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U ovom radu bit će prezentirani rezultati istraživanja trase i značajki Salonitanskog akvedukta koji su provedeni tijekom prve godine znanstvenog projekta “Antički vodni sustavi grada Salone i Dioklecijanove

Study of the Aqueduct of Salona 2014-2015

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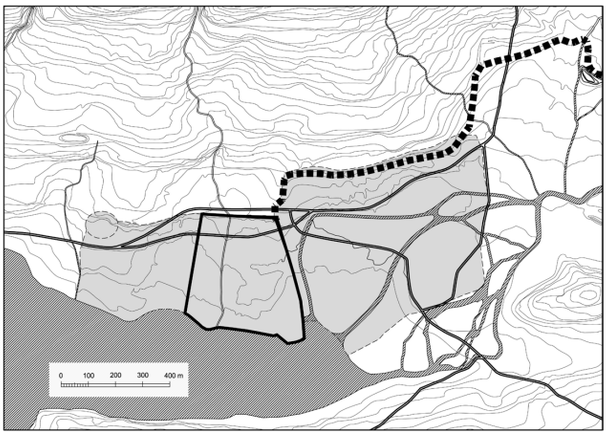
This paper will present the results obtained by the study of the route and the physical characteristics of the Aqueduct of Salona. The study was conducted during the first year of the research project entitled “Ancient Water Systems of Salona and the Diocletian’s Palace and Their Impact on the Sustainability of the Urban Environment”, which has been financed by the Croatian Science Foundation. The significance of the

palače i njihov utjecaj na održivost urbane sredine" koji financira Hrvatska zaklada za znanost. Prvi put je u cijelosti utvrđena trasa akvedukta, njegov uzdužni profil, kapacitet i karakteristični presjeci u različitim terenskim uvjetima, kao i način gradnje.

Ključne riječi: Vodovod, Akvedukt, Salona, Jadro

study lies in the fact that, the overall route of the Aqueduct, its longitudinal profile, capacity, typical sections in various field conditions, as well as the method of construction have been determined for the first time.

Keywords: Water supply system, Aqueduct, Salona, Jadro



Sl. 1. Salona na prijelazu era (izvor: autori)
Fig. 1. Salona at the turn of eras (source: authors)

Od 1. rujna 2014. na Fakultetu građevinarstva, arhitekture i geodezije Sveučilišta u Splitu provodi se istraživački projekt Hrvatske zaklade za znanost koji će trajati četiri godine.[1] Multidisciplinarni tim znanstvenika, sastavljen od arheologa, arhitekata i inženjera građevinarstva, istražit će dva rimska vodna sustava napajana s istog mjesta, izvora rijeke Jadro. Prvi je sustav urbane sredine, Salone, glavnoga grada antičke provincije Dalmacije iz 1. st. pr. Kr., a drugi onaj palače cara Dioklecijana iz 4. stoljeća. Ovdje se prvi put prikazuju rezultati istraživanja Salonitanskog vodovoda koji su ostvareni u prvoj godini istraživačkog projekta.

Pregled ranijih istraživanja

Najstariji tragovi prisutnosti čovjeka na području areala antičke Salone datiraju iz kasnog brončanog doba, a pronađeni su 2008. u središtu današnjeg Solina.[2] Za vrijeme željeznog doba ušće rijeke Jadro s otočićem Vranjicom bilo je važno pristanište i mjesto kontakta autohtonih Delmata i mediteranskog svijeta. Delmatska utvrđena naselja nalazila su se na

1 Oznaka projekta: HRZZ IP-11-2013-9852; Akronim projekta: RWSCSDP; voditelj: prof. dr. sc. Jure Margeta dipl. ing. građ.; istraživači: doc. dr. sc. Davor Bojanić dipl. ing. građ., dr. sc. Miroslav Katić dipl. arheolog; izv. prof. dr. sc. Katja Marasović dipl. ing. arh., doc. dr. sc. Snježana Perojević dipl. ing. arh. Sve arheološke radove i topografska snimanja obavila je tvrtka *Neir* d. o. o. iz Splita, i to: arheolozi Anita Penović i Nebojša Cingeli te geodet Klara Šolić. Kartu šireg područja Solina izradili su volonteri: mag. ing. arh. Irena Margeta, mag. ing. građ. Olgica Erceg, mag. ing. arh. Tajana Pandžić, mag. ing. arh. Anka Ban i kand. ing. građ. Nikola Marčić.

2 Šuta 2012, str. 154; Katavić 2010, str. 15.

A research project, financed by the Croatian Science Foundation, has been conducted at the Faculty of Civil Engineering, Architecture and Geodesy, University of Split on September 1st, 2014.[1] The project is envisioned to last four years. A multidisciplinary team of scientists consisting of archaeologists, architects and civil engineers has set out to investigate the two Roman water systems fed by the same source–the Jadro river spring. The first one is the water system of Salona, the capital of the ancient province of Dalmatia from the 1st century BC, while the second one is the water system of the Emperor Diocletian's palace from the 4th century AD. In this paper, the results of studying the Salonitan water supply system, obtained during the first year of the above mentioned research project, will be presented for the very first time.

Overview of Previous Studies

The earliest traces of human presence in the territory of ancient Salona's areal, which were unearthed in the centre of present-day Solin in 2008, date back to the late Bronze Age.[2] The Jadro river mouth, with the islet of Vranjic, was an important port and contact point of the indigenous Delmatae tribe and the Mediterranean world during the Iron Age. The Delmatian fortified settlements were situated at elevated positions: at Klis, Sutikva and the so-called Illyrian Salona, located at Ilijin potok, about two kilometres north of the port of Salona.[3] The first information on Salona, preserved in written historical records, date back to 119 BC, when consul Lucius Caecilius Metellus, following the conquest of Siscia, spent the winter there with his army. The oldest city, the so-called *"Urbs Quadrata",* was positioned west of the Jadro river mouth. It had a trapezoidal ground plan area of

1 Project code: HRZZ IP-11-2013-9852; Project acronym: RWSCSDP; Project manager: Professor Jure Margeta, Ph.D., B.S.Civ.Eng.; Researchers: Assistant professor Davor Bojanić, Ph.D., B.S.Civ.Eng.; Miroslav Katić, Ph.D., B.S.Arch.; Associate professor Katja Marasović, Ph.D., B.S.Arch.; Assistant professor Snježana Perojević, Ph.D., B.S.Arch. All archaeological and topographic surveys were performed by the company Neir d.o.o. from Split, namely: archaeologists Anita Penović and Nebojša Cingeli and geodesist Klara Šolić. The map of the wider area of Solin was created by volunteers: Irena Margeta, M.S.Arch.; Olgica Erceg, M.S.Civ.Eng.; Tajana Pandžić, M.S.Arch.; Anka Ban, M.S.Arch., and Nikola Marčić, candidate for M.S.Civ.Eng.

2 Šuta 2012, p. 154; Katavić 2010, p. 15.

3 Katić 2010, pp. 7-19.

uzvišenim položajima: na Klisu, Sutikvi i tzv. Ilirskoj Saloni, koja se nalazila na Ilijinu potoku, oko dva kilometra sjeverno od salonitanske luke.[3] Prve vijesti o Saloni u pisanim povijesnim izvorima datiraju iz 119. g. pr. Kr., kada je konzul Lucije Cecilije Metel, nakon zauzimanja Siscije, sa svojom vojskom u njoj prezimio. Najstariji grad, tzv. *Urbs Quadrata*, bio je smješten zapadno od ušća rijeke Jadro. Imao je trapezni tlocrtni oblik površine 15 ha i zauzimao je središnji dio buduće velike Salone.

Prije nego je od izvora rijeke Jadro sagrađen vodovod grad je vjerojatno imao uređene sustave vodoopskrbe i odvodnje otpadnih i oborinskih voda, što je bilo neophodno za normalan život. U tom se razdoblju mogla koristiti voda potoka Kapljuč,[4] koji je prolazio kroz grad, a mogla se, izgradnjom bunara, koristiti i podzemna voda koja se na tom području nalazi na maloj dubini.[5] Naime, u obalnom području slatka se voda nalazi iznad morske vode tako da je moguće koristiti te podzemne vode, što je do izgradnje suvremenog vodovoda bilo uobičajeno na području Kaštelanskog zaljeva. Ti raniji vodoopskrbni sustavi Salone bit će istraženi u drugoj godini znanstvenog projekta.

U 1. st. pr. Kr., za vrijeme Cezara, na samo 100 metara istočno od vrata najstarije jezgre grada sagrađen je kameni most na pet lukova po kojemu je lokalitet nazvan Pet mostova.[6] Na temelju analize konfiguracije terena Dyggve je pretpostavio postojanje zapadnog rukavca rijeke Jadro koji je tim mostom premošćen.[7] U okviru istraživanja 2014.-2015. godine, ponovnom analizom visinskih odnosa terena u istočnom dijelu Salone, potvrđena je Dyggveova pretpostavka, uz manju korekciju najistočnijeg dijela tog rukavca (sl. 1).

Dva luka mosta građenog istom tehnikom, koji na uzvodnoj strani pilona ima isti trokutasti element za razbijanje toka vode, pronađena su ispod istočnog bedema Salone.[8] Taj je most prelazio preko nedavno iskopanog rukavca rijeke Jadro prije nego su u 2. stoljeću na tom mjestu sagrađeni bedemi. Na pravcu iskopanog rukavca pronađena su četiri kamena pilona koja su nosila drveni most.[9] Stotinjak metara južno od

15 ha and it occupied the central part of the later, great Salona.

Prior to building the Aqueduct, fed by the Jadro river spring, the city probably had organized water supply systems, as well as wastewater and rainwater drainage systems which were essential for a normal life. At the time, it was possible to use the water of the Kapljuč creek[4] that was running through the city or, to use the groundwater that could easily be found at shallow depths in this area by constructing wells.[5] Namely, it was possible to make use of water due to the fact that underground sweet water was located above the level of sea water in the coastal area. This was a common practice in the Kaštela Bay area prior to the construction of modern water supply system. These early water supply systems of Salona are scheduled to be explored in the second year of the research project.

In the 1st century BC, during the rule of Caesar, only 100 meters east of the gate of the oldest town core, a five arches stone bridge was built, after which the site was named *Pet mostova* (*eng. Five bridges*).[6] On the basis of his analysis of the configuration of the terrain, Dyggve assumed there once existed a western armlet of the Jadro river that was spanned by this bridge.[7] During the 2014-2015 study, a re-analysis of the altitudinal ratios of the terrain in the eastern part of Salona confirmed the assumption of Dyggve, with a minor correction in the easternmost part of this river armlet. (Fig. 1)

Two arches of a bridge were found under the eastern rampart of Salona. This bridge was constructed by using an identical technique; furthermore, it had the same triangular element on the upstream side of the pillar which was used to split the flow of water.[8] This bridge spanned the recently excavated armlet of the Jadro river, prior to the erection of the aforementioned rampart in the 2nd century AD. Four stone pillars, that had carried a wooden bridge, were found on the route of the excavated armlet.[9] A culvert, surmounted by an arch, was discovered about one hundred meters south of this armlet, in the eastern rampart of Salona. All of

3 Katić 2010, str. 7-19.

4 Gerber 1917, str. 140: "Sačuvani su i ostaci vodoopskrbnog kanala starijeg zapadnog dijela grada, čiji je tok općenito odgovarao toku potoka Kapljuč…"

5 Cambi 1991, str. 7: "...voda pod tlom tvori jastuk na većem području rasprostiranja grada. S obzirom na to da se voda nalazi na maloj dubini, lako se crpi, omogućujući snabdijevanje čak i za dugotrajnih i iscrpljujućih opsada."

6 Cambi 1991, str. 466; Rendić Miočević 1991, str. 52.

7 Dyggve 1989, str. 157.

8 Mardešić 1999.

9 Jeličić-Radonić 2009, str. 308.

4 Gerber 1917, p. 140; *"The remnants of the water supply channel of the older, western part of the city have been preserved, and the channel route generally corresponds to the flow of the "Kapljuč" creek..."*.

5 Cambi 1991, p. 7; *"...the water under the soil forms a cushion at the larger part of the area the city is laid out on. Considering the water is sited at a shallow depth, it is easy to draw water, ensuring the supply even at times of long and exhausting sieges."*

6 Cambi 1991, p. 466; Rendić Miočević 1991, p. 52.

7 Dyggve 1989, p. 157.

8 Mardešić 1999.

9 Jeličić-Radonić 2009, p. 308.

tog rukavca u istočnom je bedemu Salone pronađen jedan propust za vodu presvođen lukom. Svi ovi nalazi, kao i nalazi naslaga sedre na cijelom tom području, potvrđuju više rukavaca rijeke Jadro unutar istočnog proširenja grada, tj. prostiranje delte Jadra na širem prostoru.[10] Nakon izgradnje bedema taj je prostor isušen i pretvoren u građevno zemljište, a delta Jadra potisnuta je prema jugu, na područje izvan gradskih zidina.

Očito je da je u blizini Salone bilo dovoljno vode za razne namjene. Međutim, visinski položaj vodnih resursa nije omogućavao razvoj gravitacijskog sustava opskrbe. Isto tako, moguće je da kakvoća vode nije bila dovoljno dobra za ljude jer se radi o otvorenim površinskim vodama koje je mogao onečistiti otpad iz grada kao i životinje koje su tu boravile. Zato je bilo potrebno planirati pouzdani vodoopskrbni sustav s vodom dobre i pouzdane kakvoće, koji je mogao trajno u dovoljnoj količini gravitacijski opskrbljivati cijeli grad. Sve te uvjete ispunjavao je izvor rijeke Jadro smješten na koti od oko 33 m n. m.

Na temelju natpisa na olovnim cijevima C.JUL. AN.X.,[11] *Iulius Eucarpus i C. Iulius Xantus*,[12] raniji istraživači datiraju Salonitanski vodovod u vrijeme neposredno nakon što je u 1. st. pr. Kr. Salona dobila status kolonije.[13] Smatra se da je akvedukt prestao funkcionirati u 7. stoljeću, nakon što je oštećen za vrijeme opsade grada.[14]

Koliko je do sada poznato, prvi je ostatke antičkog akvedukta Salone uočio opat Pirona, profesor iz Udina, za vrijeme svog posjeta 1842. U svojem pismu Francescu Carrari, koji je od 1842. bio ravnatelj solinskih iskopina,[15] navodi de je Salona "bila prekrivena šikarom i travom i osim ostataka vodovoda gotovo nikakvi drugi ostatci ne ukazuju prolazniku na pokopani grad".[16] Iste je godine u blizini sjevernih vrata pronađena olovna cijev vodovoda.[17] Alfonso Frisani je tijekom svog posjeta Saloni 1845. također vidio

10 Mardešić 1999, str. 151.

11 Carrara 1991, str. 125; cijev je pronađena 1842. u blizini sjevernih vrata. "Ako je Julije Cezar, koji je primio poruku o pokoravanju Delmata 45. godine prije Krista, u znak zahvalnosti je vrlo vjerojatno dao koloniji Saloni naslov Julia, vodovod i shodno tome fortifikacije bi morale biti iz tog razdoblja."

12 Gerber 1917, str. 139, CIL III 3217 1, 2 Julius Eucarpus i 3217, 3 C. Julius Xan(thus).

13 Abramić 1991, str. 42; Kähler 1991, str. 230.

14 Novak 2005, str. 42.

15 Jeličić-Radonić, Pereža 2010, str. 181.

16 Carrara 1991, str. 107.

17 Carrara 1991, str. 125.

these findings, in addition to travertine deposits discovered throughout the area, confirmed the existence of several armlets of the Jadro river within the area of the eastern enlargement of the city, i.e. the Jadro river delta was occupying a wider area than previously supposed.[10] After the erection of the rampart, the area was drained out and turned into a construction lot, and the Jadro river delta was suppressed further south, to the area outside the city walls.

Clearly, there was enough water, for various purposes, in the surroundings of Salona. However, the altitudinal position of water resources did not allow for the development of gravity fed water supply system. Furthermore, it is necessary to point out to the possibility that the water quality was not good enough for people at the time, mainly because these open surface waters might have been contaminated by the city waste, and by the animals dwelling in the area, as well. Therefore, it was necessary to plan the construction of a reliable water system to ensure good quality water, which could permanently and in sufficient quantities supply the entire city by means of the gravity. All of these conditions were met by the Jadro river spring, situated at an elevation of about 33 meters above sea level.

On the basis of the inscriptions discovered on a lead pipe, "C.JUL.AN.X.",[11] *Iulius Eucarpus and C. Iulius Xantus*,[12] earlier researchers dated the Aqueduct of Salona in the time immediately after Salona had been granted the status of a colony in the 1st century BC.[13] It is believed that the Aqueduct ceased functioning in the 7th century AD, after being damaged during the siege of the city.[14]

As far as is known, abbot Pirona, a professor from Udine, was the first who noted the remains of the ancient Aqueduct of Salona, while visiting the site in 1842. In his letter to Francesco Carrara, who acted as the director of the Salonitan excavations from 1842 onwards,[15] he stated that *"Salona is covered in coppice and grass and, in addition to the remains of the aqueduct; almost no other trace indicates the existence*

10 Mardešić 1999, p. 151.

11 Carrara 1991, p. 125; The pipe was found in 1842 near the city's northern gate. *"If Julius Caesar, who had received a message on subjugating Delmatae in 45 BC, quite likely gave the colony the title of Julia as a sign of gratitude, then the water supply system and, consequently, the fortifications should date from the same period."*

12 Gerber 1917, p. 139, CIL III 3217 1, 2 Julius Eucarpus and 3217, 3 C. Julius Xan(thus).

13 Abramić 1991, p. 42; Kähler 1991, p. 230.

14 Novak 2005, p. 42.

15 Jeličić-Radonić, Pereža 2010, p. 181.

Sl. 2. Ejnar i Ingrid Dyggve na Salonitanskom akveduktu u Majdanu (foto: Arhiv Dyggve)
Fig. 2. Ejnar and Ingrid Dyggve at the Aqueduct of Salona at Majdan (photo: Dyggve Archives)

ostatke antičkog vodovoda.[18] Carrara je 1846. započeo velika istraživanja u Saloni te je, među ostalim važnim nalazima, pronašao dijelove Salonitanskog akvedukta: "Nedaleko vratašca za nuždu u prvom traktu sjevernih zidina, ali nešto južnije, kako se vidi na planu, najduži je otkriveni dio vodovoda. Taj dio (visok 3', širok 2,2') otkrio sam 180 stopa u dužinu, a osim toga po sredini i spoj za distribuciju. Drugi ostaci vodovoda vide se duž zidina prvog sjevernog trakta, blizu sjeverozapadnog kuta, zapadno od Porta Andetria, istočno od spomenutih vrata i duž čitavog zida u kojima su Porta Cesarea. Vrijedilo bi mnogo da se istraži čitavo protezanje antičkog vodovoda, čemu bi uvelike pomogla prije spomenuta otkrića, a i mnoga druga koja su slučajno otkrili seljaci na raznim drugim mjestima."[19]

Don Frane Bulić, ravnatelj Arheološkog muzeja od 1884. do 1926., na više je mjesta zabilježio postojanje kanala Salonitanskog vodovoda. Kanal unutar Salone, koji je Carrara već ranije pronašao i zatrpao, Bulić je ponovo istražio te je do danas ostao vidljiv. Osim kanala tu je pronašao i jedno revizijsko okno te vodorazdjelnu građevinu (*castellum divisorium*) sjeverno od *Porta Suburbia II*.[20] Bulić je zabilježio i nalaze kanala prilikom poljodjelskih radova u istočnom dijelu Salone te na prostoru istočno od grada navodeći

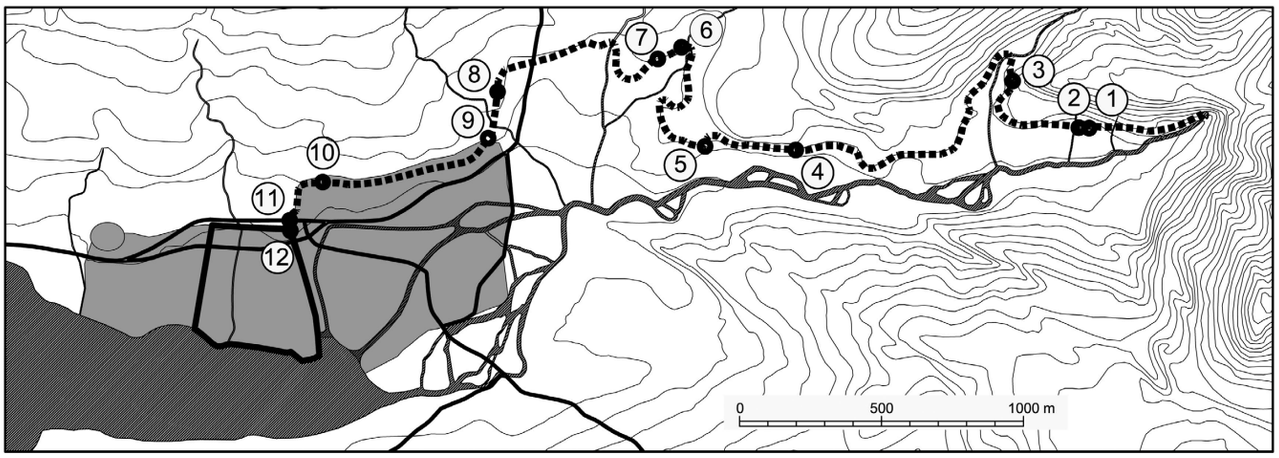
18 Carrara 1991, str. 107; dnevnik *La Dalmazia* br. 12, 1845. Rovine di Salona di Alfonso Frisani.
19 Carrara 1991, str. 163.
20 Bulić 1911, str. 68.

of the buried city to a passer-by."[16] That same year, the aforementioned water lead pipe was found near the north gate.[17] During his visit to Salona in 1845, Alfonso Frisano also noticed the remains of the ancient Aqueduct.[18] In 1846, Carrara began a large-scale archaeological excavation in Salona and, among other important findings, discovered parts of the Aqueduct of Salona: *"Near the emergency gate in the first tract of the northern ramparts, yet somewhat further south, as shown in the plan, is the longest discovered part of the water supply system. Of that part (3' high, 2,2' wide), I unearthed 180 feet in length and, in addition to this, found a distribution junction in the middle. Other remains of the Aqueduct can be seen along the ramparts of the first northern tract, near the northwest corner, west of Porta Andetria, east of the gate and along the entire rampart in which Porta Cesarea is placed. It would be much worth to explore the whole length of the ancient Aqueduct, to which the aforementioned discoveries would greatly contribute, in addition to many others accidentally made by farmers at various sites."*[19]

Don Frane Bulić, the director of the Split Archaeological Museum from 1884 to 1926, recorded the existence of the channel of the Aqueduct of Salona at multiple sites. Bulić re-explored the channel within Salona that Carrara had previously found and buried, leaving it unearthed to this very day. In addition to the channel, he also found a revision shaft and a water distribution tank (*castellum divisorium*) located north of *"Porta Suburbia II"*.[20] Bulić also recorded the discoveries of the channel made during agricultural works in the eastern part of Salona and in the area east of the city, indicating the numbers of cadastral lots on which they were found.[21] In 1908, he explored the first 200 meters of the channel, extending from the Jadro river spring towards the city, above which a new channel was built for the purpose of the "Società Annonima Spalato" cement factory and hydroelectric plant. In 1912, west of the cement factory, he also found the channel that was surmounted by a stone arch.[22]

The very first comprehensive description of the Salonitan water supply and sewage system, situated mainly within the explored part of the city, was

16 Carrara 1991, p. 107.
17 Carrara 1991, p. 125.
18 Carrara 1991, p. 107; La Dalmazia no. 12, 1845. Rovine di Salona di Alfonso Frisani.
19 Carrara 1991, p. 163.
20 Bulić 1911, p. 68.
21 Bulić 1892, p. 53; Bulić 1895, p. 78; Bulić 1899, p. 244; Bulić 1901, p. 176.
22 Bulić 1911, p. 67.



Sl. 3. Trasa Salonitanskog akvedukta s označenim sondama (izvor: autori)
Fig. 3. The route of the Aqueduct of Salona with Probees (source: authors)

brojeve katastarskih čestica na kojima su pronađeni.[21] Godine 1908. istražio je prvih 200 metara kanala, od izvora Jadra prema gradu, iznad kojega je sagrađen novi kanal za potrebe hidrocentrale tvornice cementa *Società annonima Spalato*. Godine 1912. pronašao je i kanal zapadno od tvornice cementa koji je na tom mjestu bio presvođen svodom od kamena.[22]

Prvi cjeloviti opis salonitanskog vodovoda i kanalizacije, uglavnom unutar istraženog dijela grada, dao je Gerber 1917. godine.[23] On je opisao način izgradnje kanala i njegove dimenzije te je uočio kalcifikat na njegovim stijenkama koji pokazuje do koje je razine kanal bio napunjen. Na temelju presjeka vode u kanalu i nagiba od 0,2 % prvi je put izračunao kapacitet vodovoda, koji po njemu iznosi 0,140 m^3 u sekundi, tj. 12000 m^3 na dan.

Salonitanski akvedukt istraživao je i danski arhitekt Ejnar Dyggve u sklopu svojih radova u Saloni od 1922. nadalje (sl. 2). U njegovu je arhivu na nekoliko skica zabilježen tlocrtni položaj nalaza kanala i njegov presjek. Također se može zaključiti da je on prvi uočio velike kamene pilone koji su nosili kanal akvedukta južno od *Porta Suburbia II*, tj. most akvedukta koji je poslije inkorporiran u zid istočnog proširenja grada.[24] O istome mostu akvedukta poslije su pisali Heinz Kähler[25] i Duje Rendić Miočević.[26]

21 Bulić 1892, str. 53; Bulić 1895, str. 78; Bulić 1899, str. 244; Bulić 1901, str. 176.
22 Bulić 1911, str. 67.
23 Gerber 1917, str. 140.
24 Konzervatorski odjel u Splitu, Arhiv Dyggve, Vodovod 178, DST 20/2-87. Na tom se listu na kojemu je upisana godina 1922. vidi presjek kroz most Vodovoda i gradski bedem u vratima *Porta Suburbia II*.
25 Kähler 1991, str. 230.
26 Rendić Miočević 1991, str. 58-59.

provided by Gerber in 1917.[23] He described the way the channel was constructed, noted its dimensions, and spotted the calc-sinter on its walls showing the level to which the channel was filled with water. On the basis of the cross-section of water in channel and the 0.2% slope, he calculated the capacity of the Aqueduct for the first time, which, according to him, amounted to 0.140 m^3 per second, i.e. 12 000 m^3 per day.

The Aqueduct of Salona was also explored by Danish architect Ejnar Dyggve as a part of his expedition to Salona from 1922 onwards (Fig. 2). In his archive, recorded on several sketches there is a ground plan of the positions in which the channel was discovered and its cross-section. It can also be concluded that he was the first who spotted the great stone pillars that carried the Aqueduct channel south of *"Porta Suburbia II"*, i.e. the Aqueduct bridge that was later incorporated into the walls of the eastern enlargement of the city.[24] The same Aqueduct bridge was later discussed by Heinz Kahler[25] and Duje Rendić Miočević.[26]

From the late 20th century to date, the Aqueduct of Salona was mostly the interest of the archaeologists then employed in the Conservation Department of Split, particularly Jasna Jeličić and Miroslav Katić. The Aqueduct channel on Bilankuša was found in front of the northern city rampart, and later, during various utility or construction works, at several sites

23 Gerber 1917, p. 140.
24 Conservation Department of Split, Dyggve Archives, Aqueduct 178, DST 20/2-87. In this paper, on which the year of 1922 is inscribed, we can see a cross-section through the Aqueduct bridge and the city rampart in the gates *"Porta Suburbia II"*.
25 Kähler 1991, p. 230.
26 Rendić Miočević 1991, pp. 58-59.

Sl. 4. Sonda 2 (foto: N. Cingeli)
Fig. 4. Probe 2 (photo: N. Cingeli)

Od kraja 20. stoljeća do danas Salonitanskim akveduktom najviše se bave arheolozi, tada zaposleni u splitskom Konzervatorskom odjelu, i to naročito Jasna Jeličić i Miroslav Katić. Oni su kanal akvedukta pronašli najprije na Bilankuši pred samim sjevernim gradskim zidom, a poslije i na nekoliko mjesta izvan gradskih zidina prilikom raznih komunalnih ili građevinskih radova.[27] Iz iznesenog se vidi da je Salona imala vodoopskrbni sustav uređen u skladu s pravilima struke rimskih graditelja, zasnovan na zahvatu vode s izvora rijeke Jadro. Nova istraživanja, koja su provedena 2014. i 2015., pokušaj su da se prvi put dade cjelovita slika i rekonstrukcija Salonitanskog vodovoda od izvora do grada.

Nova istraživanja

Kako bi se mogla planirati nova arheološka istraživanja, u svrhu definiranja trase Salonitanskog akvedukta trebalo je najprije objediniti sva ranija istraživanja na jednome mjestu. Zbog toga je na temelju starih geodetskih karata i novoga digitalnog katastra Solina, Mravinaca i Klisa izrađena karta šireg područja Salone u mjerilu 1 : 1000, sa slojnicama izvornog i današnjeg terena, koja je temelj za sva istraživanja i prezentiranje nalaza. Za rekonstrukciju izvorne konfiguracije terena, na mjestima gdje je ona u potpunosti preobražena eksploatacijom lapora i urbanizacijom, dragocjene su bile karte sa slojnicama iz sredine 20. stoljeća te stare fotografije i crteži. Za rekonstrukciju izvornog toka rijeke Jadro korišten je katastar iz 1831.

27 Katić 1999, str. 58-63.

outside the city walls.[27] From the stated, it can be discerned that Salona had a water supply system organized in accordance with the rules of the profession of the Roman architects, based on water intake from the Jadro river. The new studies, conducted in 2014 and 2015, are an attempt to deliver a comprehensive depiction and reconstruction of the Aqueduct of Salona from its source to the city for the first time.

New Studies

In order to be able to plan a new archaeological excavations for the purpose of defining the route of the Aqueduct of Salona, it was necessary to bring all the previous researches together. Thus, based on old topographic maps and the new digital cadastre of Solin, Mravinci and Klis, a map of the wider Salona area was made in the scale of 1:1000 with the contour lines of the original and the present terrain. The map represents the basis of all the research and presentation of the findings. For the reconstruction of the original terrain configuration in the areas where it has been completely transformed by marl exploitation and urbanization, the mid-20th century maps with contour lines were extremely valuable sources, as well as old photographs and drawings. The map of Klis territory made in 1675 by Zorzi Calergi[28] and the 1831 cadastre[29] were used for the reconstruction of the original flow of the Jadro river. (Fig. 3)

Firstly, all the channel sites, discovered by earlier researchers, were added to the map. After this, the field research began by clearing the area, and by topographic and architectural survey of the seven known and accessible parts of the ancient channel, namely, three sites within Salona (Fig. 3, no. 10, 11, 12), one at Bilankuša at the northeast corner of Salona (Fig. 3, no. 9), two in the valley of the Kamenica creek (Fig. 3, no. 6 and 7) and one on the south slope of the Glavica hill, west of the mentioned cement factory (Fig. 3, no. 4). Hence, precise ground plan and elevation data on the preserved parts of the channel were obtained. These enabled the drafting of the presumed route of the Aqueduct of Salona in a way that the channel, in its average drop of about 0.25%,[30] conformed to the configuration of the terrain. With the help of the presumed route map and GPS field measurements, a

27 Katić 1999, pp. 58-63.
28 State Archives in Zadar, Map Archives.
29 State Archives in Zadar, Venetian Cadastre No. 59.
30 Vitruvius 1997, p. 166. "*If water is conducted through channels, may their construction be as solid as possible and may the constructed channel have the drop of at least a quarter of a foot per hundred feet.*"

godine[28] te karta kliškog teritorija koju je 1675. izradio Zorzi Calergi[29] (sl. 3).

Najprije su u kartu unesena mjesta nalaza kanala svih ranijih istraživača. Nakon toga pristupilo se terenskim istraživanjima: čišćenju te geodetskom i arhitektonskom snimanju sedam poznatih i dostupnih dijelova antičkog kanala, i to: na tri mjesta unutar Salone (sl. 3; br. 10, 11, 12), na jednom mjestu na Bilankuši, na sjeveroistočnom uglu Salone (sl. 3; br. 9), na dva mjesta u dolini potoka Kamenice (sl. 3; br. 6 i 7) te na jednome mjestu na južnoj padini Glavica, zapadno od tvornice cementa (sl. 3; br. 4). Na taj su način dobiveni precizni tlocrtni i visinski podaci o sačuvanim dijelovima kanala. Oni su omogućili da se nacrta pretpostavljena trasa Salonitanskog vodovoda, i to na način da kanal u prosječnom padu od oko 0,25 %[30] prati konfiguraciju terena. Uz pomoć karte s pretpostavljenom trasom i terenskog mjerenja GPS-om obavljeno je rekognosciranje terena te je kanal pronađen na još četiri mjesta, i to: s istočne strane potoka Žakulića (sl. 3; br. 3), na južnom obronku Pozirala (sl. 3; br. 5) i na dva mjesta na Majdanu, zapadno od hidrocentrale (sl. 3; br. 1 i 2).

- SONDA 1 (Na Majdanu, zapadno od hidrocentrale - čest. zem. 1845 K. O. Klis)

Koordinate G-K projekcije[31]- X = 6 380 544.82; Y = 4 823 082.23

Na skici[32] i fotografijama koje se čuvaju u Arhivu Dyggve vide se ostaci kanala Salonitanskog vodovoda na Majdanu zapadno od hidrocentrale, na uzvisini koja je sa zapada, sjevera i istoka okružena tupinolomom. Prema pretpostavljenoj trasi kanala na tom se mjestu nalaz dna kanala očekivao na apsolutnoj koti od oko 32 metra. Nakon određivanja položaja GPS-om napravljena je sonda dimenzija 2 x 4 metra okomita na smjer pružanja kanala i u njoj je pronađen samo negativ kanala, tj. zasjek u živom kamenu i nešto antičkog vodonepropusnog morta (*opus signinum*) na prosječnoj koti od 31,50 metara.

- SONDA 2 (Na Majdanu, zapadno od hidrocentrale - čest. zem. 6454 i 1846 K. O. Klis) Koordinate G-K projekcije–X = 6 380 526.52; Y = 4 8230 81.10

terrain reconnaissance was carried out and the channel was discovered at four additional sites, namely, on the east side of the Žakulić creek (Fig. 3, no. 3), on the southern slope of Pozirala (Fig. 3, no. 5) and at two Majdan sites, west of the hydroelectric power plant (Fig. 3, no. 1 and 2).

- PROBE 1 (at Majdan, west of the hydroelectric power plant–no. 1845–Cadastral Municipality of Klis)

G-K projection coordinates[31]–X = 6 380 544.82; Y = 4 823 082.23

The sketch[32] and the photographs (Fig. 2) kept in the Dyggve Archives show the remains of the channel of the Aqueduct of Salona at Majdan, west of the hydroelectric power plant, on a hill that is surrounded by a marl mine on the north, west and east side. Based on the presumed channel route, the channel bottom at this site was expected to be found at an absolute elevation of about 32 meters. After determining the position with GPS, a probe, measuring 2 by 4 meters in size, was dug perpendicularly to the direction of the channel. Only a negative of the channel was found in it, i.e. a notch in the solid rock and some of ancient watertight mortar (*opus signinum*) at an average elevation of 31.50 meters.

- PROBE 2 (at Majdan, west of the hydroelectric power plant – no. 6454, no. 1846–Cadastral Municipality of Klis)

G-K projection coordinates–X = 6 380 526.52; Y = 4 8230 81.10

In hopes of finding better preserved remains of the channel, a new probe was dug on the western edge of the same hill, about 20 meters west of Probe 1, i.e. on the very border with the terrain owned by the "Voljak" enterprise. The approx. 5-meters-long probe was dug in the east-west direction, i.e. in the direction of the channel. Only a negative of the channel, i.e. a notch in the solid rock, was found in the western part of the probe. However, in the eastern part, discovered were several stone slabs for flattening the channel base as well as a layer of fill made of crushed stones and lime mortar, originally located between the notch and the side stone slab of the channel. The flattened base is placed at an absolute elevation of 31.66–31.69 meters.

28 Državni arhiv u Splitu, Arhiv mapa.

29 Državni arhiv u Zadru, Mletački katastar br. 59.

30 Vitruvius 1997, str. 166. "Ako se voda vodi kanalima, neka gradnja bude što čvršća i neka kanal ima pad najmanje od četvrtine stope na stotinu stopa."

31 Pozicije točaka akvedukta transformirane su u stari geodetski datum HDKS s temeljnim elipsoidom Bessel 1841 (y, x. ortometrijska visina (Trst)–H).

32 Konzervatorski odjel u Splitu, Arhiv Dyggve, Vodovod 178, DST 20/6- 87.

31 The positions of the points of the Aqueduct have been transformed in the old HDKS geodetic datum with the Bessel 1841 basic ellipsoid (y, x orthometric height (Trieste)–H).

32 Conservation Department of Split, Dyggve Archives, Aqueduct 178, DST 20/6- 87.

Sl. 5. Sonda 3 (foto: A. Penović)
Fig. 5. Probe 3 (photo: A. Penović)

U želji da se pronađu bolje sačuvani ostaci kanala otvorena je nova sonda na samom zapadnom rubu iste uzvisine, oko 20 metara zapadno od sonde 1, tj. točno na granici s terenom u vlasništvu poduzeća *Voljak*. Sonda dužine oko 5 metara postavljena je u pravcu istok-zapad, tj. u pravcu pružanja kanala. U zapadnom dijelu sonde pronađen je samo negativ kanala, tj. zasjek u živoj stijeni, a u istočnom nekoliko kamenih ploča za izravnanje podloge kanala te nabačaj lomljenog kamena u vapnenom mortu koji se izvorno nalazio između zasjeka i bočne kamene ploče kanala. Zaravnana podloga nalazi se na apsolutnoj koti 31.66 – 31.69 metara.

Sudeći po Dyggveovim fotografijama i crtežu čini se da je kanal na tom mjestu u njegovo vrijeme još bio djelomično sačuvan. Naime, na fotografiji (sl. 2) Dyggve stoji na kamenim pločama dna kanala, a dalje prema istoku vide se presječene stijenke kanala dok poklopnice nisu sačuvane (sl. 4).

SONDA 3 (Istočno od potoka Žakulić - čest. zem. 1882/1 K. O. Klis)

Koordinate G-K projekcije – X= 6 380 290,08; Y=4 823 241,59

Judging by Dyggve's photographs and drawings, it seems the channel had still been partially preserved in his time. Namely, in one of the photographs (Fig. 2) Dyggve is standing on the stone slabs of the channel bottom. In addition, the channel walls can be seen further east while the coverings hadn't been preserved at the time. (Fig. 4)

- PROBE 3 (east of the Žakulić creek – no. 1882/1 of the Cadastral Municipality of Klis)

G-K projection coordinates – X= 6 380 290.08; Y=4 823 241.59

Following the presumed route of the Aqueduct of Salona, a terrain reconnaissance was carried out along the Žakulić creek in the area where the original terrain has not been devastated by marl mines. A cross-section of the channel of the Aqueduct of Salona was found on the east side of the creek, in the area of an open building material storage. In late 2014 or early 2015,[33] the owner of this open storage slashed the natural terrain in order to create two different-level plateaus connected by a ramp, within an area of 50 to 60 meters. In doing so, he destroyed the ancient Aqueduct channel that used to be situated on his land lot. Therefore, on the border with the neighbouring lot only its cross-section remained visible. Looking through the channel opening, it can be concluded that it is still preserved further to the north, in the area of the neighbouring lot, no. 1882/2 of the Cadastral Municipality of Klis, under a meter-thick layer of soil. The same channel cross-section was also searched for at the southern border of the lot, where it has not been found at the appropriate height, which means it had already been destroyed.

The discovered cross-section of the channel was quite deformed due to recent demolition. At this site, the channel was built by using unusually thin slabs of rubble stones. The slabs of the channel sides and bottom were 8 to 10 cm thick, while the covering measured 13 cm in thickness. Unlike the channels found in other sections of the Aqueduct of Salona, here the side slabs do not rely on the bottom slab, but are leaning sideways against it. Also, only here, the whole channel is plastered. In addition to the angular gasket, the channel bottom is also plastered with two layers of watertight ancient mortar (*opus signinum*) of a total thickness of 10 cm. The side slabs are plastered along their whole height with total thickness of 2 cm. The stone slab of the channel bottom rests directly on a flattened solid rock of marl. Unevenly stacked rubble stones are laid in lime mortar behind the side slabs.

33 The storage was not recorded in the ARKODA orthophotography of July 4th, 2014.

Sl. 6. Sonda 4 (foto: K. Marasović)
Fig. 6. Probe 4 (photo: K. Marasović)

Sl .7. Sonda 5 (foto: K. Marasović)
Fig. 7. Probe 5 (photo: K. Marasović)

Prateći pretpostavljenu trasu Salonitanskog akvedukta, obavljeno je rekognosciranje terena uz potok Žakulić na prostoru gdje izvorni teren nije devastiran tupinolomima. S istočne strane potoka, na prostoru otvorenog skladišta građevinskog materijala, pronađen je presječeni kanal Salonitanskog vodovoda. Naime, krajem 2014. ili početkom 2015. godine[33] vlasnik tog otvorenog skladišta zasjekao je prirodni teren kako bi na površini od 50 na 60 metara stvorio dva platoa na različitim razinama povezana rampom. Tom je prilikom porušio kanal antičkog vodovoda koji se nalazio na njegovoj parceli, pa je na granici prema susjednoj parceli ostao vidljiv samo njegov presjek. Gledajući kroz otvor kanala, može se zaključiti da je on sačuvan dalje prema sjeveru na prostoru susjedne parcele čest. zem. 1882/2 K. O. Klis, ispod metar debelog sloja zemlje. Za istim se presjekom kanala tragalo i na južnoj granici parcele, gdje na odgovarajućoj visini on nije pronađen, što znači da je na tom mjestu uništen već ranije.

Presjek kanala pronađen je poprilično deformiran, što je posljedica nedavnog rušenja. Na tom je mjestu kanal sagrađen od neuobičajeno tankih ploča lomljenog kamena. Ploče bokova i dna kanala debljine su 8 do 10 cm, a poklopnica 13 cm. Za razliku od kanala koji su pronađeni na drugim mjestima Salonitanskog vodovoda, ovdje se bočne ploče ne oslanjaju na podnu ploču, već su prislonjene bočno uz nju. Isto tako samo je ovdje cijeli kanal ožbukan. Osim ugaonog brtvila vodonepropusnom je antičkom žbukom (*opus signinum*) ožbukano dno kanala, i to u dva sloja ukupne debljine 10 cm te bočne ploče po cijeloj visini u debljini od 2 centimetra. Kamena ploča dna kanala

The dimensions of the clear opening of the plastered part of the channel measure 70/92, and the bottom is at an absolute elevation of 31.17 meters. (Fig.5)

- PROBE 4 (west of the cement factory – no. 2788/2 of the Cadastral Municipality of Klis)

G-K projection coordinates – X = 6 379 531.90; Y = 4 822 998.49

On the southern slope of the Glavica hill, north of the entrance to the "Cemex" factory complex, preserved is a 12-meters-long retaining wall of the Salonitan Aqueduct.[34] It was built of massive blocks of rubble stones on an extremely steep terrain. Therefore, the retaining wall height exceeds 3 meters. The 40 to 60 cm high blocks were laid in a mildly steep slope to ensure a better stability of the wall. The channel bottom made of 30 cm thick stone slabs is preserved above the retaining wall. At the eastern end of the channel, the fill was removed in order to determine its cross-section. On this occasion, a 15-20 cm thick side slab was found, inclined towards the middle of the channel due to the pressure of the soil from above, i.e. from its north side. Behind the slab, towards the notch in the terrain, is a layer of fill made of rubble stones and lime mortar. The remains of an angular gasket made of watertight mortar (*opus signinum*) are visible on the bottom channel slab, on both sides. In view of this, the width of the channel can be determined, and it amounts to 100 cm. The channel bottom at this point is at an absolute elevation of 28.27 meters. (Fig. 6)

- PROBE 5 (channel remains at Pozirala – no. 2770 of the Cadastral Municipality of Klis)

33 Skladište nije zabilježeno na ortofotografiji ARKODA od 4. 7. 2014.

34 Katić 1999, p. 59.

oslonjena je izravno na zaravnani živac od lapora, a iza bočnih ploča grubo je složeno lomljeno kamenje u vapnenom mortu. Dimenzija svijetlog otvora ožbukanog dijela kanala je 70/92, a dno je na apsolutnoj koti 31,17 metara (sl. 5).

- SONDA 4 (Zapadno od tvornice cementa - čest. zem. 2788/2 K. O. Klis)

Koordinate G-K projekcije – X = 6 379 531.90; Y = 4 822 998.49

Na južnoj padini brda Glavice, sjeverno od ulaza u tvornički kompleks *Cemexa*, sačuvao se zidani nosač Salonitanskog vodovoda u dužini od 12 metara.[34] Sagrađen je od masivnih blokova lomljenog kamena na izrazito strmom terenu tako da visina nosača iznosi više od 3 metra. Blokovi visine 40 do 60 cm slagani su u blagom stepenastom pokosu kako bi osigurali stabilnost zida. Nad nosačem se sačuvalo dno kanala od kamenih ploča debljine 30 cm. Na istočnom kraju kanala uklonjen je nasuti materijal kako bi se mogao utvrditi njegov presjek te je tom prigodom pronađena bočna ploča, debljine 15-20 cm, nagnuta prema sredini kanala zbog pritiska zemlje s gornje, odnosno sjeverne strane. Iza ploče, prema zasjeku u terenu, nabačaj je lomljenog kamena u vapnenom mortu. Na donjoj ploči kanala, s obje strane, vide se tragovi ugaonog brtvila od vodonepropusnog morta (*opus signinum*) pa se zahvaljujući tomu može odrediti širina kanala, koja iznosi 100 cm. Dno kanala na tom mjestu je na apsolutnoj koti 28,27 metara (sl. 6).

- SONDA 5 (Ostaci kanala na Poziralima - čest. zem. 2770 K. O. Klis)

Koordinate G-K projekcije – X = 6 379 206.69; Y = 4 823 011.83

Prateći dalje prema zapadu pretpostavljenu trasu vodovoda, na južnim obroncima Pozirala pronađen je ostatak gornjeg, odnosno sjevernog zida kanala u dužini od 4 metra, jedini ostatak kanala koji su u dužini od 20 metara porušili vlasnici parcele prilikom uređenja kolnog pristupa svojim kućama. Iako je u lošem stanju on se sačuvao do danas zahvaljujući tomu što služi kao potporni zid gornje terase terena. U razgovoru s vlasnicima parcele saznali smo da bi se ostaci kanala vodovoda mogli očekivati dalje prema zapadu.

Sačuvani dio kanala zapravo je nabačaj lomljenog kamena u vapnenom mortu s dodatkom tučene opeke koji je izvorno stajao između bočne kamene ploče kanala i zasjeka u prirodnom terenu, na ovome mjestu od lapora (sl. 7).

34 Katić 1999, str. 59.

Sl. 8. Sonda 6 (foto: Z. Sunko)
Fig. 8. Probe 6 (photo: Z. Sunko)

G-K projection coordinates – X = 6 379 206.69; Y = 4 823 011.83

Following the presumed route of the Aqueduct of Salona further to the west, the rest of the upper i.e. northern channel wall, in a length of 4 meters, was found on the southern slope of Pozirala. It is the only remainder of the channel that was, in a length of 20 meters, demolished by the land owners during the construction of a vehicle access to their homes. Although in poor condition, it has been preserved to date, owing to the fact that it still serves as a retaining wall of the upper terrace of the terrain. In an interview with the land owners, we learned that the remains of the Aqueduct channel could perhaps be found further to the west.

The preserved part of the channel is actually a fill made of rubble stones and lime mortar with the addition of brick, which was originally placed between the side stone slab of the channel and the notch in the natural marl terrain. (Fig. 7)

- PROBE 6 (west of the Kamenica creek – no. 2869 of the Cadastral Municipality of Klis)

G-K projection coordinates – X = 6 379 123.92; Y = 4 823 359.26

In 2004, the Conservation Department of Split was conducting archaeological excavations in the area of the Kamenica creek in Solin due to potential construction works at this site, and on this occasion found a perfectly preserved, 15-meters-long channel of the Aqueduct of Salona with the coverings and a revision shaft. During the 2004 excavations, the archaeologists removed the westernmost channel covering in order to explore its cross-section. Due to the fact the planned construction works were never actually undertaken, in January 2015 the probe was cleared of vegetation and topographically and architecturally surveyed in detail.

Sl. 9a. Sonda 7 (foto: Z. Sunko)
Fig. 9a. Probe 7 (photo: Z. Sunko)

- SONDA 6 (zapadno od potoka Kamenica - čest. zem. 2869 K. O. Klis)

Koordinate G-K projekcije – X = 6 379 123.92; Y = 4 823 359.26

Godine 2004. splitski je Konzervatorski odjel proveo arheološka istraživanja na području Kamenica u Solinu zbog moguće gradnje na tom mjestu te je tom prilikom pronađen izvrsno sačuvan kanal Salonitanskog akvedukta u dužini od 15 metara zajedno s poklopnicama i jednim revizionim oknom. U istraživanjima godine 2004. arheolozi su otklopili najzapadniju poklopnicu kanala da bi mogli istražiti njegov presjek. Kako do gradnje na tom mjestu ipak nije došlo, u siječnju 2015. je sonda očišćena od raslinja i detaljno geodetski i arhitektonski snimljena.

Kanal je izgrađen u zasjeku na gotovo ravnom terenu koji se blago spušta prema potoku Zakulić na jugoistoku. Uzdužna os kanala na ovome je mjestu izrazito zakrivljena i najmanji radijus iznosi 10 metara. U istočnom dijelu sonde pronađeno je revizijsko okno presjeka 62/62 cm. Kanal od velikih kamenih ploča s jugoistočne, odnosno donje strane obzidan je priklesanim kamenom manjeg formata tvoreći tako zid ukupne debljine 63 cm, a sa sjeverozapadne, odnosno gornje strane pronađen je nabačaj kamena u vapnenom mortu iza bočne ploče kanala koji je na vrhu širok 77 cm. Kompletna zidana konstrukcija kanala leži na masivnoj ploči debljine 20 cm, koja je ujedno i dno kanala. U unutrašnjosti, iznad bočnih ploča visine 87 do 109 cm, položena su dva reda pločastog kamena nad kojima leži poklopnica debljine 20 cm. Neke su poklopnice duže od 2 metra, tako da na pojedinim mjestima prelaze širinu cijele zidane konstrukcije kanala. Dimenzije svijetlog otvora kanala su 62/121 cm, a dno je na koti 26,23 metara (sl. 8).

- SONDA 7 (Zapadno od potoka Kamenica - čest. zem. 2872/1 K. O. Klis)

Sl. 9b. Sonda 7 (foto: Z. Sunko)
Fig. 9b. Probe 7 (photo: Z. Sunko)

The channel was built in a notch on an almost flat terrain that slopes mildly towards the Kamenica creek on the southeast. At this site, the longitudinal axis of the channel is highly curved and its smallest radius measures 10 meters. In the eastern part of the probe, a revision shaft of a 62/62 cm cross-section was found. The channel was made of large stone slabs. On its southeast side, i.e. the lover side, the channel is walled by the smaller-format rough cut stone, thus creating a wall of a total thickness of 63 cm. Furthermore, on the north-west side, i.e. the upper side, a layer of fill made of rubble stones and lime mortar was found behind the channel side slab, which is 77 cm wide at the top.

The complete masonry structure of the channel lies on a 20 cm thick massive slab, which is also the bottom of the channel. Inside it, just above the 87-109 cm high side slabs, there are two rows of flat stone, over which lies the 20 cm thick covering. Particular coverings are longer than 2 meters hence, exceeding the width of the entire masonry construction of the channel on certain positions. The dimensions of the channel's clear opening are 62/121 cm, and the bottom is at an elevation of 26.23 meters. (Fig. 8)

Sl. 10. Sonda 9 (foto: Z. Sunko)
Fig. 10. Probe 9 (photo: Z. Sunko)

Koordinate G-K projekcije – X = 6 379 048.47; Y = 4 823 323.55

Osamdeset metara zapadno od sonde 6 sačuvan je kanal akvedukta u nekoliko segmenata u ukupnoj dužini od oko 40 metara u obliku podzida polja.[35] Na licu podzida može se razlučiti izvorno zide i kasniji popravci. Izvorni zid sazidan je od pločastog lomljenog kamena manjeg formata. Na jednome mjestu sačuvao se čak i antički vapneni mort s mljevenom opekom kojim je zid bio ožbukan. Na sredini spomenutog podzida nalazi se otvor koji vodi u malo poljsko spremište smješteno unutar kanala akvedukta. Unutar tog spremišta u zapadnom dijelu sačuvao se izvorni presjek. Iznad bočnih ploča visine 90 cm položena su dva do tri reda pločastog kamena nad kojima leži poklopnica kanala debljine 24 cm. Na spoju ploča dna i bokova vide se tragovi ugaonog brtvila od vodonepropusnog antičkog morta trokutastog presjeka približnih dimenzija 10 x 20 cm. Ploča dna kanala debljine 11 cm položena je izravno na zaravnani živac od lapora. Dimenzije svijetlog otvora kanala su 70 x 119 cm, dno je na koti 25,91 m, a visina kalcifikata je 57 centimetara.

Na oko 60 metara zapadno od spomenutog spremišta nastavak istog vodovodnog kanala mogao se vidjeti u antičkoj cesti prije asfaltiranja (ulica Mezanovci, čest. zem. 6383/4 K. O. Klis)[36] (sl. 9).

-SONDA 8 (Zapadno od ceste Solin Klis - čest. zem. 4622/2 K. O. Solin)

Koordinate G-K projekcije – X = 6 378 475.80; Y = 4 823 203.75

Prije desetak godina, prilikom građevinskih radova u dvorištu kuće u Trpimirovoj ulici, uočeni su ostaci

35 Katić 1999, str. 59.

36 Prema zaštitnim istraživanjima J. Jeličić-Radonić i M. Katića.

Sl. 11. Sonda 10 (foto: K. Marasović)
Fig. 11. Probe 10 (photo: K. Marasović)

- PROBE 7 (west of the Kamenica creek – no. 2872/1 of the Cadastral Municipality of Klis)

G-K projection coordinates – X = 6 379 048.47; Y = 4 823 323.55

Several segments of the Aqueduct channel used as a field retaining wall, with a total length of about 40 meters, are preserved 80 meters west of Probe 6.[35] On the retaining wall facade, the original masonry can be distinguished from subsequent repairs. The original wall was built of smaller-format flat rubble stones. Preserved is even the ancient lime mortar with ground bricks with which the wall was plastered. In the middle of the retaining wall is an opening that leads to a little campestral storage, situated inside the Aqueduct channel. Within this storage, in its western part, the original cross-section is preserved. Two to three rows of flat stones, over which lies a 24 cm thick channel covering, are placed above the 90 cm high side slabs. At the junction of the bottom slab and the side slabs, there are traces of an angular gasket. The gasket, measuring approximately 10 by 20 cm, is made of watertight ancient mortar and has a triangular cross-section. The 11 cm thick channel bottom slab is rested directly on a flattened solid rock of marl. The dimensions of

35 Katić 1999, p. 59.

Sl. 12. Sonda 11 (foto: N. Marčić)
Fig. 12. Probe 11 (photo: N. Marčić)

Sl. 13. Sonda 12 (foto: N. Marčić)
Fig. 13. Probe 12 (photo: N. Marčić)

kanala Salonitanskog akvedukta u jugoistočnom uglu parcele. Nažalost, zbog vlasničkih odnosa kanal se nije mogao u cijelosti istražiti i dokumentirati.[37]

- SONDA 9 (Sjeverozapadni ugao bedema Salone - čest. zem. 8222 K. O. Solin)

Koordinate G-K projekcije – X = 6 378 443.78; Y = 4 823 038.61

Godine 1998. splitski je Konzervatorski odjel pronašao u temeljima Bulićeva Puta mira na Bilankuši ostatak antičkog kanala Salonitanskog akvedukta u dužini od 4 metra, i to točno ispred sjevernoga gradskog bedema. Prilikom uređenja lokaliteta kanal je inkorporiran u novo stubište radi lakšeg prilaza bedemima Salone.[38]

Zidani nosač kanala visine 1,40 metara temeljen je na živcu (laporu), a sastoji se od više slojeva masivnih ploča lomljenog kamena u vapnenom mortu s obilnim dodatkom drobljene opeke. I ovdje zidani nosač ide u blagom stepenastom pokosu. Debljina kamenih ploča dna kanala varira od 12 do 20 cm. Sačuvane su samo ploče zapadnog zida, dok istočni zid i poklopnica nisu sačuvani. Širinu kanala moguće je utvrditi zahvaljujući tragovima morta ugaonog brtvila na donjoj ploči. Na donjoj ploči i bočnim pločama sačuvale su se i naslage kalcifikata. Širina svijetlog otvora kanala je 88 cm, dno je na koti 19,27 m, a visina kalcifikata je 50 centimetara (sl. 10).

SONDA 10 (Kanal sjeverno od termi u Saloni - čest. zem. 5235 K. O. Solin) Koordinate G-K projekcije – X = 6 377 858.69; Y = 4 822 884.11

the channel's clear opening are 70 by 119 cm, the bottom is at an elevation of 25.91 m, and the height of the calc-sinter measures 57 cm.

At about 60 meters west of the storage, a continuation of the same Aqueduct channel could be seen in the ancient road before its paving (*Ulica Mezanovci*, no. 6383/4 of the Cadastral Municipality of Klis).[36] (Fig. 9)

- PROBE 8 (west of the Solin-Klis road – no. 4622/2 Of the Cadastral Municipality of Solin)

G-K projection coordinates – X = 6 378 475.80; Y = 4 823 203.75

About ten years ago, during the construction works in a yard in *Trpimirova ulica*, the remains of the Salonitan Aqueduct channel were spotted in the southeastern corner of the land lot. Unfortunately, due to disputes between proprietors, the channel could not have been fully explored and documented.[37]

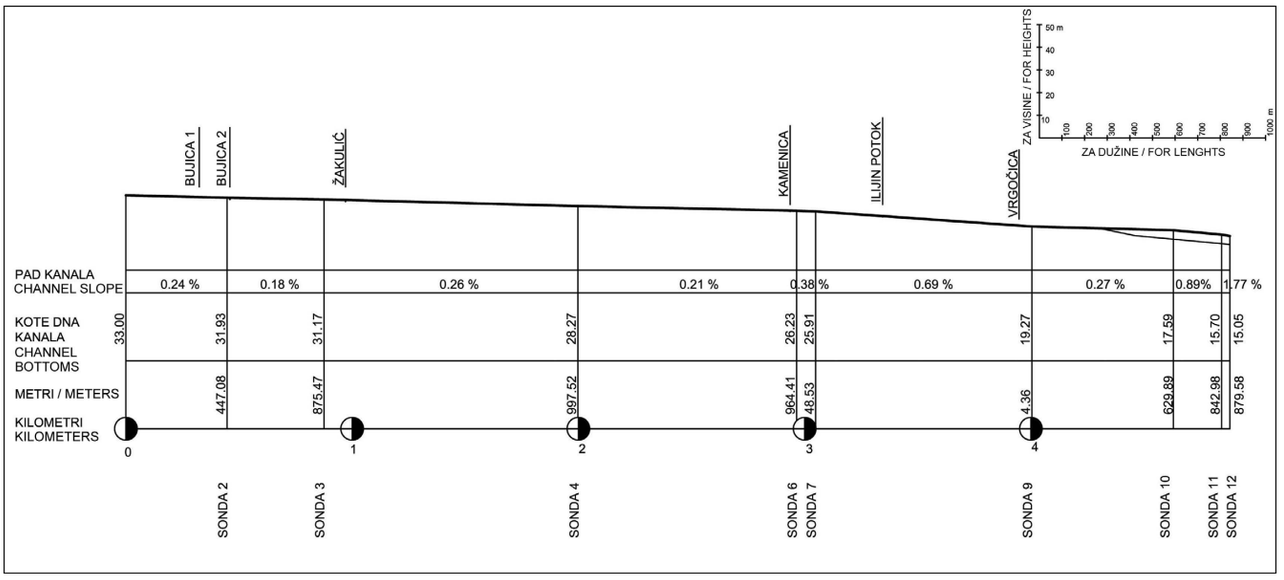
- PROBE 9 (northwest corner of the ramparts of Salona – no. 8222 of the Cadastral Municipality of Solin)

G-K projection coordinates – X = 6 378 443.78; Y = 4 823 038.61

In 1998, in the foundations of Bulić's *Put mira (eng. Path of Piece)* at Bilankuša, the Conservation Department of Split found the remains of the ancient Salonitan Aqueduct channel in a length of 4 meters, placed right in front of the northern town rampart. Upon the arrangement of the archaeological site, the

37 Prema zaštitnim istraživanjima J. Jeličić-Radonić i M. Katića.
38 Katić 1999, str. 60.

36 Based on the preservation excavations by J. Jeličić-Radonić and M. Katić.
37 Based on the preservation excavations by J. Jeličić-Radonić and M. Katić.



Sl. 14. Uzdužni profil Salonitanskog vodovoda (izvor: autori)
Fig. 14. Longitudinal profile of the Aqueduct of Salona (source: authors)

Unutar zidina Salone, sjeverno od termi očišćen je kanal akvedukta kako bi se precizno utvrdio njegov presjek. Kanal je sazidan od masivnih ploča lomljenog kamena te je s južne strane obzidan priklesanim kamenom manjeg formata ukupne širine 82 cm. Sa sjeverne strane iza bočne ploče nalazi se nabačaj lomljenog kamena u vapnenom mortu čija ukupna visina na vrhu iznosi 100 cm. Poklopnica je debela 30 cm. Na stijenkama je debeli sloj kalcifikata. Dimenzije svijetlog otvora kanala su 80/120, dno je na koti 17,59 m, a visina kalcifikata je 91 centimetar (sl. 11).

SONDA 11 (Južno od *Porta Suburbia II* - čest. zem. 8222 K. O. Solin)

Koordinate G-K projekcije – X = 6 377 743.97; Y = 4 822 752.20

Južno od *Porta Suburbia II* unutar gradskog zida vidi se kanal akvedukta u presjeku. Kanal je građen od masivnih ploča lomljenog kamena, a s obje vanjske strane bio je obzidan zidom od pločastog kamena manjeg formata, širine 70 centimetara. Debljina zapadne bočne ploče kanala iznosi 24 centimetra. Cijela konstrukcija kanala položena je na kameni most koji će biti opisan u poglavlju *Značajke Salonitanskog vodovoda*. I ovdje se na stjenkama sačuvao debeli sloj kalcifikata. Dimenzije svijetlog otvora kanala su 70/72 cm, dno je na koti 15,70 m, a kalcifikat je visine 52 centimetara (sl. 12).

SONDA 12 (u blizini *Porta Cesarea* - čest. zem. 5271 K. O. Solin)

Koordinate G-K projekcije – X = 6 377 746.11; Y = 4 822 715.71

channel was incorporated into the new staircase for easier access to the ramparts of Salona.[38]

The 1.40 meters high retaining wall has a foundation on a solid rock (marl) and consists of multiple layers of massive slabs of rubble stones laid in lime mortar with a profuse addition of crushed bricks. The retaining wall is built on a mildly steep slope. The thickness of the channel stone slabs varies from 12 to 20 cm. Preserved are only the western wall slabs, unlike the eastern wall and the covering. The channel width can be determined on the basis of the angular gasket mortar traces on the bottom slab. Calc-sinter is preserved on the bottom and side slabs. The channel's clear opening amounts to 88 cm, the bottom is at an elevation of 19.27 m, and the height of the calc-sinter measures 50 cm. (Fig. 10)

- PROBE 10 (channel remains north of the ancient baths in Salona – no. 5235 of the Cadastral Municipality of Solin)

G-K projection coordinates–X = 6 377 858.69; Y = 4 822 884.11

Within the ramparts of Salona, north of the ancient baths, the Aqueduct channel has been cleared of vegetation in order to precisely determine its cross-section. The channel has the overall width of 82 cm. It was constructed of massive slabs of rubble stones and, on its south side, walled by smaller-format rough cut stones. On the north side, behind the side slab, there is a layer of fill made of rubble stones and lime mortar, the total width of which measures 100 cm at

38 Katić 1999, p. 60.

Sl. 15. Izvor Jadra prije rekonstrukcije Dioklecijanovog Akvedukta krajem 19. stoljeća (foto: Muzej grada Splita)
Fig. 15. The Jadro river spring prior to the reconstruction of the Diocletian's Aqueduct at the end of the 19th century (photo: City Museum of Split)

Posljednja dionica sačuvanog kanala Salonitanskog akvedukta ide vrhom istočnoga gradskog zida *Urbs Quadrata* sjeverno od *Porta Cesarea*. Na tom je mjestu u dužini od 8,5 metara sačuvano samo dno kanala od antičkih tegula širine 82 cm sa debelim slojem kalcifikata. Kako je samo na ovom mjestu kanal sagrađen od tegula, može se zaključiti da je taj posljednji segment kanala kasnija intervencija, vjerojatno vezana za preuređenje *Porta Cesarea* početkom 1. stoljeća[39] (sl. 13).

Obavljena istraživanja omogućila su dobru rekonstrukciju trase kanala, visinskih odnosa te upoznavanje s različitim načinima gradnje, koji su bitno ovisili o lokalnoj situaciji na terenu, odnosno uvjetima gradnje. Financijska sredstva nisu nam omogućila istraživanje još nekih lokacija kanala, što bi svakako bilo dobro, i to osobito na mjestima gdje on nije devastiran.

39 Kähler 1991, str. 229.

Sl. 16. Most Akvedukta južno od "Porta Suburbia II" (foto: autori)
Fig. 16. Aqueduct bridge south of "Porta Suburbia II" (photo: authors)

the top. The covering is 30 cm thick. There is also a thick layer of calc-sinter on the walls. The dimensions of the channel's clear opening are 80/120, the bottom is at an elevation of 17.59 m, and the height of the calc-sinter is 91 cm. (Fig. 11)

- PROBE 11 (south of *"Porta Suburbia II"*- no. 8222 of the Cadastral Municipality of Solin)

G-K projection coordinates –X = 6 377 743.97; Y = 4 822 752.20

South of *"Porta Suburbia II"*, within the city walls, we can see the Aqueduct channel in its cross-section. The channel, 70 centimetres wide, was constructed of massive slabs of rubble stones, and walled on both sides with a smaller-format flat stone. The thickness of the western side slab of the channel measures 24 centimetres. The whole channel construction is laid upon a stone bridge, which will be later on described in the chapter "Aqueduct Characteristics". A thick layer of calc-sinter is also preserved here, on the channel walls. The dimensions of the channel's clear opening measure 70/72 cm, the bottom is at an elevation of 15.70 metres, and the height of the calc-sinter amounts to 52 centimetres. (Fig. 12)

PROBE 12 (near *"Porta Cesarea"* – no. 5271 of the Cadastral Municipality of Solin)

G-K projection coordinates – X = 6 377 746.11; Y = 4 822 715.71

The last section of the preserved Aqueduct of Salona sprawls across the top of the eastern city rampart *"Urbs Quadrata"*, north of *"Porta Cesarea*". At this site, in the length of 8.5 meters, preserved is only the channel bottom made of ancient *tegulae,* the width of which measures 82 centimetres, with a thick layer of

Sl. 17. Vodorazdjelna građevina južno od "Porta Suburbia II"
Fig. 17. Water-distribution tank south of "Porta Suburbia II"

Značajke salonitanskog vodovoda

Novim istraživanja Salonitanskog vodovoda u velikoj je mjeri definirana njegova trasa od izvora Jadra do sjeveroistočnog ugla najstarije jezgre Salone. Pokazala se ispravnom pretpostavka da trasa vijuga prateći konfiguraciju terena te da nisu građeni mostovi i tuneli kako bi se trasa skratila. Razlog tome je vjerojatno dobar/dovoljan visinski položaj zahvata vode na izvoru Jadra, koji je omogućavao gravitacijsku opskrbu vodom grada Salone. Dužina akvedukta od izvora Jadra do zadnje sačuvane točke sjeverno od *Porta Cesarea* iznosi 4879 m, dok zračna udaljenost između te dvije točke iznosi 3238 metara.

Na velikom dijelu kanala uzdužni je pad uobičajen za antičke akvedukte i varira od 0,18 do 0,27 %. Međutim, dionica između sonda 7 i 9 ima prosječni uzdužni pad od 0,69 %, što značajno odudara od ostatka trase pa bi tu dionicu trebalo dodatno istražiti i utvrditi razloge takvog pada (sl. 14). Isto tako, posljednji dio kanala u dužini od 250 metara ima veliki nagib, što također treba dodatno istražiti i objasniti.

Na izvoru Jadra nisu sačuvane antičke zahvatne građevine (*castellum fontis*) ni salonitanskog ni Dioklecijanovog akvedukta, pa je za početnu točku kanala Salonitanskog vodovoda uzeta visina rekonstruiranog Dioklecijanovog, koja je na apsolutnoj koti 33,00 metra.[40] Na fotografiji izvorišta prije rekonstrukcije Dioklecijanovog vodovoda (sl. 15) ne vide se antičke građevine već samo urušeni materijal Dioklecijanova kanala na lijevoj obali rijeke. Rekonstrukcijom Dioklecijanova vodovoda krajem 19. stoljeća i calc-sinter. Considering the channel was built of *tegulae* exclusively at this site, it can be concluded that this last section of the channel is a later intervention likely related to the renovation of *"Porta Cesarea"* at the beginning of the 1st century.[39] (Fig. 13)

The conducted study enabled a fine reconstruction of the channel route and the height relationships of its integral parts, as well as familiarising with the different construction methods that significantly depended on the actual terrain conditions of the sites, i.e. building conditions. At some additional channel sites no archaeological excavations was conducted due to lack of funding, which certainly would have been a good idea, particularly at the sites where the channel has not been devastated yet.

Aqueduct Characteristics

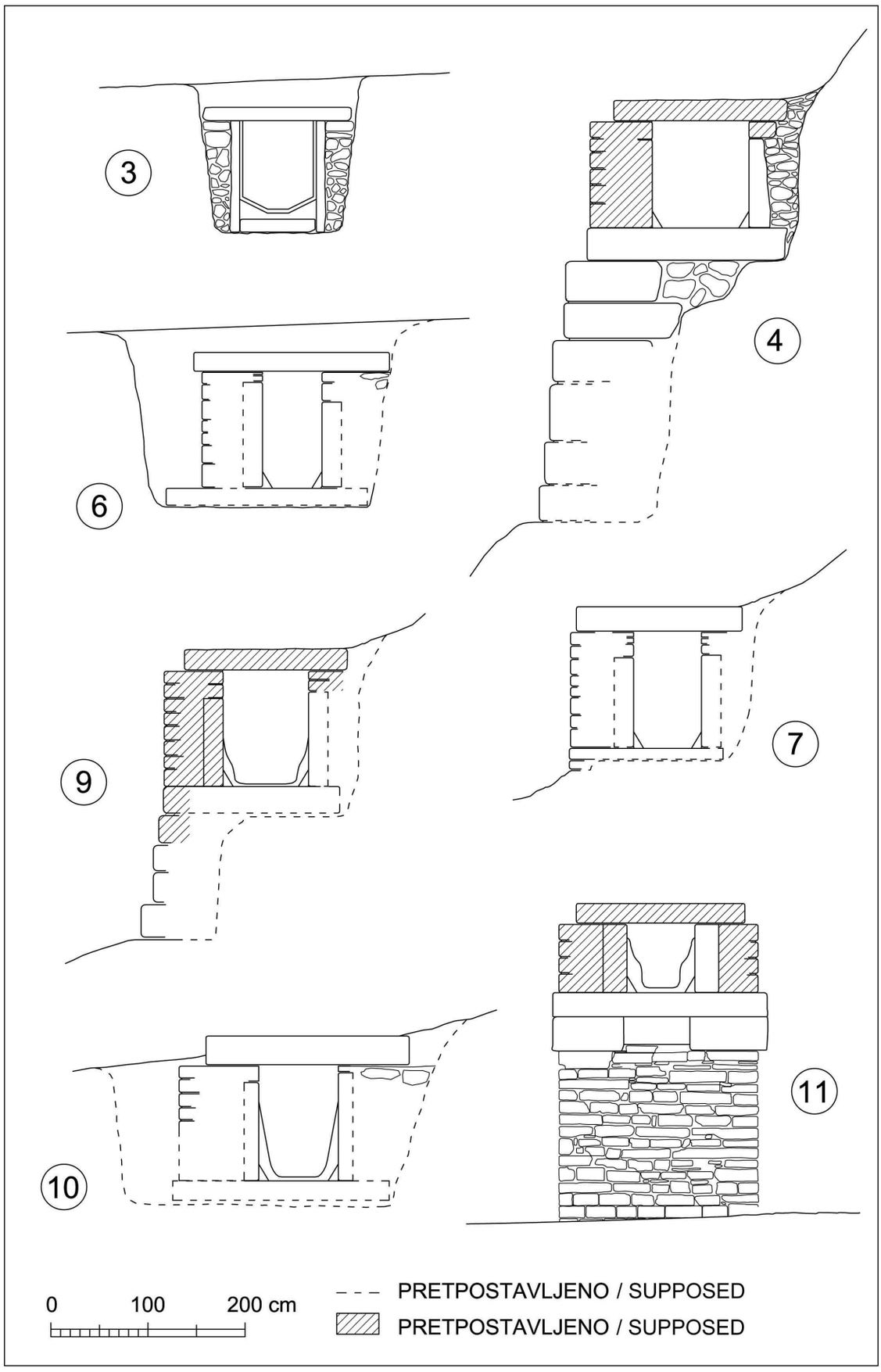
Due to the new study of the Aqueduct of Salona, its route from the Jadro river spring to the north-eastern corner of the oldest core of Salona has been defined to a large extent. The assumption that the route extended following the configuration of the terrain has proven to be correct, meaning there weren't bridges and tunnels built to shorten the route. The reason for this was probably a good/sufficient height position of the water intake at the Jadro river spring that allowed for the gravity fed water supply of the city of Salona. The Aqueduct length from the Jadro river spring to its last preserved point north of *"Porta Cesarea"* measures 4879 m, while the straight-line distance between these two points amounts to 3238 meters.

At most parts of the channel, there is a longitudinal drop typical of ancient aqueducts, and it varies from 0.18 to 0.27%. However, the section between Probe 7 and Probe 9 has an average longitudinal drop of 0.69%, which significantly differs from the rest of the route, so this section should be further explored in order to identify the reasons for such a drop. (Fig. 14) Moreover, the last section of the channel in a length of 250 meters has a large slope, which should also be further explored and explained.

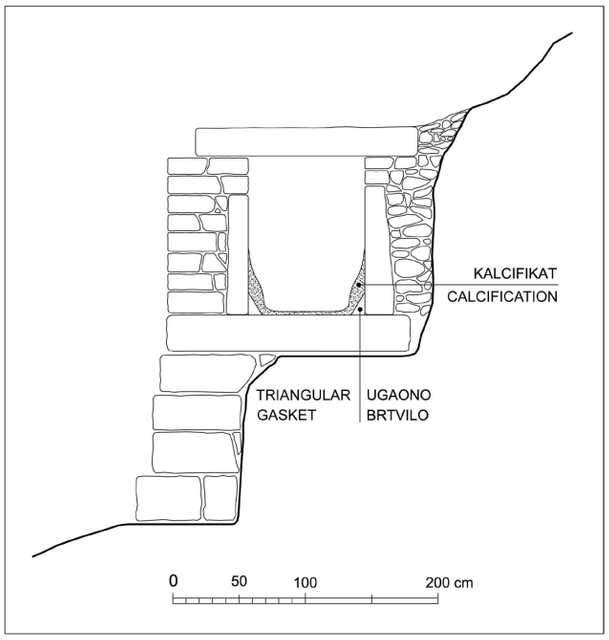
Ancient intake structures (*castellum fontis*) neither of the Aqueduct of Salona nor of the Diocletian's Aqueduct have been preserved at the Jadro river spring, so the height of the reconstructed Diocletian's Aqueduct, at an absolute elevation of 33.00 meters, was taken as its starting point.[40] In a photo of the Jadro river spring, dated before the reconstruction of the Diocletian's Aqueduct (Fig. 15), no Roman buildings can be seen, just the ruins of the Diocletian's channel

40 Katanić, Gojković 1972, str. 268.

39 Kähler 1991, p. 229.
40 Katanić, Gojković 1972, p. 268.



Sl. 18. Poprečni profili Salonitanskog vodovoda (izvor: autori)
Fig. 18. Cross-sections of the Aqueduct of Salona (source: authors)



Sl. 19. Rekonstrukcija karakterističnog poprečnog profila – Sonda 9 (izvor: autori)
Fig. 19. Reconstruction of a characteristic cross-section – Probe 9 (source: authors)

izgradnjom kanala hidrocentrale 1908. te raznim kasnijim intervencijama antički su ostaci prekriveni ili uništeni. Kako je izgledala zahvatna građevina Salonitanskog i Dioklecijanovog vodovoda može se samo pretpostaviti.

Na svojem je putu kanal Salonitanskog akvedukta na šest mjesta prelazio potoke ili bujice, relativno uskih korita, koji se ulijevaju u Jadro. Na tim su mjestima vjerojatno postojali kraći mostovi ili neke druge građevine kojima su se svladavale ove depresije (sifon i slično). Dosad ove građevine nisu pronađene te će se pokušati istražiti u nastavku istraživanja.

Posljednja dionica kanala vodovoda, pred samim gradom, u dužini od oko 25 metara bila je položena na most[41] jer na tome mjestu teren naglo pada (sl. 16). Most je bio sagrađen od kamenih zidanih pilona tlocrtnih dimenzija 185 x 205 cm, na koje su bile oslonjene masivne kamene grede/ploče debljine 35 cm, nad kojima je bio sagrađen kanal. Kako su otvori mosta bili premošteni kamenom gredom, rasponi su mali i kreću se od 1,55 do 1,85 metara.

Prema rimskoj graditeljskoj praksi vodovod je u gradu završavao vodorazdjelnom građevinom (*castelum divisorium*, *castellum aquae*), tj. cisternom iz koje su olovne cijevi vodile vodu do potrošača ili kanalima do drugih cisterni. Te druge cisterne imale su funkciju održavanja konstantne razine vode, odnosno tlaka

41 Kähler 1991, str. 232; Rendić Miočević 1991, str. 56.

Sl. 20. Revizijsko okno dimenzija 62/62 cm u Sondi 6 (foto: M. Lozo)
Fig. 20. Revision shaft in Probe 6, 62/60 cm (photo: M. Lozo)

on the left bank of the river. The reconstruction of the Diocletian's Aqueduct in the late 19th century, the construction of the hydroelectric power plant channel in 1908 and various subsequent interventions either led to the burying of the ancient ruins or their destruction. We can only hypothesize what the intake buildings of the Salonitan and the Diocletian's Aqueduct looked like.

Along its way, the Salonitan Aqueduct channel crossed the relatively narrow riverbed streams and torrents at six sites. Shorter bridges or other structures that surmounted these depressions (siphons or the like) probably existed at these sites. However, considering these buildings have not been found thus far, there will be attempts at exploring them in the upcoming phases of the research.

The last section of the Aqueduct channel, situated in front of the city in a length of about 25 meters, was laid on a bridge[41] since the terrain abruptly drops at this point. (Fig. 16) The bridge was built of stone masonry pillars of a rectangular plan, measuring 185x205 cm, which supported the massive, 35 cm thick stone beams/slabs, over which the channel was built. Considering the channel openings were bridged by the stone beams, their ranges are small and vary from 1.55 to 1.85 meters.

In accordance with the Roman architectural practice, the Aqueduct ended in the city with a water distribution tank (*castelum divisorium, castellum aquae*), i.e. a tank from which the water was lead to consumers through lead pipes, or to other tanks through channels. These other tanks had the function of maintaining constant water or pressure level in the distributing water supply system (the primary water supply net-

41 Kähler 1991, p. 232; Rendić Miočević 1991, p. 56.

Sl. 21. Kalcifikat na stijenkama kanala (foto: Z. Sunko)
Fig. 21. Calc-sinter at the channel side walls (photo: Z. Sunko)

u raspodjelnom sustavu vode (osnovnoj vodovodnoj mreži). U Saloni takva građevina, približnih tlocrtnih dimenzija 4 x 4 metra, postoji sjeverno od *Porta Suburbia II*,[42] neposredno uz ta vrata, prije ulaza vodovodnog kanala u grad (sl. 17). Može se pretpostaviti da je ta vodorazdjelna građevina opskrbljivala istočni dio grada izvan najstarije jezgre. Glavna gradska vodorazdjelna građevina trebala bi se nalaziti na mjestu ulaza kanala u grad, tj. uz sjeverni zid *Urbs Quadrata*, kako je npr. u Pompejima.[43] Upravo se na tom mjestu može uočiti promjena u gradnji kanala. Naime, do te točke kanal je, kao i na cijeloj trasi, sagrađen od kamenih masivnih ploča, dok na tom mjestu počinje kanal od tegula, što upućuje na kasnije preinake vodoopskrbnog sustava.

Nastavak kanala od tegula ide dalje prema jugu, u debljini istočnoga gradskog zida,[44] te je očito prolazio iznad *Porta Cesarea* do vodospreme koja se nalazi u debljini obrambenog zida južno od tih vrata. Sa zapadne strane vodospreme nalaze se ostaci javne česme, nimfeja.[45] Uz južnu stranu gradskih vrata dugo je curila voda iz vodovoda formiravši na tom mjestu velike naslage kalcifikata čiji se komad nedavno urušio. Ta su se vrata izgradnjom novih gradskih bedema našla u središtu grada i time izgubila funkciju, ali su se ipak sačuvala, vjerojatno zbog toga što su i dalje bila u sustavu vodoopskrbe grada. U daljnjim istraživanjima vodnog sustava Salone naročita pažnja će se

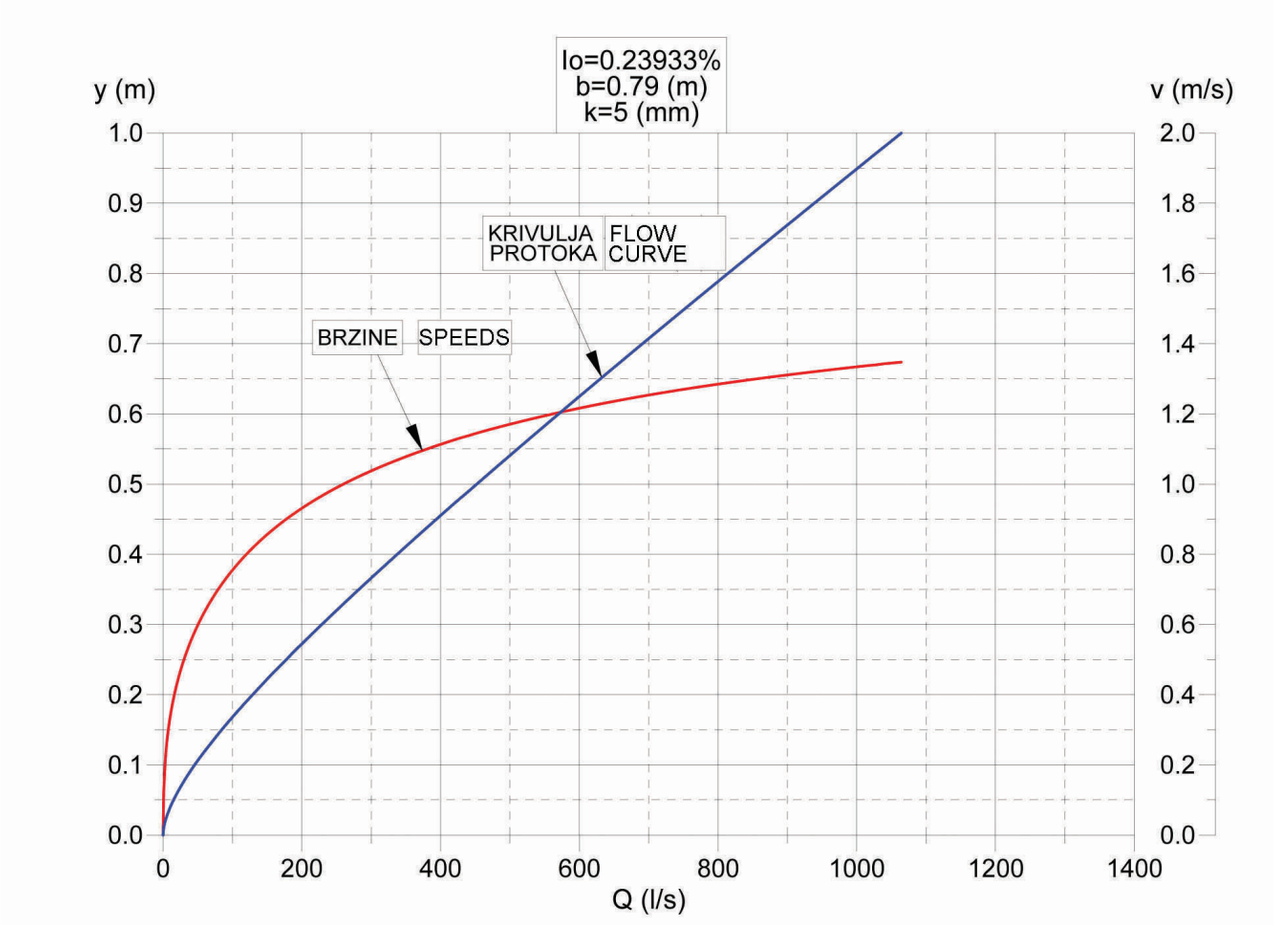
42 Carrara 1991, str. 163; Bulić 1911, str. 68.
43 Adam 2008, str. 37-72.
44 Rendić Miočević 1991, str. 57.
45 Kähler 1991, str. 216-218.

work). Such a building, of approximate dimensions 4 by 4 meters in plan, exists in Salona just north of *"Porta Suburbia II"*[42], prior to the Aqueduct channel reaching the city. (Fig. 17) It can be assumed that this water distribution tank supplied the eastern part of the city outside its oldest core. The main Salonitan water distribution tank should be situated at the point where the Aqueduct channel enters the city, i.e. along the north wall, *"Urbs Quadrata"*, as it is, for example, situated in Pompeii.[43] Precisely at this site, changes in the construction of the channel can be observed. The entire channel route preceding this point was made of massive stone slabs, while at this particular site, the channel was lined with *tegulae*, suggesting later modifications of the water supply system.

The *tegulae* channel extends further south within the eastern city wall,[44] and it obviously passed over *"Porta Cesarea"* on its way to the water tank that was located within the defensive wall, south of the gate. The remains of a public fountain – Nympheum are situated west of the water tank.[45] Along the south side of the city gate, water used to leak from the Aqueduct for a long time, forming large calc-sinter at this site, a part of which recently fell off. The city gate, upon building the new city ramparts, ended up in the city centre and thus lost its primary function. It was probably preserved as a part of the city water supply system. In further studies of the water supply system of Salona, a special attention will be given to the northeast corner of *"Urbs Quadrata"* and to *"Porta Cesarea"*.

The Salonitan Aqueduct channel, throughout the entire route, has a rectangular cross-section.[46] It was built of massive local stone slabs (bottom slab, side slabs, coverings), mainly on a slope/notch. (Fig. 18) On the lower side, with respect to the terrain slope, it is walled by smaller-format rubble stones in lime mortar. On the other side, leaning against the vertical terrain surface between the channel side slab and the notch, is a layer of fill made of crushed stones and lime mortar. At some sites, brick is added to lime mortar. In order to prevent leakage at the most sensitive position, i.e. at the junction of the bottom slab and the side slabs, a triangular gasket of waterproof mortar measuring approximately 10 by 20 cm was made. (Fig. 19) On particularly steep terrain, the channel is

42 Carrara 1991, p. 163; Bulić 1911, p. 68.
43 Adam 2008, pp. 37-72.
44 Rendić Miočević 1991, p. 57.
45 Kähler 1991, pp. 216-218.
46 Some researchers draw a trapezoidal cross-section channel probably due to the calc-sinter that has settled over many centuries, and which is difficult to distinguish from stone at some sitess.



Sl. 22a. Protočne krivulje kanala na dvije karakteristične dionice s različitim padom dna (izvor: autori)
Fig. 22a. Flow curves of the channel at two characteristic sections with different floor drops (source: authors)

usmjeriti na sjeveroistočni ugao *Urbs Quadrata* i na *Porta Cesarea*.

Kanal Salonitanskog vodovoda u cijeloj je duljini pravokutnog presjeka[46] građen od masivnih ploča lokalnog kamena (podna ploča, bokovi, poklopnica) uglavnom na kosom terenu/zasjeku (sl. 18). S donje je strane, u odnosu na pad terena, obzidan zidom od lomljenog kamena manjeg formata u vapnenom mortu. S druge strane, koja je prislonjena na zasječenu vertikalnu plohu terena između bočne ploče kanala i zasjeka nalazi se nabačaj kamena u vapnenom mortu. Na nekim mjestima u vapneni je mort dodana tučena opeka. Kako bi se spriječilo curenje na najosjetljivijemu mjestu, na spoju podne i bočnih ploča, izvedeno je trokutasto brtvilo od vodonepropusnog morta dimenzija oko 10 x 20 cm (sl. 19). Na osobito strmom terenu kanal je položen na potporni zid od masivnog

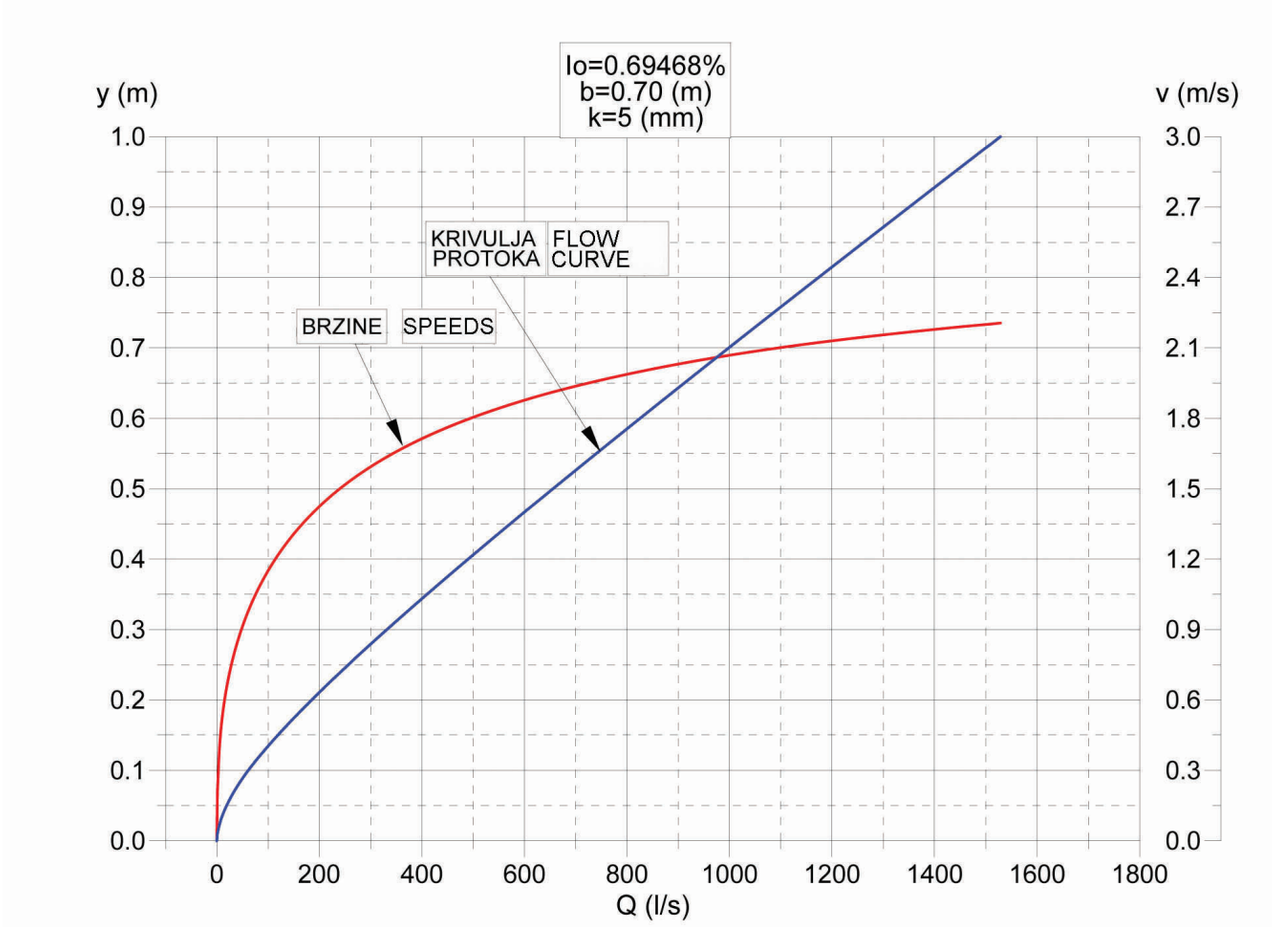
46 Neki istraživači crtaju kanal trapeznog presjeka vjerojatno zbog kalcifikata koji se nataložio tijekom više stoljeća, a koji je na pojedinim mjestima teško razlikovati od kamena.

laid on a retaining wall made of massive stones, and in front of the city on a stone bridge. Only in Probe 3, east of the Žakulić creek, the channel construction completely deviates from the usual. Here the channel is made of slabs of smaller thickness and different quality in a way that the side slabs do not rest on the bottom slab but are leaned sideways against it. Only at this site is the whole channel interior (bottom and side slabs) profusely plastered with watertight mortar for the purpose of reinforcing water permeability.

Bulić mentions a channel vault built of stone that he perceived west of the cement factory.[47] However, in the framework of this study, such a vault hasn't been found at any of the observed sites.

On the whole Aqueduct route, only two rectangular cross-section openings, which were used for revision, cleaning and repairing of the channel, have been found thus far; one in Probe 6 (Fig. 20) and one west of the episcopal assembly in Salona. With respect to

47 Bulić 1911, p. 67.



Sl. 22b. Protočne krivulje kanala na dvije karakteristične dionice s različitim padom dna (izvor: autori)
Fig. 22b. Flow curves of the channel at two characteristic sections with different floor drops (source: authors)

kamena, a pred samim gradom na kameni most. Samo u sondi 3, istočno od potoka Žakulić, konstrukcija kanala u potpunosti odstupa od uobičajene. Tu je kanal građen od tanjih ploča drugačije kvalitete, i to na način da se bočne ploče ne naslanjaju na ploču dna, već su prislonjene bočno uz nju. Jedino je na tom mjestu čitava unutrašnjost kanala (dno i bokovi) obilno ožbukana vodonepropusnim mortom radi ojačanja vododrživosti.

Bulić spominje svod kanala sagrađen od kamena koji je vidio zapadno od tvornice cementa.[47] Ovom prilikom, međutim, takav svod nije nigdje pronađen.

Na cijeloj trasi vodovoda do sada su pronađena samo dva otvora pravokutnog presjeka koja su služila za reviziju, čišćenje i popravak kanala, jedan u sondi 6 (sl. 20) i jedan u Saloni zapadno od episkopalnog sklopa. S obzirom na duljinu kanala, okana je vjerojatno bilo mnogo više.

Na nekoliko mjesta na stijenkama kanala sačuvao se kalcifikat (kalcit vezan uz stijenke i dno kanala)

47 Bulić 1911, str. 67.

the channel length, it is likely there are many more revision shafts to be discovered.

Calc-sinter is preserved (calcite bonded to the channel walls and bottom) at multiple positions of the channel, which tells us much about the amount of water that constantly flew through the channel. (Fig. 21) The further away the point from the Jadro river spring, the more calc-sinter there is. The amount of calc-sinter is a result of changes in chemical balance and of CO_2 release from the water along the channel route, which is a result of prolonged contact of water and air. The calc-sinter formed in the channel changed its cross-section profile and thus its hydraulic properties. The result of this was a constant raise in the water table working level in the channel. Hence, the lower calc-sinter levels were thicker, while the upper were thinner.

On the basis of the data collected, a hydraulic calculation of the channel capacity for different drops, i.e. for different channel sections was made. If we assume the average filling of the channel was about 50 cm (about 50% of the channel height), from the shown diagrams it can be read that about 450 l/s to 650 l/s ran

koji govori o količini vode koja je stalno tekla kanalom (sl. 21). Što je položaj udaljenijii od izvora Jadra, kalcifikata ima sve više. Količina kalcifikata rezultat je promjene kemijske ravnoteže i oslobađanja CO_2 iz vode duž trase kanala, sve kao rezultat duljeg kontakta vode sa zrakom. Kalcifikat koji se formirao u kanalu mijenjao je poprečni profil kanala i time njegove hidrauličke značajke. Rezultat je bio stalno podizanje radne razine vodnog lica u kanalu. Zbog toga su donji slojevi kalcifikata duž zida bili deblji, a gornji tanji.

Na temelju prikupljenih podataka izrađen je hidraulički proračun kapaciteta kanala za različite padove, odnosno za različite dionice. Ako se pretpostavi da je prosječno punjenje kanala bilo oko 50 cm (oko 50 % visine kanala), iz prikazanih dijagrama može se očitati da je kanalom teklo od oko 450 l/s do 650 l/s, ovisno o dionici, odnosno padu i presjeku kanala te usvojenoj hrapavosti kanala (sl. 22). Kanalom su se mogle transportirati i znatno veće količine vode, s time da su tada visine punjenja kanala bile veće. Zbog potreba aeracije vode i uvjeta tečenja u djelomično ispunjenim kanalima, kanal nikad nije bio ispunjen do vrha. Hidrauličkim analizama nastojat će se preciznije odrediti pad dna kao i kapacitet kanala različite izvedbe, dinamika formiranja kalcifikata i utjecaj kalcifikata na kapacitet kanala.

Nakon što je u VII. stoljeću akvedukt izgubio funkciju počela je njegova razgradnja. Prema kazivanju Frane Bulića krajem XIX. stoljeća uzimane su ploče Salonitanskog akvedukta za pokrivanje kanala Dioklecijanovog akvedukta koji se tada rekonstruirao.[48] Više od 1000 metara kanala Salonitanskog akvedukta uništeno je u XX. stoljeću zbog intenzivne eksploatacije lapora na Majdanu i na obroncima brda Glavice. Stanovnici tog prostora također su pridonijeli uništavanju antičkog vodovoda te su porušili poteze kanala na svojim privatnim parcelama prilikom izgradnje stambenih kuća i uređenja okućnica.

Zaključak

Salonitanski vodovod sagrađen je u I. st. pr. Kr. za potrebe grada veličine 15 ha, a na kraju svog vijeka opskrbljivao je grad od 73 hektara. Uspoređujući ga s vodovodom Dioklecijanove palače iz IV. stoljeća, može se primijetiti da je vodovod Salone izveden značajno drugačije, a moglo bi se reći i na nešto nižoj tehnološkoj razini. Najveće razlike odnose se na trasu i konstrukciju kanala. Kanal salonitanskog akvedukta strogo prati konfiguraciju terena. Krivudanje je značajno tako da je trasa oko 54 % duža od zračne udaljenosti početne i krajnje točke. Dioklecijanov akvedukt

48 Bulić 1911, str. 67.

through the channel, depending on its particular section, i.e. on the channel drop and cross-section, as well as the adopted roughness. (Fig. 22) The channel could transport even significantly greater amounts of water, but its filling heights were much higher in such cases. Due to the needs of water aeration and the conditions of water flow in partially filled channels, the channel has never been filled to the top. Hydraulic analysis will try to determine more precisely the bottom drop, as well as the capacity of the differently constructed channel sections, the dynamics of the formation of calc-sinter, and the impact of the above mentioned on the channel capacity.

After the Aqueduct had lost its function in the 7th century AD, its degradation began. According to Bulić, in the late 19th century the Salonitan Aqueduct slabs were taken away from their site to be used as the coverings for the Diocletian's Aqueduct channel, which was being reconstructed at the time.[48] Over 1,000 meters of the Salonitan Aqueduct channel was destroyed in the 20th century due to intensive exploitation of marl at Majdan and on the slopes of the Glavica hill. The residents of the area have also contributed to the destruction of the ancient Aqueduct by demolishing the parts of the channel passing through their private lots as a part of the process of constructing residential houses and the lot arrangement.

Conclusion

The Aqueduct of Salona was built in the 1st century BC for the needs of the city of 15 ha in size, while at the end of its useful life it supplied the city of 73 ha. If we compare it to the Aqueduct of the Diocletian's Palace from the 4th century AD, we can notice that it was built in a significantly different manner and, we might even argue, in a somewhat lower technological level. The greatest differences are related to the route and the construction technique of the channel. The Salonitan Aqueduct channel strictly follows the configuration of the terrain. It meanders significantly, so its route is about 54% longer than the straight-line distance between the start and the end point. The route of the Diocletian's Aqueduct was significantly shortened by constructing bridges and tunnels. Therefore, it is only 24% longer than the straight-line distance. The reasons for this lie in the channel capacity and building conditions, i.e. the terrain features between the intake and the users.

The dimensions of the Salonitan Aqueduct channel vary from 62-100 cm in width and from 72-121 cm in height. The changes in the channel dimensions

48 Bulić 1911, p. 67.

je izgradnjom mostova i tunela značajno skratio svoju trasu te je ona samo 24 % duža od zračne udaljenosti. Razlozi za ovakvu izvedbu leže u kapacitetu kanala i uvjetima gradnje, odnosno značajkama terena između zahvata i korisnika.

Dimenzije kanala Salonitanskog vodovoda variraju od 62 do 100 cm u širini i od 72 do 121 cm u visini. Promjene dimenzija i tehnika gradnje uvjetovane su lokalnim problemima, tj. konfiguracijom terena u namjeri da se izgradi dobar kanal, što slikovito govori o dobroj inženjerskoj praksi. Kanal, odnosno vodoopskrbni sustav funkcionirao je više od šest stoljeća, što svjedoči o kvaliteti izvedbe, ali još više i o kvaliteti održavanja, odnosno upravljanja tim važnim urbanim vodnim sustavom. Još jednom se pokazuje nastojanje Rimljana da u svojim gradovima osiguraju dovoljne količine kvalitetne vode. U ovom radu prikazani su dosadašnji, preliminarni rezultati jednogodišnjeg istraživanja. Analize raspoloživih podataka i arheološka istraživanja nastavit će se s ciljem da se što detaljnije prouči ova vrijedna povijesna hidrotehnička građevina.

and construction techniques were conditioned by terrain configuration, and driven by the intention to build a good channel, which illustrates the good engineering practice. The channel, i.e. the water supply system was in operation for more than six centuries, which says a lot about the quality of its performance, and even more about the quality of maintenance, i.e. management of this important urban water system. Once again this proves that the Romans cared much about providing sufficient quantities of quality water to their cities. This paper has presented the current, preliminary results of a one-year study. The analysis of available data and archaeological excavations will continue with the purpose of examining this valuable, historical, hydro-technical edifice in as much detail as possible.

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