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Ave's watermills: Territory, Architecture and Construction Systems

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The Ave River is located in the north of mainland Portugal; the specific area for this study being on the border of two regions, the Douro Litoral and the Minho, in the middle and lower course of the Ave river.

The Braga district encompasses the Vila Nova de Famalicao municipality which includes the north bank of the Ave river, and in the district of Oporto the municipalities of Trofa and Santo Tirso, which includes the south bank of the Ave as well as the Vila do Conde municipality covering both banks of the Ave. Along the course of the river, which extends for 44 kms between the mouth of the Selho river (Municipality of Guimarães) and the mouth of the Ave river (Municipality of Vila do Conde), a set of watermills, located in pairs on the northern and southern banks of the river, can be seen.

The origin of these watermills dates from the thirteenth century, as evidenced by a donation letter of King Afonso the third.[1] Their decline was evident by the late twentieth century.

Fig. 1. *Location of the hydrographical area of the Ave River in Northern Portugal.*

In the Ave Valley, from the mid-nineteenth century, agriculture became a secondary activity and during the twentieth century industrial activity began to occupy a prominent place in the region. Due to the progress of the textile industry, the Ave River suffered intense pollution that contributed to the movement of the population away from the river. In parallel, craft activities such as cereal grinding, flax manufacturing, and wool production, which had developed in the watermills, encountered strong competition within their industries which triggered an unequal struggle in the production and trade of flour and clothing. As a consequence of these factors, the Ave watermills gradually became disused and today the many examples can only be found in ruins. This heritage, exposed to permanent erosion, is disappearing year on year thus erasing the "memory" of a collective activity developed in a self-sustaining mode. Consequently the ancestral relationships between man and river are fading, secular traditions of handmade flour, flax, wool and paper have been lost, as well as the knowledge and art of traditional building techniques used in the construction and maintenance of the watermills and their weirs. These mills and weirs had been improved by the millers for generation after generation, over many centuries.

The Watermills as a "Landscape System"

In order to understand the influence of watermills over the region, we must analyse them as an interlinked 'landscape system' which follows the Ave River from its source to its mouth. Along 44 kms of the course of the Ave River the estimated existence of 82 watermills, which exploited the hydraulic energy of the river flow, accomplished several tasks such as cereal grinding, flax maceration, wool cloth fulling, paper production and sawmilling. These numerous watermills are located on both banks of the Ave River at regular intervals, forming a complex construction along the watercourse as an inter-regional system (which we term a "plurinuclear diffuse system"). This system has been designed in close inter-relationship between the parts and the whole, in an ongoing dialogue – upstream and downstream – both in the occupation of the river banks and in water energy exploitation. This systemic management of water resources allowed the balance of water levels to be maintained, as well as the proper functioning of the tens of existing watermills on the Ave.

The interrelationship between the mills is understood when the activity of the millers along the river course is analysed. For example, if the miller in Bairros' Watermill raised the height of his weir by over 0.5 m, it would back up the river flow and prevent the functioning of the Barroso Watermill, located 2 km away upstream. The implementation of quotas for the frequency of weirs along the river was meant to control the river's water levels without ever compromising the balance of the entire system, on a regional scale. Therefore the set of watermills which are distributed along the river can be understood as a

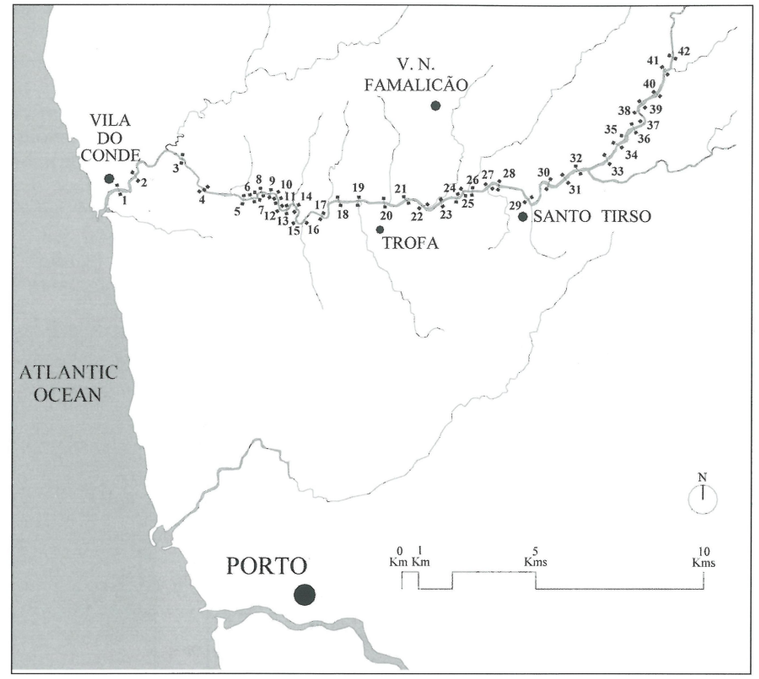

Fig. 2. *Location of the watermills in the lower and middle reaches of the Ave river (R. Bruno Matos).*

regional-scale installation that transformed the river into a large artificial watercourse, visible by satellite, with a steady surface gradient intended mainly for the production of energy to enable various activities. Despite the regional dimension of these constructions, the integration, balance and harmony established between the sites and the watercourse are surprising. In order to achieve this level of integration it was necessary to gather, generation after generation, a deep knowledge about the river's natural conditions – its currents, flows, tides and the impact of annual floods.

The location of each watermill was carefully selected depending on the river's natural design. The intensity and direction of the water currents were considered in order to ensure the required energy utilisation for a watermill's duties without compromising the integrity of the building. Moreover, the distribution of watermills along the river varies according to the topography and flow; i.e., when the river crosses a floodplain, energy efficiency becomes lower, so the watermills must be distant from each other, by approximately 2 km; the frequency of deployment is long. On the other hand, when the river runs through more sharp relief the energy efficiency increases, so the watermills are closer to each other and the frequency of deployment is short; the distance between them is only about 800 m. This produces a harmonic relationsip between topography and

Fig. 3. *Moinho no rio Ave, Vila do Conde (source, Adelaide Machado).*

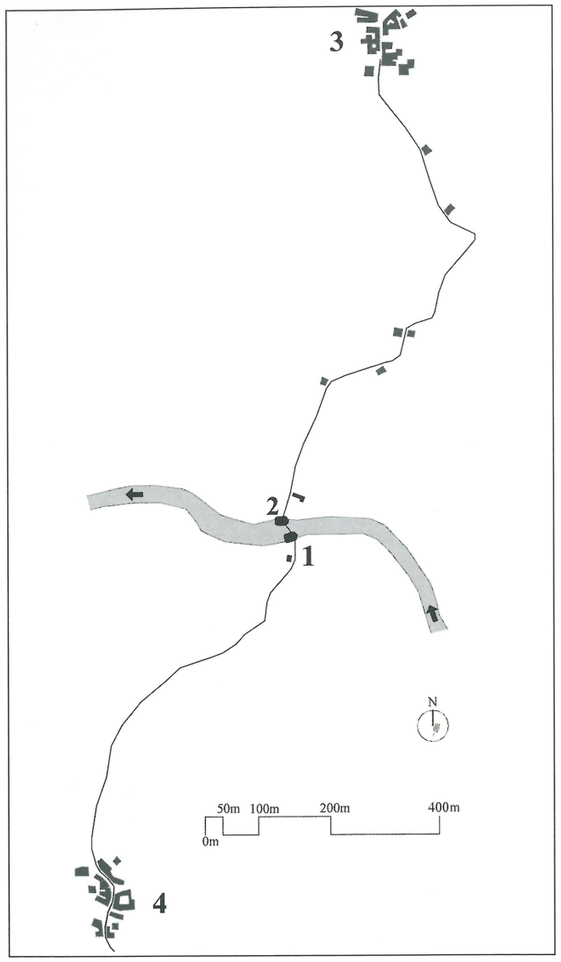

Fig. 4. Route between the villages to the north and south of the Ave River. 1 – Porto Watermill; 2. – Abade Watermill; 3 – Parada Village; 4 – Olaia Village (R. Bruno Matos).

Fig. 6. Abade Watermill (R. Bruno Matos).

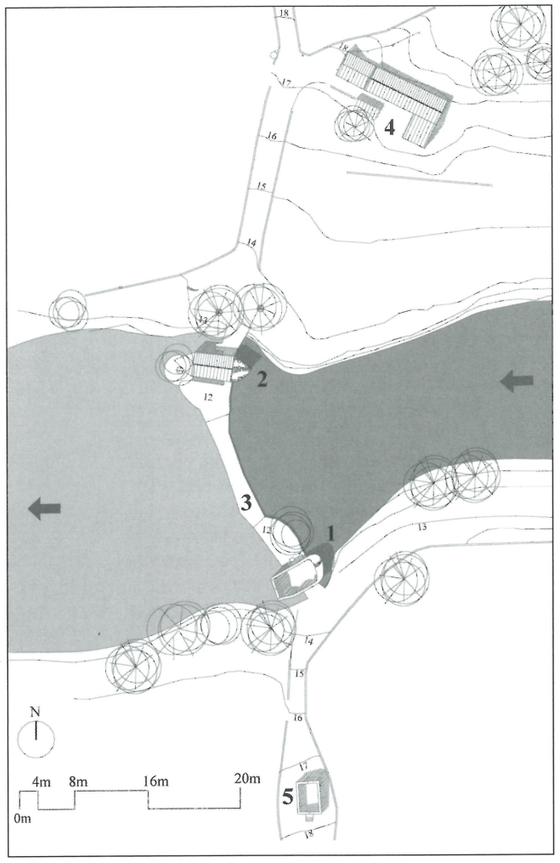

Fig. 5. Molinological site. Topographic contextualisation. 1 – Porto Watermill; 2 – Abade Watermill; 3 – Weir; 4 –Millers House; 5 - Flour House (R. Bruno Matos).

mill deployment (a "plurinuclear diffuse system") along the river which in turn produced a sympathetic pattern in the adjoining land and hinterland. In order to understand this pattern we need to analyse the deployment of the watermills and their weirs. In general, the watermills were established in pairs on opposite banks, interconnected by their weirs.

This feature, which is systematically reproduced along the river, gives rise to small bridges that unite the two river banks. This combination is replicated dozens of times along what would have been a natural barrier and allowed for the continuity of the old primitive paths and consequently communication between villages. This aspect helped to create a regional unit joining the south and the north where "*o rio não separa, mas une*" *("*the river does not divide but unites*")*.[2] From this principle several issues arise; has the communication that the watermills and their weirs, provided between opposite banks of the river, influenced the traces of the paths between people? Did these places of permanent contact with water contribute to the definition of the landscape along the river? Is there a connection between the sites of the watermills and the location of the main bridges in Ave's valley?

The Architecture of the Watermills on the Ave River

The watermills on the Ave are vernacular buildings with a constructional system similar to that used in the traditional/regional vernacular architecture, together with some peculiarities related to function and location. The main function is related to subsistence food requirements or to the performance of primary activities. The main activity was flour manufacturing for the production of bread. However, in addition to flour-milling, there were other activities related to flax maceration, wool cloth fulling, paper production and sawmilling. In this sense the watermills may be considered as multifunctional buildings.

Regarding their construction, watermills were conceived to resist permanent contact with water and the force of the river, and simultaneously accommodate and protect its mechanical system. This mechanism, of Roman origin, was driven by a vertical undershot waterwheel.

Regarding their spatial organisation, watermills have undergone transformations over the centuries. Initially they were small buildings with only two floors. The ground floor was for grinding and the lower floor, called the *cabouco* (pit), housed the gears of the mechanical system. The construction materials used were stone, wood and thatch for the roof. "*Em 1713, a 31 de Maio, se procedeu à apegação «de hua casa de Azenhas com três rodas e hum tapado» sita no lugar de Real, mas «q. no prazo velho se chamão da Asparella». Eram tais casas, segundo o respectivo auto, «ametade de colmo e metade de tilhado»* " (In 1713, on 31 May, we proceeded to 'the house of Azenhas with three wheels and heavily roofed' and situated on the place of Real 'and in the old times was called Asparella'. Such houses were known to be 'half thatch and half roofed')".[3]

The stone floor began as a small but ample space, which could reach 50 m², designed to accommodate no more than one or two sets of millstones and their hoppers, and the respective surrounding area where the miller could perform his activity, as well as store some bags of cereal and flour. At that time the mills produced flour only to supply small villages or religious establishments, such as monasteries and convents.

Over time, flour became a valuable commercial product, and Ave's watermills began to supply nearby villages, as well as to establish trade with several cities like Oporto. The watermill of Agra da Várzea, located in the municipality of Vila Nova de Famalicão, was exporting flour to Germany during the Second World War.[4] With the increase in flour production, watermills were transformed architecturally. Nowadays, watermills on the Ave River can be found with floor areas that can reach 90 m². In the municipalities of Trofa and Vila Nova de Famalicão several productive typologies can be found. There are watermills with only one waterwheel to drive two pairs of millstones; with two waterwheels to drive four pairs of grinding stones; with three waterwheels driving three pairs of grinding stones and a device for flax; with four waterwheels to operate four pairs of grinding stones, and even with seven waterwheels powering ten pairs of millstones. In some cases, architectural changes can be observed which provided a vernacular building with industrial features, giving way, in the twentieth century, to the large planned modern factories, "*…sobre o Ave, encontravam-se instalações com 10, 12 e até 15 pares de mós…*" ("around Ave, are systems with 10,12 and 15 pairs of millstones").[5]

In order to understand the spatial organisation in a watermill, the watermills of Bairros or Portela, located on the left bank of Ave River in the parish of Santiago de Bougado (municipality of Trofa), can be used as an example. The watermill of Bairros began as a two-floor building and in the mid-twentieth century it gained a third floor; it had the *cabouco* (pit), then a ground floor and a first floor. The "*cabouco*" or "hell" is the most technical area of the building where the gears of the grinding system are located. Access to this floor is restricted and is facilitated through a trap door located in the flooring of the ground floor storey. The miller goes into this space occasionally to perform maintenance and fine-tuning of the mechanism. The ground floor was designed to house the millstones which received the cereal that would become flour. On this floor there were four sets of millstones, but currently only one is fit to grind. They were driven by four waterwheels, three of them on the river side of the mill and one on the landward side. From this floor you can access the river, the weir and the bearings that supported the horizontal shafts of the waterwheels. Outside, between the building and the weir, there was once a device where flax was macerated, as well as fishing gear and a boat to cross the river. These were referenced in the parish records from the eighteenth century, called *Barquinho de Chaves*.[6] The first floor is a large space from which the roof structure is visible. It was used for the storage of cereals, flour and maintenance tools for the grinding mechanism.

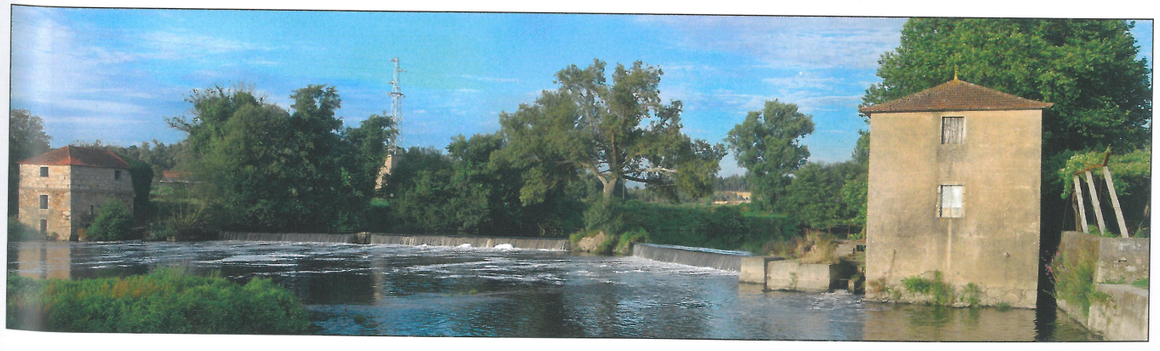

Fig. 7 Molinological site 18. Bairros Watermill, Municipality of Trofa, connected to Chaves Watermill, Municipality of Vila Nova de Famalicão, by their weir (R. Bruno Matos).

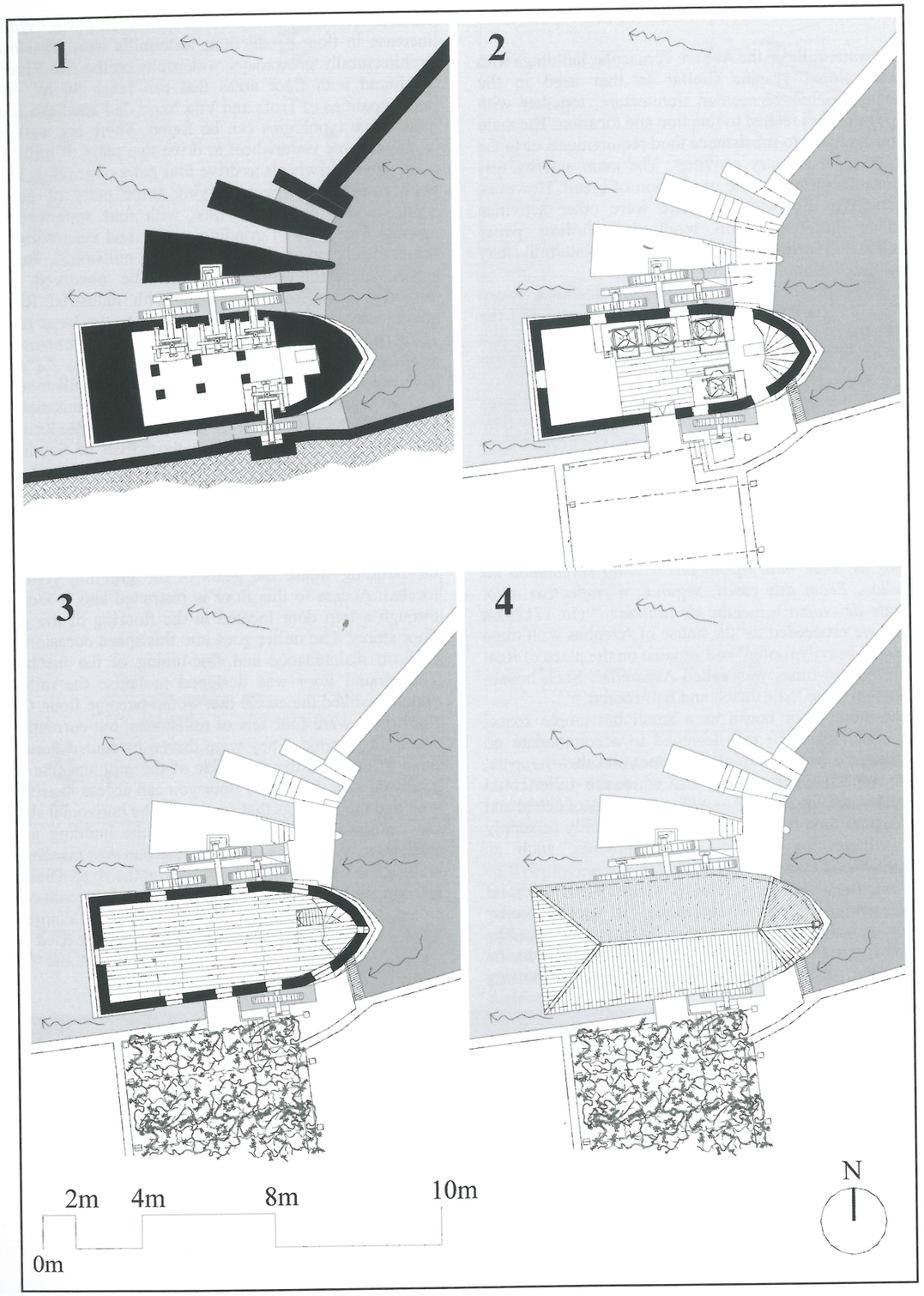

Fig. 8. *Measured study of the Bairros Watermill. 1 - Plan of the Cabouco; 2 - Ground floor plan , 3 - 1st Floor plan, 4 – Roof plan (R. Bruno Matos).*

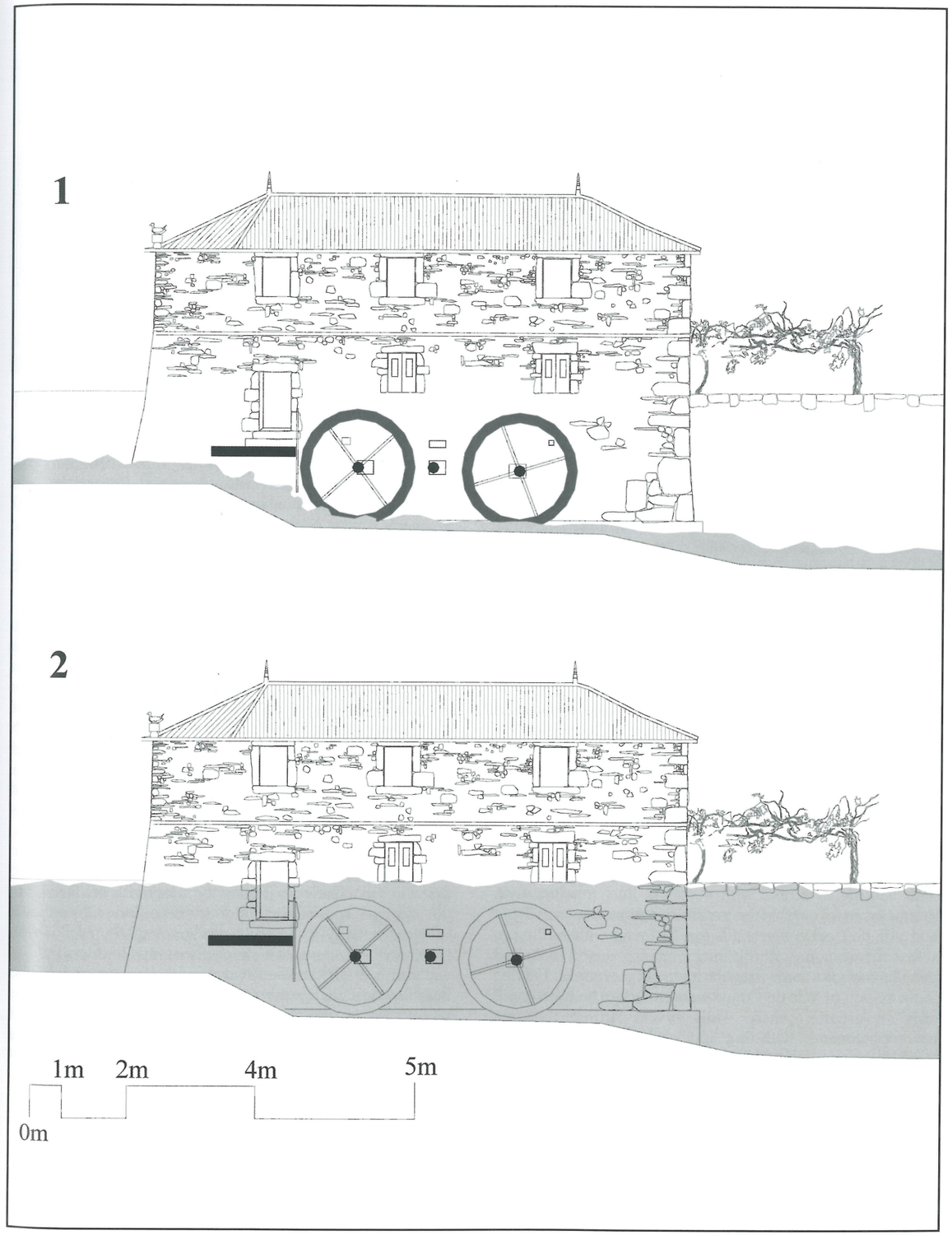

Fig. 9. *The Bairros Watermill. 1 - natural height of the water level; 2 - height of the water level during the flood of 2013 (R. Bruno Matos).*

Fig. 10. *Azurara watermill, Vila do Conde, in 2010 and the same mill when still working (R.Bruno Matos).*

Traditional Construction Systems

Ave's watermills are buildings constructed according to traditional building systems. They use local materials, such as stone, wood and iron. Whilst there are construction principles common to all of them, there are some specialities that characterize them individually. That is, on the Ave river there are watermills with modest construction systems, such as the Cerro watermill, located in the parish of Guidões (Municipality of Trofa). But there are also watermills with fine masonry work shown in the cornerstones, quoins and cutwaters, as well as minute details with stone armorials surmounting the main entrance and even battlements, such as in the Azurara watermill. This watermill is located on the left bank of the Ave River, in the Municipality of Vila do Conde. Stone is the overall structural building material and it is used for the exterior walls, the floors, the access ways, the weirs, and the structures retaining the river banks.

The type of stone used varies according to the geological characteristics of the territory. In the region of Vila Nova de Famalicão and Trofa, watermills can be found with walling in schist, with a yellow hue, together with mortar layers of clay. In the transition regions between Trofa and Vila do Conde watermills can be found with walling in schist combined with granite, quartzite and rounded pebbles that give some irregularity to the elevations. Finally, in the region of Vila do Conde watermills can be found built only in granite, where walls reveal skilled masonic accomplishments with big blocks laid without mortar (*feel-lute*).

Timber is used both for structural elements of the building and the construction of hydraulic devices. The roof structure and floor covering are in pine or oak and are made using traditional construction methods. The roof structure comprises rafters, locking pieces and the secondary structure. In the hydraulic machinery there is a much broader range of types of woods and greater constructional complexity. There was specific timber for:

1. parts in contact with water; here they used green pine, tacked to wooden laths;
2. the load bearing parts; for main support pieces, oak fashioned with axes, was used, and for trestles and support beams eucalyptus and pine was used;
3. parts subject to wear; such as gears, where wild olive was used; and finally;
4. parts in dry areas for receiving cereal; such as the hopper, seasoned pine was used.

Iron has only recently been used and is occasionally found in the remains of doors and windows as well as in certain other parts of the mill. Beyond the current traditional construction systems, Ave's watermills have some particularities that allow them to persist in the river water environment. The need for continuous contact with water, to allow transfer of energy, led to the conception of specific construction systems that morphologically characterize the building. Watermills built between land and water or completely in water, have structural systems that resist permanent water erosion and, at the same time, selecting, diverting and conducting the river's current in order to actuate the mechanical devices. The construction systems and techniques used in the watermills are similar to the systems applied in building the pillars of medieval bridges. Notably in Spain, in the municipality of Zamora, there are references which cite that the builders of the watermills on the Douro River were the same as those who built the bridges in the region, "*...como indica Nicolas Garcia Tapia, que han sido realizadas por los mismos maestros que han hecho las catedrales y los puentes*" ("as indicated by Nicolas Garcia Tapia, and had been carried out by the same masters who had made cathedrals and bridges").[7]

From this assumption it is possible to establish an analogy between the pillars of bridges and the Ave's watermills. The watermills are "inhabitable pillars" constructed in the watercourse to carry out multiple functions derived from the energy produced by the river's current. The morphological composition of Ave's watermills is the result of efficient use of space destined for function and the methods of construction for the protection of the interior, of which the cutwater stands out. The cutwater's

hydrodynamic shape, similar to a boat's prow, consists of a system built on the upstream elevation in order to protect the watermill from the impact of the river current.

According to the testimony of the millers, the construction of the cutwater should be oriented according to the current of the river in times of flood, not according to the current in normal times. The misdirection of the cutwater in relation to the current can lead to the complete collapse of the building during the first flood of the year. If the cutwater is misaligned, the power of the current will impact on the side wall, increasing friction which will cause its destruction. This implies both constructional wisdom and a deep understanding of the natural cycles of the river, the currents and water levels.

As a result of the relationship between the river's natural conditions and the construction of the watermills there is a constructional diversity that is classified into three morphological types:

Type 1 - Watermills with no cutwater - located in protected sections of the river current;
Type 2 - Watermills with a circular inhabitable cutwater - located in sections which are exposed to a weak current, frequent in alluvial areas of the middle Ave;
Type 3 - Watermills with massive rounded or pointed cutwater - located in sections which are quite exposed to a strong, rapid and aggressive current, frequent in areas of steep topography in the lower Ave.

Conclusion

From this study we conclude that associated with the Ave River there is a harmonic relationsip between topography and mill deployment (a "plurinuclear diffuse system") consisting of tens of watermills whose origins go back to the thirteenth century and which declined during the twentieth century.

- The system formed by watermills reveals a strong and ancestral relationship with the region, allowing the formation of the rural landscape in the Ave Valley to be explained and understood.
- From the architectural point of view watermills can be considered to constitute a specific typology in the panorama of vernacular architecture. Their relationship with water requires unique construction specifications.
- Morphologically, these watermills constitute a peculiar case. The various types of cutwater allow watermills to be understood as architectural constructions that are a consequence of hydrodynamics imposed by the location, currents and the river flows, whose solutions were born from an ancient wisdom passed on from generation to generation.

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Note

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