The Driest Work Ever Written – Just Add Water

A Look at the Writings of Frontinus

and

A Look at Water Systems in Ancient Rome and Modern India

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Abstract

My main research regards the ancient water system in the city of Rome in the first century AD during the time of Frontinus. In Part I of the project, the main purpose is to discuss the valid and beneficial information provided by the author Frontinus; in Part II it is to discuss the benefits and flaws of the aqueduct system at that time along with the changes the water commissioner Frontinus added to the system. The first part of the research project involves an array of numbers and figures pulled directly from Frontinus' work. For information about Roman aqueducts and water transport, I relied primarily on Frontinus' Latin text *De Aquaeductu Urbis Romae* for information. I also got information from a variety of sources in scholarly articles, magazines, and books on aqueducts and engineering in the ancient world. For the second part of the project, to supplement the research on Roman aqueducts, I chose a modern city for comparison. This city, Pune, is one in which I lived for a span of four months and on which one of my colleagues did extensive water supply research. For supplementary information on Pune, I used my colleague's research as a base and let it point me in the right direction for other sources. In this research, I have discussed ways in which water commissioner Frontinus was important to the water systems of Rome, I have found ways in which Romes ancient aqueduct system is superior to even some modern water systems, and I have also outlined some problems which seem universal to the water supply industry.

Part I

A Look at the Writings of Frontinus

When I was around ten years old, I drained the well on the family farm. I put the garden hose on to fill the front yard fish pool and fountain and left it running overnight; overnight, the farm's entire supply of water literally made a stream out of our country road. So there it was, sweltering hot summer with the liquid needs of an entire family and farm to satisfy, and no supply to fulfill that need. For weeks, until our well's supply was replenished, we had to bring water in from neighbors or buy bottled water for all our needs. Water was no longer the ever-flowing, readily available liquid that appeared with just a flip of the tap: suddenly, it was the heavy, buckets and jugs we carried from the neighbor's house, the funny-tasting chlorinated drink that the city could provide.

It was during this time that I realized something about how things work in this world: water, this common substance that fills our lakes, fuels our rivers, and even falls out of the sky is quite possibly the most precious substance in the world. It is a necessity for crops, for livestock, for luxuries like fountains and fish pools. It is the foundation of hygiene, a building block in every recipe in the kitchen, and the key to hydration and human life. Any civilization that can harness its power is a force with which to be reckoned. A civilization that managed this nearly 2,500 years ago is beyond impressive.

In first century AD Rome, the man Frontinus documents his city's history and the steps taken in the process of harnessing the supply of water. Without the words of Frontinus, we would know little about the aqueducts of Rome and how they function; without his expertise as water commissioner, the system would not have flourished as well as it did. While much of what he wrote deserves intense scrutiny and some of it may need to be discarded entirely, the information in his books is well worth the effort. Despite debate surrounding the purpose and accuracy of his work, the author Frontinus provides a plethora of useful information and insight into ancient engineering and language.

Sextus Julius Frontinus is a man of mystery. Beyond what he says in his own writing, little information is known about him. He was a member of the Julii family who lived from approximately 35AD to 103AD. He was a military man, three-time consul, and he served as governor of Britain for approximately four years.[1] Most relevantly, in the year 97AD, Frontinus was appointed by the emperor Nerva as *curator aquarum,* Rome's official water commissioner.[2] This office put him in charge of the aqueducts of Rome, the purveyors of liquid luxury and necessity. Frontinus had no technical training in the water systems of Rome, so his knowledge on the subject came primarily from reading rather than actual field work.[3] As an extension of his duties as *curator aquarum,* Frontinus wrote the book *De Aquaeductu Urbis Romae.*

Despite the technical nature of the book, Frontinus finds places to work in flagrant promotion of both himself and Nerva, the emperor who appointed him. Even in his catalog of aqueducts, his swagger and self-promotion shows. One author comments that "among the many charges leveled against the Roman aristocracy, one thing nobody has ever accused them of is an inferiority complex," and Frontinus is no exception to this rule.[4] He has primarily negative things to say about those working underneath him in the aqueduct system; however, he and those above

1 Landels, 211.
2 Frontinus, 1 & 102
3 Landels, 213
4 Blackman/Hodge 141

him receive only the highest praise within his writings. Because of this, some authors suggest that *De Aquaeductu* was written as a political bolster,[5] or that it was adapted to be a propagandized political statement.[6] Even in the very first chapter of *De Aquaeductu,* Frontinus lays the praise on thick with the statement *nescio diligentiore an amantiore rei publicae imperatore.*[7] This phrase states that he cannot tell whether the emperor devotes more love or more work to the state; it seems to be a statement better suited for a political promotion than an office guidebook to waterworks.

Beyond these misplaced embellishments, however, the book seems to be nothing more than the personal notebook of the *curator aquarum,* recording his notes and thoughts for his predecessors. While some authors praise *De Aquaeductu* as "the peak of extant Roman accomplishments in arithmetic,"[8] others say that the most interesting part of reading it is to "speculate why this particular text survived at all."[9] Frontinus intimates that his intention for writing *De Aquaeductu* was to give the specifics of each Roman aqueduct, the locations from which water was taken, the distribution statistics inside and outside of the city, and the penalties for water theft.[10] Based on this proclamation of intention and the fact that he meticulously followed through in providing detailed information in all of the mentioned categories and a few extras, *De Aquaeductu* seems to follow the format of a simple guidebook for the office of *curator aquarum.*

While Frontinus' work does seem to be primarily a guidebook, he does discuss the political

5 Evans, 57
6 Rogers, *Copia*, 353
7 Frontinus, 1
8 Maher, 386
9 Blackman, 1
10 Frontinus 3

ramifications that accompanied the building of aqueducts. Beyond giving a point of reference for the cost of construction, Frontinus tells of historical scandal in this project. While the commissioner planned to bring water into the city in a new aqueduct, the *decemviri* opposed bringing any water to the Capitoline Hill. Frontinus tells that the "*decemviri, dum aliis ex causis libros Sibyllinos inspiciunt, invenisse dicuntur, non esse fas aquam Marciam seu potius Anionem – de hoc enim constantius traditur – in Capitolium perduci*".[11] While the *decemviri* were consulting the Sibylline Books for another reason, they seemed to find that it was not right for the Marcian waters or rather the Anio – for about this it is said more regularly – to be led into the Capitoline Hill. It is suggested that the "accidental discovery" of this information in the Sibylline books was a "deliberate fabrication" to further their own political agenda.[12] Those purposes, however, are difficult to decipher. If nothing else, this passage shows the conflict and red tape that went into the building of each aqueduct.

As an aggrandized owner's manual for the Roman water system, *De Aquaeductu* is full of facts, figures, and names that make it invaluable, if not interesting. It contains what author A. Trevor Hodge describes as "several pages of the driest statistics on aqueduct lengths and pipe discharges that the mind can conceive."[13] These passages, dry as they are, contain information on aqueducts that would otherwise be lost in history.

Frontinus' work *De Aquaeductu* is divided into two books. The first of these focuses on detailing the aqueducts and describing the types of pipes used within the city. There, Frontinus introduces and describes the nine aqueducts that existed in his time: the Appia, Anio Vetus,

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11 Frontinus, 7
12 Rodgers, Sibyl, 176
13 Hodge, *Roman Aqueducts*, 18

Marcia, Tepula, Julia, Virgo, Alsietina, Claudia, and Anio Novus.[14] The second book focuses on the water discharged by the aqueducts and laws pertaining to water transport.

Both books involve long-winded series of numbers and facts about the aqueducts; however, there is debate surrounding *De Aquaeductu* as to whether Frontinus' information is either useful or accurate. When it comes to measuring the lengths of the aqueducts of Rome, Frontinus' math is impeccable. He lists the total length of the aqueducts, the lengths underground and aboveground, and sometimes, the lengths the aqueducts' aboveground portions that are supported by either arches or substructures. For every aqueduct, Frontinus' numbers add up correctly; however, they do not always add up to the estimates from modern surveys. In the case of the aqueduct Anio Vetus, Frontinus' numbers are ten kilometers shorter than what estimates say they should be.[15]

There is also question regarding Frontinus' numbers for the amount of water transported into the city. Part of this question stems from the fact that Frontinus did not explain exactly how he measured the water intake of the aqueducts.[16] Frontinus uses the *quinaria,* the standard unit of measure for water in Rome. The unit was based on the fistula *quinaria* or 5-pipe, a waterpipe with a diameter of 5/4 digits. Instead of measuring water by volume as is done today (and as they measured wine and oil),[17] the Romans measured the city's water intake based on the area of a cross-section of this *quinaria* pipe.[18] Today, to determine such numbers, that cross-section would be multiplied by the velocity of the water coming into it to determine water by volume over time. In some cases, the fact that Frontinus' math did not account for velocity can be excused: when

14 The aqueducts are catalogued in the appendix
15 Blackman, 17
16 Hodge, *Quinaria*, 205
17 Rogers, *Copia*, 354
18 Frontinus, 25

distributing water from *castella*, the *calices* or nozzles that distributed the water were set at a uniform height in the tank.[19] That uniformity standardized the velocity, making the *quinaria* a workable unit. [20]

However, where Frontinus measures the intake of the aqueducts, such standardization would be impossible. There is almost no way that the velocity of the water entering the Aqua Anio Novus from a respectably-sized river could be the same as the velocity of lake water entering the Aqua Alsietina.[21] There is also the issue that Roman aqueduct tunnels were designed to only be filled to half or two thirds capacity; the entire cross-section would not have been filled with water so using that would alter the number of *quinariae* the pipe held.[22] In these situations with such uncontrolled variables, Frontinus' numbers seem to be "totally useless."[23] With water entering the pipes at different speeds, two congruent pipes would not conduct the same amount of water. Not only taking into account the fact that the different sources flowed at different velocities, it should also be considered that each source could change over time. The Alsietina is cataloged by Frontinus as supplying a meager 254 *quinariae* to outside the city of Rome; however, in its prime during Augustus' era, that aqueduct provided enough water to fill and flush an artificial lake.[24] This means that all the careful measuring of *quinaria* that Frontinus did has no value in today's number system: there is no way to convert a *quinaria* into a modern unit.

While his data concerning the lengths of Roman aqueducts and how much water they carried may not be relevant, Frontinus did supply a plethora of other information in his book. He

19 Frontinus, 113
20 Rogers, Copia, 355
21 Frontinus, 90 11
22 Hodge, 95
23 Rogers, *Copia*, 358
24 Taylor, 472

catalogs each of Rome's nine aqueducts that existed during his time in as much detail as he was able. For each of these aqueducts, Frontinus lists the number of *quinariae* he estimates to be delivered both *extra urbem* and *in urbem.*[25] While the amount of water may not be accurate, he does provide the information as to where water from the aqueducts goes. Frontinus supplies the invaluable knowledge of where water from the aqueducts' water was dispersed.

Roman water was brought to the city in a combination of underground tunnels and aboveground arches and substructures.[26] According to Frontinus, the first aqueduct, Aqua Appia, was commissioned in 312BC, and most of its length was underground tunnels.[27] As the first attempt at an aqueduct, it was relatively basic. In the earliest Roman aqueducts, the idea of *piscinae,* settling tanks intended to slow water flow to filter out sediment, did not yet exist.[28] It was only through progressing and building new aqueducts that the more advanced features came into being. Appia's architecture was as reminiscent of the Cloaca Maxima and Etruscan waste-removal pipes called *cuniculi* as it was of the later Roman engineering feats of aqueducts.[29]

In the Roman aqueducts, underground tunnel lines had to either tunnel through stone or be lined with cement-sealed stone in order to successfully hold water. These tunnels had to be wide enough for men to enter for repairs and had to have regular air shafts to allow entry.[30] These tunnels were favored by the Romans because they were impervious to enemy attacks and required less building material than their aboveground counterparts. They were not subject to wind or water erosion, and they could be buried underground where they would not interfere with

25 Frontinus, 3
26 Frontinus, 5
27 Frontinus 5
28 Aicher, 10
29 Hodge, 45
30 Aicher, 12

building and travel on the surface. Their slope need not have been maintained as steadily because as long as the pipes at no point rose above the initial level of water intake, the pressure would have been enough to keep the water moving steadily toward the city. The pipes could go underground for long periods of time and then use water pressure to raise the water up to the desired height to enter the city above ground on majestic arches and to distribute to the higher regions of the city. Basically, closed pipelines work like siphoning out of a swimming pool: once the water starts moving through the hose with all the pressure of the pool pushing behind it, the hose can bend in any direction or angle before the output without inhibiting the flow of water.

The water that was not carried underground in tunnels was supported above-ground by either arches or on solid walls called substructures. While they only make up a small portion of the aqueduct system, a great deal of construction and planning went into the arches that are so familiar today. They had to be made to stand up against the weathering of time. If the arches were too tall or not well enough supported, they could be bent by wind or collapse under pressure. In a series of arches, if one failed, the others would lose their structural integrity and probably not be far behind. Aware of their limitations, Romans had certain guidelines for building the arches. Their arches could not exceed 70 feet in height without the risk of buckling from strong winds or sinking ground; if an aqueduct line needed to be higher from the ground than that at any point, they would build double-tiered arches resting one set of arches directly on top of another.[31] The taller the arches, the thicker the pillar bases and the narrower the arches they used. Their pillars consisted of a brick or stone square casing filled with concrete or other building materials. On top of these arched pillars rested the line of water.

Once water reached the city, Frontinus tells us how it was distributed. Just as he describes

31 Landels, 40

the *fistula quinaria* as a 5-pipe with a diameter of 5/4 digits, Frontinus describes all twenty five sizes of pipes and their capacities. These pipes, made of terra cotta or lead, conducted Roman water once inside the city.[32] Beyond the information given by Frontinus, there is little evidence concerning the lead pipes because the pipes themselves no longer remain.[33] The pipes fall into two categories: those named for their diameter, and those named by the area of their cross-section. The first category includes the 5-pipe with its 5/4 digit diameter and all the pipes up to a vicenaria or 20-pipe. The rest of the pipes, 20-pipe through the 120-pipe, are named because the area of their cross section matches the number of the pipe.[34]

As the Roman fraction system was not set up to deal with such delicate fractions, Frontinus uses a combination of available fractions, listed as either words or symbols, to achieve the desired number. For example, the *quinaria* 5-pipe is described as having *diametri digitum unum =-* .[35] *Digitum unum* clearly says one digit, and the =- is the Roman fraction notation in their duodecimal system that describes 3/12, using one – for each twelfth. This diameter of 1 digit plus 3/12 of a digit simplifies into the *quinaria*'s namesake, 5/4 digits.[36]

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32 Evans, Agrippa, 402
33 Evans, *Agrippa*, 401.
34 Frontinus 28-29
35 Frontinus, 39
36 See tables 2 and 3 in the appendix for more information on fractions and pipe sizes respectively
37 Evans, *Agrippa*, 401

their cross-section. The first category includes the 5-pipe with its 5/4 digit diameter and all the pipes up to a vicenaria or 20-pipe. Each of these pipes has a diameter approximately 1 quarter digit larger than the previous pipe. The rest of the pipes, the 20-pipe through the 120-pipe, are named because the area of their cross section matches the number of the pipe.[38]

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These pipes took their water to three different categories of distribution locations: water distributed *nomine Caesaris, privatis,*and *usibus publicis.* The *usus publicos* is further subdivided into the categories of *castra*, *opera publica*, *munera,* and *lacus.*[41] The meanings of some of these terms are still ambiguous. For example, while the term *nomine Caesaris* is clearly water distributed in the name of the emperor, the term itself does not explain for what the emperor decreed the water be used. On a basic level, water claimed by the emperor would furnish the palaces and the government buildings. However, in the time of Augustus, water in this category was also used to fill a man-made lake that held approximately 30 triremes or biremes and other smaller craft for the purpose of creating mock sea battles called *naumachiae.*[42] This wide variance occurs in the other categories such as where the term *castra* could refer to anything from a formal military camp to

38 Frontinus 28-29
39 Frontinus, 39
40 See tables 2 and 3 in the appendix for more information on fractions and pipe sizes respectively
41 Frontinus, 78
42 Taylor, *Torrent*, 467

the Roman equivalent of a simple police station.[43]

Within the category of *privati* is a number of people who had water directed to their private homes. While today, the priority of running water is mostly directed towards kitchens and bathrooms, that was not the case in ancient Rome. While tubs and basins of water can fulfill nearly every need from drinking and cooking to bathing and flushing, fountains can only be run with a source of running water. Nymphaea, garden-triclinia, and stibadia were all forms of ornamental waterworks used to liven up the gardens of *privati.*[44] These lavish personal fountains were not the only waterworks in the city, though. The *munera* that were supplied for *usus publicos* were ornamental fountains on display at various points in the city.

Frontinus' work raises the topic of city growth and the effect that had on the water supply. The growth of the city and the wearing of time exhausted the aqueducts, so repairs were required and new aqueducts were often required. At one point, 180,000,000 sesterces (*sestertium milies octingenties*)[45] were allotted by the Senate – approximately one to three million sesterces per kilometer - [46] to both with fixing the problems of these aqueducts and bringing new water into the city. Each Roman would have required two to five liters of water per day just for personal hydration, and more for hygiene and general cleaning.[47] Frontinus explains that *incrementum urbis exigere videbatur ampliorem modum aquae,* so as the population of Rome expanded over the years, more and more people were requiring that bare minimum of water.[48] Beyond the water that was an absolute necessity for survival, Romans required water to facilitate their ever-

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43 Blackman/Hodge, 119
44 De Kleijn 79
45 Frontinus, 7
46 Chanson, 1-1
47 De Kleijn, 75
48 Frontinus, 7

increasing luxuries. The Roman baths are the obvious Roman luxuries that require water, but also the famed *naumachiae* would have required a substantial amount of water to fill artificial lakes. An entire aqueduct, the Alsietina, was built to sustain the Roman lust for these staged sea-battles. Fisheries, farms, and livestock all needed a supply of fresh water to keep the Romans' pantries and stomachs full.[49]

Rome was able to harness the waters of the rivers, lakes, and streams that surrounded it, turning them into powerful tools for the state. This city was able, through a series of arches, substructures, tunnels, and pipes, was able to provide a water supply that enabled an ever-increasing population to live in luxury. Frontinus' book on this water supply is invaluable because of the information it holds, and also because it is really the only source available concerning the details of aqueducts. The fact that *De Aquaeductu* has no counterpart to either support or contradict its information means that everything in it deserves to be thoroughly challenged. However, while some of Frontinus' words or numbers may be proven wrong, that does not discount the importance of the book as a whole. *De Aquaeductu* has a plethora of invaluable information that provides insight into not only the engineering of aqueducts but also the lifestyles of Roman people.

49 De Kleijn, 76

Part II

A Look at Water Systems in Ancient Rome and Modern India

"Tot aquarum tam multis necessariis molibus pyramidas videlicet otiosas compares aut cetera inertia sed fama celebrata opera Graecorum." Frontinus, *De Aquaeductu Urbis Romae*[50]

These opening words are the keystone in the writings about aqueducts from Frontinus, the primary source of information on ancient Roman aqueducts and water supply. They sum up the Roman sentiment that Rome's accomplishments, specifically the ones involving water, surpass even the greatest achievements of the time. With an audacity backed by the magnificence of the aqueducts, Frontinus hits on a resounding truth with this quote: the innovations of the aqueducts of Rome can be considered some of the most impressive in history.

In truth, the water systems and aqueducts of ancient Rome prove to be superior to the development of water transport in even some modern places. Specifically, the city of Pune near Mumbai in India is facing many of the problems that Rome faced around the time of Frontinus. While it is not important to this study to know the virtues of Rome in comparison to specifically Pune, the focus is to examine Rome's ancient and effective system in comparison to Pune's modern and flawed one. My choice of city is biased by my own experiences living in Pune witnessing their water issues firsthand and giving me access to information regarding it through my own research and the research of my colleague in India, Molly Ingram. The city of Pune provided a great deal of insight into the importance of a functional water system.

Without a source of water, it is impossible for a city as large as Rome to grow and flourish.

50 Frontinus, 16.

Without boundless water, it would have been impossible for Rome to develop the luxurious baths or fountains for which it grew so famous. Without a steady, constant supply of water, the thousands of citizens of Rome would not have had access to the fountains and public basins full of crisp mountain spring-water. Most importantly, without the Roman feat of engineering known as aqueducts, none of these would have been possible. The city of Pune today has only one of those four ideals. While they do have an outside source of water, they lack a limitless supply, constant flow, and the ingenuity of the Roman aqueduct.

The Roman author Frontinus is responsible for two major written works: *Stratagemata* and *De Aquaeductu Urbis Romae*, the latter of which is the main focus of this research. *De Aquaeductu Urbis Romae* is Frontinus' detailed report of the inner-workings of Rome's pride in the first century AD: its aqueducts. It serves as a rulebook for the office of water commissioner as written down by Frontinus.[51] Without the words of the man Frontinus, we would know little about the aqueducts of Rome and how they function; without his expertise as water commissioner, the system would not have flourished as well as it did. However, according to A. Trevor Hodge, an author on Roman water systems, this work "must qualify as one of the driest ever written, and is wholly devoid of any literary pretensions or elegance whatever."[52] The book is analytically written by a man trying to dependably document and repair a flawed system. He pays rapt attention to the flourishing details of the aqueducts and puts little extra effort into the flourish of language. Frontinus is the primary source for information on aqueducts, and it is through his rough, unaesthetic words and figures that there is as much information available as there is. While his abrasive writing style does not put him on par with Vergil or Caesar as a literary master, and the math he uses in parts of his

51 Evans, 57.
52 Hodge, 16.

writings are questionably reliable and outdated in today's world, the information his writing preserves makes him a pivotal figure in history.

Without Frontinus' management ability and attention to detail, first century AD Rome would have come and passed without the innovations that made its aqueducts so accessible. While he did not spend the years before taking office doing manual maintenance of aqueducts, he proved to be efficient at his job. It was the idea of this man, not a surveyor or architect, that led to a map of pipelines and aqueduct channels around the city of Rome.[53] These plans, while they may seem commonplace today, were not so in the time of Frontinus. No one before had thought to chart the courses of aqueduct lines. The knowledge of the lines facilitated easy repairs because they outlined exactly where the lines laid and where blockages or damages would be likely.

In Pune, to this day there is no detailed map of the water-piping system.[54] Pune developed a piped water system in the city in the 1750's, over 2 centuries ago.[55] However, any records that may have existed of these original pipes and other older pipes are gone. Combining this lack of mapping with infrastructural weakening over time, leaks in this city often go unfixed.[56] The main signifier of a broken pipe is that its water ceases to reach the desired destination. However, without maps of pipelines, when water does not reach a destination, maintenance cannot always know where to go to fix the problem. Even if a surveyor can determine which pipeline is damaged, he would not know where that specific pipe traveled or where it might have structural formations prone to damage.

Due to these structural failures and the inability to repair them (as well as some amount of

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53 Frontinus, 17.
54 "Water Reform Plan Goes for a Toss."
55 Rode, 49.
56 Ingram, 25.

water pilferage), Pune city loses as much as 35 to 40 percent of its water.[57] While Roman aqueducts also lost a share of their water due to leakages, fraudulent siphoning, and other reasons, Frontinus cites the Aqua Tepula specifically as losing no water at all along its course.[58] This shows that over a thousand years ago, it was possible to make a pipeline that lost none of its water, much less over a quarter of it.

While it was possible for an aqueduct to maintain all of its water, that was not always the case. When discussing the degradation of the two of Rome's great aqueducts, Frontinus hits on another issue which he cleared up while in he served Rome: not only were the aqueducts old and exhausted, they were also being fraudulently tapped into by private parties[59], a horrifying concept to the intrinsically honest Frontinus. This water theft proves to be one of Frontinus' greatest peeves in his work. At another point in *De Aqueductu Urbis Romae,* Frontinus brings up Caelius Rufus, a man who gave the speech *De Aquis* years prior.[60] In this speech, Caelius Rufus discussed the fact that Rome's brothels, places of ill-repute in Frontinus' mind, were known for tapping the water system and using illegally-begotten water. [61] Frontinus goes on to mention the word *fraudem* twelve times in his work, fixating on the affront against Rome. He calls the act *intolerabilis*[62] because people are not only defiling his aqueducts and insulting the his empire, they are violating Frontinus' ethical code of honesty.

Interestingly enough, this seemingly arbitrary theft is also common in Pune; however, in Pune, the reasons may be less arbitrary.[63] While in Rome, water was being pilfered by brothels and

57 Rode, 54.
58 Frontinus, 68.
59 Frontinus, 7.
60 Frontinus, 76.
61 Bruun, 368.
62 Frontinus, 114.
63 Ingram, 26.

other instances of greed, it seems that is probably not the case in Pune. It is likely that water is fraudulently taken there because the system is so flawed that people are not getting the water they need to live. When some people receive water for only part of the day and others do not receive water at all at points because of broken pipelines,[64] it is not at all a surprise that water is being tapped illegally from the city. Frontinus brags in the first century AD that his aqueducts are capable of supplying water *interdiu et noctu.*[65] Meanwhile in modern day Pune, no part of the city receives water for more than eight hours on any given day, and some people receive it for fewer than four hours.[66]

Another innovation initiated by Frontinus that benefited Rome is the introduction of work records regarding the aqueducts. Frontinus tells that in his time, the state assigned two groups of *familiae*, state-owned slaves, to the aqueducts.[67] These men were in charge of overseeing, inspecting, maintaining, and building the aqueducts.[68] They were needed at all times to ensure the water system worked flawlessly and effectively, even in emergencies. In some cases, they were required for the repairs to damages caused by age, storms, infrastructural defects, and *impotentia possessorum* – the failings of their proprietors.[69] Beyond this, Frontinus reports that he himself initiated the use of disciplined scheduled work in the water supply system. Because of him, the schedules and completed work of the Roman watermen were planned and documented.

While the city of Pune does have hired workers to work on pipes and water issues, they do not perform regular inspections to maintain the water system's integrity.[70] The periodic

64 Ingram, 29.
65 Frontinus, 104.
66 Ingram, 29.
67 Frontinus, 116.
68 Frontinus 117.
69 Frontinus, 120.
70 Ingram, 26.

inspections of Rome ensured that the pipelines were working properly and effectively. In some cases, the inspections could keep small issues – like cracked pipes or polluted lines – from becoming large-scale problems. When a pipeline is not monitored, a small problem can easily escalate into something large and expensive to repair, and Pune's modern system has no method of doing this. Where Rome's periodic inspections allowed them to prevent serious damage before it happened, Pune is left with the expensive repair costs and water-deprived citizens when preventable issues arise.

Ensuring that water gets to the citizens of a city is a necessity. When it comes to transporting water, there are two basic different types of pipelines: open lines and closed lines. An open conduit is an open waterproofed channel with a consistent, shallow slope built into a structure and coated with plaster or cement. Oppositely, a closed conduit is a fully contained pipe filled completely with water. A closed conduit can have any slope up or down as long as it never rises above the intake point.[71] In ancient Rome, open lines were generally supported above-ground on either arches or a solid substructure, and closed conduits were lines of underground piping or tunneling.

Each of the two types of conduit has advantages and downfalls. In Pune, in the middle of the 18th century AD, a large-scale water project introduced a water system to the city in the form of four above-ground water-carrying structures.[72] Beyond this, most of their water travels through underground closed conduit pipes running along roadways to get to its destination. In Rome, as shown by the fact that approximately 80% of the aqueduct lines were underground, it seems that Romans also viewed closed conduits as more beneficial.[73] While open lines could be inspected

71 Landels, 37.
72 Gokhale, 720.
73 Aicher, 11.

more easily and facilitated repairs, in Rome, the open conduits required expensive building materials and skilled workers. Geography made it difficult to maintain a steady, direct slope in hilly areas. The exposed water line would also be prone to attack during wartime and would make it all too easy for an enemy to cut vital water from the city. It is for these reasons that such a large majority of Rome's water system is in closed lines underground.

Closed conduits were impervious to enemy attacks and required less building material. They were not subject to wind or water erosion, and they could be buried underground where they would not interfere with building and travel on the surface. Their slope need not have been maintained as steadily because as long as the pipes at no point raised above the initial level of water intake, the pressure would have been enough to keep the water moving steadily toward the city. The pipes could go underground for long periods of time and then use water pressure to raise the water up to the desired height to enter the city above ground on majestic arches and to distribute to the higher regions of the city.

Two important features along the course of the Roman water lines are their *piscinae limariae* and their *castelli.* A *piscina limaria* is a settling tank which was intended to slow down the flow of water to filter out debris and sediment carried by water from the intake point of the aqueduct.[74] *Piscinae* also serve the purpose of aerating the water in the aqueduct.[75] While not nearly as advanced as what today's technology provides to Pune, the *piscina limaria* serves the same basic purpose as water treatment plants. In Pune, there are seven water treatment plants designed to filter out bacteria, organisms, and chemicals.[76] Both the *piscinae limariae* and water treatment plants aim to make water safe for human consumption by the contemporary standards.

74 Aicher, 10.
75 Evans, *Agrippa*, 402.
76 Ingram, 22.

Not only were the aqueducts able to get consistent water to the subjects of Rome, the water was also expected to be clean, cool, and palatable.

In Pune, after going through water treatment plants, water runs to storage reservoirs and rests until it can be used.[77] The Roman counterpart to this idea is the *castellum,* a distribution chamber to which water was brought towards the end of its journey.[78] According to Frontinus, the public is at times allowed to draw water directly from these tanks;[79] however, their main purpose is to begin distributing water into the city. It was from the *castellum* that water entered the city pipes and reached the people of the city.

The reason that the Roman aqueducts are so pivotal in our history is not only because of the technology and engineering that went into them but also because of what they transported and protected: water. As said by the Indian author Salman Rushdie, "Without water we are nothing... Even an emperor, denied water, would swiftly turn to dust. Water is the real monarch and we are all its slaves."[80] Water is the substance that made Rome's existence possible, and aqueducts the vessels that carried it. In the opening quote of this paper, Frontinus said that when compared to the Roman aqueducts, the Egyptian pyramids and the famed works of the ancient Greeks would be found wanting. At first thought, the comment strikes as arrogant and cheeky, degrading the unreplicable engineering that went into the Great Pyramids of Egypt and the architecture of the Greek world. However, when stripped down to bare facts, his comment is true if for no reason other than the fact that aqueducts serve a basic human need and will always be relevant to humanity. It has been said that even with today's technology, it would be impossible

77 Ingram, 24.
78 Evans, *Agrippa*, 402.
79 Frontinus, 106.
80 Rushdie, 10.

to replicate either the Parthenon or the Pyramids to the precision that the ancients made them. They are indeed impressive structures, but what end would it fulfill to recreate them? There are many places in the world where the insertion of one of Rome's aqueducts would serve a purpose and fulfill needs; in fact, the aqueduct Virgo is still functioning today serving modern Rome[81]. The transport of water has always and will always be relevant to the course of human history, and thanks to Frontinus, one important chapter of that history was organized and documented.

81 Evans, *Agrippa*, 408.

Annotated Bibliography

Aicher, Peter J. *Guide to the Aqueducts of Ancient Rome*. Wauconda, IL: Bolchazy-Carducci, 1995.

This book is, as its title denotes, a guide to Roman aqueducts. In it, the author discusses the construction and parts of an aqueduct, going into detail about the inner workings of the water system. The author talks about the names of the pieces required to make an aqueduct and the logistics of how aqueducts became functional and usable. He discusses the pros and cons of different types of aqueducts, including sub-terrestrial piping, tunnels, and above-ground substructures and arches. The author also makes a comparison of Roman aqueducts to a method of tunneling the Assyrians used. The modern Iranian qanat tunnels are based on this Assyrian method, and this reference is what gave me the original idea to connect Frontinus with modern Indian water systems.

Becker, Barbara J. "Spinning the Web of Ingenuity." *Electronic Educational Environment*. University of California, Irvine. Web. 02 Dec. 2011. <https://eee.uci.edu/clients/bjbecker/SpinningWeb/week2c.html>.

This online resource is a translation of Frontinus' *De Aquaeductu Urbis Romae* that also provides a selection of maps depicting the Aqueducts during Frontinus' time. The creator of the site includes maps of where each individual aqueduct starts and ends as well as a map of a number of them all within the walls of the city.

Blackman, Deane R. "The Length of the Four Great Aqueducts of Rome." Papers of the British School at Rome Vol. 47 (1979): 12-18.

In this article, the author discusses four of the Roman aqueducts which are considered to be the greatest: the Anio Vetus, Marcia, Claudia, and the Anio Novus. The author explores the lengths of these aqueducts in a variety of ways (Frontinus' numbers, numbers designated on *cippi,* and numbers attained by modern surveying estimation) showing possible flaws in Frontinus' numbers. The author claims that while some confusion in Frontinus' numbers may be due to scribal error, in some cases, Frontinus' numbers are simply wrong.

Blackman, Deane R. and A. Trevor Hodge. *Frontinus' Legacy.* Ann Arbor, MI: University of Michigan Press, 2001.

This author discusses different interpretations that could be taken of certain terms in *De Aquaeductu*. One of the examples used is the word *piscina* which is general taken to be a settling tank. As the placing of *piscinae* is not uniform throughout the aqueducts (some *piscinae* are located at the intake, some near the city, and some aqueducts do not have *piscinae*) the author discusses whether they all serve the same purpose. If their only purpose is to slow down water to let sediment settle out, why do the Romans transport sediment all the way to the city? This author proposes that *piscinae* could also function as a sort of intersection for transported water. There is discussion of other words such as *castra, munera,* and *lacus* in a similar way. As well as discussing the meaning of terms in *De*

Aquaeductu, the author dedicates a section to the cost and funding of aqueducts. There is a section regarding the water theft that Frontinus complains about in his work. This author suggests that Frontinus hyperbolized the amount of theft that occurred.

Bruun, Christer. "Water for Roman Brothels: Cicero "Cael." 34." *Phoenix* Vol. 51, No. 3 (1997): 364-73.

This author offers only a small amount of information relevant to Frontinus. However, he explores a source - Cicero's speech defending Rufus Caelius - that Frontinus cites in his works in relation to inappropriate use of water. The author of this article suggests that when Cicero mentions unlawful use of water, he is referring to the practice of brothels diverting water from aqueduct lines to supply their workplaces with water. This article sheds light on one of the fraudulent uses of water about which Frontinus so openly complained.

Chanson, Hubert. *The Hydraulics of Roman Aqueducts: Steep Chutes, Cascades and Dropshafts*. Brisbane, Q. 4072, Australia: Dept. of Civil Engineering, The University of Queensland, 1998. Print.

This author goes into technical detail about the hydraulics of aqueducts. He focuses primarily on the more scientific and mathematical side of aqueducts, explaining the precision that went into the Roman engineering feat. He explains the necessary slope required for aqueducts and how altercations of the slope can affect the water's usefulness.

The author discusses the cost that went into aqueduct building, and provides a modern-day estimate to the sesterce (1/336 lbs. of silver). The author estimates that aqueducts' cost averaged from $1,000,000 to $3,000,000 per kilometer. The article mentions that it was the army which was charged with building aqueducts.

De Kleijn, Gerda. *The Water Supply of Ancient Rome: City Area, Water, and Population.* Amsterdam, Netherlands: J.C. Gieben Publisher, 2001.

De Kleijn's book provides different information than the other books I read. While most focused on either Frontinus or the aqueducts themselves in various contexts, De Kleijn's research focused on the aqueducts' ramifications to the city. The author looks at *De Aquaeductu* with a more social perspective, discussing what the aqueducts' water was necessary for, how it would have been used within the city, and why the demand for aqueducts and fresh water was ever-growing. The author discusses information such as how much drinking water each person requires per day, what other basic human needs water was required for, and then what other Roman activities involved water for recreation, luxury, or industry. Beyond this, the author discusses the necessity of *running* water for certain parts of the Roman life. While all human needs can be satisfied with water stored in a basin or jug or drawn up from a well, the Roman fountains that resided in nearly every Roman garden. The *privati* who paid for personal water lines to their houses tended to have the water line come in at their gardens rather than their kitchens, bathrooms, or toilets because the fountains were what most required running water.

Evans, Harry B. "Agrippa's Water Plan." *American Journal of Archaeology* 86.3 (1982): 401-411.

This author focuses in on the aqueducts repaired and commissioned by Marcus Agrippa. The author pulls from both Frontinus and Vitruvius, highlighting the parts of their works that related to the era of Agrippa. There are references both to what Agrippa did to the aqueducts and to the general workings of the aqueducts at the time. The author offers information on Agrippa's plan to supplement the pre-existing water system to sustain the city's steady growth. Agrippa was responsible for repairing the Tepula and building both the Julia and the Virgo. He uses the Julia to augment the supply of the Tepula and to lower the temperature of Tepula's warm industrial-use, making it more suitable for drinking, and the Virgo was the third largest aqueduct by the time of Frontinus. The new aqueducts were intended to satisfy the new need for water that accompanied the Augustan building program of the time and to supply areas of the city that had never before been supplied with water.

Evans, Harry B. *Water Distribution in Ancient Rome: the Evidence of Frontinus*. Ann Arbor: University of Michigan, 1997. Print.

In this article, Evans discusses some of the words in Frontinus that are still open to interpretation. Specifically, the words regarding the distribution of aqueduct water are dissected here. Frontinus said that water was distributed in three main categories: *nomine Caesaris*, *privati*, and *usus publici*. The *usus publici* category was sub-categorized into *castra*,

Frontinus, Sextus. "De Aquis." *Lacus Curtius*. Bill Thayer, 23 Apr. 2012. Web. 24 Apr. 2012. <http://penelope.uchicago.edu/Thayer/E/Roman/home.html>.

This is an online version of Charles Bennett's translation of Frontinus. The online version of this text allowed me to search and find terms more easily than the print copy.

Gokhale, Balkrishna Govind. "The Religious Complex in Eighteenth-Century Poona." *Journal of the American Oriental Society*, Vol. 105, No. 4 (1985): 719-724.

This author provides information about the city of Pune in the eighteenth century when its water system came into existence. He explains that before the middle of the eighteenth century, people of Pune relied on wells to supply their water, but the rapid growth of the city became too much for that supply. At this point in history, a large-scale water project happened to create a more sustainable supply. This water project involved four aqueducts.

Hodge, A. Trevor. "How Did Frontinus Measure the Quinaria?" *American Journal of Archaeology* Vol. 88, No. 2 (1984): 205-216.

This author discusses the method Frontinus used to measure water discharge from aqueducts. As most of that information on the water discharge is literary rather than archaeological, there is skepticism regarding Frontinus' numbers. The author questions Frontinus' ability to measure based on the information available at the time despite the fact that his numbers appear to be adequately accurate. The author explains some of the technical terms from *De Aquaeductu Urbis Romae* and looks at Frontinus' book from the perspective of the study of Hydraulics.

Hodge, Trevor A. *Roman Aqueducts & Water Supply.* 2nd ed. London: Duckworth, 2002.

This author provided me with the idea for my title with a quote describing Frontinus' book as "one of the driest ever written." It gives a biography and analysis of Frontinus, discussing his writing style and his personality as it shows in his writing. It discusses his pension for facts and figures and the factual, detailed way he wrote his books. The author discusses the office of *curator aquarum* and its prestige and necessity in the Roman world, and also Frontinus' view of the office. Hodge discusses Frontinus' extreme use of facts and figures, surmising that numbers were what Frontinus was comfortable with. There is also discussion as to whether *De Aquaeductu* was intended to be a manual for future curators or if its real purpose was to politically promote the image of the Roman emperor who appointed Frontinus. Beyond that, Hodge discusses the evolution of water systems throughout the world. He discusses the influence of mining, agriculture, and waste disposal on water transport, and brings in examples from Greece, Etruria, Iran, and other parts of the Middle East. The author discusses *qanats, cuniculi,* and other precursors to the aqueduct. There is a chapter dedicated to the tools used in aqueduct building and surveying: the *groma, chorobates,* and *dioptra.*

Ingram, Molly. "An Overview of the Water Supply System in Pune: Complications, Problems, and Obstacles." Pune: ACM, 2010.

This is a paper written by a colleague of mine from the ACM: India program in 2010. It contains extensive research into the water system of Pune, India, using resources from the Municipal Court and other locations. The author provides information about the mapping of Pune's pipes, water maintenance, employees to the water system, and the main sources of water to the city.

Lanciani, Rodolfo. *The ruins and excavations of ancient Rome.* Boston and New York, 1897. Courtesy of Parks Library, Iowa State University. <http://www3.iath.virginia.edu/waters/lanciani/aqueducts.html>.

Lanciani provided detailed maps of the aqueducts within the city of Rome.

Landels, John G. "Chapter 2: Water supplies and engineering." *Engineering in the Ancient World.* Berkeley: University of California, 1978. Print.

Chapter two of Landels' book focuses on the engineering of aqueducts. He calls on information from both Frontinus and Vitruvius concerning the ancient methods of water transport. The chapter begins by discussing different types and qualities of water sources and how the Romans chose from where to obtain their water. The author then discusses the differences between open and closed conduits and the benefits and downfalls of each type. He analyzes the different types of pipes that could be used and the issues that each

type presented, and he also breaks the aqueducts down to describe each of the parts that make them. Landels explains the engineering of arches and some of the the restrictions in their building. He also discusses manipulation and dishonesty within the water officials as well as charges of people stealing water for private use.

Landels, John G. "Chapter 9: The principal Greek and Roman writers on technological subjects." *Engineering in the Ancient World.* Berkeley: University of California, 1978. Print.

Chapter 9 of Landels' book discusses the authors, including Frontinus, who discussed water supplies in the Ancient world. It gives a brief biography of Frontinus that gives a great deal of background on the man and comments on some of the notable quirks in his writing.

Maher, David W. and John F. Makowski. "Literary Evidence for Roman Arithmetic with Fractions." *Classical Philology* Vol. 96, No. 4 (2001): 376-399.

Maher and Makowski discuss the Roman numeral system and the use of fractions. They discuss Frontinus' use of fractional numbers and discusses the perplexity caused by the complexity of the system. The article's purpose is to discuss how the number system was used in ancient Rome and how Romans overcame certain flaws (such as the lack of the number 0 and the troubles in denoting fractions) in the system. The authors discuss Fr. 26 where Frontinus explains the inconsistency between a 1 digit square pipe and a 1 digit circular pipe: the square pipe is larger than the circular one by 3/14 of its own size, and the circular pipe is smaller than the square one by 3/11 of its size, assuming that π is equal to 22/7.

Rode, Sanjay. "Sustainable Drinking Water Supply in Pune Metropolitan Region: Alternative Policies." *Theoretical and Empirical Research in Urban Management*. Special Number 1S. April 2009.

Rode provides statistics regarding the loss of water in Pune's water systems. He explains some of the reasons water is lost – leaks, pilferage, waste, and lack of available workers. He discusses when a piped water system became available in Pune.

Rodgers, R. H. "Copia Aquarum: Frontinus' Measurements and the Perspective of Capacity." *Transactions of the American Philological Association* Vol. 116 (1986): 353-360.

In this article, Rogers discusses the Roman unit of water measurement, the *quinaria.* The *quinaria* is a measure capacity, measuring the area of the cross-section of a pipe to determine the capacity of that pipe. Today, water is measured in volume and time, and the author discusses the feasibility of converting Frontinus' capacity measures into modern liters per second. However, the issue of velocity makes that impossible in most circumstances. Within the settling tanks, the water system requires discharge pipes to be uniform sizes and to be placed all at an even level. In these circumstances, with the velocity standardized and controlled, the *quinaria* passed as an acceptable unit of measure.

However, at the points of intake for the aqueducts, where the rivers, streams, and lakes had unmeasurable velocities, a measure of capacity would have been useless.

Rodgers, R. H. "What the Sibyl Said: Frontinus AQ. 7. 5." *The Classical Quarterly* Vol. 32, No. 1 (1982): 174-177.

Here, Rogers discusses the decimvirs' attempt to cease the commissioning of an aqueduct to the Capitoline hill. It goes into depth about the decimvirs' use of the Sibylline books to try to stop the aqueduct from coming into that area of the city. The article focuses in on the grammatical structure of Frontinus and different ways it could be interpreted: whether it was the Anio or the Marcia that could not bring water into the city. It also discusses water- theft in the second century BC, something that Frontinus complained about in his t ime.

Rushdie, Salman. *The Enchantress of Florence*. New York: Random House, 2008: 10.

Salman Rushdie provided my paper with a quote regarding water: "Without water we are nothing... Even an emperor, denied water, would swiftly turn to dust. Water is the real monarch and we are all its slaves."

Taylor, Rabun. "Rome's Lost Aqueduct." *Archaeology* Mar.-Apr. 2012: 34-40.

This author focuses on the Aqua Traiana, one of the largest aqueducts in ancient Rome and the aqueduct which fed the baths of Trajan and the naumachia of Trajan. Traiana was built

in 109AD, shortly after the time of Frontinus, so it was not mentioned in *De Aquaeductu*. However, Taylor has information about how Roman aqueducts worked, and it explains how the Romans got water into their aqueducts and what happened along the course of the line.

Taylor, Rabun. "Torrent or Trickle? The Aqua Alsietina, the Naumachia Augusti, and the Transtiberim." *American Journal of Archaeology* Vol. 101, No. 3 (1997): 465-492.

In this his article, Taylor provides information focusing on one specific aqueduct from Frontinus' time, the Alsietina. The article relies on both Frontinus and his contemporaries as sources. From reading Frontinus, I obtained very little information about the Alsietina other than that it was used for *naumachiae.* Since Frontinus did not detail those very thoroughly, it seemed that they occurred before his time and that the Alsietina no longer was used for its original purpose. This author analyzes the information Frontinus wrote about this work and contains information from other sources about the Alsietina.

It cites Suetonius, Tacitus, and even Augustus in regards to the Augustan aqueduct and its naumachiae. Taylor discusses the fact that the Alsietina, despite being made to fill the naumachia arena, was barely an unstable trickle by the time of Frontinus. According to Taylor, it would have taken nearly a month in Frontinus' time to fill the pool with the aqueduct's flow. He suggests that by Frontinus' time, the Alsietina was no longer used for the purpose it was made for as the water flow had been severely lessened over the years. Taylor discusses Frontinus' trustworthiness as an author, placing him above Pliny the

Elder and Vitruvius as an authority on aqueducts. It also discusses the gladiatorial games and naumachiae, giving some description as to what went into them.

Van Deman, Esther Boise. *The Building of the Roman Aqueducts,*. [Washington]: Carnegie Institution of Washington, 1934. Print.

While Van Deman's book contains a chapter dedicated to each of the Roman aqueducts, it also has a section dedicated to water systems before the aqueducts. It discusses oriental storage basins and canals; the wells, springs, and cisterns of the ancient Greeks, and the precursors to Roman aqueducts. Likewise, before Romans developed aqueducts, they used wells, springs, and the Tiber river to supply their water. In the 6th century BC, the island of Samos had a 1,000ft long underground channel to transport water, and other locations (Ephesus, Smyrna, Lesbos) had similar lines. The Etruscans had a system of drains and sewers to transport water and waste out of the cities. The Romans used these as a basis for their aqueducts.

"Water Reform Plan Goes for a Toss." *Times of India.* 8 Sept. 2010 Web. 23 Nov. 2010. <http://articles.timesofindia.indiatimes.com/2010-09-08/pune/28249229_1_water-supply-total-water-consumption-24x7 >.

This article in the *Times of India* explains a proposal to improve Pune's water system. The plan hoped to provide water to the citizens of Pune 24/7. The proposal was rejected due to the state of Pune's current system. The city of Pune uses too much water and cannot account for a large portion of the water it receives. Its pipes are rusted and damaged, and the city's meter system faulty. The city lacks records of water distribution and also lacks maps of the old pipe network.

Appendix

Important Terms and Phrases

aquarius, -ii – watermen, overseers of water supply

calix, calicis – bronze nozzle (approximately 9 inches long and varied in diameter) located in the wall of a castellum to distribute water

castellum, -i – an aqueduct's distribution chamber

closed line – pipe or tunnel that can travel at any slope up or down so long as it does not rise above the intake point of the aqueduct; also *specus*

cuniculi– Etruscan 'rabbit hole' or underground tunnel intended to remove unwanted water from an area[82]

curator aquarum – water commissioner, the office held by Sextus Julius Frontinus ca. 97AD

De Aquaeductu Urbis Romae – Frontinus' book on aqueducts, On the Aqueducts of the City of Rome

digitus - 1/16 of a Roman foot

extra urbem – water delivered by an aqueduct to an area outside the city

familia, -ae – state-owned slaves in charge of aqueducts and water supply

fistula, -ae - pipe

fraus, fraudis – fraud, appears 12 times in Frontinus' work to describe illegal siphoning of water

Frontinus – Member of the Julii family who lived from 35AD to 103AD and wrote *De Aquaeductu Urbis Romae*

impotentia possessorum – failings of proprietors

82 Hodge

in urbem – water delivered by an aqueduct into the city

interdiu et noctu – by both day and night; Frontinus claims the water supply runs constantly

modulus, moduli – adjutages or pipes intended to disperse water; there are 25 in total

naumachia, -ae - staged sea-battle

open line – open waterproofed channel with a consistent, shallow slope built into a structure and coated with plaster or cement

passus, passus – a Roman measurement indicating one pace

piscina, -ae – an aqueduct's settling tank

quinaria, -ae - a size of *moduli* with a diameter of 5/4 of a digit; a measure of area that uses the cross-section of a *quinaria;* the standard unit of measure for water

Q.D.E.R.F.P.D.E.R.I.C.: quid de ea re fiere placeret, de ea re ita censuerunt – resolved

sesterce - 1/336 lb silver – Frontinus tells that the Senate budgeted 180,000,000 sesterces (535,714.2857 lbs silver) for the construction of Aqua Marcia and the repair of Anio Vetus and Appia.

Sibylline books – books of prophecy that the decemviri claimed prohibited the use of water from the Anio to the Capitoline Hill

uncia - fraction denoting 1/12; expressed in shorthand notation as -

Water Distribution Terms[83] -

Nomine Caesaris: water whose use was decreed by the emperor

imperial palaces

83 Fr. 78

imperially controlled buildings

privatis: water that was used by private citizens *beneficeo principis*

usus publicos: water that was designated for public use

castra - military camps

opera publica - all buildings used for public purposes

munera - ornamental fountains

lacus - public basins

Numbers and Fractions

Table 1: Roman Numerals

1	unus -a -um	I		**10**	decem	X		**100**	*centum*	C
2	duo -ae -o	II		**20**	viginti	XX		**200**	*ducenti -ae -a*	CC
3	tres, tria	III		**30**	trigenta	XXX		**300**	*tricenti -ae -a*	CCC
4	quattuor	IIII		**40**	quadraginta	XL or XXXX		**400**	*quadringenti -ae -a*	CCCC
5	quinque	V		**50**	quinquaginta	L		**500**	*quingenti -ae -a*	D
6	sex	VI		**60**	sexaginta	LX		**600**	*sexcenti -ae -a*	DC
7	septem	VII		**70**	septuaginta	LXX		**700**	*septingenti -ae -a*	DCC
8	octo	VIII		**80**	octoginta	LXXX or XXC		**800**	*octingenti -ae -a*	DCCC
9	novem	VIIII		**90**	nonaginta	LXXXX or XC		**900**	*nongenti -ae -a*	DCCCC
								1,000	*mille*	M

Table 2: Fractions on a Duodecimal Scale

scripulus	1/12 x .5/12	∋	1/288
sextula	1/12 x 2/12		1/72
semuncia	.5/12	£	.5/12
uncia	1/12	- or ·	1/12
sescuncia	1.5/12		1/8
sextans	2/12	=	1/6
quadrans	3/12	=- or :·	1/4
triens	4/12	== or ::	1/3
quincunx	5/12	==- or ::·	5/12
semissis	6/12	S	1/2
septunx	7/12	S-	7/12
bes	8/12	S=	2/3
dodrans	9/12	S=-	3/4
dextans	10/12	S==	5/6
deunx	11/12	S==-	11/12
unus	12/12	I	1

Other Fractions:

pi digitus	22/7 1/16	π	(3.1428571)

Frontinus' Nine Aqueducts

Aqua Appia

date:	312 BC (441 AUC)
commissioned by:	Appius Claudius Crassus and C. Plautius enox
paid for by:	public funds
intake:	on the Lucullan Estate
length (total):	11,190 *passus*
length underground:	11,130 *passus*
length aboveground:	60 *passus*

Fr. 4: *Ab urbe condita per annos quadringentos quadraginta unum contenti fuerunt Romani usu aquarum, quas aut ex Tiberi aut ex puteis aut ex fontibus hauriebant...*
Fr. 5: *M. Valerio Maximo P. Decio Mure consulibus, anno post initium Samnitici belli tricesimo aqua Appia in urbem inducta est ab Appio Claudio Crasso censore.... Collegam habuit C. Plautium, cui ob inquisitas eius aquae venas Venocis cognomen datum est.... Concipitur Appia in agro Lucullano Via Praenestina inter miliarium septimum et octavum deverticulo sinistrorsus passuum septingentorum octoginta. Ductus eius habet longitudinem a capite usque ad Salinas, qui locus est ad Portam Trigeminam, passuum undecim milium centum nonaginta; ex eo rivus est subterraneus passuum undecim milium centum triginta, supra terram substructio et opus arcuatum proximum Portam Capenam passuum sexaginta....*

Water Transport (Fr. 79):

castella:	20
piscinae:	0
extra urbem:	5 quinariae
in urbem:	699 quinariae
nomine Caesaris:	151 quinariae
privatis:	194 quinariae
usus publicos:	354 quinariae
1 *castra:*	4 quinariae
14 *opera publica:*	123 quinariae
1 *munera:*	2 quinariae
92 *lacus:*	226 quinariae

Anio Vetus

date:	272 BC (481 AUC)
commissioned by:	M Curius Denatus and Fulvius Flaccus
paid for by:	with the proceeds from Pyrrhus
intake:	above the Tiber at the 20th milestone
length (total):	43,000 *passus*
length underground:	42,779 *passus*
length aboveground:	221 *passus*

Fr. 6: *Post annos quadraginta quam Appia perducta est, anno ab urbe condita quandringentesimo octogesimo uno M'. Curius Dentatus, qui censuram cum Lucio Papirio Cursore gessit, Anionis qui nunc Vetus dicitur aquam perducendam in urbem ex manubiis de Pyrro captis locavit, Spurio Carvilio Lucio Papirio consulibus iterum... Tum ex senatus consulto duumviri aquae perducendae creati sunt Curius, qui eam locaverat et Fulvius Flaccus. Curius intra quintum diem quam erat duumvirum creatus decessit; gloria perductae pertinuit ad Fulvium. Concipitur Anio Vetus supra Tibur vicesimo miliario extra Portam RRa_nam, ubi partem dat in Tiburtium usum. Ductus eius habet longitudinem, ita exigente libramento, passuum quadraginta trium milium: ex eo rivus est subterraneus passuum quadraginta duum milium septingentorum septuaginta novem, substructio supra terram passuum ducentorum viginti unius.*

Water Transport (Fr. 80):

castella:	35
piscinae:	1
extra urbem:	
nomine Caesaris:	169 quinariae
privatis:	404 quinariae
in urbem:	1,508 ½ quinariae
nomine Caesaris:	66 ½ quinariae
privatis:	490 quinariae
usus publicos:	503 quinariae
1 *castra:*	50 quinariae
19 *opera publica:*	196 quinariae
9 *munera:*	88 quinariae
94 *lacus:*	218 quinariae

Aqua Marcia

date:	145 BC (608 AUC)
commissioned by:	Marcius
paid for by:	Senate, 180,000,000 sesterces
intake:	36th milestone on Valerian Way
length (total):	61,710 ½ *passus*
length underground:	54,247 *passus*
length aboveground:	7,463 *passus*

Fr. 7: *Post annos centum viginti septem, id est anno ab urbe condita sexcentesimo octavo, Ser. Sulpicio Galba Lucio Aurelio Cotta consulibus cum Appiae Anionisque ductus vetustate quassati privatorum etiam fraudibus interciperentur, datum est a senatu negotium Marcio, qui tum praetor inter cives his dicebat, eorum ductuum reficiendorum ac vindicandorum. Et quoniam incrementum urbis exigere videbatur ampliorem modum aquae, eidem mandatum a senatu est, ut curaret, quatenus alias aquas posset in urbem perducere. Priores ductus restituit et tertiam illis salubriorem duxit, cui ab auctore Marciae nomen est. Legimus apud Fenestellam, in haec opera Marcio decretum sestertium milies octingenties, et quoniam ad consummandum negotium non sufficiebat spatium praeturae, in annum alterum est prorogatum... Concipitur Marcia Via Valeria ad miliarium tricesimum sextum deverticulo euntibus ab urbe Roma dextrorsus milium passuum trium.... Ductus eius habet longitudinem a capite ad urbem passuum sexaginta milium et mille septingentorum decem et semis; rivo subterraneo passuum quinquaginta quattuor milium ducentorum quadraginta septem semis, opere supra terram passuum septem milium quadringentorum sexaginta trium: ex eo longius ab urbe pluribus locis per vallis opere arcuato passuum quadringentorum sexaginta trium, propius urbem a septimo miliario substructione passuum quingentorum viginti octo, reliquo opere arcuato passuum sex milium quadringentorum septuaginta duum.*

Water Transported (*quinariae*) (Fr. 81):

castella:	51
extra urbem:	
nomine Caesaris:	261 ½ quinariae
in urbem:	1,472 quinariae
nomine Caesaris:	116 quinariae
privatis:	543 quinariae
usus publicos:	439 quinariae
4 *castra:*	42 ½ quinariae
15 *opera publica:*	41 quinariae
12 *munera:*	104 quinariae
113 *lacus:*	256 quinariae

Aqua Tepula

date:	125 BC (627 AUC)
commissioned by:	the Censors, Gnaeus Servilius Caepio and Lucius Cassius Longinus
intake:	Lucullan Estate, 10th milestone on the Latin Way

Fr. 8: *Cn. Servilius Caepio et L. Cassius Longinus, qui Ravilla appellatus est, censores anno post urbem conditam sexcentesimo vicesimo septimo, M. Plautio Hypsaeo M. Fulvio Flacco cos., aquam quae vocatur Tepula ex agro Lucullano, quem quidam Tusculanum credunt, Romam et in Capitolium adducendam curaverunt. Tepula concipitur Via Latina ad decimum miliarium deverticulo euntibus ab Roma dextrorsus milium passuum duum inde suo rivo in urbem perducebatur.*

Water Transport (Fr. 82):

castella:	14
extra urbem:	
nomine Caesaris:	58 quinariae
privatis:	56 quinariae
in urbem:	331 quinariae
nomine Caesaris:	34 quinariae
privatis:	237 quinariae
usus publicos:	50 quinariae
1 *castra:*	12 quinariae
3 *opera publica:*	7 quinariae
13 *lacus:*	32 quinariae

Aqua Julia

date:	34 BC (719 AUC)
commissioned by:	Marcus Agrippa
intake:	12th milestone on the Latin Way
length (total):	15,426 ½ *passus*
length aboveground:	7,000 *passus*

Fr. 9: *Post Agrippa aedilis post primum consulatum imperatore Caesare Augusto II L. Volcatio cos., anno post urbem conditam septingentesimo nono decimo ad miliarium ab urbe duodecimum Via Latina deverticulo euntibus ab Roma dextrorsus milium passuum duum alterius aquae proprias vires collegit et Tepulae rivum intercepit. Adquisitae aquae ab inventore nomen Iuliae datum est, ita tamen divisa erogatione, ut maneret Tepulae appellatio. Ductus Iuliae efficit longitudinem passuum quindecim milium quadringentorum viginti sex S.: opere supra terram passuum septem milium: ex eo in proximis urbem locis a septimo miliario substructione passuum quingentorum viginti octo, reliquo opere arcuato passuum sex milium quadringentorum septuaginta duum....*

Water Transport (Fr. 83):

castella:	17
extra urbem:	
nomine Caesaris:	85 quinariae
privatis:	121 quinariae
in urbem:	548 quinariae
nomine Caesaris:	18 quinariae
privatis:	196 quinariae
usus publicos:	383 quinariae
castra:	69 quinariae
opera publica:	181 quinariae
3 *munera*:	67 quinariae
28 *lacus*:	65 quinariae

Aqua Virgo

date:	22 BC (731 AUC, 12)
commissioned by:	Marcus Agrippa
intake:	Lucullan Estate, 8th milestone on the Collatian Way
length (total):	14,105 *passus*
length underground:	12,865 *passus*
length aboveground:	1,240 *passus*

Fr. 10: *Idem cum iam tertio consul fuisset, C. Sentio Q. Lucretio consulibus, post annum tertium decimum quam Iuliam deduxerat, Virginem quoque in agro Lucullano collectam Romam perduxit. Dies quo primum in urbe responderit, quintus idus Iunias invenitur. Virgo appellata est, quod quaerentibus aquam militibus puella virguncula venas quasdam monstravit, quas secuti qui foderant, ingentem aquae modum invenerunt. Aedicula fonti apposita hanc originem pictura ostendit. Concipitur Virgo Via Collatina ad miliarium octavum palustribus locis, signino circumiecto continendarum scaturiginum causa. Adiuvatur et compluribus aliis adquisitionibus. Venit per longitudinem passuum decem quattuor milium centum quinque: ex eo rivo subterraneo passuum decem duum milium octingentorum sexaginta quinque, supra terram per passus mille ducentos quadraginta: ex eo substructione rivorum locis compluribus passuum quingentorum quadraginta, opere arcuato passuum septingentorum. Adquisitionum ductus rivi subterranei efficiunt passus mille quadringentos quinque.*

Water Transport (Fr. 84):

castella:	18
extra urbem:	200 quinariae
in urbem:	2,304 quinariae
nomine Caesaris:	509 quinariae
privatis:	338 quinariae
usus publicos:	1,167 quinariae
16 *opera publica*:	1,380 quinariae
2 *munera*:	26 quinariae
25 *lacus*:	51 quinariae

Alsietina

date:	2 BC
commissioned by:	Augustus
intake:	Alsietinian Lake, 14th milestone on Claudian Way
length (total):	22,172 *passus*
length aboveground:	358 *passus*

Fr. 11: *Quae ratio moverit Augustum, providentissimum principem, perducendi Alsietinam aquam, quae vocatur Augusta, non satis perspicio, nullius gratiae, immo etiam parum salubrem ideoque nusquam in usus populi fluentem; nisi forte cum opus Naumachiae adgrederetur, ne quid salubrioribus aquis detraheret, hanc proprio opere perduxit et quod Naumachiae coeperat superesse, hortis adiacentibus et privatorum usibus ad inrigandum concessit. Solet tamen ex ea in Transtiberina regione, quotiens pontes reficiuntur et a citeriore ripa aquae cessant, ex necessitate in subsidium publicorum salientium dari.Concipitur ex lacu Alsietino Via Claudia miliario quarto decimo deverticulo dextrorsus passuum sex milium quingentorum.Ductus eius efficit longitudinem passuum viginti duum milium centum septuaginta duorum, opere arcuato passuum trecentorum quinquaginta octo.*

Water Transported (*quinariae*) (Fr. 85):

castella:	0
piscinae:	0
extra urbem:	392 quinariae
nomine Caesaris:	254 quinariae
privatis:	138 quinariae

Augusta

commissioned by:	Augustus
length:	800 *passus* (before it meets the Marcia)

Fr. 12: *Idem Augustus in supplementum Marciae, quotiens siccitates egerent auxilio, aliam aquam eiusdem bonitatis opere subterraneo perduxit usque ad Marciae rivum, quae ab inventore appellatur Augusta. Nascitur ultra fontem Marciae. Cuius ductus donec Marciae accedat, efficit passus octingentos.*

Claudia and Anio Novus

date:	39 AD (791 AUC)
commissioned by:	Gaius Caesar

Fr. 13: *Post hos C. Caesar, qui Tiberio successit, cum parum et publicis usibus et privatis voluptatibus septem ductus aquarum sufficere viderentur, altero imperii sui anno... anno urbis conditae septingentesimo nonagesimo uno duos ductus incohavit.*

Claudia

intake:	38th milestone on the Sublacensian Way
length (totals):	46,406 *passus*
length underground:	36,230 *passus*
length aboveground:	10,176 *passus*

Fr. 14: *Claudia concipitur Via Sublacensi ad miliarium tricesimum octavum deverticulo sinistrorsus intra passus trecentos ex fontibus duobus amplissimis et speciosis, Caeruleo qui a similitudine appellatus est, et Curtio. Accipit et eum fontem qui vocatur Albudinus, tantae bonitatis, ut Marciae quoque adiutorio quotiens opus est ita sufficiat, ut adiectione sui nihil ex qualitate eius mutet. Augustae fons, quia Marciam sibi sufficere apparebat, in Claudiam derivatus est, manente nihilo minus praesidiario in Marciam, ut ita demum Claudiam aquam adiuvaret Augusta, si eam ductus Marciae non caperet. Claudiae ductus habet longitudinem passuum quadraginta sex milium quadringentorum sex: ex eo rivo subterraneo passuum triginta sex milium ducentorum triginta, opere supra terram passuum decem milium centum septuaginta sex: ex eo opere arcuato in superiori parte pluribus locis passuum trium milium septuaginta sex, et prope urbem a septimo miliario substructione rivorum per passus sexcentos novem, opere arcuato passuum sex milium quadringentorum nonaginta et unius.*

Anio Novus

intake:	42nd milestone on the Sublacensian Way
length (totals):	58,700 *passus*
length underground:	49,300
length aboveground:	9,400 *passus*

Fr. 15: *Anio Novus Via Sublacensi ad miliarium quadragesimum secundum in Simbruino excipitur ex flumine, quod cum terras cultas circa se habeat soli pinguis et inde ripas solutiores, etiam sine pluviarum iniuria limosum et turbulentum fluit. Ideoque a faucibus ductus interposita est piscina limaria, ubi inter amnem et specum consisteret et liquaretur aqua. Sic quoque quotiens imbres superveniunt, turbida pervenit in urbem. Iungitur ei rivus Herculaneus oriens eadem via ad miliarium*

tricesimum octavum e regione fontium Claudiae trans flumen viamque. Natura est purissimus, sed mixtus gratiam splendoris sui amittit. Ductus Anionis Novi efficit passuum quinquaginta octo milia septingentos: ex eo rivo subterraneo passuum quadraginta novem milia trecentos, opere supra terram passuum novem milia quadringentos: ex eo substructionibus aut opere arcuato superiore parte pluribus locis passuum duo milia trecentos, et propius urbem a septimo miliario substructione rivorum passus sexcentos novem, opere arcuato passuum sex milia quadringentos nonaginta unum. Hi sunt arcus altissimi, sublevati in quibusdam locis pedes centum novem.

Water Transport (Fr. 86):

castella:	Claudia: 92
piscinae:	Anio Novus: 1
extra urbem:	
nomine Caesaris:	Claudia: 217 quinariae, Anio Novus: 728quinariae
privatis:	Claudia: 439 quinariae
in urbem:	3,498 quinariae
nomine Caesaris:	820 quinariae
privatis:	1,067 quinariae
usus publicos:	1,014 quinariae
9 *castra:*	149 quinariae
18 *opera publica:*	374 quinariae
12 *munera:*	107 quinariae
226 *lacus:*	482 quinariae

Total Water Transported by Frontinus' Aqueducts: 14, 018 quinariae

decem quattuor milia decem et octo

Roman Pipe Sizing

Roman Moduli (25 total)	English Name	Measure	Frontinus' Description
Quinaria	5 pipe	5/4 digits diameter	Fistula quinaria: diametri digitum unum =-, perimetri digitos tres S ==-Ͽ III, capit quinariam unam. [84]
Senaria	6 pipe	6/4 digits diameter	Fistula senaria: diametri digitum unum semis, perimetri digitos IIII S = £ ϿII, capit quinariam I = = – Ͽ VII. [85]
Septenaria	7 pipe	7/4 digits diameter	Fistula septenaria: diametri digitum I S ∴ , perimetri digitos V S, capit quinariam I S = = – £ ; in usu non est. [86]
Octonaria	8 pipe	8/4 digits diameter	Fistula octonaria: diametri digitos duos, perimetri digitos sex = – Ͽ X, capit quinarias II S £ Ͽ quinque. [87]
Denaria	10 pipe	10/4 digits diameter	Fistula denaria: diametri digitos duos et semis, perimetri digitos septem S = = Ͽ VII, capit quinarias IIII. [88]
Duodenaria	12 pipe	12/4 digits diameter	Fistula duodenaria: diametri digitos III, perimetri digitos VIIII = = – Ͽ III, capit quinarias quinque S = – Ͽ III; in usu non est. Apud aquarios habebat diametri digitos III £ Ͽ VI, capacitatis quinarias sex.[89]
Quinum denum	15 pipe	15/4 digits diameter	Fistula quinum denum: diametri digitos III S = – , perimetri digitos XI S – = Ͽ X, capit quinarias novem. [90]

84 Fr. 39
85 Fr. 40
86 Fr. 41
87 Fr. 42
88 Fr. 43
89 Fr. 44
90 Fr. 45

Vicenaria	20 pipe		Fistula vicenaria: diametri digitos quinque £ ∍ , perimetri digitos XV S = = ∍ VI, capit quinarias sedecim = – £ . Apud aquarios habebat diametri digitos IIII S, capacitatis quinarias XIII. [91]
Vicenum quinum	25 pipe		Fistula vicenum quinum: diametri digitos quinque S · £ ∍ V, perimetri digitos decem et septem S = £ ∍ VII, capit quinarias XX = = ∍ VIIII; in usu non est. [92]
Tricenaria	30 pipe		Fistula tricenaria: diametri digitos sex = ∍ III, perimetri digitos decem et novem = = – , capit quinarias viginti quattuor = = – ∍ quinque. [93]
Tricenum quinum	35 pipe		Fistula tricenum quinum: diametri digitos sex S = ∍ II, perimetri digitos XX S = = – £ ∍ IIII, capit quinarias XXVIII S ∍ III; in usu non est. [94]
Quadragenaria	40 pipe		Fistula quadragenaria: diametri digitos septem – £ ∍ III, perimetri digitos XXII = = – , capit quinarias XXXII S – . [95]
Quadragenum quinum	45 pipe		Fistula quadragenum quinum: diametri digitos septem S £ ∍ octo, perimetri digitos XXIII S = – £ , capit quinarias XXXVI S – £ ∍ octo; in usu non est. [96]
Quinquagenaria	50 pipe		Fistula quinquagenaria: diametri digitos septem S = = – £ ∍ quinque, perimetri digitos XXV £ ∍ VII, capit quinarias XL S = £ ∍ V. [97]
Quinquagenum	55 pipe		Fistula quinquagenum quinum: diametri digitos

91 Fr. 46
92 Fr. 47
93 Fr. 48
94 Fr. 49
95 Fr. 50
96 Fr. 51
97 Fr. 52

quinum			octo = = ∋ decem, perimetri digitos XXVI = – £ , capit quinarias XLIIII S = – £ ∋ II; in usu non est. [98]
Sexagenaria	60 pipe		Fistula sexagenaria: diametri digitos VIII S = £ ∋ octo, perimetri digitos XXVII = = – £ , capit quinarias XL octo S = = ∋ XI. [99]
Sexagenum quinum	65 pipe		Fistula sexagenum quinum: diametri digitos novem – ∋ III, perimetri digitos XX octo S – , capit quinarias quinquaginta duas S = – £ ∋ octo; in usu non est. [100]
Septuagenaria	70 pipe		Fistula septuagenaria: diametri digitos novem = = – ∋ sex, perimetri digitos XXIX S = , capit quinarias LVII ∋ V. [101]
Septuagenum quinum	75 pipe		Fistula septuagenum quinum: diametri digitos novem S = – ∋ sex, perimetri digitos XXX S = ∋ VIII, capit quinarias LXI – ∋ II; in usu non est. [102]
Octogenaria	80 pipe		Fistula octogenaria: diametri digitos decem – ∋ II, perimetri digitos XXXI S = £ , capit quinarias LXV = . [103]
Octogenum quinum	85 pipe		Fistula octogenum quinum: diametri digitos decem = = £ ∋ septem, perimetri digitos XXXII S = ∋ IIII, capit quinarias LXVIIII = – ; in usu non est. [104]
Nonagenaria	90 pipe		Fistula nonagenaria: diametri digitos decem S = ∋ X, perimetri digitos triginta tres S – £ ∋ II, capit quinarias septuaginta tres = – £ ∋ V. [105]

98 Fr. 53
99 Fr. 54
100 Fr. 55
101 Fr. 56
102 Fr. 57
103 Fr. 58
104 Fr. 59
105 Fr. 60

Nonagenum quinum	95 pipe		Fistula nonagenum quinum: diametri digitos X S = = – £ ∋ VIIII, perimetri digitos XXXIIII S £ , capit quinarias LXXVII = = £ ∋ II; in usu non est. [106]
Centenaria	100 pipe		Fistula centenaria: diametri digitos XI = – ∋ VIIII, perimetri digitos XXXV = = – £ , capit quinarias octoginta unam = = – ∋ X. Apud aquarios habebat diametri digitos XII, capacitatis quinarias nonaginta II. [107]
Centenum vicenum	120 pipe		Fistula centenum vicenum: diametri digitos duodecim = = ∋ VI, perimetri digitos XXXVIII S = = , capit quinarias LXXXXVII S = – . Apud aquarios habebat diametri digitos XVI, capacitatis quinarias centum sexaginta tres S = = – , qui modus duarum centenariarum est. [108]

106Fr. 61
107Fr. 62
108Fr 63

Maps

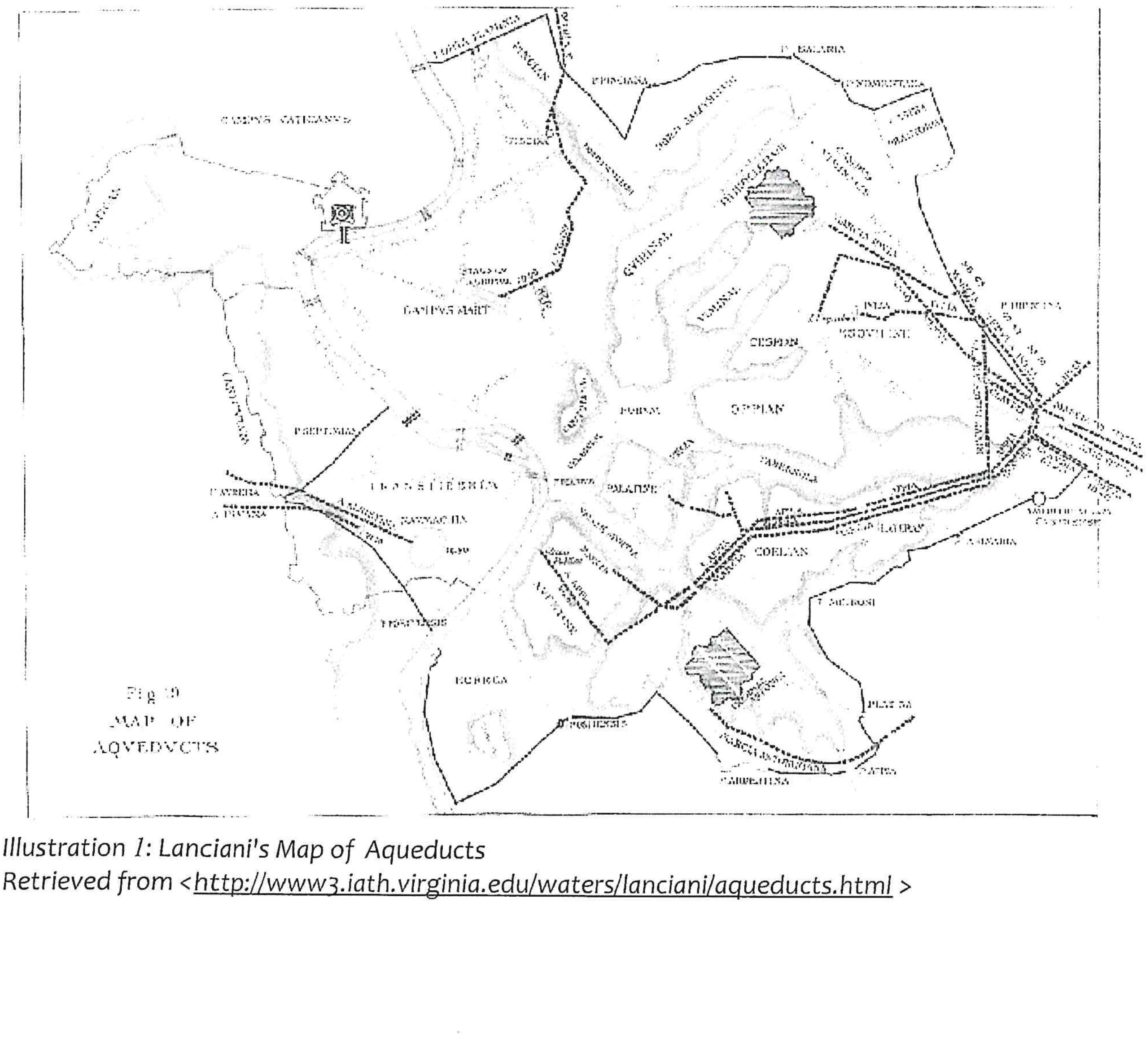

Illustration 1: Lanciani's Map of Aqueducts
Retrieved from <http://www3.iath.virginia.edu/waters/lanciani/aqueducts.html >

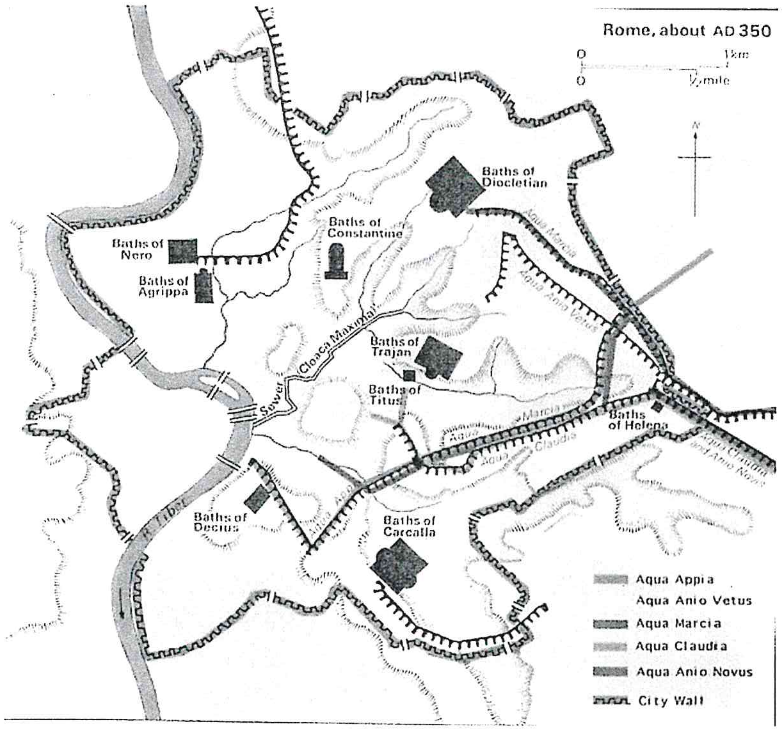

Illustration 2: Basic Map of Roman Aqueducts ca. 350 AD
Retrieved from <https://eee.uci.edu/ >

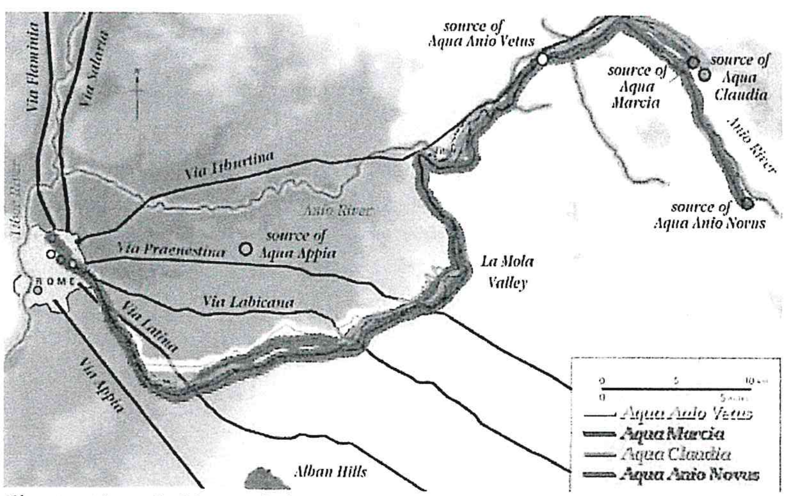

Illustration 3: Map of the Anios, Claudia, and Marcia from intake points
Retrieved from <https://eee.uci.edu/>

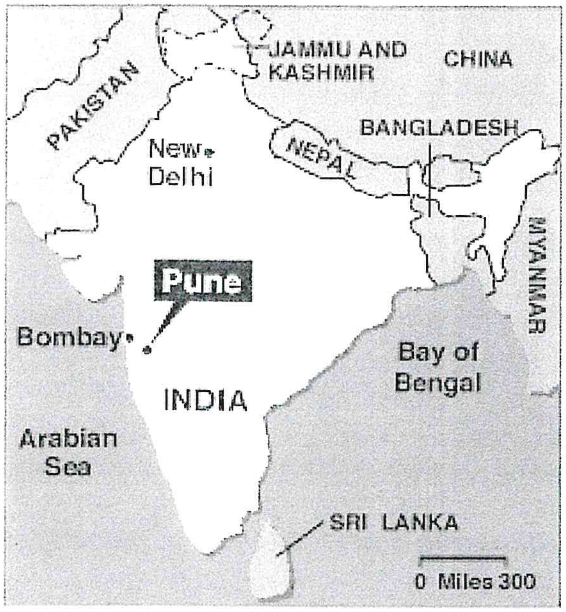

Illustration 4: Map of India locating Pune City
Retrieved from <http://www.punehotels.info/>

Self Evaluation

How do I think I did on this research project? Well, let us think back 8 months to August, 2011. I had nothing except a jumble of disconnected ideas bouncing around in my head about what I might want to spend the next few months researching. Considered topics: Catullus poetry, elegiac poems, epic poetry of the East and West. All of these are topics that I find interesting, but they are also topics that I have at some point or another already broached. I can recite Catullus 32 by heart; I can scan an elegiac couplet; and, to be fair, I was not looking to start another major project where I had to learn something about the Eastern fine arts. I wanted to try something new for this project, and water systems seemed like a perfect fit.

Roman aqueducts and water systems are a topic I have been interested in for years but have never taken the time to really study. In high school, I read Robert Harris' *Pompeii*, a novel which discusses the eruption of Mount Vesuvius from the point of view of the waterman in Pompeii. At that point, I was fascinated by the little information the book contained about aqueducts, water storage, and pipelines, and I was curious about the effect of such natural events on the water supply. Years later, when I visited the Basilica Cistern in Istanbul, Turkey, I was once again struck with awe at what the Romans were able to do with water storage. Of all the places I visited in Turkey, that cistern was the most interesting. While I was in India, a country full of water but with so much of it polluted beyond use, I found myself drawn in to a classmate's study on the Punean water system. So I had a theme of enjoying aqueduct-related information. With this interest in water in mind, Frontinus and his work *De Aquaeductu Urbis Romae* was my new shiny topic of research.

As for the work I did on the project, the first step was to read the text. I read Book I and II of Frontinus' work in Latin. This required not only knowledge of the Latin language, but also knowledge of the Roman numeral and fraction system. Before I was able to make any sense of a large number of pages in the books, I had to re-familiarize myself with Roman counting and Roman numerals; I then had to learn their methods for denoting fractions. Beyond just being able to translate what Frontinus said, I had to gain a basic understanding of what the man was talking about in his works. Frontinus used some very aqueduct-specific terms in his Latin with which I had to acquaint myself. Some of the information he shared involved a certain level of understanding in hydraulics, engineering, and math.

To be able to even understand some of the technical topics Frontinus talked about – like methods of measuring water, pipe-sizing, and conduit inclines – I had to read a supply of scholarly articles and books. Beyond reading to help me just understand *De Aquaeductu*, I read a number of books and articles that expanded on Frontinus' study of aqueducts. I left the humanities section of the library and branched out into engineering and technology categories. I experienced quite a bit of frustration in books and articles on this topic because there is a limited pool of authors from whom to choose. Many of the authors cite each other and use each others' findings, and they seem to cycle through a lot of the same information with varying conclusions.

The syntax and writing style in *De Aquaeductu* was straight-forward enough that they were nt the most interesting parts of the book to me. While some of the vocabulary was interesting and open to discussion due to its specific nature, I was generally more interested in the math and engineering information than the linguistic nuances in the writing. Because of this, Part I of my research deals with a lot of the technical information from Frontinus.

As I read *De Aquaeductu* and my collection of other water-related works, there were numerous occasions in which I found myself referencing back to something I had learned in India about Pune's water pipelines or water maintenance. Frontinus' book seemed to parallel nicely with the ACM study on water supply, and that parallel gave me the idea for Part II of my project.

My appendix is nearly as long as my papers for a number of reasons. Primarily, I needed to make charts of the numeral system, water-capacity of aqueducts, and pipe sizes as I was reading the sections in Frontinus because the visual aid helped me understand the information more clearly. Once I had the charts made, it seemed prudent to include them in my final project. I also felt the need to include a section of maps in the appendix so that readers would have a reference for the locations I discussed. India's geography especially is not common knowledge in the Classics world, so locating Pune within the country seemed necessary.

All in all, this project is my baby. When I started out, I had no idea what I was doing and I was not quite ready to take on something of this magnitude. As I got into the flow of researching, I still did not quite know what I was doing or if I was doing it right, but I have genuinely enjoyed

Part I

A Look at the Writings of Frontinus

When I was around ten years old, I drained the well on the family farm. I put the garden hose on to fill the front yard fish pool and fountain and left it running overnight; overnight, the farm's entire supply of water literally made a stream out of our country road. So there it was, sweltering hot summer with the liquid needs of an entire family and farm to satisfy, and no supply to fulfill that need. For weeks, until our well's supply was replenished, we had to bring water in from neighbors or buy bottled water for all our needs. Water was no longer the ever-flowing, readily available liquid that appeared with just a flip of the tap: suddenly, it was the heavy, buckets and jugs we carried from the neighbor's house, the funny-tasting chlorinated drink that the city could provide.

It was during this time that I realized something about how things work in this world: water, this common substance that fills our lakes, fuels our rivers, and even falls out of the sky is quite possibly the most precious substance in the world. It is a necessity for crops, for livestock, for luxuries like fountains and fish pools. It is the foundation of hygiene, a building block in every recipe in the kitchen, and the key to hydration and human life. Any civilization that can harness its power is a force with which to be reckoned. A civilization that managed this nearly 2,500 years ago is beyond impressive.

In first century AD Rome, the man Frontinus documents his city's history and the steps taken in the process of harnessing the supply of water. Without the words of Frontinus, we would know little about the aqueducts of Rome and how they function; without his expertise as water

Abstract

My main research regards the ancient water system in the city of Rome in the first century AD during the time of Frontinus. In Part I of the project, the main purpose is to discuss the valid and beneficial information provided by the author Frontinus; in Part II it is to discuss the benefits and flaws of the aqueduct system at that time along with the changes the water commissioner Frontinus added to the system. The first part of the research project involves an array of numbers and figures pulled directly from Frontinus' work. For information about Roman aqueducts and water transport, I relied primarily on Frontinus' Latin text *De Aquaeductu Urbis Romae* for information. I also got information from a variety of sources in scholarly articles, magazines, and books on aqueducts and engineering in the ancient world. For the second part of the project, to supplement the research on Roman aqueducts, I chose a modern city for comparison. This city, Pune, is one in which I lived for a span of four months and on which one of my colleagues did extensive water supply research. For supplementary information on Pune, I used my colleague's research as a base and let it point me in the right direction for other sources. In this research, I have discussed ways in which water commissioner Frontinus was important to the water systems of Rome, I have found ways in which Romes ancient aqueduct system is superior to even some modern water systems, and I have also outlined some problems which seem universal to the water supply industry.

learning what I have about aqueducts. I like to think that I have earned an A on this project. I have put a lot of energy, effort, and work over the last nine months into this project, and I hope that shows through in the finished product.

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Evaluation of Anne Cave's Senior Independent Project on Frontinus

The annotated bibliography demonstrates excellent research and grasp of the relevant secondary material. You are correct in noting that the number of scholars dealing with this author is limited but you did a good job in gathering good sources on related materials. The bibliography in itself is a valuable resource which could be made accessible to other students of Frontinus. We might consider posting it on the Classics Department website.

The appendix of important terms and phrases is a useful glossary of terms employed by Frontinus. It would have been appropriate and useful to have provided the reader some examples of Frontinus' use of these terms. More detailed analysis of these terms rather than simple definitions would also have been helpful. Similarly, the appendix on numbers and fractions would have been more useful if it had been put more directly in the context of Frontinus' work. Your reader needed to know how these terms were used by Frontinus and how they relate to the study of aqueducts.

The appendix providing information on Frontinus' nine aqueducts offers basic information on these structures. I would like to have seen more specific details regarding the route and location of these aqueducts and their relation to the present water system in modern Lazio (Latium). The Latin quotes from Frontinus needed to be translated and analyzed for your reader. At the least you should have explained what these quotes tell us about the aqueducts in question and how accurate this information is.

The appendix on Roman pipe sizing needed an introduction explaining how to understand and interpret this very technical information and why it is important. What can be learned about the Roman aqueduct system from this appendix?

The paper itself offers a good introduction to Frontinus and his work. I thought that the personal way in which you introduced the topic was successful in drawing your reader into what could be, as you yourself point out, a very dry topic. While I understand why you divided your work into two separate parts, one specifically on Frontinus and the other on a comparison of water systems in ancient Rome and modern India, I think that the project would have been improved by a summary or concluding section in which you drew the two parts together more directly.

I learned a great deal from this project and thank you for leading me into the fascinating world of Roman aqueducts. The quality of your work has been demonstrated by the fact that your paper on water systems in ancient Rome and modern India was selected for the 2011 Eta Sigma Phi convention at the University of Missouri in Columbia and that you will also read this paper at the 2013 Eta Sigma Phi Undergraduate Panel at the meetings of the American Philological Association in Seattle, Washington.

Based upon the comments I have provided above, I think that you have earned a grade at A for your paper and for your project, including research and writing.

I wish you the best of luck as you begin your career as a graduate student in Classics at the University of Missouri and would encourage you to share this project with your graduate professors.

Si vales, valeo.

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