

Water Management, Protection and Conservation of Aqueducts as Cultural Heritage: Problems and Solutions, the Example of the Gades Roman Aqueduct (Andalusia, Spain)

María del Mar Castro García
Ángel David Bastos Zarandieta¹

Abstract

We propose a thesis within the framework of this 11th International Conference of the Graduate Student Association of the History Department of Université Laval from the fields of ancient history, environmental history and the protection of historical and archaeological heritage of water management in the Roman province of “Hispania Baetica”. The main purpose of this paper is the exposure of our research into water management and the interactions between society and the environment in the Roman Empire, specifically in the Roman province of Andalusia (Spain). Moreover, we intend to present a methodological proposal that combines historical, archaeological and geographical data from the Geographic Information Systems (GIS) applications, as a method of remote exploration of ancient aqueducts. Research on historic aqueducts faces specific problems because of certain characteristics inherent in their morphology. This adds to the difficulty of implementing protection measures and also for their preservation by government.

In this paper, we will present the principles of our doctoral research by defining the problem, establishing the objectives and stating our methodology. Subsequently, within the scope of our research, we would like to apply our methodology to the existing knowledge and boundaries of one of the most important elements of hydraulic heritage, namely aqueducts. Ancient aqueducts, due to their morphology and structural characteristics, present difficulties in defining them precisely, with the consequent problems around establishing a protection and conversation regime by government agencies. To overcome this issue of definition, we propose to use a remote sensing technique to gather the complete shape of aqueducts through the use of GIS methodologies. To validate this approach, we applied this technique to a real case, namely a stretch of the Roman aqueduct in Cadiz; we therefore present the initial results of this methodology for scrutiny. These preliminary results are given in this paper to reveal the problems we encountered.

Our research is focused on the application of the concepts of “environment-society interactions” and “integral management of natural resources”: namely, water in the Roman province *Hispania Ulterior Baetica*. This research from the so-called “New Environmental History” began with studies of North America in order to study the relationship between man and his environment and is based on the principle that human changes made in the environment may affect societies and their historical development². This type of trend is applied to different historical eras and through the benefit of hindsight, the research can contribute to solving current environmental problems³. The current interest of historians in environmental issues from the past is to discover and preserve traditional knowledge by viewing it as a cultural heritage. There are also benefits to be gained through communication between ancient and modern historians that may pose the same questions⁴.

Influenced by this trend is the concept of “society-environment interaction” applied to the Roman Empire as a long-term phenomenon and this can be taken as the same interpretive paradigm. To observe this interaction and to reconstruct this paradigm, in this case the Roman Empire and its ways of managing natural resources, taking into account the political formation generating these forms of management, we have two scales of analysis: global and peripheral⁵.

Integrated management of natural resources and integrated spaces are concepts from ecology that have influenced the study of the Roman Empire. The concept of “integrated area” in this analysis is applied as a catalyst for interaction between society and natural environment that creates and renews it⁶. Water management is a key issue at present mainly due to the social awareness of the problems associated with this resource. More specifically, the concept of “integrated water management” comes from a holistic approach to the complexity of the interactions involving humans and their activities within their supply chain operations, collection, storage, distribution and employment, and their relationship to the environment. Their interaction with society allows us to analyse the technical, legal and economic dimensions of natural resource management and water management⁷. Understanding water as a heritage to protect and conserve, we must make a conceptual examination of past experiences of water management at different times and places in order to see its relevance and influence on modern management practices⁸. One of the main proponents of this new line of research is Professor Ella Hermon, holder of the Canada Research Chair in Society and the Natural Environment in the Roman Empire, who is dedicated to the analysis of these concepts in the Roman Empire and who has organized numerous conferences regarding this issue relating to different historical periods.

These concepts are applied to the Roman Empire as the first society to legally protect its natural environment and they pose a particular concern regarding the collective goods that ensure the protection of the values shared by the whole community. Within this context, these studies focus mainly on the different domains of the ecosystem, in urban areas and techniques of management and exploitation of water in ancient times. Our research is placed within this conceptual framework, from the integrated management of water in the peripheral area of the Empire and in the province *Baetica*.

Relating to the study of Hispanic provinces, these concepts are being introduced in the current historiography topically⁹. Overall, water management strategies and the establishment of this resource planning have been studied as a contribution to a territory of a whole system of water supply and management associated with the cities. One of the most important elements that has been the subject of much research in this area is the aqueduct, a hydraulic structure that transported and distributed water to Roman cities. There are many remains of aqueducts throughout *Hispania*. Studies from the historical, archaeological and technical aspects of Hispanic territory aqueducts were carried out from different perspectives. On the one hand, current research has developed a technical aspect dedicated to the study of Roman aqueducts from the field of engineering. These studies are discussed in purely technical aspects and do not discuss the merits or historical significance of these structures¹⁰.

From the disciplines of archaeology and history, aqueducts have been analyzed as parts of a water supply system to the city. There are many archaeological and technical studies on the main aqueducts of *Hispania*. These studies analyse the solutions and construction techniques employed in building the aqueducts. They also consider documentation and registration of the sections of the aqueduct and descriptive analysis in relation to construction techniques employed in *Hispania*. In general these studies have not responded to the need to include these elements as part of a complex system of water supply to the city: as a comprehensive management system that some authors have called a global system of water management in Roman cities¹¹. A study using the latest advances in geographical analysis of the Roman water supply systems in the city of Toledo is very interesting and innovative in this regard, as it analyses all the water distribution systems as a whole¹².

“Integrated water management” in the Roman cities of *Baetica* is an aspect that is of great historical importance for the Roman conquest of this territory. The Romans brought a new form of interaction to the societies inhabiting this space and a new form of natural resources management, in this case: water. We believe that the analysis of this new relationship necessitates a detailed study of cases in order to

analyse the forms of water management and their technical, legal, social, cultural and economic implications and so on.

Those are the main objectives that we seek from this research:

- We pursue to address and distinguish the historical changes made by the introduction of new forms of water management and the establishment of a hydraulic supply network in the province *Hispania Baetica*, taking this space as an interpretive paradigm for the entire Roman Empire.
- To analyse how new “society-environment interaction” and integrated management of water were produced from the Roman conquest of an area which had a previous settlement.
- Study different models of water management in indigenous communities and Roman cities of *Baetica*, through the analysis of archaeological remains associated with the territory where they are based.
- The study of Roman hydraulic structures and their relationship with the municipal and civic settlements of *Baetica*.
- The systems analysis of water management and its link with economic activities and productive operation.

The methodology being used to achieve the goals set for our research in the study of water management in the province *Hispania Ulterior Baetica* is mainly based on historical analysis of the various related sources, the use of archaeological methods and the application of different tools, especially the Geographic Information Systems (GIS). This method will help us to collect historical and archaeological information and allow for the spatial analysis of this information.

There are many studies that analyse the different water management systems developed in these communities. One of the most characteristic material elements of the water management developed in the province of *Baetica* from coming into contact with the Romans are the aqueducts. Aqueducts will be examined in this article in relation to territory, settlements and related financial holdings.

The protection and conservation of hydraulic heritage

The aqueducts are one of the most characteristic and representative systems for water supply and management in different historical periods and the most representative element of the hydraulic culture, related to the study of “integrated water management” and a contribution to the so-called “water culture”. Because social awareness of the scarcity of this vital resource is being promoted at different levels, a common culture of water is being created to influence laws on water management. Also this concept is in line with the trend that defends the

work of recovery of cultural and historical heritage related to water management from different historical periods, and the recovery of traditional knowledge of water management that may help current policy¹³.

The identification, protection, management and conservation of cultural and historical heritage is a project with contributors from different fields, mainly from the agencies involved in the investigation and from public authorities that have the responsibility for their protection, as provided by legislation and following the model of regional powers and institutions that ensure the protection of our heritage. These agencies carry out a series of management strategies applied to heritage based on the so-called Cultural Resources Management. One of the management strategies that has become a major instrument for the protection policies of historical heritage¹⁴ is to develop catalogues or archaeological site inventories.

Aqueducts, as far as they represent the techniques of water management in Roman times and in successive historical periods, need to be protected and preserved under the auspices of the protection and management of historic heritage. Aqueducts have their own characteristics that make research into them difficult and therefore we need full protection and implementation of management strategies by agencies responsible for them. An aqueduct is a type of infrastructure to transport and supply water to a particular site, whether it is a town centre or an industrial area. They are intended to move water, based on the principle of maintaining a certain slope with minimal variation to allow the transport of water and taking into account the morphology of the terrain. Such structures have a specific problem due to certain characteristics.

Their characterization is that they are linear and continuous structures. The aqueducts are spread over for a continuous and uninterrupted length and can reach 80 km in length. Various construction solutions are necessary to help maintain the minimum slope in adapting to the topography. These characteristics cause an irregular path, which makes it difficult to document them using ground survey techniques. Because of this, there is a real lack of understanding of the aqueducts as assets to be identified, protected and conserved.

In Spain, there are many examples of ancient and modern aqueducts that are not protected due mostly to ignorance or limited knowledge. Others have limited protection measures and only their visible parts are catalogued. We can mention as an example the case of the aqueduct of the Caños de Carmona, which supplied water to the city of Seville in the Islamic time and probably in the Roman times and that recently has been the subject of exploration and documentation¹⁵, or the case that we presented referring to the present situation of the Roman aqueduct of Cadiz. This aqueduct has in four registries in the

Database of the Andalusian Real Estate Heritage (BDI), that is part of the Information System of the Andalusian Historical Heritage (SIPHA)¹⁶. The Roman aqueduct course are protected in this parts: reference to the Roman aqueduct's passage through San Jose del Valle, the visible structure siphon of the Valley of the Arquillos, structures in the municipality of Puerto Real in the denominated place Llanos de Guerra and the rest of the aqueduct in its arrival at Cadiz, still unprotected its integral course.

Faced with this problem, we propose a method for applying technology to gain a remote view of the territory or as a predictive model in order to know the entire path of the aqueduct and thus to serve as a tool to its further protection. This method is based on the application of the GIS. The GIS has been used for the management and protection of archaeological heritage, to develop predictive models of reservoir location and as one of the methods used in the CRM and archaeological survey¹⁷. The GIS is a tool used in historical studies of territory due to the possibility to link historical to geographical information and to get spatial analysis from historical variables¹⁸.

The roman aqueduct of the city of Gades (Cadiz): example of application of the methodology

Gades is one of the major cities in the historical process of Romanization of the south of the Iberian Peninsula¹⁹. The Phoenician colonies, specifically the city of Tyre, bearing the name of *Gadir*, began to hear of its existence from ancient authors from the early 7th century BC, but it was not until the late 4th century BC²⁰ that *Gadir* began to have contact in the Mediterranean, becoming one of the major commercial colonies in the West²¹. The city's geographical location is unique because of its importance both in ancient times and in more recent historical periods. It is located at the southern end of the Iberian Peninsula, close to the Strait of Gibraltar²². This important Phoenician-Punic settlement made contact with Rome during Second Punic War against Carthage (218-202 BC) and contributed to the final dominance of the Mediterranean. Military events took place mostly in the territory of the Iberian Peninsula, and it is in this context, specifically in 206 BC, that *Gadir*²³, after a long war, became part of the Roman hegemony. It then began a process of conversion into a Roman city from a legal, politic, social, economic, planning and ideological point of view. From this moment in the late 3rd century BC, the city became a major focus for Romanization of the peninsular South, especially during the late Republic and Early Empire. It started a process of urban conversion in the image and likeness of Rome following the policy of the seat of imperial power and its leaders including members of the local oligarchy of *Gades*²⁴.



Location map of the ancient city of *Gades*

One of the greatest urban projects that express the magnificence of the city is its aqueduct. Roman aqueducts are one of the most striking and representative expressions both of Roman engineering and of the techniques and methods of water supply and management within the city. They are also one of the main legacies received by successive civilizations, since many of them have remained in use and have been the main source of supply for human populations well into the 20th century. They have been studied both by historians and engineers and even today impress us with the construction techniques, hydraulic engineering and topographical and geographical knowledge of a civilization that lived more than two thousand years ago.

The aqueduct of the Roman city of *Gades*, constructed mainly for supply of the city has an uncertain chronology and an unknown developer²⁵. We know that it is between 70 and 75 km in length. The remains are well-known, its functional rehabilitation has been attempted in the past²⁶ and there have been some studies on the subject, but none that are appropriate for its size²⁷. That is because of the many surface surveys and rescue excavations carried out in recent decades that have often affected areas crossed by the route of the aqueduct. It has been documented in different representations and there has recently been research in the Roman aqueduct of *Gades* with the application of new computing methodologies such as GIS. After a first attempt to reconstruct the path using the GIS²⁸, members of the research group *Seminar Agustín de Horozco Economic Studies of*

Ancient and Medieval History of University of Cadiz resumed the study. Developing it in depth and establishing a protocol for application of the method in order to reconstruct the entire path of the historic aqueduct that we will summarise later, as they have been discussed in other publications and it is not the main objective of our paper²⁹.



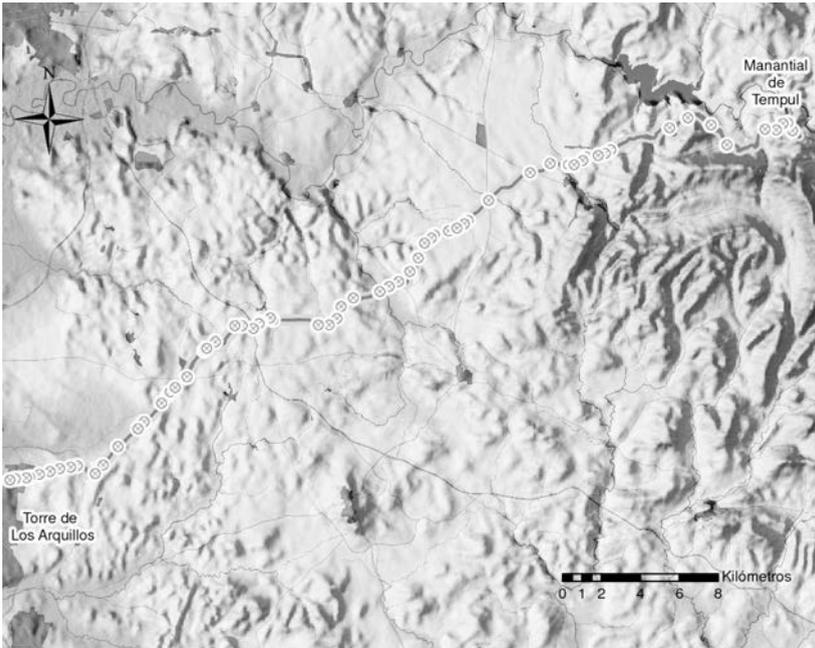
Proposed route of the Roman aqueduct of Cádiz (blue) and the ancient settlement

References to the aqueduct of *Gades* made in writing began almost immediately after its abandonment. Muslims named it³⁰, and after them medieval Christians and humanists³¹. There are known documents resulting from the research commissioned by Count Alejandro O'Reilly at the end of the 18th century to several engineers of the time with the firm intention of rehabilitating the aqueduct to supply the city³².

In the framework of this project, our research team has traced the hypothetical reconstruction of the aqueduct with the application of GIS methodology and software for remote sensing³³.

The methodology applied in the reconstruction of the path was the study of the topography, measured from the level heights and contours and also the hydrography. We gave a numerical value to the workforce needed for the building of different architectural constructs³⁴ and pointed out known points through the remains observed in the field. By interpolation of this data and the use of the GIS software tool, ArcGIS 9, "Shortest path", we created a track in a hypothetical way that reflected the path of the Roman aqueduct of Cadiz. These results were compared with the rests described in the reports to the Count O'Reilly, as well as those who still could be observed in the mapping of 1956³⁵, with *in situ* checking of the remains of the aqueduct at the surface.

This method of restoration of the aqueduct's path is presented as a technique for remote exploration of the territory. After obtaining the hypothetical path using GIS software, we can make a *buffer*, or area of influence, which we can call the area of high probability for the path of the aqueduct. With the exact coordinates, we can check the ground and thus provide effective protection measures.



Representation of the path and the affectations and risks observed

Presentation of the demarcation and protection measures of the roman aqueduct of Cadiz

As noted, the Roman aqueduct of Cadiz went over 70 km from its source to the distribution tanks of the ancient city. In this paper, we study a part of the entire path between the points of *Spring of Tempul*, municipality of San José del Valle and *Torre de Los Arquillos*, municipality of Puerto Real. In this article we contribute with a portion of our research since they are being made up by our group at this time. Therefore we only present a section of the complete trail of the Roman aqueduct, because we are working on the rest of the trail.

To the path obtained by applying the GIS, we apply an option of a *buffer* to define a reasonable protection area that accompanies the entire path³⁶. The ultimate aim, which we wanted to suggest above, is a

prediction to help the understanding of the full path of the aqueduct and not, as has happened so far, only occasional or random findings.

Carrying out this research, we identified up to 65 risks of various kinds: the most damaging were those caused by road traffic³⁷ and modern pipes pipelines, gas pipelines and aqueducts. We have also found examples of transformations of the environment made by humans that are so violent they have destroyed or threatened to completely wipe out the remains could be preserved. Such is the case with mines, quarries, wind farms, and so on.



Proposed route of the Roman aqueduct of Cádiz (blue) and buffer (orange) and risks detected from modern roads and paths

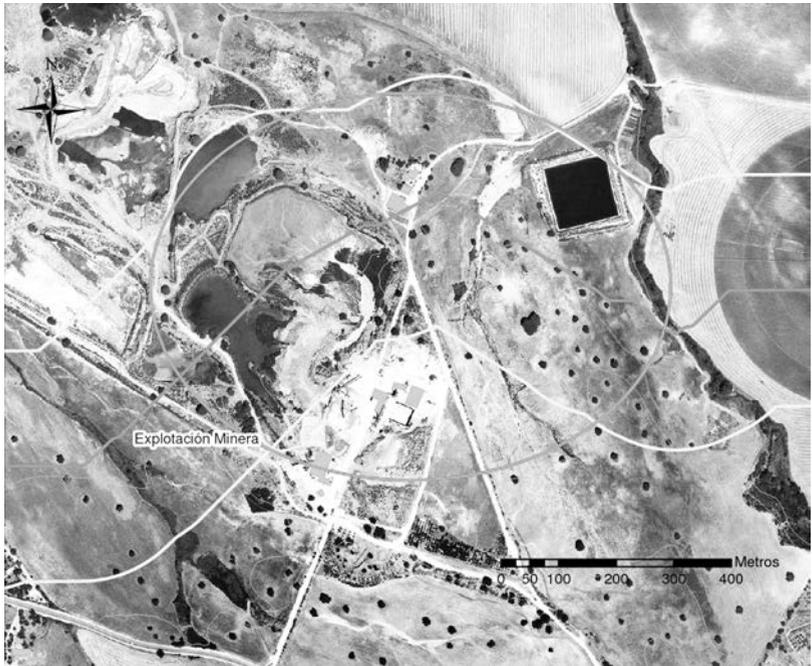
It is notable as an observation from the research that occasionally the damage to the aqueduct was made longitudinally. That is, along a stretch of the trace elements and especially from infrastructure construction features and requirements similar to the old pipe³⁸. This is so because the technical requirements for these works are almost the same as those that which faced by Roman engineers, especially contours, slopes and soil types. This could help identifying future damages in linear constructions because we would have a better idea how they develop. From its *caput aquae* we will note briefly the most serious intrusions affecting the possible remains of the Roman aqueduct of Cadiz.

The first risk to the aqueduct is only 500 metres away from its source. This is the road that runs along the old *Cañada Real de la Sierra* in the area of *Los Cuquillos*. The Roman aqueduct is reached through an area that is a natural pass between *El Vicario* and *Tempul*. With the construction of the road, it was necessary to destroy the aqueduct, and there are now only a few traces of it on the edge of the road. In the construction of a rear hydraulic line that supplied the city of Jerez de la Frontera, the aqueduct of engineer Ángel Mayo³⁹ of the late 19th century, the remains of Roman work were discovered. Both pipelines maintain direction, altitude and a very similar path until the area known as *Vegas de Elvira*.

Another type of intrusion on the path is caused by the rural buildings such as cottages, and also by their access roads. We have part of *Cortijo de Fuente Imbro*, *Cortijo de Las Vegas de Elvira*, *Cortijo La Arenosa*, *Cortijo de los Isletes Bajos*, *Cortijo de las Piletas*, and so on. We also know that they influence the path of the Roman aqueduct for drainage of the fields that cross our track on numerous occasions.

As we mentioned earlier, we also analyzed the impact of the construction of modern pipelines, gas pipelines and aqueducts⁴⁰ in the path of the Roman one. Thus, apart from the hydraulic work of the engineer Ángel Mayo that lies at a short distance from archaeological heritage, we have found the intrusions of the Tarifa-Córdoba gas pipeline in the area called *Isletes Bajos*, and the oil pipeline of San Roque-Rota-Arahal-Moron de la Frontera in the area called *Haza Marina*. These were because there was no knowledge or legal necessity to protect the path of the Roman aqueduct.

Finally, we note that the most destructive effect that we have found to the path of the Roman aqueduct is *Malduerme II*. The main local construction took place in 1960 for purely residential use. Later, the land was dedicated to industrial use⁴¹, with permits for the extraction of silica sand. As can be seen in the picture, the path of the aqueduct crossed completely what is now the mining space.



Proposed route of the Roman aqueduct of Cádiz (blue) and buffer (orange) as it passes through Malduerme II

This is only a small contribution to the work being undertaken within the framework of this project with the overall purpose being to study water management and the interaction of society and the environment in these communities. Without doubt, to understand the need to protect this vital element for our survival we must learn from our mistakes and avoid future ones.

On the one hand we have clarified the main points of our doctoral research on the application of concepts of “society-environment interaction” and “integrated water management” in the province *Hispania Ulterior Baetica*, all this without departing entirely from the combination of Ancient History and New Environmental History and without applying a strictly analytical model to the study. Similarly, there are no overall historical conclusions generated from this form of historical analysis.

On the other hand, and in relation to our doctoral research as part of a body of work that represents an extraordinary method of integrated water management, we have presented a method for researching the

aqueducts in order to protect our historical heritage. In this paper we want to draw attention to the destruction of an important part of our common heritage that is representative of different water management systems developed in various historical periods and whose conservation is the responsibility of everyone. It is a reality not only in Andalusia (Spain) but for all sites that have this type of hydraulic infrastructure. We have to provide real and valid solutions from the fields of history, heritage management and archaeology and the GIS method provides us with these.

Notes

1. Ángel Bastos Zarandiet, the second author of this paper, was not present at the symposium, even though he has participated in the elaboration of it.
2. Donald Hughes Johnson, *What is Environmental History? (What is History Series)*, London, Polity Press, 2006, p. 1.
3. *Ibid.*, p. 2-3.
4. Ella Hermon, "Les interactions société-environnement : l'évolution diachronique des concepts", in Robert Bedon and Hermon (ed.), *Concepts, pratiques et enjeux environnementaux dans l'Empire romain*, Limoges, Pulim, 2005, p. 23-40. Regarding this issue, we must mention the great contribution of the research work of the Canada Research Chair in Society and the Natural Environment in the Roman Empire, led by Professor Ella Hermon and the numerous symposia and conferences that she organised.
5. Global and regional policies, an issue addressed in the symposium by Monique Clavel-Lévêque and Hermon (ed.), *Espaces intègres et ressources naturelles dans l'Empire romain : Actes du colloque de l'Université Laval, Québec 5-8 mars 2003*, Besançon, Presses Universitaires de Franche-Comte, 2004.
6. Hermon, "Conclusion", in Clavel-Lévêque and Hermon (ed.), *op. cit.*, p. 253-256.
7. Hermon, "Introduction. Pour une histoire comparée de la gestion de l'eau : savoirs traditionnels et pratiques modernes", in Hermon (ed.), *Leau comme patrimoine : de la Méditerranée à l'Amérique du Nord*, Québec, Presses de l'Université Laval, 2008, p. 4.
8. Hermon, "The integrated water management approach as a paradigm for the analysis of transfer in time and space of water management-related knowledge", in Hermon (ed.), *Leau comme patrimoine..., op. cit.*, p. 19-20.
9. Like some input from the Hispanic world at conferences organized by the *Chaire de recherche en interaction société - environnement naturel dans l'Empire Romain*. For example, see Alberto Prieto, "Les guerres de l'eau dans l'Hispanie Romaine", in Hermon (ed.), *Vers une gestion intégrée de l'eau dans l'Empire romain, Actes du colloque Gestion intégrée de l'eau dans l'histoire environnementale : Savoirs traditionnels et pratiques modernes. Université Laval 27-29 octobre 2006*, vol. II, 'L'Erma di Bretschneider, col. *Atlante tematico di topografia antica, Supplementi*, n° 16, Roma, 2008. p. 79-88; Vassileios Tsiolis, "L'approvisionnement en eau de Toletum. Des convictions anciennes aux découvertes récentes dans un *municipium* du centre de l'Espagne", in Hermon (ed.), *Leau comme patrimoine..., op. cit.*, p. 325-338.
10. This trend is represented in Spain by the engineer Carlos Fernández Casado: Carlos Fernández Casado, *Acueductos romanos en España*, Madrid, Instituto Eduardo Torroja de la Construcción y del Cement, 1972; Casado, *Ingeniería hidráulica romana*, Madrid, 1983; current studies from the field of civil and hydraulic engineering that have more a historical basis: Ignacio Gonzalez Tascón, Isabel Velázquez, *Ingeniería romana en Hispania. Historia y Técnicas constructivas*, Madrid, Fundación Juanelo Turriano, 2005.
11. Alejandro Egea Vivancos, "Fuentes literarias aplicadas al estudio de la ingeniería hidráulica romana", *MASTIA*, n° 4 (2005), p. 88-89. We must take into account a number of works in the field of Hispanic provinces: namely, certain cities that constituted a change in Spanish historiography in the analysis of water supply systems related to the Roman cities, which examine the water supply system to the city from a global perspective, taking into account all the elements that

- enable its operation: Angel Ventura Villanueva, *El abastecimiento de agua a la Córdoba romana. I El Acueducto de Valdepuentes. Monografías*, no 197, Córdoba, Universidad de Córdoba, 1993; Villanueva, *El abastecimiento de agua a la Córdoba romana II. Acueductos, ciclo de distribución y urbanismo. Monografías N° 251*, Córdoba, Universidad de Córdoba, 1996; Lourdes Burés Vilaseca, *Les structures hidráuliques a la ciutat antiga: l'exemple d'Empuries, Monografies Emporitanes*, n° 10, Barcelona, Museu d'Arqueologia de Catalunya-Empuries, 1998.
12. Miguel Arenillas Parra, Marisa Barahona Oviedo, Fernando Gutiérrez Argul and Carlos Cauce Cañizares, *El abastecimiento de agua a Toledo en época romana*, Madrid, Confederación hidrográfica del Tajo, 2009.
 13. Hughes, *op. cit.*, p. 1-3; Hermon, "Introduction..."; *loc. cit.*, p. 1-18; Hermon, "The integrated water management ..."; *loc. cit.*, p. 19-32.
 14. Mainly for the ministries and regional administration and in some cases for the universities or the research groups.
 15. Asociación Sociedad Espeleológica Geos, "El Acueducto a Sevilla desde Alcalá de Guadaíra", in *Las técnicas y las construcciones en la Ingeniería Romana, V Congreso de las Obras Públicas romanas 7-29 octubre 2010*, Córdoba, Fundación de la Ingeniería Técnica de Obras Publicas, 2010, p. 205-223.
 16. Registries of the Roman Aqueduct of the city of Cadiz in the Data Base of the Andalusian Real Estate Heritage to the IAPH (Andalusian Institute of the Historical Heritage), Andalusian Autonomous Government; Entity 1: Roman aqueduct of Cadiz municipal district, code 110120084. Entity 2, Roman aqueduct of Arquillos in Jerez municipal district, code 110200097. Entity 3: Roman aqueduct of Tempul, San Jose del Valle municipal district, code 119020085 and finally the last entity, Roman Aqueduct of Llanos de Guerra, Puerto Real municipal district, code 110280030. Andalusian Autonomous Government, Andalusian Institute of the Historical Heritage, *Web site of the Data Base of the Andalusian Real Estate Heritage to the IAPH*, <http://www.juntadeandalucia.es/cultura/iaph/bdi/> (consulted November 3rd 2010).
 17. From the 1960s onwards, due to the need to locate, identify and manage archaeological evidence in countries where urban sprawl threatens the archaeological heritage, the GIS has been used for the surveys and for spatial analysis and territorial and inventory management. See Leonardo García Sanjuán, *Introducción al reconocimiento y análisis arqueológico del territorio*, Barcelona, Ariel, 2005, p. 161.
 18. The GIS has been used in the study of linear structures of different eras, with similar characteristics to the aqueducts, such as traces of the division of rural land or the analysis of road network in antiquity, see Frank Vermeulen, Beatrijs Hageman and Torsten Wiedemann, "Photo-interprétation et cartographie des systèmes spatiaux anciens: l'archéologie des routes et parcellaires en Belgique", in Clavel-Lévêque and Almudena Orejas (ed.), *Atlas historique des cadastres d'Europe II*, Luxembourg, Dossier 5T., 2002, p. 1-12.
 19. *Later Roman Hispania*.
 20. Francisco Javier Lomas Salmonte, "Cádiz en la antigüedad", in Francisco Javier Lomas Salmonte, Rafael Sánchez, Manuel Bustos, José Ramos and José Luis Millán-Chivite (ed.), *Historia de Cadiz*, Madrid, Silex Ediciones, 2005, p. 15.
 21. *Ibid.*, p. 34.

22. This is a strategic point of great historical significance, even today. It represents the geographical point of union between the Atlantic Ocean and the Mediterranean Sea, establishing itself as the gateway in the west of the Mediterranean Sea and a communication site between Europe and the African continent, hence the great value of human contact in this area with North Africa since Prehistoric times. For this reason this area has been called in the recent historiography "Cicle of the Straight", too to refer to the area of economic and political influence of *Gadir* following the fall of *Tiro*. The first author who coined this concept is Miquel Tarradell in the sixties. See Miquel Tarradell, *Marruecos púnico*, Tetuan, Cremades, 1960, p. 61. For other examples of this concept; Oswaldo Arteaga Matute, "La liga púnico-gaditana. Aproximación a una visión histórica occidental, para su contrastación con el desarrollo de la hegemonía cartaginesa en el mundo Mediterráneo", in *Cartago, Gadir, Ebusus y la influencia púnica en los territorios hispanos. VIII Jornadas de Arqueología fenicio-púnica de Ibiza*. Ibiza, 1993, 1994. *Trabajos del Museo Arqueológico de Ibiza*, n° 33 (1994), p. 25; Dario Bernal Casasola, *Economía y comercio en la Bética mediterránea y del Círculo del Estrecho en la Antigüedad Tardía* (ss. III-VI d. c.) a través del registro anforico, doctoral thesis (history), Madrid, Universidad Autonoma de Madrid, 1998; Ana Maria Niveau, "El espacio geopolítico gaditano en época púnica. Revisión y puesta al día del concepto Circulo del Estrecho", *Gerion*, n° 19 (2001), p. 313-354; Casasola, Baraka Raissouni and Ramos Muñoz (ed.), *En la orilla africana del Círculo del Estrecho: historiografía y proyectos actuales: Actas del I seminario hispano-marroquí de especialización en arqueología, Coleccion de monografías del Museo Arqueologico de Tetuan 2*, Cadiz, Universidad de Cadiz: Servicio de Publicaciones, 2006.
23. Later the roman *Gades*.
24. We must quote a leading figure of the Roman Senate that was born in *Gades*, *Lucius Cornelius Balbus "Maior"*, from the time of Julius Caesar, protagonist of the famous speech of Cicero in his defense, "*Pro Balbo*", and his grandson *Lucius Cornelius Balbus "Minor"*, 60-13 BC belonging to the *Gens Cornelia*, *homo novus* of the Augustean age.
25. Lázaro Lagóstena and Francisco Zuleta, "Gades y su acueducto: una revisión", in Lagóstena; and Zuleta (ed.), *La captación, los usos y la administración del agua en "Baetica": estudios sobre el abastecimiento hídrico en comunidades cívicas del "Conventus gaditanus"*, Cadiz, Universidad de Cadiz, Servicio de Publicaciones, 2009, p. 115-116.
26. Ángel Mayo, "Memoria relativa a las obras del Acueducto de Tempul para el abastecimiento de aguas a Jerez de la Frontera", *Anales de Obras Públicas*, n° 3 (1877), p. 1-243.
27. The main reference works on it are: Juan Antonio Fierro Cubiella, "El acueducto romano de Gades", *Revista de Arqueología*, n° 95 (1989), p. 19-24; Ángel Muñoz Vicente, "Intervención arqueológica en el acueducto romano de Cádiz: los sectores de El Mimbrial (Jerez) y Tres Caminos (Puerto Real)", *Anuario Arqueologico de Aandalucia vol. III, Actividades de Urgencia*, 1989, 1991, p. 89-103; Fierro Cubiellas, "Esplendor y ocaso de la técnica hidráulica en Cádiz: entre la Antigüedad y el Medievo", in Juan Manuel Barragán (ed.), *Agua, Ciudad y Territorio*, Cádiz, Universidad de Cadiz, Servicio de Publicaciones, 1993, p. 85-135; Maria Jesus De León Morgado, "El agua en la antigüedad. La etapa

- medieval”, Barragán (ed.), *Aguas de Jerez, Evolución del abastecimiento urbano*, Jerez, 1994, p. 55-84; Francisco Javier Guzmán Armario, “El agua en Cádiz en época romana”, Confederación Hidrográfica del Guadalquivir (ed.) *Patrimonio Histórico Hidráulico de la cuenca del Guadalquivir*, Sevilla, 2002, p. 427-438.
28. Javier Baena, Concepción Blasco, Lourdes Roldán, Carlos Almonacid, Jesus Bermúdez, Alberto Río and Javier Espiago, “Applications of GIS to the archaeology of Roman Hispania”, in John Peterson (ed.), *COST ACTION G2. Paysages antiques et structures rurales. The use of Geographic Information Systems in the study of ancient landscapes and features related to ancient land use*, Brussels, European Commission, 1998, p. 1-20; Roldán, Baena, Blasco, Bermúdez, García, “SIG y arqueología romana. Restitución del trazado del acueducto de Cádiz”, in Baena, Blasco and Quesada (ed.), *Los S.I.G. y el análisis espacial en Arqueología*, Madrid, UAM Ediciones, 1999, p. 255-272.
 29. Lagóstena and Zuleta, *op. cit.*; Lagóstena, Zuleta, Castro, Bastos and Talavera, “Infraestructuras hidráulicas en Baetica: propuesta para el estudio del trazado de sus acueductos”, in *Actas del V Simposio Internacional de Arqueología de Mérida. Sistemas de Información Geográfica y análisis arqueológico del territorio, 2007, Mérida*, [congress paper], <http://www.scribd.com/doc/55089081/Infraestructuras-hidraulicas-en-Baetica-Propuesta-para-el-estudio-del-trazado-de-sus-acueductos> (consulted November 3rd 2010); Zuleta and Bastos, *Análisis Geomático del trazado del acueducto Tempul-Gades. Captación, usos y administración del agua en los municipios de la Bética romana*, [poster presentation], <http://www.safecreative.org/work/1004296141071> (consulted December 1st 2010).
 30. Lázaro Gabriel Lagóstena Barrios and Francisco de Borja Zuleta Alejandro (ed.), *La captación, los usos y la administración del agua en Baetica: estudios sobre el abastecimiento hídrico en comunidades cívicas del conventus Gaditanus*, Cádiz, Universidad de Cádiz, 2009.
 31. As Agustín de Horozco in *Historia de la ciudad de Cádiz*, Impr. M. Bosch, 1845.
 32. Lagóstena and Zuleta, *op. cit.*, p.139.
 33. *Ibid.*, p. 137-139; Zuleta and Bastos, *op. cit.*; Lagóstena, Zuleta, Castro, Bastos and Talavera, *loc. cit.*, p. 4-11.
 34. *Arcuationes, substructiones, tunnels and siphones.*
 35. For this check we used the photos of the area carried out by the so-called “American Flight” between 1956 and 1957.
 36. In the past this has proved to be an extremely valuable and effective method: Zuleta and Bastos, *op. cit.*
 37. Motorways and national, regional and forestry roads.
 38. Such as roads and water pipes.
 39. For more information see Mayo, *loc. cit.*
 40. This information has been obtained from the layers of Energy Infrastructures and Hydraulic Infrastructures of the SDIA (Spatial Data Infrastructure of Andalusia).
 41. This information has been obtained from the mapping of the Cadastre General Directorate of the Ministry of Economy and Finance of Spain.