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Hydraulic Engineering in Hippo Regius: Techniques and Innovations in Ancient Water Resource Management

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Abstract:

This study investigates the hydraulic infrastructure and water management system of Hippo Regius (modern-day Annaba) and its pivotal role in sustaining urban life. Thanks to its coastal location and the efficient administration of its aqueducts and hydraulic installations, the city maintained a consistent water supply, as attested by epigraphic evidence; The research examines the key elements of the hydraulic network, including water sources, aqueducts for transportation, cisterns, and reservoirs, with particular emphasis on the latter as exemplary models of hydraulic engineering in Roman North Africa.The study further explores the distribution mechanisms, such as castellum divisoria, and their role in channeling water to public amenities like thermae (baths), nymphaea (fountains), and private households. It also highlights the integrated drainage and sewer systems (cloacae), which reflect the city's advanced urban planning. Modern schematics and visual reconstructions complement the analysis, alongside archaeological findings and epigraphic sources, particularly Latin inscriptions that identify the curatores aquarum and other officials responsible for overseeing the water supply infrastructure.

Keywords: Hippo; Hippo Regius; water network; Hydraulic; Roman spring.

Introduction:

Water management was a central aspect that contributed to enhancing urban life and the development of cities in the ancient world. Hippo Regius, known today as the city of Annaba in Algeria, stands as a prominent example in this regard. Water played a vital role in supporting the daily activities of the city's inhabitants, and the steady flow contributed to Hippo Regius's prosperity and self-sufficiency across ages. Historical and archaeological sources confirm that the city faced no significant issues in securing water supplies, owing to its coastal geographic location and its exceptional management of the water network. The city had adopted a unique and integrated system for managing water resources, based on precise organization that ensured an abundant water supply and its appropriate distribution across all sectors.

The management of the water network was an integral part of the city's urban organization, with the system including specialized officials to oversee the regular maintenance and distribution of water. Archaeological inscriptions indicate that Lucius Arrius Amabibianus, a prominent figure, held the position of "permanent priest" and was responsible for the maintenance of wells and for ensuring water supply to irrigate gardens and fruit trees. This advanced organizational role suggests the city's strong commitment to meeting diverse water needs, including domestic and industrial uses, as well as supplying water to operate both public and private baths and fountains. This reflects

a profound awareness of the importance of water in meeting urban life demands and supporting productivity.

This study aims to explore the technical and architectural characteristics of the water network in Hippo Regius and to assess how well this network was integrated with the city's urban planning. The network's meticulous design not only provided water to homes and baths but also included drainage systems connected to public infrastructure, allowing the system to harmonize with the entire urban fabric. The city employed relatively advanced techniques for storing and transporting water, including the construction of large reservoirs, transport channels, and a well-regulated drainage system to prevent flooding. This reflects architectural and scientific skill in the effective management of natural resources. These reservoirs are considered unique models in North Africa, showcasing a blend of innovative engineering design and scientific knowledge in storage and distribution methods suited to the local environment.

To achieve these goals, the study relies on a range of written and archaeological evidence, especially Latin inscriptions that provide precise insights into the individuals who managed these installations and contributed to the development of the water network, enhancing our understanding of the community structure and individual roles. Additionally, the study uses modern images and schematics that document the remnants of the water network, offering a visual representation of the water systems implemented in the city. By analyzing these sources, the study aims to provide a deep understanding of the technical and architectural features of the water network in Hippo Regius and to highlight the impact of this system on the city's overall planning, making it one of the leading water architecture systems of the ancient world.

I- City Water Sources:

01-The Sources in the High Idugh Mountain Range:

The springs in the high Idugh mountain range were the primary water source for the city. From here, the main water channel extended approximately 11 kilometers to supply the city. The limited remaining archaeological evidence from this channel reveals that it was constructed using the Opus Mixtum technique. Mr. Maitrot documented the channel in a report, tracing its route from the high Idugh mountains to the ancient city, and provided a schematic that illustrates the construction method of this significant architectural structure (Maitrot, 1925).

The channel starts from the main spring, *Caput Aquae*, in the form of an underground square-shaped conduit with each side measuring 0.66 meters, while the channel depth is estimated at 0.55 meters. It was built using the *Opus Signinum* technique. This conduit extends for a length of about 30 meters and was covered in a pyramid shape with slabs of gneiss, the characteristic stone of the Idugh range, which was also used in the drainage channels along the city streets.





Image 01: Main Spring *Caput Aquae*
Figure 01: Sections of the aquaduc

At the foot of the mountain range, more than 760 meters away, just after crossing the Wadi Al-Bidah, the remains of a double channel system could be found, consisting of two parallel rows of arches made from fired bricks, which have disappeared in modern times. According to Mr. Maitrot, the channel included around twenty towers and hydraulic structures designed to regulate the flow of water. The height of the channel's arches reached 9.30 meters, with a width of 4.26 meters and a wall thickness of 2.10 meters (Maitrot, 1925).

02-Wells and Groundwater:

As previously mentioned, the Latin inscriptions mention the permanent priest, Lucius Arrius Amabibianus (L. Arrius Amabibianus), who was responsible for well maintenance. Wells were considered one of the most important water sources in the city, distributed across all neighborhoods from the north to the south and from the west to the east. The wells in Hippo Regius typically had a uniform design, with a depth ranging from 6 to 7 meters. Their openings were adorned with square marble slabs, with an average side length of 0.80 meters. The well's central opening had a diameter of 0.60 meter





Image 02- 03: A model of Roman wells in the city (prepared by the researcher).

II- Water Storage System:

01-The Great Hadrianic Reservoirs:

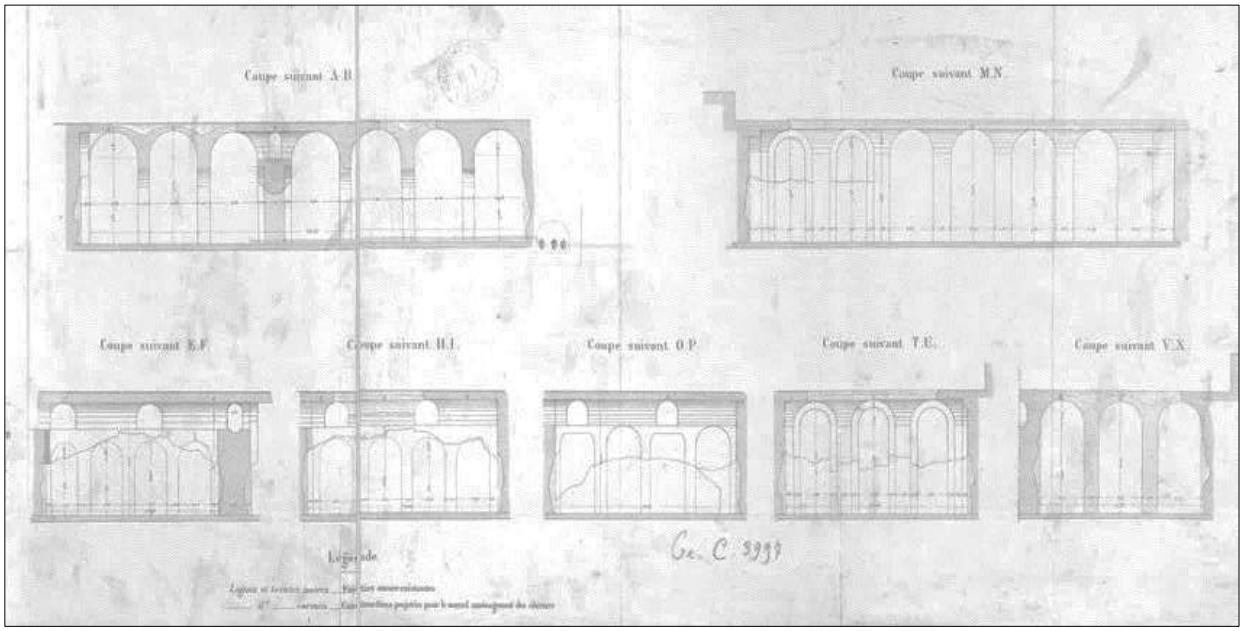
The city of Hippo Regius houses one of the most important examples of water reservoir architecture in Roman North Africa. These massive structures are located on the northern slope of the Saint Augustine plateau overlooking the city and are among the first archaeological sites discovered by French colonial authorities in Hippo Regius. They were discovered by chance in 1863 by engineer Alexandre Papier, who published a detailed report starting from the excavations that began in 1883 until their restoration work in 1893, overseen by engineer Soulier (Soulier, 1932). The purpose of the restoration at the time was to reuse the reservoirs for supplying water to the city of Annaba
The total water capacity of the reservoirs is 12,000 cubic meters, which is a very large volume considering its historical context, as they were built in the 2nd century AD during the reign of Emperor Hadrian, from whom they take their name. The Great Reservoirs consist of two large halls, each measuring 43.60 meters in length. The first hall is 17.90 meters wide, and the second hall is 16.75 meters wide. Their height is estimated at 10 meters. The halls are divided by rows of arches supported by two series of square pillars, each with dimensions of 1.60 meters

a. First Hall:

The first hall is divided into two sections by a wall with a thickness of 2 meters. The first section contains four basins, while the second section contains three basins. Both sections are supported by semicircular arches, each with a diameter of 4.80 meters

b. Second Hall:

Unlike the first hall, the second hall is a single, vaulted space. The width of its semicircular arches is 4.10 meters



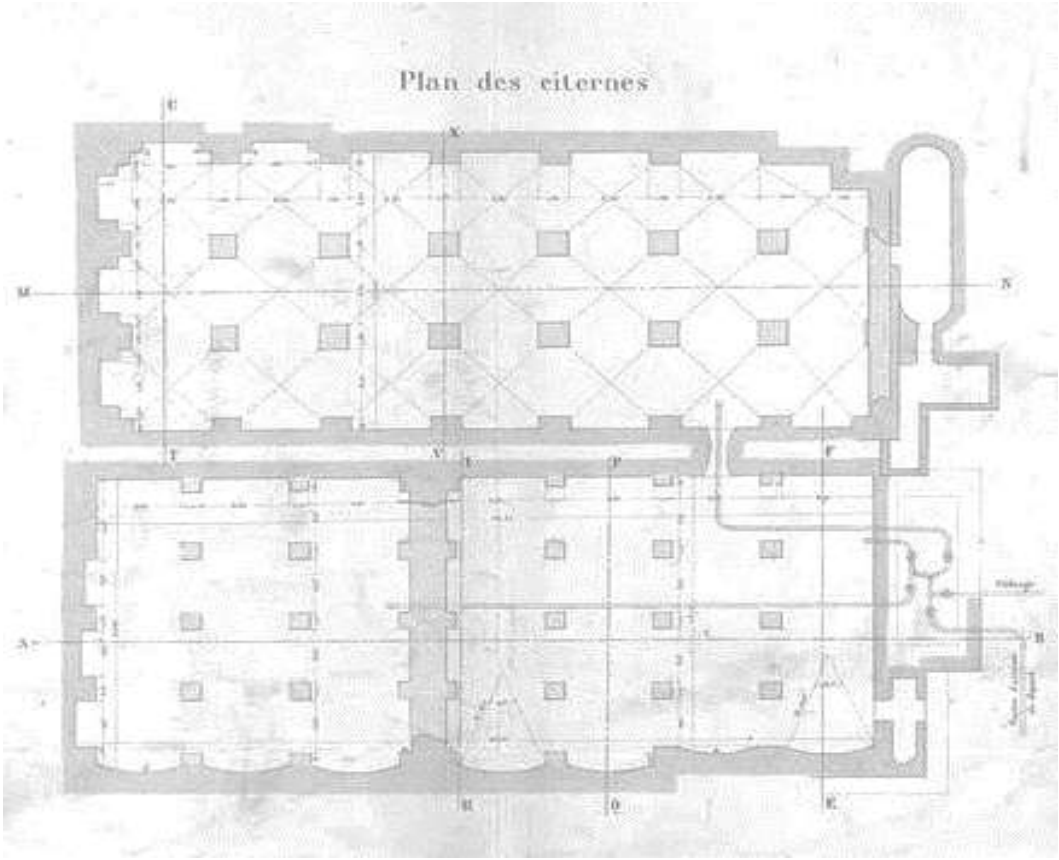


Figure 02 and 03: Plan of the Hadrianic Reservoirs in Hippo Regius
Soulier, F., *Les Citernes d'Hippone, Revue Les Chantiers Nord-Africains*, No. 07, 1932, p. 802.

02-The Reservoir of the Temple of the Twelve Gods (DII CONSENTES):

This reservoir is situated against one of the walls of the facade of the Temple of the Twelve Gods, located south of the museum hill and next to the southern baths. It is one of the largest reservoirs found within the urban area of the city. The reservoir has a rectangular cylindrical shape with a vaulted roof, measuring 16 meters in length, 5 meters in width, and a height of 6 meters.



Image 04: Reservoir of the Temple of the Twelve Gods (prepared by the researcher).

03- Reservoirs of the Gorgon Spring:





First Reservoir: Located directly behind the spring, with dimensions ranging from a length of 6 meters and a width of 4 meters. Its height is estimated at 1.10 meters. It is constructed using fired bricks and lime mortar.

- **Second Reservoir:** Located to the west of the spring, this is an underground reservoir with a large vaulted ceiling. The northern and southern ends of the ceiling are shaped into niches, with two columns placed in the center of the southern niche. Its dimensions are: length 8 meters, width 2.20 meters, and depth 2.10 meters. It is connected to the Gorgon Spring via an underground channel.
- **Third Reservoir:** Located to the east of the spring, inside a house that appears to have had an upper floor, as the underground reservoir lies below the stairs leading to the upper floor. It is rectangular in shape, with walls coated in cement mortar made from a mixture of brick remnants and lime mortar. Its dimensions are: length 3.20 meters, width 2.50 meters, and depth 2.10 meters.

04-Reservoirs of the Christian Quarter:





Image 07: Reservoir of the Christian Quarter
Image 08: Reservoir of the Church of Peace (prepared by the researcher).

- **First Group:** Located inside the Church of Peace, one of the reservoirs has been converted into a crypt for the church. The second one, which is likely to have retained its function as a water reservoir, is rectangular in shape, measuring 7 meters in length, 2.55 meters in width, and an estimated depth of 3.20 meters. Its walls are constructed with cement mortar made from a mixture of brick remnants and lime mortar, with a thickness of 0.60 meters.
- **Second Group:** Located in the southern house adjacent to the Church of Peace, these reservoirs are rectangular in shape and connected via a channel to the baptismal house. Their dimensions are: length 4.20 meters, width 1.14 meters, and an estimated depth of 5.30 meters.

05-Reservoirs of the Seafront Quarter:

In his article on excavations conducted in 1936, Choupaut describes the seafront reservoirs as being built from "concrete mixed with gravel, with a width of 0.80 meters, length of 1.60 meters, and depth of 1.40 meters. Both ends are rounded in vertical semi-cylindrical shapes, and their walls are fully coated with fine concrete. The floors are tiled with mosaics" (Choupaut.M, 1936). Choupaut also mentions a reservoir described as "having an odd shape," measuring 4 meters in length, 0.75 meters in width at the base, and 0.60 meters in height. The upper and lower corners are rounded, and it is equipped with a circular opening on one side, with its interior covered in cement.



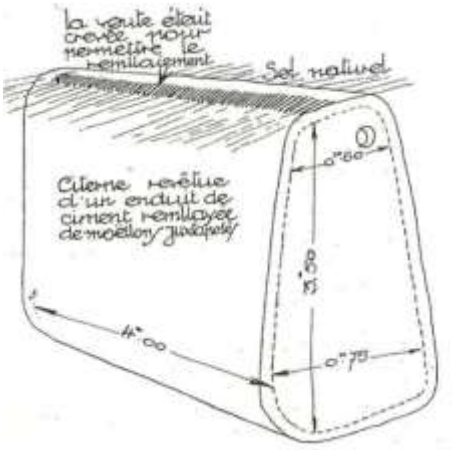


Image 09: Reservoir of the Seafront Quarter
Figure 04: Approximate plan of the reservoir. (*Choupaut M, 1936, p. 244)*

III- Water Distribution in the City of Hippo Regius:

The water channels in the city were distributed across various neighborhoods following a complex system that combined advanced Roman engineering and technology. Archaeological inscriptions and remnants of the channels show that they were systematically arranged, which helped improve the flow and distribution of water efficiently.

The water channels were connected to a large number of public and private baths and fountains, which were prominent features of the city of Hippo Regius. The baths contained an advanced heating system and comfort facilities, while the fountains were part of the urban design, decorating the streets and public squares.

01- Public Water Fountains:

a. Forum Fountain:

Located in the northeastern corner of the forum, near the main entrance to the public square, at the intersection of the two main streets (Cardo and Decumanus), it faces the main Cardo road, at the extreme northeastern corner of the square, where it leans against the northern wall of the forum. It was discovered in 1938 by L. Figuière. The fountain is rectangular, measuring 10 meters in length and 7 meters in width, with a semicircular end with a diameter of 2.20 meters. It has side basins and maintains a height of about 2 meters. Its interior semicircular section is covered with white marble, while the exterior walls and the floor are covered with local marble brought from the Ras el-Hamra quarries.



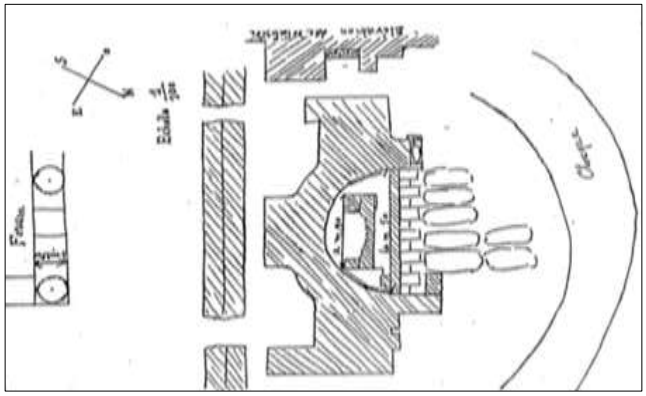


Figure 05: Plan of the Forum Fountain
Image 10: Forum Fountain

b. Gorgon Fountain:

In 1936, along the main road of Decumanus leading to the main entrance of the forum, a public Roman spring was discovered. The fountain is rectangular in shape, measuring 6 meters in length and 4 meters in width. It is located to the right of the main street, heading west towards the public square, where it intersects with the secondary Cardo street. Its façade was adorned with a large white marble mask, and the fountain is supported by an elevated reservoir, which supplied it with water that flowed from the open mouth of the marble mask depicting the famous Greek mythological figure, the Gorgon. The marble mask is 1 meter high and 0.80 meters wide, with an open mouth 0.30 meters in width.





Images 11 and **12**: Gorgon Fountain and mask **(**Prepared by the researcher).

c. Fountain of the Market:

The fountain was completely destroyed during the renovation of the market. However, it can still be identified by the remnants of the canal network connected to it, especially the lead pipes found beneath the base of the *Tholos* (a round building) at the center of the market. The fountain was linked to a water drainage channel, which measured 0.70 meters in width and an estimated height of 1 meter, reflecting the significant size of the water source and the strong flow of water.

d. Fountain of the Secretariat in the Christian Quarter

Located in the southern aisle of the B wing of the Christian Quarter, specifically at the end of the southern corridor of the Secretariat, this fountain supplied water to the religious sites and spaces within the Christian complex. Only the channel leading to the Tripartite Oratory remains. The water supply was facilitated through a clay pipe, extending north behind the niche of the Secretariat, and was connected to the main channel running along the secondary Cardo street that separates the Christian Quarter from the market.

e. Private Homes Fountains:

1). Fountain of the Villa at the Seafront: In the central courtyard of the Villa at the Seafront, there are two fountains.

- First Fountain: Located in the middle of the courtyard, it is enclosed on its western side with a semi-circular shape. The wall, constructed from fired brick, remains intact with a thickness of 0.40 meters and a height of approximately 1 meter. It is entirely covered with tiles of different colored marble. In front of the fountain's façade, two marble columns with base diameters of 0.60 meters stand. The floor of the hall in front of the fountain is paved with floral mosaic tiles.





Images 13 and 14: Fountains of the Villa at the Seafront (Prepared by the researcher).

- **Second Fountain:** Located on the eastern side of the courtyard, it is raised about 1.20 meters above the floor, accessible by a three-step staircase. It is noted that a second staircase leads to

the basement of the house. The fountain's walls are built from fired brick and are decorated with five semi-circular niches. These walls were also covered in marble, which still appears on the faces of the walls. The fountain includes two marble basins, which are adorned with mosaic decorations using the *Opus Spicatum* technique.

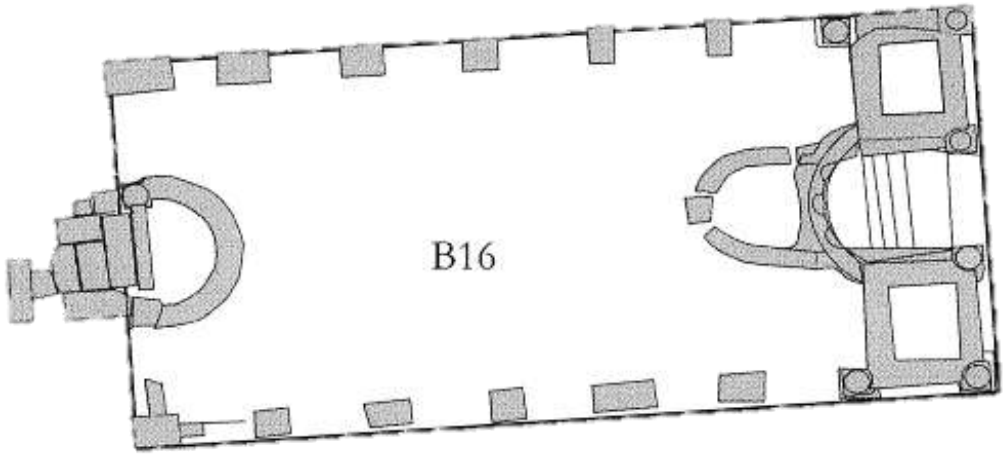


Figure 06: Site Plan of the Two Fountains in the Courtyard of the Villa at the Seafront
Delestre, X., Hippone, Paris, 2005, p. 117.

2). Fountain of the House of Julianus:

In the center of the atrium courtyard is a circular Lavacrum fountain, with a diameter of 1.40 meters, located in the place of the impluvium. The center of the fountain rises with a square well, with traces of rope marks still visible on the rim of its marble mouth. The fountain provided water to a private bath located in the southeast corner of the house, with only a small pool remaining, measuring 1.60 x 1.55 meters.

IV- Public Baths:

The city of Hippo Regius has around ten baths spread across various neighborhoods (Delestre, X, 2005), including two main public baths: the "Great Severan Baths in the North" and the "Small Baths in the South."

01- Great Severian Baths (Northern):

Located at the far northern part of the archaeological site, about 120 meters from the Christian quarter, this is one of the most well-preserved structures in the city, standing over 10 meters tall. Despite early discovery in the 19th century, the baths didn't undergo excavations until 1924-1926.

In 1950, the excavations were expanded to the northern sector of the site, where Marec managed to excavate the entire bath complex and restore the underground corridors' vaults.



Image 15: General view of the Northern Baths from the southeast (prepared by the researcher).

The layout of the Northern Baths is rectangular, with dimensions of 75 meters in length and 60 meters in width, covering an area of 2000 square meters, excluding its annexes. This architectural data corresponds to a medium-sized building by Roman bath standards. The structure is preceded by a 55.50-meter-long courtyard, entirely paved with marble and surrounded by a columned portico. To the north, there is a street running east to west, about 50 meters long, which separates the baths from the northern residential units, which remain unknown. On the western side, a portico runs along the entire western facade. Finally, to the east, the main facade opens onto a large square, which contains several swimming pools paved with marble.

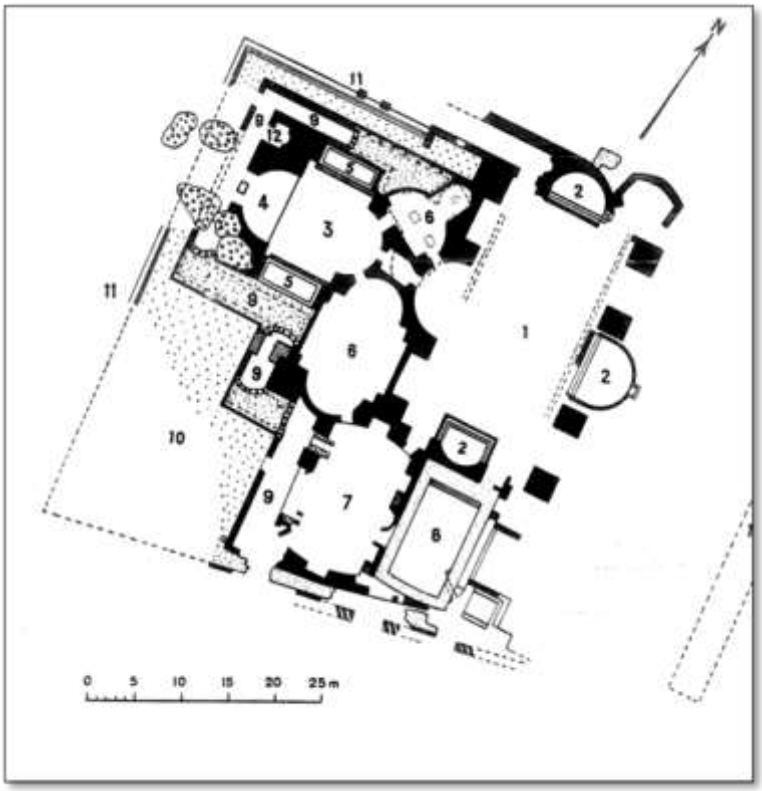


Figure 07: Plan of the Northern Baths, according to Marec (1954), with adaptations.

- **The Frigidarium (Cold Hall):**

It is the largest and most luxurious hall in the northern baths (number 1 on the plan). It is rectangular in shape, oriented from north to south, with a length of at least 30 meters and a width of 15 meters, not including the depth of the semicircular niches that open on all four sides of the hall. The hall contains three cold swimming pools, accessed by three steps, all of which were covered in gray-white marble (Gréco Stricto) and yellow saffron marble (Marmurum Numidicum) sourced from the Chemtou quarries. The ceiling of the grand hall is supported by four massive columns on each side. The floor is paved with a multicolored mosaic made from various types of marble, and even includes multicolored glass tiles. The corners were adorned with marble statues of gods, with a large number of statues found, including those of Hercules, Minerva, Aphrodite, and Bacchus, all of which are preserved in the Hippo Regius Museum.



Image 16: Photo of the entrance to the Frigidarium (Hippo Museum Archive)

The Frigidarium in the northern baths of Hippo Regius, due to its large size of 450 square meters, plays the most important role in the structure of the cold sector. It is one of the largest cold halls discovered in any Roman bathhouses in North Africa, which typically do not exceed 100 square meters in size. For example, the cold hall in Thuburbo Maius is no larger than 125 square meters, and the same size is found in the cold hall at the city of Madaure. In the great baths at the fishermen's baths of Lambèse, the size reaches 150 square meters, and 250 square meters at Caesarea, even 300 square meters in Maktar, and 330 square meters in Sbéitla. It is even larger than the cold hall in the northern baths of Timgad, which measures about 400 square meters. Therefore, the cold hall in the northern baths of Hippo Regius is an exceptional case. (Thébert.Y, 2003)

- **The Large Tepidarium (Warm Hall):**

Located at the southern end of the third hall, it is accessed through a narrow corridor (number 7 on the plan). It is a large rectangular room, measuring 17 meters in length and 12 meters in width, ending in two niches on each side. A small rectangular recess was carved into each side, and in the

center, there is a large swimming pool (number 8 on the plan), measuring 10 meters in length and 6 meters in width. The pool extends from north to south, with its walls covered in marble. The floor was heated via the hypocaust system, which is lower in height compared to the hot hall, and 29 rows of the hypocaust system can be counted, although a large part of it is damaged. As for the walls of the hall, Marac mentions that the Tepidarium was decorated with frescoes depicting figures and plants (Marec.E, 1954).



Image 17: General view of the remains of the swimming pool in the Tepidarium (prepared by the researcher).

On the western side of this large pool, there are two small rooms, of which only the side sections and remnants of the marble pavement remain. Next to them is a deep well with a square shape, each side measuring 3 meters. On the long eastern side of the Tepidarium, there is a long corridor that was used to provide hypocaust services to the hot and warm rooms. (Number 9 in the plan). This corridor makes four right-angle turns, with the first turn from north to south being 12 meters, then 6 meters, 9 meters, and reaching 12 meters, where it makes another similar turn heading north, extending for another 20 meters. In the far northeastern corner of the building, the corridor turns again at a right angle and descends along the long northern wall of the large hot room, leading to a room located below the hot room directly. This room is semi-circular in shape, with a length of 8.10 meters, a width of 3.50 meters, and a height of 2.80 meters. Its ceiling is a dome supported by two large supports, dividing the room into two sections. At the top of the semi-circle, there is a vaulted ceiling, 1.25 meters high, containing a circular pool with a diameter of 1 meter. Its walls are coated with a solid layer of cement, and it is believed to have been the main room for the water supply that fed the hot room directly above it.

- The Large Hot Room (Caldarium):

From a functional perspective, this bathhouse offers a layout almost identical to the imperial baths known during the Roman era. The large hot room, *Caldarium* (number 3 in the plan), where bathing takes place, is located at the center of the facility. On either side of it are two rectangular-shaped pools (*Alvei*) for collecting hot water (number 5 in the plan). One of these pools lies directly beneath the remnants of the tall structure and is rectangular in shape, measuring 10 meters in length and 7 meters in width. At both ends of the pools, there are stairs equipped with air ducts. The *Caldarium*

is directly connected to the *Lacunicum*, a high-temperature steam room (number 6 in the plan), which was used for sweating, eliminating fat, and removing dirt from the body through intense vapor exposure. Remnants of the marble tiles that once covered its walls and floors can still be seen in this room. Marec confirms that it contained the *Labrum* (number 4 in the plan), a basin used to store hot water for use in the sweating room (Marec.E, 1954).



Image 18: Remains of the Caldarium (Prepared by the Researcher).

On the opposite side, a narrow corridor connects to the Frigidarium, with passageways leading to two new hot rooms on either side. The first one is located to the north and is a small semi-circular room that ends with a deep pool (alveus), also connecting to the Frigidarium. The second hot room is located to the south, with the same design and dimensions as the main Caldarium. It extends vertically and connects to the Tepidarium. These three rooms were also built on floors equipped with a hypocaust system. The structure of the main Caldarium has higher supports for the hypocaust system compared to the Tepidarium, especially under the side pools, where the column heights reach 1.20 meters. All three rooms' walls were clad in marble supported by fired brick tiles, and all contain interior walls lined with vertical thermal pipes, which are still clearly visible, despite significant collapse and damage. It is also worth noting the severe damage to the hypocaust system, especially under the main Caldarium.

- **Appendices :**

The site has two courtyards, one located to the south and the other to the east. The eastern courtyard is a large area entirely paved with marble, making it a wide vestibule for the bathing complex. It is equipped with three porticos, supported by marble columns crowned with Corinthian capitals (number 10 in the plan). Access to the courtyard is through two stairways, and it is equipped with a drainage channel similar to the one in the forum. The western portico is also paved with marble

and extends from east to west. The eastern courtyard is connected to it through a portico located at the southeastern corner, stretching approximately 50 meters in length from north to south. The courtyard has retained its concrete flooring, which Marec believes was dedicated to physical exercises or sports activities. At the center of the courtyard is a wide threshold that opens to the right. This is believed to be the main entrance to the bathing complex, through which one enters the large Frigidarium. Excavations carried out in the 1920s revealed numerous epigraphic inscriptions, the most important of which is an honorific inscription dedicated to Emperor Septimius Severus, allowing the dating of the site to the period of his reign between 211 and 217 AD (AE 1958).

02- The Great Southern Baths:

The southern bathing complex is located at the base of the museum hill. It spans a total area of 2,500 m². The layout of this complex is similar to that of the baths in the city of Timgad, differing only in size, as its length is approximately 48 meters and its width is 40 meters. Regarding the internal architectural organization of the site, the following observations can be made:

- **Main Entrance of the Site:** The main facade of the site consists of a wall with a thickness of 0.80 meters, from which one enters through a portico that extends eastward for 2.20 meters. Here, a small entrance leads into the Frigidarium (cold room). To the south, another portico extends for 3.10 meters in length and 1.20 meters in width, ending at a staircase with 12 steps and a total height of 4.10 meters. Below this staircase, a narrow portico extends, equipped with underground channels, likely dedicated to service areas, as it connects to a secondary entrance on the southern facade. This narrow portico provides access to seven hypocaust furnaces located in the southern half of the complex, ensuring the heating of both the hot and warm rooms.
- **The Great Frigidarium:** It occupies the northern half of the bathhouse and is accessed directly through an entrance in the main hall's portico. In fact, the Frigidarium consists of three rooms, with the main hall located in the center. It is 7 meters long and 4.20 meters wide, containing two semi-circular basins for collecting cold water, each 3.95 meters in length and 3.25 meters in width, with a depth of 0.62 meters. The floor is made of concrete, though it was originally paved with marble tiles. The two secondary rooms are equal in size, each measuring 3.25 meters in length and 3.10 meters in width, positioned on the east and west sides of the main hall.



Image 19: The main entrance and the eastern corridor (prepared by the researcher)

- The Large Tepidarium:

It is located at the center of the complex and connects directly to the cold room via two entrances located to the north. It consists of three rooms, one of which is the main hall, measuring 5.30 m in length and 4.20 m in width, situated centrally within the complex. This room has two rectangular pools located to the south, with two square rooms, each 3 meters long, to the left and right of the main hall.

- The Large Caldarium:

The entrance to the large caldarium of the southern baths is via a corridor located between the two pools of the Tepidarium. The caldarium is a large hall that opens onto two smaller rooms, unlike the previous cold and tepid rooms. The caldarium is trapezoidal, extending from east to west with a length of 5.25 m and width of 4.10 m. It narrows to the south, reaching a length of 4.20 m and a width of 3.05 m, and is equipped with three rectangular pools. The eastern and western pools each measure 2 m in length and 1.10 m in width, while the southern pool is 2.50 m in length and 1.10 m in width.

Numerous inscriptions have been discovered, the most significant of which are dedicated to Julia Domna and Aurelius Honoratus. An inscription found at the main entrance indicates that the building was renovated in 198 AD by the city council. (Marec E., 1954)

03- Minotaur Baths:

Located southwest of the southern baths, about 75 meters away, the Minotaur baths are rectangular in shape, extending from north to south, covering an area of about 250 square meters. To the north, it is bounded by a road leading towards the forum, 2.20 meters wide. The main entrance is located in this wall, raised 0.20 meters above the road level. Archaeological research in this site began in

1927 by researcher Marec (Marec E., 1952), who made a crucial discovery immediately after the entrance. A rectangular hall measuring 7.50 m by 6.90 m, paved with black-and-white mosaic, was uncovered. This hall connects to two rooms: one to the east, measuring 6.90 m by 3.90 m, also paved with black-and-white mosaics, and a third room opposite the main entrance, separated by a small corridor (1 meter wide), which is also decorated with white and black mosaic tiles featuring geometric patterns. The third room is square, measuring 7.50 m on each side, and its floor is decorated with a multicolored mosaic depicting a labyrinth with an image of the mythical creature, the Minotaur, at its center.

In 1952, Marec continued his excavations and uncovered the cold room, which, in addition to the previously discovered features, includes a series of pools located to the east of the Minotaur room. Directly to the right of the room is the first pool, made of white marble, measuring 3.25 m in length, 2.80 m in width, and 1.15 m deep. The pool is accessed via two steps, each 0.35 meters wide, and its sides are covered with marble tiles measuring 1.10 m by 0.50 m. The pool has a lead pipe in its southeast corner, 0.08 meters in diameter. To the south of this pool is another pool, built with rubble mixed with small stones, measuring 3.90 m in length and 3.75 m in width, with a depth of 0.70 m. This pool has been significantly damaged. Further south, a third pool is found at the farthest extent of the excavation, appearing to be larger than the previous two.

The wing containing the hot rooms is located to the west of the Minotaur room and includes a square room in the center of the building, equipped with a hypocaust system. The room measures 10 m in length and has two entrances: one in the northern wall and the other in the southern wall, both leading into large spaces with concrete floors. The northern space contains 13 tiles from the hypocaust system, although much of it has been damaged. The southern space has a small pool located at the extreme south of the room, connected to a channel that extends from east to west through a narrow corridor surrounding the hot wing, which runs from north to south and is 1.50 meters wide. The wing with the warm rooms is located west of this corridor and extends from north to south. This wing is divided into several rooms that are unclear due to significant damage caused by dense vegetation covering.

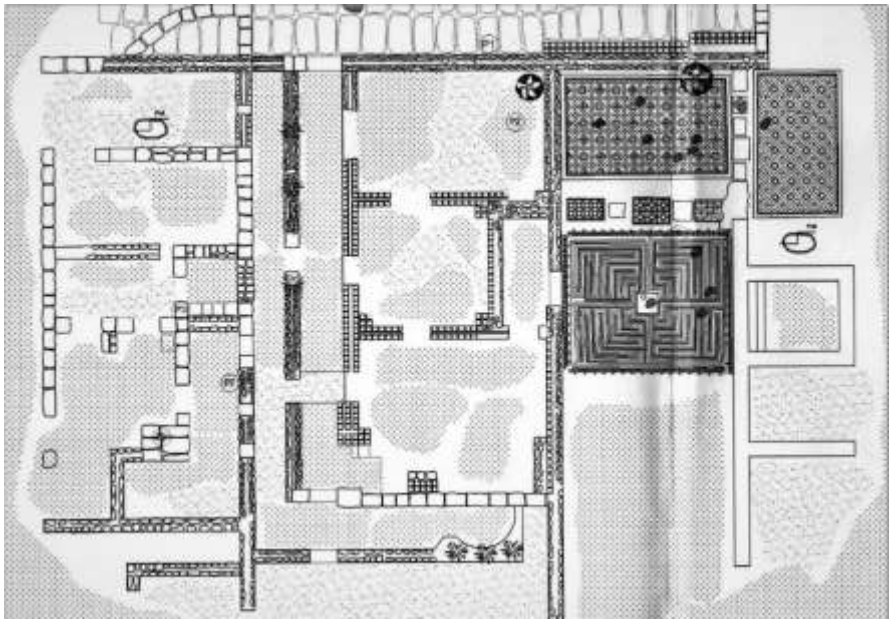


Figure 07: Plan of the Remains of the Minotaur Baths (Prepared by the Researcher)

V- Water Drainage System in the City:

As previously mentioned, excavations by the researcher Marec have confirmed that the rainwater drainage system in the city was directed entirely to the north. Every street was equipped with a precisely constructed drainage system, where all the channels were connected to a main drainage channel located in the northern part of the city, which then emptied into the Boujamia valley. (Lassus, J., 1958).





Image 20 and 21: Models of Water Drainage Channels in the City of Hippo Regius
(Prepared by the researcher)

This system reflects the pre-planned design of streets equipped with a large drainage system, as well as the volume of flowing water, with channels that are over 1 meter deep and 0.70 meters wide. The streets and drainage channels were designed in such a way that the latter were never perpendicular to the facades of the residential blocks (Insulae). Despite this careful planning, the network was insufficient to meet the needs of stormwater drainage, due to the constraints imposed by the morphological structure and the natural environment of the city's geographic location.

Conclusion:

The management and operation of the water network in the city of Hippo Regius stands as an exemplary model of urban and engineering planning in Roman times. Through an integrated and precise hydraulic system, the city utilized diverse water sources such as mountain springs, wells, reservoirs, and canals for water transportation, in addition to the fountains that adorned public spaces. This system played a vital role in providing a sustainable water supply to meet the daily needs of the city's inhabitants, as well as the industrial and agricultural demands.

The role of the water network was not limited to meeting basic needs; it also contributed to improving the quality of life in the city. It helped provide clean water to residents and played a crucial role in promoting public hygiene and health, thus supporting social and economic stability. Furthermore, this network contributed to the sustainability of urban growth, as it facilitated the expansion of the city and supported its diverse economic activities.

The Romans' attention to this hydraulic system reflects an advanced level of scientific and engineering appreciation and demonstrates the civilization's ability to adapt to environmental and geographical challenges, including the city's location, which posed problems related to water provision and distribution. Through the innovation of complex engineering solutions, they ensured the long-term sustainability of the city's water resources.

This engineering and architectural legacy serves as a testament to the genius of Roman civilization in natural resource management and remains a valuable source for modern archaeological and hydrological studies. The remains of this water network continue to symbolize the development of applied and engineering knowledge that helped thrive Roman cities, offering important insights into how water was sustainably managed in ancient times.

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