https://doi.org/10.18485/gsad.2026.42.5

ROMAN AQUEDUCTS NORTH OF THE PALACE COMPLEX AT GLAC NEAR ANCIENT *SIRMIUM*. RESULTS OF ARCHAEOLOGICAL SURVEYS

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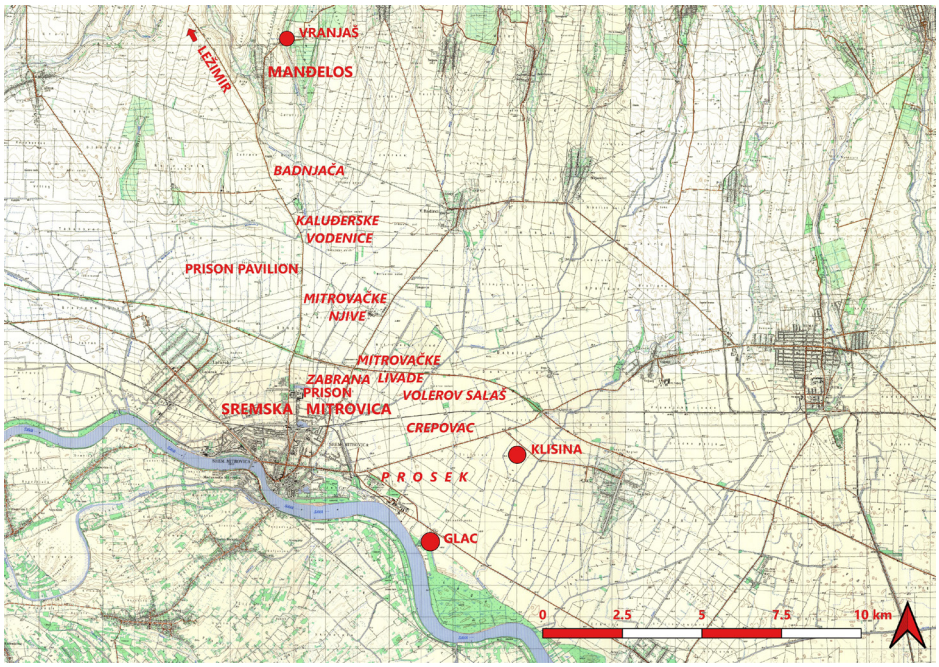
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Original scientific paper
Received: 19. 5. 2026.
UDC: 904:626.823.82(497.113)
Accepted: 28. 7. 2026.
902.2(497.113)"2017/2026"

Abstract: *As part of a comprehensive archaeological survey of the area around Roman Sirmium in the north-west of Serbia, an examination has been undertaken of water infrastructure around the city. The field survey investigations in 2019, 2023, 2024, 2025, and 2026 identified Roman era terracotta pipes and a trench, possibly for a siphon system, north, north-east, and east of Sirmium. This paper outlines the findings of these investigations and considers the meaning, context, and significance of those findings as they relate to water supply aqueducts servicing the Roman military camps at Klisina and the Glac palace complex.*

Keywords: *aqueducts, Glac, Klisina, Pannonia, Pannonia Inferior, Pannonia Secunda, Roman pipes, siphon, Sirmium, terracotta pipes, water supply*

Introduction

The provision of infrastructure for the supply of water to cities, villages, hamlets, farmhouses and industrial facilities is a notable feature of the Roman world. Such infrastructure was also a feature of earlier civilisations, such as the great Mesopotamian civilisations as well as the Greek and Hellenistic worlds. Aqueducts, *nymphaea*, fountains, and baths have long been a characteristic feature of the Roman world. The transportation of water for irrigation, industrial and mining uses, potable supplies for cities, towns, villages and farms, and for ostentation and display posed many challenges for ancient civilisations in terms of engineering, planning, and construction. Evidence for such transportation is of significance in understanding settlement patterns and economy of urban and rural areas.



Map 1. Surroundings of Sremska Mitrovica with indicated research areas

Карта 1. Околина Сремске Митровице са означеним подручјима истраживања

An archaeological survey in the vicinity of Sremska Mitrovica in the north-west of Serbia commenced in 2017 as a joint Australian–Serbian cooperative program, now involving the Glac Survey Incorporated (an Australian NGO) and the Institute of Archaeology, Belgrade.

The Glac Survey Project is directed at understanding the spatial and temporal settlement patterns during the Roman period in the vicinity of ancient *Sirmium*, amongst other topics. Part of the work of the Glac Survey has been directed towards identifying major infrastructure, including water supply, in the vicinity of *Sirmium*. This paper examines new evidence regarding water infrastructure north, north-east and east of ancient *Sirmium* (modern Sremska Mitrovica) derived from the field survey work of the Glac Survey in the context of existing literature on the *Sirmium* aqueduct (Map 1). The finds include numerous pieces of Roman terracotta pipes. This new evidence indicates a branch aqueduct from the main aqueduct supplying the city of *Sirmium*, which provided water to the Roman military camps at Klisina, situated 5 km north-east of Sremska Mitrovica (Dimitrijević and Whitehouse 2025) and to the likely imperial palace built by Maximian Herculius at Glac, positioned 3 km south-east of the city (Institute of Archaeology, Belgrade, *Glac Project* n.d.).

In addition to the *Sirmium* aqueduct, Roman era subterranean aqueducts in modern Serbia have been found at *Singidunum* (Belgrade), *Viminacium* (near Kostolac) and *Naissus* (Niš), while the complex at *Mediana* had a water supply system, and the 6th century complex at Caričin Grad (*Justiniana Prima*) had an extensive aqueduct system.

The research questions addressed in this paper are:

a. Were the pieces of terracotta pipes discovered in the survey part of a pipeline system?

b. If so, what was the role of the pipeline system? Was it for water supply, drainage or wastewater disposal?

c. If the pipeline was used for water supply, was it for domestic use, industrial use, irrigation or some other use?

d. If the pipeline was used for water supply, what was the source of the water, what was its destinations, and what was its route?

The city of *Sirmium* was served by an aqueduct from the spring of Vranjaš at Manđelos (Map 1, Map 3), 14 km north of the city (Jeremić 2016, 179–185; Milošević 2001, 70–73). The aqueduct was an underground system from the source but it emerged above ground at the field of Badnjača, 3.5 km south of the spring, with a roofed channel supported by two parallel walls, and from the area of Kaluđerske Vodenice, 6 km south of the spring and further south along Mitrovačke Njive, the channel was supported with a series of arcades that were visible until 1908 (Milošević 1969; Milošević 1995, 192, 193; Milošević 2001, 70–72). The above-ground parts of the aqueduct were, sadly, demolished in the early 20th century, as noted by Ignjat Jung, a teacher in Sremska Mitrovica and collaborator of the Archaeological Museum in Zagreb (Miladinović-Radmilović and Radmilović 2015, 199; Милошевић 2001, 70).[1] The dating for the construction of this aqueduct is not precise, with Jeremić considering this occurred either in the 2nd century CE or at the beginning of the 3rd century CE (Jeremić 2016, 179, 181, 304, 307). Milošević considered that both the water catchment facilities at Vranjaš and the 0.8 m wide and 14 km long gravity flow channel (*specus*) between the spring and *Sirmium* were built in the middle of the 2nd century CE (Milošević 1995, 192, 193; 2001, 70). Just north of the city walls, there was a *castellum aquae* to distribute the water (Map 3), which was archaeologically investigated by Lučić (Lučić 2018). Excavations of the water tower and the aqueduct segment next to it, conducted in 2012, confirmed the chronology suggested by Milošević, with the aqueduct foundation segment being found on top of ceramic

[1] Noted in the letter of Ignjat Jung to the Archaeological Museum in Zagreb of 24 April 1908.

debris dated between the second half of the 1st and the middle of the 2nd century CE (Lučić 2018, 11, Fig. 5). As Lučić concluded, the segments of the aqueduct on the northern and southern sides of the water tower were built at the same time as the *castellum aquae*, in the second half of the 2nd century CE, with the water tower being repaired in the middle of the 4th century CE (Lučić 2018, 13, 15, 32). Ignjat Jung suggested that north of the prison complex, there was a deviation in the direction of the main aqueduct from a northerly to a north-easterly direction (Miladinović-Radmilović and Radmilović 2015, 95).[2] Archaeological research in 1987 confirmed there was aqueduct debris under the Fruškogorska Street and below the eastern edge of the Sremska Mitrovica – Ležimir road, which, at the intersection with the motorway, has a south-westerly/north-easterly direction (Dautova Ruševljan 1989, 112). However, the 1987 trenches along the approach to the viaduct over the motorway did not continue further north so the north-easterly deviation in the area further north of the motorway has not been confirmed archaeologically (Dautova Ruševljan 1989, 112). Nevertheless, research by Milošević closer to the Manđelos village confirmed the north–south direction of the aqueduct in its upper section (Milošević 1995).

Early notes on the water supply at Glac and north of the site

First indications of the existence of a water supply system for the tetrarchic complex found at the site of Glac were noted in 1903 by a researcher of ancient *Sirmium* Ignjat Jung, who sent his reports to the Archaeological Museum in Zagreb (Miladinović-Radmilović and Radmilović 2015, 47–49, 148; Милошевић 2001, 26).[3] In his texts and a drawing, Jung noted that the farm owner Peter Glatz dug at four places; in addition to the discovery of Roman buildings and mosaic floors, 10 terracotta water pipes were found in the northern part of the site (Miladinović-Radmilović and Radmilović 2015, 47–49, 120, 148, Table 4). Jung concluded that the ancient complex at Glac had an aqueduct coming from the north, being an extension of the aqueduct remains found in the field of a postman surnamed Katanac, north of Glac (the so-called "Katančev Vodovod"), which Jung examined in 1902, when clay water pipes were also found in the postman's land (Miladinović-Radmilović and Radmilović 2015, 47–49, 120, Table 4). In addition to the aqueduct, in a location at Glac labelled as position "b" in his drawing, Jung identified a building which he described as looking like a

[2] Drawn in the letter of Ignjat Jung sent to the Archaeological Museum in Zagreb in 1907.

[3] Two letters of Ignjat Jung to the Archaeological Museum in Zagreb, nos. 233 of 12 February 1903, and 239 of 28 December 1903.

water "reservoir", situated in the south-western part of Glac, at the site's highest point, described as a "small hill" (Miladinović-Radmilović and Radmilović 2015, 47–48). The building had a 0.5 m thick brick wall, plastered with yellowish lime mortar (Miladinović-Radmilović and Radmilović 2015, 47). Also at the position "b", Jung identified a room with a lower floor level compared to the discovered mosaic floors, with a rounded wall in the western side, described as being likely a "house bath" (Miladinović-Radmilović and Radmilović 2015, 47).

During the First World War, the Austro-Hungarian Army dug trenches along the southern edge of the Glac Farm; in a letter from 29 January 1915, Lieutenant Dragutin Trstenjak reported on the discoveries made by the troops, which, in addition to a mosaic floor, lead sarcophagus, and stone head of a woman, also included finds of terracotta water pipes with a diameter of 0.3 m (Miladinović-Radmilović and Radmilović 2015, 121, 161, 162, Table 5). Lieutenant Trstenjak further reported, in the same letter, that a well-preserved manmade channel, still protruding from the direction of the Fruška Gora mountains, was connected with the ruins found at the Glac Farm at the time (Miladinović-Radmilović and Radmilović 2015, 162).

In relation to the water pipes discovery in 1915, in a record from 1993 made in the Institute for the Protection of Cultural Monuments in Sremska Mitrovica, it was noted that both ceramic and lead pipes were found by the Lieutenant's troops (Milošević et al. 1993, 1, 2).

It is unclear whether the terracotta and lead water pipes were found within the built complex or outside of it. For water distribution within a city, town or building complex, the Greek practice of using terracotta pipe distribution systems continued in the Roman period in the eastern Mediterranean, while the use of lead pipes for urban distribution was favoured in the Roman areas of the central and western Mediterranean region (Wilson 2008, 303). The characteristic Greek use of terracotta pipes for urban water distribution is seen at *Morgantina* in Sicily (Crouch 1984, 358), while the characteristic western Roman use of lead pipes for urban water distribution is seen at *Pompeii* (Olsson 2015; Brown, 2001). If the lead pipes at Glac were within the building complex, they are likely to have been part of the internal water distribution system, but if they were outside of the complex, they may have been part of a siphon.

Roman terracotta pipes

The terminology used to describe Roman terracotta pipes (*tubulus* or *tubus*) is varied and often confusing. For clarity, a starting point needs to identify the terminology for describing terracotta pipes and their elements and a typology

of those pipes. The terminology used here is that contained in the *US National Clay Pipes Institute Engineering Manual* (National Clay Pipe Institute 2017, Glossary). The key terms and their definitions as derived from this manual are indicated in Table 1.

TERM	DEFINITION
Vitrified Clay Pipe (VCP)	A pipe made from various clays or combinations thereof which are shaped, dried, and fired to a point where the glass-forming components fuse to form a bond between the crystalline grains.
Pipeline	Pipes joined to provide a conduit through which fluids flow.
Barrel	The cylindrical portion of a vitrified clay pipe exclusive of branches, spurs, joints, and handling rings or lugs.
Bell	The flared-end portion of a vitrified clay pipe or fitting, designed to function in the joining of other such pipes.
Joint	An individual length of pipe, or the means of closure to form a pipeline.
Socket	The portion of a jointing system that is designed to accept a plain-end pipe or a spigot-end pipe.
Spigot	That portion of a vitrified clay pipe that fits into the bell or coupling of the preceding pipe.

Table 1. Pipe terminology from *US National Clay Pipes Institute Engineering Manual*

Табела 1. Терминологија цеви из инжењерског приручника Националног института за глинене цеви Сједињених Држава

Additionally, it is noted that a bell is often called a collar. The spigot end pipe may be either plain, or have incised bands, a raised stop point or a recessed stop point. A flange is a flat projection outwards, perpendicular to the barrel at the end of a pipe. This terminology for pipe description is used in this paper.

Archaeological typologies for vitrified clay pipes are generally poor and based on varied and confusing descriptive terminology. Hodge does not provide any typology but just a figure with six various forms instead (Hodge 2002, 111, Fig. 67). Bedal examined the ceramic pipes from the Petra Garden and Pool complex in Jordan from the Hellenistic and Roman periods (Bedal 2022). She noted that between the 1st and 4th and 5th centuries CE there was a shift from pipes with thin walls and narrow and tapered forms with sharply carinated shoulders to pipes with thicker walls and rounded shoulders for the smaller diameter pipes (Bedal 2022, 402). But she concluded that establishing a broader typology was complicated by variations in the scale of pipes, primarily due to variations in their function. She indicated that a collared neck and waisted body are only found in the

largest pipes in Petra's public water supply system (Bedal 2022, 402). Romaniuk examined the terracotta pipes from the residential district of Nea Paphos in Cyprus from the Hellenistic and the Roman era (Romaniuk 2021). Romaniuk identified eight types of pipes based on shape, dimensions, fabric and special features (Romaniuk 2021, 369). Almost all of these types of pipes were spigot-socket forms, apart from Form 7, which had a thickened lip at the end. Three types had hourglass-shaped, helically ridged bodies; one type had an hourglass-shaped body with a smooth surface; two types had a slight hourglass shape with a smooth or undulating surface; one type was bellied in the middle with a smooth or undulating surface (Romaniuk 2021, 369). In distinguishing types, there was little differentiation in terms of jointing morphology and the key distinguishing feature in determining pipe type was fabric (Romaniuk 2021, 399). As clay for making pipes would have been procured locally and it is unlikely that pipes would have been transported at great distances, a pipe typology based on fabric is likely to have no wider application than the site in which they were found.

Campbell identified a typology for clay pipes from ancient to modern times based on jointing morphology (Campbell 2021). He identified four types of pipes (Campbell 2021, 36):

a. Conical pipes that fit into each other, with one pipe inserted into another (Conical Type);

b. Pipes with a projecting flange on one end that fits on the flared end of the other (Projecting Flange Type);

c. Pipes with a socket, with the outer surface of the pipe slightly recessed at the end, fitting neatly into the normal end of the pipe at the other end (Socket and Spigot Type);

d. Pipes with a bell and spigot, where the end of the pipe flares out in bell shape into which the other regular end of the tube fits (Bell and Spigot Type).

The Projecting Flange Type of joints usually has holes for bolting onto another flange and hence it is generally suited for PVC or metal pipes, rather than terracotta pipes. Roman lead water pipes feature the Projecting Flange Type of joint (as can be seen in the example in the Museum at Xanten in Germany). Roman terracotta water pipes show all these jointing morphologies except for the Projecting Flange Type. A typology of pipes based on that developed by Campbell is indicated in Table 2 and is adopted here as the most appropriate typology for Roman water pipes, based on ease of recognition and clarity of defining elements. However, it is noted that these types do not have any chronological significance, although there may be some functional significance. The use of other

morphological features of the barrel of a pipe is not favoured as the differences between an hourglass, bellied, or conical barrel may well be an accidental incident of making a tall object on a pottery wheel with clays of varying consistency. Also, such features may not be readily distinguished on pipe fragments as opposed to complete pipes.

ROMAN TERRACOTA WATER PIPES TYPOLOGY			
PIPE TYPE	**DESCRIPTION**	**RECEIVING ("FEMALE") END**	**INSERTING ("MALE") END / SPIGOT**
The Conical Type	Conical pipes that fit into each other, with one pipe inserted into another.	The wide end of a conical pipe barrel.	The narrow end of a conical pipe barrel.
The Socket and Spigot Type	Pipes with a socket, with the outer surface of the pipe lightly recessed at the end, fitting neatly into the normal end of the pipe at the other end.	The straight end of a pipe barrel, sometimes with a stop point on the inner surface, forming a socket into which is inserted the recessed end of the inserting pipe.	The end of the pipe is recessed inwards to fit into the socket of the receiving pipe.
The Bell and Spigot Type	Pipes with the end of the pipe flares out in bell shape into which the other regular end of the tube fits.	The end of a pipe flares outwards in a bell-like shape to receive the straight end of the inserting pipe.	The straight end of a pipe barrel, sometimes with a stop point on the outer surface.

Table 2. Typology of Roman terracotta water pipes

Табела 2. Типологија римских глинених водоводних цеви

Differentiating terracotta pipes from other ceramics

It is fundamental to be able to differentiate terracotta pipes from other ceramics, particularly when they are found in fragments. The primary method of differentiating terracotta pipes from other ceramics is the presence of a characteristic end form of a terracotta pipe, either a socket or a bell, or on the straight end spigot, either a plain end or a stop point. It is noted that terracotta water pipes do not have a rim characteristic of ceramic vessels.

Additionally, as joints between pipes were sealed with mortar, the presence of mortar on parts of either end of a pipe is indicative (Hodge 2002, 114; Romaniuk 2021, 373). However, this requires a person to have a fragment of the end of a terracotta pipe and not a fragment of the pipe barrel.

Additionally, the presence of other accretions, such as traces of calcareous sinter, may indicate that a terracotta fragment was a part of a water pipe (below in text).

For parts of the barrel of a terracotta pipe, differentiation requires greater care. Terracotta pipes of all types were fashioned on a potter's wheel and not formed in a mould (Hodge 2002, 113; McComish 2015, 19; Campbell 2021, 36; Bedal 2022, 392; Landels 2000, 44). White claims that earthenware pipes were made in moulds (White 1984, 165), but this appears to be incorrect.

Fragments of terracotta pipes can be confused with a Roman roof tile – *imbrex*. *Imbrices* take the form of a hollow half-cylinder that tapers towards the top and are designed to cover the junction between *tegulae* on a roof (McComish 2015, 13). They are manufactured using a trapezoidal clay slab bent over a mould (McComish 2015, 13). Hence, a fragment of a terracotta water pipe without any other differentiating features can be distinguished from a fragment of an *imbrex* by the presence of evidence of wheel manufacture, either horizontal patterning in the fabric, or helically ridged patterns and undulations in the fabric. Where there is evidence of wheel manufacture, then the possibility that something is a fragment of an *imbrex* can be discounted.

Differentiating a part of the barrel of a terracotta pipe and a part of a large ceramic vessel, such as a storage jar or amphora, is a more difficult task. This is particularly the case as terracotta pipes are generally not cylindrical and hence part of a barrel may show curves also found in large ceramic vessels (Hodge 2002, 113). This requires careful judgment to exclude the possibility that a fragment is derived from a large ceramic vessel. Pipe fragments also have greater variability in wall thickness compared to ceramic vessels. A comparison of fragments reveals variations in the ratio of wall thickness to circumference. Being building material, conducting terracotta water pipes need to be stronger than ceramic vessels of the same circumference intended for storage or transport. This relates to both inside pressure of the fluid in the pipeline and outside pressure if the structure is buried. The total inside pressure includes static and dynamic pressures to the walls, which change depending on fluid speed through the pipe and the height (Julien 2022, 23ff). The static pressure includes hoop, longitudinal and radial stresses, and the dynamic pressure includes wall shear stress, dynamic impacts and transient stresses, produced by the flow of the fluid inside the pipeline and the changes of the volume, speed and direction of the fluid. So, the wall thickness of conducting pipes is required to be larger compared to the wall thickness of ceramic storage and transport vessels of the same circumference, due to higher forces that pipes need to resist to function properly and to last. Also, the weight of ceramic vessels, especially in the case of transport vessels, would have to be lower for easier carrying, thus, wall thickness would have been reduced to the needed optimum. Hence, the bigger the circumference of an object in comparison

to its wall thickness – the weaker the object, and vice versa. In other words, terracotta water pipes tend to have thicker walls then ceramic vessels of the same circumference. Calculating the ratio between the two measurements (wall thickness and an object's circumference) and comparing different fragments, enables us to distinguish terracotta water pipes from ceramic vessels either through established typologies for those objects or through calculations of their resistance to pressure.

Differentiating between functions of terracotta pipes

Roman terracotta pipes served several uses, not solely for conveying potable water in an aqueduct. A Roman terracotta pipe could be used for following purposes:

a. as part of a drinking water supply aqueduct;

b. as part of a private drinking water supply for a house, a farm, or an industrial facility;

c. as part of the drainage of rainwater into a cistern from a roof or other surface;

d. as part of public drainage of stormwater in a city, town or village;

e. as part of private drainage from a house, farm or industrial facility;

f. as part of public drainage of a road, street or public place;

g. as part of a public sewer or wastewater disposal system;

h. as part of a private sewer or wastewater disposal system, whether connected to a public system or not.

The question of the function of a pipe could be partly resolved by tracing the entire pipeline system, or a significant portion of it, that a given pipe or pipe fragment were part of. This could provide a basis for inferring the role and function of a pipe. Finds of pipes and pipe fragments in locations not accompanied by other forms of human activities are also indicative of a pipeline system which traversed land so as to reach buildings and settlements.

Vitruvius noted that the supply of water is made by three methods, by conduits along artificial channels, by lead pipes, or else earthenware pipes (Vitruvius, *De Arch.*, VIII.6.1). Hence, not all pipelines were for water supply aqueducts, and not all water supply aqueducts were made of terracotta pipes.

There is one additional means of ascertaining if terracotta pipes were used for water supply. This method is only applicable where the water in a pipeline system is derived from springs emanating in limestone karst areas. Karst springs were the source of many Roman aqueducts, and this applies to the water

source for the *Sirmium* aqueduct. The main aqueduct to *Sirmium* used water from the spring of Vranjaš at Manđelos, located in the foothills of Fruška Gora from a karst aquifer (Urošev, Pešić, Kovačević-Majkić, Štrbac 2022, 69; Nyiro n.d.). This spring is still used as part of the water supply for Sremska Mitrovica.

Rainwater moving through the ground becomes charged with higher concentrations of carbon dioxide (CO_2) than is present in the atmoshere. This dissolves carbonate rocks as it passes through an aquifer.

Upon exiting at a spring, this water starts to degas the CO_2 until the water becomes supersaturated with $CaCO_2$ and calcite is precipitated on the sides and base of the aqueduct channel or pipeline. The process requires an interval from when the water emerges from a spring before precipitation starts. Once the carbonate has been precipitated from the water, and the level of carbon dioxide in the water is similar to that in the atmosphere, precipitation ceases (Sürmelihindi, Passchier, Spötl, Kesser, Bestmann, Jacob, Baykan 2013, 962–963). Thus, calcareous sinter deposits will not be present on an aqueduct immediately after the water emerges from a spring but will be present for some period thereafter. However, precipitation might start closer or immediately at the spring, but typically there is a "clear zone" at the immediate spring source, with the length of the clear zone varying and sometimes being even non-existent (Passchier, Sürmelihindi 2010, 274–274). But by the time the water would have been used and afterwards disposed of as wastewater, there would be no precipitation of carbonate. Similarly, water which fell directly on the ground as rainwater would contain no carbonate. Thus, terracotta pipes serving as part of a water supply aqueduct sourcing water from a karst spring would be expected to show precipitated calcareous sinter on the inner surfaces of the pipes for the entire route of the aqueduct except for its initial distance from the source spring. However, terracotta pipes used for supply systems sourced from rainwater would not have calcareous sinter on their inner surfaces, nor would terracotta pipes used for drainage or wastewater disposal.

Hence, the presence of calcareous sinter on the inner surfaces of terracotta pipes indicates that these pipes formed part of a water supply system derived from a karst spring. The absence of calcareous sinter on the inner surfaces of terracotta pipes indicates that these pipes were not part of a water supply system derived from a karst spring, but were pipes used for rainwater supply systems, other local supply systems, or for drainage and wastewater disposal.

Equally, the absence of calcareous sinter in pipes which did conduct water from a karst aquifer can suggest that that particular part of a pipeline was at a water source or in proximity to the source, given the necessary interval between the water emergence from a spring and the precipitation of calcite, although that interval may be non-existent.

Terracotta pipe fragments found in the Glac Survey

During the field survey work of the Glac Survey in the 2019, 2023, 2024, 2025 and 2026 seasons, numerous pieces of Roman terracotta pipes have been found north, north-east and east of *Sirmium* (Map 2). Having regard to the previous discussion, each piece has been carefully examined to confirm whether it was part of a Roman terracotta pipe. Once confirmed as part of a Roman terracotta pipe, features of each piece were recorded together with the find location.

All pieces of Roman terracotta pipes found were fragments. Tables 3, 4, 5, and 6 indicate the find locations of Roman pipe fragments, together with the total numbers of fragments found, morphological features of the fragments, details of accretions such as calcareous sinter and mortar and estimated inner diameters. The locations of find spots are indicated on Map 2. A selected overview of the finds is shown in Figs. 1, 2, 3, 4, 5, and 6.

GLAC SURVEY TERRACOTTA PIPE FRAGMENTS							
FIND LOCATION	**Mitrovačke Livade Centre East Far East** 4984508, 7395091						
• Field Survey Method	Prelim. Recon.	Grid 9					
		Sq.7	Sq.8	Sq.12	Sq.13	Sq.14	Sq.18
QUANTIFICATION							
• No. of Fragments	1	7	1	45	61	5	71
MORPHOLOGY/FREQUENCY							
• Elbow	-	1	-	-	-	-	-
• Barrel	-	2	-	32	51	3	61
• Socket	-	4	1	8	5	2	6
• Spigot	1	-	-	5	5	-	4
ACCRETIONS							
• Presence of Sinter	1	7	1	44	61	4	71
• Presence of Mortar	1	7	1	45	61	4	71
MEASUREMENTS							
• Inner Diameter I	-	-	X	114 (1)	-	-	-
• Inner Diameter II	-	-	-	124 (1)	-	-	124 (1)
• Inner Diameter III	-	164 (4)	-	164 (43)	164 (61)	164 (4)	164 (68)
• Inner Diameter IV	-	170 (3)	-	-	-	170 (1)	170 (2)
• Inner Diameter V	178 (1)	-	-	-	-	-	
NOTE: • GPS coordinates relate to a central zone of a site; Gauss-Krüger Projection, Balkans Zone 7. • Dimensions of Grids 100 by 100 m; of Squares 20 by 20 m. • Dimensions of pipe diameters in mm. • In brackets – no. of fragments. • X – Ellipse cross section: diameter 1 = 112 mm, diameter 2 = 93 mm.							

Table 3. Frequency, technical parameters and attributes of Roman terracotta water pipe fragments found at Mitrovačke Livade – Centre-East / Far East

Табела 3. Учесталост, технички параметри и атрибути фрагмената римских глинених водоводних цеви нађених на Митровачким ливадама – центар – исток и даље ка истоку

GLAC SURVEY TERRACOTTA PIPE FRAGMENTS				
FIND LOCATION	**Volerov Salaš Further Southeast** 4983567, 7396345	**Crepovac Northeast** 4983416, 7396499	**Klisina** 4982160, 7398161	
• Field Survey Method	Prelim. Recon.	Prelim. Recon.	Prelim. Recon.	Grid 1 Sq. 19
QUANTIFICATION				
• No. of Fragments	3	1	11	1
MORPHOLOGY/FREQUENCY				
• Elbow	-	-	-	-
• Barrel	2	-	9	-
• Socket	1	-	1	-
• Spigot	-	1	1	1
ACCRETIONS				
• Presence of Sinter	3	1	11	1
• Presence of Mortar	3	1	10	1
MEASUREMENTS				
• Inner Diameter I	-	-	-	-
• Inner Diameter II	124 (1)	-	-	-
• Inner Diameter III	164 (2)	164 (1)	164 (11)	164 (1)
• Inner Diameter IV	-	-	-	-
• Inner Diameter V	-	-	-	-
NOTE: • GPS coordinates relate to a central zone of a site; Gauss-Krüger Projection, Balkans Zone 7. • Dimensions of Grids 100 by 100 m; of Squares 20 by 20 m. • Dimensions of pipe diameters in mm. • In brackets – no. of fragments.				

Table 4. Frequency, technical parameters and attributes of Roman terracotta water pipe fragments found at Volerov Salaš – Further South-East, Crepovac – North-East, and Klisina

Табела 4. Учесталост, технички параметри и атрибути фрагмената римских глинених водоводних цеви нађених на Волеровом салашу – даље ка југоистоку, Цреповцу – североисток, и Клисини

Pipe sizes

The use of a potter's wheel limited the length of a pipe to about 300–500 mm (Campbell 2021, 36). No complete pipes were found in the survey. However, the diameter of pipes can be calculated by extending the circumference of the fragment of the barrel of pipes. This enables the inner diameter of pipes to be measured. The estimated diameters of the pipe fragments found were generally consistent, with the overwhelming majority of pipes having an internal diameter of 164 mm. This is particularly the case with pipe fragments in the locations of Crepovac – North-East, Volerov Salaš – Further South-East, Mitrovačke Livade – Centre East / Far East, Klisina, and Prosek – Concrete Factory. Additionally, all pipes used the Socket--Spigot jointing system. This indicates that these pipe fragments formed part of a pipeline system, using consistently sized pipes.

GLAC SURVEY TERRACOTTA PIPE FRAGMENTS		
FIND LOCATION	**Prosek Concrete Factory** 4980479, 7395448	**Zabrana West** 4984447, 7391852
• Field Survey Method	Prelim. Recon.	Grid 1 Sq. 21
QUANTIFICATION		
• No. of Fragments	17	1
MORPHOLOGY/FREQUENCY		
• Elbow	-	-
• Barrel	14	1
• Socket	2	-
• Spigot	1	-
ACCRETIONS		
• Presence of Sinter	7	1
• Presence of Mortar	4	1
MEASUREMENTS		
• Inner Diameter I	-	-
• Inner Diameter II	-	-
• Inner Diameter III	164 (10)	164 (1)
• Inner Diameter IV	170 (1)	-
• Inner Diameter V	-	-
NOTE: • GPS coordinates relate to a central zone of a site; Gauss-Krüger Projection, Balkans Zone 7. • Dimensions of Grids 100 by 100 m; of Squares 20 by 20 m. • Dimensions of pipe diameters in mm. • In brackets – no. of fragments.		

Table 5. Frequency, technical parameters and attributes of Roman terracotta water pipe fragments found at Prosek – Concrete Factory, and Zabrana – West

Табела 5. Учесталост, технички параметри и атрибути фрагмената римских глинених водоводних цеви нађених на Просеку – фабрика бетона и Забрани – запад

Because the flow capacity of a terracotta pipe is significantly less than that of an open channel aqueduct, where terracotta pipes are found in aqueducts, they tend to be in smaller main line aqueducts, as well as local distribution centres and drains (Hodge 2002, 113). Hodge considers that terracotta pipes used in aqueducts had internal diameters of up to 100 or 150 mm (Hodge 2002, 113) or in another work 200 to 250, although that may be the external diameter (Hodge 2000, 41). Campbell indicates the diameter is typically 100 to 150 mm (Campbell 2021, 36). In the study on Nea Paphos, Romaniuk indicated that the diameter of pipes was in the range of 142 to 205 mm (Romaniuk 2021, 400). The sizes of terracotta pipes found during the Glac Survey match maximum sizes for terracotta

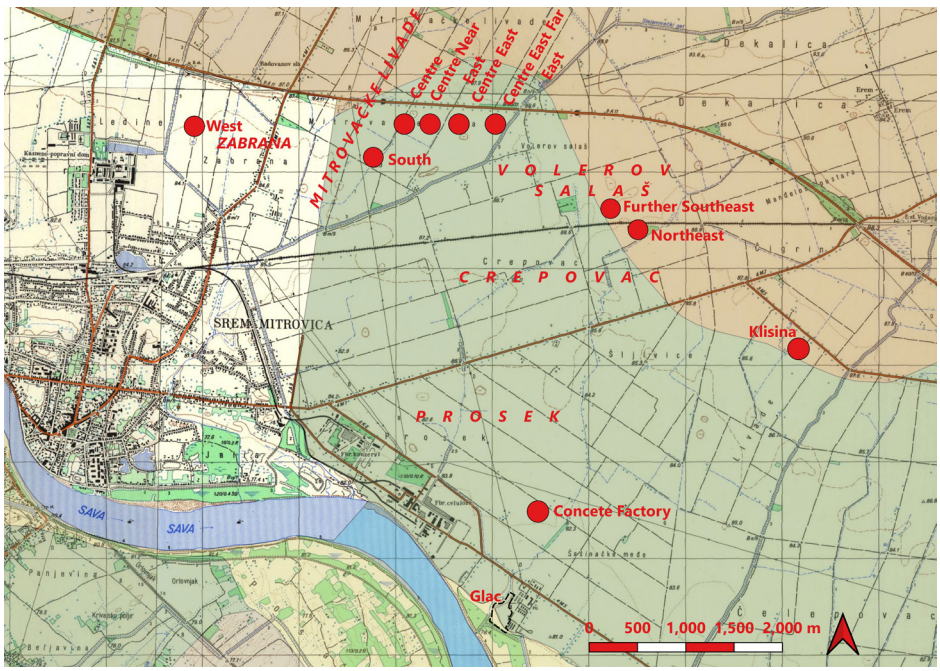
GLAC SURVEY TERRACOTTA PIPE FRAGMENTS							
FIND LOCATION	**Mitrovačke Livade South** 4984070, 7393726		**Mitrovačke Livade Centre** 4984467, 7394240		**Mitrovačke Livade Centre Near East** 4984493, 7394369	**Mitrovačke Livade Centre East** 4984508, 7394775	
• Field Survey Method	Grid 2		Prelim. Recon.		Prelim. Recon.	Grid 2	Grid 7
	Sq. 9	Sq.10	Central part	Eastern part	Central part	Sq. 23	Sq. 12
QUANTIFICATION							
• No. of Fragments	1	1	1	1	1	1	1
MORPHOLOGY / FREQUENCY							
• Elbow	-	-	-	-	-	-	-
• Barrel	1	-	1	-	-	-	1
• Socket	-	1	-	-	1	1	-
• Spigot	-	-	-	1	-	-	-
ACCRETIONS							
• Presence of Sinter	1	1	1	1	1	1	1
• Presence of Mortar	1	1	1	1	1	1	1
MEASUREMENTS							
• Inner Diameter I	-	114 (1)	-	-	-	-	X
• Inner Diameter II	-	-	-	-	-	-	-
• Inner Diameter III	164 (1)	-	164 (1)	164 (1)	-	-	-
• Inner Diameter IV	-	-	-	-	-	-	-
• Inner Diameter V	-	-	-	-	-	-	-
• Inner Diameter VI	-	-	-	-	-	250 (1)	-
• Inner Diameter VII	-	-		-	254 (1)	-	-
NOTE: • GPS coordinates relate to a central zone of a site; Gauss-Krüger Projection, Balkans Zone 7. • Dimensions of Grids 100 by 100 m; of Squares 20 by 20 m. • Dimensions of pipe diameters in mm. • In brackets – no. of fragments. • X – Irregular ellipse cross section, approx. measurements: diameter 1 = 112 mm, diameter 2 = 93 mm.							

Table 6. Frequency, technical parameters and attributes of Roman terracotta water pipe fragments found at Mitrovačke Livade – South, Mitrovačke Livade – Centre, Mitrovačke Livade – Centre / Near East, Mitrovačke Livade – Centre East

Табела 6. Учесталост, технички параметри и атрибути фрагмената римских глинених водоводних цеви нађених на Митровачким ливадама – југ, Митровачким ливадама – центар, Митровачким ливадама – центар – ближи исток, Митровачким ливадама – центар – исток

water supply pipes recorded elsewhere. The consistency of pipes sizes found during thise Glac Survey suggests that all of the pipe fragments were part of the one water supply pipeline system.

Terracotta pipes were used as aqueducts where the required volume of water flow being conveyed was generally not great and hence required a smaller



Map 2. The locations of find spots of Roman terracotta water pipe fragments

Карта 2. Локације наласка фрагмената римских глинених водоводних цеви

sized conduit than an open channel; further terracotta water pipes would operate at a neutral pressure or could be modestly pressurised (Gallo 2015, 121).

Terracotta water pipes could be used where such pipes were adequate for the expected volume of water to be conveyed. In Britain, terracotta pipes were used for aqueducts at Chester, Lincoln and Netherby (Burgers 2001, 112).

The Mitrovačke Njive – Prison Pavilion to Klisina Aqueduct

Mitrovačke Livade – Centre East / Far East, where the largest number of pipe fragments was found, appears to be the location of a Roman bathhouse, just west of the Čikas Canal and at the eastern end of a Roman village or hamlet extending on both sides of an east–west road. Worked marble and painted wall plaster were also found at this site. At Volerov Salaš – South-East, a Roman building was located, largely devoid of pottery, while at Volerov Salaš – Further South-East, pipe fragments were found not accompanied by any structure or building, indicating the existence of a pipeline traversing open land. The location of Crepovac – North-East includes remains of a building, and it is of approximately the same size as that at Volerov Salaš – South-East. At Klisina, 12 fragments of Roman terracotta pipes were found west/north-west of the circular mound.



Fig. 1. Fragments of Roman terracotta water pipes in the field north of the Concrete Factory, in the area of Prosek in 2025

Сл. 1. Фрагменти римских глинених водоводних цеви на пољу северно од Фабрике бетона, на потесу Просек, 2025. године

Connecting a line between Klisina, Crepovac – North-East, Volerov Salaš – Further South-East, and Mitrovačke Livade – Centre East / Far East indicates the likely line of the pipeline aqueduct (Map 3). At the south-eastern limit of this line is Klisina, where a number of short-term military camps were located (Dimitrijević and Whitehouse 2025). Extending this line to the north-west reaches the Manđelos to *Sirmium* aqueduct near the site of Mitrovačke Njive – Prison Pavilion.

The area east of the Manđelos to *Sirmium* aqueduct was surveyed east of the site of Mitrovačke Njive – Prison Pavilion and the route of the *Sirmium* aqueduct was located together with the accompanying *Sirmium* to *Bononia* Road. It is evidenced by a moderate carpet of stones, brick pieces and mortar. Just south of the prison pavilion, a line of stone, mortar and brick fragments was found heading in a south-easterly direction and associated with no other features. While no pipe fragments were found, it is likely this represents an offtake from the main *Sirmium* aqueduct, given that it corresponds with the line connecting Klisina to Crepovac – North-East, Volerov Salaš – Further South-East, Mitrovačke Livade – Centre East / Far East.



Fig. 2. Selected overview of the fragments of Roman terracotta water pipes collected at the site north of the Concrete Factory, the area of Prosek

Сл. 2. Преглед одабраних фрагмената римских глинених водоводних цеви прикупљених на локалитету северно од Фабрике бетона, на потесу Просек

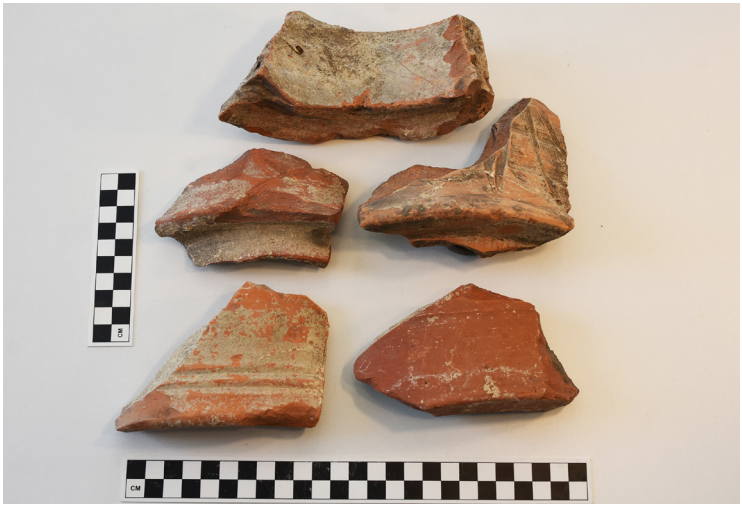


Fig. 3. Selected overview of the fragments of Roman terracotta water pipes collected at the site of Mitrovačke Livade – Centre-East / Far East

Сл. 3. Преглед одабраних фрагмената римских глинених водоводних цеви прикупљених на локалитету Митровачке ливаде – центар исток и даље ка истоку



Fig. 4. Selected overview of the fragments of Roman terracotta water pipes collected at the site of Volerov Salaš – Further South-East

Сл. 4. Преглед одабраних фрагмената римских глинених водоводних цеви прикупљених на локалитету Волеров салаш – и даље ка југоистоку



Fig. 5. Fragment of a Roman terracotta water pipe collected at Crepovac – North-East

Сл. 5. Фрагмент римске глинене водоводне цеви прикупљен на локалитету Цреповац – североисток



Fig. 6. Fragments of Roman terracotta water pipes collected at Klisina

Сл. 6. Фрагменти римских глинених водоводних цеви прикупљених на локалитету Клисина

The presence of calcareous sinter on nearly all of the pipe fragments found at Klisina, Crepovac – North-East, Volerov Salaš – Further South-East, and Mitrovačke Livade – Centre East / Far East indicates that these pipes were utilised to convey potable water derived from a karst spring. It should be noted that this does not establish that the karst spring was the spring of Vranjaš at Manđelos. The area between Fruška Gora and the Sava contains many springs with hard water, indicating a karst origin. Although many have been disrupted due to modern drainage and channel building, particularly in the agricultural areas in the River Terrace Land System and the Fan Srem Land System, they are noticeable in the urban area of Sremska Mitrovica, where some are utilised for domestic consumption by the modern population in preference to the municipal supplies. Hence, the presence of calcareous sinter on pipes indicates they were utilised to convey potable water derived from a karst spring and that they were not generally in close proximity to the water spring, but not necessarily from the main aqueduct from Manđelos, as it could have been from other local springs. This explains the presence of calcareous sinter on pipe fragments from locations not connected to the offtake branch line from the main aqueduct being considered here, such as Zabrana – West, the location of a farmhouse complex, which may have been

serviced by another offtake branch line from the main aqueduct or from another spring. However, the presence of calcareous sinter on a pipe fragment excludes the likelihood that the pipe was used to convey other surface flows or for drainage or waste disposal.

Klisina was identified as the likely destination of this pipeline as it was the last point at which pipe fragments were found and due to the identification of Roman military camps there (Dimitrijević and Whitehouse 2025), with the presence of brick structures, which were originally suggested to be the camp *principia* but could also include a bathhouse.

Baths in military camps and forts

The work of the Glac Survey has located a series of identifiable Roman military camps at Klisina, 6.5 km north-east of *Sirmium* (Dimitrijević and Whitehouse 2025). There appears to be a minimum of 11 identifiable Roman temporary military camps. There are additional 2 features which could either be additional separate Roman temporary military camps, bringing the total to 13 camps, or they could be internal features within a Roman temporary military camp. These camps have supporting literary and epigraphic evidence indicating the timeframe for the camps, from the reign of Marcus Aurelius to Constantine II (Dimitrijević and Prica 2023, 229–232; Dimitrijević and Whitehouse 2025). These camps could have accommodated less than half a legion of 6 notional cohorts. This suggests that the Klisina camps accommodated the imperial guard, which would accompany an emperor when he was in *Sirmium*.

An examination of surface finds indicated that some of the camps contained structures with Roman brick and tiles, suggesting that these were not just tented camps – they had brick and tile structures instead. These brick and tile structures were interpreted as the *principia* of the camp. Thus, these camps were semi-permanent and perhaps winter encampments (Dimitrijević and Whitehouse 2025). Roman terracotta pipe fragments found at Klisina were discovered to the west/north-west of the moated area in Grid 1 Square 19, and during the preliminary field survey, west of the farm track running north-east/south-west, west of the moated area. These finds were within the smaller rectangular features noted in Dimitrijević and Whitehouse (2025, 185–187, Figs. 5–8).

For a Roman legionary, a bathhouse in the camp was standard equipment (Hodge 2002, 6). It is noted that on Hadrian's Wall in Britain, all Roman forts had baths as a standard element and that bathhouses were attached to each Roman fort and fortress (Hodge 2002, 49; Southern 2007, 237; Fischer 2019, 237). Such comforts were recorded by Cassius Dio in the context of the last military

campaign of Marcus Aurelius in spring 179 in the territories of the *Quadi* and the *Marcomanni*, after which the Roman troops erected military camps that included baths (Cassius Dio, 72 [71].20.1–2).

In Roman forts, the preferred location for a bathhouse was the *praetentura*, in front of the *praetorium* (Reddé 2015, 85). This location adjoins the *principia*. In an examination of baths in *Moesia Superior*, for forts on the Danube *limes*, no baths were built inside fortifications or camps, but in close proximity to the fort outside the ramparts instead (Novović, Janković, Nikolić 2019, 29). Given that the imperial guards posted at Klisina would have been based in Rome with the emperors, it is unlikely that the local characteristics in *Moesia Superior* would have been adopted at Klisina for the location of baths.

If the Klisina camps were semi-permanent and perhaps winter encampments of the imperial guard, such camps would have contained a bathhouse. As the aqueduct was connected to the Klisina camps, then the brick structures identified at Klisina by the Glac Survey are likely to include a bathhouse. Given the high status of the imperial guard accompanying the emperors, it is likely that any bathhouse in their semi-permanent or winter encampments would require a volume of water that could only be supplied by an aqueduct. On this basis, Klisina is likely to have been the destination of the aqueduct from the Manđelos to *Sirmium* aqueduct near the site of Mitrovačke Njive – Prison Pavilion via Mitrovačke Livade – Centre East / Far East.

Mitrovačke Livade – Centre East – Far East bathhouse and Mitrovačke Livade – Centre East village

The branch aqueduct from the main *Sirmium* aqueduct from near the Mitrovačke Njive – Prison Pavilion to Klisina proceeds via Mitrovačke Livade – Centre East / Far East, where there was likely a Roman bathhouse. The Roman bathhouse would have been located at the eastern end of a Roman village or hamlet at Mitrovačke Livade – Centre East straddling an east–west road. It appears that the bathhouse and the village were supplied with water from the branch aqueduct to Klisina (Map 3).

Rural villages or hamlets consisted of long narrow rectangular "strip houses", without a courtyard, with 2-3 rooms. They may have been inhabited by workers and crafts persons, usually with no livestock. Houses were grouped in a linear fashion, usually following a road. They are sometimes found near main farms, and despite their modest size, they have roof tiles and other luxury features. They are best recognised in survey work as elongated habitation areas with a lengthy habitation boundary compared to the area enclosed, and a linear shape, straddling a road.

In the Late Roman period, bathhouses were reaching rustic consumers. There was a trend to build private bathhouses both on large estates, for the benefit of the landlord, and in villages and hamlets, where they may have had private operators making a profit. In the Segermes survey in northern *Africa Proconsularis*, a large number (20) of rural bathhouses was found, 8 associated with villas, 2 with villas with hamlets, 2 were located near medium farms, 4 near independent villages, indicating that farmers and villagers were using bathhouses in the Late Roman period (Dossey, 2010, 81–82; Hansen 1995, 361–363). It is interesting to note that Hansen, writing about the Segermes survey, commented that one of the surprises of the survey was the presence of isolated rural bathhouses (Hansen 1995, 361–363). It appears that this pattern was replicated in Roman *Pannonia* as indicated by the findings of the Glac Survey at Mitrovačke Livade – Centre East / Far East.

Finds of pipe fragments in the village of Mitrovačke Livade – Centre East, west of the bathhouse not located on the route of the pipeline aqueduct to Klisina, at Mitrovačke Livade – Centre, Mitrovačke Livade – Centre Near East, Mitrovačke Livade – Centre East, and Mitrovačke Livade – South (Table 6) suggest a supply line from the bathhouse offtake to supply the village, as the pipe fragments from the village have calcareous sinter on the inner surface. This challenges the general assumption that Roman aqueducts were designed to serve cities and not the countryside, an assumption which has been challenged by Wilson (Wilson 1999) and discussed further below.

If the existence of a water supply by an aqueduct to a rural bathhouse at Mitrovačke Livade – Centre East / Far East and its associated village is considered anomalous, this could be simply a happy coincidence that the aqueduct line to Klisina passed by the village, or that residents of the village of Mitrovačke Livade – Centre East had some imperial connection, or the bathhouse was connected to the elite farmhouse complex east of the Čikas Canal at Volerov Salaš – North, ("Livade, Site 23"), discovered in the 1980s and excavated (Brukner 1995b, 140, 141). The bathhouse at Mitrovačke Livade – Centre East / Far East is immediately to the west of the Čikas Canal (Map 2, Map 3). It sits at the eastern periphery of the rural village at Mitrovačke Livade – Centre East. On the eastern side of the Čikas Canal there is a mausoleum excavated as part of the motorway survey (Brukner 1995a) and adjacent thereto at Volerov Salaš – North more material was located, suggesting a large farm complex and necropolis and a road running east to west. It is understood that a geomagnetic survey conducted in February 2026 by the Institute of Archaeology in Belgrade identified a farmhouse in an area of 100x100 m with a number of buildings. It is possible that the bathhouse at Mitrovačke Livade – Centre East / Far East is associated with the elite farmhouse

complex at Volerov Salaš – North ("Livade, Site 23" according to Brukner) and is not part of the village at Mitrovačke Livade – Centre East. However, as will be discussed below, the view of Roman aqueducts as being directed to servicing urban populations at the exclusion or expense of the countryside reflect the excessive attention given to urban areas in Roman archaeology and a lack of appreciation of the role of the Roman countryside.

The Glac aqueduct

At Prosek Concrete Factory, just north of Glac, location a significant number of Roman water pipe fragments were found by the Glac Survey in 2025 (Map 2, fig. 1, fig. 2). These fragments were in a line running north/north-east for a length of 250 m, and were not associated with any other structures. This indicated a pipeline crossing fields. Some pipe fragments had calcareous sinter on their inner side, but the number of fragments with sinter was less than elsewhere. The presence of calcareous sinter indicated that the pipeline was a conduit for water from a karst spring. The fact that not all fragments had calcareous sinter indicated the pipeline did not run at full capacity.

In 2019, in Glac Creek, on the north-western side of the site of Glac, outside of the site fence, the Glac Survey team located a straight cut in the ground running in a NE/SW direction for 40 m towards the site. The cut is 0.4 m wide, with a depth of 0.3 m, and it can be clearly seen in LiDAR images (fig. 7, fig. 8). The cut sides contained Roman brick, stones and considerable mortar and crushed bricks, with finds of hydraulic mortar, stone, red coarse ware and grey wares. The cut is likely to have related to the provision of water supply to the Glac palace. This may have been the feature noted by Ignjat Jung. Further, the alignment of the cut is consistent with the alignment of pipe fragments located north of the concrete factory north of the Jarak road.

The nature of the cut indicates a likely casing to contain a pressurised pipe as part of a siphon system. This could be either a lead pipe, as part of a siphon, or terracotta water pipes. The lack of finds of any pipe fragments in the accompanying cultural debris near the cut could indicate it housed a lead pipe which was subsequently removed, whereas if it housed a terracotta pipeline, fragments may have remained following the destruction of the system.

The use of inverted siphons was relatively common in Roman aqueducts (Hodge 2000b, 78; Hodge 2002, 151). But a siphon system required a header tank and a lower recovery tank, and no evidence of these structures has been located, although the reservoir at Glac that Jung mentioned may have been the recovery tank. The presence of casing within which a pipe could be located as was found in Glac

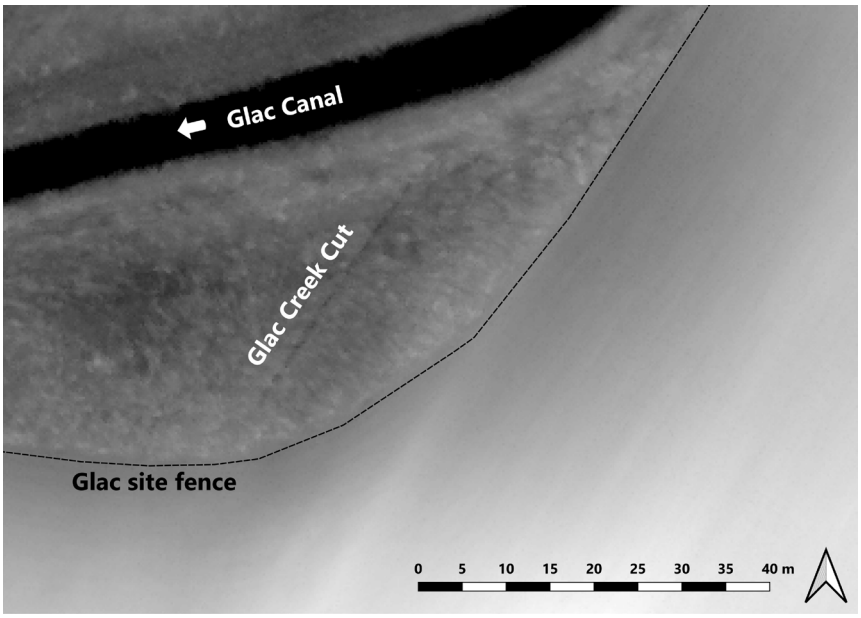


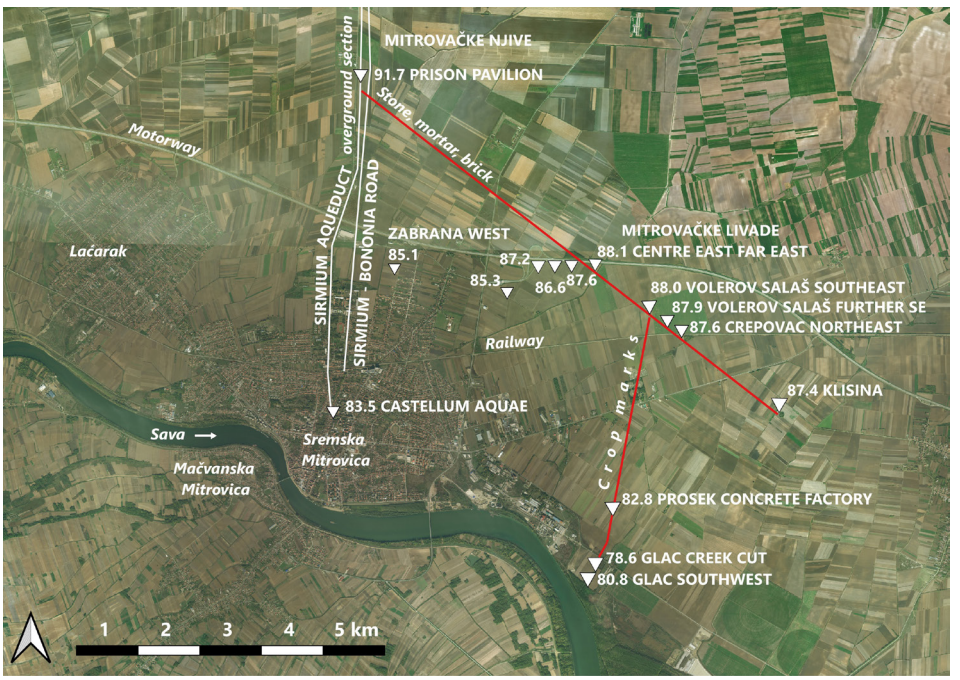
Fig. 7. Glac Creek Cut, LiDAR Digital Terrain Model

Сл. 7. Усек код Глацовог канала, *лидар*, дигитални модел терена



Fig. 8. Glac Creek Cut, looking towards the south-west

Сл. 8. Усек код Глацовог канала, поглед ка југозападу



Map 3. Positions and directions of the Roman aqueducts toward Klisina and Glac, with marked altitudes above sea level

Карта 3. Позиције и правци римских водовода према Клисини и Глацовом салашу, са означеним надморским висинама

Creek suggested the need for containing a pressurised pipe and hence suggesting the presence of a siphon. Siphons at a large scale are found at Lyon, France, and at Aspendos, Turkey (Burdy 1988; Hodge 2002, 147–160), but the Romans used siphons extensively, on both large and small scale (Hodge 2002, 147).

Extending a line connecting Prosek Concrete Factory and Glac Creek Cut would indicate the likely line of the pipeline aqueduct. Extending this line connects to the south/south-east to Glac, where the remains of a Late Roman palace complex have been found, and to the north-west to meet the Mitrovačke Njive – Prison Pavilion to Klisina Aqueduct (Map 3).

The offtake point of the Glac aqueduct from the Klisina aqueduct appears to be at Volerov Salaš – South-East, where a Roman building was located, largely devoid of pottery. This structure may be a water tower and the point where the Glac aqueduct branched off the Klisina aqueduct (Map 3).

According to the *Epitome de Caesaribus*, attributed to Aurelius Victor, Maximian Herculius, the co-ruler with Diocletian from 285 CE, erected a palace near *Sirmium*, where his parents used to work as day labourers (Pseudo Aurelius

Victor, *Epitome* XL, 10; Banchich 2009). This palace is likely to be located at the site of Glac, 4 km east of Sremska Mitrovica, on the Sava, on the road to Jarak. Recent archaeological excavations, which commenced in 2017 but ceased in 2024, identified a high-status palatial building, which suggests that Glac is the site of the palace built by Maximian Herculius (Institute of Archaeology, Belgrade, *Glac Project*, n.d.).

Hence, the pipeline to Glac is likely to have been a further branch aqueduct off the Mitrovačke Njive – Prison Pavilion to Klisina aqueduct, designed to supply the imperial palace complex there.

Pipeline gradients

Water flow increases with higher pressure and larger pipe diameters. Flow rate is governed by the formula of flow equals area times velocity, with pressure providing the driving force, though friction from small pipes and long lengths limit flow. In gravity fed systems, head pressure is the vertical height difference between the point of origin of a pipeline and its destination. Hence the key variables in a water supply pipeline are the pipe size, the head pressure and the pressure loss through friction and turbulence.

A pipeline could be at a constant gradient or could go up and down over minor irregularities, as a pipeline that runs full would be under at least nominal pressure and sometimes more (Hodge 2000a, 42; Hodge 2002, 115).

Gradient may be expressed in either degrees or as a percentage. Gradients are most easily understood as percentages. The formula for calculating a slope is the rise divided by the run and multiplied by 100, where the rise is the vertical distance (height), and the run is the horizontal distance: $100 \times \frac{\text{rise}}{\text{run}}$ %.

Thus a 100% slope represents a 45-degree angle.

Pliny indicates that the slope on an aqueduct should not be less than a quarter inch per hundred feet of length (Pliny, *Natural History* 31.31; Jones 1963, 413–415). This slope equals 1 in 4,800 or a gradient of 0.02%. Gallo notes that this slope is the most common in known Roman channels, and that the aqueduct at Nîmes rarely exceeds that slope and has lower slopes for much of its course (Gallo 2015, 120).

The Nîmes aqueduct has a very shallow gradient, particularly when compared to the gradients of the aqueducts supplying Rome. The water source for the Nîmes aqueduct at Fontaine d'Eure spring at Uzès is 17 m higher than the *castellum aquae* in Nîmes, 49 km distant, giving an average gradient of 0.34 m/km (0.03%), but some sections of the aqueduct have a gradient of 0.03 m/km (0.003%) and 0.07 m/km (0.007%) (Hodge 2002, 184–191; Ortloff 2021, 63, Fig. 7).

DISTANCES BETWEEN SITES				
KLISINA AQUEDUCT				
SITE	SITE	DIRECTION	KILOMETRES	ROMAN MILES
Mitrovačke Njive-Prison	Klisina	NW – SE	8.440	5.700
Mitrovačke Njive-Prison	Mitrovačke Livade Centre East-Far East	NW – SE	4.852	3.277
Mitrovačke Livade Centre East-Far East	Volerov Salaš Southeast	NW – SE	1.156	0.780
Volerov Salaš Southeast	Crepovac Northeast	NW – SE	0.555	0.374
Crepovac Northeast	Klisina	NW – SE	1.880	1.269
GLAC AQUEDUCT				
SITE	SITE	DIRECTION	KILOMETRES	ROMAN MILES
Volerov Salaš Southeast	Glac Southwest	N – S NE – SW	4.388	2.963
Volerov Salaš Southeast	Prosek – Concrete Factory	N – S	3.200	2.161
Prosek – Concrete Factory	Glac Creek Cut	N- S NE – SW	1.048	0.707
Glac Creek Cut	Glac Southwest	NE – SW	0.140	0.094
1 Roman Mile = 1.4805 km				

Table 7. Distances between various locations along the routes of the aqueducts

Табела 7. Удаљености између различитих локација дуж водовода

ALTITUDES		
SITE	POSITION	ALTITUDE ASL (m)
• Crepovac Northeast	4983416, 7396499	87.6
• Glac – Audience Chamber Mosaic Floor	4979316, 7395076	79.9
• Glac – SE Corner of the Terrain	4979299, 7395127	81.6
• Glac – SW Corner of the Terrain	4979395, 7395031	80.8
• Glac Creek Cut	4979550, 7395096	78.6
• Klisina	4982196, 7398130	87.4
• Mitrovačke Livade Centre	4984467, 7394240	87.2
• Mitrovačke Livade Centre East	4984508, 7394775	87.6
• Mitrovačke Livade Centre Near East	4984493, 7394369	86.6
• Mitrovačke Livade Centre East Far East	4984508, 7395091	88.1
• Mitrovačke Livade South	4984070, 7393726	85.3
• Mitrovačke Njive Prison Pavilion	4987464, 7391406	91.7
• Prosek Concrete Factory	4980479, 7395448	82.8
• Volerov Salaš Further Southeast	4983567, 7396345	87.8
•Volerov Salaš Southeast	4983734, 7395974	88.0
• Zabrana West	4984447, 7391852	85.1
• GPS coordinates relate to a central zone of a site; Gauss-Krüger Projection, Balkans Zone 7. • Sources: LiDAR DTM and DSM 2018, 2020, 2022; Maps of the Military Geographical Institute: Vojnogeografski institut 1968 – 1979a; Vojnogeografski institut 1968 – 1979b.		

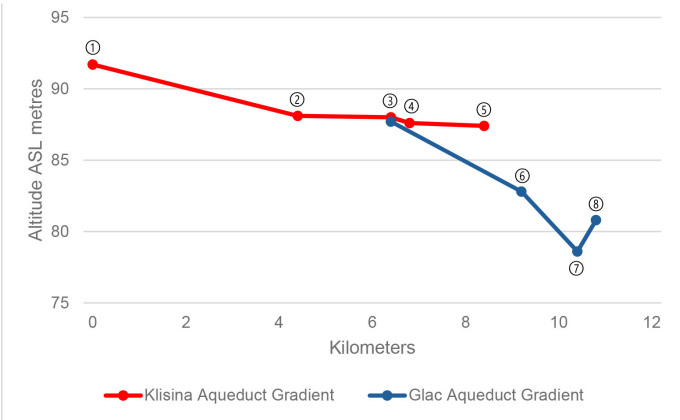
Table 8. Altitudes above sea level of various locations along the routes of the aqueducts

Табела 8. Надморске висине различитих локација дуж водовода

ESTIMATED PIPELINE GRADIENTS				
KLISINA AQUEDUCT				
LOCATION	LOCATION	HEIGHT DIFFERENCE	DISTANCE	GRADIENT PERCENTAGE
Mitrovačke Njive-Prison	Klisina	4.3 m	8,440 m	0.05%
Mitrovačke Njive-Prison	Mitrovačke Livade Centre East-Far East	3.6 m	4,852 m	0.07%
Mitrovačke Livade Centre East-Far East	Volerov Salaš Southeast	0.1 m	1,156 m	0.008%
Volerov Salaš Southeast	Crepovac Northeast	0.4 m	555 m	0.07%
Crepovac Northeast	Klisina	0.2 m	1,880 m	0.01%
GLAC AQUEDUCT				
LOCATION	LOCATION	HEIGHT DIFFERENCE	DISTANCE	GRADIENT PERCENTAGE
Mitrovačke Njive-Prison	Glac Southwest	10.9 m	10,396 m	0.10%
Volerov Salaš Southeast	Prosek – Concrete Factory	5.3 m	3,200 m	0.17%
Prosek – Concrete Factory	Glac Creek Cut	4.2 m	1,048 m	0.40%
Glac Creek Cut	Glac Southwest	+ 2.2 m	140 m	+1.57%

Table 9. The height differences of the researched sites and the estimated pipeline gradients

Табела 9. Висинска разлика између истражених локалитета и нагиб водовода



Key:
① Mitrovačke Njive Prison Pavilion
② Mitrovačke Livade Centre East Far East
③ Volerov Salaš Southeast
④ Crepovac Northeast
⑤ Klisina
⑥ Prosek Concrete Factory
⑦ Glac Creek Cut
⑧ Glac – SW Corner of the Terrain

Diagram 1. A gradient profile of the aqueduct pipelines

Графикон 1. Профил нагиба цевовода аквадукта

For the aqueducts to Klisina and Glac, the distances between various locations along the routes of these pipelines are indicated in Table 7, while the estimate heights of these locations are indicated in Table 8. Based on these, the height differences of these locations and the estimated pipeline gradients are indicated in Table 9. A gradient profile of the aqueduct pipeline is at Diagram 1. It provides a gradient profile of the aqueduct pipelines, with the gradients for various sections.

It will be appreciated that the estimated heights are based on existing ground surface heights, while the pipeline was buried. Also, the cautionary note on aqueduct gradients expressed by Hodge should be noted (Hodge 2002, 218). Subject to these qualifications, the percentage slopes for the aqueducts to Klisina and Glac are such that water would flow in the pipelines by gravity, with the exception of the crossing of Glac Creek by the Glac aqueduct, where a siphon was required.

Chronology for aqueducts construction

The aqueducts to Klisina and Glac were offtakes from the main aqueduct supplying *Sirmium* from the Vranjaš spring at Manđelos. According to Jeremić, this main aqueduct was probably constructed in the 2nd or the 3rd centuries CE (Jeremić 2016, 304, 307). Hence, the offtakes to Klisina and Glac could not have predated the construction of the main aqueduct. The literary and inscriptional evidence indicate that the Klisina military camps dated from the time of Marcus Aurelius to Constantine II. Hence, the offtake branch to Klisina could have been constructed at the time of the original building of the main aqueduct from at least 180 CE onwards.

The Glac palace was constructed by Maximian Herculius, the co-ruler with Diocletian from 285 CE, although it appears there were earlier buildings on the site, but an adequate stratigraphy of the site is lacking. It is likely that the offtake to Glac would have been constructed with the palace and, hence, can be dated after 285 CE. The Glac offtake was added onto the pre-existing offtake to Klisina.

During the field survey in 2026 at the rural village of Mitrovačke Livade – Centre, Roman ceramics, which included *Terra Nigra* and Late Antique glazed ware, were found along with other Roman ceramics. This suggests a chronological range for Roman occupation from the initial Roman conquest through to Late Antiquity. But none of these indicators apply to the bathhouse area, which may have been added when the aqueduct line to Klisina was built, or it may have predated the aqueduct and existed in a more rustic form.

Rationale and role of Roman aqueducts

A study of Roman aqueducts, such as those surrounding *Sirmium*, raises two important questions:

a. Why were aqueducts build?

b. What was the impact of an aqueduct upon the countryside from where the water was extracted and through which it was transported?

The first question is whether the driving force behind aqueduct construction was the provision of a public service for the recipient community, or whether it was driven by the Roman passion for baths and ostentatious water displays in fountains and *nymphaea*.

The view of Roman aqueducts as utilitarian and public goods for the benefit of communities is well expressed by Frontinus: "*Tot aquarum tam multis necessariis molibus pyramidas videlicet otiosas compares, aut cetera inertia sed fama celebrata opera Graecorum*" (Frontinus, *De Aquaeductu Urbis Romae*, 1.16; Rodgers 2004, 75) ("With such an array of indispensable structures carrying so many waters, compare if you will, the idle Pyramids, or the useless, though famous, works of the Greeks") (Bennett 1925, 357–359). The view that aqueducts were built for utilitarian and public good reasons underlay early studies on aqueducts. Subsequently, aqueducts were viewed as luxuries designed to support baths and ostentation fountains (Wilson 2008, 308). Hodge considered that the construction of a large bath complex was the chief reason for building an aqueduct (Hodge 2002, 6).

Wilson sees a need to balance these two competing purposes, noting that cities would not have been able to grow to the extent they did in the Roman world if they were reliant upon water from wells, rainwater cisterns and local springs (Wilson 2008, 308–309). It is more a question of the individual circumstances in each case. Many urban complexes of considerable sizes could manage on wells, cisterns and local springs, while others could not, with supplies needing augmentation by large public aqueduct schemes if they were to support increased populations. The other factor is whether there were practical options to construct an aqueduct system to deliver water to a town or city; there may or may not have been reliable springs or water sources in reasonable proximity of a town or city, or the delivery of water to a town or city was either not technically or economically feasible.

There is no doubt that large Roman baths were major users of water. But that is not the case with all baths. There were many smaller private or public baths that did not require large volumes of water and did not require an aqueduct

to supply them (Hodge 2008, 49; Yegül 1992, 390). However, a large continuous water supply enabled a bath to become more grandiose and in all likelihood more enjoyable to patrons. Hence, the presence of an aqueduct would considerably enhance the bathing experience and enable baths to take on a monumental and luxurious style. Thus, the construction of a set of grand baths often followed the construction of an aqueduct to a town or city, but whether there was a direct causal relationship, remains unclear. Hence baths could have been the driver for the construction of an aqueduct, or the construction of an aqueduct would provide the opportunity to build major baths; baths could either be the impetus for aqueduct construction or the consequence of aqueduct construction. Wilson disputes that aqueducts were chiefly built to supply public baths; he accepts that baths and aqueducts form part of the display of wealth but considers they had a utilitarian role in water supply to urban areas (Wilson 1999, 315).

There remains a significant duality of the role of an aqueduct, making discerning its driving purpose problematic. In the case of the aqueduct to Klisina, its primary purpose is likely to have been to supply baths, as the camps could potentially have obtained adequate supplies for other uses from wells, but there is no doubt it served dual purposes for both baths and potable supplies. In the case of the aqueduct to Glac, it would have had a dual purpose of supplying potable supplies in addition to baths and fountains. In both cases, they could take the benefit of an existing aqueduct from Manđelos to *Sirmium* by constructing an offtake branch. Such offtake branches occur particularly to supply imperial facilities. Thus, after Commodus confiscated the *Villa dei Quintili* outside of Rome, he added an arcade from the *Anio Novus* aqueduct (Wilson 1999, 316). Offtakes to supply military camps of the imperial guard at Klisina or imperial palaces such as Glac fit this pattern.

The second question of the impact of an aqueduct upon the countryside from where the water was extracted and through which it was transported raises an underlying issue in Roman archaeology, namely, the excessive attention given to urban areas and the lack of appreciation of the role of the Roman countryside. All too often the importance of the Roman countryside is obscured in generalised discussions about an architectural form of the so-called *villa rustica*, or amorphous concepts of cultural identity or Romanisation, or unproductive debates about Weber's concept of the consumer city, instead of models derived from detailed ground survey evidence and analyses.

The general assumption that Roman aqueducts were designed to serve cities and not the countryside and that they may been at the expense of the countryside does not bear scrutiny. The provision of an aqueduct to supply the local

baths of a rural village at Mitrovačke Livade – Centre as well as the entire rural village or hamlet is a good example of the sharing of the benefits of an aqueduct with the countryside. Indeed, rural usage of the water from aqueducts was quite prevalent, particularly in Late Antiquity (Wilson 1999, 324).

Further, the emphasis on the major aqueducts tends to ignore the multitude of small water supply systems and branch offtakes from major aqueducts, both public and private. These smaller water supply systems supplying villages and farmsteads equally merit attention.

Conclusion

The work of the Glac Survey has identified branches from the main aqueduct of Vranjaš (Manđelos) to *Sirmium* aqueduct. These branch aqueducts are pipelines. One branches off the main aqueduct at the Mitrovačke Njive – Prison Pavilion to the semi-permanent military camps at Klisina to supply a likely bathhouse for the troops encamped there, with a distance of 8.4 km. Along its route, the Klisina aqueduct passed by a Roman hamlet or village at Mitrovačke Livade – Centre, where it supplied a rural bathhouse and the village itself. The Klisina aqueduct is likely dated to sometime around or after 180 CE. The second aqueduct branches off the Klisina aqueduct at Volerov Salaš – South-East and proceeds to the tetrarchic palace complex at Glac, built by Maximian Herculius after 285 CE, with a distance of 4.3 km. The Glac aqueduct is likely to have been constructed at the same time as the palace complex at Glac. The Glac aqueduct required the installation of a siphon to cross Glac Creek. Aside from the crossing of Glac Creek, both aqueducts could have functioned effectively by gravity flow.

The provision of an aqueduct offtake to supply the rural bathhouse at Mitrovačke Livade – Centre / Far East and the adjoining village or hamlet is a good example of the sharing of the benefits of an aqueduct between urban and rural areas and between imperial facilities and the army and local rural communities. It points to the complex, multifaceted, and intensive nature of Roman settlement and land uses in the countryside around *Sirmium*.

Acknowledgements: We would like to thank the following graduate and postgraduate volunteers who participated in the field survey in February and March 2023, February and March 2024, February and March 2025 and February and March 2026, for their dedication and professionalism. In 2023, these were: Mihajlo Džamtovski, Stefan Gajić, Stefan Novaković, Ivana Protić, Aleksandar Stamenković, Jovan Stipić, Uroš Svirčević, and Bojan Tajhmeister. In 2024, these were: Jana Bogdanović, Anastasija Đurđević, Stefan Gajić, Maja Jekić, Stefan Novaković, Ivana Protić, Simeun Srdanović, Aleksandar Stamenković, Matija Šušel, Uroš Svirčević, and Bojan Tajhmeister. In 2025, these were: Jana Bogdanović, Anastasija Đurđević, Mihajlo Džamtovski, Stefan Gajić, Maja Jekić,

Zorana Laketić, Stefan Novaković, Aleksandar Stamenković, Zorana Tripković, and Bojan Tajhmeister. In 2026, these were: Jovana Dragićević, Stefan Gajić, Maja Jekić, Dušan Kojić, Uroš Lekić, Stefan Novaković, Aleksandar Stamenković, Biljana Stojković, Bojan Tajhmeister, and Zorana Tripković.The assistance of Aleksandar Stamenković as permit holder and local resident Petar Mackanić is greatly appreciated. This paper would not have been possible without their valued contribution.

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РИМСКИ ВОДОВОДИ СЕВЕРНО ОД КОМПЛЕКСА ПАЛАТЕ НА ГЛАЦУ КОД АНТИЧКОГ СИРМИЈУМА. РЕЗУЛТАТИ АРХЕОЛОШКИХ РЕКОГНОСЦИРАЊА.

Кључне речи: *аквадукти, водоснабдевање, Глацов салаш, Доња Панонија, Друга Панонија, Клисина, римски водовод, глинене цеви, Сирмијум, сифон*

Систематска археолошка рекогносцирања околине античког Сирмијума у Срему и Мачви и непосредне околине локалитета Глацов салаш југоисточно од Сремске Митровице спроводе се од 2017. године, најпре кроз сарадњу Археолошког института у Београду и Универзитета у Сиднеју, а након тога у сарадњи са удружењем *The Glac Survey Incorporated* из Сиднеја.

Током теренских кампања 2019, 2023, 2024, 2025. и 2026. године предузета су испитивања римске водоводне инфраструктуре северно, североисточно и источно од античког града, када су на више локација прикупљени површински налази делова глинених водоводних цеви и откривен сегемент водоводног сифона северно од локалитета Глацов салаш. Чланак представља резултате тих истраживања, узимајући у обзир контексте, значења и значај ових налаза за водоснабдевање римских војних логора на локалитету Клисина и комплекса тетрархијске палате на Глацовом салашу.

Приликом теренске проспекције утврђени су огранци римског водовода који на његовој северозападној страни полази рачвајући се од главног античког аквадукта Сирмијума у јужном делу трасе која води од извора Врањаш до града. Ови огранци главног водовода били су конструисани као подземни цевоводи.

Један крак водовода пружао се од рачвања на потесу Митровачке њиве у близини павиљона КПЗ северно од Сремске Митровице, према југоистоку, до локалитета Клисина, који се налази североисточно од града. На Клисини је утврђено постојање остатака више римских привремених војних логора и овај крак водовода вероватно је снабдевао јавно купатило изграђено за потребе римске војске. На траси овог водовода, на потесу Митровачке ливаде – центар, утврђено је постојање остатака античког руралног насеља

са јавним купатилом поред канала Чикас, које се, као и само насеље, снабдевало водом из аквадукта Клисине. На месту купатила постојало је рачвање водовода према западу, односно према центру руралног насеља. Датирање аквадукта Клисине може се ставити у време око 180. године или у период убрзо након 180. године.

Други огранак античког водовода рачвао се од аквадукта Клисине на потесу Волеров салаш – југоисток; пружао се правцем север–југ до тетрархијске палате, чији су остаци откривени на Глацовом салашу југоисточно од Сремске Митровице, коју је изградио Максимијан Херкулије након 285. године. Овај римски водовод је највероватније изграђен у време градње саме палате. За потребе функционисања аквадукта Глаца, на његовом јужном крају било је неопходно изградити сифон како би водовод прешао Глацов поток. Остаци те структуре откривени су северно од остатака палате на Глацовом салашу, поред Глацовог (Цреповачког) канала. Оба аквадукта су спроводила воду према Клисини и према Глацовом салашу помоћу гравитационе силе.

Водоснабдевање купатила и руралног насеља рачвањем водовода на потесу Митровачке ливаде – центар пример је расподеле користи од водовода између урбаних и руралних зона Сирмијума, између царских здања, римске војске и руралних заједница током антике.