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# Technical, economic and social rehabilitation of old canals to cope with global change: the case of the Neste Canal (France)

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**Abstract.** Many canals were built during the 19th century to satisfy multiple uses, which have since highly changed, calling into questions about their function. This article assumes that these old hydraulic works can help the territories to adapt, if reforms of their hydraulic, economic and institutional management are carried out at the same time. It illustrates this assumption and its consequences with the Neste Canal (in South France). The evolution of the multiple uses and the decrease in the flows derived over the last 70 years are described conducting to a structural imbalance of its economic model. Its future depends on the political recognition of its contribution to the minimum water flows of the rivers of Gascony, the introduction of a payment for this ecological function, and changes in the hydraulic regulation system to satisfy this last function previously managed as a hydraulic constraint.

**Keywords.** UPH 18, UPH 22, SDG 6; inter basin water transfers in France, economic rehabilitation

## 1 Introduction

Interbassin water transfer (IBWT) is defined as "the transfer of water from one geographically distinct river catchment, or basin to another, or from one river reach to another" (Davies et al., 1992). The first large transfer canals, in Mesopotamia, date back to 2500 BC, but they grew in number especially between 1970 and 1990 (Rollason et al., 2021). In France, many were built in the 19th century for multiple-use purposes (irrigation, hydropower, navigation, drinking water, dilution of domestic pollution). With increasing water demands and decreasing resources, water transfers could account for 25 % of the world's water withdrawals by 2025 (Gupta and van der Zaag, 2008). The environmental, social, political and economic consequences of recent and future transfers are being critically analysed (Gao et al., 2021; Rollason et al., 2021). The modernization of old transfer infrastructure to adapt them to current demands also comes into question. After more than a century of functioning, they have profoundly modified aquatic ecosystems, sometimes described as "hybrid" (Crifasi, 2005), and have historically embedded in the relationships of populations to water and to these developed landscapes. However, climate change and the growing pressure on water resources are destabilizing the governance of these old structures. Water rights, historical uses and the maintenance of these "hybrid" ecosystems may be challenged (Wiener et al., 2008). In this article, we illustrate how the economic model on which the sustainable management of these old transfer structures is based is also altered by these changes in uses, resource availability and societal expectations. The illustration will focus on the Neste Canal, operational since 1862, in the south-west of France, in the foothills of the Pyrenees. In the first part, we present the context of this study and the methods used. The next part deals with the history of this canal, its operation and the evolution of its multiple uses. It emphasizes on environmental objectives, translated into management constraints. And it details flow sharing between uses. The third part describes the current economic model and its difficulties to cover the sustainable cost of the water transfer system. The fourth part discusses the recognition to supply water to hybrid ecosystems as a priority use, involving then flow support pricing and a governance reform to ensure the water transfer system's sustainability.

## 2 Background and methodology for the Neste Interbasin Transfer Study

The IBWT is based on the 28 km long Neste Canal, taking water from the River Neste at Sarrancolin, a tributary of the Garonne, at up to 14 $m^3\,s^{-1}$ (Fig. 1). It feeds 17 rivers in Gascony, almost at their source, directly from the canal, or via a network of 200 km of secondary earth canals and 15 dams (78 $Mm^3$) in the foothills, which store water diverted by the canal in winter. Upstream of the Neste River, 48 $Mm^3$ kept in 4 hydroelectric dams are mobilized to feed the canal when the river flow at Sarrancolin is insufficient to ensure the IBWT and the minimum environmental flow in the Neste River (4 $m^3\,s^{-1}$) (Fig. 2). This complex and interconnected hydraulic system constitutes the Neste system. Prior to the canal, the rivers of Gascony were intermittent in their upstream part. In the absence of an exploitable aquifer, drinking water was taken from these rivers, which were highly polluted by domestic wastewater, causing serious epidemics, a major argument for the construction of a transfer canal to ensure a cleanliness flow. Navigability at the confluence of these rivers with the Garonne was the other major justification for the building of this transfer canal by the State (Fernandez and Trottier, 2012) along with the operation of wheat mills. Industrial uses (cooling, agro-industry), irrigation (by gravity on the upstream slopes, by sprinkler from river pumping after 1970), and small hydroelectricity (on some river weirs) were very secondary. They became increasingly significant with the building of hydroelectric dams upstream on the Neste at the beginning of the 20th century, and the piedmont reservoirs from 1950 to 2010. The canal and most of the piedmont reservoirs belong to the State, which granted the concession to the "Compagnie d'Aménagement des Coteaux de Gascogne" (CACG) since 1990. The article is the result of an audit entrusted to INRAE during the transfer of infrastructure ownership to the two concerned Regions. This audit focused on the physical condition of the infrastructure, the water use dynamics, the sustainable cost of the Neste System, and the threats and opportunities of inter-basin transfers in the light of climate change and societal expectations (Garin et al., 2019a, b). The study methods combined document analyses (internal to the CACG, external study reports), visits to works, audits of accounts and customer database, semi-directive surveys of 40 local water stakeholders (to estimate the perceived benefits of the Neste system and the management issues) and 20 irrigators (to identify irrigation practices, water-saving potential and the economic value of irrigation).

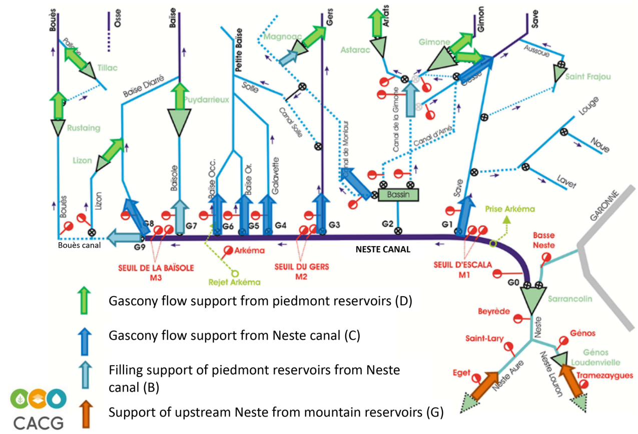


**Figure 1.** Scheme for the operation and distribution of water diverted from the Neste inter-basin transfer canal (CACG, 2018).

## 3 Brief history and hydraulic principles of the Neste System

### 3.1 An IBWT regulated by upstream since their inception

A decree published in 1909 defined the canal's diversion right – with an obligation of a minimum flow of 4 $m^3\,s^{-1}$ remaining in the river Neste – and the rules for sharing the water between the rivers re-fed by the canal. These rules took into account the uses: flow water support for drinking water and sanitation along rivers, several hundred hectares of irrigated meadows from the canal's gullies, and river navigation over 30 to 60 km downstream. This decree is currently still in application, even if uses have highly changed. The hydraulic operating rules have become more complex with the management of the kept volume in the upstream hydroelectric dams and the integration of the piedmont reservoirs. The upstream allocation is used during the low-water period (June to October) as soon as the flow of the Neste at Sarrancolin is less than 7 $m^3\,s^{-1}$ (3 $m^3\,s^{-1}$ minimum for the canal + 4 $m^3\,s^{-1}$ for the in-stream flow of the Neste River downstream of the catchment). The piedmont reservoirs are partly filled by the transfer canal during low water (43 $Mm^3\,yr^{-1}$ on average, with a maximum flow of 6 $m^3\,s^{-1}$, the rest comes from the watershed flow – 61 $Mm^3\,yr^{-1}$ on average). During low water, the transfer canal and the emptying of the piedmont reservoirs are managed together to satisfy the uses, under environmental constraints. As mentioned earlier, uses have changed over a century. The supply of 14 $Mm^3\,yr^{-1}$ of raw water for drinking water utilities now supplies 300 000 inhabitants. This urban demand has been relatively stable over the last 20 years, with the fall of individual consumption and the improved efficiency of the networks compensating for the increase in population. Industrial water now concerns only two companies, directly taking 7.3 $Mm^3$ from the canal for cooling. Their discharge into a small tributary of the Garonne is not used for

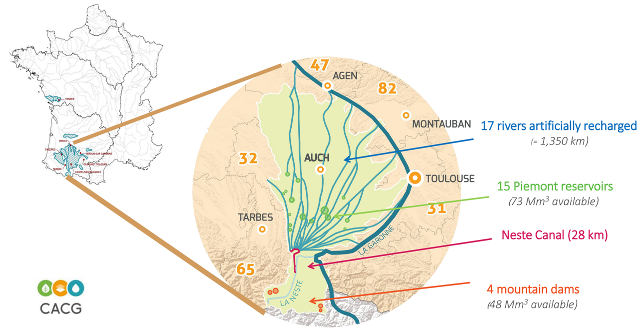


**Figure 2.** Simplified map of the Gascony rivers recharged by the transfer of water from the river Neste (CACG, 2018).

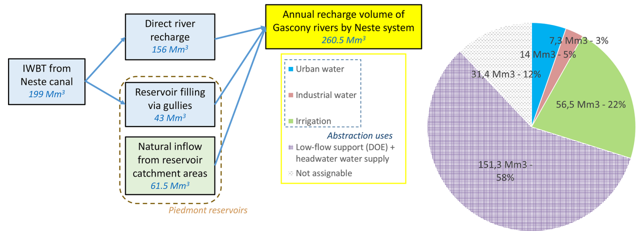


**Figure 3.** Annual water flow balance in the Neste system and uses (in millions of $m^3\,yr^{-1}$) (Garin et al., 2019a).

other purposes in the territory. Drinking water and industrial water represent a continuous flow of about 0.7 $m^3\,s^{-1}$.

## 3.2 Irrigation, the key issue for the last 50 years

Since the 1970s, irrigation from pumping in the recharged rivers has developed substantially (65 000 irrigable hectares). Irrigators sign an annual contract with CACG, tacitly renewed, mentioning the maximum flow that they take. This subscribed flow entitles them to a quota with two components (1000 $m^3\,L\,s^{-1}$ on June + 3000 $m^3\,L\,s^{-1}$ from July to October, during the peak of the low water support). Since the end of the 1990s, two declarations of the index of individual meters (June, October) make it possible to check consumption and to invoice penalties in the event of overruns (less than 1 % per year). Smart meters have been deployed for the past five years at all abstraction points to provide a precise map of the abstractions and to improve the regulation of the canal and the reservoirs. This allowance of 4000 $m^3\,L\,s^{-1}$ can be revised according to the hydrological situation evaluated each spring by the Neste commission. This commission brings together CACG, State services and Water Agency, as well as representatives of all water uses, but irrigators form the majority. This power struggle explains why 32 $m^3\,s^{-1}$ and 130 $Mm^3$ are subscribed for irrigation, to ensure access to water without constraint, even if the effective consumption is much lower: indeed, for the past twenty years, irrigation has withdrawn between 30 and 85 $Mm^3$ per year depending on the climate (56 $Mm^3$ on average for 2015-2020). The crop diversification (soya, arboriculture, legumes) does not compensate for the drop in water demand caused by the decline of irrigated corn.

## 3.3 Downstream regulation, more recently, to comply with environmental regulations

The environmental constraints of this IBWT have been sharpened and strengthened over time on the resupplied rivers. Each piedmont reservoir must respect an in-stream flow at its outlet. The resupplied rivers have also been given an objective low-water flow (DOE "Débit Objectif d'Etiage") at their confluence with the Garonne, like most non-intermittent rivers in France. The DOE is calculated to allow good water status to be achieved downstream of the measurement point and to satisfy all uses on average 8 years out of 10. The DOE is checked a posteriori to see whether it has been met, i.e. whether the lowest average flow of 10 consecutive days has been maintained above 80 % of its value. Other threshold values are used to trigger restrictions on use. The DOEs of the 10 main resupplied rivers have become one of the major set points for hydraulic regulation downstream of the Neste system. At the head of the basins, the cleanliness objectives have led to raising the target flows on the canal intakes and in the gullies, in order to dilute effluents from the nearest treatment plants. The system must thus combine a complex upstream and downstream regulation with different abstraction contexts depending on the season. The hydrological regimes of the resupplied rivers are inverted: from June to October, flows are higher than in spring and autumn, to compensate agricultural abstractions in addition to satisfying the maximum demand for cleanliness during the tourist period. After several decades of this hydrological regime, the aquatic ecosystems and the riverside vegetation have been deeply modified. Human activities depending on these hybrid ecosystems have then developed: recreational fishing, river recreational activities and boating along the banks and reservoirs, and micro-hydroelectricity. The living conditions have thus been profoundly changed. All local water stakeholders interviewed are aware of the territory's dependence on the Neste system. Most of them are attached to its long-term maintenance in order to cope with climate change and the expected decrease in natural flows. However, some environmental associations question the justification for maintaining these hybrid ecosystems. But they find it difficult to propose an alternative vision for the re-supply of water to the territory through this inter-basin transfer. However, despite this general awareness of the territory's dependence on the Neste system, most of the stakeholders interviewed are convinced that the transfer primarily serves irrigation, reflecting the composition of the Neste Commission. They consider that the water not withdrawn constitutes a minor part of the hydrological balance of the Neste system. However, this view is questionable: withdrawals only represent 30 % of the vol-

**Table 1.** Average revenue of the Neste system and estimated costs (Operation and Maintenance – O&M, and Renovation) (in EUR thousands) following two cost assignment scenarios according to the types of use (Garin et al., 2019b). In italic, the part of costs taken by low-flow support for each scenario.

| | Receipts | Cost scenario 1 (2024 value) | | | Cost scenario 2 (2024 value) | | |
|---|---|---|---|---|---|---|---|
| | (2011–2017) | O&M costs | Renovation costs | Total costs | O&M costs | Renovation costs | Total costs |
| Irrigation (rivers) | 2766 | 1086 | 689 | 1775 | 2190 | 2405 | 4595 |
| Urban water | 1000 | 473 | 242 | 715 | 952 | 842 | 1794 |
| Industrial water | 300 | 298 | 129 | 427 | 601 | 451 | 1052 |
| *Low-flow support* | | *1887* | *2638* | *4525* | | | *0* |
| Total | 4066 | 3744 | 3698 | 7442 | 3744 | 3698 | 7442 |

umes managed (transfers and reservoirs), while environmental regulations require 58 % (cleanliness of the headwaters of the basin and low water levels downstream) (see Fig. 3 which presents the hydrological balance, breaking down the share of water withdrawn and the support for the flows of the resupplied rivers). The inefficiency of the system can thus be estimated at 12% (volumes not allocated to an objective). Considering the hydrological impacts of the various climate scenarios for the year 2050 (Lamblin et al., 2015) and assuming that the objective low-water flows remain unchanged as well as drinking water needs, the volumes available for agriculture would be reduced to zero. The sustainability of the system is therefore problematic, especially as today the contribution of the various uses to the system financing does not reflect their water needs.

## 4 Economic model and sustainable cost of the Neste System

In order to guarantee the long-term water supply, the manager must cover the sustainable cost, i.e. the sum of the costs of renewal, maintenance and operation, as defined by Tardieu (1999). This cost, whose structure is mainly fixed as in all the network industries, must effectively be "*supported by the current beneficiaries who will hand over the assets in good condition to future generations*" (Tardieu, 1999).

The audit (Garin et al., 2019b) attempted to estimate it. The two parallel methods applied (current international standards and the state of the networks) gave similar estimates, evaluating the need to collect at EUR 3.7 million per year to ensure the sustainability of the infrastructure, in addition to operation and maintenance costs also evaluated at around EUR 3.7 million.

However, today only withdrawers pay for water, with revenues not exceeding EUR 4 million. Irrigation provides the greater part (70 %), with a fixed rate per litre subscribed, independent of the volumes consumed. As 90 % of the subscribed flows for irrigation are signed up, there is little hope of additional revenue without a radical change in the pricing system.

This reform is needed to better reflect the sustainable cost of the system, to encourage water savings and improve the equity of the effort requested between all uses. To do so, two contrasted scenarios have been built. In the first, the sustainable cost is broken down by use, based on the costs of specific services and by allocating non-allocable costs, according to the annual volumes required by each (Table 1). Compared to current average revenues per use, it leads to a doubling of the water average price for these uses. In the second scenario, following an alternative equity approach, the financial effort has to be assumed by the industry (50 % increase) and by the beneficiaries of low water support. The questions of the implementation of the low-water support service payment and its level are currently the key issues (between EUR 0 and EUR 4525 million per year).

## 5 Discussion: introducing low water support pricing and reforming the Governance

The Neste system is an illustrative case of these old inter-basin water transfers, carried out for multiple, interconnected, and intended (irrigation, industry, drinking water, navigation, sanitation and low-water support) or indirect (tourism, landscape, hybrid ecosystems) uses, which evolve over time. They thus profoundly shape the territories they serve (Rollason et al., 2021). However, these structures require costly long-term maintenance, whose financial impact is often underestimated during the first few decades, when the primary aim is to recover the heavy initial investments made by the end users.

When the time comes for costly renovations, the governance system and the economic model are destabilized: how to finance them and how to justify this new expenditure? Beneficiaries have become accustomed to not paying for services rendered, directly or indirectly, at their sustainable costs. By raising the problem of equitable sharing of these costs, the actors concerned are questioning the nature, importance and distribution of the benefits within the territory served, and the public interest in this transfer. In addition, the representations of these old structures, their economic, social and environmental functions today, and their justifications are being called into question, as was the case when they were built.

A related question concerns the effects of basins supplying the water, which could also valorize it, especially from a climate change perspective, even if this aspect was not covered in the terms of reference of the Neste System audit. Indeed, it is possible to note that 182 $Mm^3$ return to the Garonne out of the 199 $Mm^3$ taken from the Neste, one of its tributaries (cf. Fig. 3) but 150 km downstream, which deprives them of the corresponding flows. All these issues highlight the need to rethink the whole governance and sustainable cost sharing of the Neste system, which is currently underway. It is very likely that this will involve a change in the political balance of power between withdrawal and non-withdrawal users. The new governance will need to reflect better the priorities of existing uses and the contribution levels of direct and indirect beneficiaries. This renewed governance will have to be even more robust than the previous one to regulate the sharing of water and its costs, in the context of climate change and water demand increased by rising temperatures.

**Code and data availability.** The raw data used in this article is confidential, being for the most part a company secret.

**Author contributions.** PG and MM analysed the case of the Neste Canal, in close collaboration with DL and PC. PC calculated and presented hydraulic elements of the Neste System (especially Figs. 1 to 3); DL described the history of the system and calculated economic elements; PG and MM wrote the manuscript with contribution from DL and PC; MM, with the help of PG and DL, reviewed and edited the manuscript.

**Competing interests.** The authors declare that they have no conflict of interest. At the time of the study and the writing of the article, Daniel Lepercq and Pascal Chisne belonged to the company that operates the Neste system.



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