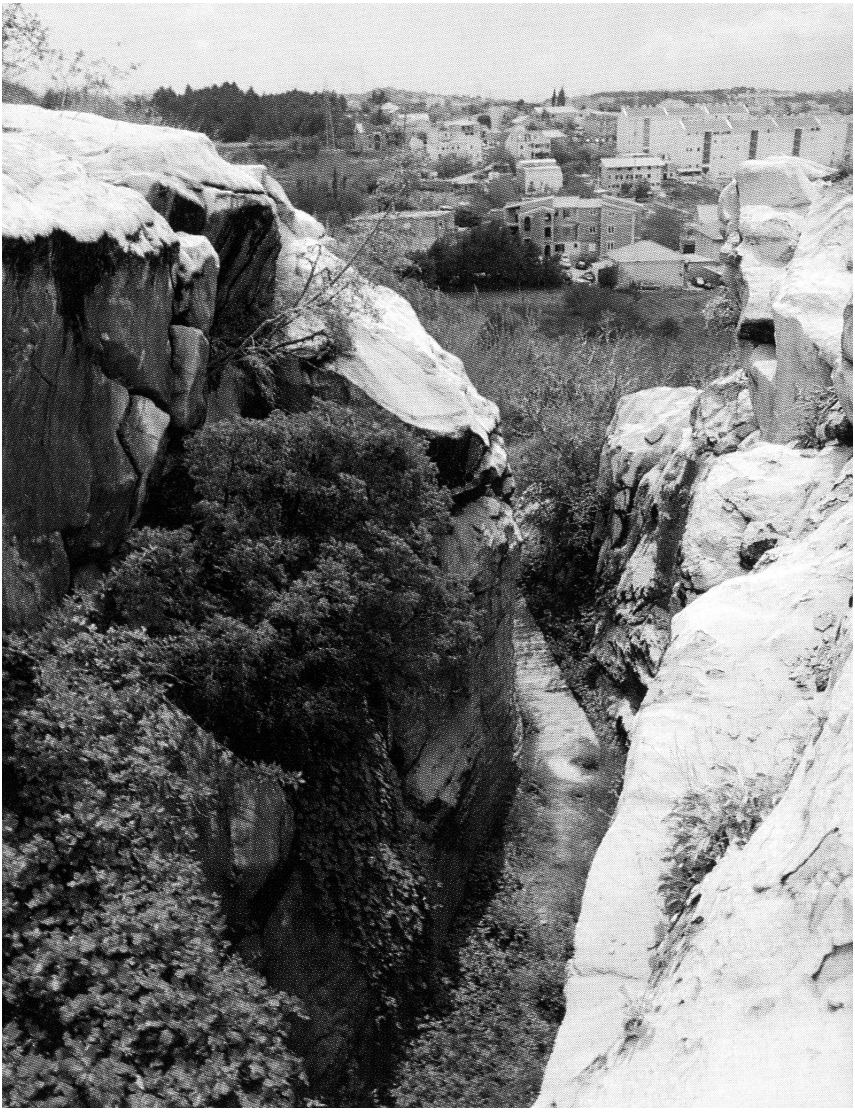
The gravitational channel of the aqueduct consists of a water intake structure (*castellum fontis*); a part where the channel has been cut into the rock (Fig. 2); arches supported by columns (*opus arcuatum*) which are the most prominent part of the aqueduct (Fig. 3); and underground tunnels (*cuniculus*) (Fig. 5). Therefore, the aqueduct is a good example of various designs of water supply elements in the Roman era. The original Roman water intake structure on the Jadro spring is not preserved, but the initial elevation of the channel is well-known. It is located at 33 m above sea level, 9.5 km northwest of Diocletian's Palace[8]. Following its natural slope, the channel of the Diocletian aqueduct (7100 m) was mainly laid on the ground. In addition, columns and arches support a channel that runs across four valleys, covering the length of 670 m. The best preserved section of the aqueduct is located at the site called „Dry Bridge" in Mostine, a suburb of Split (Fig. 3). This section looks rather impressive since it is 180 m long and rises on 22 arches which are 16.5 m high[9]. It has been described and illustrated by many travelers,

6 J. Belamarić (ed.), Dioklecijanov akvedukt (Split 1999).

7 J. Marasović et al., Kanalizacija i vodovod Dioklecijanove palače. In: Belamarić 1999 (note 6) 65–75; J. Marasović/K. Marasović/S. Perojević, Aqueduct and Sewage of Diocletian's Palace. Second International Conference on Waters in protected areas (Zagreb 2007) 156–160; K. Marasović/T. Marasović, Settling in Diocletian's Palace. In: M. Jurković/A. Milošević (eds.), Munuscula in honorem Željko Rapanić. Festschrift on the occasion of his 80th birthday (Zagreb 2012) 93–113; G. Nikšić, Dioklecijanova palača – reinterpretacija izvorne namjene i arhitekture. In: M. Rakocija (ed.), Niš i Vizantija. Zbornik radova 10 (Niš 2012) 219–236; K. Marasović/S. Perojević/J. Margeta, Water supply system of Diocletian's palace in Split – Croatia. In: I. K. Kalavrouziotis/A. N. Angelakis (eds.), IWA Regional Symposium on Water, Wastewater and Environment: Traditions and Culture. E-Proceedings (Patras 2014) 163–173 <http://wwetc2014.env.uwg.gr/wms/images/e-PROCEEDINGS_v1.12.pdf> (9.10.2014); K. Marasović/S. Perojević/J. Margeta, Roman sewer of Diocletian's palace in Split. Građevinar 66, 2014, 237–249.

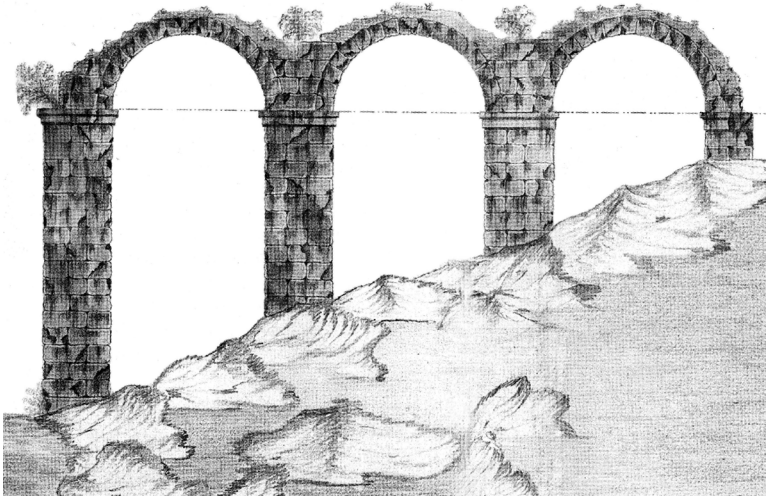
8 D. Kečkemet, Obnova Dioklecijanovog vodovoda. In: Belamarić 1999 (note 6) 29–49 here 29.

9 J. Belamarić, Dioklecijanov vodovod i njegove obnove. In: Belamarić 1999 (note 6) 5–27 here 9.

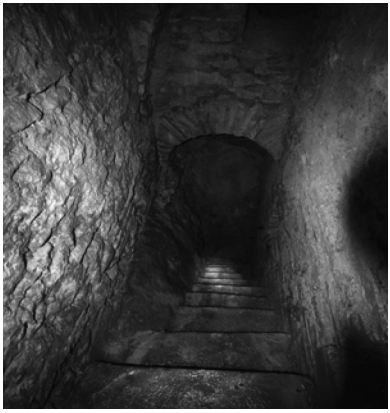


2 On the second kilometre of the route the channel intersects a natural reef through a cut called Prosik. – After Belamarić 1999 (note 6).

3 Columns and arches of the aqueduct at the site called „Dry Bridge" in Mostine. – http://www.romanaqueducts.info/aquasite/split/foto14.html.



4 V. Andrić, Roman aqueduct, 1845. – Archive of the Department of Conservation in Split.



5 Ravne njive tunnel stairway. – After Marasović/Perojević/Margeta 2014 (note 7) 170 fig. 10.

scholars and artists who visited Split during the 18th and 19th century[10]. Judging by the drawing of V. Andrić (Fig. 4), only columns and arch intrados were preserved before the 19th century reconstruction.

Above-ground sections of Diocletian's aqueduct were mainly built of regular cut stone blocks fixed with cement where necessary. From an archaeological point of view the most interesting section of the aqueduct was the 1268 m long underground tunnel at the site Ravne njive in the north-eastern part of Split (Fig. 1). The tunnel was cut into the bedrock stone at a depth of 21 m[11]. The soft parts of the tunnel's sidewall were covered with cut stone blocks consolidated with mortar while the vaults were built with *tegulae*. The bottom of the channel was lined with a thick layer of waterproof mortar. Underground tunnel profiles vary in shape and width. The tunnel includes 32 vertical rectangular shafts that were constructed to determine the direction; to enable ventilation; to take out unearthed stone; and to provide access for subsequent maintenance[12]. Above ground the shafts were protected by irregular stone slabs. Steep stairways enabled descending from the surface into the tunnel (Fig. 5).

Roman builders were able to execute a constant channel inclination and adequate water supply. The channel that brought water to the palace had a cross section 0.75 m wide and 1.60 m high. Based on this data, V. Andrić calculated at the end of the 19th century that the water supply amounted to 13 m^3 per second, which was equal to 1.1 million m^3 per day, and it would

10 R. Adam, Ruins of the Palace of the Emperor Diocletian at Spalatro in Dalmatia (London 1764) Tab. 61; J. Lavallée/L. F. Cassas, Voyage pittoresque et historique de l'Istrie et de la Dalmatie (Paris 1802) Tab. 57, 59.

11 Lj. Gudelj, Izvješće o arheološkim istraživanjima Dioklecijanova akvedukta na Bilicama. In: Belamarić 1999 (note 6) 77–85 here 79.

12 Gudelj 1999 (note 11) 79.

have been enough for 173,000 residents of Split[13]. It was clear that the capacity of the aqueduct was oversized for the population of the palace and the surrounding area in the 4th century. In other words, the channel dimensions must have been related to the technology of construction and maintenance. The channel was wide enough and high enough for Roman constructors to build vaults, roughcast the channel and, after its construction, remove wooden supports. Also, size was important in order to facilitate the maintenance of the channel. Mud had to be removed regularly. Today we know that the estimated capacity of useable profile (0.60 × 1.20 m) of the channel is 715 liters per second, or 61,776 m^3 of water per day[14].

Inside the palace

Through the gravitational channel of the aqueduct water flowed from the source of the Jadro rivulet to the main distribution basin (*castellum divisorium*) at 20 m above sea level and some 250 m away from the palace (Fig. 6).[15]. The *castellum divisorium* marked the end of the aqueduct channel and the starting point of the water supply system with lead or stone pipes inside the palace. The finding of a lead pipe in the eastern baths (*thermae*) has confirmed the existence of a water supply system within the palace[16]; in addition, the shaft of the sewage canal has been found in the north-western part of the palace. Furthermore, elements of stone pipes with traces of ancient mortar are kept in the cellars (Fig. 7), the substructure of the Emperor's quarters. Originally coming from other parts of the palace, these stone pipes could have been a part of the water distribution system inside the palace.

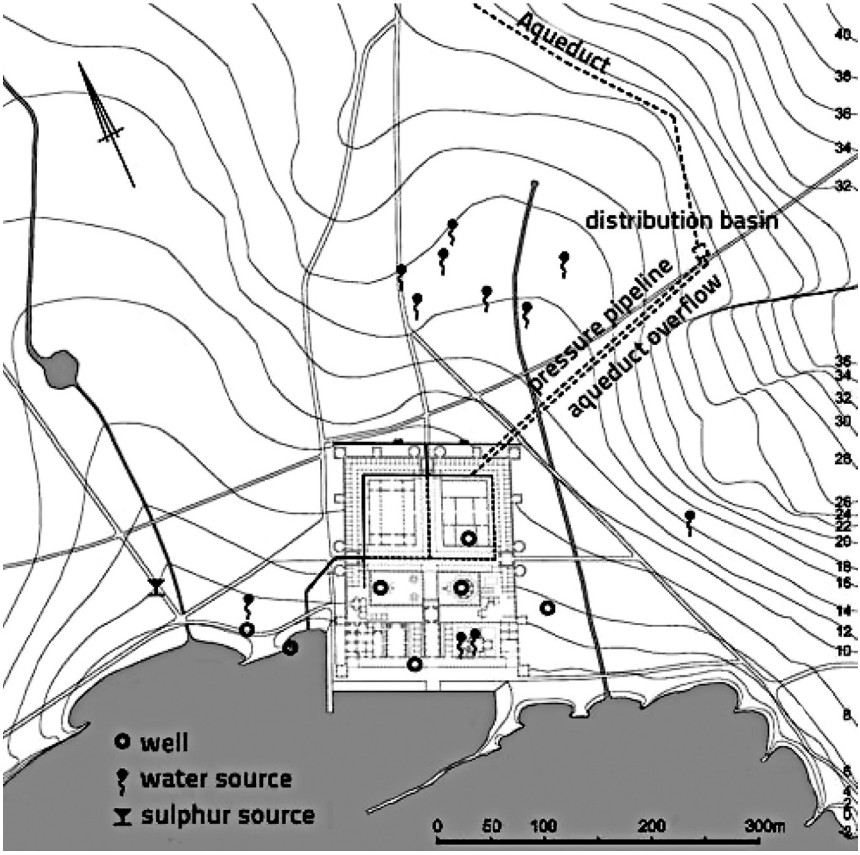
The water supply system served for basic needs of the inhabitants of the palace; but it also supplied the public fountains (*lacus*), provided water for the needs of a textile workshop, two thermal complexes, the surrounding

13 Belamarić 1999 (note 9) 11. Note that at the 2nd half of the 19th century Split had 11,000 residents.

14 Marasović/Marasović 2012 (note 7) 96.

15 Marasović/Perojević/Margeta, Roman sewer 2014 (note 7) 239.

16 B. Gabričević, Novija istraživanja o antičkoj kanalizaciji u Dioklecijanovoj palači u Splitu. Acta Hist. Medicinae et Pharmaciae Veterum 3, 1963, 45–49; F. Bulić, Higijenski uređaj u palači cara Dioklecijana u Splitu. Liječnički vjesnik 4, 1934, 1–3.



6 Assumed position of the *castellum divisorium*. – After Marasović/Perojević/Margeta 2014 (note 7) 241 fig. 7.

parks and gardens, and for sewage cleaning[17]. Fragments of an ancient fountain (Fig. 8) were discovered in the Emperor's quarters which are located in the southern part of the palace. The fountain is dated to the 4th century[18]. It was very ornamental and probably the water rushed up like the one we can

17 Gudelj 1999 (note 11) 79.

18 R. Bužančić, Fontana Dioklecijanove carske palače. Klesarstvo i graditeljstvo 20, 2009, 54–65 here 58.

7 Elements of stone pipes kept in the cellars of Diocletian's Palace. – After Nikšić 2012 (note 7) 231 fig. 8.

see on a mosaic depicting Empress Theodora in the Basilica of San Vitale in Ravenna.

The Emperor had his own baths in the north-western corner of his quarters. Two other baths, the so called eastern and western baths, were built later. Until recently, the eastern and western baths have also been attributed to the time of Diocletian, however studies have shown that they did not form part of the original palace design[19]. This type of subsequent addition to the palace indicates that the aqueduct was still in use during late Antiquity.

In the *Notitia Dignitatum* (385–425), a *procurator gynaecei Iovensis Dalmatiae Aspalatho* is listed[20]. Joško Belamarić believes that this refers to a weaving facility, named *Jovensis* after the Emperor's divine attribute, which existed in the northern part of the palace already in Diocletian time[21]. Such a facility would certainly require a substantial amount of water to process wool, wash and dye fabrics. An aqueduct would have been very useful for this kind of work. However, the existence of a *gynaeceum* has not been confirmed so far

19 J. Marasović et al., Dioklecijanova palača. Izvještaj o Jugoslavensko-američkom projektu istraživanja jugoistočnog dijela Palače (Split 1972).

20 Bulić/Karaman 1927 (note 4) 181.

21 J. Belamarić, Gynaeceum Iovense Dalmatiae – Aspalatho. Prilozi Povijesti Umjetnosti Dalmaciji 40, 2004, 5–42.

8 Fragments of an ancient fountain, 4th century. – After Bužančić 2009 (note 18) 55.

by any findings inside the palace. Other authors think that 'the *gynaeceum* was located literally in *Asphalatos*, somewhere outside the palace[22].

The aqueduct's reconstruction in the 19th century

With the invasion of Avars and Slavs in the mid-7th century, the aqueduct was partly destroyed[23]. In the beginning of the 19th century, due to Split's rapid development, the city required a modern water supply system. Therefore, in 1845, V. Andrić began to survey the remains of the aqueduct (Fig. 4). He found out that they were very well preserved and that a reconstruction

22 Ž. Rapanić, Split. Od carske palače do srednjovjekovne općine (Split 2007) 58; Marasović/Marasović 2012 (note 7) 94.

23 Kečkemet 1999 (note 8) 29; Marasović/Perojević/Margeta, Roman sewer 2014 (note 7) 239.

of the ancient aqueduct would be much cheaper than building an entirely new public water supply system. In 1880 the aqueduct was restored (Fig. 3) and started to work once again[24].

Modern archaeological excavations

In 1999 the construction of the highway Split – Klis resulted in the discovery of a new section of the aqueduct at the site of Bilice near Solin (Fig. 9). By comparing architectural elements, conservators noticed that the construction methods applied on the sections at Bilice and Mostine were not the same. Roman builders used megalithic square blocks (*opus quadratum*) joined with iron clamps to build columns at the site of Mostine (Fig. 3). Today only holes remain after the clamps were removed during the Middle Ages. On the other hand, at the site of Bilice builders used coarse cut stone (*opus mixtum*) for the construction of columns. At the same time, vaults were made with cheaper but equally functional *tegulae*[25] (Fig. 10).

The archaeological excavations at Bilice also revealed that renovations were made on Diocletian's aqueduct in late Antiquity. According to scholars, the aqueduct was damaged during the Goth occupation of Salona in the middle of the 5th century[26]. In the course of the renovation arches were knocked down and columns were lowered. In the gaps between the columns stone masonry infill has been found. Researchers interpreted this infill as the substructure of a late Antique road that was built along the route of the aqueduct[27]. This interpretation was based upon 6th century pottery findings and a coin attributed to the Emperor Justinian I (527–565)[28]. However, some scholars believe that the masonry infill between the columns could have been simply a repair of the aqueduct in the 6th century[29]. The same kind of masonry infill along the route of the Pont du Gard is interpreted accordin-

24 Belamarić 1999 (note 9) 12–15.

25 Gudelj 1999 (note 11) 82.

26 Major Goth raids against Salona were recorded in 449, 457 and 458 AD (M. Abramić, O povijesti Salone. In: N. Cambi [ed.], Antička Salona [Split 1991] 39–46 here 44).

27 Belamarić 1999 (note 9) 16; Gudelj (note 11) 84–85.

28 T. Šeparović, Akvedukt na Bilicama. Numizmatički nalazi. In: Belamarić 1999 (note 6) 87–95 here 88.

29 Marasović/Marasović 2012 (note 7) 99.

9 Section of the aqueduct at Bilice near Solin. – After Belamarić 1999 (note 6).

10 Reconstructed section of the aqueduct at the site called Bilice near Solin. – Picture: V. Bubić

gly[30]. This as well as the discovery of the lead pipe in the eastern baths of Diocletian's Palace indicates that the aqueduct may have been in function until the mid-7th century.

Archaeological excavations in 1999 also revealed that the 1880 reconstruction did not use the same techniques as the Romans, the number of Roman arches was reduced and a section of the aqueduct was built as a solid wall. Also the 19th century columns were not set up precisely at the same positions as the original ones. In addition, the Roman foundations, which measured 2.4 m, were slightly wider than the new ones with only 2 m in width[31].

Modern landscaping

In order to present the Bilice section of the aqueduct *in situ*, the ancient columns had to be temporarily relocated without dismantling. An artificial

30 G. Fabre et al., Le pont du Gard. L'eau dans la ville antique (Paris 1993) 90.
31 G. Nikšić, Akvedukt na Bilicama. In: Belamarić 1999 (note 6) 97–102 here 98.

road tunnel was built and covered with a layer of earth to evoke an earlier appearance of the field. Hereafter the ancient columns were returned to the same coordinates and the original arches were reconstructed. The 19th century reconstruction is considered a valuable record of this period and represents a significant construction project; hence the wall of the 19th century aqueduct was rebuilt above the Roman arches (Fig. 10)[32].

Conclusion

Planning and constructing of the Diocletian aqueduct was carried out along with all the factors and standards required for this type of structure even today. It was built exclusively for the needs of the palace. Its construction comprises three phases: The first phase was completed simultaneously with the palace in Diocletian's time at the beginning of the 4th century; the second phase includes its maintenance and upgrading during late Antiquity; and the third phase was the 19th century reconstruction. Due to the recent discoveries we have substantially more information about these phases; however, the important question for how long Diocletian's aqueduct was in use, is still unanswered. Scientists mainly believe that the aqueduct was in continuous use until the mid-7th century, when it was destroyed during the invasion of Avars and Slavs. At the end of the 19th century the aqueduct was reconstructed for the residents of Split and it is still in function, so that the water supply of the city of Split, the second largest city in Croatia, is based on the same water supply concept as Diocletian's Palace. This gives us the opportunity to study Roman water supply engineering and technology.

Summary

Diocletian's aqueduct is a rare example of Roman construction still in use today. Starting from the Jadro rivulet source, 9.5 km north-west from present-day Split, the aqueduct supplied Diocletian's Palace with fresh water. It was built at the beginning of the 4th century. Due to specific conditions of the landscape its route

32 Nikšić 1999 (note 31) 99.

ran partially underground. Its best preserved section is located at the entrance to modern Split, and consists of arches 16.5 m high. The aqueduct was in function during late Antiquity and it was thoroughly reconstructed in the late 19th century as part of the contemporaneous water supply system. In this paper we would like to present the way of construction and preservation of the aqueduct's newly discovered section.

Zusammenfassung

Der zu Beginn des 4. Jahrhunderts errichtete Diokletiansaquädukt ist ein seltenes Beispiel für ein heute noch in Nutzung befindliches römisches Bauwerk. Beginnend an der Quelle des Flüsschens Jadro, 9,5 km nordwestlich des modernen Split, versorgte der Aquädukt den Diokletianspalast mit Frischwasser. Aufgrund besonderer Landschaftsverhältnisse verlief er streckenweise unterirdisch. Sein am besten erhaltener Abschnitt liegt am Stadtrand von Split und besteht aus Bögen von 16,5 m Höhe. Der Aquädukt ist seit der Spätantike in Nutzung und wurde im späten 19. Jahrhundert für die Versorgung der Einwohner von Split umfassend instand gesetzt. Dieser Aufsatz behandelt die Konstruktionsweise des Aquädukts in einem neu entdeckten Teilbereich und die daran durchgeführten modernen Konservierungsmaßnahmen. (Übersetzung: Ch. Later)

Vinka Bubić, MA
University of Zagreb
Faculty of Humanities and Social Sciences
Department of Archaeology
Ivana Lučića 3
HR-10000 Zagreb
vibubic@ffzg.hr