

A COMPARATIVE ANALYSIS OF ROMAN
WATER SYSTEMS IN POMPEII AND NÎMES

by

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Abstract

This thesis compares the Roman water systems in Pompeii and Nîmes in order to understand the relationship of the water systems to the urban layout of the city.

Analyzing the nature and location of an urban water system enables a better understanding of the urban functions within a city, as well as prediction of the nature and location of particular structures within an urban plan. I examine the primary sources of Vitruvius and Frontinus, the topography of each city, the urban orientations, the hydro-technologies employed, and the public and private buildings to which water would have been supplied. My survey of water systems begins with the source of water and the aqueduct that supplies each city and also assesses the relationship of the aqueduct to the rural landscape. In both Pompeii and Nîmes, water from the aqueduct is deposited in a central settling tank within the city and dispersed from the settling tank to various destinations. I have analyzed the buildings, public and private, that had or would have required direct access to this water source and created water supply routes for each colony.

Chapter 1

Introduction

The urbanization of Rome and the Roman provinces was significantly facilitated by the development of hydraulic water systems. Before the invention of hydraulic water systems, urban development was necessarily confined to areas near wells, rivers, springs, and other bodies of water. The availability of a water supply limited both the site and extent of settlements. The development of aqueducts and other urban water distribution systems enabled a steady and substantial supply of water to be conveyed from a source of abundant supply, such as a spring, to a place of abundant use, such as a city. The ability to migrate water to remote destinations facilitated agriculture, industrialization, and urban development.

Roman water supply and distribution systems were a complex and an integral part of the urban design of a city. They had a direct relationship to the city plan and the location of certain monuments. A water supply system encompassed not only an aqueduct, which traversed the landscape from the water source to the city, but also an urban storage and dispersal system. Scholarship tends to ignore the second part of the water system, focusing mainly on the engineering and architectural aspects of aqueduct construction.¹ A premise of this thesis is that it is important to observe the entire water system to assess the impact of Roman water distribution on urbanization.

To understand the correlation between urban planning and water supply systems, this thesis compares the water supply and distribution systems of the two Roman colonies of Pompeii and Nîmes. These cities have well-preserved water systems that allow for a

¹ Hodge, 1992, 20

comprehensive study of not only the pipe framework but also the various monuments and residences that drew water from the system. The parameters for my study of the water system of each city are the city plan, the aqueduct, the *castellum divisorium*, the pipe networks, and the baths, fountains, private residences, and public buildings with water-related functions. I believe that this comprehensive study will yield stronger conclusions about the spread of hydro-technology in the Western Roman Empire, the socio-economic status of the two colonies, and the urban planning of Roman colonies in general.

Before undertaking a comparative analysis of the water systems of Pompeii and Nîmes, however, it is helpful to understand the methods and components of urban water distribution, including how aqueducts operated and the features of the urban dispersal system. Accordingly, Chapter 2 of my thesis provides an introduction to hydraulics and the technology used in aqueduct and water supply construction. I evaluate the writings of Vitruvius and Frontinus on water distribution. I also describe briefly the history of aqueduct building, including Bronze Age, Archaic and Classical Greek, Hellenistic, and Etruscan examples. This helps to understand the spread of hydro-technology in the Mediterranean, specifically where the Romans learned aqueduct building and how they deviated from previous practices. The chapter concludes with a summary of the principal components of Roman water systems, focusing on aqueducts and the *castellum divisorium*. Although aqueducts and the *castellum divisorium* are only part of the larger picture of water distribution, the modern ruins of aqueducts and *castella divisorium* are mostly all that remain today of the ancient water supply systems.

Chapter 3 discusses the aqueduct and urban water distribution of Pompeii. I begin this chapter by laying out a brief history of Pompeii from its time as an Oscan and

Hellenistic city to the foundation of the Sullan colony. Pompeii's aqueduct is something of an enigma and is believed to have been a branch of the *Aqua Augusta*. Christoph Ohlig has written in depth on the Pompeii water supply system, and I use much of his data to supplement my own study. I created a map of plausible routes for Pompeii's water distribution based on the elevations, street grids, the location of secondary *castella*, and pipe grooves on secondary *castella*.

Chapter 4 discusses the aqueduct and urban water distribution of the Roman colony of *Colonia Augustus Nemausus*, which is located in modern day Nîmes, France. Roman Nîmes was an important colony in the *Narbonensis* region of Gaul. Water was supplied to Roman Nîmes from the La Fontaine d'Eure near Uzès via a 50-kilometer aqueduct. I created a map of plausible urban water distribution routes. Similar to my study on Pompeii, I analyzed the spatial relationships between the various monuments, private residences, and other buildings within the city and their connections to the water supply system. I was able to determine five routes from the *castellum divisorium* and an additional route from the Jardin de La Fontaine. Also, a closer study of the organization of the city helps to confirm the orthogonal layout of the city.

Chapter 5 is a comparison between the two cities, and Chapter 6 sets forth my conclusions regarding Roman water supply practices in general and the urban water distribution systems of Pompeii and Nîmes. I have compiled the relevant comparative data into tables that allow for a side-by-side comparison of the two cities in regard to their urbanization, aqueducts, *castella divisorium*, and urban water distribution. My comparison determined that Nîmes was much larger than Pompeii in population and that

hydro-technology for aqueduct construction and urban water distribution had become standardized by as late as the 1st century CE.

Chapter 2

Hydraulics and Technology

2.1 Roman Hydraulic Systems and Urbanization

The aqueduct was a key component of the Roman water supply system. The system also encompassed, however, catchments and urban distribution.² The *castellum divisorium* was the focal point of the urban water distribution system and was located at a high point, if not the highest point, in the city (**Figure 2.1**). Water was distributed from the *castellum divisorium* through the city by means of pipes underneath the streets and sidewalks. The Romans incorporated in their settlements certain features necessary to urban life or to enhance the standing of a city such as gates, arches, shrines, and fountains.³ Waterworks can similarly be understood as a source of civic pride; they complemented the status of the colony. A *castellum divisorium* was built within an enclosure that displayed various aesthetic features and architecture that attracted people to go see it.⁴ The same can be said for fountains and *nymphaea*, which also were integral parts of the urban water distribution system. Like aqueducts, the urban water storage and dispersal system was directly related to the topography and elevations of the city. By locating the *castellum divisorium* at a high point in the city, the downward slope of the terrain moved the water by gravitational force through the pipes to specific locations.

Water was supplied to specific monuments and private residences in the city, and the distribution system was an integral part of the urban layout of the city. Marcus Vitruvius Pollio and Sextus Julius Frontinus recorded that water was delivered to baths,

² Evans, 2013, 287

³ Kaiser, 2011, 197

⁴ Anderson, 2013, 193

fountains, and certain private residences.⁵ *Ita in medio ponentur fistulae in omnes lacus et salientes, ex altero in balneas vectigal quotannis populo praestent, ex quibus tertio in domus privatas, ne desit in publico, non enim poterint avertere.*⁶ Much of the water supply was devoted to the functional needs of the population and was accessed through street fountains.⁷ Baths created another demand for water that was part recreational and part functional.⁸ The private residences that received a direct line from the urban water system had to obtain specific permission for the water line from the government and were often taxed on it.⁹ Therefore, the private residences that were supplied water no doubt had elite status. Water was frequently used in these residences to supply private baths and fountains, as well as elaborate gardens. It is evident that water was a luxury item, as well as a public necessity. With this in mind, social divisions can be observed within the urban landscape, defining elite neighborhoods in the city. This is why it is important to look at aqueducts and urban water systems not just as ruins and monuments, but also as dynamic social elements that represented attributes of the society that built them.

2.2 History of Aqueducts

Although Rome refined and exploited hydraulic water technology, it was not the first civilization to use hydro-technology. Water supply systems first appeared in the Mediterranean in the Babylonian Kingdom in the Bronze Age around 4,000 BCE and were mostly used for irrigation. Another example, the Assyrian *qanat* was a tunnel that

⁵ Frontinus, 1.3; Vitruvius 8.6.2

⁶ Vitruvius, 8.6.2: From this central tank, pipes will be laid to all the basins and fountains; from the second tank, to baths, so that they may yield an annual income to the state; and from the third, to private houses, so that water for public use will not run short; for people will be unable to divert it

⁷ Hodge, 1996, 261

⁸ Jones and Robinson, 2005, 695

⁹ Evans, Harry, 1997, 9

was dug into a hillside to tap an aquifer. The tunnel had a downward slope for the water to flow by gravity and was punctuated at intervals of 20 m by vertical shafts to the surface.¹⁰

Minoan palaces on Crete in the Middle and Late Bronze Ages also had intricate water systems. The lack of water on Crete made it necessary to develop an external water source. The source of water was often karstic springs found at high elevations. The Minoan hydro-technology consisted of cisterns, aqueducts, and urban water, wastewater, and storm water management systems that ensured superior water quality and sanitation against pollution and sabotage.¹¹ Sites like Knossos and Tylissos employed stone-lined and terracotta conduits to channel water to the community, and even stored the water in stone cisterns (**Figure 2.2**).¹² The water conduits of these settlements traveled several kilometers from the source in a trench that was dug into the ground or carved into rock or via a stone-lined channel that was covered with stone slabs (**Figure 2.2**).¹³ Interestingly, a charcoal filtration device was found at the entrance to the Tylissos aqueduct, which consisted of burnt wood that would have activated the carbon process.¹⁴

The innovations seen on Crete spread to mainland Greece and Italy and continued into the Classical and Hellenistic periods. Peisistratus constructed an aqueduct system in Athens around 510 BCE and the "fountain house" in the Agora. This aqueduct carried water from the foothill of Hymettus mountain for a distance of 7.5 km. In the Archaic period, aqueducts supplied water mainly to public fountain houses, but, by the 5th century

¹⁰ Hodge, 1992, 20

¹¹ Evans, Harry, 1997, 9

¹² Mays, 2010, 10

¹³ Mays, 2010, 10

¹⁴ Mays, 2010, 10

BCE, people were illegally tapping the public water system for private use.¹⁵ The Greeks established colonies on Sicily and mainland Italy starting in the 8th and 7th centuries BCE. The three earliest aqueducts at Syracuse belong to the reign of Heron II (270-215 BCE) and are rock-cut tunnels with access shafts.¹⁶ Unlike their later Roman counterparts, the Greek aqueduct builders did not use arcades to carry aqueducts across the terrain, and the aqueducts followed the contours of the landscape in either rock-cut channels or terracotta pipelines.¹⁷

The Etruscans also had a profound impact on water planning. The Etruscans learned water technology from the Greeks. As far back as the 7th century BCE, the Etruscans had trade connections with Samos. The tyrant Polycrates of Samos funded the construction of the tunnel of Eupalinos in the 6th century BCE, and this knowledge would have been available to the Etruscans.¹⁸ Water channels, *cuniculi*, were used for the construction of the Cloaca Maxima, the giant sewer that drained the Forum Romanum.¹⁹ According to Livy, Tarquinius Priscus, an Etruscan King of Rome, built the Cloaca Maxima.²⁰ The Etruscans also used hydro-technology outside of Rome, specifically at Orvieto and Chianciano Terme.

At Orvieto (ancient Velzna) the settlement exhibited evidence of orthogonal planning, as seen in the grid at the Crocifisso del Tufo cemetery.²¹ Additionally, the

¹⁵ Wilson, 2008, 294

In 490 BCE, Themistocles, as *hydaton epistates*, fined those who illegal diverted water from the public system. (Plutarch, Them. 31.1)

¹⁶ Wilson, 2008, 294

¹⁷ Wilson, 2008, 294

¹⁸ Bizzarri and Soren, 2016, 136

¹⁹ Bizzarri and Soren, 2016, 136

²⁰ Livy 1.38.6, 1.56.2

²¹ Bizzarri and Soren, 2016, 138

drainage network under the city streets of Orvieto was also designed in a grid plan.²² The water was accessible to the population via vertical shafts that were cut into the bedrock.²³ This is indicative that water planning was happening alongside urban design. Chianciano Terme, near Chiusi, had a sacred spring with medicinal properties. The Etruscans built a series of buildings surrounding the spring and a central pool in the 2nd century BCE. The pool was colonnaded and had access ramps. It measured 18 m x 18 m, and had a drain at one end and an overflow pipe to remove excess water and to keep the area free from flooding.²⁴

Although the previous technological advances of the Greeks and Etruscans were passed onto them, the Romans adapted, transformed, and exploited the technology like never before. The Romans constructed hundreds of aqueducts throughout the Roman Empire, beginning with the *Aqua Appia* in Rome in 312 BCE. As Wilson observes, the Roman innovations included the use of arcades to carry aqueduct channels over valleys, the use of concrete as a cheap and adaptable building material, the adoption of waterproof cement linings, the expanded use of lead piping, and the introduction of settling tanks and storage and regulation reservoirs in the network.²⁵ Eleven aqueducts were constructed in Rome by the 3rd century CE and they supplied the city with an estimated 300 million gallons of water a day and had an estimated combined conduit length of approximately 800 kilometers.²⁶ Rome's political dominance of Italy enabled the construction of

²² Bizzarri and Soren, 2016, 138

²³ Bizzarri and Soren, 2016, 138

²⁴ Bizzarri and Soren, 2016, 139

²⁵ Wilson, 2008, 296

²⁶ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

aqueducts outside of Rome, as evidenced by the aqueduct that censor L. Betilienus Varus built for his hometown of Alatri in 130/120 BCE.²⁷

The most informative ancient sources on aqueducts and water distribution are Vitruvius and Frontinus. In his treatise *De Architectura*, Vitruvius provides the ensuing details regarding aqueduct construction and urban water dispersal.²⁸ Roman water systems distributed water to destinations in the urban plan through lead pipes, masonry conduits, or terracotta pipes.²⁹ When the aqueduct reached the city, the water was collected in a reservoir with a distribution tank.³⁰ The reservoir had three partitioning tanks and three pipes, one for each of the partitioning tanks, and each tank was dedicated to a specific use. From this central distribution tank, pipes would distribute water, first, to all the basins and fountains, second to baths, and third to private houses.³¹ Vitruvius states that these divisions of water were made so individuals who were supplied water to their residences could be taxed on the water supply to help maintain the system.³²

One-hundred years after Vitruvius, Sextus Julius Frontinus, who was the water commissioner of Rome (*curator aquarum*) under the emperor Nerva, wrote a treatise on aqueducts.³³ Frontinus catalogued the seven major aqueducts of Rome, beginning with the *Aqua Appia*, Rome's first aqueduct (**Figure 2.3**). His writings indicate that aqueduct construction in the Republican period was funded by individuals and spoils of war, as

²⁷ Wilson, 2008, 296

²⁸ Vitruvius, 8.6

²⁹ Vitruvius, 8.6.1

³⁰ *Cumque venerit ad moenia, efficiatur castellum et castello coniunctum ad recipiendam aquam triplex inmissarium, conlocenturque in castello tres fistulae* (Vitruvius, 8.6.1).

³¹ *Ponentur fistulae in omnes lacus et salientes, ex altero in balneas vectigal quotannis populo praestent, ex quibus tertio in domus privatas* (Vitruvius, 8.6.2).

³² *Uti qui privatim ducent in domos vectigalibus tueantur per publicanos aquarum ductus* (Vitruvius, 8.6.2).

³³ Frontinus, *The Stratagems and Aqueducts of Rome*.

attested by the *Aqua Appia*, *Aqua Anio Vetus*, *Aqua Marcia*, and the *Aqua Tepula*. The *Aqua Appia* was built by Appius Claudius, the *Aqua Marcia* was built by the Praetor Quintus Marcius Rex, the *Aqua Anio Vetus* was constructed with money acquired in the Pyrrhic War, and the *Aqua Tepula* was built by the censors G. Servilius Caepio and L. Cassius Longinus. By the 1st century BCE, aqueduct construction received imperial attention under Agrippa and Augustus, although it was often still funded privately. Agrippa made a conscious effort to repair conduits of the *Appia*, *Anio Vetus*, and the *Marcia* aqueducts, as well as provide baths and fountains for the city, and he built the *Aqua Julia* and the *Aqua Virgo*. Augustus later funded the *Aqua Asietinian*, and Claudius built the *Aqua Claudia*.

2.3 Components and Operation of Roman Water Systems

The typical Roman hydraulic water system comprised the following: (a) an abundant water source, usually a mountain spring; (b) an aqueduct that carried the water many kilometers by gravity flow from the water source to a city; (c) a large holding tank at the terminus of the aqueduct into which the water was deposited for redistribution within the city; (d) and a system of pipes within the city to distribute water from catchments, local springs, and the aqueduct holding tank to buildings in the city and to remove sewage and waste water from the buildings to beyond the city. The urban water system also encompassed purification of water using filters, sieves, sluice gates, and settling tanks.

An aqueduct traveled many kilometers from its source of water through the rural countryside to the city while maintaining a gradient that allowed a sufficient quantity of

water to flow.³⁴ As it neared the city, the aqueduct terminated at a *castellum divisorium*, a central holding, settling, and distribution tank to which pipes were attached for distribution of the water to specific locations inside the city. Mountain springs were by far the most common sources of water for aqueducts, and the spring water was maneuvered into the mouth of the aqueduct via channels.³⁵ Roman aqueducts moved water via conduits that generally were buried in tunnels that were dug into the bedrock below ground, constructed as canals at ground level, or carried above ground across arcades, which were bridgework consisting of a series of low arches (*substructio* and *arcuatio*).³⁶ The Roman surveyors had to plan carefully the route of the aqueduct to exploit the gradient of the terrain and to create specific twists and turns to build enough pressure to move the water through the aqueduct by gravity flow. They coated the interior of the aqueduct channel with *cocciopesto*, which was mortar mixed with broken pieces of tile (*opus signinum*), to prevent leakage but also to provide a smooth, continuous surface to reduce friction and thereby increase the flow rate. It is evident that the topography and elevations of the landscape directly affected not only the aqueduct's route through the terrain, but also the aqueduct's slope, design, and construction methods.

Along its course (usually near the beginning and at the end before reaching the *castellum divisorium*), the aqueduct channel would pass through one or more decanting or sedimentation tanks that Frontinus called *piscina limaria*. Their purpose was to remove debris and particulate impurities from the water.³⁷ None are preserved in the ruins of the water supply systems of Pompeii and Nîmes.

³⁴ Blackman, 2001, 52

³⁵ Mays, 2010, 115

³⁶ King, 1990, 78

³⁷ Frontinus, 1.32

The aqueduct would enter the city through the city walls in an underground channel that would empty into the *castellum divisorium* (**Figure 2.4**). The *castellum divisorium* was the most important component of the urban water distribution system. The two best-preserved examples of a *castellum divisorium* are the ones at Pompeii and Nîmes. The *castellum divisorium* marked the end of the aqueduct proper and the beginning of the urban water distribution system. As previously indicated, the basin of the *castellum divisorium* was enclosed in a structure that had aesthetic features and architecture. The aqueduct would enter the *castellum divisorium* on one side and the water would be distributed within the city through pipes inserted through holes on the other side of the *castellum divisorium*. The pipes ran underground along the major streets of the city. The *castellum divisorium* also functioned as a settling tank to remove sediment and other foreign matter from the water before it was distributed throughout the city. The *castellum divisorium* often had drainage holes at the bottom that were used to cleanse the system. The urban water system relied on gravity flow to circulate the water, so the *castellum divisorium* had to be located on ground high enough to assure adequate pressure in the distribution system, perhaps at least 12 m above the populated parts of the town.³⁸

The water in the *castellum divisorium* was divided through pipes (*fistulae*) that were attached to the *castellum divisorium* by a *calix*.³⁹ A *calix* was a bronze sleeve that was inserted through the holes of the wall of the *castellum divisorium* and then into the external distribution pipes (**Figure 2.5**). The external distribution pipe was soldered to the *calix* to prevent leaks as water flowed from the basin into the external distribution pipe.

³⁸ Hauck, 1988, 75

³⁹ Evans, Harry, 1997, 6

The size of the distribution pipes was measured in *quinariae*, a Roman unit of area that is approximately equal to 4.2 square centimeters and was used primarily to measure the cross-sectional area of the water pipes. Eventually, a pipe known as *quinaria* (or the 5-pipe) became the standard size used in the water systems. The diameter of the *quinaria* pipe, according to Frontinus, was $5/4$ digits, and that measure was likely the derivation of the name of the pipe.

Sometimes the urban water system included secondary *castella*. The secondary *castella* were supplied water through pipes from the *castellum divisorium* and were usually in the form of vertical water towers. They were used in areas with a steep slope to reduce the water pressure and also served as secondary holding tanks for the redistribution of water to nearby baths, fountains, and residences. Two designs were used to lay out the pipe network from a secondary *castellum*: (1) water was distributed from the secondary *castellum* through a main pipe with smaller branch pipes attached to it to serve individual users, and (2) water was distributed from the secondary *castellum* through individual pipes that ran directly to the individual users, which was the normal Roman practice.⁴⁰

2.4 Design and Priorities

Building a water supply system required an in-depth knowledge of the topography, as well as an extensive survey of the landscape before and during construction. The most significant feature of Roman aqueducts was their total reliance on gravity flow to move water through the channels and conduits. Therefore, an appropriate

⁴⁰ Mays, 2010, 117

slope had to be established using leveling, plumb line level, *dioptra*, or the *libra*.⁴¹ The first step would be to find a spring of suitable volume and quality, which was located high enough for the water to flow by gravity along an aqueduct.⁴² A *castellum divisorium* would be built at the terminus of the aqueduct, ideally at a point high enough to supply water by gravity flow to the whole city.⁴³ Then, the exact difference in height between the water source and the *castellum divisorium* would need to be measured by careful leveling.⁴⁴

The main tool used in leveling aqueducts was the *chorobates* (**Figure 2.6**). The *groma* and *dioptra* could be used to take sightings, but they did not measure differences in the level.⁴⁵ *Chorobates* were used to determine the horizontal level and maintain the slope against the terrain.⁴⁶ The *chorobates* consisted of a wood beam that was approximately 6 m in length and was supported by two legs and equipped with two plumb lines at each end.⁴⁷ The legs were joined to the beam by two diagonal rods with carved notches.⁴⁸ If the notches corresponding to the plumb lines matched on both sides, it showed that the beam was level.⁴⁹ On top of the beam, a groove or channel was carved.⁵⁰ If weather conditions were too windy for the plumb bobs to work effectively,

⁴¹ Lewis, 2001, 200

⁴² Lewis, 2001, 200

⁴³ Lewis, 2001, 200

⁴⁴ Lewis, 2001, 200

⁴⁵ Hodge, 1992, 203

The *dioptra* is described as a flat disc mounted on top of a pedestal or tripod and can be tilted in the vertical plan and rotated horizontally. The *groma* is composed of two short rods intersecting at a right angle with a plumb attached to each end mounted on top of a pole.

⁴⁶ Hodge, 1992, 198

⁴⁷ Hodge, 1992, 200

⁴⁸ Hodge, 1992, 200

⁴⁹ Hodge, 1992, 199

⁵⁰ Hodge, 1992, 199

the surveyor could pour water into the groove and measure the plane by checking the water level.⁵¹

Since aqueducts are based on gravity flow, maintaining a constant gradient throughout the landscape was an important part of both survey and construction. The slope, or fall, of an aqueduct was a crucial factor. If the slope was too shallow, the water would not move and would stagnate in the channel, but, if it was too steep, the water would move too rapidly and damage the channels. The slope of the aqueduct had to be adjusted for changes in the elevation of the landscape. For instance, if the gradient of a valley was too flat, a bridge (or *substructio*) would need to be built to maintain a constant slope to keep the water moving. To have functioning water flow, the slope of an aqueduct could be no steeper than 1 in 1370, although slope varied by region and aqueduct.⁵²

After measuring the distance between the water source and the aqueduct terminus, a few key intermediate points had to be determined, as well as alternative routes.⁵³ The effectiveness of the aqueduct was completely reliant on the capabilities of the architect, engineer, and survey team. Not all aqueducts were successful. Pliny the Younger reported to Trajan in 112 CE that the city of Nicomedia in Asia Minor had made two attempts at building an aqueduct and subsequently abandoned both of them.⁵⁴ Pliny asked the emperor to send him a surveyor or engineer because the previous ones had been incompetent.⁵⁵

⁵¹ Hodge, 1992, 199

⁵² Lewis, 2001, 200

⁵³ Lewis, 2001, 201

⁵⁴ Lewis, 2001, 201

⁵⁵ Lewis, 2001, 201

Water was carried along the aqueduct in stone, terracotta, and even wood conduits that were enclosed (*specus, rivus*) and usually ran through channels that were trenched or tunneled below ground or carried on a low wall above ground from the water source to the terminus of the aqueduct at the *castellum divisorium* (**Figure 2.7**).⁵⁶ The conduits were usually covered by stone slabs to protect the water from external contaminants. Stone channels were most often used for aqueducts. The stone conduits could also be above ground in *substructio* and *arcuatio* and traverse the landscape on a series of arcades. The inside of the conduit was lined with *opus signinum* (a waterproof plaster) to smooth out the walls and decrease the friction of the water flow.⁵⁷ For maintenance purposes, shafts were installed every 35.5 m, or one *actus*.⁵⁸ Occasionally, these shafts were marked by a *cippus* every 71.3 m (240 Roman feet), or two *actus*.⁵⁹

For structures above ground, channels were built using brick, concrete, and rough-stone construction. The stone conduits were usually made from local stones that were cut and fitted. Stonework was rare for underground channels.⁶⁰ The size of the channel was determined by its accessibility for cleaning and maintenance, rather than the volume of water to be transported.⁶¹

Pipes were used for the water distribution system within the city. They were usually made of terracotta, but also could be made of lead or wood. Vitruvius recorded that the use of lead was discouraged because of the limited knowledge of lead poisoning.⁶² Lead pipes withstood water pressure better than clay pipes, but they were

⁵⁶ Hodge, 1992, 94

⁵⁷ Hodge, 1992, 95

⁵⁸ Hodge, 1992, 103

⁵⁹ Hodge, 1992, 103

⁶⁰ Hodge, 1992, 94

⁶¹ Hodge, 1992, 102

⁶² Vitruvius, 8.6.1

more expensive and required specialists to design them.⁶³ Most of the lead pipes that were used in the urban water systems no longer exist; they were stolen and used for other things. *Tubuli fictile* (terracotta pipes) were made in shorter lengths with one end tapering to seal the joints.⁶⁴ Terracotta pipe sections were normally around 40-60 cm long with an internal diameter of 10 to 15 cm (**Figure 2.8**).⁶⁵

The Romans used siphons in aqueducts throughout the empire, and siphons were especially numerous in Gaul (**Figure 2.9**).⁶⁶ Inverted siphons were used to conduct water through a valley, as seen in parts of the aqueduct of Lyon.⁶⁷ According to Hodge, the Roman aqueducts used inverted siphons, rather than true siphons, with the bend or elbow at the bottom instead of at the top.⁶⁸ Hydraulically, an inverted siphon will begin running as soon as the water is admitted, but a true siphon has to be started artificially by a pump.⁶⁹ The siphons were composed of a header tank, a bend called *geniculus*, a *venter* bridge, and a receiving tank.⁷⁰ Siphons are hardly mentioned in ancient accounts. Vitruvius is the only source that discusses siphons, and he just describes the system without giving it a name.⁷¹

Maintenance of the water systems was necessary to repair damage, remove debris and sediment, and keep the channels and conduit from becoming clogged. A major maintenance problem was incrustation of the conduits caused by calcium carbonate (CaCO_3), also known as "sinter" (**Figure 2.10**). Sinter is a substance that derives from

⁶³ Hodge, 1992, 110

⁶⁴ Hodge, 1992, 113

⁶⁵ Hodge, 1992, 113

⁶⁶ Hodge 1985, 220

⁶⁷ Hodge 1985, 179

⁶⁸ Hodge 1985, 174

⁶⁹ Hodge 1985, 174

⁷⁰ Hodge 1985, 178

⁷¹ Hodge 1985, 175

high calcium levels in the water (or hard water) flowing through the water systems from springs in areas with limestone.⁷² Sinter build-up inside the conduit adversely affected the slope and restricted both the water pressure (velocity of water) and quantity of discharge (amount of water flowing through the conduit).⁷³ Sinter could choke the conduit opening by as much as 50% and could reduce the cross-section of pipes by the square of the reduced diameter.⁷⁴ The incrustation of sinter inside the conduit could become so thick that it was sometimes cut and used as a construction material.⁷⁵ Clearly, the maintenance of the water system and the removal of sinter build-up from the conduits were vital to the function of the water system. The lead pipes were cut open to remove the sinter and then were soldered back together.⁷⁶ Notably, the incrustation of sinter can be used for comparative dating, although it supplies only a *terminus ante quem* for the last removal of sinter.⁷⁷

⁷² Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

⁷³ $Q=A \times V$ (Discharge= Flow Area x Velocity of Flow)

⁷⁴ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

⁷⁵ Hodge, 2002, 233

⁷⁶ Hodge, 1992, 8

⁷⁷ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

Chapter 3

Water Supply System of Pompeii

3.1 Introduction

The Roman city of Pompeii is famous for its state of preservation due to the volcanic eruption of Mount Vesuvius in 79 CE that covered the city in ash. Pompeii sits on a volcanic plateau 30 m above sea level, overlooking the Sarno River Valley, and about 3 km from the Tyrrhenian Sea. Before Pompeii became a Roman colony, the water supply was limited to wells and cisterns that stored rainfall, but those wells went out of use by the Augustan period.⁷⁸ This transition is evidenced by the excavation of a deep well at the crossroads of Via delle Consolare and Via di Narciso, which was filled with trash and debris dating to the Augustan period. Therefore, it seems likely that, by the Augustan period, the colony was supplied water by another source, specifically an aqueduct. Concurrently with the construction of the aqueduct, a water distribution system would have been planned inside the circuit walls of Pompeii. Because of the eruption of Vesuvius, however, knowledge about the Pompeii water system is mostly limited to what existed at the end of 79 CE. Regardless, it is evident that the system supplied water to various sectors of city via three pipes that divided the water into routes. These routes dispensed water to 14 secondary water towers (*castella*) and 42 fountains. These pipes also provided water to four public baths, 32 private households, and possibly even a number of workshops. Importantly, the water routes assist in understanding the orthogonal grids and orientations of the city and provide a guide for the extension of those layouts into the unexcavated regions of the city.

⁷⁸ Laurence, 2010, 46

3.2 History of Pompeii

The urban organization of Pompeii began around the 7th century BCE. The colony consisted mostly of the crude huts that have been excavated in Region VII.4.42-43.⁷⁹ The inhabitants of early Pompeii were indigenous to the upper Sarno Valley and had a commercial relationship with the Greeks at Pithekoussai.⁸⁰ The site began to undergo specific urban changes in the beginning of the 6th century BCE.⁸¹ The major building projects undertaken at this time were the Doric Temple, the Temple of Apollo, and the 3-kilometer defensive wall.⁸² The 6th century also saw an increase of population in the Sarno Valley, as well as an urban reorganization through the abandonment of old sites in favor of new ones.⁸³ According to Pier Guzzo, the new building projects were initiated by either Greeks along the Bay of Naples or Etruscans at Capua, which would have influenced the local tribe known as the *Sarrasti*.⁸⁴ The name Pompeii is of Oscan origin, which perhaps alludes to a synoecism among the indigenous populations. Guzzo says that these various groups occupied discrete areas within the town walls of Pompeii, and this conclusion is supported by the distribution of finds from the 6th century BCE.⁸⁵ The Etruscan cultural influence is displayed in the orthogonal layout of the town and the Temple of Apollo, which was oriented to the south and decorated with terracotta ornaments.⁸⁶ The dedicatory inscriptions found there were in the Etruscan language and inscribed into shards of bucchero.⁸⁷ At the end of the 6th century BCE, Pompeii was a city

⁷⁹ Guzzo, 2011, 12

⁸⁰ Guzzo, 2011, 11

⁸¹ Guzzo, 2011, 12

⁸² Guzzo, 2011, 12

⁸³ Guzzo, 2011, 12

⁸⁴ Guzzo, 2011, 13

⁸⁵ Guzzo, 2011, 13

⁸⁶ Guzzo, 2011, 13

⁸⁷ Guzzo, 2011, 13

with an indigenous population and culture that had been influenced by the Greeks and Etruscans.⁸⁸ It has been suggested that Pompeii was an *emporion* (trading center), but there is no literary support for that idea.⁸⁹

Pompeii began to decline in the late 5th century BCE in the wake of the Samnites' conquest of cities along the coast of the Bay of Naples. The Samnites were able to dominate the entire Sarno Valley region through the political formation of the Nucerian League.⁹⁰ The Samnites inhabited Pompeii by the end of the 5th century BCE, resulting in the city becoming highly urbanized during this period.⁹¹ This is indicated by the reconstruction of the fortification wall, restoration of the Doric Temple, the construction of *tabernae* on the east side of the Forum, and new housing developments.⁹² This building activity was finished by the end of the 4th century BCE.⁹³ The entire urban plan of Pompeii can be securely dated to the Samnite period during the 4th and 3rd centuries BCE.⁹⁴

In the 3rd century BCE, Hellenistic Pompeii became part of the *civitates foederatae* of Rome, and this changed the landscape of the town.⁹⁵ This is evident through the organization of religious areas, the construction of infrastructure, and the expansion of domestic zones.⁹⁶ This period is also distinguished by the new social

⁸⁸ Guzzo, 2011, 14

⁸⁹ Guzzo, 2011, 14; Lomas, 2006: *Emporion* is Greek word meaning trading place. The Greeks created several of these trading ports all over the Mediterranean, with some in Egypt, Spain, and southern France.

⁹⁰ Guzzo, 2011, 16

⁹¹ Guzzo, 2011, 14

⁹² Guzzo, 2011, 14

⁹³ Guzzo, 2011, 15

⁹⁴ Guzzo, 2011, 15

⁹⁵ F. Coarelli and F. Pesando, 2011, 48

⁹⁶ F. Coarelli and F. Pesando, 2011, 49

cohesion of an elite class.⁹⁷ This is indicated by the remains of two structures dated to the 4th century BCE that have Greek styled dining rooms.⁹⁸ By the 2nd century BCE, new houses were built on top of older dwellings and all of Region VI was occupied, which manifests the intensity of building activity during this period.⁹⁹ The Sanctuary of Apollo was given to the city in 146 BCE by Lucius Mummius in honor of Pompeii's service to the *civitas foederata* of Rome.¹⁰⁰

In the 1st century BCE, Pompeii joined the Italic rebellion against Rome in the Social War and was besieged and eventually defeated by Lucius Cornelius Sulla.¹⁰¹ Sulla's nephew Publius Cornelius Sulla refounded the city as a Roman colony in 80 BCE and named it *Cornelia Veneria Pompeianorum*.¹⁰² The colony became home for many veteran soldiers, and, as a consequence, the city was revitalized with new public and private buildings. Paul Zanker has estimated that at least 2,000 veterans settled in Pompeii during this period.¹⁰³ The Sullan period of Pompeii saw the addition of baths, the amphitheater, the Temple of Venus, the roofed theater (*theatrum tectum*), and possibly the water supply system (**Figure 3.2**). The forum also became a central focal point of the public life of the colony (**Figure 3.5**). The *capitolium* was added to the forum, which was modeled after Rome's and was dedicated to the three divinities, Jupiter, Juno, and Minerva.

⁹⁷ F. Coarelli and F. Pesando, 2011, 49

⁹⁸ F. Coarelli and F. Pesando, 2011, 49: underneath Casa delle Forme di Creta

⁹⁹ F. Coarelli and F. Pesando, 2011, 54

¹⁰⁰ F. Coarelli and F. Pesando, 2011, 54

¹⁰¹ Appian, *Bellum Civile*, 1.5.39-40

¹⁰² *Ac ne haec quidem P. Sullae mihi videtur silentio praetereunda esse virtus, quod, cum ab hoc illa colonia deducta sit, et cum commoda colonorum a fortunis Pompeianorum rei publicae fortuna diiunxerit ...* (Cic. Sul. 21)

¹⁰³ Zanker, 1998, 62

Many additions were made to the infrastructure of Pompeii during the Augustan period, including the amphitheater, the water supply system, the monumental forum, and many public administrative buildings (**Figure 3.5**). As Zanker notes, almost all of the public construction around 20 BCE was undertaken as a result of the establishment of the Empire by Augustus and his policies of cultural and religious renewal.¹⁰⁴ The Augustan period saw the renovation of important cults and temples in Pompeii, especially those of Pompeii's patron divinities, Apollo and Venus. The worship of the cult of the emperor also began under the rule of August. In Pompeii, the first sanctuary built to honor the emperor was the Temple of Fortuna Augustus, erected by M. Tullius who was an influential citizen and *duumvir* (**Figure 3.2**).¹⁰⁵ It is evident that the Augustan building projects in Pompeii led to a closer connection to Rome, and that Augustan ideology influenced the outward appearance of public space in Pompeii.

The earthquake of 62 CE destroyed much of Pompeii. Many citizens fled the city at this time, but the few that remained began to rebuild.¹⁰⁶ The rebuilding in the Forum is evident in the *macellum*, Eumachia building, and the Imperial Cult building (**Figure 3.2**).¹⁰⁷ The post-earthquake building program shows a desire of the inhabitants to rebuild on a grand scale and to add new public buildings.¹⁰⁸ According to John Dobbins, the earthquake at Pompeii presented its inhabitants with a challenge and a need to rebuild, as well as an opportunity to rebuild in a manner and on a scale that they might never have undertaken in the absence of the earthquake disaster.¹⁰⁹ Unfortunately, some

¹⁰⁴ Zanker, 1998, 78

¹⁰⁵ Zanker, 1998, 82

¹⁰⁶ Zanker, 1998, 197

¹⁰⁷ Dobbins, 1994, 632

¹⁰⁸ Dobbins, 1994, 629

¹⁰⁹ Dobbins, 1994, 631

of these repairs were never finished due to the eruption of Vesuvius in 79 CE. One example of this is the Central Baths, which were under construction at the time. The eruption of the volcano provides an interesting snapshot of the time between 62 and 79 CE. After the earthquake, some of the population vacated the city and relocated to other towns along the coast of the Bay of Naples, so many of the buildings in Pompeii were no longer in use or still under reconstruction at the time of the volcanic eruption. This circumstance is pertinent to the urban water system of Pompeii. The water system was operating only at half capacity when the eruption occurred, and several of the channels had fallen into disuse.¹¹⁰ Accordingly, what is known about the water system is based on the infrastructure that was in use in 79 CE and does not represent a holistic view of the urban water system from its inception in the Sullan period.

3.3 Orientation of Urban Plan

The urban plan of Pompeii reveals four distinct urban orientations (**Figure 3.3**). First, the northwestern section of the city in Region VI has 12 distinct *insulae* (city blocks). These blocks are formed by right-angle intersections of the streets and are in axial alignment with the forum and the southwestern area of Region VII. Accordingly, it is plausible that both Region VI and Region VII date to the 1st century BCE, when the forum was first constructed. This orientation has many important Republican and Early Imperial buildings, and it seems that they were constructed with this urban layout in mind.

¹¹⁰ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

A second orientation worth noting is the eastern side of the Via Vesuvio/Via Stabiana bordering Regions V, IX, and I (**Figure 3.3**). Approximately seventeen blocks are visible on the map, and this layout presumably continues in the unexcavated areas of Regions V, IX, and I. The blocks in this part of the City are more square than rectangular and are in alignment with the Triangular Forum. Therefore, this orientation may date as far back as the Greek occupation of the city around the end of the 4th century BCE.

A third orientation is apparent in the eastern side of the city. These blocks take up about half of the city's urban area. The first set of blocks is located along Via di Nola. Sixteen blocks are visible on the map in Figure 3.3, but the orientation probably continues in the unexcavated areas of Regions V and IV. Another set of blocks are along Via dell' Abbondanza and Via di Castricio (**Figure 3.3**). Only thirty-one of these blocks are visible in Eschebach's map, but the urban orientation and grid pattern most likely continue in the unexcavated areas of Regions I, III, and IX. In this orientation, fountains were evenly dispersed between each block or two. This orientation is in alignment with the *palaestra* and the amphitheater, which is probably a result of the urban expansion in the 1st century CE. A stronger conclusion could be made regarding the date of the orientation through an analysis of the domestic architecture in these blocks, but this is beyond the scope of this thesis.

A fourth orientation appears in the small triangular area in Region VII and Region VIII between the Forum, the Stabian baths, and the Triangular forum, south of the intersection of Via Nola and Via Vesuvio (**Figure 3.3**). The blocks in this area are square-shaped, rather than rectangular as in Region VI, and the orientation is more north-south than any of the other three orientations. The area also includes the few curved

streets in the city, which might follow the path of an earlier city wall. This part of Region VII is also the location of the previously mentioned crude huts from the 7th century BCE, so I believe that this orientation is the oldest in the city. This area is also the closest in proximity to both the Forum and the Triangular Forum, which had some of the oldest buildings in the city, such as the Temple of Apollo and the Doric Temple.

3.4 The Aqueduct

The aqueduct that supplied Pompeii is the subject of considerable debate in scholarship regarding its route, terminus, water source, and date of construction. The majority view is that Pompeii was supplied water via a branch of a regional aqueduct called the *Aqua Augusta* (or the Serino Aqueduct) that was constructed in the early Augustan period and derived water from a spring near Serino (**Figure 3.7**).¹¹¹ This view is based on an observation in 1560 CE by Pietrantonio Lettieri of a visible branch of the *Aqua Augusta* that was headed north toward Pompeii and had its source downstream of a branch to Nola.¹¹² Others contend that a Sullan or Samnite aqueduct system preceded the Augustan aqueduct.¹¹³ There is no evidence, however, of any piped aqueduct water supply in Pompeii before the Augustan period.

Christoph Ohlig has reevaluated these hypotheses based on a geochemical analysis of sinter (calcium carbonate) incrustation in the aqueduct channel that connected to the *castellum aquae* in Pompeii. He concluded that an early phase of the aqueduct brought water to the colony around 80 BCE (Sullan) from a source near Avella in the

¹¹¹ Hodge, 1992; Ohlig, 2001

¹¹² Keenan-Jones, 2015, 200; Recorded in a letter written to Fabio Giordano

¹¹³ Keenan-Jones, 2015, 191

Apennine mountains and that the *Aqua Augusta* was joined it in the Augustan period.¹¹⁴ Ohlig's investigation of the oldest sinter deposits establishes that the first water source for the Pompeii aqueduct was not the *Aqua Augusta*.¹¹⁵ His examination of a second stratum of sinter indicates that it was produced from a mixture of water from both the Avella and Serino water sources.¹¹⁶ Therefore, it seems evident that Pompeii was initially supplied water by an aqueduct that had an Avella water source and was later mixed during the Augustan period with water supplied by a branch of the *Aqua Augusta* to provide an adequate water supply for the city.

Another possibility has been posited by Duncan Keenan-Jones. He contends that Pompeii was supplied water from a spring (or springs) on the slopes of Somma-Vesuvius. The only evidence for a supply from this source is recent travertine analysis, which according to Keenan-Jones has been published only in preliminary form.¹¹⁷ He suggests a new, two-source, water supply theory: supply initially from the *Aqua Augusta* and then later from a spring on the slopes of Somma-Vesuvius.¹¹⁸ He points to the ruins of the *Aqua Augusta* at Ponte Tirone as support for his proposition that Pompeii was supplied water from Somma-Vesuvius. Keenan-Jones observes that Ponte Tirone is located on the watershed connecting the Apennines and Somma-Vesuvius, making it a probable location for an aqueduct coming from the Apennines, crossing Somma-Vesuvius, and continuing south or west.¹¹⁹ Additionally, two parallel aqueduct channels that were only 1 or 2 m apart were found at Ponte Tirone, and one of them ran in a westerly direction toward

¹¹⁴ Keenan-Jones, 2015, 198

¹¹⁵ Ohlig, 2001, 49

¹¹⁶ Ohlig, 2001, 79

¹¹⁷ Keenan-Jones, 2015, 109

¹¹⁸ Keenan-Jones, 2015, 109

¹¹⁹ Keenan-Jones, 2015, 110

Pompeii. Furthermore, a thick layer of tephra from the volcanic eruption in 79 CE partially buried the northern channel, which was at ground level before the eruption. The southern channel appears to be an attempt to restore the *Aqua Augusta* sometime after either the earthquake of 62 CE or the volcanic eruption of Vesuvius in 79 CE. The distance between Ponte Tirone and the *castellum aquae* in Pompeii is 14 km and the elevation drops from 52 m to 43 m, both of which are well within the distance and gradient metrics of other Roman aqueducts.

This thesis focuses on the *Aqua Augusta* (Serino Aqueduct) as the main supply of water to Pompeii. The *Aqua Augusta* was constructed between 33 BC and 12 BCE and supplied water from sources in Serino to cities along the Bay of Naples. The main destination of the aqueduct was Misenum, about 105 km from Serino and about 96 km from Pompeii, making *Aqua Augusta* one of the longest Roman aqueducts. Along its route from Serino to Misenum, the aqueduct had branches that ran to other cities, including a branch that ran from Sarno toward Pompeii and Herculaneum. Serino was near the city of Avellino at an elevation of 370 m, and the average gradient of the *Aqua Augusta* was 3.4 m/km.¹²⁰ The branch of the aqueduct between Sarno and Pompeii was about 35 km long.

The only remains of the Pompeii branch of the *Aqua Augusta* is a 15.5 m segment of channel that is connected to the *castellum aquae*.¹²¹ The aqueduct was vaulted with a sunken channel and measured 1.30 m x 1.66 m over all (**Figure 3.8**).¹²² The sunken channel measured just 25 cm x 25 cm.¹²³ The height of the vaulted channel was

¹²⁰ Olsson, 2015, 13

¹²¹ Hodge, 1992, 97

¹²² Hodge, 1992, 97

¹²³ Hodge, 1996, 263

undoubtedly for the purpose of providing maintenance access rather than indicative of the volume of water supply. The sunken channel had two small ledges on its sides, perhaps allowing maintenance without stepping into the water supply. The water, according to Hodge, flowed only in the sunken channel. The channel terminated in the *castellum aquae* the Porta Vesuvio.

3.5 The *Castellum Aquae*

The *castellum aquae* was the main holding, settling, and partitioning tank (a *castellum divisorium*) for the water supply system of Pompeii (**Figure 3.6**). From the *castellum aquae*, water was dispersed into three pipe networks that routed the water to water towers that served as secondary *castella*. The *castellum aquae* was located at the highest point of the city at the Porta Vesuvio, 42.6 m above sea level. The *castellum aquae* of Pompeii was originally dated to the Claudian period, but it is now viewed as Augustan because of its construction technique, making its construction contemporary with the construction of the aqueduct. The *castellum aquae* was a square, bricked building with a vaulted roof. The cupola of the vault had a diameter of 5.8 m. The facade of the building had a three-part design with arches (**Figure 3.9**). On the sides of the building was a painting of a river god and three nymphs. The water from the aqueduct entered on one side of the *castellum aquae* and flowed into a shallow circular basin, where it was divided into three distribution channels.¹²⁴

The *castellum aquae* had ten zones created by a series of channels and cross walls of a complicated design (**Figure 3.10**). These zones were used to purify and circulate the

¹²⁴ Hodge, 1992, 275

water into the distribution channels.¹²⁵ The main zones consisted of the entrance, sluice gates, a circulating wall, a trapezoidal channel, the central holding channel, and a triangular regulation channel.¹²⁶ The distribution channel was triangular in shape and had at different levels sluice gates made from lead sheets.¹²⁷ No trace of the sluice gates survives, but it is thought that there were three gates corresponding to the three distribution channels, which allowed the water to be apportioned among the distribution channels.¹²⁸ The existence of sluice gates implies that the three distribution channels were not being apportioned the same quantities of water, at least not at the same time.

Water was discharged from the *castellum aquae* through three large lead pipes that were buried under the paved streets and distributed the water through a network of pipes and secondary *castella* to various urban users (**Figure 3.10**). The middle (central) pipe had a diameter of 30 cm and the two outer pipes on the east and west side of the middle pipe had a diameter of 25 cm.¹²⁹ Because of its larger size, the middle pipeline seemingly would have been used to distribute most of the city's water supply. The middle pipeline was also at a higher elevation (43 m), which Olsson suggested made it theoretically possible for it to cross over the pipe connected to the east side of the *castellum aquae* to supply the largest quantity of water to the largest urban area of the city. There is not, however, any historical or archaeological evidence that occurred.¹³⁰ Hodge observed that the pipes were too big for the small amount of water that could have been carried through the sunken channel of the aqueduct.¹³¹ In fact, the capacity of the

¹²⁵ Ohlig, 2001, 21

¹²⁶ Ohlig, 2001, 20

¹²⁷ Ohlig, 2001, 16

¹²⁸ Hodge, 1996, 266

¹²⁹ Hodge, 1992, 275

¹³⁰ Olsson, 2015, 29

¹³¹ Hodge, 1992, 275

pipes was probably more than double the volume of water that the aqueduct could supply.¹³²

The *castellum aquae* was discovered in 1902, and the original observations regarding it were based on the Vitruvian descriptions of a *castellum divisorium*. Paribeni assumed that the *castellum aquae* was Vitruvian in design because its three distribution channels corresponded to the Vitruvian description of tripartite water division.¹³³ However, this is the only element of the *castellum aquae* that is Vitruvian in design. The Vitruvian assumptions also influenced views that water was distributed inside the city to baths, fountains, and private houses in that order of priority. This is a misconception that Ohlig and others have helped resolve. It is evident that water was supplied in Roman Pompeii to many more users than those three categories of facilities.

The Pompeii urban water system included 14 secondary *castella* (water towers) that were located throughout the city and were supplied water via the pipes from the *castellum aquae* (**Figure 3.11**). These secondary *castella* have been classified by their design: 1 citadel; 4 pillars; and 9 towers.¹³⁴ The water towers ranged from 5-8 m in height and had inlaid vertical grooves for the pipes. On top of each water tower was a lead container measuring 0.65 m x 0.65 m in which water was stored. Only one of these containers was found during the excavations of Pompeii, and it was later lost due to bombing in WWII. The atmospheric pressure on the water in the water tower container and gravitational force moved water from the container on the top of one water tower through a pipe to the container on top of another downhill water tower, provided that the

¹³² Olsson, 2015, 86

¹³³ *Ita in medio ponuntur fistulae in omnes lacus et salientes, ex altero in balneas vectigal quotannis populo praestent, ex quibus tertio in domus privatas* (Vitruvius, 8.6.2) Ohlig, 2

¹³⁴ Eschebach, 1993

elevation of the second container was at a lower level.¹³⁵ The water towers served a dual function. First, they gradually reduced water pressure, which was beneficial when the gradient of the topography was too steep. Second, they functioned as re-distributors of water to users within the vicinity of the towers.¹³⁶ Four of these water towers were free standing along the Via del Vesuvio/Via Stabiana (**Figure 3.3**). The other ten secondary *castella* are connected to buildings. Some of the secondary *castella* seem to have been rebuilt after the earthquake in 62 CE.¹³⁷

3.6 Urban Distribution Scheme

The three pipes from the *castellum aquae* distributed water in three distinct routes. The routes of these water lines have been debated, and this thesis furthers the debate. For purposes of the ensuing discussion, references to the east, west, and central routes indicate the ordinal direction of the water line, rather than where the pipes connect to the *castellum aquae*, and references to *castella* numbers (e.g., *castellum* no. 1) are to the numbers assigned to each secondary *castellum* on the accompanying maps of water distribution (**Figure 3.11** and **Figure 3.12**).

Ohlig and Richard Olsson have mapped water distribution routes for Pompeii based on the location of the secondary *castella* (**Figure 3.14**), the location of fountains and private houses, and, in the case of Olsson, the direction of the grooves for the water pipes on the secondary *castella* (**Figure 3.16**). Ohlig's water distribution map depicts three distinct routes labeled in green, blue, and yellow, which connect various water towers and fountains in the city (**Figure 3.14**). His map has the central water pipe with

¹³⁵ Olsson, 2015, 30

¹³⁶ Olsson, 2015, 31

¹³⁷ Olsson, 2015, 32

the 30-cm diameter (the green route) running down the Via Vesuvio/Via Stabiana and then branching off at two secondary *castella* (*castella* nos. 3 and 4) toward two other secondary *castella* (*castella* nos. 9 and 10) to service the eastern side of the forum in Regions VII and VIII (**Figure 3.14**). His central route continues south and services the triangular forum (**Figure 3.14**). This area does not have any secondary *castella*, but it does have at least five fountains.

Ohlig's western route (the orange route) travels south down Vico dei Vetti and has a branch from *castellum* no. 7 down Vico di Mercurio to supply Region VI (**Figure 3.14**). It continues down Vico Dei Vettii to Via della Fortuna where it branches again to supply the Forum Baths in the northern part of Region VII (**Figure 3.14**). His western route then travels south from the Forum baths toward the Temple of Venus and the Porta Marina (**Figure 3.14**).

Ohlig's eastern route (the blue route) is entirely hypothetical due to the unexcavated sections of Regions I, II, III, IV, V, and IX (**Figure 3.14**). His map has the route going down Via Vesuvio, with a first branch at Via di Nola that runs east to service the fountains and secondary *castella* on that street (**Figure 3.14**). His eastern route continues down Via Vesuvio to Via dell' Abbondanza, where it turns west to service the *insulae* (city blocks) of Regions I and II (**Figure 3.14**).

Although Ohlig's proposed map is plausible, it does not take into account the unexcavated regions, the direction of the pipe grooves on the secondary *castella*, and the street elevations of the secondary *castella*. Importantly, Ohlig does not incorporate the east-west slope of the city, which drops approximately 1 m every 50 m along both Via di Nola and Via dell' Abbondanza. I have mapped three different routes that incorporate the

missing elements (**Figure 3.15**). I used Eschebach's plan of Pompeii because of its scale and detail and denoted on that plan the location of the fountains and the secondary *castella*.

My western route (which is highlighted in green) differs from Ohlig's and has the pipeline running west along the circuit wall to service *castellum* no. 13, the most western water tower (**Figure 3.15**). At *castellum* no. 13, my western route turns south to supply the two secondary *castella* north of the Forum baths (*castella* nos. 12 and 8) (**Figure 3.15**). Eschebach noted houses in Region VI.2.7.9 that received water from the supply system, and those houses could only be accessed if the water route ran north along the circuit wall (**Figure 3.17**). My western route continues to run south along the western side of the forum to service the southern *castellum* no. 10 that is located near the Temple of Venus (**Figure 3.15**). Water would be supplied along this western route to blocks in Region VI, the Forum Baths, the fountains located on the north side of the forum, the fountains located near the Temple of Venus, and the Suburban Baths.

I determined that the western route should run along the circuit walls based primarily on the elevations of the secondary *castella* in Region VI (**Figure 3.12**) and the direction of the grooves on *castella* nos. 12 and 13 (**Figure 3.16**). My route along the circuit wall is more plausible than Ohlig's route down Via Mercurio, because the grooves on *castellum* no. 13 run north and south, indicating a pipe system running down from the circuit wall. Additionally, the grooves on *castellum* no. 12 run west and south, rather than east and north, making it impossible for the pipe system to run west down Via Mercurio (**Figure 3.16**).

The elevations of the secondary *castella* in Region VI also support my western route. Ohlig's route has the water flowing uphill from *castellum* no. 7 at an elevation of +35.6 m to service *castellum* no. 12 and *castellum* no. 13 at elevations of +39.9 m and +39.8 m, respectively (**Figure 3.11** and **Figure 3.12**). If the western pipeline travels north of Region VI following the circuit walls, as proposed in my map, the water would have to flow uphill only +0.01 m, which is physically more plausible than Ohlig's route. Water can flow uphill for limited distance under certain conditions, but water flowing from *castellum* no. 7 to *castellum* no. 12, as proposed in Ohlig's map, would not be able to gain enough pressure to rise up +4.3 m to bottom of *castellum* no. 12, let alone another 5-8 m to the container at the top of *castellum* no. 12. The system of secondary *castella* (water towers) depends on water flowing from a higher elevation to a lower elevation.

My central route (which is highlighted in red) runs down Vico dei Vettii from the *castellum aquae* to *castellum* no. 7 (**Figure 3.15**). From *castellum* no. 7, the route travels south to supply the secondary *castella* in Region VII, the fountains along the eastern side of the Forum, Region VIII, and the western side of the triangular forum (**Figure 3.15**). My central route connects *castella* nos. 7, 9, and 11, which Ohlig's route does not. Ohlig's route also fails to adequately service the eastern side of the forum, which my route takes into account. Some of the most important buildings are located on the eastern side of the Forum, specifically the administrative building, *comitium*, Eumachia, Temple of Vespasian (imperial cult), *lararium*, and *macellum* (**Figure 3.2**). Therefore, it is probable that these buildings would have required a water supply. My central route steadily decreases in elevation from +42.6 m to +28.0 m (**Figure 3.12**). This water supply route would service primarily the forum, the triangular forum, and the blocks of Region

VII. This route also would supply the Sarno Baths located south of the Forum (**Figure 3.13**).

My eastern route (which is highlighted in blue) is definitely the longest and supplies the most regions inside the city (**Figure 3.15**). This water line seemingly would need to supply the largest quantity of water, so, as Olsson has suggested, this area of the city probably was serviced by the central pipe with the 30 cm diameter, rather than a pipe with 25 cm diameter. To service the eastern side of the city, the central pipe would have to cross over the pipe connected to the east side of the *castellum aquae*. As previously indicated, this was theoretically possible since the central pipe was connected to the *castellum aquae* at a higher point than the pipes on the east and west sides. My eastern route runs directly down the Via Vesuvio/Via Stabiana, possibly even as far as the Porta Stabia (**Figure 3.15**). My map has two distinct branches coming off this main line (**Figure 3.15**). The first branch is at *castellum* no. 1 and turns to service the unexcavated part of Region V before heading south along the Via di Nola to supply the water tower and the fountains along that street (**Figure 3.15**). Ohlig's route does not take into account the unexcavated area, which most definitely had a water supply. My map shows a hypothetical continuation of the branch into Regions V and IV, as it seems likely that the *insulae* in that region also had fountains and one or more secondary *castella* (**Figure 3.15**).

The second branch of my eastern route begins at Via dell' Abbondanza and runs east toward the Porta di Sarno (**Figure 3.15**). Along this route, the branch would supply two secondary *castella* and several fountains. The direction of the grooves indicate that the pipes from secondary *castella* nos. 5 and 6 would run south to service the fountains in

Regions I and II (**Figure 3.16**). This route also would supply the Stabian Baths (**Figure 3.13**), the eastern side of the Triangular Forum, the unexcavated parts of Regions V and IV, and the city blocks in Regions I and II. It also seems highly likely this waterline supplied Regions IX and III, although they have yet to be excavated. Based on elevations, this route is highly plausible, with the uphill difference in elevation only +0.9 m (**Figure 3.12**).

The main sewer and drainage line also ran down Via Vesuvio/Stabia. Pompeii's sewer system was built to deal with specific drainage problems in various points in the urban plan, rather than a network of sewer channels and drains.¹³⁸ The main branches were connected to buildings where large amounts of water had to be disposed of, such as the Central, Stabian, and Forum Baths and the large palaestra near the amphitheater.¹³⁹ Most residences, however, used water from the water supply pipes to flush latrines into cesspits rather than a sewer channel. Additionally, the sewer system is hardly mentioned at all by either Ohlig or Olsson, and it seems evident that waste was either drained into cesspits or was dumped into the streets to be flushed by runover water from fountains and basin or rainwater.

My analysis of the urban water distribution routes confirms that the water supply system of Pompeii dispensed water to 4 public baths, 14 secondary *castella*, 42 street fountains, the Forum, and the Triangular Forum. The baths supplied were the Forum, Sarno, Stabian, and Suburban baths (**Figure 3.13**). The Central baths were still under construction at the time of the eruption of Vesuvius, but they presumably would have been supplied by the water system because they are located directly across the street from

¹³⁸ Koloski-Ostrow, 2015, 76

¹³⁹ Koloski-Ostrow, 2015, 76

a secondary *castellum* (*castellum* no. 2) along Via Vesuvio. Additionally, water would have been supplied to houses through a separate pipe from the top container of a water tower and through an individual distribution system inside the house that had distributors and closing valves.¹⁴⁰

Eschebach identified 63 houses that were supplied water, although Olsson confirmed only 32 of them (**Figure 3.17**).¹⁴¹ These houses are scattered all over the city, and display varying degrees of wealth. The houses supplied with water appear to be located around the secondary *castella*, and along the same streets as the supply routes. Olsson identified these houses based on evidence of closing valves, pipe systems, fountains, and distributors. Of the 32 houses that Olsson examined, I concluded that 24 of them displayed incredible wealth and can be classified as elite residences (**Table 3.1** and **Figure 3.17**). The houses that I have noted (**Table 3.1** and **Figure 3.17**) are primarily positioned along the major roads, which the water lines followed. The major roads for these elite residences are Via Vesuvio/Stabiana, Vico dei Vettii, Via Mercurio, Via di Nola, Vico di Eumachia, and Via dell' Abbondanza.

Table 3.1 List of Elite Pompeii Houses with Water Supply (By Author, Based on Olsson)

Location	House	Evidence
I.4	House of the Citharist	Closing valve
I.7	House of Ephebus, House of Paquius Proculus	Garden area
II.2	House of D. Octavius Quartio	Garden area
II.4	House of Julia Felix	
III.2	House of Aulus Trebius Valens	
V.1	House of the Bull	Mosaic water feature
V.2	House of the Silver Wedding	Peristyle garden

¹⁴⁰ Olsson, 2015, 71

¹⁴¹ Olsson, 73

V.5	House of the Gladiators	
VI.9	House of the Centaur, House of Meleager	
VI.12	House of the Faun	
VI.14	House of Orpheus, Casa degli Scienziati	Closing valve, garden area
VI.15	House of the Vettii	Peristyle, closing valve
VI.16	House of the Golden Cupids	
VI.17	House of Julius Polybius	Baths, courtyard Fountain
VII.2	House of the Bear	
VII.12	House of the Hanging Balcony	Fountain
VIII.4	Domus Cornelia	
IX.3	House of M. Lucretius	Latrine, fountain, waterfall
IX.7	House of the Arches	Mosaic fountain
IX.8	House of the Centenary	Nymphaeum
IX.14	House of M. Obellius Firmus	

The location of a house in Region VI.9 supports my route along the circuit walls, and the houses in Region VII are located along the west side of the Forum, which location corresponds exactly to my central route. Olsson also concluded that water was supplied directly to individual workshops, although the number of workshops connected to the water system is not known. Eschebach identified in his city plan 46 workshops, such as laundries, tanneries, and dye-houses that would have high water consumption.¹⁴²

3.7 Conclusion

Pompeii was supplied water from a branch of the *Aqua Augusta* (Serino Aqueduct) that began in the Apennines and extended to Misenum. The aqueduct possibly branched near Sarno or Ponte Tirone. The *Aqua Augusta* dates to the Augustan period, but there possibly was an earlier aqueduct that would have brought water from Avella,

¹⁴² Eschebach, 453-464

just north of Pompeii. This conclusion is based on a geochemical analysis by Christoph Ohlig of two layers of sinter from the remains of the aqueduct channel at Pompeii, which indicates the presence of two distinctive water sources. The aqueduct supplying water to Pompeii terminated into the *castellum aquae*, which was located at the highest point of the city at the Porta Vesuvio. Inside the *castellum aquae*, the water was filtered through several zones and divided into three pipes. These pipes represent three main water lines that distributed the water to 4 public baths, 14 secondary *castella*, and 42 street fountains. The secondary *castella* piped the water to fountains, public baths, private houses, and workshops. The city has a fairly steep slope, with the highest elevation at +42.6 m and the lowest at +22.9 m. The secondary *castella* helped decrease the water pressure in the pipes, which was substantial due to the steepness of the gradient of the terrain.

Using Eschebach's map of Pompeii, the location of the *castellum aquae*, the elevations and locations of the secondary *castella*, and the known locations of pipes, I mapped three routes for the urban water distribution. My first route services the western sector of the city, Region VI, the west side of the forum, the southern area near the Temple of Venus, and the Suburban baths. My central route runs down Vico dei Vettii and services Region VII and the eastern side of the Forum. The main route is the eastern route, which supplies about half of the city. It runs south along Via Vesuvio/Via Stabiana and supplies the triangular forum. It then branches into two waterlines: one along Via di Nola; and the second along Via dell' Abbondanza. These branches allocate water to the eastern blocks through public fountains and secondary *castella*. These routes correspond to the orthogonally planned street blocks and adhere to the principal of gravity flow to successfully dispense water to the urban infrastructure that defined Pompeii.

Chapter 4

Water Supply System of Nîmes

4.1 Introduction

The Roman colony of *Colonia Augusta Nemausus* (modern day Nîmes, France) was located south of Orange along the *Via Domitia*, the main road that led from Arles to Spain. The colony was supplied water from springs that were located due north of Nîmes near Uzès via a 50-kilometer aqueduct. The water distribution system undoubtedly played an important role in the selection of sites within the city for particular ancient structures. The modern city is directly on top of the ancient city, so it is hard to define the urban layout of the city. By determining the water distribution scheme of Roman Nîmes, however, I have been able to locate parts of the orthogonal grid plan, determine the location of major buildings, and assess the social status of neighborhoods (**Figure 4.1** and **Figure 4.2**).

4.2 History of *Colonia Augusta Nemausus*

The city of Nîmes had a long period of occupation dating back to an Iron Age *oppidum*. The early Gallic tribe, the *Volcae Arecomidi*, organized a settlement around a sacred spring that had a native shrine that celebrated the water divinity *Nemausus*, the namesake for the Roman colony.¹⁴³ Caesar conquered Gaul between 58 and 51 BCE, and Roman coins began to appear in the *oppidum* of Nîmes around 44 BCE, indicating the

¹⁴³ King, 1990, 70

increasing “Romanization” of the site.¹⁴⁴ Augustus founded the Latin colony *Colonia Augusta Nemausus* in 27 BCE, to settle his army veterans following his victory at Actium in 31 BCE.

Under the new sphere of Roman influence, Nîmes and other power colonies in Gaul, like Arles and Orange, undertook the construction of specific Roman buildings and monuments, such as baths, temples, and fortification walls (**Figure 4.2**). These were all markers of a colony’s prestige and prosperity in Augustus’ new empire. In Nîmes, other structures were also erected pursuant to the Augustan building program, including the aqueduct, the forum, the Maison Carrée, the orthogonal street plan, and the six-kilometer fortification walls and towers. Later in the 1st century CE, a stone amphitheater was built, the fortifications were expanded, and an aqueduct was constructed between the city and Uzès. The population grew to be about 30,000 during the 1st century of the Empire.¹⁴⁵

The emperors in the 2nd century also revitalized the urban scheme. This was attributable in part to the ancestral connections between the imperial families and *Nemausus*. The wife of Trajan, Pompeia Plotina, was from a Nemausan family, and Antoninus Pius descended from a family based in Nîmes, though he was born in Rome.¹⁴⁶ Also, Nîmes probably became the capital of *Narbonensis* after 145 CE, when Narbo was destroyed by a fire.¹⁴⁷ It has been suggested that the Maison Carrée was rebuilt by Hadrian.¹⁴⁸ This is very likely since the construction dates for the Maison Carrée do not correspond to an Augustan date. This is similar to what Hadrian did with the Pantheon in

¹⁴⁴ Hauck, 1988, 4

¹⁴⁵ Kleiner, 2010, 119

¹⁴⁶ Anderson, 2013, 53

¹⁴⁷ Anderson, 2013, 53

¹⁴⁸ Anderson, 2013, 49

Rome. Hadrian also built a basilica or temple for Pompeia Plotina. Although no archaeological remains of this structure have been found, there is literary evidence of its existence. Hadrian travelled the provinces and initiated imperial building projects for temples and amphitheaters, as mentioned in Cassius Dio's *Roman History*: Ἀδριανὸς δὲ ἄλλην ἀπ' ἄλλης διαπορευόμενος ἐπαρχίαν, τάς τε χώρας καὶ τὰς πόλεις ἐπισκεπτόμενος ... ἐποίει δὲ καὶ θεάτρα καὶ ἀγῶνας, περιπορευόμενος τὰς πόλεις (69.9-10).¹⁴⁹ The *Historia Augusta* specifically mentions his temple in Nîmes: *per idem tempus in honorem Plotinae basilicam apud Nemausum opere mirabili exstruxit*.¹⁵⁰ The temple was probably located in the forum area.¹⁵¹ The Temple of Diana also dates to the Hadrianic period. It was originally thought to be a temple, but it is probably a library or nymphaeum.¹⁵² It became part of the water sanctuary, along with the native spring, a nymphaeum, and a portico. This complex is sometimes referred to as the *Augusteum*.¹⁵³

4.3 The Aqueduct

The aqueduct of Nîmes is one of the most famous aqueducts in the Roman Empire. It was constructed in the second half of the 1st century CE, is considered a hallmark of Roman engineering, and is best known for its massive bridge, the Pont-du-Gard, which is the highest and one of the best preserved Roman aqueduct bridges in the Roman world. The aqueduct was approximately 50 km long, beginning at La Fontaine d'Eure (**Figure 4.4**), a group of karst springs located northeast of Uzès along the left bank

¹⁴⁹ Hadrian travelled through one province after another, visiting the various regions and cities and inspecting all the garrisons and forts ... He also constructed theatres and held games as he travelled about from city to city (Cassius Dio, 69.9-10)

¹⁵⁰ During this same time he reared a basilica of marvelous workmanship at Nîmes in honor of Plotina (Hadrianus.12)

¹⁵¹ Anderson, 2013, 52

¹⁵² Anderson, 2013, 52

¹⁵³ Anderson, 2013, 52

of the Alzon River, and ending in Nîmes (**Figure 4.3**). It is estimated to have moved 30,000 m³ of water per day and to have cost approximately 100 million *sesterces* to erect.¹⁵⁴

The aqueduct begins at an elevation of approximately 76 m and traverses the slope of the topography at an average gradient of 0.34 m/km to its terminus in Nîmes at an elevation of approximately 59 m (**Figure 4.3**).¹⁵⁵ The aqueduct travels south from the Source d'Eure (**Figure 4.4**) toward Saint-Maximin, following the piedmont of the valley, and then proceeds southeast from Saint Maximin to Vers-Pont-du-Gard, where it crosses the River Gardon via a massive bridge, the Pont-du-Gard (**Figure 4.5**). After crossing the Pont-du-Gard, the aqueduct continues in a southeasterly direction toward Remoulins and then turns southwest toward Saint-Bonnet-du-Gard, Sernhac, Saint-Gervasy, and Marguerittes. The aqueduct enters Nîmes through the city walls north of the Porte d'Auguste at Rue Edmond Rostra and travels parallel to the *Via Domitia*, ending in a *castellum divisorium* near Fort de Nîmes Vauban, a 17th century military fort that is now the Université de Nîmes. The *castellum divisorium* is located below the westernmost bastion of the 17th century fort.

Aqueducts moved water via conduits that generally were buried in tunnels that were dug into the bedrock below ground, constructed as canals at ground level, or carried above ground across arcades (bridgework consisting of a series of low arches).¹⁵⁶ All three kinds of aqueduct construction were used in the aqueduct of Nîmes. The most famous remnant of the Roman aqueduct is the Pont-du-Gard that bridges the River

¹⁵⁴ King, 1990, 78

¹⁵⁵ Hodge, 1992, 184

¹⁵⁶ King, 1990, 78

Gardon and dates approximately to the mid-first century CE. The River Gardon is approximately 30 m wide and a distance of 12 km from Nîmes (**Figure 4.5**).¹⁵⁷ The Pont-du-Gard is designed with three tiers of arches composed in *opus quadratum* and was constructed primarily with local limestone.¹⁵⁸ The entire structure is 275 m long and 49 m above the river from its topmost arcade, and the gradient is very shallow, with the lower stretch almost horizontal.¹⁵⁹ The aqueduct ran across the top tier in a covered, rectangular channel (**Figure 4.7**).¹⁶⁰

Other monumental ruins of the aqueduct are found at La Lône (**Figure 4.6**), which has a viaduct of 28 arches; Pont de la Valive, a bridge with 29 arches; 3 ashlar arches at Bornègre bridge and its conduit; Bridge of Roc-Plan in Vers, which is actually two aqueduct bridges and is 12 m long, 4 m high, and has three arches; and the Pont Roupt arcade, which has 37 arches that are preserved up to 7.5 m high.¹⁶¹ There are many more ruins of the aqueduct, but these are the major ones that are well-preserved in arcade length and height.

Leaving the rural area, the aqueduct traveled closer along the *Via Domitia* toward the city walls of Nîmes, where it crossed on the north side of the city and traveled underground toward the *castellum divisorium*. Parts of the underground tunnel of the aqueduct, as it travels towards the *castellum divisorium*, have been located at Rue Crucimelle, Impasse Wimille, Voie Ferree Ales-Nîmes (railway lines), Rue du Crémat,

¹⁵⁷ Hauck, 1988, 4

¹⁵⁸ Hauck, 1988, 4

¹⁵⁹ King, 1990, 78

¹⁶⁰ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info>.

¹⁶¹ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

and La Providence, as well as underneath the 17th century fort.¹⁶²

The research of Trevor Hodge and George Hauck established that the route of the aqueduct had a direct relationship with the topography. By analyzing the landscape, archaeologists have been able to trace the route of the aqueduct from Uzès to the *castellum divisorium* in Nîmes. The difference in elevation between Uzès and Nîmes is a mere 17 m, and the ideal average gradient is 0.34 m/km.¹⁶³ Hodge calculated the gradient profiles for the Nîmes aqueduct. His calculations indicate that the slope was 0.07 m/km between the source and the Pont-du-Gard, 0.07 m/km between Pont du Gard and St. Bonnet, 0.17 m/km between St. Bonnet and St. Gervasy, and 0.30 m/km between St. Gervasy and the *castellum divisorium*.¹⁶⁴ By exploiting the elevations of the land, and through innovative engineering and construction methods, the Romans were able to build an efficient water flow for supplying Nîmes.

4.4 The *Castellum Divisorium*

The *castellum divisorium* (**Figure 4.8**) is a circular settling and distribution tank at the north side of the city of Nîmes. It marks the end of the aqueduct and the start of the urban water distribution system.¹⁶⁵ It is located at an elevation of 59 m, which is the highest point above planned city blocks.¹⁶⁶ The basin was 6 m in diameter and was surrounded by a wall with painted plaster. The basin sat within some kind of square enclosure that was roofed with tiles. The enclosure had a Corinthian columnar colonnade

¹⁶² Fiches, 1996, 70

¹⁶³ Hodge, 1992, 184

¹⁶⁴ Hodge, 1992, 189

¹⁶⁵ Hodge, 1992, 280

¹⁶⁶ Hodge, 1992, 280

and entablature and was decorated with aquatic themed frescoes.¹⁶⁷ The foundations for the enclosure are rectangular. The pipes emanating from the *castellum* sloped steeper than the aqueduct. The aqueduct was covered by a stone grille and had a sluice gate to control the flow of water. The floor of the basin has three holes for drainage. The drainage water was used to flush the major sewers.¹⁶⁸ Ten circular holes penetrate the upper part of the *castellum* wall along the western half of the basin perimeter approximately 0.60 m above the floor of the basin. Each hole is about 0.40 m in diameter, and the holes are separated from one another by comparable amounts of space.¹⁶⁹ Lead pipes with an inside diameter of 0.30 m were inserted into these holes to carry the water to various parts of the colony.¹⁷⁰ The lead pipes emanating from the basin were grouped outside the basin into pairs of five channels leading to various destinations in the city.¹⁷¹

4.5 Urban Distribution Scheme

The urban water system of Roman Nîmes has never been mapped, so I prepared a plausible hypothetical map of the water distribution routes based on an evaluation of *in situ* evidence and the layout of the city (**Figure 4.9**). By analyzing city maps, a catalogue of excavations by Jean-Luc Fiches, and topographical elevations (**Figure 4.10**), I have distinguished areas and buildings that would have been part of the urban water distribution scheme (**Figure 4.9**). My map has five water supply routes, which accounts for the 10 pipes being grouped together in pairs of two. My first route (which is highlighted in yellow in **Figure 4.9**) runs toward several *domus* style houses with

¹⁶⁷ Hodge, 1992, 280

¹⁶⁸ Hodge, 1992, 280

¹⁶⁹ Hodge, 1992, 395

¹⁷⁰ Hodge, 1992, 395.

¹⁷¹ Hodge, 1992, 396

extravagant mosaics. The houses are located due west of the *castellum divisorium*.

Excavations have revealed piping from the *castellum divisorium* leading this way down Rue d'Albenas (**Figure 4.11**). Furthermore, the direction of the pipes points toward the Jardin de La Fontaine and the downward slope of elevation. Though the Jardin de La Fontaine had its own water supply from the native spring, the water supply for that sector of the city probably was supplemented by water from the *castellum divisorium*.

A second route (which is highlighted in green in **Figure 4.9**) leaves the *castellum divisorium* and travels south down Rue de la Lampeze before turning west to service a domus on Rue des Bénédictins and a bath on Rue Pasteur. The remains of a subterranean channel located at Rue des Bénédictins confirm this route.¹⁷² The water supply line then turned south to service the blocks located on the eastern side of Avenue Jean Jaurés via a long underground canal of 150 m in length that was discovered at Place d'Assas.¹⁷³ The canal was 2.30 m wide and 1.50 m deep, and would supply the central region of the city. This is supported by the remains of a canal, stamped pipes, and a basin near Rue Saint-Laurent.

A third route from the *castellum divisorium* (which is highlighted in orange in **Figure 3.9**) would have serviced the south sector of the city. South of the *castellum divisorium* was the forum, the Maison Carrée, and a few residential blocks. The Maison Carrée is a hexastyle temple that was dedicated to Gaius and Lucius Caesar, the adopted heirs and grandsons of Augustus (**Figure 4.13**).¹⁷⁴ The Maison Carrée is one of the best-

¹⁷² Fiches, 1996, 140

¹⁷³ Fiches, 1996, 295

¹⁷⁴ CIL XII, 3156

preserved Corinthian temples in the Roman world and exhibits precise Vitruvian proportions. I believe this route existed because of the collectors discovered under the Maison Carrée,¹⁷⁵ which was located just east of the forum. Also, just a few meters north of the Maison Carrée, a monumental canal was discovered underneath the streets. Furthermore, the gradient of the terrain declines considerably from the *castellum divisorium* to the Forum, so it seems likely that the ancient engineers would have exploited this slope to keep the water flow at a constant rate. Just south of the Maison Carrée is the remains of a bath complex along Boulevard Victory Hugu. The direction of this third route is further supported by the discovery of stamped lead pipes between the Maison Carrée and this bath complex. Finally, the last probable target of this route from the *castellum divisorium* is the amphitheater (**Figure 4.14**). It also had collectors beneath its floors.¹⁷⁶ Moreover, I believe that the arena would have been supplied water from the *castellum divisorium* because of its axial position to the forum, Maison Carrée, and the *castellum divisorium*.

I have determined that a fourth route from the *castellum divisorium* (which is highlighted in cyan in **Figure 4.9**) would have led to the bathing complex located at Des Halles, just northeast of the forum complex.¹⁷⁷ The baths are located down the slope from the *castellum divisorium*, thus it is evident that they would have been supplied water from the *castellum divisorium*. From the baths at Des Halles, the water supply route would head south to another bath complex and an aqueduct channel and then east to part of the drainage system. The water

¹⁷⁵ Fiches, 1996, 212

¹⁷⁶ Fiches, 1996, 139

¹⁷⁷ Fiches, 1996, 139.

supply line would dump into the drainage system and be discarded past the Ported'Auguste with other waste water.

The fifth water distribution route (which is highlighted in purple in **Figure 4.9**) supplied the eastern urban grid. Remains of this grid along the *Via Domitia* are visible in the landscape today and I have outlined them on my map. The remains found in this sector of the city include hypocausts, hydraulic features, and irrigation canals, all of which indicate that this area of the city received water from the *castellum divisorium*. Furthermore, the elevations of this area are very flat and differ by about 1 m at most, making this route physically plausible.

Worthy of attention is the natural spring located on the northwestern side of the city, which I have determined was the source of a sixth (and separate) water distribution route (which is highlighted in red in **Figure 4.9**). This water route begins at the Jardin de La Fontaine (**Figure 4.12**). This area comprised a theatre, a nymphaeum, the Temple of Diana, a propylon structure, and the source of the native spring. The nymphaeum consisted of two *exedrae* basins that were fed by the natural spring. The foundation would have been rectangular, measuring 16 m by 20 m.¹⁷⁸ The Temple of Diana, which is a misnomer, consists of complex niches, vaulting, and Corinthian style columns and pilasters.¹⁷⁹ The function of this building is still unknown, but it is hypothesized to be another nymphaeum or a library.¹⁸⁰

My sixth water route runs west from the Jardin de La Fontaine down Quai

¹⁷⁸ Fiches, 1996, 244

¹⁷⁹ Fiches, 1996, 250

¹⁸⁰ Anderson, 2013, 52

de la Fontaine, as evidenced by canals found along this street. This allowed for the waste water from the Jardin de La Fontaine to be taken out of the city and disposed through the gate located at the western end of the *Via Domitia*. Also, this route from the Jardin de La Fontaine serviced the southern orthogonal layout of this city. This is supported by the remains of hypocausts, an aqueduct channel, and lead pipe that were discovered along Avenue Jean Jaurés.¹⁸¹ Water would have been supplied to the western side of Avenue Jean Jaures by stamped lead pipes found in this area. It is probable that the western water route followed the east-west streets and distributed water to the regularly planned blocks in this sector of the city.

4.6 Other Noteworthy Buildings

North of the native spring is the Tour Magne (**Figure 4.15**), a hexagonal bastion that is a remnant of the once massive fortification walls circuiting the city. The Tour Magne is 36 m high and would have been decorated with pilasters and columns. The fortification walls consisted of 10 gates and 80 towers.¹⁸² The towers had various shapes, specifically round, square, and polygonal. The main gate servicing the *Via Domitia* was the Porte d'Auguste, which was a monumental gateway comprising two central portals and two pedestrian portals on the sides (**Figure 4.16**).¹⁸³ The gateway would have had two bastions on either side of it that were connected to the circuit wall. Another main gate was the Porte de France (or Porte d'Espagne), which was located near the

¹⁸¹ Fiches, 1996, 127

¹⁸² Fiches, 1996, 153

¹⁸³ Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

amphitheater and still stands with a semi-circular arch on top of two Tuscan pilasters. The aqueduct entered the city north of the Porte d'Auguste along Rue Bonfa and traveled along the north side of the *Via Domitia*, where it entered into the *castellum divisorium*.

4.7 Distribution of Wealth

My analysis of the water distribution from the *castellum divisorium* and the catalogue of excavations by Jean-Luc Fiches indicate that private houses received a direct supply of water from the aqueduct. The direct connection between *domus* style houses and the aqueduct are Vitruvian examples of private residences receiving permission to have a direct water supply line.

Private residence located directly west of the *castellum divisorium* received water from the aqueduct, as evidenced by a line of pipes running from one of the distribution holes in the *castellum divisorium* toward that neighborhood of private elite residences (**Figure 4.17**). The status of these homes is revealed to be elite through their excavation remains, which display opulent mosaics and marble sculptures. Whether or not the Nîmes houses were taxed on their water privilege is unknown.

Another area of wealth shown through water supply (**Figure 4.17**) is the site of two houses that are located south of the Jardin de La Fontaine complex. One *domus* was located directly below the Temple of Diana and was decorated with sculptures, intricate mosaics, and decorative wall paintings. Just south of this complex, in the northern edge of the preserved orthogonal plan, was another *domus* that also had rich mosaics.

Two additional residences that might have received water supply were located in the northern block of the Maison Carrée (**Figure 4.17**). The archaeology indicates that these two homes were not as wealthy as those located near the Jardin and the *castellum*

divisorium, but they have an axial alignment to the pipes and collectors in the area of the forum and Maison Carrée and display moderate wealth in the form of mosaics and sculpture that indicates possible association with elite status.

4.8 Orientations of Urban Plan

In my drawing of the city plan and water distribution routes of Nîmes, a distinct urban plan is seen in the layout of the streets and city blocks. The orthogonal street plan of Roman Nîmes had a NW/SE orientation and divided the city into blocks measuring 5 x 5 actus, which is approximately 177 m x 177 m.¹⁸⁴ The orthogonal street plan might have derived its layout from a 2nd century BCE military camp and the centuriation of the countryside. In fact, many other colonies in Gaul also planned their streets after military camps, as seen at Aix-en-Provence and Toulouse.¹⁸⁵

The main orthogonal layout shown in my drawing is in the southwest sector of the city just below the Jardin de La Fontaine (**Figure 4.2**). Much of this orthogonal plan is still preserved in the modern city streets, which made it obvious to identify in my plan. The modern streets running east-west correlate to the route of the *Via Domitia*, which ran through the center of the city from the Porte d'Auguste to the western gate. A few other streets in the south of the city run parallel to this grid system, and I have included them in my orthogonal grid.

This orthogonal layout may have extended farther than the area indicated on my map. I believe it could have extended toward to the forum and the southeast sector of the city. Further excavation of the roads and *insulae* would be required to determine if this

¹⁸⁴ Fiches, 1996, 135

¹⁸⁵ Anderson, 2013, 50

sector of the grid exists. It is also quite possible that the city had more than one orientation. It appears that the *Via Domitia* changes direction right after coming through the Porte d'Auguste. There could have been a separate orientation correlating to the change in the direction of the main road. There is another orthogonal layout located just below the 17th century fort. The blocks here extend east towards the Porte d'Auguste and run along the *Via Domitia* on its northern side. This area was definitely urbanized since there are remains of baths, canals, and pipes.

The northern sector of the city is not as thoroughly excavated as the southern sector. Most of the excavations in the northern sector relate to the fortifications, the Tour Magne, and a few burials near the Tour Magne. There might have been another urban sector in this part of the city, although none of the scholarship of the ancient city mentions it. The gradient of the terrain in this part of the Nîmes is much steeper, and, therefore, the area probably was not urbanized like the southern part of the city and most likely did not receive water from the *castellum divisorium*.

4.9 Conclusion

The aqueduct of Nîmes is one of the best examples of a Roman hydraulic system in the Roman world. The aqueduct can successfully be traced from its headwaters at La Fontaine d'Eure near Uzès through the Alzon River Valley, across the Pont-du-Gard, and following the *Via Domitia* towards the colony of *Nemausus*. The aqueduct, due to a low gradient, exploits the topography of the region to create a successful water flow through various bridges, channels, and tunnels. As the aqueduct reaches Nîmes, it crosses the fortification walls and empties into the *castellum divisorium*, circular water tank that distributed water to various places inside the city. Examining the topography, the city

plan, and the excavations of houses, channels, and public buildings, I located five likely routes of the urban water distribution from the *castellum divisorium*. I have concluded from my drawing and the differences in elevation between the *castellum divisorium* and the lower city that the water would have been directed to the Jardin de La Fontaine, the southern orthogonal layout, the forum complex, and the amphitheater, as well as private homes and bathing complexes. The urban water distribution of Nîmes would have serviced many more users than the buildings that I have highlighted. The existence of the modern city above the remnants of the Roman colony, however, makes it difficult to identify all the features of the ancient city. It is clear, nevertheless, that the colony of Nîmes had a specific urban plan that drew its orthogonal layout from the route of the *Via Domitia* and affected the planning of the water distribution routes in the city.

Chapter 5

Comparison of Water Systems of Pompeii and Nîmes

5.1 Introduction

Water was essential for the success of a Roman colony. The Romans piped in water from mountain springs by gravity flow through aqueducts that terminated in a holding, settling, and distribution tank known as a *castellum divisorium*. The *castellum divisorium* was located at the highest point of a city and distributed the water from the aqueduct by gravity flow within the city through pipes underneath the city streets and sidewalks. Sometimes the water was piped from the *castellum divisorium* to a secondary *castellum* or catchment for redistribution through another network of pipes. These water systems were planned from the conception or expansion of a colony and integrated into the urban framework of the city blocks and streets. The water systems of Pompeii and Nîmes exemplify Roman planning, surveying, and engineering in the complexity of their orthogonal layouts and urban water distribution systems. The two systems are similar in that the aqueduct terminated in a *castellum divisorium*, from which main pipes distributed water throughout city. This chapter presents a comparison of the two best preserved Roman water systems at Pompeii and Nîmes.

The two cities both date to the 1st century BCE as Roman colonies, with Pompeii becoming a Roman colony around 80 BCE and Nîmes later in 27 BCE. The colonies were used to settle veteran soldiers: Pompeii for Sullan veterans from the Social War; and Nîmes for Augustan veterans from Actium. The Augustan influence is evident in the grid layout of both cities and in the architectural style of the buildings. Both cities had periods

of occupation before becoming Roman colonies, and the influence of prior occupations on the urban plan, monuments, and development was more extensive in Pompeii than in Nîmes. Pompeii's street network appears to have been built in phases, as the city

	Pompeii	Nîmes
Population	10,000-11,000	40,000-60,000
Area Inside Walls	64-67 hectares	220 hectares
Population Density (Estimated)	156 people/hectare - 172 people/hectare	182 people/hectare - 273 people/hectare
Date of Founding of Roman Colony	80 BCE	27 BCE
Orthogonal Layout	Yes (4 distinctive)	Yes
Fortifications	3.22 km long	6 km long, 9 m high
Towers	12	14
Gates	7	5

Table 5.1 Urban Statistics of Pompeii and Nîmes (By Author)

expanded and reconstituted under different occupations and after the earthquake of 62 BCE, which destroyed a good portion of the city. The orthogonal layout of Nîmes, on the other hand, was planned when the colony was founded and dates to the Augustan period. The Augustan period of both cities saw the construction of fortification walls. Pompeii's wall was about 3.22 km long, and Nîmes' wall was about 6 km long and 9 m high. Both fortification walls have towers evenly placed and gates at strategic cross roads. Pompeii had seven gates and Nîmes had 14 gates. The length of the fortification walls reflects that Nîmes encompassed a much larger land area than Pompeii (**Table 5.1**). The land area inside the walls of Pompeii is only 64-67 ha, whereas Nîmes is 220 ha. The urban area of Nîmes was limited, however, to the southern area of the city due to the hilly terrain in the northern sector.

The population of Nîmes was far greater than the population of Pompeii, and, despite its substantially greater land area, Nîmes was about 16% - 58% more densely populated than Pompeii. The higher population density in Nîmes was attributable in part to the hilly terrain in the northern section of the city, which restricted urban development. Pierre Grimal has estimated that the population of Nîmes was between 40,000 - 60,000 people.¹⁸⁶ The population of Pompeii has been estimated to have been between 9,600 - 16,000 people.¹⁸⁷ The population densities of the cities suggest that people lived closer together in Nîmes than they did in Pompeii, although that conclusion is subject to other variables, including the number of inhabitants per residence. As would be expected, the water systems of Nîmes and Pompeii reflect the difference in population between the cities, but more about that later.

5.2 The Aqueducts

The two colonies had very different aqueduct scenarios (**Table 5.2**). More is known about the Nîmes aqueduct because it has more remains. The earthquake in 62 CE destroyed much of the infrastructure of Pompeii and the surrounding area. The only remains of the Pompeii aqueduct are the last 15.5 m of channel before it entered the *castellum aquae*.¹⁸⁸

The Pompeii aqueduct dates to the late 1st century BCE. The construction of the Nîmes aqueduct was completed at a later date, most likely in the late 1st century CE. As discussed in Chapter 3, the Pompeii aqueduct that was in use at the time of the volcanic eruption in 79 CE is Augustan, but a current hypothesis is that it was preceded by a

¹⁸⁶ Grimal, 1983: Grimal does not clarify if this includes the rural populations around Nîmes as well

¹⁸⁷ Flohr and Wilson, 2017, 32

¹⁸⁸ Hodge, 1992, 97

Sullan aqueduct.¹⁸⁹ My comparison of the aqueducts of Nîmes and Pompeii is based on the Augustan aqueduct of Pompeii. The Pont-du-Gard, which is a famous part of the Nîmes aqueduct, is now believed to date to the middle of the 1st century CE, but the aqueduct was probably planned soon after the founding of Nîmes as a Roman colony in 27 BCE.¹⁹⁰ Marcus Vipsanius Agrippa served officially and unofficially as the *curator aquarum* of Rome from 33 BCE until his death in 12 BCE and was primarily responsible

	Pompeii	Nîmes
Date	Late 1 st century BCE	Late 1 st century CE
Source	Avella/Serino	Uzès
Source Elevation	366 m	76 m
Length	35 km (branch from Aqua Augusta) 105 km (total length of Aqua Augusta)	50 km
Average Gradient	3.3 m/km	0.34 m/km
Volume (m ³ /day)	4,000 m ³ /day before 62 CE 2,000 m ³ /day after 62 CE	30,000 m ³ /day
Dimensions Entering Castellum Divisorium	0.60 m x 1.20 m 0.25 m x 0.25 m (sunken channel)	1.20 m x 1.60 m
Notable Features	Ponte Tirone	Pont-du-Gard
Shape of Conduit	Vaulted with sunken channel	Rectangular channel

Table 5.2 Aqueduct Statistics for Pompeii and Nîmes (By Author)

for the restoration of four aqueducts and the construction of two new aqueducts in Rome.¹⁹¹ Since Agrippa was an expert on the construction of aqueducts and had recently built the *Aqua Virgo* in Rome in 19 BCE before his visit to Nîmes in 14 BCE, it seems likely that he was involved in planning the Nîmes aqueduct and water supply system. The

¹⁸⁹ Keenan-Jones, 2015, 191

¹⁹⁰ Anderson, 2013, 52

¹⁹¹ Agrippa extensively restored the Appia, Anio Vetus, and Marcia aqueducts in Rome, combined the Tepula aqueduct with a new aqueduct (Aqua Julia), and built the Aqua Julia (33 BCE) and the Aqua Virgo (19 BCE).

Nîmes aqueduct was not completed, however, until the second half of the 1st century CE, and the reason for the time lag is uncertain. The Nîmes aqueduct is about 50 km long, and the construction of the Pont-du-Gard was a massive undertaking, so a project of that scale and complexity would take decades to plan and build. Nevertheless, the *Aqua Augusta*, of which the Pompeii aqueduct was a part, is believed to have been constructed between 30 and 20 BCE, and it was twice as long and certainly as complex as the Nîmes aqueduct. Perhaps the start of the Nîmes aqueduct project was stalled after the death of Agrippa in 12 BCE and the death of Augustus in 14 CE. It is also plausible that the construction of the Nîmes aqueduct encountered delays attributable to design problems. In any event, the aqueduct was not completed until the second half of the 1st century CE.

Nîmes was supplied more aqueduct water than Pompeii. Nîmes had a dedicated aqueduct. Pompeii's aqueduct was a branch of the *Aqua Augusta* (Serino Aqueduct), an aqueduct that traveled approximately 105 km from Serino to Misenum and split its water among various cities along the coast of the Bay of Naples. Accordingly, Pompeii did not receive the full amount of water that the *Aqua Augusta* supplied. This might explain why the channel of the Pompeii aqueduct was so small, only 0.6 m x 1.2 m for the entire vaulted channel and even smaller (25 cm x 25 cm) for the sunken channel. Although Nîmes probably shared its aqueduct water with the countryside, it did not share that water with other large colonies. The Nîmes aqueduct also moved more water per day, approximately 30,000 m³/day, than the Pompeii aqueduct, which moved approximately 4,000 m³/day before the earthquake in 62 CE and approximately 2,000 m³/day after the earthquake. In relative terms, Nîmes had about four times as many people as Pompeii but received more than seven times as much aqueduct water per day as Pompeii before the

earthquake and 15 times more water per day after the earthquake. Nîmes also benefited from wells and a native spring, which supplied additional water to the city. Conversely, many of the wells and cisterns in Pompeii became contaminated as result of the earthquake. Clearly, water was more precious in Pompeii than in Nîmes.

The construction of both the Nîmes aqueduct and the *Aqua Augusta* were, for different reasons, complex undertakings that required significant engineering skills. The primary issue in the construction of the Nîmes aqueduct was the flatness of the elevations in the Alzon River Valley, which challenged Roman surveyors and engineers to design a route and structures that would provide enough slope for the gravity flow of water. The opposite problem existed with the construction of the *Aqua Augusta*. The mountainous terrain of its source high in the Apennine Mountains was too steep, requiring engineering strategies to diminish the gradient and reduce the water pressure to avoid damage to the aqueduct. Also, the length and vastness of the *Aqua Augusta*, the first regional aqueduct network, posed enumerable engineering challenges. While the engineers for the Nîmes aqueduct built arcades, bridges, and other substructures in a quest to increase slope, the engineers for the *Aqua Augusta* were building hydraulic chutes and 2 km long tunnels through the mountains in a quest to decrease slope.¹⁹² The average gradient for the Nîmes aqueduct was approximately 0.34 m/km, and the average gradient for the Pompeii aqueduct was approximately 3.3 m/km (**Table 5.2**).

Both aqueducts crossed water. The famous Pont-du-Gard was built to carry the Nîmes aqueduct across the River Gardon. The Ponti Rossi bridges were built for the Naples branch of the *Aqua Augusta*. The Ponti Rossi and Pont-du-Gard and bridges are

¹⁹² Passchier, W.D. Schram and C.W., Wilke Schram, and Driek Van Opstal. Roman Aqueducts.<http://www.romanaqueducts.info/>.

visible in the landscape today.

5.3 The *Castellum Divisorium*

Both the Pompeii and Nîmes urban water systems had a *castellum divisorium*, a large water tank for receiving, settling, and distributing within the city water from the aqueduct. The *castellum aquae* of Pompeii and the *castellum divisorium* of Nîmes both served the same function as the connection between the aqueduct and the urban water

	Pompeii	Nîmes
Date of Construction	1 st century BC	Late 1 st century CE
Basin Diameter (from wall to wall)	5.8 m	5.5 m
Basin Depth	0.87 m	1.0 m
Elevation	42.6 m/43 m	59.0 m
Maximum Volume Capacity	22.41 m ³	23.75 m ³
Building Shape	Square, brick building with three arches and a vaulted roof	Vaulted square enclosure with balustrade and Corinthian columns,
Building Dimensions	5.7 m x 4.3 m	N/A
Castellum Layout	Trapezoidal basin inside a circular structure, with cross walls, 10 zones	Circular basin with drainage holes in bottom
Aesthetics	Wall painting of River god with Nymphs	Aquatic themed frescoes, Corinthian entablature and columns
Number of Drain Holes	0	3
Number of Pipe Holes	3	10
Diameter of Pipes	25 cm, 30 cm, 25 cm	30 cm
Pipe Material	Lead	Lead
Secondary Castella	14	N/A
Substructures for water division	Yes	No

Table 5.3 *Castellum* Statistics for Pompeii and Nîmes (By Author)

system and the primary distribution center for the urban water system. The building of the *castellum aquae* at Pompeii is well preserved and evidences that *castellum divisorium* were housed inside larger enclosures that were decorated with frescoes and architecture.

The remains of the *castellum divisorium* at Nîmes indicate that the water tank sat within an enclosure. Although there are not any remains of that enclosure, the archaeology of the *castellum divisorium* at Nîmes reveals that the enclosure had a platform and balustrade above that allowed people to walk around it and look down into the *castellum divisorium*. Both the Pompeii and the Nîmes *castella* held similar amounts of water, around 23 m³. The Nîmes *castellum divisorium* was emptied and refilled, however, at a much faster rate because it had 10 pipe holes, rather than 3 holes as in Pompeii, and because the aqueduct of Nîmes supplied a greater quantity of water. This suggests that the Nîmes *castellum divisorium* distributed more water on a daily basis than the Pompeii *castellum divisorium* and supports the conclusion that Nîmes had a larger population than Pompeii.

With respect to secondary *castella*, Pompeii had 14 water towers that were strategically located at specific intervals to reduce water pressure and facilitate the redistribution of water through separate sub-networks of pipes. There is not any archaeological evidence of water towers in the Nîmes urban water distribution system.

Three reasons can be discerned for the absence of water towers in Nîmes. First, the gradient of the city was not as steep as in Pompeii, so there was no need to interpose secondary *castella* to reduce water pressure. The elevations in Pompeii ranged from approximately 42.6 m at the *castellum aquae* to approximately 9.5 m at Porta di Stabia, with cross elevations at the west and east ends of Via di Nola of approximately 37.5 m and 24.5 m, respectively. The elevations in Nîmes ranged from 59 m at the *castellum divisorium* to 48 m at the Maison Carrée and 43 m at the amphitheater, with cross elevations of approximately 44 m at Porte d'Auguste and 69 m at Porte d'Espagne. Second, the *castellum divisorium* at Nîmes had ten discharge pipes for distributing the

aqueduct water within the city, instead of just three as in Pompeii. The additional pipes enabled water to be routed to more sectors of the city without redistribution through a secondary *castellum*. Third, the Nîmes urban water system employed other, less obtrusive means for secondary water storage and redistribution. Several of the public buildings, such as the Maison Carrée and the amphitheater, had collectors underneath them that would have been used to store water. Also, Nîmes had the native spring in the Jardin de La Fontaine that was integrated into its urban water system to store water in the two-*exedrae* basin and to facilitate water distribution in the southwest sector of the city.

The *castellum aquae* of Pompeii and the *castellum divisorium* of Nîmes used similar technology but were designed differently in some respects. Both of the *castella* had the aqueduct channel connected to one side and the discharge pipes connected to the other side and used sluice gates to control the amount of water flowing into the distribution outlets. The sluice gates would have been made out of lead and controlled by a rope and pulley system. As previously noted, the Pompeii *castellum divisorium* discharged the water to the city through three pipes, one 30 cm in diameter and two 25 cm in diameter, whereas the Nîmes *castellum divisorium* was designed with ten discharge pipes, all 30 cm in diameter. The use of more and bigger pipes in Nîmes was consistent with its greater population and the substantially larger quantity of water supplied by its aqueduct. The capacity of the two *castella* were about the same, so, if the discharge of water from the aqueduct to the *castellum divisorium* was greater in Nîmes than in Pompeii, water would need to be dispersed from the Nîmes *castellum divisorium* faster and in a larger volume than from the Pompeii *castellum aquae*, hence more and bigger discharge pipes. The shape of the basin inside the Pompeii *castellum aquae* differs from

the one in Nîmes and appears to reflect a different filtration and purification process. The basin in the Pompeii *castellum aquae* is not truly circular, like the basin inside the Nîmes *castellum divisorium*. Inside the circular retention wall of the Pompeii basin was an area in the shape of a trapezoid that was further subdivided by raised substructures that filtered the water as it flowed from the aqueduct to the distribution channel. These divisions inside the basin probably facilitated better water control through the use of sluice gates and helped to filter and oxidize the water before dispersing it through the urban water system. The Nîmes *castellum divisorium* filtered the water by the use of sluice gates and three drainage holes in the floor of the basin, which discharged sediment and debris that sank to the bottom of the basin.

The evidence of decoration and architectural aesthetics on enclosures for both of the *castella* indicates that they were more than just holding tanks for water. They also were aesthetic and architectural monuments to be viewed and appreciated. It is clear that the Romans beautified these buildings and created balustrades for people to observe the water distribution process without falling into the water. I believe that the *castellum divisorium* played an important social role, as well as functional role, in urban life and was an artistic and entertainment amenity of the city.

5.4 Urban Water Distribution

Vitruvius stated in *De Architectura* that water was to be apportioned within the *castellum divisorium* into three tanks and that each tank was to have a separate pipe, with the pipe from the central tank running to all the basins and fountains, a pipe from a second tank running to baths, and the pipe from the third tank running to private

residences.¹⁹³ In other words, each of the three classified uses (baths, fountains, and private residences) was to have its own dedicated water supply. Many scholars, like Hodge and Hauck, focused on this statement and saw that the *castellum divisorium* at both Pompeii and Nîmes did not conform to this tripartite description, and, as a result, it has for the most part been ignored or rejected in recent scholarship. I believe that what Vitruvius wrote remained relevant in regard to water distribution priorities, but that urban water system design and distribution practices evolved to respond to the urbanization of cities after he wrote *De Architectura* between 30-20 BCE. Notably, Vitruvius wrote his treatise years before the Nîmes *castellum divisorium* was constructed, the Pompeii *castellum aquae* does have three pipes, and both *castella* distributed water to baths, fountains, and private residences. The archaeology tells us that urban water distribution in Pompeii and Nîmes was expanded to uses other than the three categories enumerated by Vitruvius and was not partitioned in the *castellum divisorium* to provide a dedicated supply for each category of use. This change in the system for the distribution of water from the *castellum divisorium* was no doubt caused by the urbanization of the cities and the expansion (urban sprawl) of monuments, infrastructure, and private residences into different areas of the city. This expansion is evident in the evolution of the urban plan of Pompeii, as baths, temples, housing developments, and public buildings (such as the amphitheater) were built at different times in different regions of the city. The Vitruvian tripartite division of water was workable when all the baths were located in one area, all the fountains were located in a second area, and all the private residences were located in a third area. The concept became problematic, however, when those structures became

¹⁹³ Vitruvius, 8.6.2

dispersed throughout the city.

Sometimes cities have or need to develop a supplemental water supply due to natural disaster, an insufficient supply of water from the aqueduct, or other reasons. Nîmes had a native spring at the northern sector of the city, which was used to facilitate urban water distribution in the city. This spring water was held in a *nymphaeum*, which effectively served as a secondary *castellum* by accumulating and redistributing water to the southwest *insulae* of the city. As discussed in Chapter 2, Pompeii was possibly supplied water at various times from Avella, Serino (via the *Aqua Augusta*), or Somma-Vesuvius or a combination of the foregoing sources.

	Pompeii	Nîmes
Secondary Castella	14	1 [Nymphaeum]
Fountains	42	1 [Jardin de La Fontaine]
Baths	4	4/5
Private Residences	32 (63 according to Eschebach)	7
Workshops	46	Unknown
Temples	Unknown	2 [Temple of Diana, Maison Carrée]
Theater/Odeum	2	1
Amphitheater	1	1

Table 5.4 Urban Water Distribution Destinations for Pompeii and Nîmes (By Author)

The urban water distribution system of Nîmes serviced a much larger population and a much wider geographic area than Pompeii. It hardly seems a coincidence that the *castellum divisorium* of Nîmes had ten main discharge pipes, instead of three like Pompeii. It also seems evident that the Nîmes water distribution scheme had specific destinations in mind, such as the Maison Carrée, whereas Pompeii serviced public buildings like those through nearby fountains, baths, and water towers (**Table 5.4**). This

difference is possibly attributable to the specific development of the Pompeii urban plan and the redevelopment of the Pompeii water distribution system during the Augustan period and after the earthquake of 62 CE.

Pompeii's urban water distribution scheme was supported by secondary *castella* in the form of water towers (**Table 5.4**). The water towers effectively worked like a siphon. Water flowed downhill from the underground pipeline to a connecting pipe that ran up one side of the water tower and was discharged into a lead container on top of the water tower, and then the water would flow out of the container into a pipe that ran down the other side of the water tower and back into the underground pipeline. These water towers reduce water pressure caused by the steepness of the grade of the terrain in the city and also facilitated redirection and redistribution of the water to separate sub-networks of waterlines that serviced particular sections of the city. The archaeology of Nîmes does not evidence any water towers, but it seems possible that the native spring, the nymphaeum, and the collectors below the Maison Carrée, the amphitheater, and other public buildings served this purpose.¹⁹⁴ It would be just like the Romans to devise a more efficient and aesthetically pleasing way to provide secondary storage and redistribution of water. The archaeology of Nîmes also does not indicate the presence of street fountains.¹⁹⁵ It seems logical and reasonable that Nîmes augmented water distribution through street fountains like Pompeii. The Jardin de La Fontaine was a large public fountain complex that had an important role in the water distribution plan of Nîmes, but it is not the equivalent of numerous street fountains.

The private residences to which water was independently distributed were

¹⁹⁴ Fiches, 1996

¹⁹⁵ Fiches, 1996

typically elite residences. This is confirmed in both Pompeii and Nîmes. Eschebach identified 63 houses connected to the water supply, of which Olsson confirmed only 32. Of the 32 houses identified by Olsson, I distinguished 24 of them as elite residences based on the area of the house, the archaeological remains (such as gardens, mosaics, and frescoes), and water features (fountains, basins, peristyles). Based on the location of these 24 houses, the majority of them are located along the routes of water distribution that I have proposed in my map (**Figure 3.10**). Therefore, the proximity to the *castellum divisorium* also played an important role for the residences who received a water line. This is also displayed at Nîmes with respect to the houses located near the *castellum divisorium*, the Jardin de La Fontaine, and the Forum. The houses at Nîmes that were along my proposed water routes also displayed a certain degree of wealth.

It is evident that the water distribution systems of both Pompeii and Nîmes followed the street grid (**Figures 2.15 and 3.9**). The waterlines went under the streets and were designed with sufficient slope to generate water flow. Therefore, it seems highly likely that the urban water distribution routes were planned concurrently with the orthogonal grid system. The correlation between the two is too similar for it to be otherwise. This design is also evidenced at Roman Corinth in a section of road in the Panayia Field. The road was one of the *cardines*, running north to south, and ran parallel to the *cardo maximus*. The grid and centuriation of Corinth began shortly after its recolonization in 44 BCE.¹⁹⁶ In the 1st and 2nd centuries CE, this road was given much urban attention. Curbed sidewalks were added, but more importantly, multiple pipelines

¹⁹⁶ D.G. Romano, "City Planning, Centuriation, and Land Division in Roman Corinth: *Colonia Laus Iulia Corinthiensis* and *Colonia Iulia Flavia Augusta Corinthiensis*" in *Corinth XX, The Centenary*, C.K. Williams and N. Bookidis, eds., American School of Classical Studies at Athens, 2003, pp. 279-301.

were established under the sidewalks and street bed. The first drain dates to the late Augustan period and the terracotta pipes to the middle of the 2nd century CE.¹⁹⁷ These water supply lines follow the north-south orientation of the road.¹⁹⁸ The pipes run towards unknown destinations or amphora settling basins.¹⁹⁹ Between the 2nd and 5th centuries CE, there were 31 pipelines constructed under this road.²⁰⁰ Corinth's road proves that water supply design was happening alongside the planning of the urban layout and street grids, and supports the same conclusion for Pompeii and Nîmes.

¹⁹⁷ Palinkas and Herbst, 2011, 299

¹⁹⁸ Palinkas and Herbst, 2011, 307

¹⁹⁹ Palinkas and Herbst, 2011, 307

²⁰⁰ Palinkas and Herbst, 2011, 309

Chapter 6

Conclusion

My investigation of the water systems at Pompeii and Nîmes has engendered deeper observations of the urban layout and infrastructure of each city. Through my investigation of Pompeii, I was able to evaluate and propose three primary urban water distribution routes based on elevations, the urban plan, the location of secondary *castella*, the direction of water pipe grooves on the secondary *castella*, and the location of the public baths and buildings that used water. My routes differ, especially as to the western route, from those previously mapped by Christoph Ohlig and others. My map of the water routes confirms that water was subdivided between fountains and secondary *castella* and was further distributed from there to baths, workshops, and private residences.

My analysis of Pompeii helped me to identify those buildings associated with secondary water distribution in Nîmes. I located five routes from the *castellum divisorium* to various public and private buildings in the city. Nîmes did not have secondary *castella* (water towers) like Pompeii, but Jardin de la Fontaine (nymphaeum) served as a holding basin and a center for redistribution of water to the southern orthogonal layout. Furthermore, the collectors below the Maison Carrée, the amphitheater, and other public buildings seem to have served a similar purpose. My suggested routes of the urban water distribution systems in Pompeii and Nîmes confirm that water was distributed to baths, fountains, private residences, and public buildings, such as temples, theaters, and amphitheater. The orthogonal grid plans of the cities are also supported by my maps.

I have also determined that Nîmes was nearly four times larger than Pompeii in

both area and population, had a greater population density, and received substantially more water from its aqueduct than Pompeii did from its aqueduct. Water was scarcer in Pompeii, and perhaps that is why it had a significant number of public fountains. On the other hand, my examination of the archaeology indicates that many more private residences received water from the urban water system in Pompeii than in Nîmes, which suggests that Pompeii had a wealthier population.

The hydro-technology used for the aqueducts and urban water distribution systems for Pompeii and Nîmes evidences that the Roman planning and technology for these systems had become standardized by as late as the 1st century CE. This conclusion is confirmed by the similarities of the water systems in Pompeii and Nîmes and the conformity of the likely water distribution routes to the streets grids. This standardization spread from Rome to the Italian peninsula during the 1st century BCE and to the western provinces by the end of the 1st century CE. Both systems incorporated advanced knowledge of physics and engineering to use gravity flow and pressure reduction techniques to supply water to the necessary buildings in the urban framework.

Figures

Chapter 2 Figures

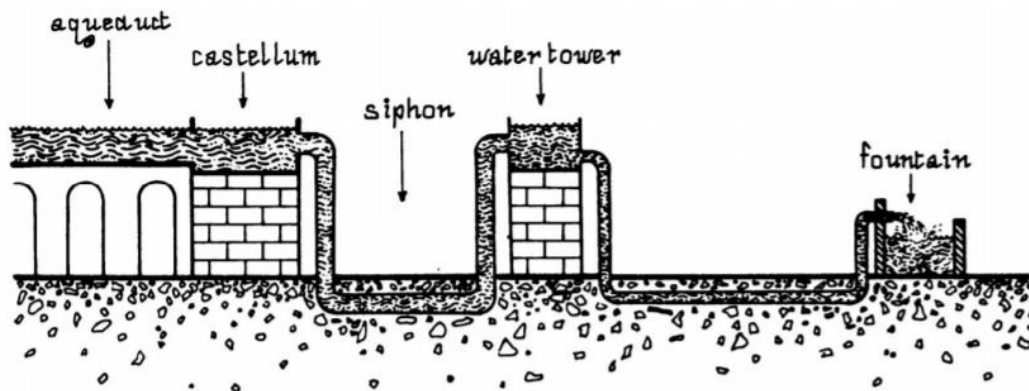


Figure 2.1 Diagram of Roman Water Distribution System (Hodge, 2002)



Figure 2.2 Aqueduct Conduit from Tylissos, Crete (Mays, 2010, 244)

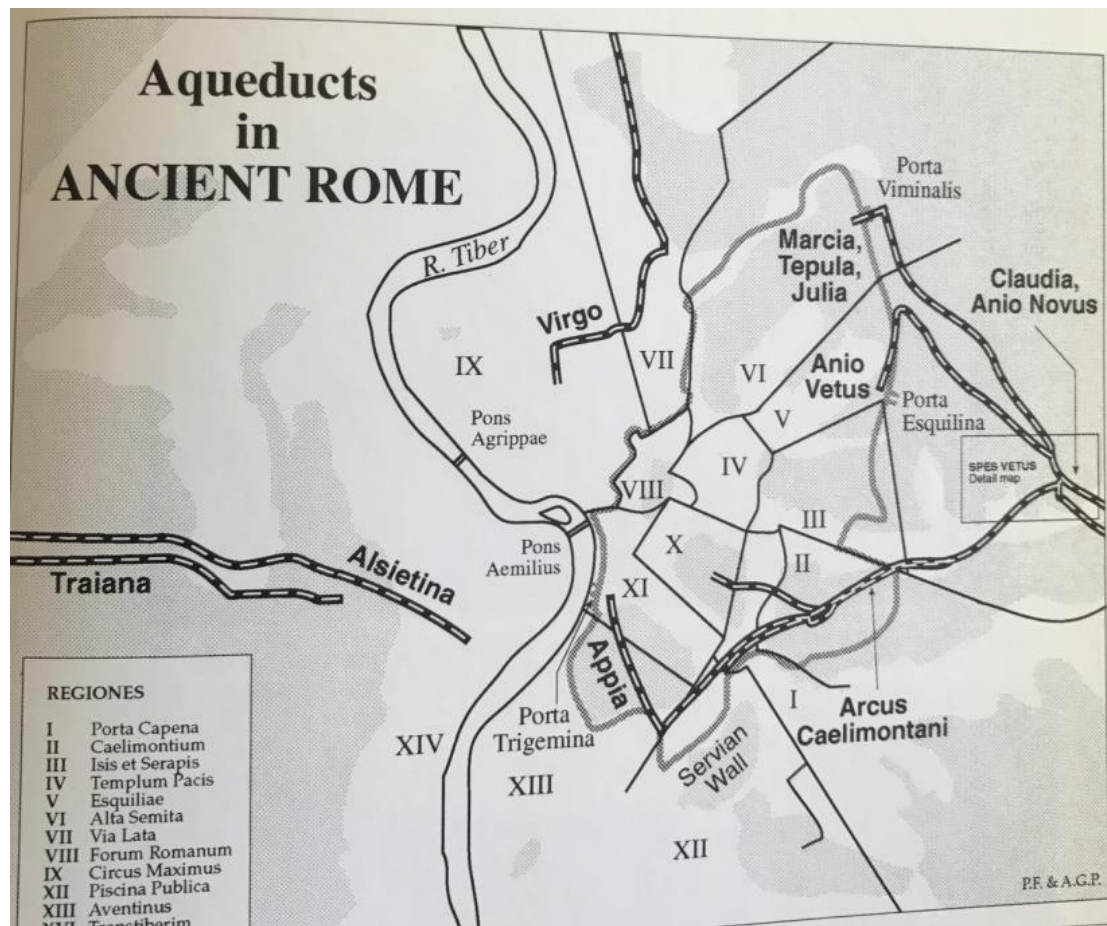


Figure 2.3 Map of the Aqueducts of Rome (Evans, 1993)

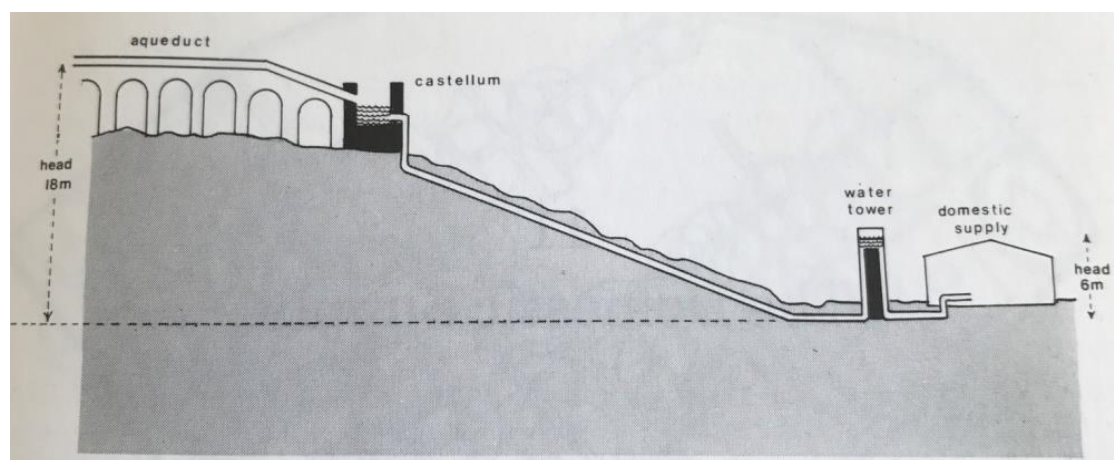


Figure 2.4 Water Distribution Scheme (Based on Pompeii) (Hodge, 1992, 303)

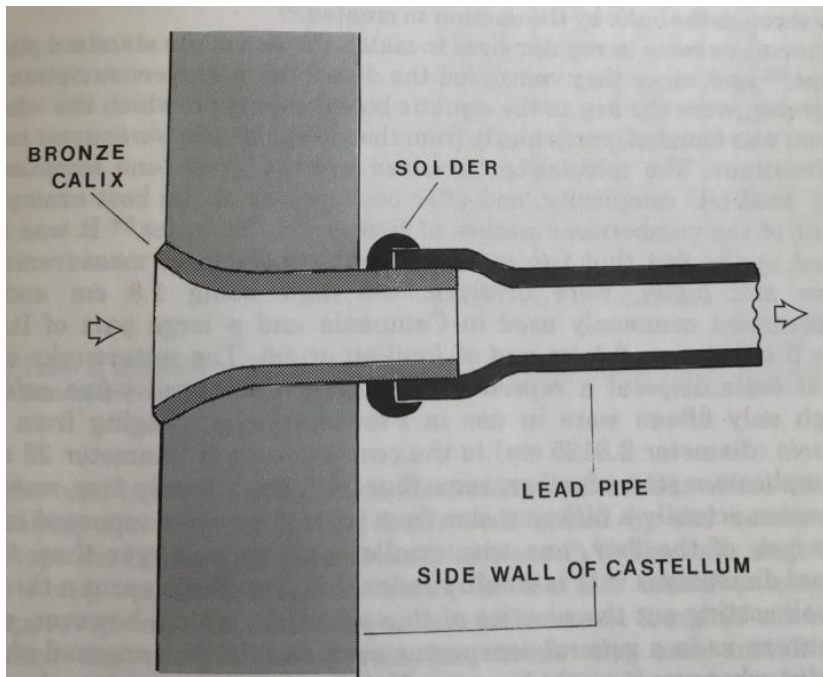


Figure 2.5 Diagram of Calix Inside Castellum Wall (Hodge, 1992, 295)

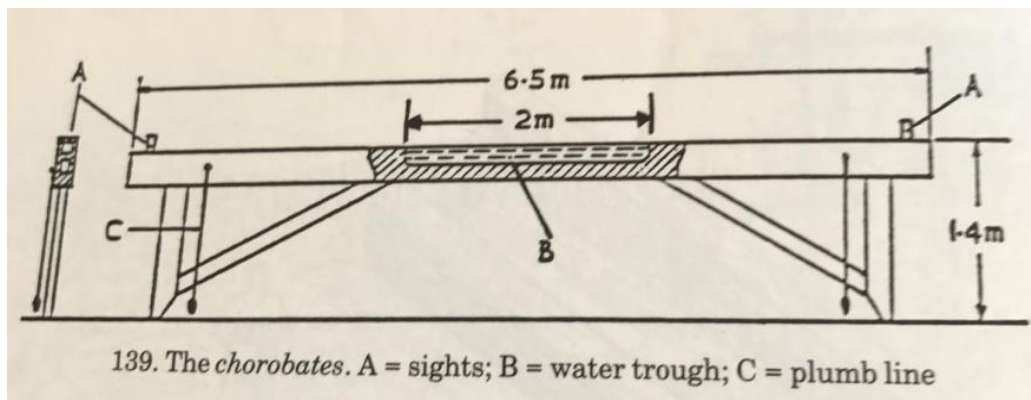


Figure 2.6 Diagram of Chorobates (Hodge, 1992, 200)

Figure 2.7 Underground Tunnel of the Cologne Aqueduct (Hodge, 1992, 94)



Roman size	Lead required per "10-foot" length		Diameter, allowing for overlap	
	lb	kg	in	cm
100-digit	864	392.25	22.6	57.4
80-digit	691	313.7	17.9	45.5
50-digit	432	196.1	10.9	27.8
40-digit	346	157	8.6	22
30-digit	259	117.6	6.3	16
20-digit	173	78.5	4	10.2
15-digit	130	59	2.8	7.2
10-digit	86	39	1.7	4.3
8-digit	72	32.7	1.2	3
5-digit	43	19.5	0.52	1.32

Overlap doubtful, so very approximate in this range

A 20-digit pipe required 1 ton per 125 ft approx.

Figure 2.8 Table of Standard Lead Pipe Sizes (Hodge, 1992, 297)

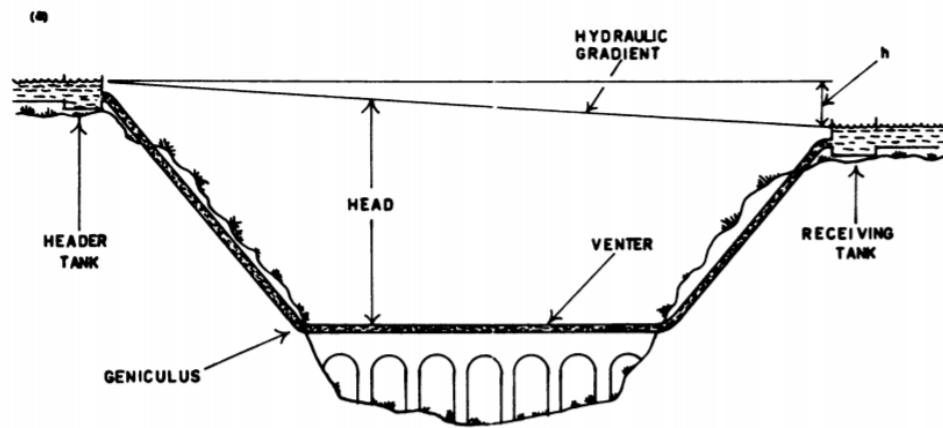


Figure 2.9 Diagram of a Roman Siphon (Hodge, 1983, 178)



Figure 2.10 Sinter Incrustation in Eifel Aqueduct (Cologne) (Hodge, 1992, 231)

Chapter 3 Figures



Figure 3.1 Satellite Image of Ancient Pompeii with City Walls (outlined in gray) (Image from Google Earth, Drawing by author)

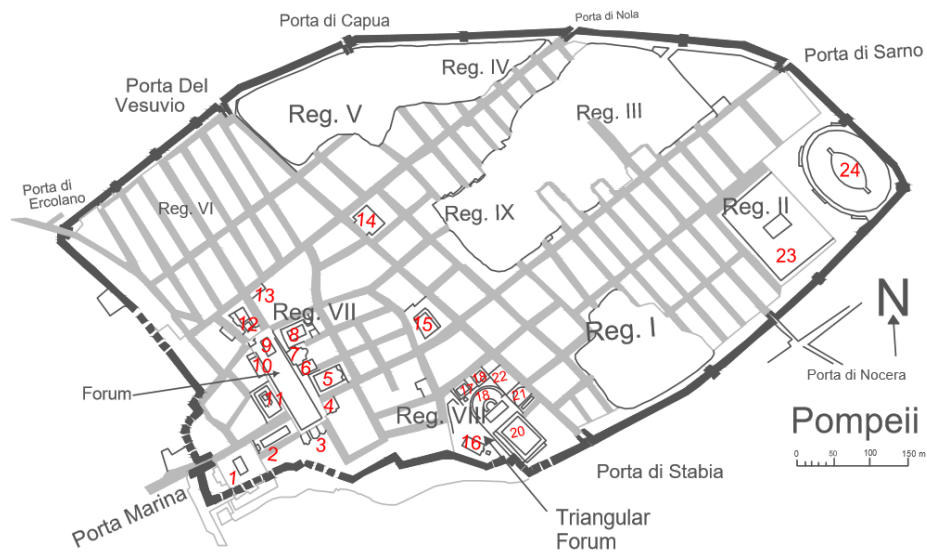


Figure 3.2 Map of Pompeii with Labeled Public Buildings (Drawing by Author, Based on Eschebach): 1. Temple of Venus; 2. Basilica; 3. Administration building; 4. Comitium; 5. Eumachia building (and Chalcidicum); 6. Building for the imperial cult (Temple of Vespasian); 7. Forum exedra (Lararium); 8. Market; 9. Capitolium; 10. Produce market; 11. Temple of Apollo; 12. Forum baths and cistern; 13. Temple of Fortuna Augusta; 14. New central baths; 15. Stabian baths; 16. Triangular Forum and archaic temple; 17. "Samnite" palaestra; 18. Temple of Isis; 19. Large theater; 20. Presumed gymnasium; 21. Covered theater; 22. Temple of Zeus Meilichios; 23. Campus; 24. Amphitheater



Figure 3.3 Street Map of Pompeii (Eschebach); Highlighted Streets: Vico di Mercurio; Via Mercurio; Via della Terme; Via delle Fortuna; Vico dei Vettii; Via Vesuvio; Via Stabia; Via di Nola; Via dell'Abbondanza; Via di Castricio; Via Marina (Laurence, 2)

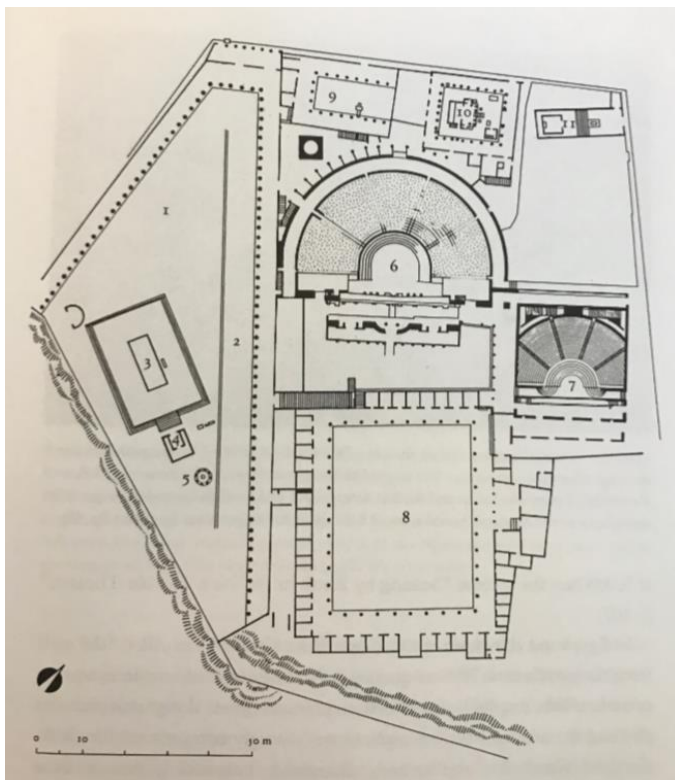


Figure 3.4 Plan of Triangular Forum (Zanker, 45)

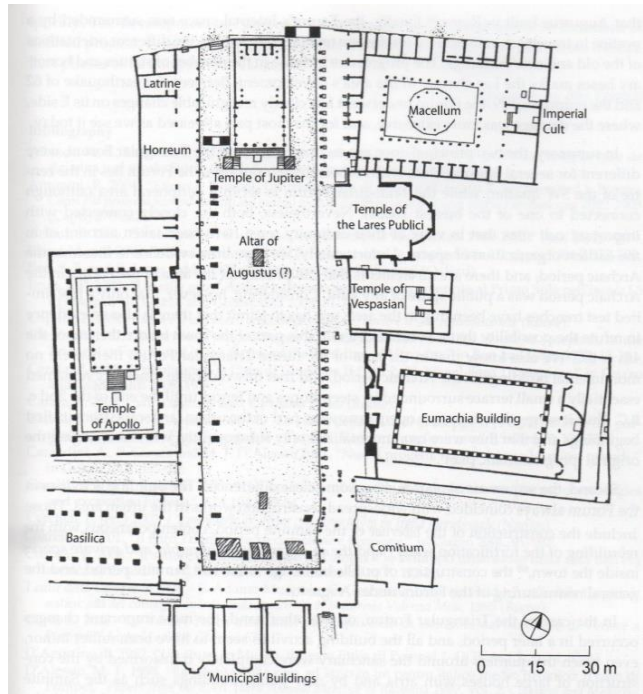


Figure 3.5 Pompeii Forum (Zanker, 1998)

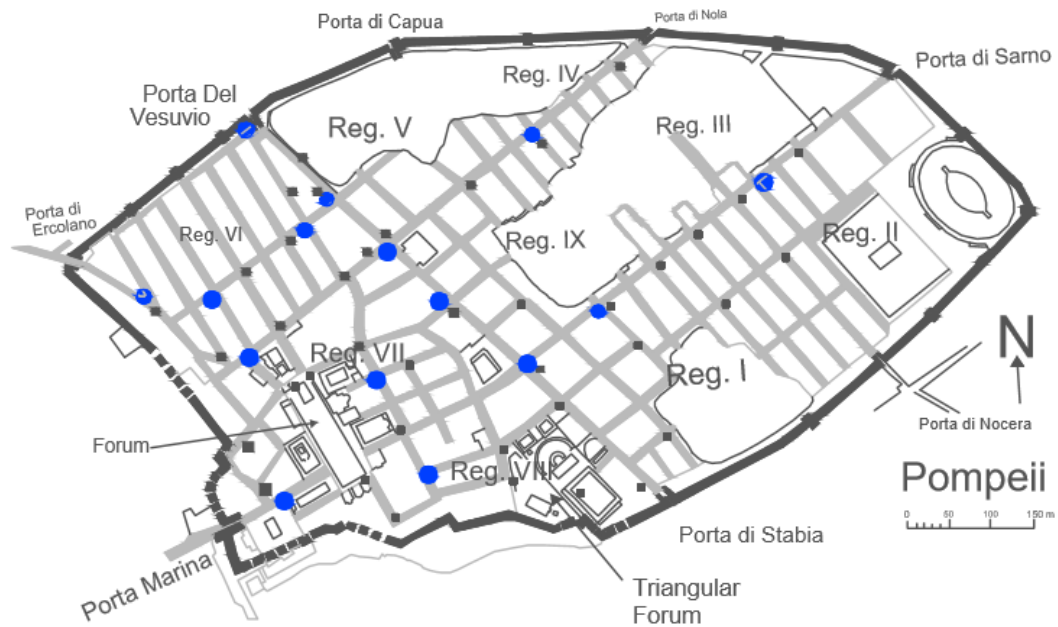


Figure 3.6 Plan of Pompeii with Locations of *Castella* (in blue) and Fountains (in black) (Drawing by Author, Based on Eschebach)

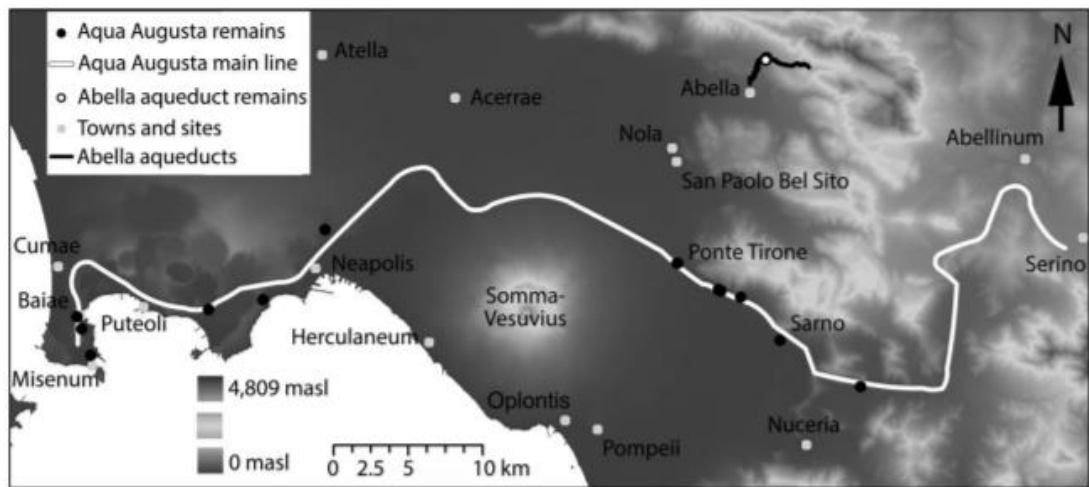


Figure 3.7 Route of the Aqua Augusta (Keenan-Jones, 201)

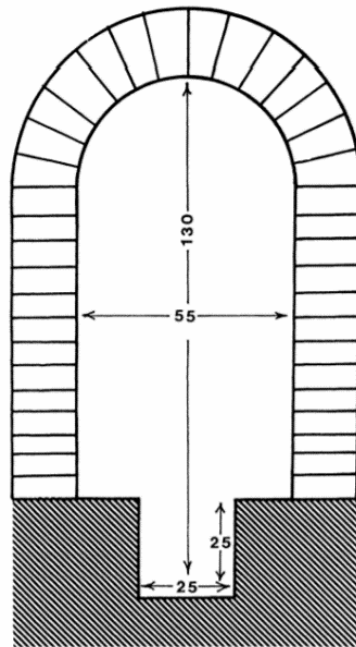


Figure 3.8 Cross-Section of Pompeii Aqueduct Channel (Hodge, 1993, 263)

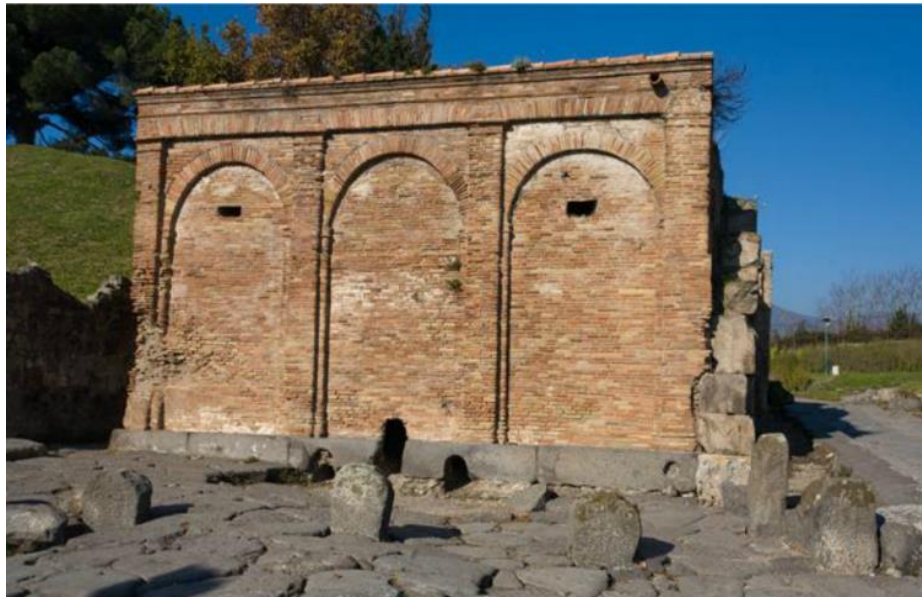


Figure 3.9 Facade of the Castellum Aquae (Artstor)

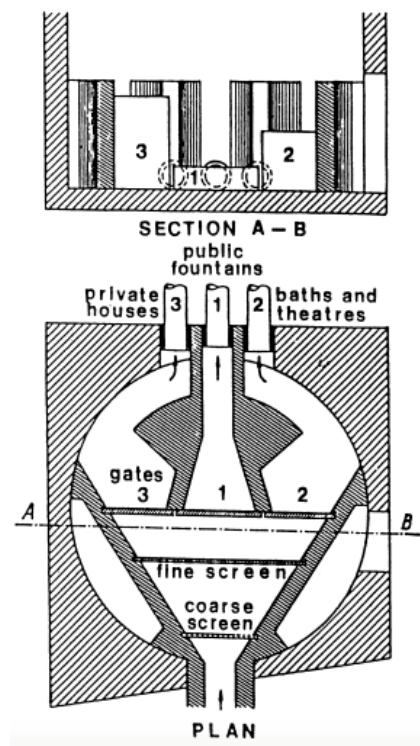


Figure 3.10 Plan of Pompeii *Castellum Aquae* (Hodge, 1992, 266)

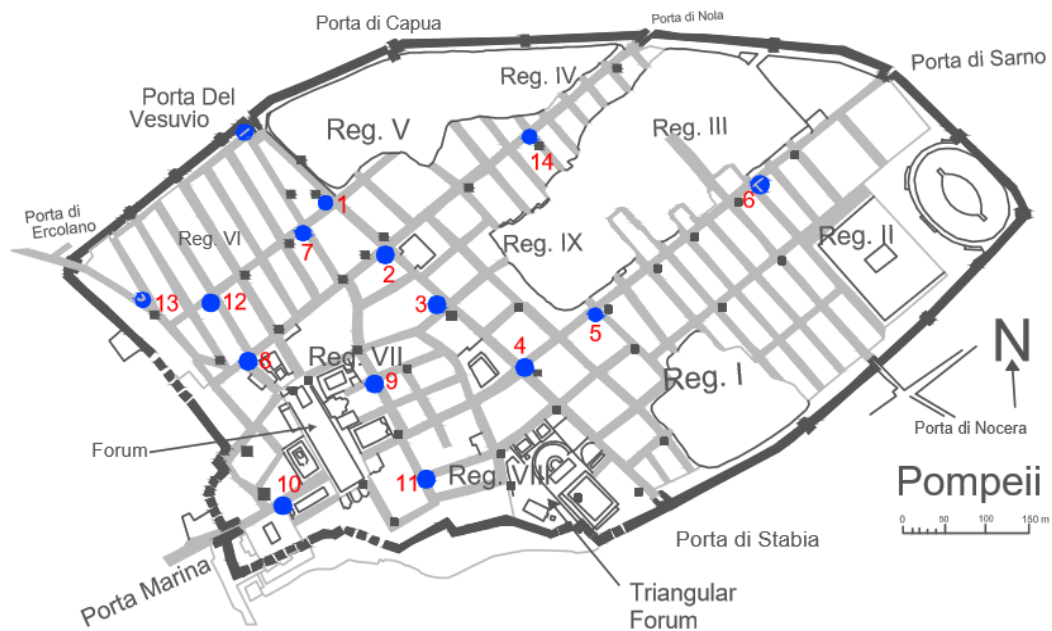


Figure 3.11 Locations of Numbered Castella (blue dots) and Fountains (black squares)
(Drawing by Author, Numbers by Olsson, Based on Eschebach)

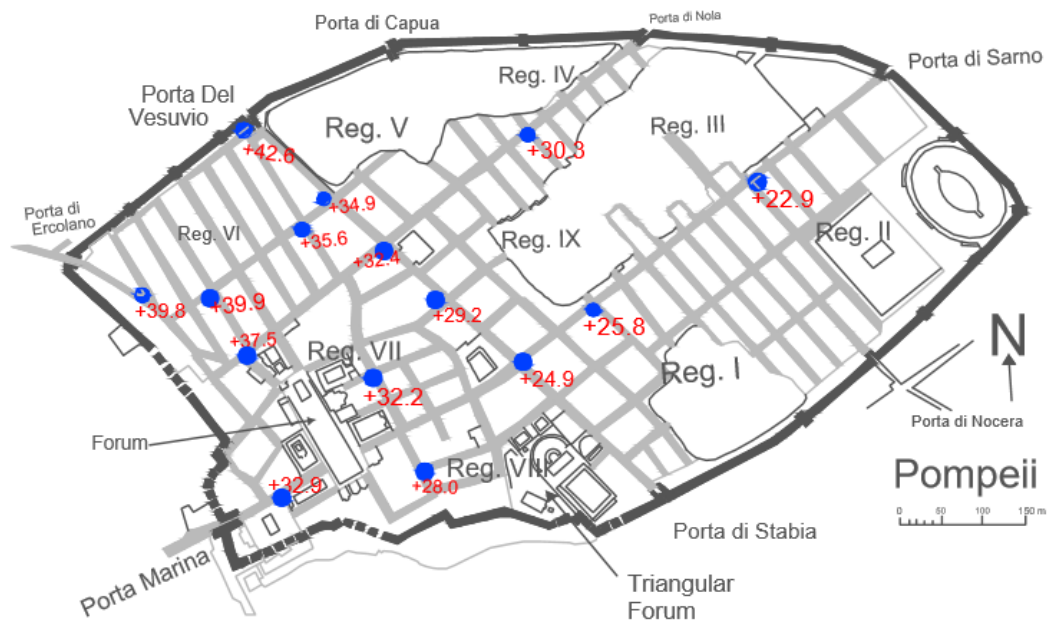


Figure 3.12 Locations of Castella (In blue) with Elevations (Drawing by Author, Based on Eschebach)

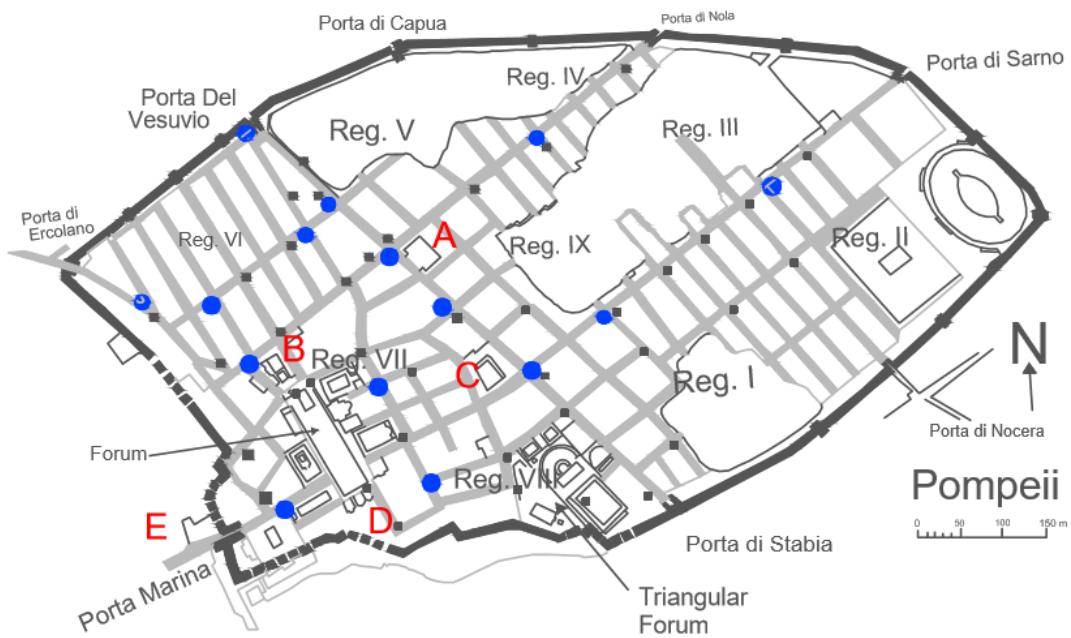


Figure 3.13 Locations of Baths with Castella (in blue) (Drawing by Author, Based on Eschebach): A. Central Baths; B. Forum Baths; C. Stabian Baths; D. Sarno Baths; E. Suburban Baths

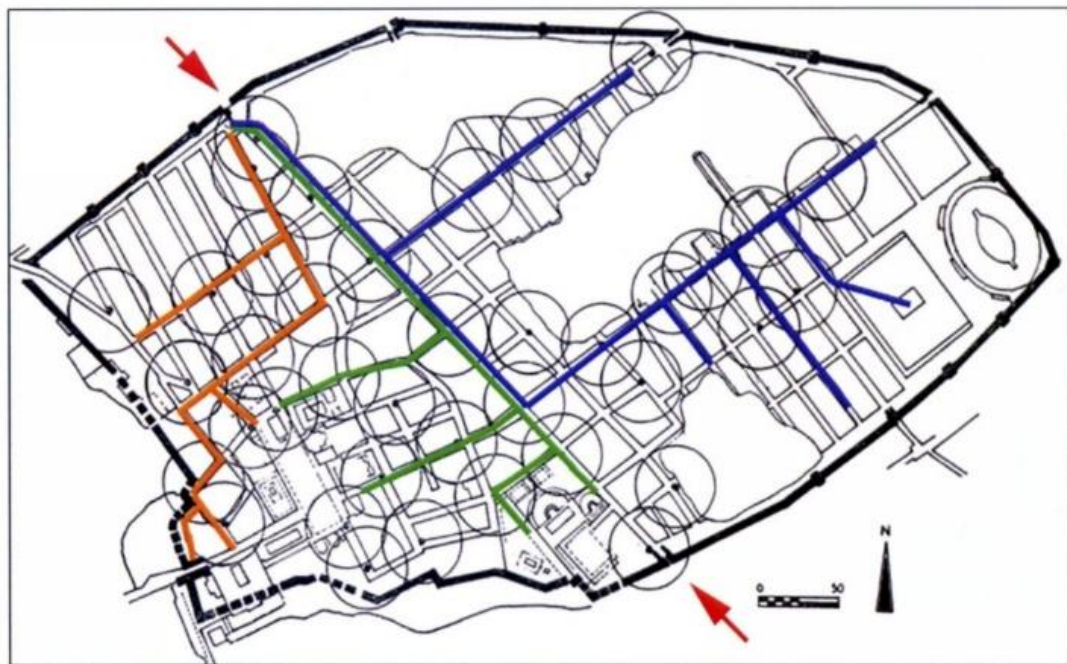


Figure 3.14 Ohlig Water Distribution Map (Ohlig, 2016)

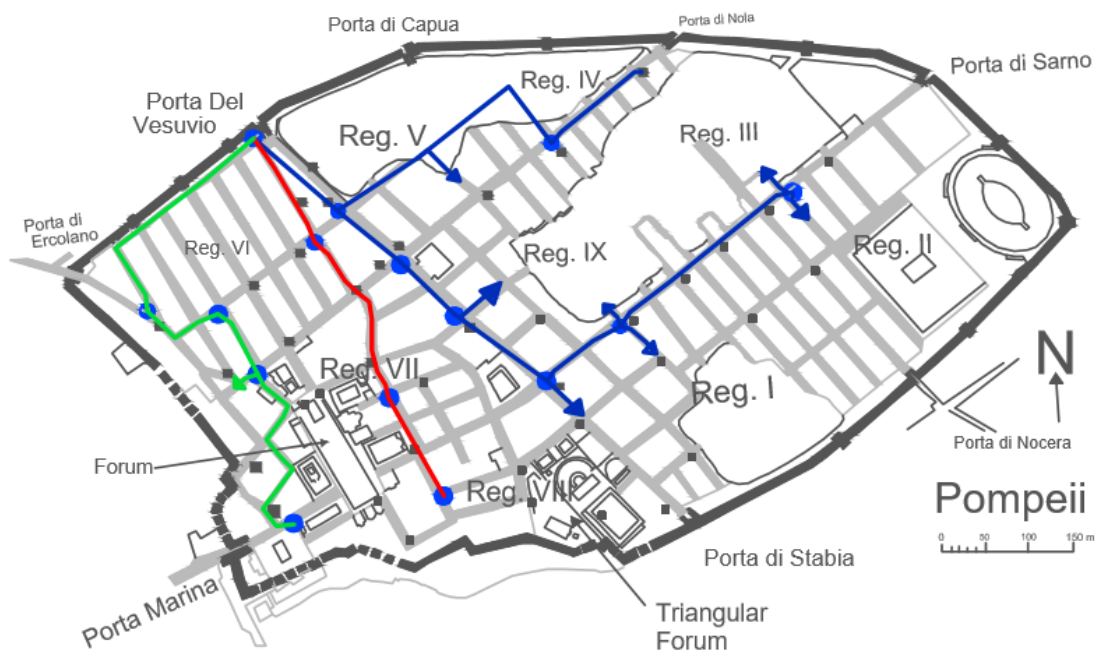


Figure 3.15 Urban Water Distribution Routes (Drawing by Author, Based on Eschebach):
 Eastern Route (in blue); Central Route (in red); Western Route (in green)

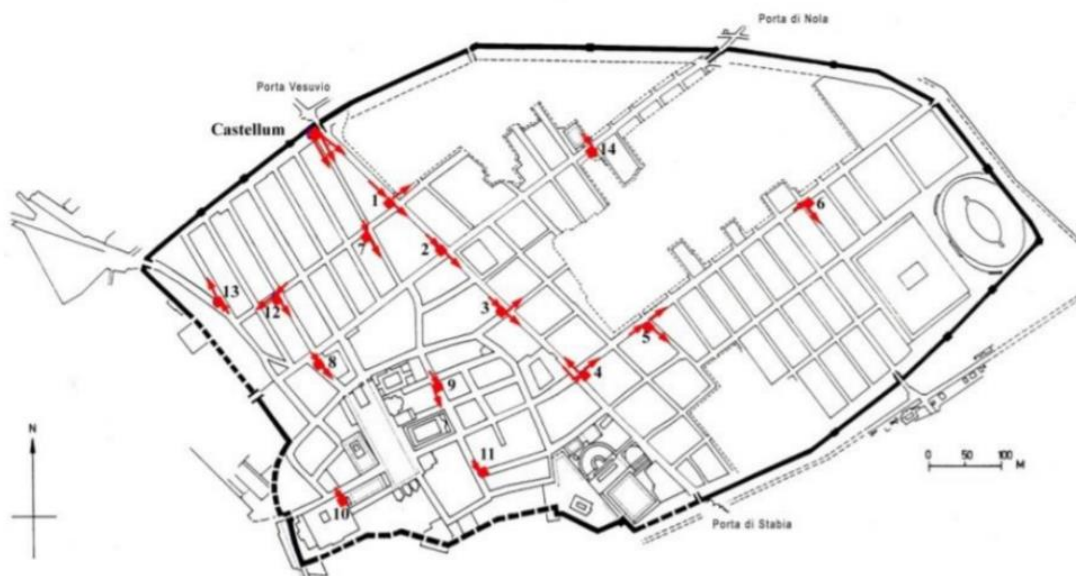


Figure 3.16 Direction of Grooves on Secondary *Castella* (Olsson, 39)

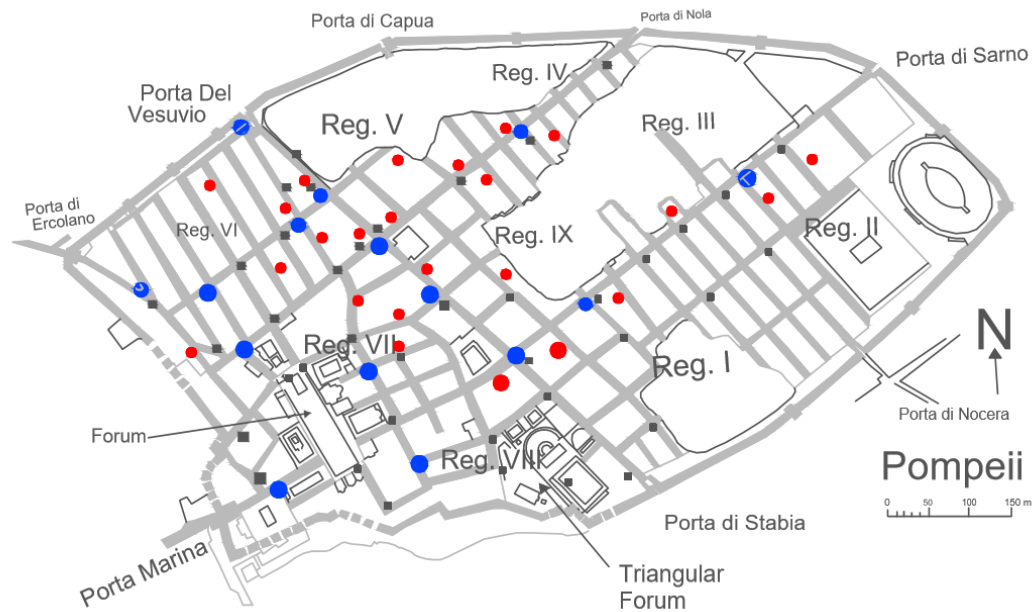


Figure 3.17 Locations of Elite Houses with Water Supply (Drawing by Author, Based on Eschebach 1993)

Chapter 4 Figures

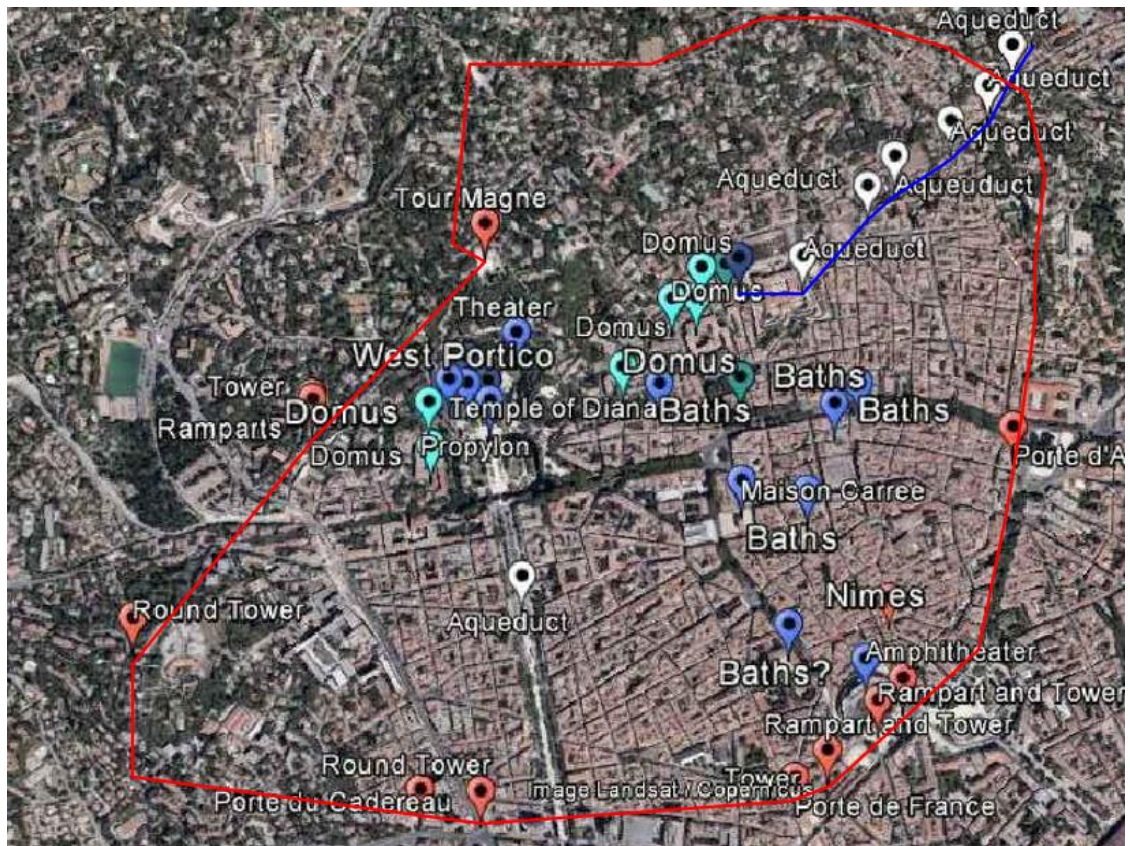


Figure 4.1 Satellite Image of Nîmes with Labeled Public Buildings and Outlined City Walls (in red) (Google Earth, Labels and Drawing by Author)

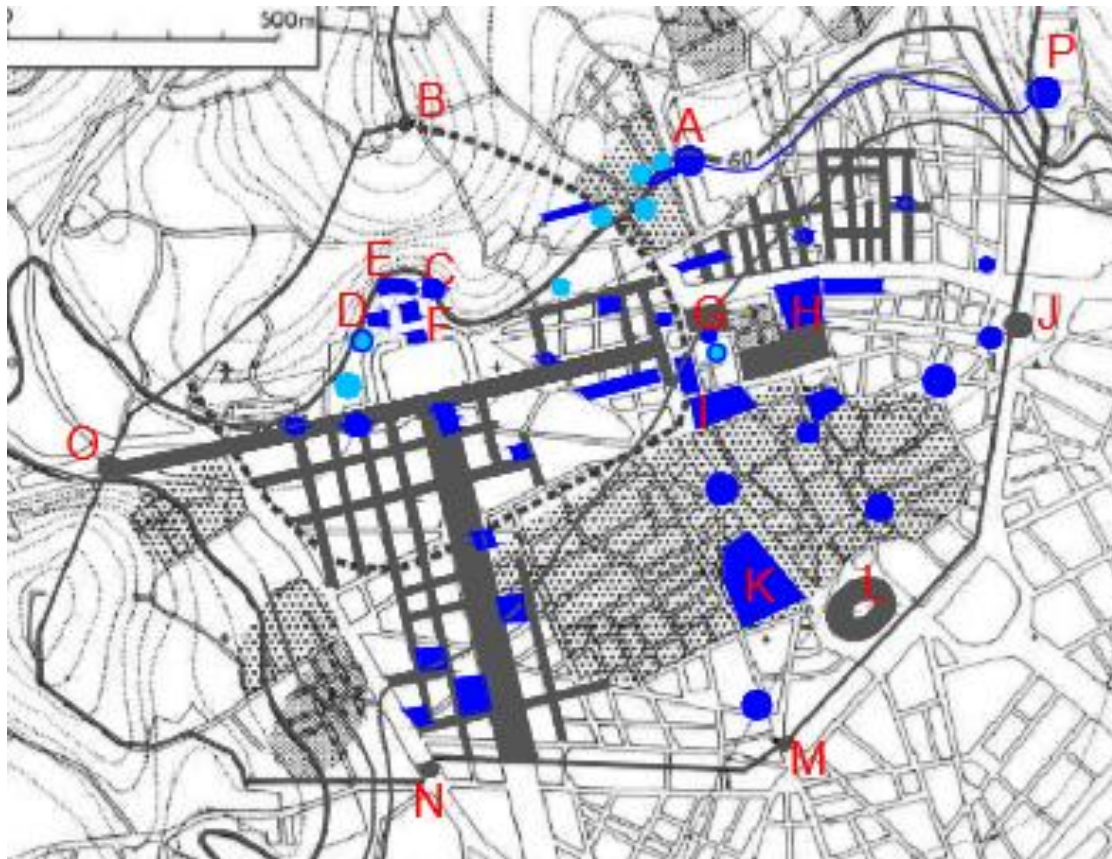


Figure 4.2 City Plan of Nîmes with Labeled Monuments (Drawing by Author, Map by Fiches):
A. Castellum Divisarium; B. Tour Magne; C. Theater; D. Temple of Diana; E. Native Spring;
F. Nymphaeum; G. Forum; H. Baths; I. Maison Carrée; J. Porte d'Auguste; K. Baths; L. Amphitheater;
M. Porte de France; N. Porte de Cadereau; O. Gate; P. Aqueduct

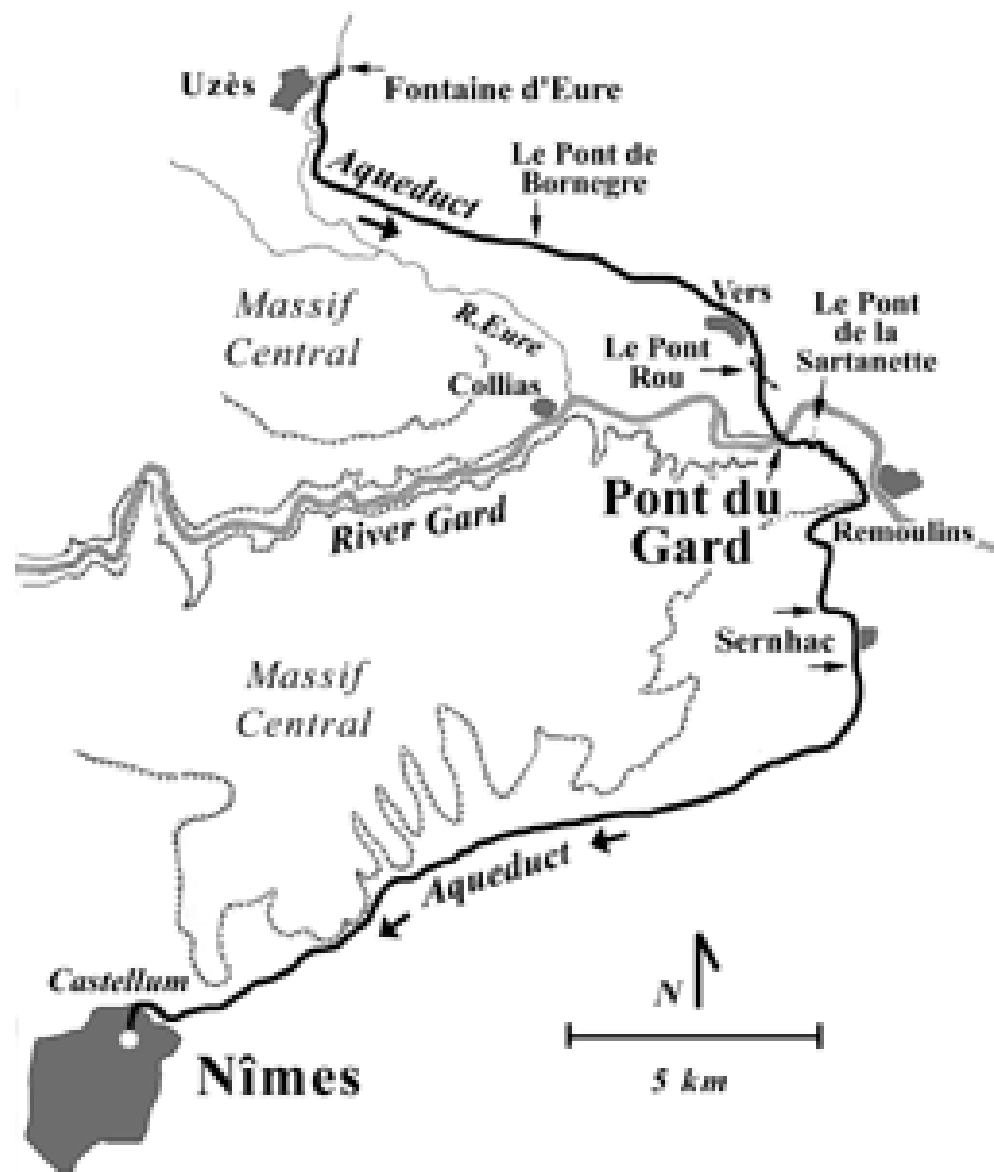


Figure 4.3 Route of Aqueduct (Fiches, 1996)



Figure 4.4 Source d'Eure, Uzès (Artstor)

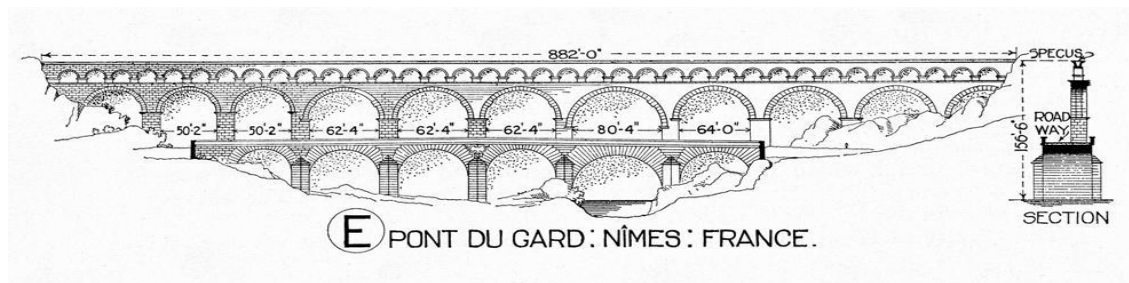
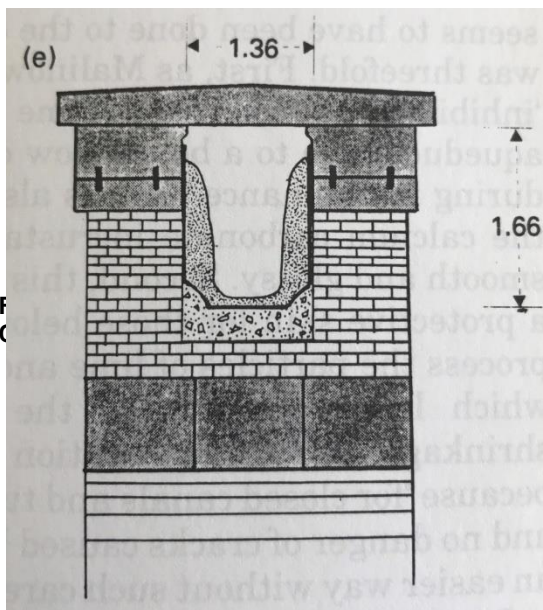


Figure 4.5 Pont-du-Gard (Artstor)



Figure 4.6 La Lône (Artstor)



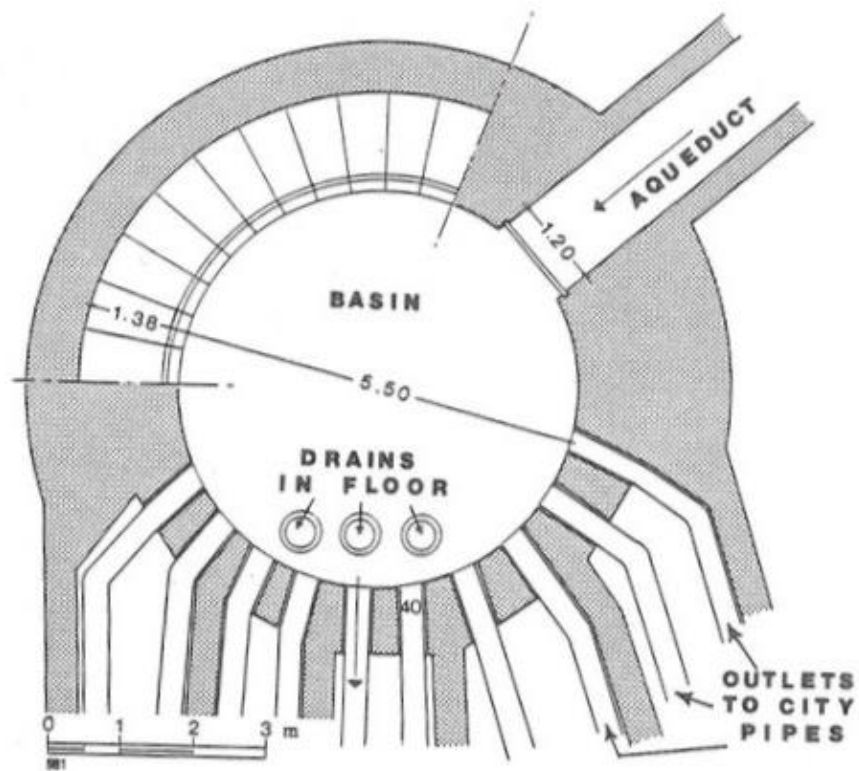


Figure 4.8 *Castellum Divisorium* Plan (Hodge, 1992)

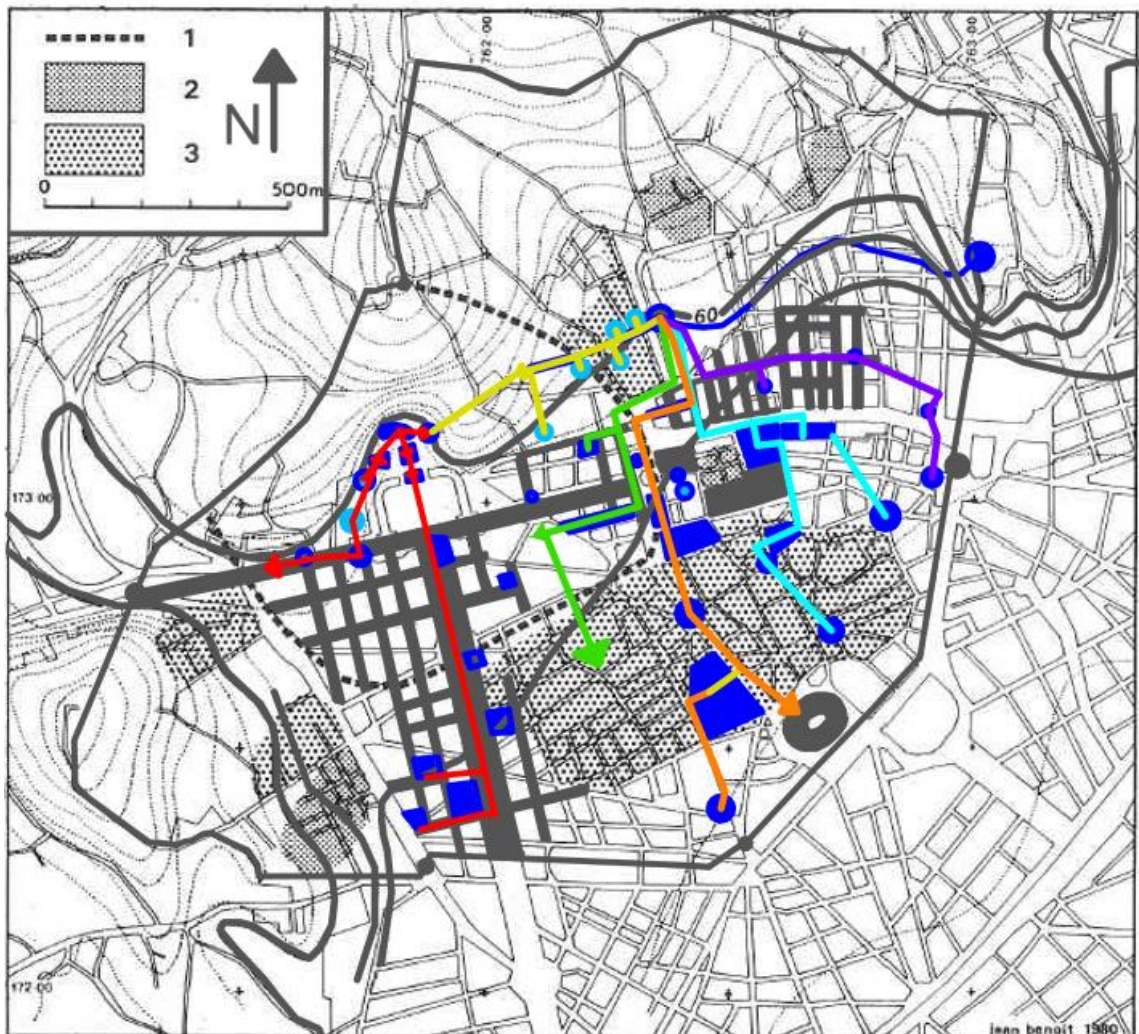


Figure 4.9 Urban Water Distribution Routes (in red, yellow, purple, green, and orange); Water Related Buildings (in blue); Elevations and Contour Lines (in gray) (Drawing by Author, Map by Fiches)

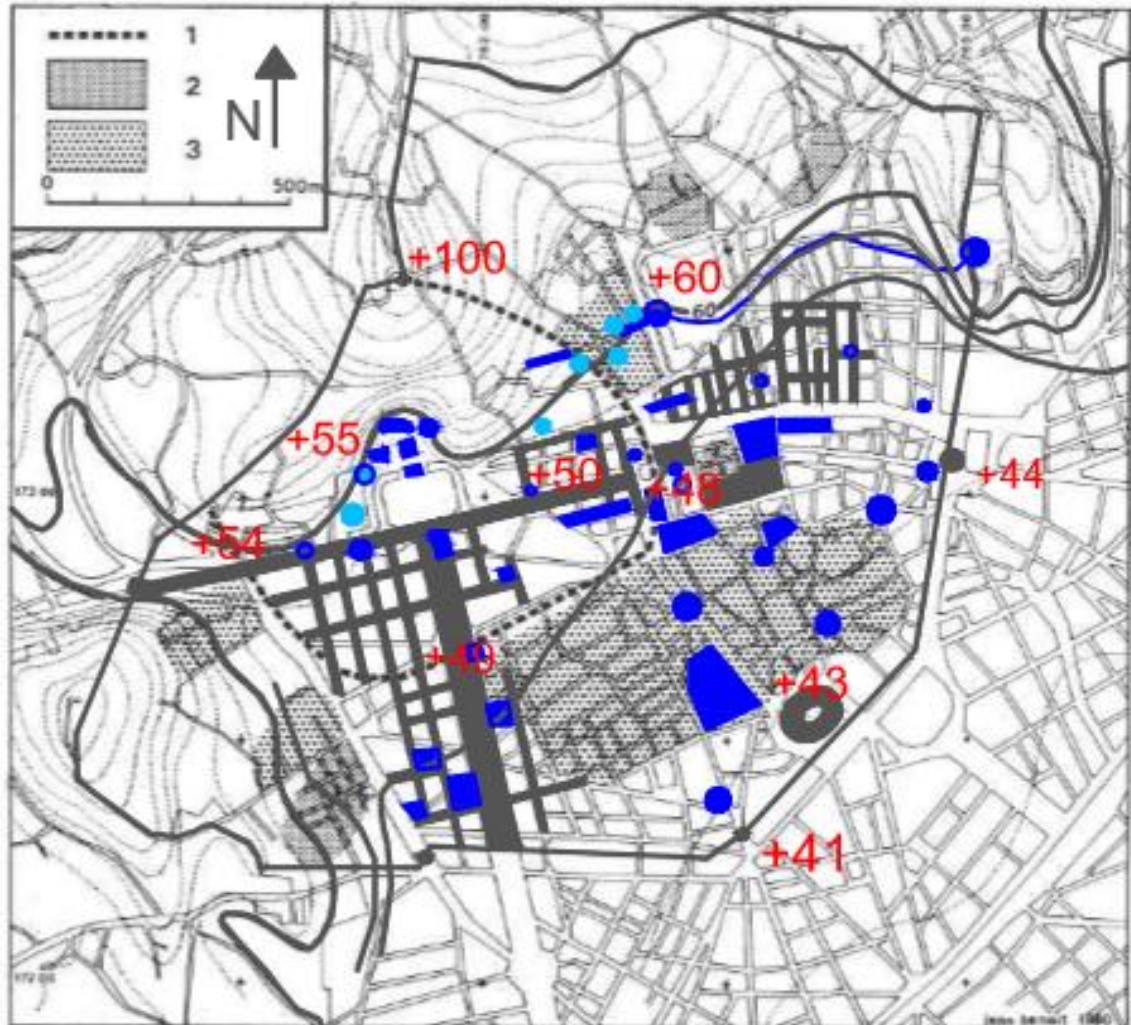


Figure 4.10 Nîmes Elevations (Drawing by Author, Map by Fiches)



Figure 4.11 Water Pipes Leaving the *Castellum Divisorium* (Drawing by Author, Original Plan by Fiches)

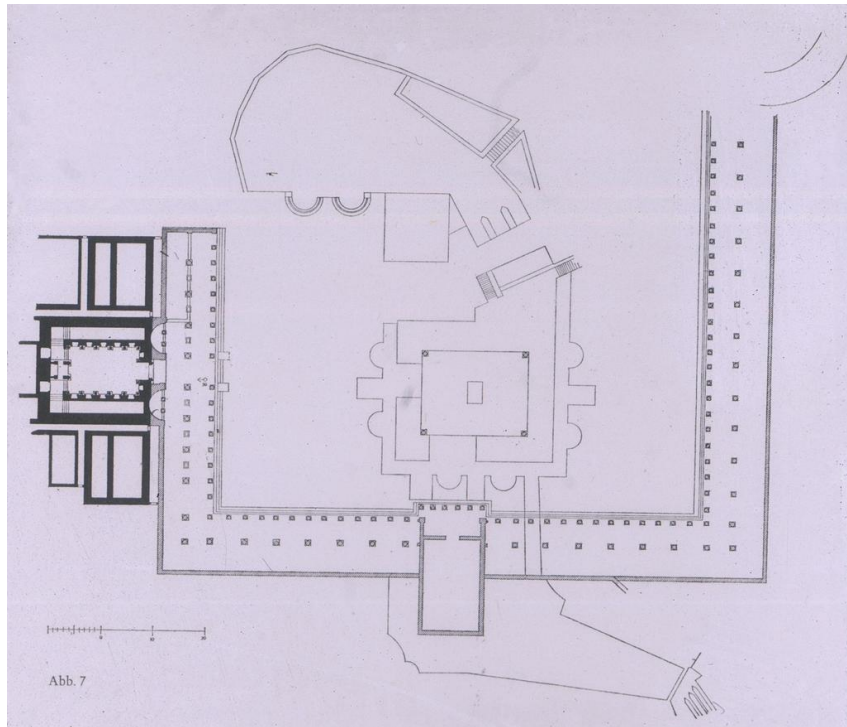


Figure 4.12 Plan of Jardin de La Fontaine (Fiches, 1996)



Figure 4.13 Maison Carrée (Artstor)



Figure 4.14 Amphitheater of Nîmes (Artstor)



Figure 4.15 Tour Magne (Artstor)



Figure 4.16 Porte d'Auguste (Artstor)

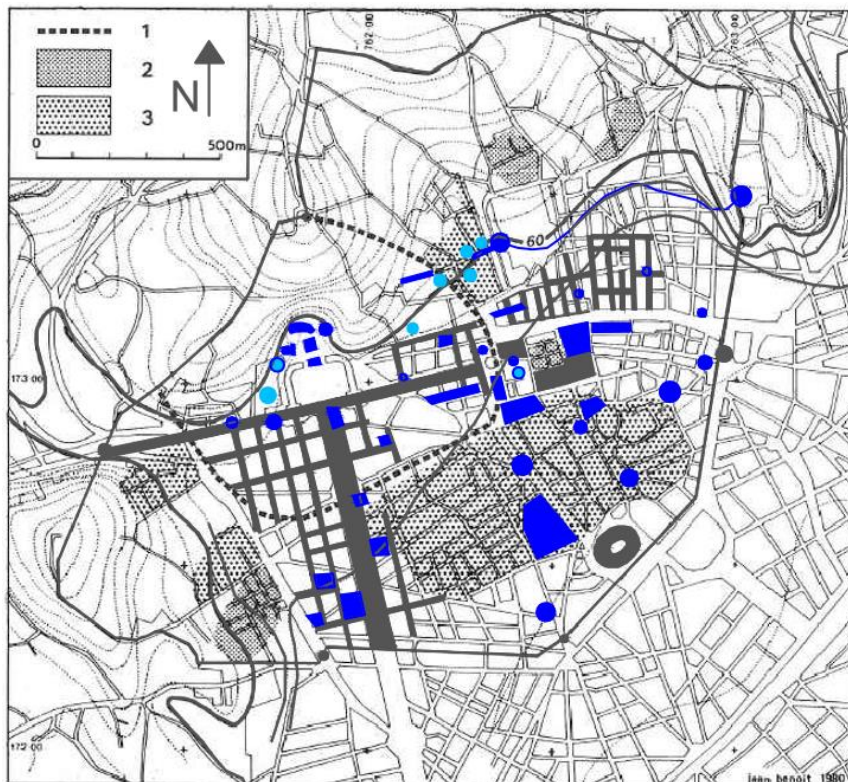


Figure 4.17
Locations of
Houses with
Water Supply (in
light blue)
(Drawing by
Author, Map by
Fiches)

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