concurrently through the appendices in the second volume so as to gain access to the full references on the sites. It is a challenge to read this two-volume set and yet this comprehensive analysis of the archeological sites contains many important insights.

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New and multidisciplinary methods investigating Roman water management: aqueducts and castella in Rome and Pompeii

Duncan Keenan-Jones

University of Manchester <duncan.keenan-jones@manchester.ac.uk>

WIPLINGER, G., ed. 2020. *De aquaeductu urbis Romae. Sextus Iulius Frontinus and the Water of Rome: Proceedings of the International Frontinus Congress Rome, November 10–18, 2018*. Babesch Supplementa 40. Leuven: Peeters. Pp. xxxiii, 403. ISBN 978-90-429-4311-7.

This volume presents the proceedings of the most important conference in studies of ancient Mediterranean water systems (given that the Cura Aquarum conference seems in abeyance), held only once every four years or so. Hence it represents a vital overview of recent work in the field. For reasons of space, this review will focus on the water supply of Rome (the conference's focus) and Pompeii.

The book starts with Anthony Jennings's gripping speculation about the assassination of Domitian and its aftermath, including the possible involvement of Frontinus ("Gods of Blood and Water: Frontinus and the Dead of Domitian," 3–12). This is a novel and refreshing start to an academic volume. Then, in "The Aqueducts of Rome: Principles of Water Supply and Questions of Research" (53–64), Jens Köhler gives a succinct introduction to ancient Rome's water supply (useful for those with or without previous knowledge of the topic), which outlines the future possibilities and challenges. He highlights how dramatically the Aqua Marcia improved on those aqueducts that had gone before and outlines the many dangers these aqueducts faced: urban development, earthquakes, the ravages of time. Köhler interprets the increase in Tiber flooding during the Roman warm period as solely due to human impact, as he believes this to have been a predominantly dry period. While temperature reconstructions are broadly applicable across large areas of the Mediterranean, as Jennings's Table 1 (57) suggests, rainfall shows much more local variation. Surveys of recent research into cave and lake indicators (or *proxies*) of past rainfall have shown opposite rainfall trends in the northern (drier) and southern (wetter) Mediterranean.[1] The lack of rainfall proxies for central and southern Italy means it is not clear where the Tiber Basin falls between these two trends.[2] It was not clear to me how determining the number of aqueducts constructed could assist here, given that they seem often not to represent vital drinking water supply, but I agree that limestone deposits, called travertine or sinter, have promise. It is true that these deposits are more likely from aqueducts supplied by springs than by lakes, but we do see some spring-fed aqueducts without travertine (such as Rome's Aqua Virgo) and some river-fed aqueducts with travertine (such as Rome's Anio Novus and Vetus).[3] Köhler provides an excellent case study of the Aqua Alexandrina, with new information based on his own fieldwork. I would specify here the other possible identification of this aqueduct as the Aqua Antoniniana.[4] Köhler closes by alluding to travertine ripples and waves that can yield information about water speed and flow rate. The justification and details of this calculation have recently been published,[5] allowing its application to the Aqua Alexandrina if such waves can be found.

Luca Messina, Mauizio Pagano, and Riccardo Ribacchi ("In the Footsteps of Ashby: Colle Papese in the Tivoli Area," 65–74) are properly cognizant of both the usefulness and limitations of Ashby's pioneering work on the Roman aqueducts, providing new data on a difficult stretch of ancient Rome's four Aniene aqueducts. The detailed fieldwork of Sotterranei di Roma (continuing on from previous publications[6]) has turned up remains not found by Ashby, as well as rediscovering a lost Augustan *cippus*, in a welcome tale of increasing rather than decreasing evidence since Ashby's time. This work promises to solve the thorny problem of the attribution of sections to these aqueducts.

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[1] Labuhn et al. 2016.

[2] Labuhn et al. 2016; Finné et al. 2019; Hu et al. 2022; Zanchetta et al. 2021.

[3] Sivaguru et al. 2022; Keenan-Jones et al. 2015; Keenan-Jones et al. 2014; Motta et al. 2017.

[4] Coates-Stephens 1998; Hostetter et al. 2011.

[5] Keenan-Jones et al. 2022.

[6] Pagano et al. 2017.

Edoardo Gautier di Confiengo and Elettra Santucci ("The Distribution of Aqua Claudia and Anio Novus in Rome," 85–100) present an interesting piece on the distribution of the water of the Aqua Claudia and Anio Novus aqueducts within the city, based on thorough research in the literature coupled with field observation. Santucci's Figure 2 (p. 86) is a very useful depiction of the estimated distribution network. As a minor quibble, I would argue that the authors take too little consideration of the problems with Frontinus's measurements of the flow rate (*quinariae*),[7] particularly in aqueduct channels, but they present interesting reconsiderations of Frontinus's (and other) evidence elsewhere (e.g., in relation to the terminal castellum of the Anio Novus). This chapter is full of interesting new ideas and hypotheses to be tested, perhaps by analysing the composition of carbonate deposits in some of the cisterns mentioned and linking them to different aqueducts.[8] It will help chart the course for future study of water distribution within the city of Rome. On the basis of elevations, the authors argue that the Aqua Claudia or Anio Novus supplied the Nymphaeum Alexandri and Baths of Diocletian, and the arcades leading to them, rather than the Julia, Tepula, and Marcia. In particular, the chapter considers the nodes that linked the masonry aqueduct channels to the lead pipe distribution system, the *castella aquae*. Gautier di Confiengo and Santucci present a useful classification system that can be applied elsewhere. They divide castella into two main categories: those that connect the aqueduct channel to a reservoir and those whose function is purely distribution, containing no reservoirs (*castella divisoria*). The first category is further divided into three different classes:

1. lateral, which run alongside the aqueduct, divert part of the flow, store it and distribute it to pipes, and send the remaining flow back into the main aqueduct channel
2. terminal, which take all of the flow from the end of the aqueduct and distribute it to a piped distribution system, and
3. axial, which are on the main axis of the aqueduct, i.e. which take all the flow of the aqueduct and distribute it to the piped system and aqueduct channels.

Gautier and Santucci also give a general reconstruction of either an axial (most likely) or else a lateral castellum (Figure 5, where it is labelled a terminal castellum, but this cannot be right, according to their classification, as it sends some water back to an aqueduct channel). I wonder, however, if the pipes would often leave from the very base of the structure, since this would meant that the water could only rise to the water level of the lowest tank (no. 5 in their diagram). At times of high demand relative to supply, this would be near ground level, sacrificing the height maintained over nearly 100 km of aqueduct channel at the cost of hundreds of millions of *sesterces*. Perhaps we should imagine pipes also coming from the higher tank, no. 3, with their own valve, to preserve onward supply to the next castellum? It could be that pipes in A1–4 in the Vigna Belardi cistern actually supplied major or elevated structures nearby (such as nymphaea), rather than Room 1, under pressure, as the authors suggest for the "disappeared" castellum on the Esquiline (92–93). Further structures that would fit Gautier di Confiengo and Santucci's castellum schema are two cisterns at the upstream and downstream ends of the Parco Tor Tre Teste.[9] If

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[7] For these, see Keenan-Jones et al. 2015.

[8] Hostetter et al. 2011.

[9] Aicher 1995, 106–9.

these were castella and not just cisterns, they must have served the Aqua Antoniniana/ Alexandrina (see discussion of the Köhler chapter above). Similarly, the Villa delle Vignacce cistern[10] may have been a castellum serving the Aquae Julia, Tepula, and/or Marcia. Both of these cisterns are much further from the city than those described by Gautier and Santucci, however, which may be evidence of considerable distribution of water to suburban properties, already suggested by Wilson.[11]

Staying with distribution systems, Richard Olsson presents the results of work in progress involving his calculations of flow rates within the best-preserved system from the Roman world: Pompeii ("Aqueduct Water-Supply System in Pompeii," 103–8). He estimates flowrates along the mains pipes running from the terminal castellum (to use Gautier di Confiengo and Santucci's classification) to the water towers (*castella divisoria*). Despite the well-preserved nature of Pompeii's system, almost all these mains pipes are missing and their size must be estimated, as must the functioning heights of the water towers, which have been damaged. Several further issues could be raised with Olsson's reconstruction. He has three mains pipes leading from the castellum to match the three holes leading from the castellum. Archaeological excavations in front of the castellum revealed only two trenches, however, for mains pipes. Mauri earlier suggested that a mains pipe from the central hole could have shared a trench with one of the two other mains pipes but also thought it likely that the central hole supplied a fountain immediately below it.[12] In addition, Olsson includes all water towers known in 2018 (and not the water tower in Regio V discovered in 2019, of course), but not all these water towers seem to have been operating at the same time.[13] All these issues introduce considerable uncertainty into Olsson's estimates. The uncertainty is not yet quantified, but he is prudent in rounding to the nearest whole number. Olsson stresses the importance of balance between inlets and outlets of the *castella divisoria* to avoid overflow from the tanks (inlet flow too large) or reduced supply to end users (inlet flow too small). It is very likely, however, that overflow did occur, since considerable carbonate deposits (travertine) have been left behind by evaporating water running down the side of the majority of water towers that supported the tanks (see Table 1 below), and this is unlikely to have been caused by leaks alone. Unless the outlets from the tanks (which are unknown) were much more restrictive of flow than the pipe roughness, at times the flow from the mains pipes into the tanks must have been greater than the outflows. The only water towers where little or no travertine is found are 5 (trace), 10, 11, 12 (trace), 13, and perhaps 6 (although this is unclear as it has been damaged and reconstructed in modern times). Towers 12 and 13 were probably out of use at the time of the eruption.[14] All the towers lacking travertine are located at the downstream end of the system, suggesting that, by this point, so much water had been drawn off upstream that demand was significantly outstripping supply. Recent work can be integrated here to investigate this balance. Monteleone and her co-authors have recently performed similar estimates of flow rate at the next stage downstream compared to Olsson's work: from the water towers to the public fountains,[15] using the same tower

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[10] Ashby 1935, 133–34.

[11] Wilson 1999.

[12] Maiuri 1931, 564.

[13] Keenan-Jones 2015.

[14] Keenan-Jones 2015.

[15] Monteleone et al. 2023.

heights as Olsson, and from the water towers to two of the roughly 91 houses supplied[16] by the piped system.[17] They have estimated the roughness of different pipes (an important factor in estimating the flow rate inside them) using endoscopy, microscopy, and laboratory experiments on preserved Roman pipes, yielding absolute roughness estimates of 0.1–0.5 mm. In this chapter, Olsson has not published details of his calculations, including roughness, so it is difficult to know if the two studies are comparable. The inflows and outflows (Olsson's mains, and the means and minima of Monteleone et al.'s fountains) for each water tower are shown in Table 1.

Both input and output flow estimates represent the capacity of the pipe. It is clear that under Olsson's estimated mains inputs, the output capacities of mains pipes (Olsson) plus fountain and two house pipes (Monteleone et al.'s means) for towers 1, 3–12, and 14 would never be reached, let alone if the output capacity of pipes leading to baths and the further 89 or so private properties were added, as well as (for towers 3 and 5) unestimated mains pipes leading to unexcavated parts of the city. Thus, only at fountain 2, and possibly 13, depending on other outputs, should there ever be overflow. Given that travertine shows there was overflow in many more towers in the upstream system, there are a number of possible explanations:

1. The sizes of the pipes were different (during some periods at least) from those assigned in the calculations;
2. Taps were used at certain times to shut off some of the outflows from water towers with travertine; and/or
3. Olsson is using a larger roughness than Monteleone et al., decreasing Olsson's capacities.

There is a large discrepancy in the overall water system balance, considerably more than the combined output of the castellum, which represents the inflow into the system. The maximum sizes of the castellum outflow pipes are constrained by the holes in the castellum wall, so explanation 1 above would not improve this system imbalance and is less likely to explain the imbalance for so many individual water towers. Even where Monteleone's minimum pipe size and flow rate values are used (Table 1), the situation does not appreciably change. There are still many towers with substantial travertine deposits with negative or small positive balances where overflow shouldn't happen. Explanation 2 is very possible, given the large number (112) of taps found in Pompeii,[18] even if they weren't used so much to store water as to divert it.[19] We look forward to the full publication of Olsson's calculations to judge explanation 3, although, even here, a reduced roughness would also increase Olsson's mains pipes outflows to some degree. I suspect that he is underestimating the flows into the piped system and hence into each water tower, by choosing a roughness that is too large. I would also argue that balancing inflows and outflows in Pompeii's water system was not as important as he argues. There was likely storage of water in public and private castella at times of low demand, especially in the last phase of the city's water supply,[20] particularly if flow rates were as low as Olsson estimates.

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[16] Jansen 2001, 27.

[17] Monteleone 2020.

[18] Jansen 2001, 29.

[19] Kessener 2017.

[20] Keenan-Jones 2015.

Table 1.

Balances of input and output water flow capacities for the castellum, each water tower, and Pompeii's water system as a whole. (* Negative values represent greater output capacity than input capacity, where overflow of the tank should never happen; ** That is, total distribution system input).

Water tower	*Travertine?*	*Input From Mains l/s Olsson 2020*	*Output to Mains l/s Olsson 2020*	*Output to Fountains Mean l/s Monteleone et al. 2023*	*Output to Houses Mean l/s Monteleone 2020*	*Balance* Mean l/s*	*Output to Fountains Minimum l/s Monteleone et al. 2023*	*Output to Houses Minimum l/s Monteleone 2020*	*Balance* Minimum l/s*
castellum			17**	2.445	0	–19.445	0.71	0	–17.71
1	Substantial	11	10	1.55	0	–0.55	0.69	0	0.31
2	Substantial	10	5	2.745	0	2.255	1.06	0	3.94
3	Substantial	5	4	0.785	0.775	–0.56	0.43	0.7	–0.13
4	Substantial	4	1.4	6.73	0	–0.413	2.37	0	0.23
5	Trace	1.4	0.8	6.695	0.4	–6.495	2.25	0.3	–1.95
6	Unclear: reconstruction	0.8	0	5.16	0	–4.36	1.7	0	–0.9
7	Substantial	4	3	2.92	0	–1.92	0.97	0	0.03
8	Substantial	1.4	0.7	3.18	0	–2.48	1.03	0	–0.33
9	Substantial	3	1	6.475	0	–4.475	2.15	0	–0.15
10	None	0.7		2.345	0	–1.645	0.75	0	–0.05
11	None	1		3.265	0	–2.265	1.1	0	–0.1
12	Trace	2	1.9	1.645	0	–1.545	0.45	0	–0.35
13	None	0.5		0.325	0	0.175	0		0.5
14	Substantial			2.96	0	–2.96	1.13		–1.13
15	Substantial	Recently discovered and not included							
Total System Balance		**17**		**49.225**		**–32.225**	**16.79**		**0.21**

Paul Kessener ("Frontinus' *Quinaria* and Direct Discharge," 321–32) addresses the thorny problem of the value of the *quinaria* and ancient measurement of flow rate. After reviewing previous approaches to the problem, Kessener makes many useful fluid mechanical observations regarding Roman measurement of flow rate, *quinariae* and *castella divisoria*, leavened with a thorough knowledge of post-Roman, pre-modern practice. He finishes with a novel mechanism that could have been used by ancient *aquarii* to measure flow rate, joining others conjectured by Blackman, Hodge, and Taylor:[21] a box with *quinaria*-sized orifices.

Charles R. Ortloff ("The Pont du Garde Aqueduct and Nemausus (Nîmes) Castellum: Insight into Roman Hydraulic Engineering Practice," 333–48) also considers the *castellum divisorium*, both optimized and the example found at Nîmes, from a fluid mechanical point of view, while Jan Pieter Lubbers ("Planning and Building Aqueducts of Ancient Rome without the Use of Surveying Instruments," 349–60) considers the surveying and construction of Rome's Anio Vetus aqueduct in depth. The volume also considers systems supplying Taurmenion, Split, Parion, Ephesus, Syedra, Gerasa, Sepphoris, and the province of Africa, as well as including sections devoted to Roman toilets, and chapters on wastewater in Ostia and water machines in medieval Arabic texts.

The quality of the contributions is variable but generally good. Some chapters were in need of further editing; for example, the otherwise welcome contribution by Cinti ("The *Aqua Alsietina*: An Unknown Aqueduct with the Worst Water in Rome: Resources and Instruments for a Correct Analysis and Interpretation of the Aqueduct," 75–84) on the neglected Aqua Alsietina could have done with a little more peer review and editing to clarify the language and argument (e.g., Frontinus is said to refer to the Aqua Traiana; *CIL* VI.1261 describes "for certain" irrigation for private individuals from the Alsietina, when a more nuanced discussion is needed here[22]). The English of many contributions could be more idiomatic, but the meaning is almost always clear, and the authors' facility with what for many of them is a second language is impressive.

The volume is handsomely illustrated, with many large color diagrams and pictures. As always, I found the endnotes annoying, necessitating constant flipping to the end of a chapter to chase down references (also for images that didn't face the text discussing them, such as that on the distribution of the Aqua Claudia and Anio Novus). All in all, this is an excellent and timely volume that covers exciting new research into water systems around the Roman Mediterranean. It is required reading for all those interested in pre-modern water management.

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[21] Blackman 1978, 71–72; Hodge 1984, 210–14; Taylor 2000, 38.

[22] Wilson 2009.

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Roman justice

Thomas A. J. McGinn

Vanderbilt University <thomas.a.mcginn@vanderbilt.edu>

HEKSTER, O. and K. VERBOVEN, eds. 2019. *The Impact of Justice on the Roman Empire: Proceedings of the Thirteenth Workshop of the International Network Impact of Empire (Gent, June 21–24, 2017)*. Impact of Empire 34. Leiden: Brill. Pp. viii + 237. ISBN 978-90-04-40045-0.

The title of this collection of 12 essays, which obviously plays a variation on that of the distinguished series it joins, might as easily have been *The Impact of the Roman Empire on Justice*. The editors lose no time in establishing the terms of a paradox that stands at its core. The Romans cherished a social hierarchy that privileged a small number of persons in contrast to the vast multitudes that ranked beneath them, while creating and maintaining through almost unceasing violence a far-flung dominion over non-Romans and slaves. Yet they valued justice, or at least purported to do so, holding out this virtue as a moral linchpin of their very claim to rule over others. By way of coming to terms with this bundle of contradictions, the editors promise a series of contributions linked by three strands of "notions, practice, and ideology" relating to justice (3). While, perhaps not surprisingly, the Romans prove remarkably adept at molding principle to purpose, the central question of interest to us remains not so much how their vision differs from ours as whether and to what extent they were able to realize their ideals.

The book is divided into three parts: "Part 1: The Emperor and Justice," "Part 2: Justice in a Dispersed Empire," and "Part 3: Justice for All?".

Part 1: The emperor and justice

Much of the discussion centers, as one might expect, around the emperor, and we are well served in this regard by Stéphane Benoist and Anne Gangloff in their essay, "Culture politique impériale et pratique de la justice: Regards croisés sur la figure du prince 'injuste'" (19–48).[1] The authors take their point of departure from Cicero's famous

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[1] Limitations of space forbid taking adequate notice of the extensive contributions of these authors, but two recent works are certainly worth mentioning: Gangloff 2018 and Benoist 2020.