THE ROMAN WATER SYSTEM:

ITS CONTRIBUTION TO THE SUCCESS AND FAILURE OF ANCIENT ROME.

A Thesis

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INTRODUCTION

By learning from the past, we hope to avoid failure in the present. Discovering the reasons for the success and failure of other societies seems logical. Probably the single most asked question relating to the Roman empire is "Why did it fall?" From this question alone scholars have come forth with countless reasons: malaria, rampant homosexuality, lead water pipes, poor sanitary conditions, barbarian invasions, plague, Christianity, etc. It must be understood that Rome did not fall; it declined, slowly. Rome's fall was not due to one devastating factor that can be pointed out with the naked eye, but rather a variety of many problems that require a magnifying glass.

This study does not pretend to be more than an attempt to suggest one of the factors that affected the history of Rome: its water system. More and more information is uncovered daily by archeologists concerning the Roman water system. Some evidence comes from people who lived in ancient Rome and saw the water system at work. This evidence, together with that unveiled by the archeologists, has helped us develop a clearer picture of how the Roman water system functioned.

An obvious question which has been directed to the Romans is, "What drove them to such lengths to secure water from such great distances?" Almost every ancient city of importance was founded on the banks of a river. Ancient Rome had the Tiber river, which flowed all year. Judging from the amount of effort put into the entire Roman water system, one would think that the site of Rome was a poor choice. But, on the contrary, we know from ancient authors that Rome was selected because of its beneficial hills and abundant water supply.[1] We have no evidence that the Tiber was polluted by 312 B.C., when the first aqueduct was built. We do know, however, that the Tiber carries a large amount of silt throughout the year, giving it a cloudy or muddy appearance. It is possible that this made the Tiber an unsatisfactory source of drinking water. Perhaps it never was considered a water source except in times of drought. If this was the case, the Roman pre-aqueduct water supply consisted solely or mostly of rain water, spring water, and well water.

It must be remembered that Rome had been sacked by the Gauls just seventy-eight years before the building of the first aqueduct. Far from being the legendary, stable, all-conquering empire, in 312 B.C. Rome was simply another small city on the Italian peninsula. Its location was twenty-four kilometers from the sea, which allowed easy access to trade, without much vulnerability from attack. Rome was still barely standing on its own, yet it was capable, and willing, to construct a channel eighteen kilometers long in order to bring additional water to the city. It takes men with great initiative, as well as a firm belief in the future, to commit themselves to such a demanding undertaking.

I contend that the strength and efficiency of the Roman aqueduct system directly reflects the strength and efficiency of the Roman people and their government. As the Roman government declined so too did the Roman aqueduct system. The aqueducts and the city of Rome appear to be on a balance; each serves the other, and one without the other cannot exist.

Many authors, ancient and modern, are quick to point out the success of Rome by reciting the various accomplishments of Rome. For example, an efficient Roman administration cared for all its citizens; ever-expanding boundaries incorporated new peoples; the hundreds of roads expanded trade; practical architecture was used; and, of course, the aqueducts brought health to the city of Rome. When it becomes necessary to discover the reasons why Rome withered away, amazingly the same accomplishments are cited, but the inferences have changed to the administration being endlessly corrupt, boundaries too far to enforce, roads facilitating invasion by the barbarians, architecture in decline, and, finally the aqueducts poisoning the population with lead.

Historians who create sweeping conclusions like these are easy to find. Drawing concrete conclusions based on real evidence, written or excavated, is in fact very difficult. It has become so easy to say that Rome had a great water system that it appears almost unnecessary for one to do research on it. Certainly these colossal structures deserve praise, but they are not sacred. In fact, it must be recognized that throughout its history Rome's water supply system was defective. We know that the aqueducts leaked all of the time, and that only on a few occasions did all the aqueducts provide water to the city. Lime piles beneath the arches of the aqueducts are a visible indication of a constant leaking of water in great quantity. A continuous supply of water is neccessary to create such large deposits of lime.

Why did the Romans not see the need to find another kind of water system? They could have at least discontinued the repairs to the more costly aqueducts to focus their efforts on the more reliable and productive aqueducts. Moreover, why did the Romans stop building new and better aqueducts? Why did the Romans choose not to perfect their water system? It certainly was not flawless; in fact it was cost-inefficient. The aqueducts did not change in design to any degree in over six centuries. Did the Romans truly believe that their water system was as good as it could be? Aqueduct building continued throughout the empire, yet in Rome they were content with patching their archaic system year after year.

These are the questions that this paper intends to address.

Chapter 1

SUMMARY HISTORY OF THE ROMAN WATER SYSTEM

The water system of ancient Rome consisted of two parts: the aqueduct system, and the drain system. The drain system preceded the aqueduct system, so I will briefly describe its history.

Rome has always had a natural, abundant supply of water. The hills on the left bank of the Tiber form three valleys, each having its own river conveying the spring, rain, and waste waters to the Tiber. The area between the Capitoline and Palatine hills was a swamp created by this abundance of water. Historical tradition has it that around 625 B.C. the Etruscan king of Rome, Tarquinius Priscus, constructed a channel through this swampy area in order to regulate these rivers.[1] This prevented the spreading and wandering of flood water, and provided the swampy valleys with permanent drainage. The largest of the drains was appropriately titled the Cloaca Maxima - big drain[2] (Plate I). Eventually the increase in the population caused the boundaries of the city to be extended; it then became necessary to cover the channels and make them run underground. The reclaimed area between the Capitoline and Palatine became the Roman forum, the center of Roman government for the next ten centuries.

PLATE I

Plate I - **Cloaca Maxima.** This is the mouth of the Cloaca Maxima as seen today.

Undoubtedly, this area as well as the surrounding ones became much more wholesome with the elimination of the marsh and its accompanying malaria. Ancient Romans had not associated the malaria with the mosquitoes that are prevalent in swampy areas; rather, they attributed it to odors of rotting swamp vegetation.[3] Later the drainage system was used as a method for the removal of excretal wastes, as the city expanded in size and population.

The aqueducts followed the drainage system by three hundred years. The eleven aqueducts of Rome were the foremost achievements of the city. The first aqueduct was the Aqua Appia, built in 312 B.C. and named after the censor Appius Claudius, who also constructed the famous Appian Way.[4] This aqueduct, although only eighteen kilometers long (which is short in comparison to other aqueducts), was no small feat. It was a subterranean channel for all but ninety-one meters, which was on low arches. One reason for building the channel underground was most likely to prevent sabotage from invaders.[5] Remarkably, it entered the city fifteen meters underground.

The second aqueduct, the Aqua Anio, was built forty years after the Aqua Appia in 273 B.C. The Aqua Anio was later renamed the Aqua Anio Vetus (old Anio) when a future aqueduct built by the emperor Claudius also originated from the Anio river (and was named the Aqua Anio Novus). The Aqua Anio, like the Aqua Appia, is mostly subterranean. Of its sixty-nine kilometers only 334 meters were above ground. Its channel was 122 centimeters wide and 243 centimeters high.

It was 126 years after the Aqua Anio was completed that the third and most famous aqueduct was built, the Aqua Marcia. The Aqua Marcia was built in 146 B.C. by the praetor Quintus Marcius Rex at a cost of 180,000,000 sesterces.[6] The Aqua Marcia was 103 kilometers long. Twelve of these miles were above ground on high arches. The water from the Aqua Marcia was renowned for its coolness and purity. It was the first aqueduct to run for a long distance on arches.

The fourth aqueduct, the Aqua Tepula, was completed in 125 B.C., twenty-one years after the Aqua Marcia. Its name is derived from the temperature of the water it conveyed (63 degrees F.).[7] The water originated from the volcanic springs of the Alban mountains, eighteen kilometers from Rome. The water, being warm and not of particularly good quality, was eventually mixed with the Aqua Julia. This aqueduct was superimposed upon the arches of the Aqua Marcia for the last ten and one half kilometers of its course.

The Aqua Julia was the fifth aqueduct to be built and was named after the Julia family, of which Julius Caesar was a member. It was completed in 33 B.C. during the reign of Augustus, the adopted nephew of Julius Caesar. This aqueduct was twenty-four kilometers long, but for only about a third of its total length did it travel on its own; like the Aqua Tepula it was superimposed upon the arches of Aqua Marcia for most of its course.

The sixth aqueduct was the Aqua Virgo built in 19 B.C. It ran for twenty-four kilometers on a low level. Like the Aqua Marcia, it was known for its fine quality.[8] The Aqua Virgo today supplies the water for the ship fountain at the Spanish steps, as well as for the Trevi fountain (Plate II).

The Aqua Alsientina was the seventh aqueduct to be built. The emperor Augustus was responsible for the construction of this aqueduct in A.D 10; it was built to supply the water for his marine circus or Naumachia. The quality of this water was too poor for human consumption, so the overflow was used for gardens.

The eighth and ninth aqueducts were begun by Caligula in A.D. 38,[9] and both were completed by Claudius in A.D. 52.[10] The Aqua Claudia was seventy-two kilometers long; sixteen of these kilometers were above ground on arches. The longest aqueduct was the Aqua Anio Novus. It was one hundred kilometers long; fourteen and one half of these kilometers were on arches. Eleven out of these fourteen arched kilometers were added on top of the arches of the Aqua Claudia (Plate III).

The Aqua Trajana was the tenth aqueduct to be built. It was completed in A.D. 109 and was named after emperor Trajan, who had it constructed. This aqueduct follows

PLATE IIa

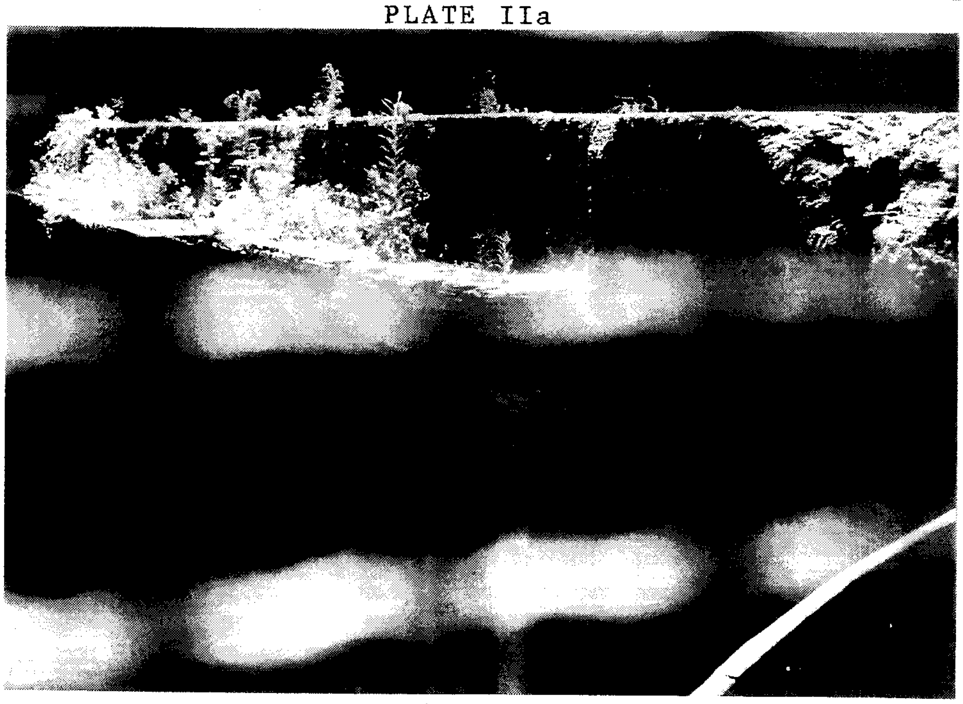

PLATE IIb

Plates IIa and IIb - **Aqua Virgo**. This is an arch from Aqua Virgo located at 14 via Nazzareno in Rome. According to its inscription, it was restored by Claudius after its destruction by Caligula. Note: The blurs in the plates are due to the chain link fence that surrounds this arch.

PLATE IIIa

A--->

B--->

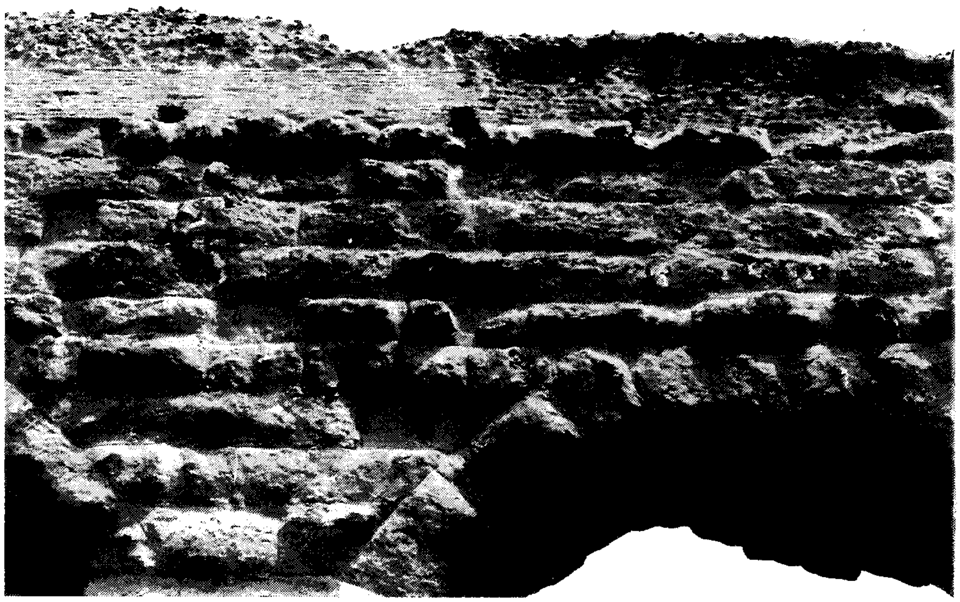

PLATE IIIb

Plates IIIa and IIIb - **Aqua Claudia and Novus.** Plate IIIa - Aqua Claudia with Aqua Novus riding on top. Plate IIIb - Close up - A, indicates Aqua Novus of brick and concrete. B, indicates Aqua Claudia of cut stone.

nearly the same route as the Aqua Alsientina and is fifty-eight kilometers long (fig. 1).

The eleventh and final aqueduct was built 116 years after the Aqua Trajana, in A.D 226. It was named the Aqua Alexandriana after Alexander Severus, who had it built. The course of this aqueduct ran for a length of twenty-four kilometers.

The Roman water system was not as complex as the system we have today, mainly because the Roman system worked on the principle of gravity flow. The Roman system, unlike today's high-pressure system, avoided high-pressure. This is not to say that the ancient system did not have its complexities. Conveying water for eighty, ninety, or even one hundred kilometers on a consistent slope over and through a variety of terrains would indeed be difficult. If the Roman engineers inadvertently miscalculated the descent of the slope, then the water would not have enough elevation to reach the city; likewise, not enough slope would result in the aqueducts being less productive. Years of labor and a fortune spent on an aqueduct that conveyed only a dozen liters of water an hour would have surely displeased any emperor.

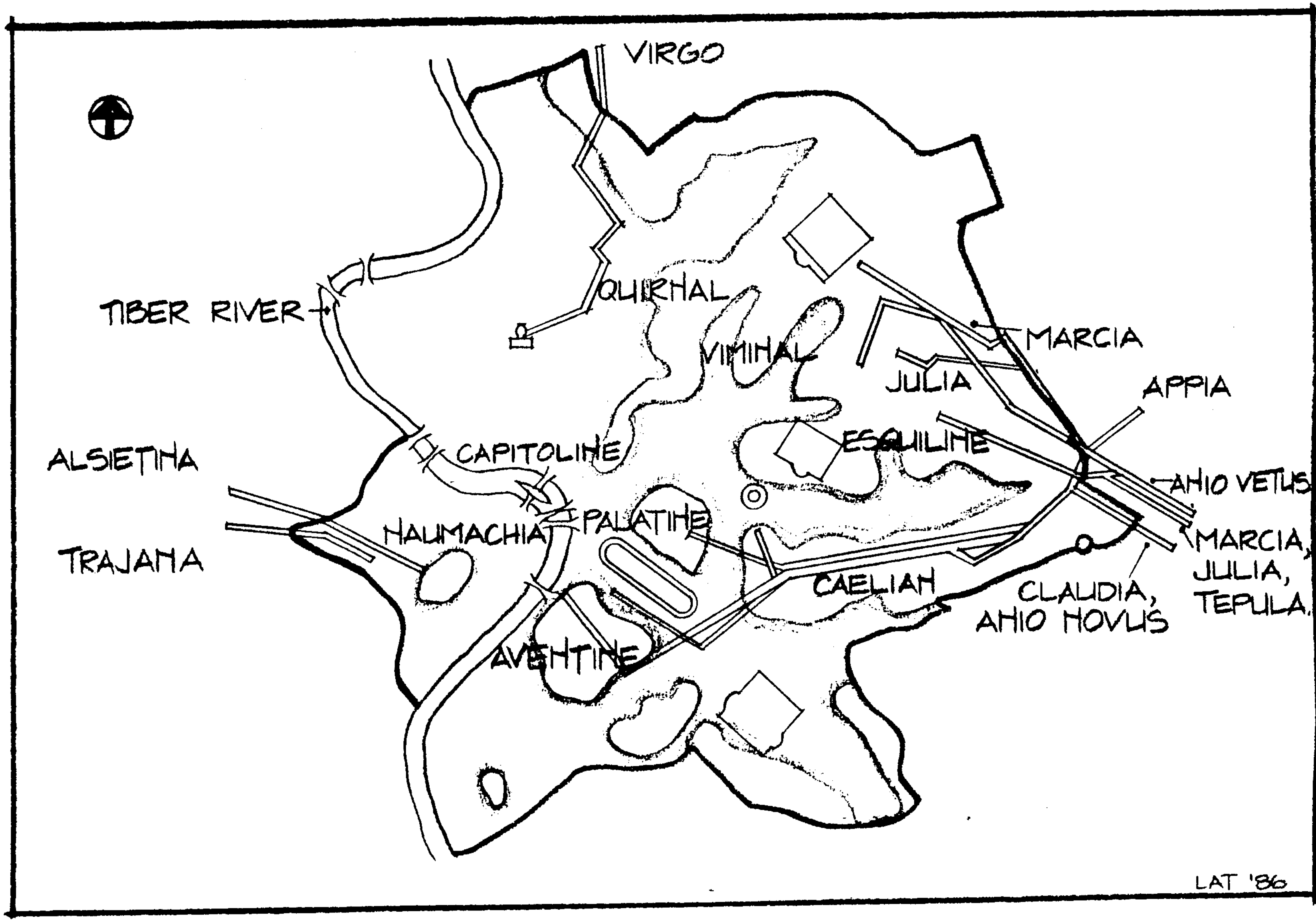

Figure 1 - **Distribution of the Aqueducts in Rome.**

Chapter 2

LOCATING AND CLASSIFYING WATER SOURCES

The characteristic achievements of the Romans show their work to be based on a sober sense of reality. The roads, walls, bridges, aqueducts, sewers, drains, military siege works, and the great public buildings on the whole are more typically Roman than their religious temples, sculptures, and paintings. Although the Romans were a very practical people, they also enjoyed the same architectural decorations that the Greeks enjoyed.

The Roman aqueduct building era spanned 538 years. In that period, mountains were tunnelled and levelled, rivers and valleys were crossed, and in some cases huge inverted siphons were made to overcome the steepest of terrains. The labor to build and maintain this water system was expended in order to insure a water supply that was both pure and plentiful.

Building the channel was half the problem. The other half was locating a source of water that was both abundant all year round and was of the highest quality. To determine quality required acute observations. Lacking the use of the microscope Romans had to go to great lengths to insure the pureness of the water source. Pollio Vitruvius was an architect during the reign of emperor Augustus (33 B.C. -

A.D. 14) and was hired by Augustus to write a kind of how-to manual to locate and test water for his military personnel. Vitruvius is very diligent when he speaks of securing a reliable water source. He wrote:

> Water is so necessary to maintain life, that one can be deprived of many things, but without water, neither the animal frame nor any virtue of food can originate, be maintained, or provided. Hence, great diligence and industry must be used in seeking and choosing springs to serve the health of man.[1]

It must be acknowledged that Vitruvius was writing 300 years after the construction of the first aqueduct. While the techniques of his day may have been different from those of his predecessors, Vitruvius' procedures for seeking out water did not require any special materials. It is therefore very possible that his techniques for locating water could have been the same as or similar to those techniques used by the earlier engineers of the first aqueducts.

Vitruvius enlightens us with the scientific knowledge of his day. He explains his methods for seeking out water and verifying its purity. Although Vitruvius was at a scientific disadvantage, his observations are most accurate. For instance, he asserts that the influence of sunlight on water is detrimental, since it causes the purest particles to evaporate and scatter, leaving behind the, "heavy, coarse, and unhealthy parts." [2] This is of course true and easily observable. One of his tests to back up his statement is boiling water in a metal pot, and seeing whether solid impurities come out of solution.[3] This is simply an intensified version of his first observation. He does point out, however, that the polluting effect of the sun is most obvious when the water is exposed on level ground and is stagnant. It then causes the growth of algae and insect larvae. (It would be another twenty centuries before this ancient theory of spontaneous generation would be disproven).

Vitruvius explains a variety of methods for locating sources of water which included methods varying from the very simple to the very complex. The simplest procedure mentioned by Vitruvius is to search for water vapor rising from the ground. This he says is best done at sunrise, when moisture has risen to the surface during the night, and before it evaporates with the warming of the soil surface. Vitruvius wrote:

> The best way to observe it is to lie face down on the ground and look along the surface, where the moisture forming curls rising into the air can be most easily seen. This is a sign of water, and justifies a test dig in the area.[4]

Another good indicator of a water resource is plant life. There is a particular variety of plants that grows only in areas that have a suitable water source. Six of these plants recognized by the ancients for this quality are bullrush, wild osier, alder, withy, reeds and ivy.[5] Of course these plants grow in marshy sites too, which are unsuitable as water sources, but where they grow in other places, they mark a possible source.

The digging for water at a possible location of a source was the next step. Vitruvius recognized that digging a series of non-productive or non-existing water sources was costly. Additional evidence beyond plants and rising moisture was needed. A series of tests were to be carried out before finally starting the actual digging. Vitruvius wrote:

> If the indications merit digging then a pit should be dug about 1 meter square and 1 1/2 meters deep. A metal basin is to be placed in it, upside down and smeared with olive oil on the inside, this should then be covered over with reeds or tree branches with the leaves still on and a light covering of soil on top. This should be done in the evening and the covering left undisturbed overnight. In the early morning it should be opened up and the basin should be examined for droplets of condensation. The olive oil will make the droplets more easily visible. If there is a clear indication of water vapor, it is almost certainly worthwhile to sink a well-shaft, and if a spring of water is found, more wells must be dug thereabouts, and all conducted by means of subterranean channels into one place.[6]

From passages like this we can infer what knowledge Vitruvius had about biology, chemistry, and so on. Furthermore, it is understood that the source of water is not intended for irrigation but for human consumption, which requires the utmost care to secure a reliable water source.

The health of man was the main concern of those who brought water to Rome. The varieties of water were categorized by their wholesome qualities. Most desirable was rain water, because it is made up of the purest parts of all the springs; after being filtered through the air, it is liquified by storms and so returns to earth.[7] The Romans used rain gutters and cisterns for the collection of rain water. This source, although desirable, was not plentiful. The next best source that the Romans preferred was spring water. The qualities of spring water were venerated by the Romans. They desired spring water mostly for the health that it brought. Rodolfo Lanciani's illustration of the Roman fondness toward spring water and its continuity throughout the ages is eloquent. His account explains what happened when laborers inadvertently discovered layer upon layer of gold and silver votive offerings in an ancient sulphur spring. Lanciani wrote:

> A gang of masons were sent from Rome to clear the mouth of the the central spring, and to put the whole into neat order. In draining the well, a few feet below the ordinary level of the water, they came across a layer of brass and silver coins of the fourth century after Christ. Then they discovered a second layer of gold and silver imperial coins of the first period, together with a certain quantity of votive silver cups. In the third place they came across a stratum of silver family or consular coins belonging to the last centuries of the republic; and under this they found bronze coins. Seeing that there remained nothing but brass to plunder, after having partaken of the precious booty in equal shares, the masons resolved to announce their discoveries. It is unnecessary to say that when padre Marchi, the well known numismatist, ran to the spot, he found only a few hundred pieces of "Aes Grave Signatum," the earliest kind of Roman coinage. Under these there was a bed of "Aes Rude,"- That is to say, of shapeless fragments of copper, there was nothing but gravel, at least, the workmen and their leaders thought so. It was not gravel,

> however; It was a stratum of arrow-heads and paalstabs and knives of polished stone, offered by the half-savage people living in the area.[8]

This passage is an excellent example of the reverence the Romans had for spring water, beginning in the stone age and carrying on through the bronze and iron ages and ending with the fourth century Christian era.

The third type of water source in descending order was river and lake water. Although this is ranked third it was used most often as a source because rain water and spring water were less abundant and less reliable.

The Romans tapped streams but found that this was a less desirable technique. This was because they were not conveying just water like that of a spring but were rerouting the river through the channel. The Anio river was tapped in this manner, and it was soon discovered that not just water was conveyed, but debris and sediment were also carried through the channel. When it rained, the river Anio became muddy, making the water no longer potable in the city. Roman engineers developed several techniques to resolve this problem. First, they dammed up the Anio river upstream from the aqueduct's intake. This created a settling reservoir, so that the river might come to rest and clarify itself. But in spite of this construction the water reached the city in a discolored condition whenever there were heavy rains.[9] The engineers developed the method of mixing the discolored water with the clearer water of the

Aqua Claudia; this made the Aqua Anio water supply more desirable but reduced the excellent water of the Aqua Claudia to a mediocre quality.[10] The Aqua Tepula and Aqua Julia, too, were mixed together, but for a different reason, (as noted above on page 9). This practice appeared to be more successful than that of mixing water on a large scale to make one source better. It was not until the time of Frontinus, at the beginning of the first century A.D., that the mixture of the Aqua Anio Novus and Aqua Claudia was stopped.[11] Furthermore, the practice of mixing water to supplement other sources was changed by Frontinus because he discovered that those who had charge of the distribution of water did not give it proper care. Frontinus wrote, "We have found even Aqua Marcia, so charming in its purity and coldness, used for baths, fulling-mills, and I may not say what vile appointments."[12]

This practice of mixing was generally replaced with the more involved settling tank system. This method of having the water reach a small reservoir along its route not only allowed the water to improve its clarity but also enabled the watermen to redistribute water to new locations without stopping the service to other locations. These settling reservoirs were suggested by Vitruvius to be constructed at 7,300 meters intervals so that if a break occurred anywhere, it could easily be found.[13] Moreover, the amount of water that entered a settling tank could be measured against the amount of water that entered at the previous settling tank or river intake. In this way the water commissioner could determine a possible leak or an illegal tap along the line.

The mathematics used by the Romans was far from accurate. The Romans measured water by cross-sectioning the specus to determine how much water was being conveyed[14]; they never developed an equation that included a variable for water pressure or velocity.[15] We know that the Romans were familiar with water pressure, because Vitruvius mentions high-pressure in the inverted siphons. High-pressure, however, was avoided as often as possible.

Frontinus is credited with separating the aqueducts from each other and restoring their individual integrity. Each aqueduct was categorized by its quality, and then arranged to be used where its characteristics were best served. The Aqua Marcia was now reserved for only drinking, and the others were used for purposes adapted to their special qualities. For example, it was ordered that Aqua Anio Vetus was not to be channeled to basins for drinking but to watering the gardens, and for the dirtier uses of the city, (e.g. flushing the sewer system).[16]

In summmary, the water was diverted from a river or tapped from a spring or lake. It traveled through a masonry channel underground and/or on arched substructures if necessary. The aqueducts invariably followed the contour of the terrain to maintain the necessary gradient. The Romans avoided tunnels and bridges as often as possible because they required expertise, materials and labor. In order to carry an aqueduct across a valley the Romans relied on two solutions: a bridge, which merely maintained the gently declining slope of the aqueduct, or a siphon made of lead pipes which carried the water in a steep plunge down one side of the valley and a steep climb up the other side, relying on the principle that water in a pipe will always rise to its original height. A siphon was the solution if the valley was so deep that a dangerously high bridge would be required.

Siphons

The Roman siphon is called an inverted siphon because the path followed by the water is a "U." The siphon started as soon as the water was introduced into one arm of the "U." Because of the friction created within the pipes the receiving end had to be somewhat lower than the originating end.

It is interesting to note that although many siphons have been identified, the role of siphons in Roman hydraulics is generally unrecognized. Few siphon remains have been discovered, probably because they are at ground level and easily salvaged for materials, unlike the imposing aqueduct bridges like the Pont du Gard. Furthermore, siphons played a small part in the aqueduct system of metropolitan Rome, which is the system modern scholars have studied most intensively. However, we do know from archeological discoveries that siphons were used to deliver water to the Capitoline and Palatine hills.[17] Thus, the study of the extent of knowledge the Romans had of the principles involved in building and maintaining siphons is incomplete. It is uncertain how fully the Romans understood the principles of pressure and velocity. Obviously the Romans could have applied the principles empirically, simply because the siphons were built and did work.[18] Ancient writings provide little help. Frontinus does not mention siphons, perhaps, because siphons were not prominent in Rome. Vitruvius gives a description that provides some insights. Vitruvius is confused on a few points that discuss air pressure in the pipes. The inverted siphon does not have air in it, simply because it is full of water. Since the water is under pressure the air can not come out of solution. Most likely, Vitruvius did not fully understand all of the principles of the siphon.

The inverted siphon was avoided if at all possible because of its cost and the engineering know-how necessary. Every step was taken to relieve pressure within the siphon. Instead of plummeting to the valley floor, a low substructure was built to allow the siphon to travel on a level as long as possible. This substructure was called a venter[19] (fig. 2). This allows the water to level off and shorten the fall, rather than to have it fall to an elbow at the base of the valley and return back up the opposite side. Without the venter it would be nearly impossible to create a practical system that could maintain the enormous pressure that would be created. It would simply burst the pipes and destroy the system.

The siphon required two tanks. The first was the header tank. This tank was a holding tank with numerous pipes leading from it. The second tank was the receiving tank which was lower than the header tank. The receiving tank had to be lower for two reasons: First, to maintain

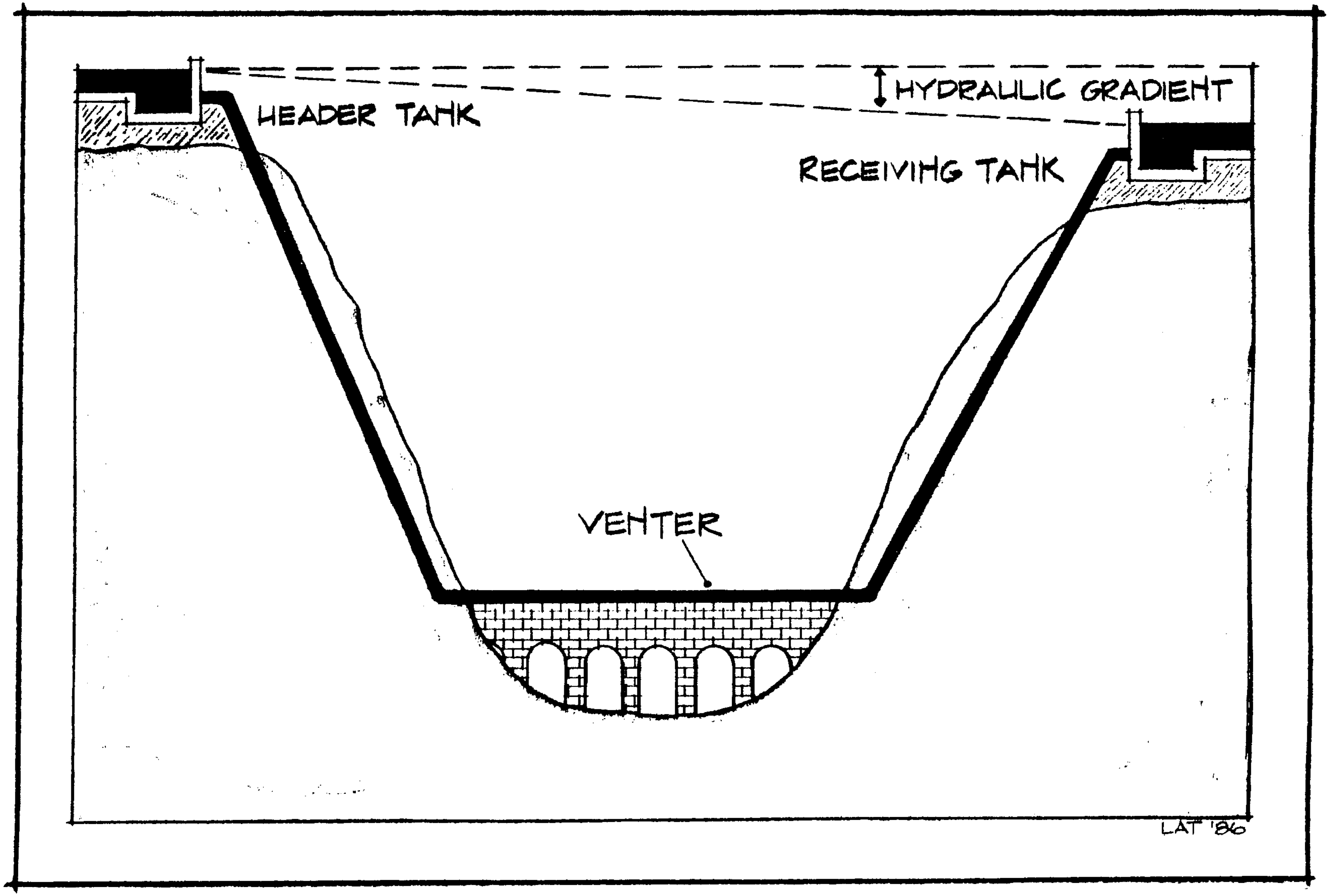

Figure 2 - **Venter.**

the slope of the aqueduct, and second, since the small diameter lead pipes created friction on the inside, the receiving tank still had to be further lowered below the level of the header tank to ensure an adequate flow of water (fig. 2).

The reasoning behind the use of several small diameter pipes instead one or two large pipes is twofold. By distributing the water into several pipes the water pressure would be less per square inch, and thus more manageable. Also, the siphon constantly required repairs to the pipes and cleaning due to mineral deposits (Plate IV). If one pipe burst or was choked with deposits, it could be repaired or cleaned without shutting down the system. This made maintenance more efficient.

The Romans built only siphons that were difficult to construct and avoided easy ones. It seems clear that the most likely explanation for why the Romans did not elaborate on the principle of the siphon and resort to constructing them more often was their cost, and the difficulty of the engineering. Had the Romans expanded this practice they might have discovered the advantages of a high-pressure system. Unfortunately, lead pipe was the only conduit the Romans used that could withstand the high-pressure. They did not have today's cast iron and they did not develop the concrete pipe. The Romans had three basic kinds of pipes: lead, earthenware, and solid stone (Plates V through VII).

PLATE IV

Plate IV - **Mineral Deposits.** This lead pipe represents damage caused by mineral deposits. Left unchecked the deposits would choke the pipe.

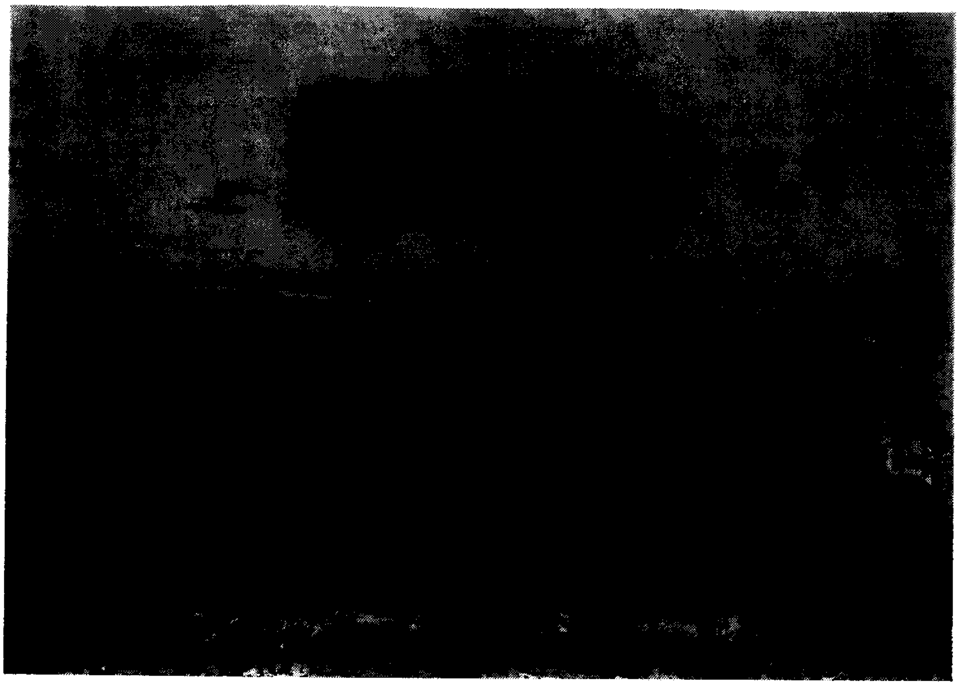

PLATE Va

PLATE Vb

Plates Va and Vb - **Lead Pipes.** Va - The two longer pipes in this plate are about twelve feet long. Plate Vb - This is a close up of the middle pipe of Plate Va. This inscription dates the pipe to the reign of Marcus Aurelius.

PLATE VIa

PLATE VIb

Plate VIa and VIb - **Clay Pipes**. Plate VIa - This plate shows three clay pipes tapped into Aqua Claudia. These sets of arches are located near Porta Maggiore. Plate VIb - This is a longer view of plate VIa. Lower right corner shows the three clay pipes emerging from the concrete.

PLATE VIIa

PLATE VIIb

Plates VIIa and VIIb - **Stone Pipe.** Plate VIIa - This is the female end of the stone pipe. It appears to have been cut for a drain cover like that of plate VIII. Plate VIIb - This is the male end of the same stone pipe.

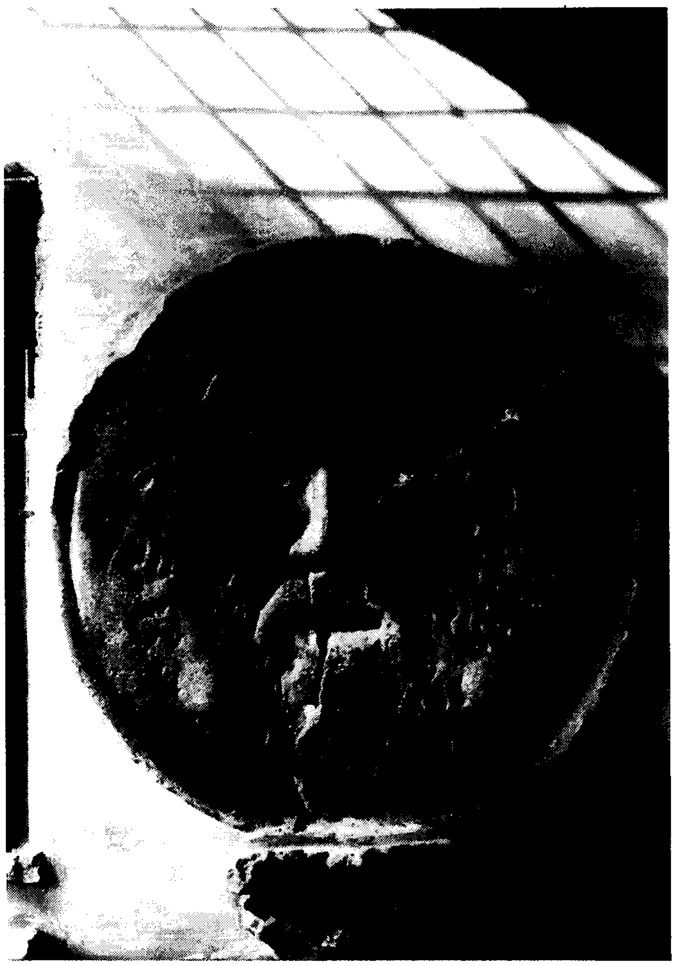

PLATE VIII

Plate VIII - **Bocca della Verita** - Better known as the mouth of truth, is in fact an ancient drain cover.

The solid stone pipe was seldom mentioned because it was used infrequently.[20] The earthenware pipes were cheaper than the other two varieties. Earthenware pipes could withstand small amounts of pressure, but were unreliable with high-pressure. These clay pipes did have many advantages over the lead pipes, which possibly played a role in the continuation of a low-pressure water system. Clay pipes were very easy to work with in construction. If anything happened to the pipes, little skill was needed to repair the damage. Furthermore, Vitruvius understood that "Water from clay pipes is much more wholesome than that which is conducted through lead pipes."[21] He wrote that lead is harmful to the human system because plumbers work with lead and their natural color is replaced with a deep pallor. Plumbers exposed to the fumes during the casting of lead have all the "virtues of blood" taken away from their limbs. "Hence, water ought by no means be conducted in lead pipes, if we want it wholesome."[22]

We know too, that when water was channeled through clay pipes people refrained from using metallic vessels, but rather resorted to earthenware vessels in order to preserve the purity of taste.[23]

Distribution

A schematic diagram gives the reader an idea of the typical Roman distribution system (fig. 3). The system had two primary functions: First, the aqueducts were to supply water to the public basins and fountains, and second, to the public baths. For instance, the Aqua Virgo was built by Marcus Agrippa to supply water for the public bath he was constructing in the Campus Martius. In this way he would secure a permanent supply of water for the bath without depleting the already existing supply. The excess water from this newly created source would be channeled into the public basins and fountains.[24] Many times public baths were built with permission from the emperor, and the already existing supply of water would be the source. Once a public bath had a supply of water from an aqueduct it could not be revoked in the future. Private houses were supplied with water only after these first two needs were met. The private houses had to pay a special water tax which went toward the maintenance of the aqueducts. The amount of money that was collected was not nearly enough to keep the system working.

Since the water supply worked on a low-pressure gravity flow, the water ran continuously day and night. The water filled the public basins and fountains and the overflow would then continously wash the streets and flush the sewage

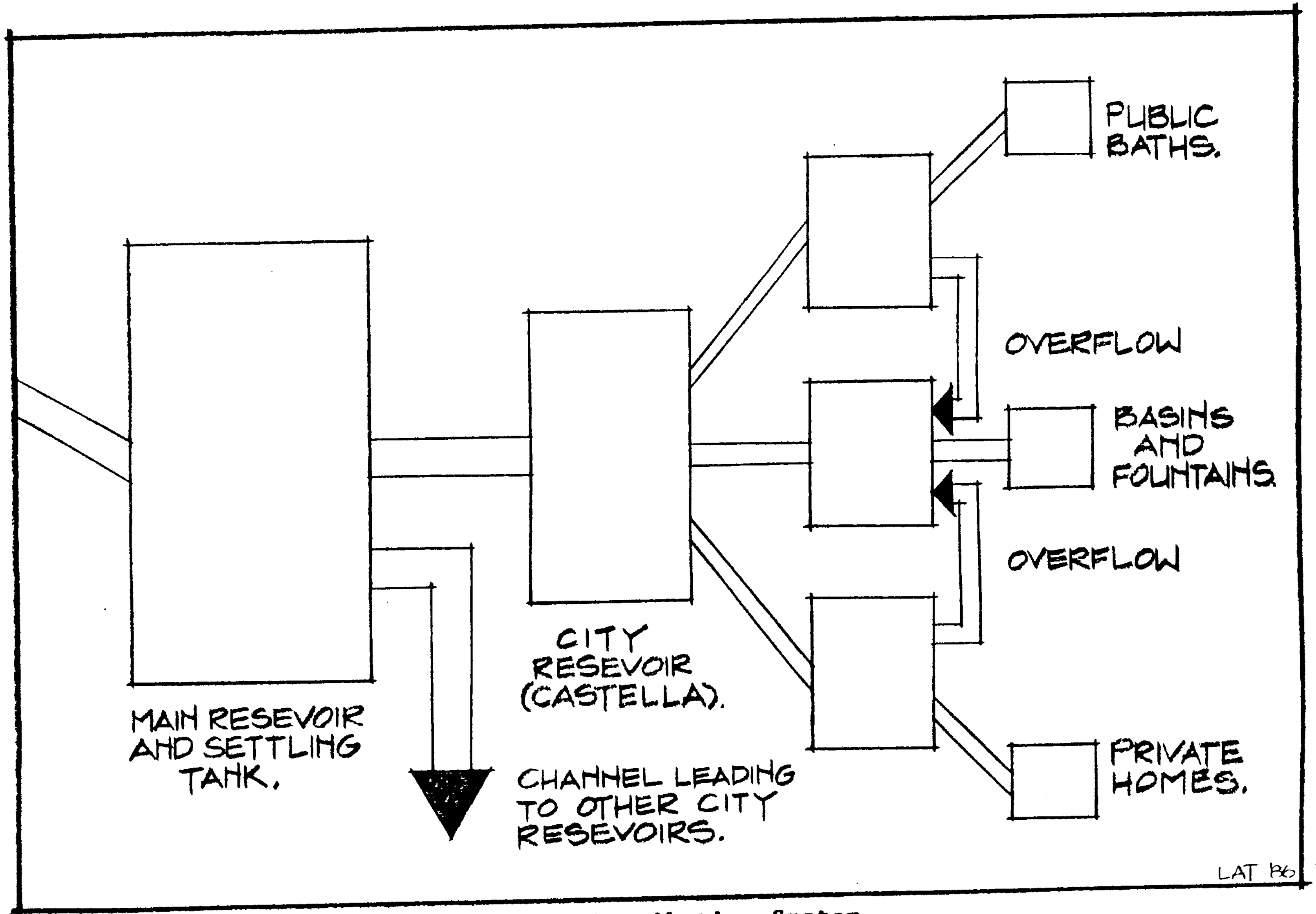

Figure 3 - **Distribution System.**

system.

Once the water had been conveyed from its source to the walls of the city it was discharged into the main reservoir and was ready for delivery. The main reservoir did not supply water directly to the consumer. It supplied water to urban reservoirs, located throughout the city and usually on a high elevation to maintain water pressure in order to supply water on the many hills of Rome.

From the city reservoir water was distributed to the consumer. Three pipes of equal diameter led from the city reservoir to three distribution tanks. These three tanks were earmarked for a particular function. The functions were to supply 1) public baths 2) pools and fountains and 3) private houses.[25]

The two outer distribution tanks had an overflow conduit which connected to the middle distribution tank. In this way, overflow water was not used for simply flushing the sewer system, at least not until all other needs were met first. Pools and fountains received the overflow because this was where the majority of the city population received its drinking water. To receive water directly into one's home or business required fees. Private persons in this category were not allowed to draw off water from the basins, since they had their own limited supply from their distribution tank.[26]

Private water supplies were regulated by the type of pipe that tapped the distribution tank or conduit. The unit value was a quinaria. The amount of water entering Rome was based on this value. Frontinus, unsure of the origin of the value, gives two explanations for it. The first explanation is credited to Marcus Agrippa. Frontinus wrote that Marcus Agrippa replaced the old reckoning of ajutages or punctures, by which water was formerly dealt out, with the quinaria, which was equal to five ajutages.[27] According to the second theory, Vitruvius is credited with the quinaria, and it took its name from the circumstance that a flat sheet of lead five digits[28] wide, made up into a pipe will form this ajutage (fig. 4).[29]

Frontinus goes into minute detail describing the quinaria in relation to the other size diameter taps and pipes. His discussion illustrates the difficulties in measuring volumes of water. More than likely the aediles[30] became less diligent in their duties of monitoring taps when new aqueducts were brought into Rome.[31] Frontinus tried to address this problem of illegal and incorrect taps to bring the system into good order so the next water commissioner could continue where he left off. Unfortunately, Frontinus' measurements, wholly inaccurate, are incredibly tedious and impossible to follow.

Frontinus, although inaccurate in his measurements of water, made up for these deficiencies by being a most able administrator. He mapped out the aqueduct system for the

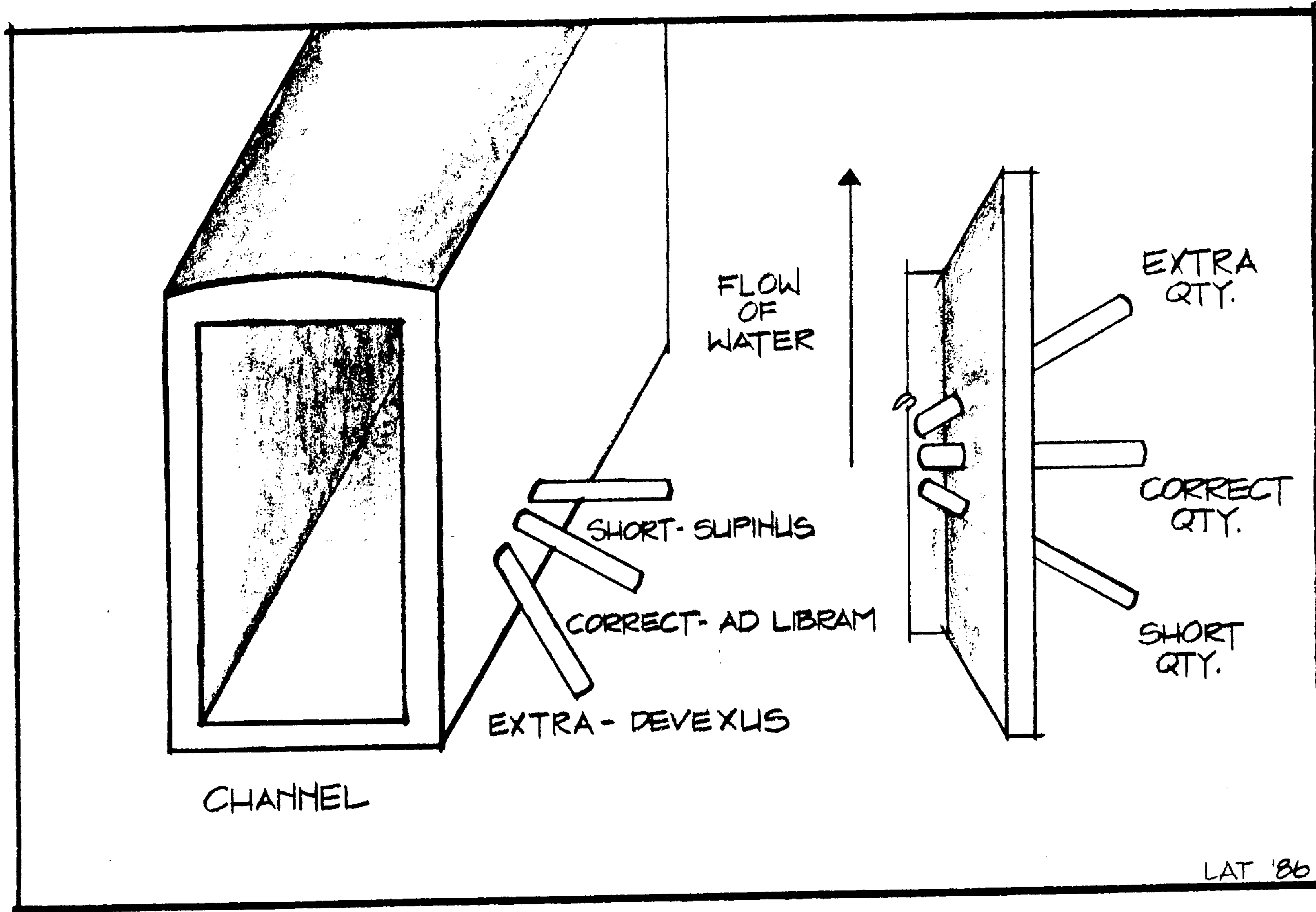

Figure 4 - **Quinaria.**

first time and destroyed branch pipes through which water was secretly diverted. He recovered the water that was unlawfully drawn by previous watermen or lost as the result of official negligence. Frontinus wrote that the recovered amount of water was virtually the same as finding a new source of supply.[32] Along with the locating of illegal taps, he was responsible for repairing the numerous leaks that plagued the aqueducts.

One can see how what appears, at first glance, to be a simple water system was in fact a demanding problem. The upkeep and repairs required an enormous administrative body that had to be both responsible and efficient.