# Impacts of Recent Urban Development on Historic Reservoirs

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## Abstract

*In the environment of Proserpina Dam (Mérida, Spain), of Roman origin, an urbanized area lacking sewage has been developing since the 1950s. The detailed study of its urban characteristics, the main polluting aspects and the proposal of the technical solution closest to its reality are the main objectives of this work. To avoid the main urban impact, the infiltration of leachates into the reservoir, a comparative study has been made between two possible solutions to choose among them the one that is best adapted to the area: design and implementation of a separative wastewater sewerage network and "in situ" treatment of wastewater through individual treatment systems. With the same or greater capacity to treat wastewater that some public facilities, the use of total oxidation biological treatment plants as a private system is the best alternative to the lack of sewerage network in the urban area within the basin of Proserpina.*

**Keywords**: Polluting, historic, Proserpina, reservoirs, urban.

## *Introduction*

The water quality of a reservoir is influenced by multitude of natural and anthropogenic factors. To determine the degree of influence of each one of them, it is first necessary to analyze the main environmental features of the basin (Galindo, 2016). Among the factors of an anthropic origin is urban pressure. There are many technical solutions to prevent or reduce the impact on the water quality of a reservoir caused by urbanized areas nearby. Choosing the most effective and reasonable one requires prior analysis and assessment of the real situation of each area. In the environment of the reservoir of Proserpina, declared "Intercommunity Sensitive Area of Spain" in 2006, an urbanized area lacking sewage has been developing since the 1950s. The detailed study of its urban characteristics and the proposal of the technical solution closest to its reality are the main objectives of this work.

## *Study area*

Proserpina reservoir is located five kilometers north of Merida, capital of the Autonomous Community of Extremadura, and south-west of Spain (Fig. 1).

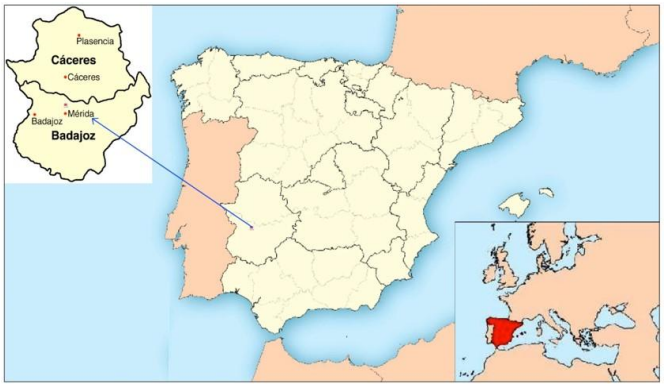



***Figure 1***. *Location of study area*

Fed by the streams "Las Pardillas" and "Las Adelfas" and other minor river beds, its contribution basins cover an area of 2500 hectares. The reservoir has an almost permanent volume of water of 5 Hm3 and its shore is around 7 kilometers long. The dam, of Roman origin, does not allow bottom outlets.

Occasional excess stored water is removed through a surface spillway of the side of the dam. Its backwaters are used exclusively for leisure and practicing water sports.

### *Work Development*

From the knowledge of former and current urban planning, cadastral information, multitemporary study of aerial photographs (dated 1945-2015) and maps (1936-2015), and field work, detailed information of urban character of each and every one of the urban or developable plots surrounding Proserpina has been obtained. Amongst the data obtained there is information on its main use, year of housing construction, plot area, urban area where it is located or sports facilities present there.

All these alphanumeric data, more than 10,000, have been introduced in a computer application that has been called "Urban and descriptive database of urban plots of Proserpina". With it, once completed, it has been intended to analyze, quantify and weigh different general urban aspects of the area which are essential to achieve the objectives of this work.

For a better understanding of polluting aspects to consider, various environmental studies concerning Proserpina conducted by the Center for Studies and Experimentation of Public Works (1993) and the Guadiana Hydrographic Confederation (2009) have been taken into account.

The main polluting aspects for the backwaters of urban origin estimated are leachate infiltrations, urban storm water runoffs and garbage littering.

After all of the above, the mandatory technical and legal considerations in the implementation of any proposal to improve the situation have been examined.

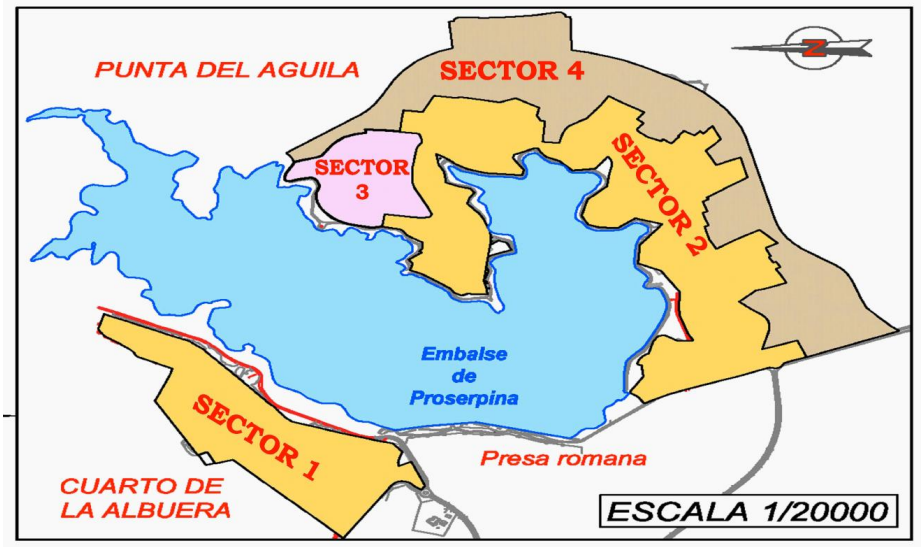



*Figure 2. Sectors of the urbanized area*

Once the problem is known in its depth, the possible corrective measures have been studied. Being the evacuation and treatment of wastewater in the area the main problem, a comparative study between two possible solutions has been made.

On the one hand, the execution of a sewerage network of separative type leading black waters to a wastewater treatment plant to be built downstream of the dam, and on the other hand, the use of biological treatment of total oxidation in the area itself.

### *Results*

The number of inhabitants of the area is very variable. It ranges from a minimum of 203 people in winter (National Institute of Statistics 2013), and an approximate maximum in the summer of 1518 residents, deduced from the urban database created. There are 522 plots of urban nature. For a better analysis of its characteristics, the urbanized area has been divided into four sectors (Fig. 2) and the number of dwellings has been quantified (Tabe I):

| URBAN SECTORS AND NUMBER OF HOUSES IN PROSERPINA | | | FINAL SUMMARY | | | |
|---|---|---|---|---|---|---|
| SECTOR | LOCATION AND CODE | LAND CALIFICATION | TOTAL AREA (M2) | BUILT HOUSES | HOUSES TO BE BUILT | TOTAL HOUSES |
| 1 | CUARTO DE LA ALBUERA | NON CONSOLIDATED URBAN PLOT | 149558 | 136 | 81 | 217 |
| 2 | SOUTH AND EAST OF PROSERPINA | NON CONSOLIDATED URBAN PLOT | 381921 | 262 | 61 | 323 |
| 3 | PUNTA DEL AGUILA (CODE UE-PR-01 | NON CONSOLIDATED URBAN PLOT | 60152 | 10 | 35 | 45 |
| 4 | SOUTH AND EAST OF PROSERPINA (CODE SUNP-PR-01 | UNSCHEDULED DEVELOPABLE LAND | 254133 | 22 | 173 | 195 |
| | | **TOTAL AREA OF PROSERPINA** | **845764** | **430** | **350** | **780** |

**Table I. Distribution of housing in urban areas**

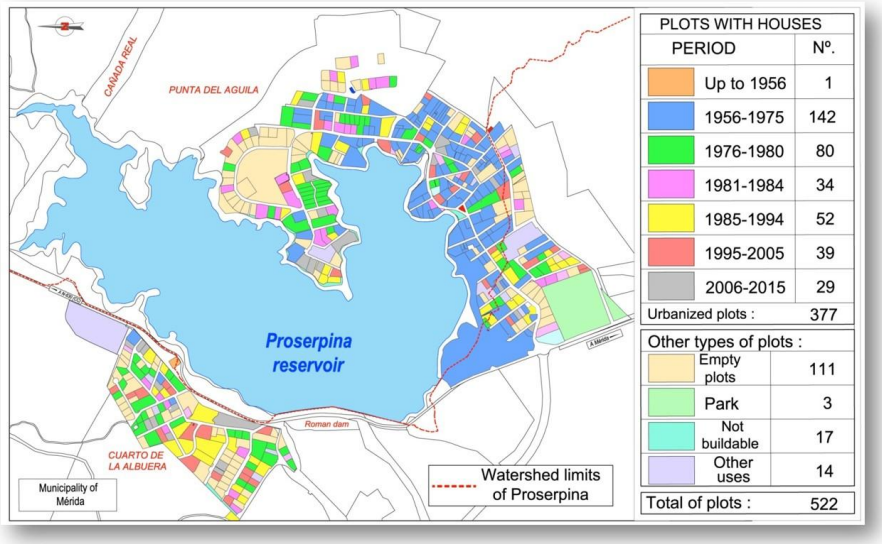
| TYPES OF USE | NUMBER OF PLOTS | PORCENTAGE (%) |
|---|---|---|
| RESIDENTIAL | 354 | 67,82% |
| EMPTY PLOT | 114 | 21,84% |
| NOT BUILDABLE | 17 | 3,26% |
| STORAGE, PARKING … | 14 | 2,68% |
| SPORTS | 12 | 2,30% |
| INDUSTRIAL | 5 | 0,96% |
| LEISURE, HOSPITALITY | 3 | 0,57% |
| PARK | 2 | 0,38% |
| RELIGIOUS | 1 | 0,19% |
| **TOTAL OF PLOTS** | 522 | 100,00% |

**Table 2. Current distribution of uses**

Under the current General Urban Plan (in Spanish, Plan General de Ordenación Urbana or PGOU), approved in 2000, the area is classified as residential. The type of construction permitted is the semi-detached and the detached house. In Table 2 you can see the current distribution of the different types of uses of the property plots, being predominantly residential (67.82%) and empty plots (21.84%). The pace of housing construction in the area has been highly variable since the beginning of urbanization in the 1950s (Barbudo, 2006). The period of greatest growth was from 1963 to 1980. In those years more than half of urbanization (51.6%) was built (Fig. 3.1 y Fig. 3.2). The potentially most polluting processes for the backwaters with urban origin occur in inland areas of the basin: the contribution, through the porous subsurface, of leachate (there is no type of sewage at all), polluting materials in urban storm water runoffs (plastics, organic matter, paper ...) and the uncontrolled dumping of garbage, cleaning products and pruning waste. The number of homes currently on the landward side of the basin of Proserpina are 244. When the development of the current General Plan is completed, it will reach 439 homes.


**Figure 3.1. Building development in Proserpina (1956-2015)**

**Figure 3.2. Building development in Proserpina (1956-2015)**




It is estimated that the resident population in this inner area of the reservoir ranges from a minimum of 116 people in winter and up to 861 in summer. The parcels are almost entirely for residential and sports use. There are no polluting industries or economic activities there.

It is estimated that currently, the total pollution load of wastewater produced in the inner urban area to the basin of Proserpina is 999 population equivalent (PE) and once the PGOU 2000 is completely developed, it will reach the figure of 1823 PE. To avoid the main urban impact, the infiltration of leachates into the reservoir, a comparative study has been made between two possible solutions to choose among them the one that is best adapted to the area.

-Design and implementation of a separative wastewater sewerage network:

This solution is covered by public projects and plans drawn today (Merida Town Council, 1991; Guadiana Hydrographic Confederation, 2007. Due to Proserpina dam's high historical value, the full implementation of gravity sewers through the reservoir is not possible. It is necessary, in addition to a network of collectors throughout the urbanization, a pumping system, surrounding the whole perimeter of the lake, which, concentrating the waste water at low points, pumps effluents outside the inner basin towards a sewage treatment plant built downstream of the dam.

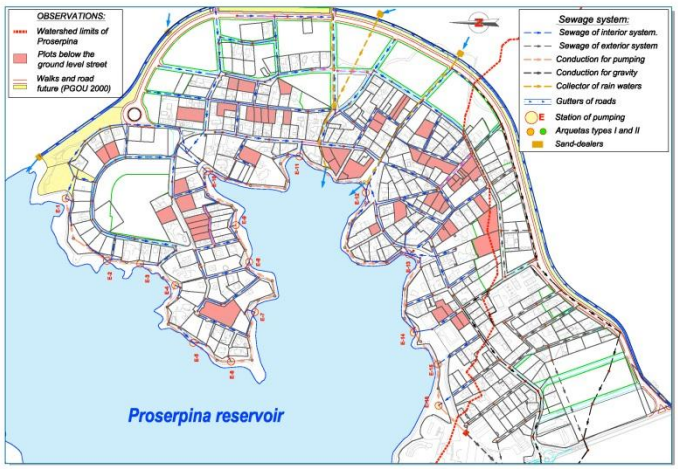



*Image 4. Detail of the study of a separative wastewater sewerage network. South and east of Proserpine*

This presents as main problems for implementation: the geological and geomorphological nature of the terrain (located on a granitic batholith), lack of space in the streets (mostly of widths less than seven meters) as well as on the shore of the reservoir (road of five meters maximum amplitude) and difficulties in connection with the particular network facilities (20% require auxiliary pumping facilities being plots below the ground level street). For its technical complexity and the proximity of pumping stations to the reservoir there is a high environmental risk both during implementation and during its operation.

-"In situ" treatment of wastewater through individual treatment systems:

Given the construction period of each home, 24.2% of them use pit latrines, 66.4% septic tanks, and 9.4% of total oxidation biological treatment plants.

The replacement of cesspools and septic tanks for total oxidation biological treatment plants would solve infiltrations of pollutants to the reservoir. These treatment plants have the ability to perform secondary treatments to wastewater coming from isolated homes in the area, reducing the biological oxygen demand in 5 days (BOD5) to 90% (equivalent results to those obtained in a public treatment plant). The private investment necessary to apply this solution is possible cause for social opposition to the measure. To avoid this, it is necessary to apply public aid or compensatory measures already covered by some laws, to offset the costs involved for both installation and for maintenance.

This solution, to make it safer and effective, must be complemented by other measures normative as, for example, not to authorize new areas for development to those already provided by the current General Urban Plan 2000 in the interior of the reservoir, or the reform and enactment of municipal ordinances governing the proper use of private purification systems by individuals (Merida Town Council, 2008).

## *Conclusions*

With the same or greater capacity to treat wastewater that some public facilities, the use of total oxidation biological treatment plants as a private system is the best alternative to the lack of sewerage network in the urban area within the basin of Proserpina. In addition to its lower environmental impact and lower running cost (estimated 75 %), this solution means lower operating expenses as it reduces the volume of wastewater to be treated in the treatment plant to be built downstream of Proserpina, reduces energy costs (less electric pumping consumption) and maintenance costs (in the simplest systems there is less chance of failure). In Directive 91/271 / EEC of the European Council of 21 May 1991 regarding the treatment of urban waste water, Article 3 expresses the requirement that all Member States ensure that all urban agglomerations are provided with systems collectors. However, in the last paragraph, it adds "When the installation of a collecting system is not justified either because it does not lead to any advantage for the environment or because it would involve excessive cost, individual systems or other appropriate systems will be used to achieve the same level of environmental protection."
The solution here raised is therefore in accordance to the regulations in force in the European Economic Community.

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