

MULTIPURPOSE SMART WATER NETWORKS: IOT AND DIGITAL TECHNOLOGY FOR OPTIMIZED WATER USES AND GLOBAL IRRIGATION MANAGEMENT

RÉSEAUX D'EAU INTELLIGENTS POLYVALENTS: IOT ET TECHNOLOGIE NUMÉRIQUE POUR L'OPTIMISATION DES USAGES D'EAU ET LA GESTION D'IRRIGATION À L'ÉCHELLE MONDIALE

Frédéric Bonnadier¹, Guillaume Dallard², Arnaud Ouedraogo³, Emmanuel Patenotre¹,
Evelyne Tepinier³

ABSTRACT

The article presents the REImu program developed by the Société du Canal de Provence (SCP), which aims to transform its multipurpose water distribution networks into "Smart Water Networks" using digital technologies such as IoT, Big Data, artificial intelligence, and hydraulic modeling. This initiative responds to increasing pressures on water resources due to climate change and seeks to improve water allocation, efficiency, and sustainability at a territorial scale.

SCP operates a vast infrastructure of 6,000 km of pipelines and 68,000 delivery points supplying water for multiple uses, including irrigation, drinking water, industry, and urban services. Launched in 2020, REImu is mainly based on the deployment of smart water meters, with around 45% already installed by 2026. These devices produce detailed consumption data (hourly to monthly), which are integrated into a cloud-based information system alongside other datasets such as weather, SCADA, GIS, and remote sensing data.

This data-driven approach provides significant benefits for both the operator and users. For SCP, it improves the understanding of network behavior, enables better anticipation of peak demand, and supports more efficient system design and operation. For customers, digital services such as consumption monitoring dashboards, leak alerts, and personalized recommendations encourage more responsible and informed water use. Additionally, the data support more flexible and sustainable contractual arrangements.

Two key innovations are highlighted. First, the development of a new connected irrigation turnout (Prisunik/Prizius), equipped with an ultrasonic full-flow meter, improves measurement accuracy, reliability, and ease of handling compared to older devices. This solution is intended for large-scale deployment across the network.

Second, the project introduces digital twins of water networks, combining real-time data with advanced modeling tools. By integrating artificial intelligence and adapting the historical Clément probabilistic formula into the EPANET modeling environment, SCP has developed a new platform (OSIREM) for simulation, design, and operational optimization. Finally, the project paves the way for the FutureHydro initiative, which aims to create a large-scale living laboratory integrating hydraulics, agronomy, and data science to enhance climate resilience and promote sustainable water management.

Keywords: Smart Water Networks; water allocation; drinking water; hydraulic modeling; water networks.

¹ Société du Canal de Provence, Engineering and Services, AIX EN PROVENCE, France

² Société du Canal de Provence, Purchase, AIX EN PROVENCE, France

³ Société du Canal de Provence, Water Service, AIX EN PROVENCE, France

RESUME

L'article présente le programme REImu développé par la Société du Canal de Provence (SCP), qui vise à transformer ses réseaux de distribution d'eau polyvalents en «Réseaux d'eau intelligents» grâce à des technologies numériques telles que l'IoT, le Big Data, l'intelligence artificielle et la modélisation hydraulique. Cette initiative est une réponse aux pressions croissantes exercées sur les ressources en eau dues au changement climatique et recherche à améliorer l'allocation de l'eau, son efficacité et sa durabilité à l'échelle territoriale.

La SCP exploite une vaste infrastructure de 6 000 km de conduites et 68 000 points de distribution fournissant de l'eau pour usages multiples, y compris l'irrigation, l'eau potable, l'industrie et les services urbains. Lancée en 2020, le programme sREImu repose pour l'essentiel sur le déploiement de compteurs d'eau intelligents, dont environ 45% étant déjà installés d'ici 2026. Ces dispositifs produisent des données de consommation détaillées (horaires à mensuelles), qui sont intégrées dans un système d'information basé sur le cloud aux côtés d'autres ensembles de données tels que les données météorologiques, SCADA, SIG et de télédétection.

Cette approche basée sur les données offre des avantages significatifs à la fois pour l'opérateur et les usagers. Pour la SCP, elle améliore la compréhension du comportement du réseau, permet une meilleure anticipation de la demande maximum et soutient une conception et une exploitation plus efficaces du système. Pour les clients, des services numériques tels que des tableaux de bord de suivi de la consommation, des alertes de fuites et des recommandations personnalisées encouragent une utilisation plus responsable et mieux informée de l'eau. En outre, les données soutiennent des dispositifs contractuels plus flexibles et durables.

Deux innovations clés sont mises en évidence. Tout d'abord, le développement d'un nouvel ouvrage de prise d'eau d'irrigation connecté (Prisunik/Prizius), équipé d'un débitmètre ultrasonique complet, améliore la précision des mesures, la fiabilité et la facilité de manipulation par rapport aux anciens dispositifs. Cette solution est destinée à un déploiement à grande échelle sur le réseau.

Deuxièmement, le projet introduit des jumeaux numériques de réseaux d'eau, combinant des données en temps réel avec des outils de modélisation avancés. En intégrant l'intelligence artificielle et en adaptant la formule probabiliste historique de Clément à l'environnement de modélisation EPANET, la SCP a développé une nouvelle plateforme (OSIREM) pour la simulation, la conception et l'optimisation opérationnelle.

Enfin, le projet ouvre la voie à l'initiative FutureHydro, qui vise à créer un laboratoire vivant à grande échelle intégrant l'hydraulique, l'agronomie et la science des données afin d'améliorer la résistance climatique et de promouvoir une gestion durable de l'eau.

Mots-clés : Réseaux d'eau intelligents; Allocation de l'eau; Eau potable; Modélisation hydraulique; Réseaux d'eau.

CONTEXT: THE COMPANY AND THE PROJECT

The Société du Canal de Provence (SCP)

The Société du Canal de Provence (SCP) is a major player in water management and infrastructure related to water resources in the Sud Provence-Alpes-Côte d'Azur (PACA) region, in France and internationally. For nearly 70 years, SCP has developed unique expertise to address the ecological, economic and social challenges associated with sustainable water management. SCP stands out through its commitment to innovation, energy transition and social responsibility.

SCP addresses the daily challenge of securing food and water access across territories, thereby contributing to their development and economic growth. Its expertise enables it to provide solutions tailored to the challenges caused by climate change. Whether within the framework of the regional

concession of the Canal de Provence, within its engineering and services offerings or in renewable energy production, SCP meets the needs of a wide range of clients at regional, national, and international levels, maintaining the same high standards. It innovates to preserve, control and enhance water resources and to support the optimization of their use.

As the concessionaire of the Sud Provence-Alpes-Côte d'Azur Region and as a "regional development company", SCP manages the exceptional regional hydraulic asset of the Canal de Provence. This concession primarily mobilizes water from the Verdon River to transport and distribute it throughout the entire Provençal territory. By mobilizing only 4% of the approximately 6 billion cubic meters flowing annually through the Durance–Verdon watershed, the Canal de Provence secures 40% of the regional water supply needs, while applying the principle of upstream–downstream solidarity. From the outset, hydraulic infrastructures have been designed and operated to ensure the most efficient management of water resources, notably through the use of digital technology for remote control of facilities and dynamic regulation of the canal, allowing notably an efficiency of 95% on the main infrastructure.

The multipurpose water distribution networks, comprises 6,000 km of pipelines of various diameters, and supplies 68,000 delivery points (irrigation hydrants, underground outlets, etc.) to serve 50,000 customers. These networks support a wide range of uses, including crop irrigation, watering of gardens and parks, supply for enterprises and industries, drinking water for cities, and fire protection. Thus, SCP represents a key instrument for the rational sharing of water resources at the regional level, helping to mitigate the consequences of climate change.

The REImu project

Since 2020, SCP has been implementing the so-called *REImu* program to transform its multipurpose networks into "Smart Water Networks" using IoT, Big Data, AI and modelling technologies. This program aims to expand and enhance the available data assets with the dual objective of providing online services to customers and implementing applications for process optimization by SCP network designers and operators. Among other initiatives and projects at different scales (territory, network, plot and use) resource to usage, it addresses the major challenges of efficient water management and equitable water sharing in the context of climate change.

The ambition of this project is noteworthy due to its comprehensive approach implemented at the extensive scale of the multipurpose networks of the regional concession. The objectives are consistent with the SCP's mission of general interest, which aims to promote solidarity, innovative and controlled water management. Within this framework, data, as information, are essential to the network operator to measure, understand, and anticipate water needs across different uses, and then act accordingly to adapt operations, optimize processes and methods, secure access to water, compensate for insufficient rainfall by delivering just the required quantities, and preserve overall resources.

The project began with a 3-year pilot phase from 2020 to 2022. During this phase, different technical solutions were developed and tested on pilot networks (IoT solutions, communication protocols and coverage, data collection and organization, pipelines and data platform, data processing, first services and applications, etc.), after which the selected solutions, adapted to future growth in data volumes, were implemented. From 2023 onwards, the project has been progressively implemented in operational conditions and deployed at larger scale, while continuing numerous developments and addressing new challenges.

The foundation of the project is the deployment of connected water meters at the delivery points of SCP's networks. By mid-2026, approximately 45% of the 68,000 rural contracts are equipped with smart meters (using LoRa communication devices plugged onto them). Full deployment is targeted by 2032.

The data payloads transmitted from these devices are transformed into monthly, weekly, daily and hourly water consumptions values, along with other indicators and alarms. These data are aggregated in a cloud-based platform integrated into SCP's Information System, together with numerous other datasets (including other IoT data from pressure sensors for example, weather observations and forecasts, GIS

data, customer data, SCADA data, etc.). Other data from external sources are also used, such as remote sensing data analyzed in other SCP projects called IAGO and ASICS [2].

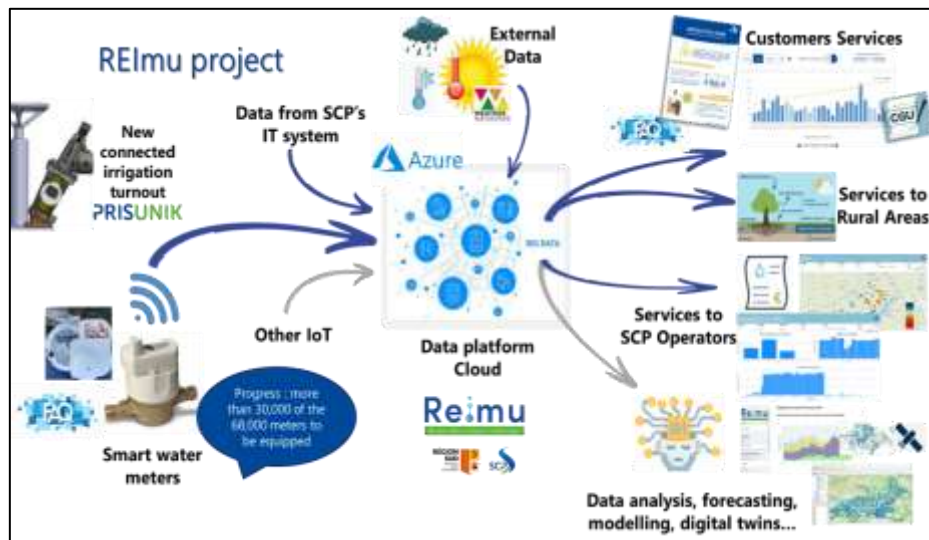


Figure 1. The REImu project general architecture

On the SCP's side, the aim is to achieve a better understanding of network operation and user practices – particularly in irrigated agriculture, especially under conditions of water stress – in order to optimize the utilization of network capacities, especially during peak consumption periods, and to improve design assumptions so as to reduce economical et ecological impacts.

On the customer side, data constitute a powerful incentive tool, enabling users to become aware of their actual consumption and to actively contribute to water savings. It is also a key lever for developing new contractual solutions that are more flexible and, above all, encourage less water consumption.

Various use cases have been developed and implemented:

- The direct use of remote consumption records for billing purposes,
- Digital services for customers, such as consumption monitoring through graphical interfaces, alerts in case of suspected leakage or overconsumption if user thresholds are exceeded, and personalized recommendations for gardens watering.
- Numerous dashboards for the SCP staff:
- Customer relationship support tools providing dedicated staff with access to indices, consumption data, and alerts from connected meters, enabling better monitoring of customer behavior and more effective responses to their inquiries.
- Decision-support tools for operators, particularly in situations of network stress regarding their capacities, thanks to an hour-by-hour visualization of consumption over recent days, using aggregated curves, and indicators displayed in maps or sortable tables.
- Dynamic dashboards designed for all SCP technicians and engineers wishing to analyze consumption across distribution networks - over time, space, and by use - based on measurements from connected water meters.
- An investigation tool, particularly valuable for engineering purposes, for analyzing and modeling "consumption at delivery points" (hourly time series), including data consolidation

and reconciliation, exploration of links with contextual data (such as spatialized weather, land use, crops, and remote sensing), and prediction and classification processing to define consumption behavior categories using AI techniques.



Figure 2 - Examples of dashboards for consumptions monitoring

Among the many achievements of the project, two specific topics are detailed below: the development of a new irrigation turnout, and the implementation of network digital twins.

THE DEVELOPMENT OF A NEW IRRIGATION TURNOUT

The origin of the project called “Prisunik”

A emerging project initiated before 2020 was included in the REImu program because it concerned, in particular, the measurement of irrigation consumption, which is highly predominant in peak operation and in the sizing of multi-purpose networks. An irrigation turnout is a hydraulic device connected to a hydrant and used to deliver water for irrigation through on-farm installations linked to it. Typically, this device performs the functions of volume measurement, pressure reduction and flow limitation.



Figure 3 – One turnout connected to a hydrant

The existing irrigation turnouts installed on the hydrants are based on outdated designs and present significant drawbacks:

- From a metrological perspective, they incorporate bypass water meters through which only part of the flow passes, resulting in inaccurate measurements and even unreliability due to frequent obstruction by particles. This is not suitable when the objective is to obtain high-quality data from connected meters.

- From a procurement and logistics perspective, multiple models and brands exist, and their incompatibilities require managing many references including spare parts. In addition, their weight exceeds 12 kg (26 lbs.) and handling them can lead to musculoskeletal disorders or even injuries.

During the initial phase of the REImu project, the bypass meters of the existing turnouts were equipped with communication devices, in the same way as water meters in measuring lines. This enabled immediate data collection, although the quality of the data was not always satisfactory.

Challenging the suppliers

In parallel, SCP sought to challenge the suppliers to design a new generation of irrigation turnout. To this end, a competitive dialogue procedure was launched based on detailed technical specifications defining the framework of requirements within which candidate suppliers were asked to propose their solutions. The main challenges included adaptability to all types of hydrants in the networks, improved reliability of water consumption measurements (in raw water conditions), and reduced weight for safer and easier handling.

Regarding the water meter, it was requested that the measurement be carried out on the full flow passing through the turnout rather than on a bypass thereof. The meter was expected to operate without moving mechanical parts. Technologies based on turbines, propellers, or pistons were therefore excluded. The accuracy requirement was to approach MID⁴ certification standards up to 40 m³/h. At the conclusion of this process, a design and development contract was awarded for a new connected irrigation turnout, named Prizius, to the company Claire Solutions (brand Sainte Lizaigne Irrigation), which was selected through this innovative procedure.



Figure 4 - Leaflet of the PRIZIUS product and the QR code to the technical sheet

⁴ Measuring Instruments Directive. The MID directive is a European regulation that sets common rules for the design, manufacture and verification of measuring instruments in order to ensure their accuracy and reliability on the European market.

After a extensive process of development, testing and industrialization, the final solution combines a full-flow communicating water meter - an ultrasonic Intelis wSource DN50 from ITRON, integrating native remote communication - and a polymer-based hydromechanical system providing pressure reduction and flow limitation functions.

The final product, named Prizius by the manufacturer, is now available in the SL Irrigation catalog and a focus on the PRIZIUS solution is available on the website: <https://groupe-claire.com/en/solutions-and-services/irrigation-networks/>⁵.

The first series were delivered to SCP in April 2026 allowing deployment to begin on the initial targeted networks. This new turnout is integrated into the overall deployment of connected water meters across SCP's networks. It is intended to replace approximately 20,000 existing turnouts over the next 10 years and to equip all new networks with this product. Deployment requires particular attention to adjustments that farmers may need to make to their private connections due to dimensional changes.

Ultimately, this modern product represents a significant and practical lever for improving consumption management, enhancing knowledge of irrigation practices, and contributing to balanced water resource management at the territorial level.

THE IMPLEMENTATION OF NETWORK DIGITAL TWINS

The approach in the REImu program

The availability of consumption data from communicating meters naturally opens up numerous opportunities for value creation, including their use in network models to accurately reproduce system operation. The intention was to combine artificial intelligence algorithms with network modeling tools, clearly relying on the integration of these analytical and statistical techniques. More generally, a key objective of the REImu project from the outset was to reassess the methods used to calculate distribution networks by confronting them with the actual behavior of users and the real functioning of networks, particularly during peak periods.

The aim is to provide a more accurate representation of network operation, whether for existing systems - used to monitor compliance with delivery contracts over time- or for future irrigation networks, in order to improve design and ensure accurate sizing. With the emergence of large volumes of consumption data at delivery points, and by combining them with aggregated consumption measurements from the SCADA system, significant work was initially carried out to explore the capabilities of predictive AI algorithms. Three main sub-objectives were identified: short-term forecasting of network-level consumption, understanding consumption patterns at delivery points, and calibrating analytical model parameters using measured data. The studies, prototypes and evaluations conducted - including tests entrusted to SCP teams - led to the development of two tools named "REImu Forecaster" and "REImu Explorer"⁶.

More specifically, the "REImu Explorer" tool allows multiple and in-depth analysis of consumption data from connected meters in conjunction with other parameters, particularly weather and land use. It includes the following functionalities:

- reconstruction of consumption data and generation of formatted, consistent and as complete as possible datasets, using various selectable techniques (including interpolations, neighborhood-based methods, machine learning approaches to fill measurements gaps, use of upstream flow data, sharing of contractual characteristics, or a multivariate set regression model to try to estimate unobserved consumption).

⁵ See the technical sheet for details.

⁶ Developed by Aiway, the first SCP's data science partner

- filtering and exploring consumption data in combination with other "contextual" datasets (such as production lines flow rates, usage types and contracts, spatialized weather data, land use and crops information, and remote sensing data).
- Clustering, i.e., grouping delivery points according to similarities in consumption behavior, with the possibility of applying different AI algorithms and distance metrics.
- The development of consumption profiles for integration into network modeling tools, including the generation of curves or parameters using various methodologies.

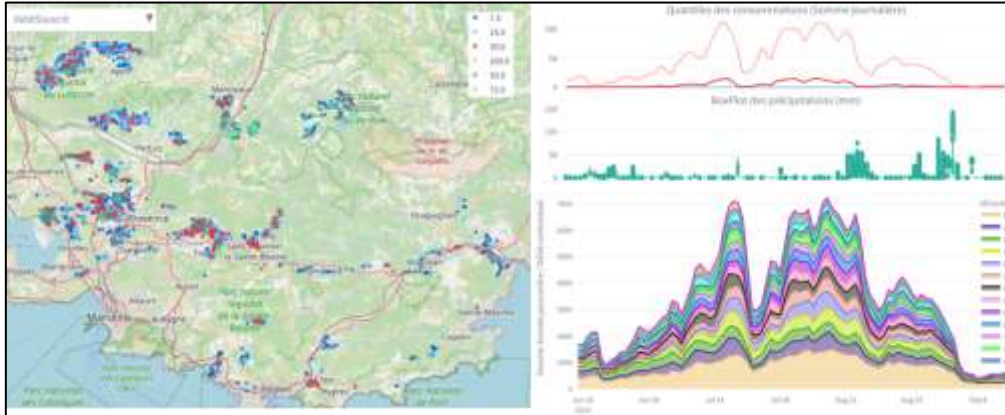


Figure 5 - Some views of REImu Explorer tool

The evolution of the water networks modeling tools and the Clément Formula

In the field of hydraulic modeling of pressurized networks, the software historically used by SCP is called IRMA. This in-house software has been maintained over the years, because it lies at the core of methodologies for designing new networks and monitoring networks in operation.

A distinctive feature of this software is the integration of the well-known "Clément's Formula" named after René Clément, former general director of SCP. This probabilistic formula, developed in 1966 [1], represents a major innovation and is a powerful tool for estimating, in a theoretical yet efficient and robust manner, peak flows in on-demand distribution networks, particularly for irrigation or multipurpose systems. More specifically, the Clément formula estimates the theoretical peak discharge of a set of irrigation outlets (or other withdrawals) operating under on-demand conditions, by accounting for temporal and spatial dispersion of withdrawals. This involves defining a probability of opening for each outlet (since they are not all operating simultaneously) and a target level of "operational quality," corresponding to the probability that the calculated peak flow will not be exceeded.

$$Q = \sum_i d_i p_i n_i + U(P) \cdot \sqrt{\sum_i n_i p_i (1 - p_i) d_i^2}$$

Figure 6 – The Clément Formula [1]

This formula is notably absent from standard hydraulic modeling tools available on the market. In fact, its probabilistic nature results in a representation of the flows in the network at peak times, which does not respect the conservation of the flows at the nodes and is not directly compatible with standard tools.

However, over time, the IRMA software became increasingly difficult to maintain for various reasons, and no satisfactory alternative had been identified despite several attempts.

During the REImu project, the idea therefore emerged to integrate the Clément Formula into EPANET, an open-source hydraulic modeling engine that is widely used and recognized worldwide within the hydraulic engineering community. To achieve this, several methodological approaches were developed to reconcile probabilistic demand modelling with conventional hydraulic solvers. Following this major breakthrough, further development led to the creation of an integrated multifunctional tool.

Towards a modular, interoperable, and scalable hydraulic tool for design, operation, and business development

Indeed, the module developed around the EPANET solver constituted the first step toward building a comprehensive environment, composed of several components, capable of executing different types of simulations on the same water system and comparing their results.

This approach paved the way for advanced tools for network design and optimization, including sizing, scenario analysis, and technical and economic performance assessment. Beyond design applications, these tools also form a foundation for future network operation. The convergence of field data from connected sensors, hydraulic models, and computational tools enables the creation of a true hydraulic digital twin, based on explicit physical laws and enhanced by learning mechanisms and artificial intelligence.

In particular, it becomes straightforward to compare theoretical modeling of the “peak hour” with the actual dynamic operation observed during “peak periods” (hourly variations over several days or weeks), using REImu measurement data.

That is how the OSIREM platform was born⁷.

The objective is to provide, within a single environment, all the functions required by modelers - whether designers or operators - in order to facilitate the following:

- Model creation and updating (including conversion of legacy models and integration with GIS systems).
- Execution of both static simulations (based on the theoretical peak using Clément’s Formula) and dynamic simulations over defined time periods.
- Implementation of digital twins through automated integration of consumption data from connected water meters.
- Advanced analysis of flow and pressure results, including comparison between different simulation outputs.
- Optimization of network structural characteristics (such as layout, delivery point locations, pipe diameters, etc.).
- Deployment of additional functionalities, including network performance indicator curves, calculation of flow margins, and assistance in the design and positioning of specific components (air valves, drain valves, purge systems, etc.).

This working environment for network modelers has been designed to ensure excellent ergonomics (for example, in the visualization of results and representation of networks and associated metadata on various geographic backgrounds), as well as seamless navigation and interconnection between modules. Fluidity, interactivity and responsiveness are key design principles.

⁷ In French “Outil de Simulation Intelligent des Réseaux d’Eau Multiusages” translated as “Intelligent Simulation Tool for Multipurpose Water Networks” or alternatively “Optimized Simulation for Intelligent Resource & Energy Management”.

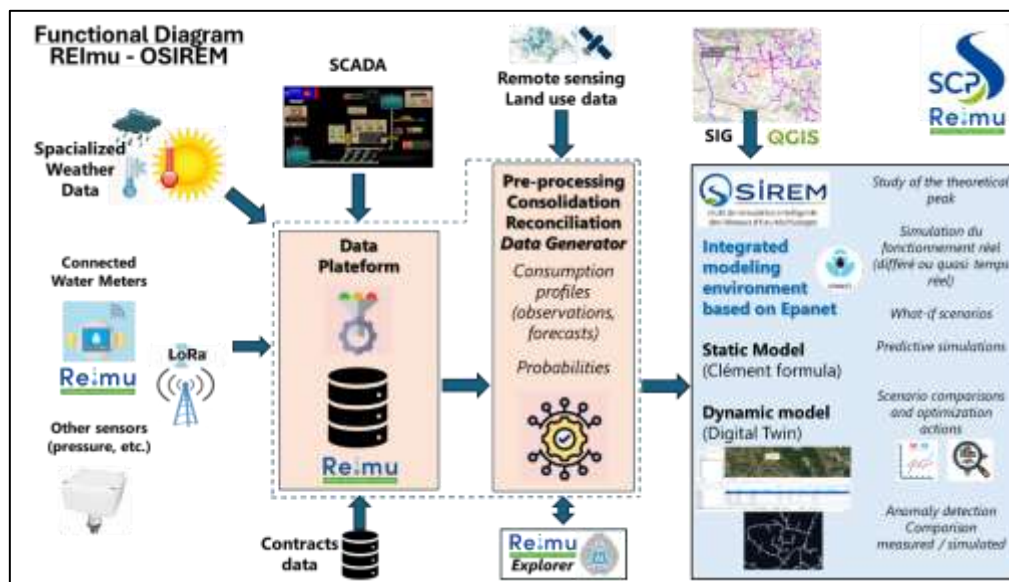


Figure 7 - Functional diagram of the REImu-OSIREM system

Continuous testing by expert users across a wide range of use cases ensures both the relevance of functionalities and the robustness of the solution. Based on the existing modules, a structured development roadmap is maintained over time.

The benefits are numerous, including significant time savings for both network design studies and operational analyses. In addition, the performance of the tool facilitates the evaluation of multiple scenarios. Finally, the platform enables tangible economic benefits through its modules dedicated to optimized network design.

Actually, studies are already being carried out using OSIREM, including the following:

- Reinforcement studies of hydraulic systems combining pumping stations and reservoirs, and verification of tank filling using digital twin.
- Reassessment of parameters used in Clément's Formula (such as opening probabilities and operational quality levels) during the design phase,
- Analysis of introducing modified contracted flow values for irrigation turnouts, closer to actual needs as known thanks to REImu, in order to evaluate benefits through more accurate sizing and/or increased availability of flows for new connections.

Turning infrastructure into intelligence

SCP develops these tools primarily for its own internal use but seeks to share its expertise through a "controlled open-source" or "open-core" approach. Indeed, within the specific field of pressurized irrigation, there is currently no truly modern equivalent tool that integrates:

- A statistical approach based on Clément's Formula.
- Coupling with GIS and remote sensing data.
- Integration with operational data and digital twins to objectify and utilize design margins in real conditions.
- Optimization of pipe diameters, network layout, and delivery point locations.

- Calculation of characteristic network envelope curves, including reverse analysis through stochastic methods.
- And other advanced features.

The strength of this approach lies in the implementation of a hydraulic digital twin creating a continuous feedback loop between statistical design assumptions and actual network operation. By confronting theoretical peak-demand modelling with measured field behaviour, the system not only enables progressive refinement of design methodologies and improved understanding of user practices but also helps objectify and quantify design margins embedded in conventional sizing approaches. These margins can then be safely leveraged to optimize energy and water use, improve infrastructure utilization, support controlled network densification, and increase system adaptability while maintaining hydraulic performance and contractual service guarantees.

Bringing together different areas of expertise is the SCP's trademark and strength. For this reason, the next phase involves transforming its operational territory into a full-scale, open-air hydraulic laboratory through a new federative project called FutureHydro. This project combines hydraulics, field sensors, remote sensing, agronomy and soil science, control systems, numerical modeling, data science, hydrology, etc.

The overall objective is to strengthen the climate resilience of hydraulic systems and irrigated territories by demonstrating, at real scale, an integrated and predictive approach optimizing water use, energy consumption and infrastructure design and operation.

The vision of FutureHydro is therefore not limited to software development but extends to transforming data into actionable operational decisions and improving the integration of hydraulics, agriculture, soil management, energy systems, and natural resource management. The goal is to enhance territorial resilience in the face of drought, uncertainty, and competition for resources, through a replicable model for eco-technical territorial planning.

Because every drop counts and for every drop we need to account.

REFERENCES

- [1] Clément, R. (1966). Calcul des débits dans les réseaux d'irrigation fonctionnant à la demande. *La Houille Blanche*, 52, 553–576.
- [2] Diarra, M. – Ouedraogo A.T. – Lecollinet, J. – Urruty, N. (2026). Earth Observation and Smart Metering to Spatialize Agricultural Water Uses in Mediterranean Context. 26th ICID International Congress.