Wastewater reuse brings life back to Spain's Segura river

● Spain's river Segura suffered from severe degradation due to drought, over-abstraction for irrigation, and disposal of untreated industrial and domestic wastewater. In an astonishing ten-year turnaround for the river, a plan was put into effect to treat all wastewater flows and reuse the water for irrigation, allowing the river to recover and develop into an ecologically important habitat. **BILL McCANN** looks at this award-winning project.

It must be a rare, if not unique, experience for a nationally important European river to be transformed within ten years from the most polluted to the best quality in its homeland, but that can be said of the Segura in south-eastern Spain.

In a remarkable turnaround, the river has been changed from a source of public nuisance and complaints to an attractive playground for children and adults alike, while the water and bankside areas have become a thriving environment for fish and bird life.

As well as this, the engineering team that masterminded and implemented the scheme has also managed to boost natural water availability in the Segura basin by around 13%, a major benefit for the primary regional economic activity of irrigated fruit and vegetable farming.

For these achievements the scheme, the General System of Wastewater Reclamation and Reuse in the Region of Murcia, was awarded the 2011 Segovia Aqueduct Prize for Civil and Environmental Works by Spain's Society of Civil Engineers.

Nearly 350km long, the Segura flows generally west to east, rising in the 2000m peaks of the Sierra Segura and discharging to the Mediterranean on Spain's east coast. For about 200km, in its middle and lower reaches, the river traverses the entire Region of Murcia, a flatland blessed with plentiful sunshine but very little rainfall, generally less than 300mm/year. It is a region too of a significant volume of irrigated agriculture and related fruit and vegetable processing industries.

All these factors combine to place great stress on the resources of the

The flatland of Murcia supports a large agricultural industry that requires large volumes of water for irrigation. Pictures: Confederación Hidrográfia del Segura.

Segura, the main water source for Murcia and its 1.4 million population. During the 1990s very little water was reaching the river mouth and, in the middle and lower reaches, low natural flow combined with discharge of untreated domestic and industrial wastewater was reducing water quality to nuisance levels. Matters came to a head around the middle of the decade when a prolonged drought combined with increasing irrigation abstraction and wastewater discharges from the growing canning industry left the river as little more than an open sewer.

Taking action

But by that time the trends were well recognised, as was the need for urgent action to return the river to good environmental quality and to increase regional water availability through wastewater treatment and reuse. It was seen too that these objectives could not be realised through isolated actions by individual local authorities.

In 1995 the responsible department in Murcia's regional government, the Department of Agriculture and Water, instructed the General Directorate for Water (GDW) headed by the newly appointed Miguel Ródenas to begin planning for a regional scheme.

As Ródenas explains, that work began immediately with a team of nine – eight civil engineers and an agricultural engineer, Joaquín Griñán – all specialists in wastewater treatment plant design and construction.

From California to Spain: progression to the water quality standards of the Segura reclamation scheme

In 1984 the California State Water Resources Control Board published a report entitled 'Irrigation with Reclaimed Municipal Wastewater: A Guidance Manual'. The report was edited by Dr Stuart Pettygrove and Professor Takashi Asano; it uses the design criteria of Title 22 of California's 1978 Water Code, commonly known as the Title 22 recycled water criteria.

In 1990 the report was translated into Spanish by Professor Rafael Mujeriego of the Polytechnic University of Catalonia and published by the university as 'Manual Práctico de Riego con Agua Residual Municipal Regenerada'. When planning for the Segura project began in 1995 Miguel Ródenas and Joaquín Griñán were able to study this version and to consult Professor Asano, leading to use of the Title 22 criteria in the project, sometime ahead of their application elsewhere in Spain or Europe.

Another key senior figure in this small group was Manuel Albacete, whose focus was on the future management and operation of the comprehensive wastewater collection and treatment plant system that was being planned. He also looked at the legal and tax issues associated with the developing plan, crucial background to the legislative framework for the scheme that would need to be promoted in Murcia's Parliament. That legislation also needed to formalise the transfer of wastewater system responsibilities from local authorities to the GDW.

Over this initial preparatory period, extending to 2002, one section of the project group concentrated on these issues that would form the basis for legislation and dealt with other 'planning' necessities such as public consultations and preparation of an environmental impact assessment. In parallel, the remainder of the group concentrated on the engineering aspects of the collection and treatment system, on the quality standards of the treated water to enable maximum reuse, and on the treatment plant and processes needed to meet those standards.

Building a Master Plan

Beginning with what Ródenas describes as an 'intensive document review', there followed a number of visits to advanced treatment plants in France, Italy, Germany and Sweden. International experts were also consulted on quality standards applicable to the already-formed intention to maximise direct and indirect reuse in irrigation, a process that led to the adoption of standards in advance of any yet applied in Spain (see box).

By 1999, sufficient technical support had been amassed to allow the Secretary for Agriculture and Water to take proposals before the Regional Parliament, seeking a new law as framework for development of a

Librilla wastewater treatment plant, one of the 97 new plants built to treat wastewater in Spain's Murcia region.

'General Plan for Wastewater Reclamation' between 2001 and 2010.

In the following year the law 3/2000 was enacted and GDW had already progressed to an advanced stage with project design works. By 2001, GDW's overall Master Plan was also duly approved and initial work on the facilities began on site.

While set to comply with the requirements of EU water law, specifically the 91/271/EEC (Urban Waste Water Directive) and 2000/60/EU (Water Framework Directive), and national water and wastewater laws and strategies, the plan would have four principal objectives:

- Construction of a region-wide wastewater collection and treatment system
- Setting up of an independent regional agency to maintain and operate the new infrastructure
- Institution of a robust system for monitoring of discharges to sewers
- Facilitation and encouragement towards widespread take-up of industrial wastewater treatment at source.

Speaking of the situation at that time, Manuel Albacete says almost all agglomerations had collection systems but, on the whole, they were discharging either directly to the Segura or its tributaries, or to treatment plants rendered obsolete or poorly performing through lack of funding. 'In essence,' he says, 'we had to start from the beginning because neither the plants nor their collection systems were compliant with the directive 91/271/EEC.'

Now with the ability to cross local authority borders, the plan looked to expand the coverage of collection systems to take in as many centres of population as possible, and to enlarge the catchments draining to individual treatment plants. The inevitable increase in capital cost of sewer construction was gauged worthwhile against the longer-term gain in operation and maintenance of a reduced number of larger treatment facilities where better control could be expected to contribute to higher performance. Fewer sites would also reduce the environmental and social impact during construction and subsequent operation.

Enhanced treatment capacity

At the end of 2011 the new collection network took in 99% of the urban population of Murcia, all connected to 'large' treatment plants, of which 46 have been constructed, each capable of treating between 500 and 100,000m^3/day.

Allowing for future increases in population, industry and summer tourism peaks, the total design capacity for these plants is 525,000m^3/day or 190Mm^3/year, with tertiary treatment inbuilt for 70% of these flows. During 2010, actual treated volume was 110Mm^3, of which 50Mm^3 was given tertiary treatment and 100Mm^3 reused in irrigation, either directly or after discharge and subsequent downstream abstraction from the river. In some coastal sub-catchments a small part of treated inflow, 10Mm^3, is judged too saline for crop irrigation and is discharged to the sea. With the latter exception, all treated wastewater is reused, leaving no Segura outflow at the estuary.

Additional treatment capacity is also provided with a further 51 plants, described as in the 'small' range, with individual capacities of under 500m^3/day and an overall treatment capability amounting to less than 1% of the total constructed within the plan.

A distinct feature of the plan is that, with reuse in mind, all 97 new plants include treatment for nutrient removal and, as appropriate, tertiary processing to minimize suspended solids and disinfect the reclaimed output. High standards are essential for all final effluents because, if not going directly to irrigation, they will be discharged to the river that may offer little or no dilution. In this way environmental quality is enhanced and safety for indirect reuse improved.

The plan requires fully nitrified /

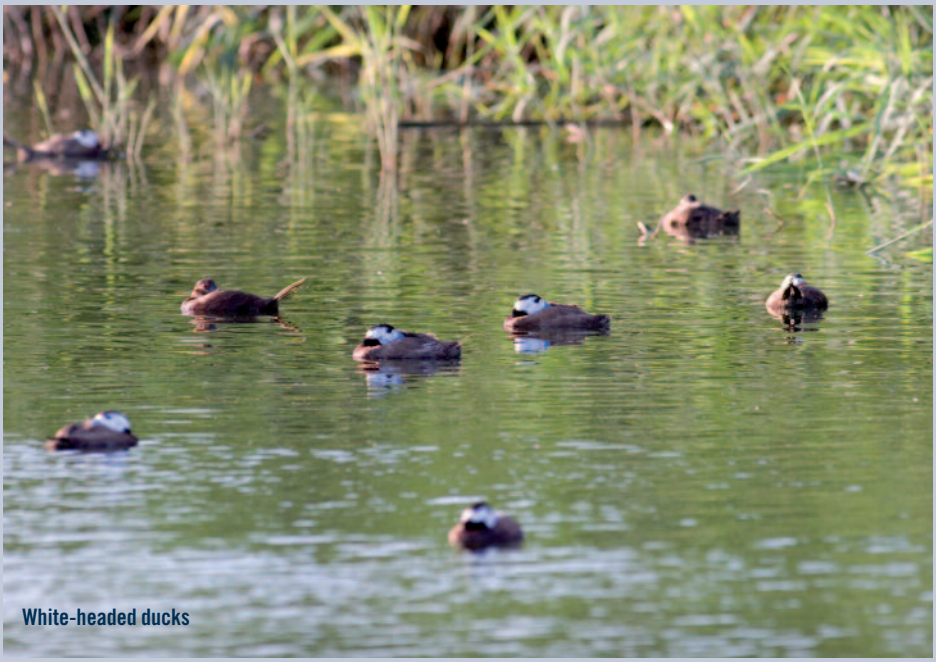
A positive outcome for nature and the environment

Natural springs and wetlands in Spain, including some in the Segura basin, have been adversely affected over many years by over-abstraction from underlying aquifers for irrigation water.

The project has encouraged a reversal of those trends by locating some new treatment plants on the site of old pond treatment systems. In several cases rehabilitated ponds are now used to store high quality treated water from the adjacent plants, prior to direct reuse in irrigation.

As large surface area, shallow lagoons, the ponds imitate natural wetlands and have become favoured resting places for large populations of migrating birds, including threatened species such as White-headed Duck and Marbled Duck.

In 2011, in recognition of this phenomenon, two of the largest lagoons, Molina-Campotéjar (300,000m^2) and Mazarrón-Les Moreras (200,000m^2) were added to the Ramsar Convention list of Wetlands of International Importance.



White-headed ducks

denitrified effluents containing total nitrogen of less than 15mg/l, or under 10mg/l for plants with over 100,000 contributing population equivalent (PE). Biological and chemical processing is also used to reduce total phosphorus in all effluents to 1 or 2mg/l, according to plant size.

Where tertiary treatment is included in the processing, the output parameters are adapted from those of Title 22 of the California Water Code (1978), imposing a turbidity limit of 2NTU and an upper limit for total coliforms of 2.2cfu/100ml.

While all the plan's new plants treat to higher standards than that required through secondary treatment by 91/271/EEC, the process trains vary widely according to local circumstances. The secondary stage, for example, always includes nutrient removal and generally uses extended aeration, but some plants depend on a conventional activated sludge process.

At the tertiary stage the processing range is more extensive, variously involving coagulation and flocculation followed by lamella settlers for further clarification, and filtration, generally on conventional sand beds but mesh and cloth filters are also used. Chlorination is always included in the disinfection process, where the main element is usually UV irradiation, although some plants use maturation ponds, and membrane bioreactors are also seen in a few cases, using ultrafiltration membranes.

In numerical terms one success of the project is quantified by the 100Mm^3/year of reclaimed water that has been added to the 803Mm^3/year naturally available in the basin – nearly 13% extra, all used in irrigation. It can also be recorded in the dramatic lowering of five-day biological oxygen demand (BOD) in the troublesome lower reaches of the river, in particular the section through the City of Murcia where, prior to 1990, the 400,000 population had become used to very low flows with an average BOD of 40mg/l. By 2002 this had been reduced to less than 10mg/l and is currently consistently in the 1 to 2mg/l range; at the same time river flow is greater due to the reclaimed input, giving the river a welcome attractive aspect as it passes through the city.

But those BOD figures tell only part of the story, because the new law 3/2000 did far more than set out the collection and treatment plan. Most importantly it formalized the 'polluter pays' principle and introduced a levy on all dischargers, a measure that has had a far-reaching and significant beneficial impact on the overall treatment picture as far as industry is concerned.

Impact of industry

Murcia's dominant industrial discharges come from fruit and vegetable canning – strong effluents but highly biodegradeable and capable of placing a heavy load on public treatment plants. The levy has encouraged industry towards on-site treatments as can be seen from the profile of BOD loading at the new plants. In 2003 incoming BOD load was 50,000 tonnes. As sewers were connected in the early project stages this rose to a peak of 56,000 tonnes in 2005 but has since dropped to the current average of 40,000 tonnes/year as industry has sought to control levy charges by treating at site. Over the same period the new public plants have pushed BOD removal rates from 84 to 98%.

Under law 3/2000 the role of the 'Wastewater Reclamation Levy' was to guarantee income for future conservation and maintenance of all the new infrastructure. Administration of that function and operation of the system in all its aspects was therefore placed in the hands of a new unitary authority ESAMUR, to be headed by Manuel Albacete, one of the core GDW team responsible for the plan.

Looking beyond the numerical measures of success the completed work has clearly improved the river and near-river environment for the people of Murcia and for flora and fauna. It has had a dramatic impact on migratory birdlife, with the creation of several extensive lagoon areas used for tertiary treatment or storage of reclaimed water (see box). These have become staging posts for birds en-route between Africa and Europe and have been acknowledged as important wetlands within the Ramsar Convention - a welcome reversal in Spain, where historically famous natural wetlands have suffered decades of deterioration through massive over-exploitation of underlying aquifers.

Ródenas sees the creation of the two regional authorities, GDW and ESAMUR, as key elements in getting the job done, giving them sole responsibility in their respective areas of construction and operational management. Getting it done in just ten years,

he says, was thanks to the 75 to 80% contribution from EU structural funds – and due to the pre-planning. 'It was carefully thought out. We knew what we had to do, how to do it and how to fund it.'

Careful phasing saw priority given initially to provision of good secondary treatment at the largest plants, followed by new construction at medium size units, providing both secondary and tertiary treatment. Emphasis then turned to providing tertiary treatment at the major plants.

Challenges

Joaquín Griñán says progress was not always smooth. 'During the planning phase we had to overcome the resistance of local authorities to losing their powers and then, of course, during construction we encountered the 'not in my back yard' syndrome. So the end product was not exactly to the plan; we tried to reduce protest by locating treatment plants at the site of former lagoon areas so that environmental impact was improved. And we made extensive use of sound-proofing and odour containment at all plants. Scheduled public visits to the first completed plants helped to dispel doubts.'

Reduction of public nuisance was also an important consideration with the enlarged collection systems, a prime example being the costly 4km long, 2.8m diameter soft ground tunnel constructed 16m below the City of Murcia.

Overall scheme costs were €645 million ($818 million), mainly invested (including EU input) through the regional government but with some input from Spain's central government and from city councils.

The scheme has attracted wide international interest and, in the view of Ródenas, represents a landmark in reclamation and reuse for its comprehensive nature, leading to complete recovery of a highly polluted river in a semi-arid region, something alluded to in the citation for the Aqueducto de Segovia award (see box).

Ródenas now has to turn his thoughts to management of the whole Segura basin, having been recently promoted to become President of the Segura River Basin Authority, a catchment that extends beyond the borders of Murcia, taking in parts of the regions of Andalucía, Valencia and Castilla la Mancha.

It is a sobering thought that, despite the good work of the last ten or 15 years, the basin lies deep in a water deficit, constraining the principal economic activity – the vital food growing that supplies fruit and vegetables to the 500 million people of the European Union.

The project has added 100Mm³/year of reclaimed water to the 803Mm³/year naturally available in the basin, although demand is such that additional inter-basin transfers may also be needed.

According to the current Basin Management Plan (BMP), total demand in the catchment is 2000Mm³/year, the bulk of which, 1600Mm³, is used to irrigate 260,000 hectares, an area that, within the BMP, cannot be expanded for lack of water.

On the supply side the natural resource of the Segura, 800Mm³/year, is augmented now with 100Mm³/year from reclamation and a further similar volume from desalination although, at a net cost of 5kWh/m³ produced, ten times the cost of reclamation, that is a least favoured option for the future. Since 1979 up to 600 Mm³/year has also been available by transfer from the Tagus basin in central Spain, at what Ródenas sees as a feasible energy consumption of 1kWh/m³.

There remains a substantial shortfall which can only be corrected, says Ródenas, by further inter-basin transfers, a much disputed component of the National Hydrologic Plan (NHP) approved in 2001, a feature abolished after a government change in 2004 but in urgent need of reinstatement.

Central to that debate is the NHP requirement that the receiving basin must first demonstrate that it has done what is possible to help itself towards self-sufficiency, a condition which Ródenas feels the Segura scheme has amply fulfilled.

Describing reclamation and reuse as an unconventional approach capable of further development, he believes the scheme has shown it is a method that has much to offer the semi-arid areas of Mediterranean Europe and other parts of the world – economic and energy-efficient and with demonstrable benefits to the water environment. ●

Reference

[1] *Holling, CS (1973), Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-23.*

Recognition by the Spanish Society of Civil Engineers

In February 2012 Spain's Society of Civil Engineers awarded the 2011 Segovia Aqueduct Prize for Civil and Environmental Works to the Segura Project. The citation read:

'This is the first time that a project of this nature is awarded. The jury has drawn attention to this 'new form of engineering' – 'systems engineering' rather than isolated projects. It has rewarded this approach to resolving a situation as complex as the complete recovery of a river, with a strategy of pre-planning for the following ten years.

'The jury also stressed that it has resolved the mechanisms of maintenance and operation of the constructed system, creating an economically sustainable project on the 'polluter pays' principle. They have valued the economic, energy and environmental efficiency in its implementation, and the overcoming of the administrative boundaries of the territories. They have also appreciated the size of the project and, specially, the achievement of the expected results, the environmental water recovery, the rise of quality of life in a big city and the contribution to the economy by guaranteeing water supplies for irrigation.'

Edelmiro Rúa Álvarez (Jury President of the Prize and President of the Spanish Society of Civil Engineers)