CEDEX

TECHNICAL AND SCIENTIFIC ACTIVITIES | 2021

CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS

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Ministry of Transports, Mobility and the Urban Agenda

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FOREWORD

Isabel Pardo de Vera Posada

Secretary of State for Transports, Mobility and Urban Agenda

President of CEDEX

One of the priorities of the Secretary of State for Transports, Mobility and Urban Agenda is to promote sustainable, safe, and connected mobility, a fundamental element for economic development, quality of life, compliance with environmental objectives, and social and territorial cohesion. To this end, the ministry is promoting a series of reforms that support its policy, such as the Preliminary Draft of the Mobility Law, the Mobility Strategy, and the Indicative Railway Strategy. Both the governing bodies and the agencies and entities attached to the department are committed to the materialization of these reforms, whose main financing instrument is the Recovery, Transformation and Resilience Plan.

Among these organizations is the Centre for Studies and Experimentation of Public Works (CEDEX), which I see as an essential instrument for the promotion of these policies thanks to its experience, independence, high degree of specialization, and scientific-technical rigour.

As Secretary of State for Transports, Mobility and Urban Agenda (MITMA), I chair the Governing Council of CEDEX, and it's an honour to present this Report on Technical and Scientific Activities for 2021.

First of all, I'd like to highlight the flexibility and efficiency with which the activity of the CEDEX during 2021 has been aligned with the needs of the general directorates and entities attached to

MITMA and MITERD, helping to promote the policies implemented by both departments. This is reflected in the effort made by the agency to further the fulfilment of its 2020-2022 Strategic Plan, of which I'd like to emphasize its commitment to promote R&D&I with the aim of providing a better service to the sector and to society at large.

Specifically, I should underscore three major contributions that outline the broad scope of services provided by CEDEX to the department in 2021:

- Firstly, the effort carried out by CEDEX to complement its knowledge and response capacity in terms of infrastructure, mobility and transport services with the development of innovative technological and digital tools within the framework defined by the Safe, Sustainable and Connected Mobility Strategy and, very particularly, with regard to the specific pillars of Safe Mobility, Low Emission Mobility and Smart Mobility.
- Secondly, it's worth highlighting the consolidation of CEDEX as a technology provider and innovative leader in the field of interoperability and railway infrastructures, activities that are in line with the Indicative Strategy for the Development, Maintenance and Renewal of the Railway Infrastructure.
- Thirdly, I'd like to heighten CEDEX's support in two essential areas: mitigation and adaptation to climate change, and environmental noise studies, both of which contribute to the implementation of the actions included in the National Plan for Adaptation to Climate Change (particularly in relation to mobility and transport) and in the Noise Action Plans.

All these services constitute an important support for the initiatives promoted by MITMA to decarbonize and digitalize transport, and to promote active mobility within the framework of the Recovery, Transformation and Resilience Plan.

I'd also like to point out that the technological difficulties associated with innovation and the resolution of specific problems make CEDEX a tool through which MITMA intends to facilitate the public-private collaboration model, making the unique scientific-technical facilities of CEDEX and its highly specialized personnel available to the private sector.

Finally, I'd very much like to make use of this opportunity to underline the efforts made during 2021 by the new CEDEX Management, its executive staff and all the personnel that make up the technical and administrative teams, in a year still marked by the exceptional conditions resulting from the Covid-19 pandemic.

FOREWORD

Hugo Morán Fernández
Secretary of State for Environment
Vice President of CEDEX

The Ministry for Ecological Transition and the Demographic Challenge (MITERD) has among its competencies the development of policies in the fight against climate change, protection of natural heritage, and the transition towards a greener productive and social model.

In particular, the Secretary of State for Environment collaborates substantially in the development of these responsibilities, as set out in Royal Decree 500/2020, which develops the structure of the department. It is within this competence framework that the Centre for Studies and Experimentation of Public Works (CEDEX) plays a fundamental role of technological support. Specifically, CEDEX provides technical support services to the different directorates-general and public bodies responsible for environmental and climate change policies, as well as for hydraulic and coastal protection infrastructures.

In my position as Secretary of State for Environment, I hold the Vice-Presidency of CEDEX and, consequently, I have the honour of presenting these lines for its Technical and Scientific Activities Report for 2021.

On balance, 2021 has been a year characterised by environmental and energy challenges that have demanded a rapid, innovative, and efficient response from MITERD. CEDEX has made a very significant contribution to the design of solutions and in the preparation of the

department's strategies through experimentation, modelling, digitalisation and the study and analysis of scientific and technical aspects.

In reviewing the activities included in this Report, I'd like to highlight three main areas in which the presence of CEDEX has been of value to this department:

- The role of CEDEX in the field of Spanish water resources management during 2021 has been based on its historical knowledge, prolonged over time, of the problems of Spanish river basins. This historical knowledge has been fundamental to address the new challenges related to the impact of climate change.
- CEDEX's contributions to coastal and marine protection have been decisive in promoting the Action Plan for the Protection of Particularly Vulnerable Coastal Areas, such as the Ebro Delta and the Mar Menor, as described in the pages of this Report. The agency has also collaborated in the Planning of the Spanish Maritime Space through the detailed analysis of the activities and uses involved and through the development of the Marine Environment Information System (InfoMAR).
- CEDEX has played a relevant role during 2021 in the compliance with Directive 2002/49 EC, of 25 June 2002, on Environmental Noise Assessment and Management promoted by the ministry. Regarding the work carried out since the beginning of the transposition and implementation of the Directive, CEDEX has focused its technological support to the department on the maintenance of the Basic Noise Pollution Information System (SICA), the creation of the National Noise Spatial Data Infrastructure (IDE-SICA) and the development of guides and instructions for the creation of maps and plans.

I conclude insisting on the scope of all the activities included in this Report for the appropriate execution of part of the competences assigned to MITERD, and I'd also like to endorse the words of the Secretary of State for Transports, Mobility and Urban Agenda on the recognition of the effort made by all the CEDEX staff in supporting some of the major challenges and strategies of the department, of which I'd like to mention the National Plan for Adaptation to Climate Change, the Marine Strategies, the Maritime Spatial Plans, the Third Cycle of Hydrological Planning and the Noise Action Maps.

INTRODUCTION

Áurea Perucho Martínez

Director of CEDEX

Ministry for Transports, Mobility and Urban Agenda

As director of CEDEX, I'm honoured to present this Report on Technical and Scientific Activities, which includes the highlights of the work carried out by this agency in 2021, when I took over with great enthusiasm by mid-February.

There is no doubt that 2021 has been a year full of serious difficulties that we've had to deal with. In this regard, we've continued to suffer severely from the Covid-19 pandemic, as we did throughout 2020, and which has caused so much damage and pain, depriving us of some colleagues, friends and family members. To this, we had to add the fact that, in January, due to the exceptional snowfall that occurred in a large part of Spain in the middle of a squall called Filomena, the roof of the structure of the Maritime Experimentation Laboratory of our Centre for Studies on Ports and Coasts collapsed, causing considerable material damage to the structure and the testing equipment, although, fortunately, no personal injuries were reported. This collapse necessitated the implementation of a costly and complex emergency project, which required a great effort of technical, economic and human resources, both from the agency and from the MITMA Undersecretariat. I'd like to take this opportunity to thank all those involved for their efforts and collaboration, which made it possible to start the reconstruction work, which we hope will be completed in 2022.

Despite all the difficulties, at CEDEX we have continued to work hard and with enthusiasm, both in technical works related to the fields of civil engineering and environment, and support-related activities, as well as in improving our internal processes.

With regard to technical work, the Secretary of State for Transports, Mobility and Urban Agenda and the Secretary of State for Environment have already referred to them in their respective introductions to this Report, highlighting the most important aspects. The pages of this document show the highlights of the technical activity during the year. It's our vocation and essential raison d'être at CEDEX to serve as the technological mainstay of the two ministries on which we functionally depend, MITMA and MITERD, to contribute to the service we provide jointly to society, improving the quality of life of people and the environment. In this sense, in 2021, special emphasis has been placed on strengthening R&D&I, which has been relevant to this agency since its inception, with the creation of an R&D&I unit centralised under the direction, with the objetive of facilitating the participation and management of our technicians in projects of markedly research nature, and technological surveillance.

On the other hand, with respect to the improvement of our internal processes, during 2021 special emphasis has been placed on improving both internal and external communication. About the former, the "We know what we do" initiative has been launched, which, on a weekly basis and virtually, allows us all to have a better knowledge of the most relevant work in which CEDEX participates, which, among other things, fosters the creation of synergies between our centres and, ultimately, boosts efficiency improvement. As for external communication, we've started to participate in social networks in order to make ourselves better known to society, for whom we work, and we've promoted the renewal of our website, still to be completed, with the aim of modernising it and making it more dynamic in terms of publishing news and updating data, complying with accessibility standards.

It's our desire to move with the times, in a constant improvement to continue making CEDEX a leading actor in its fields of action, and the technological arm of the General State Administration's main categories of action: technical assistance, R&D&I and knowledge transfer, and in the thematic areas related to civil engineering and building, transport and mobility, and environment. And all this thanks to our two main assets: our formidable human teams and our valuable facilities and equipments.

ABOUT US

ABOUT US

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The Centre for Studies and Experimentation in Public Works (CEDEX) is a public agency, of those provided for in Article 98 of Law 40/2015, of 1 October, on the Legal Regime of the Public Sector.

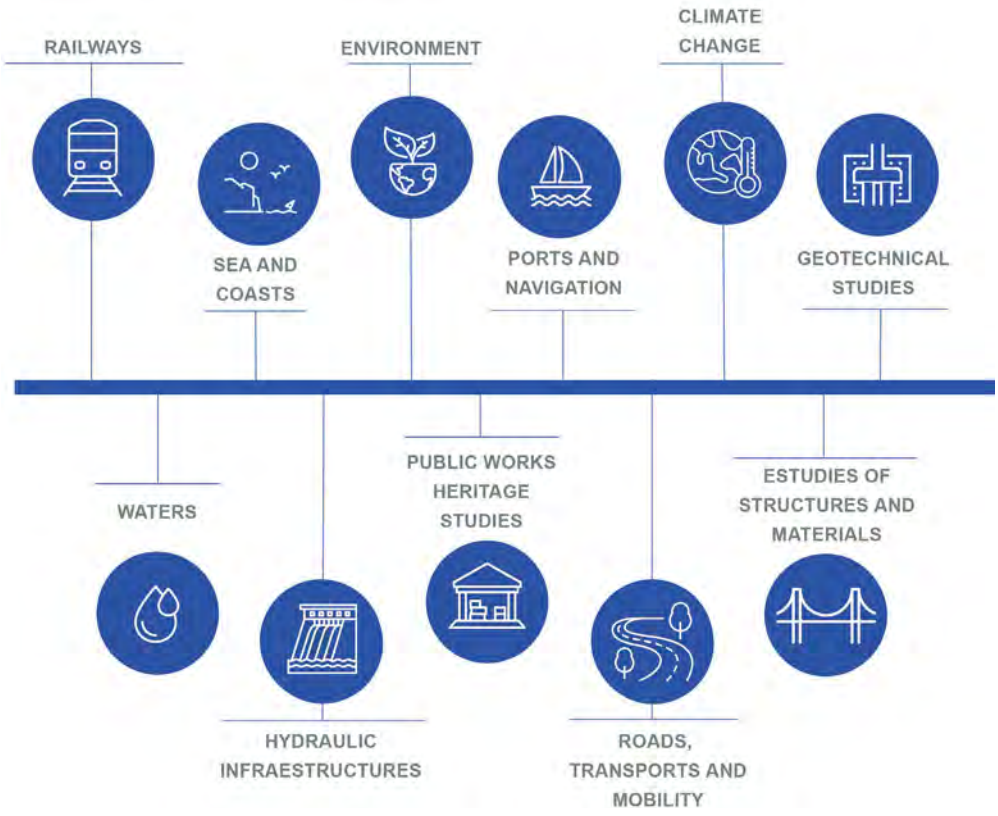
CEDEX is an instrument of the General State Administration (AGE) organically attached to the Ministry of Transports, Mobility and Urban Agenda (MITMA), through the Secretariat of State for Transports, Mobility and Urban Agenda, and is functionally dependent on MITMA and the Ministry for Ecological Transition and the Demographic Challenge (MITERD), within the framework of their respective competences.

OUR MISSION

CEDEX's mission is to address traditional and emerging problems in its different fields of specialisation, contributing to the progress of applied knowledge and serving as a channel for the introduction and dissemination of innovation. This mission entails undertaking the following functions as outlined in its statute:

- Specialised technical assistance, often based on testing and experimentation with outstanding facilities.

CEDEX'S FIELDS OF ACTIVITY



← Aerial photograph of CEDEX personnel captured by drone controlled by a CEDEX pilot.

- R+D+i in the field of public works, sustainable and connected mobility, environment, and climate change.
- Training and knowledge transfer.

The agency deals with other activity demands from both public administrations and the private sector, maintains close collaboration with similar institutions in other countries in joint applied research programmes, and keeps a continuous presence in the international arena, especially within the framework of Spanish development aid cooperation plans.

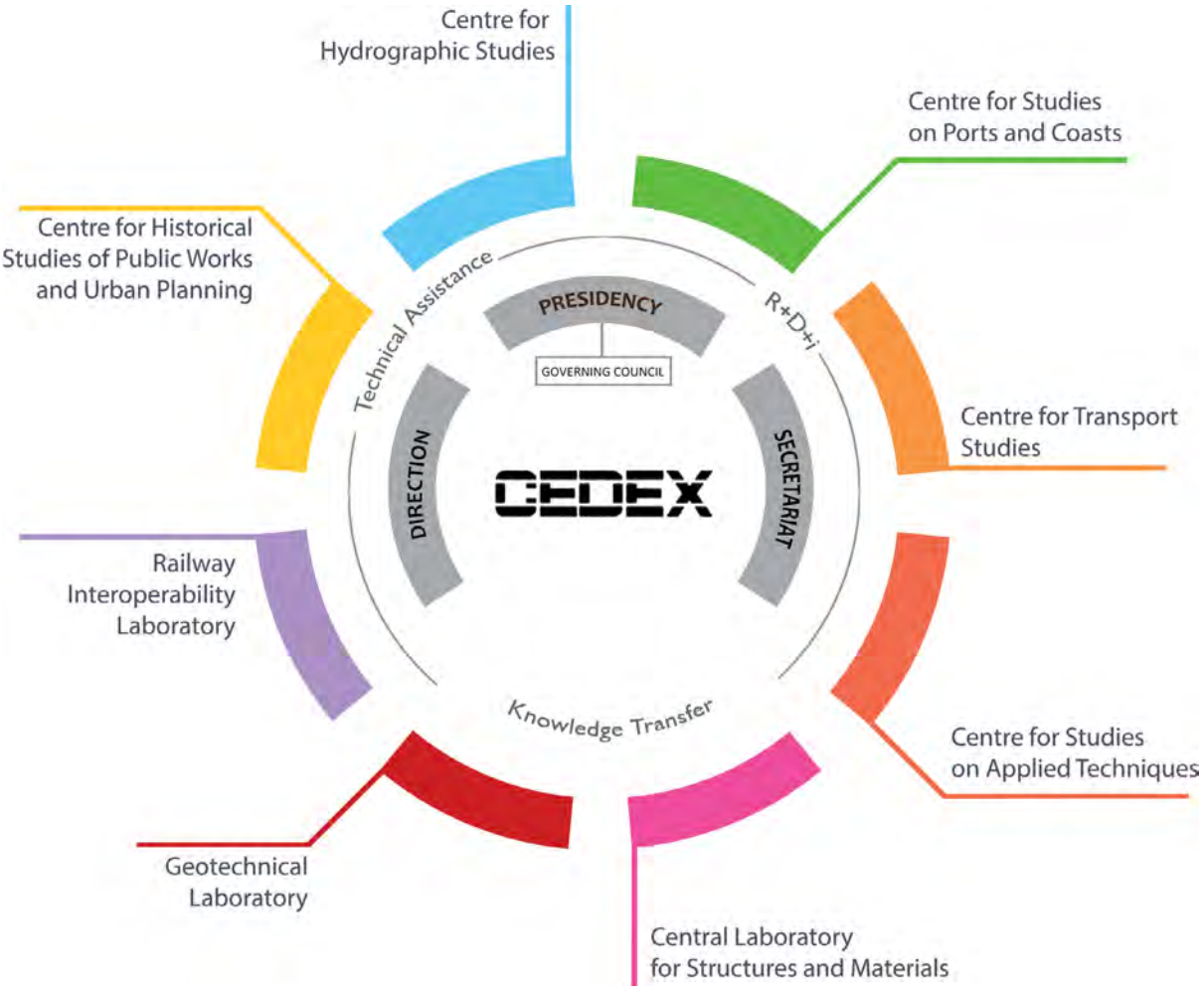
CEDEX's organization and scope of work

These functions and activities are to be carried out through CEDEX's **centres and laboratories**, all along with the support of its **secretariat**.

Governing bodies

Board. This is the body that knows and guides the agency's activities. It's chaired by the Secretary of State for Transports, Mobility and the Urban Agenda of MITMA, and its vice president is the Secretary of State for the Environment of MITERD.

CEDEX'S ORGANIZATIONAL STRUCTURE



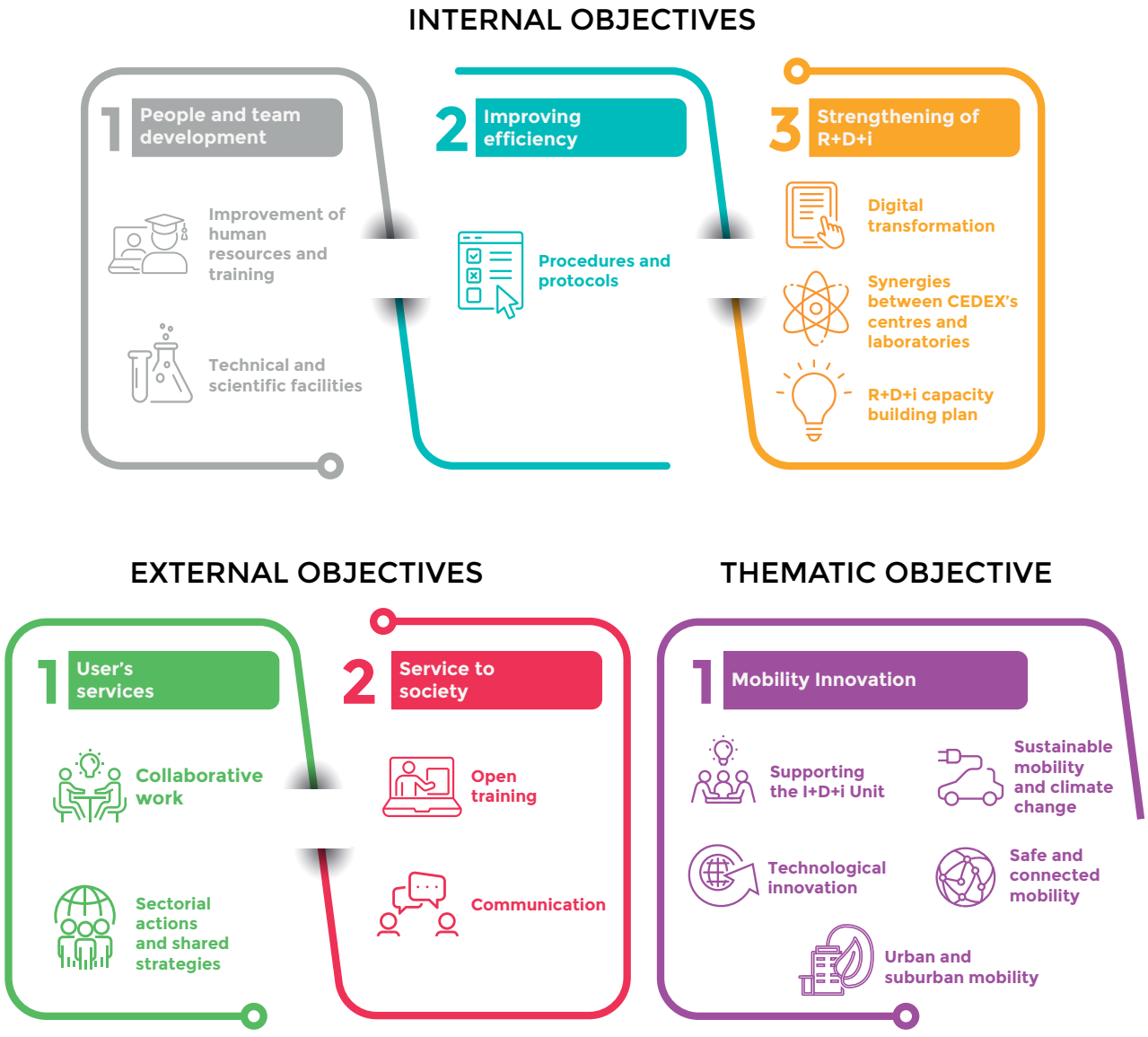
Steering Committee. This is the body that assists the director of CEDEX in the coordination and administration of the agency. It's chaired by the director of CEDEX and is made up of the directors of the different centres and laboratories, plus the secretary of the agency.

CEDEX STRATEGIC PLAN

CEDEX 2020-2022 Strategic Plan (PEC 2020-2022) aims to further the purposes and functions stated for the agency in its statute. The main objective is to be a powerhouse for R+D+i in the fields of Transports, Mobility, Urban Agenda, Environment, and Climate Change.

This plan is to be fleshed out through the accomplishment of five general objectives guiding the actions: three corresponding to internal issues, and the other two to the external projection of the agency.

In addition to these 5 objectives, there's a strategic thematic objective related to Innovation in Mobility that includes the contribution of CEDEX to the new challenges taken on by MITMA, such as those of sustainability and digital transformation in transport.

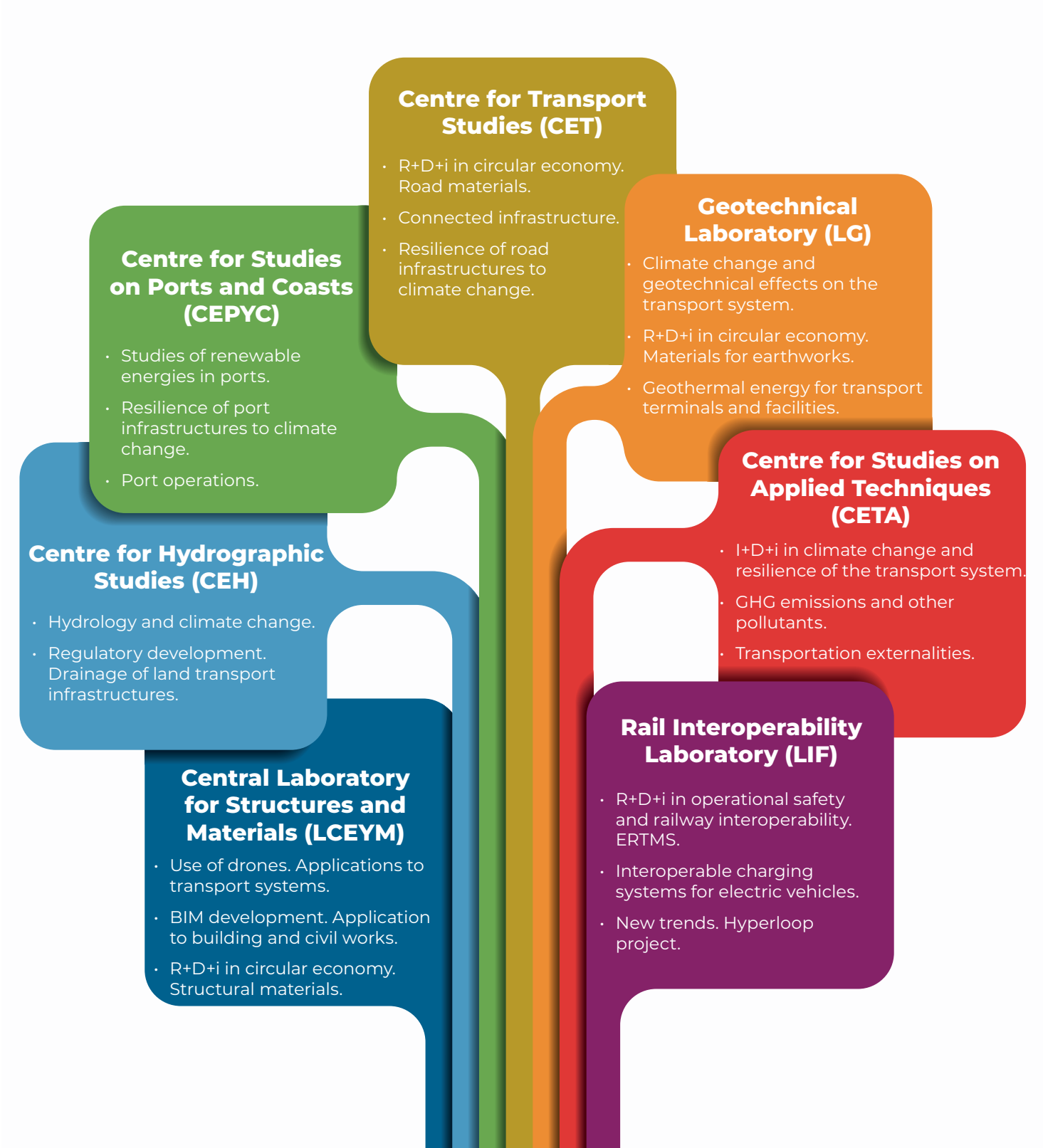


CEDEX AT THE SERVICE OF MITMA AND MITERD

CEDEX's contribution to MITMA-led Mobility Strategy

In 2021, CEDEX started a reorientation of its activities to boost R+D+i in Mobility, integrating the capabilities of the different CEDEX centres and laboratories.

The different contributions of CEDEX, considering the nine thematic outlines of the Mobility Strategy, are embodied in the document "The role of R+D+i and Specialised Technical Assistance in the Safe, Sustainable and Connec-



ted Mobility Strategy. CEDEX Input to the Open Dialogue on Mobility", and include the development of more than 60 projects, as well as the participation in different working groups and committees.

CEDEX and the National Plan for Adapting to Climate Change

The Spanish Government has developed a set of legal instruments aimed to tackle the climate emergency. The basic instrument is the Work Programme of the National Plan for Adaptation to Climate Change (PNACC) for the period 2021-2025. CEDEX participates, under the coordination of the directorates-general concerned, in 12 lines of action corresponding to 3 areas of work: Water and Water Resources, Coasts and Marine Environment, and Mobility and Transports.

CEDEX TO BOLSTER R+D+I

In 2021, the set-up of the Research, Development and Innovation Unit (UIDI), a transversal unit dedicated to promoting R+D+i in all areas of CEDEX's activity, was a highlight. Together with the UIDI, an R+D+i commission has been established, to which the members of the CEDEX Management Committee belong, to facilitate alignment between the UIDI and the activities of the different CEDEX centres and laboratories. A network of R+D+i coordinators is also at work, with one representative for each centre and laboratory, to ensure better communication and implementation of the initiatives being proposed.

Through the UIDI, CEDEX is reinforced as the technological mainstay of MITMA in R+D+i applied to mobility and transports, and of MITERD regarding the natural environment and environmen-

Effects of storm Emma storm in Matalascañas (Huelva), March 2018.

tal quality. Accordingly, the UIDI takes aim of buttressing collaboration between the different CEDEX's centres and laboratories, particularly with regard to participation in R+D+i projects, both nationally and internationally, and of managing a greater presence in networks and forums linked to knowledge transfer and R+D+i results.

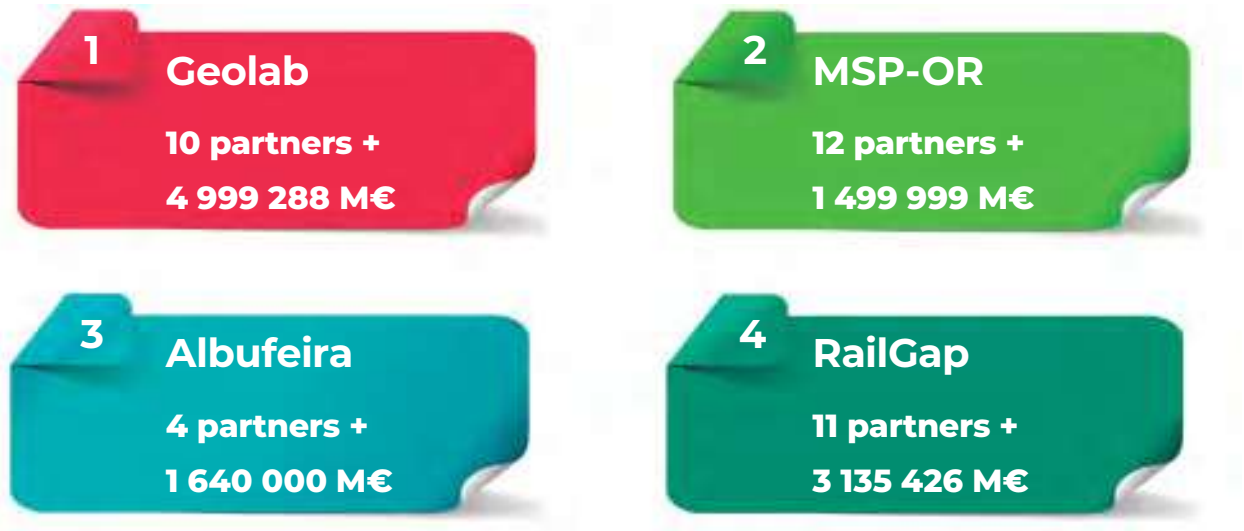
In 2021, CEDEX also counted on 42 contracted researchers for the development of R+D+i lines in the field of knowledge and technologies intended for improving social cohesion through connected, modern, and low-carbon infrastructures, guaranteeing the appropriate management of the natural environment and its sustainability.

CEDEX INTERNATIONAL ACTIVITY

CEDEX's international activity includes different aspects such as participation in projects financed with European funds, international cooperation focused on economic and social development, integration in networks formed by institutions similar to CEDEX, and the establishment of collaboration agreements with entities sharing similar aims.

The ongoing projects financed through European funds in 2021 were as follows: H2020-Geolab, MSP-OR, Albufeira, and H2020-RailGap.

Likewise, within the context of the European Union, CEDEX, along with MITMA's compa-



ny group (Adif, Renfe-Operadora, Ineco and Adif-Alta Velocidad), has officially become a founding member of Europe's Rail Joint Undertaking (ERJU), the new R+D+i partnership of the European Union specifically dedicated to railways, which from now on replaces the previous programme (Shift2Rail).

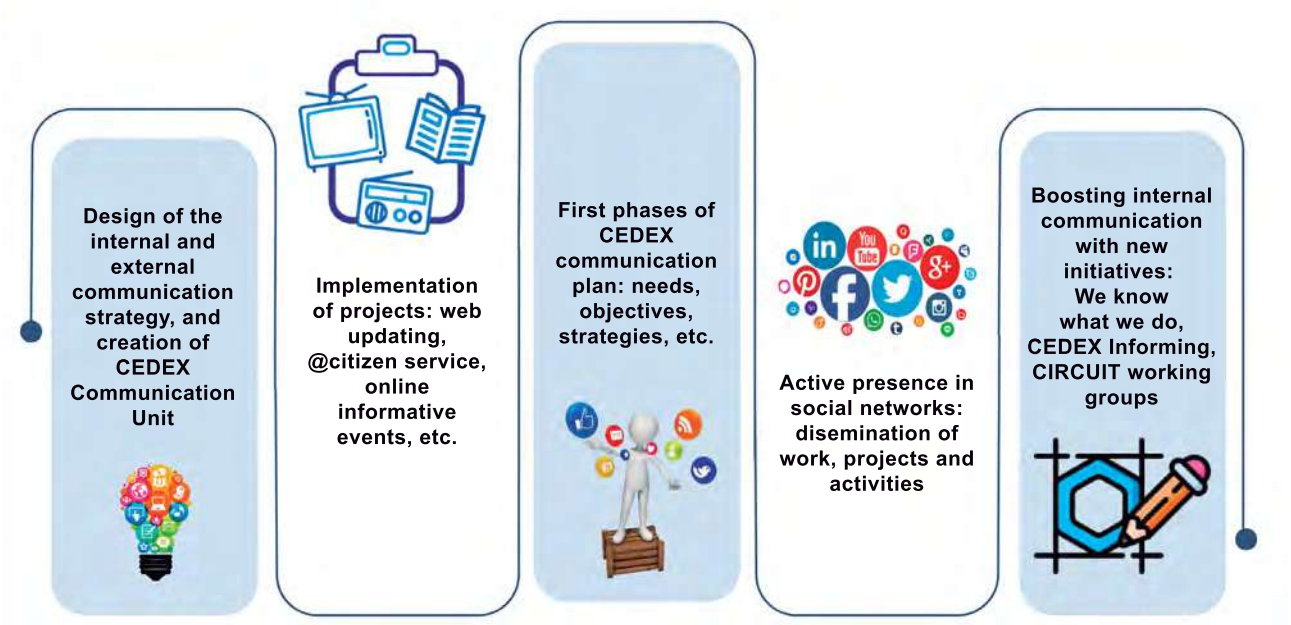
CEDEX's cooperation activities are carried out through AECID's Cooperation Fund for Water and Sanitation (FCAS), an instrument of the Spanish General Cooperation Plan that enables institutional strengthening, community development, and promotion of water and sanitation services in 18 countries in Latin America and the Caribbean. Interventions focus on rural and suburban areas, seeking to reduce pockets of poverty and inequality.

COMMUNICATION POLICY

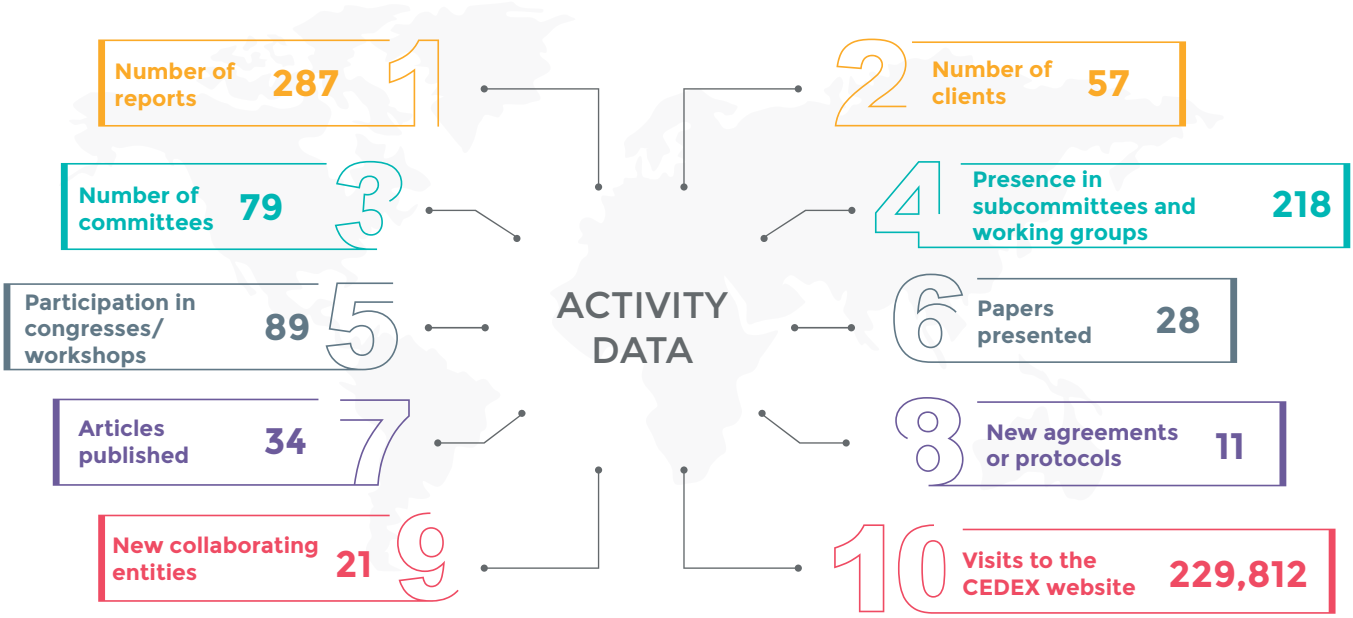
Transparency, access to public information and good governance are fundamental pillars in any public activity, and are closely related to active publicity and the right of the general public to information. To comply with these principles and the general objective of "Service to society", set out in its 2020-2022 Strategic Plan, CEDEX has launched its Communication Unit in 2021. The mission of this new team has stressed the importance of disseminating the agency's work and projects through new channels and formats that are more visual, simple, and accessible to the public.

In 2021, the foundations have been laid to draw up a CEDEX communication plan that

COMMUNICATION POLICY



CEDEX: SOME KEY INDICATORS



ECONOMIC-FINANCIAL RESOURCES. REVENUE BUDGET EXECUTION 2021			
Chapter	**Final budget**	**Final budget recognized**	**Rights execution %**
3. Fees, public prices and other revenues	12,912,330	6,677,260	52 %
4. Current transfers	16,294,512	16,335,042	100 %
5. Property income	1,550	357	23 %
7. Capital transfers	1,000,000	793,953	79 %
8. Financial assets	8,043,320	6,790	0 %
TOTAL BUDGET INCOME	**38,251,712**	**23,813,404**	**62 %**

EXECUTION OF THE EXPENDITURE BUDGET 2021			
Chapter	**Final budget**	**Final budget recognized**	**Rights execution %**
1. Personnel expenses	20,806,340	18,719,250	90 %
2. Goods and services	5,499,252	4.395,010	80 %
4. Current transfers	155,800	77,865	50 %
6. Investments	11,752,000	3,111,362	26 %
8. Financial assets	38,320	6,752	18 %
TOTAL BUDGET INCOME	**38,251,712**	**26,310,239**	**69 %**

will include all the communication objectives, strategies, and actions, both internally and externally.

THE SECRETARIAT AS THE MANAGEMENT ENGINE OF CEDEX

Human Resources

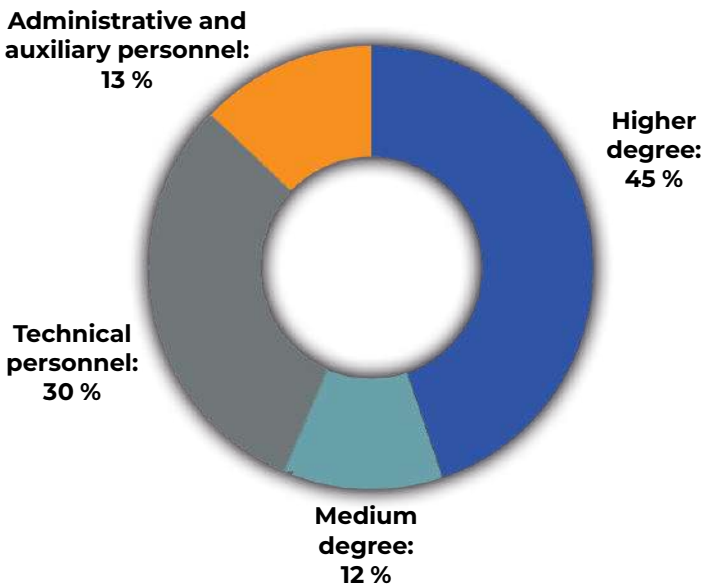
To carry out its functions, CEDEX requires specialized human capital supported by an array of first-class technological tools. The multidisciplinary composition of CEDEX teams provides complementary visions in the study of increasingly complex issues. Continuity in knowledge management and the best use of CEDEX's capabilities require a sustained incorporation of personnel.

Of all CEDEX personnel, 11 were new newcomers in 2021, all of them civil servants and from different scales.

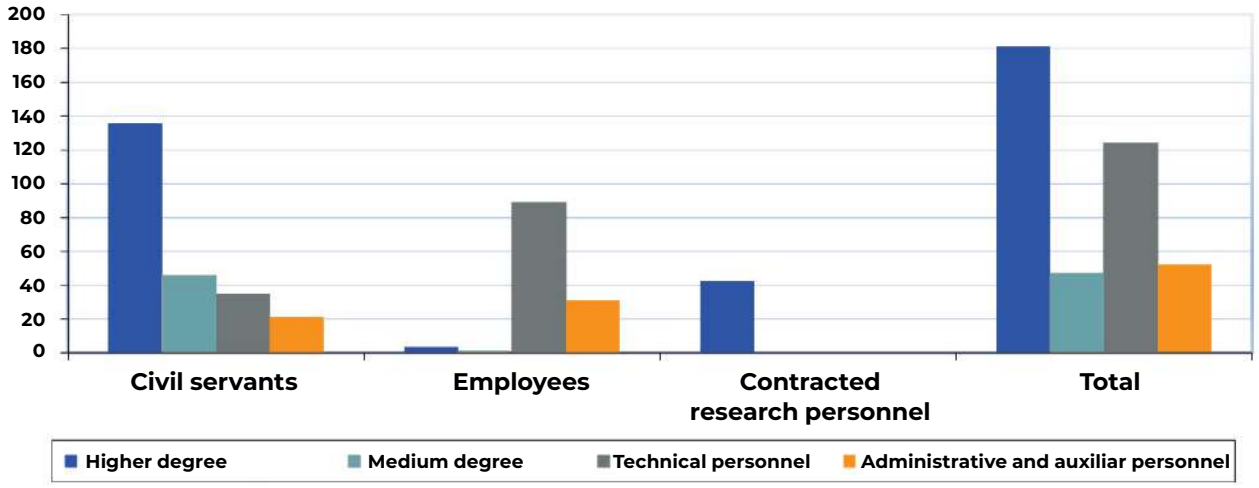
STAFF BY CATEGORY AND QUALIFICATION AS OF 31 DECEMBER 2021

		Civil servants	Employees	Contracted research personnel	Total	%
Degree	**Higher Degree**	136	3	42	**181**	45 %
	Medium Degree	46	1	0	**47**	12 %
Technical personnel		35	89	0	**124**	30 %
Administrative and auxiliary staff		21	31	0	**52**	13 %
TOTAL		**238**	**124**	**42**	**404**	100 %

STAFF BY QUALIFICATION



STAFF BY CATEGORY AND QUALIFICATION



Labor rights and policies

Social dialogue and bargaining process

The agency participates in the various collective negotiating tables existing at MITMA, through the Joint Subcommittee, the Technical Working Group on Occupational Risk Prevention, and the Social Action Joint Group, among others

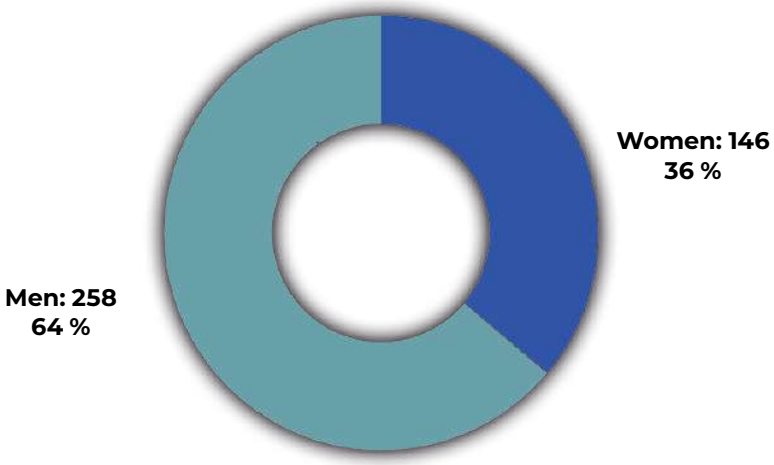
Social Action

The credit awarded in Social Aid in 2021 amounted to 63,214 euros, not including Retirement Awards or the costs of extracurricular activities for the children of its employees. There were 181 applications submitted, corresponding to 255 grants processed and 241 grants awarded.

STAFF BY GENDER AS OF 31 DECEMBER 2021

		Women		Men		Total
Degree	**Higher Degree**	74	41 %	107	59 %	181
	Medium Degree	17	36 %	30	64 %	47
	Technical personnel	22	18 %	102	82 %	124
	Administration and Assistants	33	63 %	19	37 %	52
	TOTAL	**146**	**36 %**	**258**	**64 %**	**404**

GENDER DISTRIBUTION



Equality policy

In 2021, the III Plan for Gender Equality in the General State Administration and related public bodies was approved.

It's worth highlighting the participation of CEDEX in the proposal of the III Strategic Plan for the Effective Equality of Women and Men (2022-2025), joining in the achievement of the Plan's objectives through a set of measures covering aspects such as communication, training, capacity building, coordination, and visibility of talent. In this respect, the role of CEDEXesIgualdad Group in the identification and proposal of measures to be promoted by CEDEX should be underlined.

On the other hand, in terms of attention to the disabled, it should be noted that CEDEX has taken on 18 employees with some degree of disability.

Reconciliation of work and personal and family life

CEDEX staff have enjoyed in 2021 a set of conciliation measures that have had the objective of favouring the organization management of work time, the enjoyment of recognized leaves, and working remotely during the pandemic.

Health, safety and hygiene at work

Health promotion

This has been materialized, among others, through initiatives or programs to promote healthy practices such as the establishment of a healthy company model at CEDEX, the implementation of measures for the evaluation of psychosocial risks, the personalized follow-up of cases of infection by the SARS-CoV-2 virus and their close contacts, and the control of legionella at CEDEX facilities.

Preventive activities

The main preventive activity for the protection of all the agency's workforce has been carried out through health surveillance by means of medical check-ups, in addition to the evaluation of the CEDEX job positions against exposure to SARS-CoV-2, the adoption of extraordinary measures for the protection of employees, and the action protocol for on-site reincorporation to working life. Besides, a telework program was established and all the guidelines for employee protection were followed by applying the protocols issued by the Civil Service and the Ministry of Health.

Courses were organized to prevent the emotional burden associated with conflict management at work, and civil liability insurance and group accident insurance were taken out.

Safety at work

To guarantee the safety of workers and external companies, the necessary protocols for the coordination of business activities (CAE) were implemented through the application of the provisions of RD 171/2004, of January 30.

In terms of prevention in emergency situations, the self-protection plans of the work centres were implemented to guarantee the personal safety of all workers.

Quality and environmental management

In relation to the Environmental Management System, the agency was certified by the EN ISO 14001:2004 Standard, between 2009 and 2017, in all its centres.

In 2021, the certification of compliance with the requirements under the UNE-EN ISO 14001 Standard is maintained with certificate number ES09/6695. This is a multi-site certificate that includes all CEDEX centres. This certificate is valid from 17 April 2021 to 17 April 2024.

Transparency and good governance

In promoting transparency and improve access to public information, we have continued with:

- The procedures associated with the entry into force of the Transparency Law.
- The publication of contracts once awarded in the Public Sector Procurement Platform (Communicated Order of the Minister of Public Works of June 27, 2013).
- MITMA is periodically informed, by means of scheduled questionnaires, of the activity carried out.
- 11 information request files received under the Transparency Law have been managed through the Access Request Management application (GESAT).
- Seven parliamentary initiatives from the Congress of Deputies and the Senate have been answered through the Parliamentary Initiatives application.
- Implementation of the Annual Action Plan for 2021 included in the CEDEX 2020-2022 Strategic Plan, and preparation of the 2020 Action Plan Follow-up Report, having reached a 61.07 % compliance level in the final evaluation of the overall achievement of objectives.

Ethical codes

The specific ethical codes that the organization has, following MITMA protocols, are as follows:

- Declaration of Principles on Occupational Risk Prevention (ORP).
- Statement of Principles on Labor Harassment at CEDEX (AL).
- CEDEX Environmental Policy Statement (GMA).
- CEDEX Quality Policy Statement (Q).

CENTRES AND LABORATORIES

CENTRE FOR TRANSPORT STUDIES

CENTRE FOR TRANSPORT STUDIES
Director: Antonio Sánchez Trujillano
On the Colmenar Viejo Motorway, at KP 18.2
El Goloso 28760 Madrid
Spain

"Towards decarbonization"

The activities developed in 2021 by the Centre for Transport Studies (CTS-CET), in line with its technical field of competence, include the study, laboratory testing and full-scale experimentation of road pavements, the auscultation of roads in service, and the study of heavy traffic on roads.

These issues have been addressed from circular economy approaches, the necessary decarbonization of transport, and the consideration of new traffic and transport technologies (ITS systems), which are also in direct connection with strands 2 "New Investment Policies", 3 "Safe Mobility", 4 "Low-Emission Mobility", and 5, "Intelligent Mobility", of the Mobility Strategy of the Ministry for Transports, Mobility and Urban Agenda (MITMA).

With regard to the **circular economy and the use of non-conventional materials** in road construction, two sections with bituminous mixtures have been built on CEDEX's **accelerated pavement test track**, one of them made with aggregates obtained from construction and demolition wastwe (RCD), and the other, with conventional aggregates with the aim of comparing the evolution of their behaviour. This study, carried out for the University of Extremadura and still underway at the end of 2021, is complemented by the execution of laboratory tests, and will finish once 25,000 load cycles have been applied.

In this line of use of unconventional materials, a section of the N-232 motorway in Castellón has been rehabilitated with cold recycling with emulsion. In this section, strain and temperature sensors have been placed, which, together with the data acquisition systems that are yet to be placed, will allow real-time monitoring of the behavior of the pavement.

← Gateway to Hell, Cuenca Highland tunnel near Cuenca and Fuertescusa (Source: Shutterstock).

Accelerated pavement test track of CEDEX.

Continuing with the work undertaken in previous years, during 2021 the maintenance of the 5 meteorological stations distributed throughout the Spanish territory has been carried out, in order to be able to count on the climatological data and temperature profiles of the various types of pavements. These works are necessary to adjust the prediction models of pavement temperature and the humidity of the subgrade to the existing conditions in Spain, thus permitting to explain the failure and behaviour models of the pavements, and the evolution over time of the strengthening actions performed on them.

These stations, their installation and maintenance, as well as the processing and evaluation of the climatological information they provide, allow to know the effects of climate change on roads and materials with which they're built, for bitumen and bituminous mixtures are particularly sensitive to temperatures, especially those reached at different depths of the pavement.

Likewise, the collection of real time data of measurements of the dynamic variables produced by the passage of traffic circulating on a section of the A-62 motorway in Valladolid continues. The processing of this collected data and the indicators obtained through deterioration prediction models allow us to know the pavement condition.

At the initiative of the Directorate-General of Roads (DGC), of the Ministry for Transports, Mobility and Urban Agenda (MITMA), a study on the use of **bituminous mixes with pre-digested crumb tyre rubber additives** is being carried out. Two of the motorways chosen for this study were the A-6 (Ávila) and A-68 (Zaragoza).

During 2020 and 2021, some commercial products formulated with crumb rubber from end-

Placement of sensors in the pavement.

of-life tyres (NFVU) have begun to be applied as additives in the bituminous mixes, and not only on a pilot scale in small test sections, as had been done so far, but also on large-scale road works of the National Road Network.

This method, using pre-digested rubber additives, offers certain advantages over the dry and wet processes initially developed for the addition of crumb tyre rubber. The gain of knowledge and experimentation of these potential advantages is the subject of the work now in progress.

Study of leaching in copper smelter slags (Atlantic Copper). The need to implement a circular economy based on the re-use of materials from wastes declassified as such in road construction requires, firstly, confirming that their composition doesn't include polluting substances in such high quantities as to make such re-use impossible.

End-of-life tyre treatment plant
(Source: SIGNUS ECOVALOR).

Therefore, it's of great interest to conduct leaching tests on these wastes or by-products, as they provide information on the release of soluble constituents in contact with water, thereby enabling the assessment of the potential environmental risks of their possible re-use in civil engineering applications, or whether landfill disposal is ultimately the only option.

Another line of activity is related to the study of **bituminous mixtures produced at lower temperatures** and with the incorporation of reused

Copper smelter slags.

Laying of a low-temperature mixture.

bituminous material. The manufacture of bituminous mixtures at reduced temperatures is one of the objectives pursued to reduce both energy consumption involved in its production, and the emission of polluting gases into the atmosphere.

There are several techniques to produce these mixtures: warm bituminous mixtures, in which mixing temperature is about 40 °C lower than the usual ones of hot bituminous mixtures. This makes it easier to incorporate a portion of reclaimed asphalt from the milling of aged pavements, as thermal degradation of the bitumen in this material is limited because of the lower heating temperature used.

In order to increase knowledge about the behaviour of this type of mixtures, the Laboratory for Road Materials has completed numerous tests on samples of mixes obtained from works promoted by the Road Demarcation of Western Castilla y León, where these techniques are now being used.

Also, some detailed analyses of surfactant-added bitumens for its use in these reduced temperature mixes have been carried out by means of the dynamic shear rheometer (DSR). These analyses, in addition to helping to determine the characteristics of the bitumens, allow to pay greater attention to the results of performance-related rheological tests on binders which, though not being currently included in the bitumen specifications, are expected to be soon.

Use and performance of high durability SMA mixes. These are mixes whose durability is greater than that of conventional mixes due to their composition and characteristics. They are of great importance in the construction of more sustainable pavements. Their application is

Fenix Test on SMA mixes.

growing both in road and airport pavements, with studies carried out on SMA11 type mixtures used in the wearing courses of one of the runways of the Adolfo Suárez Madrid-Barajas airport, and in works promoted by the Road Demarcation of Western Castilla y León.

To get a better understanding of the behaviour of these mixes under traffic loads, the Laboratory for Road Materials has made an evaluation of the strength, tenacity, ductility and breaking energy of the mixes using the Fénix test, as well as tests to determine the physical and mechanical properties of these materials that can be directly related to their field response on site. The results obtained are consistent with some of the

Sustainable Development Goals (SDGs), more specifically with SDG 9, Industry, Innovation, and Infrastructure (9.1 and 9.5).

In the field of **road condition surveys and full-scale road assessment**, the CET has carried on working on the task commissioned by the Directorate-General of Roads of MITMA, with the goals of monitoring, checking and supervising compliance with the values of the indicators that appear in the concession contracts for the first-generation freeways of the National Road Network. Specifically, the CET collects data and assesses the indicators related to the pavement bearing capacity (deflections and cracking), as well as safety and comfort conditions (slip resistance is

evaluated by means of the CRT and surface regularity by means of the IRI).

For its part, the Traffic and Road Safety Area of CET has carried out a series of activities during 2021 that can be included in the following lines:

Weigh-in-Motion (WIM) Systems. Starting from a piezoelectric-type dynamic weighing system installed on the A-1 motorway near El Molar (Madrid), within the framework of the REPARA 2.0 project, the evaluation of the accuracy and operation of this equipment has continued after the end of the project. Regarding the exploitation of the vehicle data that are collected with this WIM system (essentially, the total gross weight of each vehicle and the load of each one of its axles and, also, vehicle length, speed and distance between each two consecutive axles), it has been studied and verified that these data are of great practical application to pavement design and management.

These systems let detailed and continuous information be collected on traffic loads, essentially from trucks and other heavy vehicles, which are the fundamental input parameter to know the stresses that road pavements must withstand throughout their service life, thus optimizing both its design and maintenance. In fact, one of the great advantages of the weigh-in-motion systems is that they enable us to obtain all the aforementioned data automatically on large samples of vehicles, without interrupting road traffic.

Electric Road Systems (ERS). The CET participates in the Task Force 2.2 “Electric Road Systems” of PIARC (World Road Association), occupying the Spanish-speaking Secretariat of this group.

The purpose of ERS is to complement the road infrastructure with an electrical installation designed to transmit this type of energy to vehicles that circulate along it. This currently has its appli cation to achieve the decarbonisation of road transport, especially in relation to heavy vehicles (trucks and buses), in which the technical problem of their autonomy hasn’t yet been solved

Piezoelectric-type weigh-in-motion system on the A-1 motorway in El Molar.

W-profile metal safety barrier.

owing to the large size that their batteries would require (of the order of several tons), which would considerably reduce their load capacity.

Standardization of road equipment and traffic management facilities. CET's Traffic and Road Safety Area has participated in standardization activities within the UNE framework, with the aim of achieving a standardization of road and traffic management equipment involving better efficiency in the use of resources, and greater safety and comfort for the road user.

Besides the previous lines of activity, there's one of transversal nature related to the **evaluation of road projects in accordance with sustainability criteria,** both in their project and construction phases and in their operation, through the application of **Life Cycle Analysis (LCA)** and **Life Cycle Cost Analysis (LCC)**. These are tools for evaluating actions and their efficiency in terms of consumption of resources, raw materials and energy, as well as in the generation of waste, discharges and emissions to the atmosphere. These activities have been carried out within the framework of two working groups of the Asociación Técnica de Carreteras (ATC-Spanish branch of PIARC), which have been coordinated by CEDEX.

Along the same line, a study has been completed on the state of the art on **Green Public Procurement (GPP) of Roads**, encompassing different territorial areas (regional, national and international), which will be published soon as a CEDEX monograph.

CENTRE FOR HYDROGRAPHIC STUDIES

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"The Centre for Hydrographic Studies intensifies its support to the Directorate-General for Water and the Cooperation Fund for Water and Sanitation"

In 2021, the Centre for Hydrographic Studies (CHS-CEH) has worked on activities related to basic data on nature, and knowledge of water resources and water environment, has participated in the development of regulations, standards and technical specifications, and has continued to advance in R&D&I in the field of inland waters.

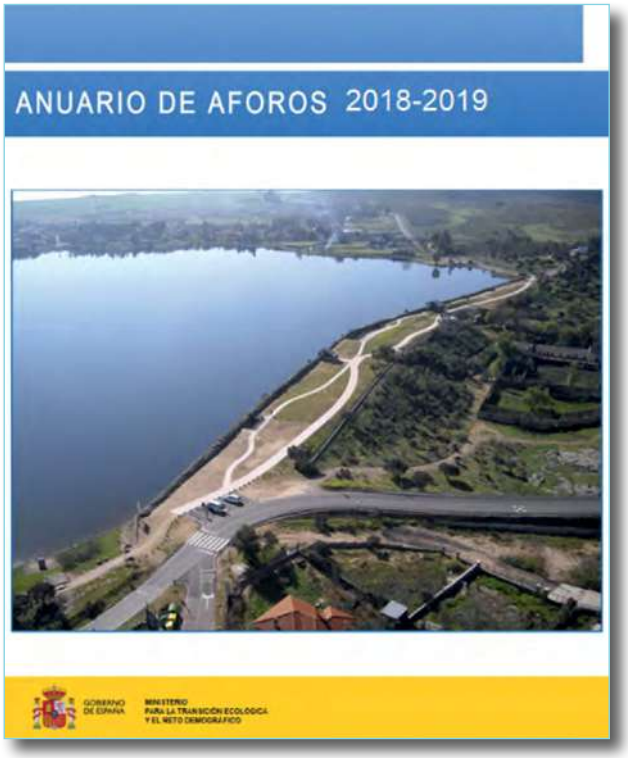
An important part of its activity has been devoted to specialized technical assistance. This assistance has been provided to the Ministry of Ecological Transition and the Demographic Challenge, through the Directorate-General for Water (DGA) and river basin authorities, and to the Spanish Ministry of Foreign Affairs. In this case, assistance was provided to the Cooperation Fund for Water and Sanitation programs commissioned by the Secretary of State of the Ibero-America and the Caribbean. This year has also seen a new collaboration with the Sierra de Guadarrama National Park, dependent on the Community of Madrid.

In terms of training, several courses have been organized, courses organized by other institutions have been participated in, and various educational stays have been facilitated. Knowledge transfer has been furthered through publications, organization and participation in seminars, conferences and congresses, and through the attention to various international delegations and national visits to the centre. Likewise, it has collaborated with different institutions, both nationally and internationally.

In relation to data **on natural resources and phenomena**, the update of the hydrological database of control network of Spanish rivers, reservoirs, and canals (HIDRO) has carried on, and the gauging yearbook corresponding to the hydrological year 2018-19 has been published. This

← View of the Castro reservoir (Zamora) from the bridge-viaduct of Requejo (Puente Pino).

yearbook, which can be consulted on CEDEX website, makes available to the public all the hydrological information collected by the official control network since being established at the beginning of the 20th century.



Cover of the 2018-19 Gauging Yearbook.
Proserpina Reservoir (Badajoz).

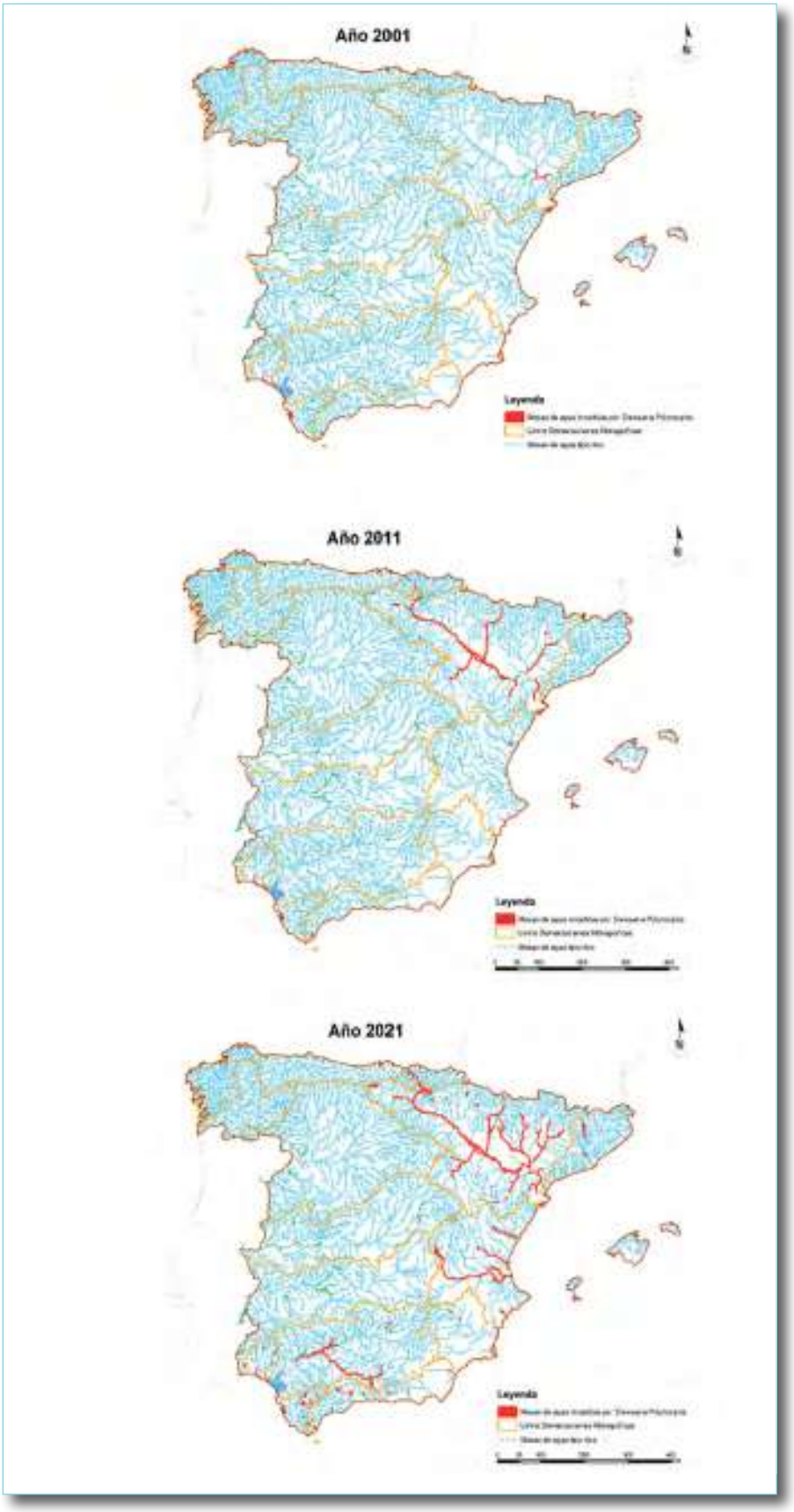
Regarding the **improvement of the knowledge of natural resources**, in 2021 the update of the inventory of water resources in the natural regime of the year 2018-19, carried out by using the Simpa model developed at CEH, was completed. Likewise, work has continued to implement a new module for the treatment of groundwater in this model, which will allow a better representation of this phase of the hydrological cycle. With this work, the CEH contributes to a better knowledge of the country's water availability, one of the purposes with which it resumed its activity in 1960.

Work has kept on with updating the map of maximum daily rainfall in Spain, drawn up by CEDEX in 1999, and with carrying out a new characterization of the relationships between intensity, duration and frequency of rainfall (IDF curves). These works not only have repercussions in the field of hydraulic administration, but also in the transport sector, since they affect the drainage of communication routes.

Similarly, work has continued to determine new emerging substances and contaminants included in the Watch List, established by the European Commission, for which analysis methodologies have been fine-tuned with the new Orbitrap equipment recently acquired by the CEH. The study of these emerging contaminants, which can now be accurately assessed thanks to the new equipment and technologies available, is becoming increasingly important in the European Union, due to their possible impact on health and their environmental effects.

Work on identifying and monitoring of exotic and invasive species of fauna and flora in continental waters has been done. Of all of them, the zebra mussel is the one that most substantially alters the ecosystems and causes the greatest economic damage, being almost impossible to eradicate once it colonizes an environment.

In the field of **regulations and technical standards**, support has continued to be provided to the DGA in the implementation of the new European Regulation on reuse and in the development of different methodologies for its application, specifically referring to health risk assessment systems and environmental and validation of treatment facilities. This is a particu-



Evolution of the colonization of Spanish basins by the zebra mussel since its emergence more than 20 years ago.

larly important regulation for Spain, as it's the EU country that reuses the largest volume of water.

Perhaps, one of the most relevant events in 2021 was the completion of the study on the impact of climate change on maximum rainfall. The results of this study, which are presented in more detail elsewhere in this report, have been incorporated into the flood risk management plans. Both the report on the work and the digital maps with its main results can be downloaded from CEH and MITERD websites.

Continuing with the technical specifications, during this year work has been done on the development of the *Guide for the Calculation of the Project and Extreme Floods of Dams,* referred to in the technical safety standards for dams and their reservoirs approved in 2021. The objective of this guide is to provide recommendations for carrying out the hydrological studies necessary to analyse the hydrological safety of dams, and it's likely to have a significant impact on the sector.

In order to advance in the understanding of the impacts that the incorporation of desalinated seawater can have on irrigation systems, a study has been carried out to determine the admissible limit of boron from these waters, considering its reduction in desalination plants, its interactions with the soil and plants, its accumulation and the effects that occur on the most sensitive crops. The results of the study have been included into the Segura hydrological plan project. This is an issue that may be of great interest, given the importance of desalinated water in this demarcation and its foreseeable upward trend in the coming years.

On the other hand, work has begun on the development of an indicator to measure the efficiency in the use of water in Spain, with a view to its use in monitoring compliance with the objective of increasing the efficiency of water use by 10 %, set by the Spanish Circular Economy Strategy.

Furthermore, the regulatory chapter ends with the participation in the preparatory work for the next revision of Directive 91/271 on urban wastewater treatment. This review should address aspects relevant to Spain, such as stormwater overflows and urban runoff, small agglomerations, individual systems, micropollutants and microplastics, industrial discharges to collectors, the elimination of nutrients and the designation of sensitive areas, integration into the circular economy (application of sludge and reuse of water, reduction of energy consumption, reduction of greenhouse gas emissions), or the control of wastewater as an early warning system. To this end, it has participated during 2021, together with the DGA, in various meetings and workshops organized by the European Commission.

In the field of **R&D&I**, work has continued on the Albufeira project, a program for the joint evaluation of waterbodies in Spanish-Portuguese hydrographic basins, included in the Spain-Portugal Cross-Border Cooperation Program (Interreg-POCTEP). The objectives of this project focus on research and the establishment of common criteria for monitoring these water bodies, improving the integration of the environmental objectives of the Water Framework Directive and the Habitats Directive, and raising awareness about cooperation in shared river basins. In 2021, several field campaigns were carried out with

Portuguese technicians to take samples from border or cross-border rivers, reservoirs, and estuaries.

After several years of work, the new version 3.0 of the Iber two-dimensional mathematical model for calculating flood zones has been completed. This new version incorporates several improvements, including the incorporation of supercomputing techniques that allow to address broader areas of study, thus reducing calculation times. The new version was presented in November at CEH, Centre for Hydrographic Studies and the session can be viewed on YouTube channel, where it has received more than 60,000 visits.

CEH has continued to support the DGA by participating as a National Focal Centre in the ICP-Waters Program (*International Cooperative Program on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes*). During 2021, it's been promoted the start of a network monitoring pilot, for which three control stations have been selected in aquatic ecosystems of the Sierra de Guadarrama and Cabañeros National Parks, which has made it possible to begin having the necessary data to study the response of these ecosystems to the deposition of atmospheric pollutants.

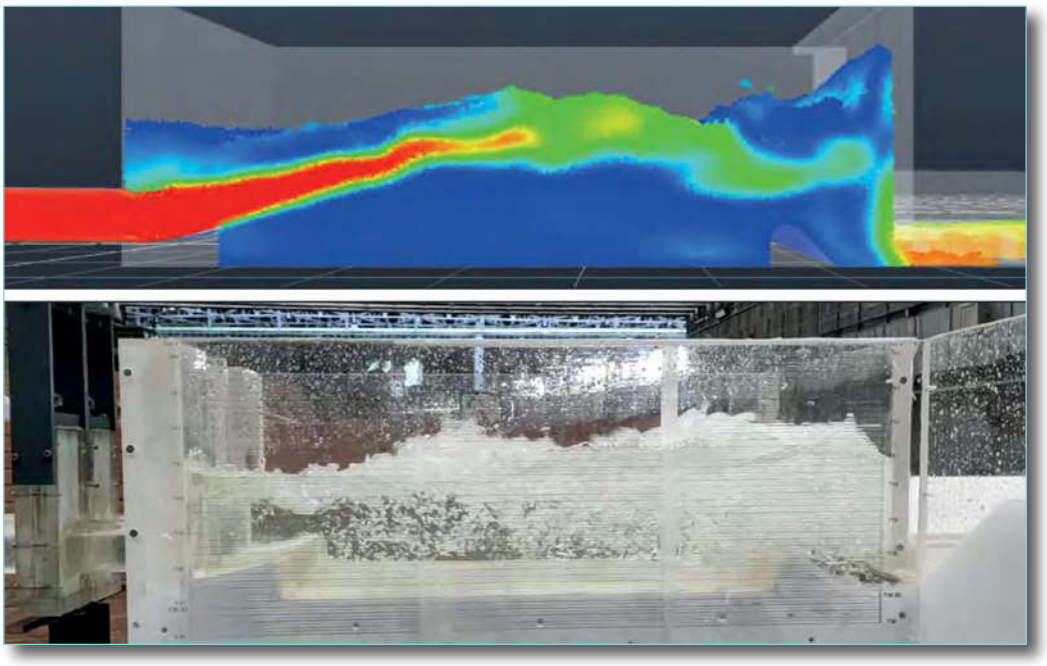
Specialized technical assistance has been provided mainly to the DGA and some hydrographic confederations. In 2021, the DGA commissioned technical assistance, research, and technological development in the field of continental hydraulics. The assignment, which has a term of three years, includes the study, through physical and numerical modelling, of 11 dams in

Joint field work by technicians from Spain and Portugal for the intercalibration of study methodologies for indicators of ecological status in water bodies.

areas of different hydrographic confederations. In this year, work has been done on the Yesa and Terroba dams, on the Ebro; Pálmaces, on the Tagus; and Rumblar, on the Guadalquivir. Further into this report these works are presented in greater detail.

In addition, due to its uniqueness, the DGA has commissioned the hydraulic study in a reduced-scale physical model of the spillway of the Arenós dam, which will be the subject of a major repair to increase its drainage capacity.

In 2021, another order was received from the DGA for the hydraulic study of the interceptor project in the northern area of the city of Murcia. It's a unique hydraulic structure whose purpose is to collect the flows of the riverbeds in this area of the city and divert them, through an underground conduit with free sheet operation, to the Segura River. Given the uniqueness of this struc-



Numerical and physical modelling of the stilling basin of the Terroba dam bottom outlet.

ture, the study seeks to verify, by using physical and numerical models, the suitability of the projected solution.

Also, the water quality of the Odiel river has been studied for the DGA in relation to the Alcolea reservoir project. With the bibliographic review carried out and with the data obtained from the monitoring networks of the Junta de Andalucía and the Guadiana Hydrographic Confederation, it has been possible to describe the recent historical evolution of the quality of the water of the Odiel basin and its relationship with mining activity and other environmental aspects.

For its part, the Guadalquivir River Basin Authority has commissioned a study of the influence of the exploitation of the Marmolejo dam on the sedimentation of the reservoir and the flooding of Andújar. This work, which gives continuity to

Upstream structure and spillway of the physical model of the Arenós dam.

other previous assignments of this Confederation, seeks to improve the safety of the population of Andújar against the floods that occur periodically.

The other major specialized technical assistance activity is that provided to the FCAS programs. The work in 2021 has consisted, mainly, in the preparation of guides and manuals and in the orientation, supervision and review of the projects developed by the Fund. Among the most noteworthy activities, collaboration has been provided in the development of a guide on the implementation of wastewater treatment systems in Bolivia; a hydrodynamic study has been carried out on the Casablanca pumping station, in the Havana sanitation network, for its rehabilitation; support for the Covid-19 environmental monitoring project on wastewater in Guatemala; collaboration in the review of the Lambaré wastewater treatment plant project in Paraguay, and collaboration with El Salvador in the review and development of its sector regulations. In addition, among the regional initiatives, the following guides have been prepared: *Analysis of Latin American Regulations on Population Discharges, Methodologies for Estimating the Costs of Wastewater Treatment in Sectoral Planning, and Protocols for Testing the Operation of Wastewater Treatment Plants*.

This year a collaboration has begun with the Sierra de Guadarrama National Park, which depends on the Community of Madrid. The work has consisted of studying several wetlands in the Peñalara Massif to monitor their trophic and ecological status, in order to assess recent changes in phytoplankton that could result from climate change and other pressures. The study has been completed with the analysis at the Water Quality Laboratory of samples taken in some of these wetlands, in support of an experimental treat-

Publications made within the framework of the programs of the for Water and Sanitation Cooperation Fund (FCAS).

ment program for amphibians affected by fungal infections.

In the **training** chapter, the *XXXVIII CEDEX Course Wastewater Treatment and Operation of Treatment Plants* was held, as well as the *Course Impact of Climate Change on Water Resources*, the latter being organized jointly by CEDEX and the International Foundation and for Ibero-America Administration and Public Policies (FIIAPP), aimed at the technical staff of the Ministry of Environment and Natural Resources of Guatemala. It also participated in the course on *Flood Risk Management*, organized by the Júcar River Basin Authority, and in the course on *Civil Protection Management of Flood Risk in the South of the Peninsula*, organized by the Directorate-General of Civil Protection and Emergencies.

In 2021, several training stays have been carried out at the CEH, welcoming two students from the IES Palomeras-Vallecas, a student from the University of Alcalá, three students from the Complutense University of Madrid, and a professor from the University of Salamanca.

Optical microscope images of some phytoplankton taxa from the wetlands of the Sierra de Guadarrama National Park.

In terms of **knowledge transfer**, in addition to the aforementioned publications and the presentation of the Iber 3.0 model, the *Conference on Lakes, Sentinels and Global Change Sensors* was held online, jointly organized by IAHR, DGA and CEDEX. Papers and communications were presented at various workshops, conferences, seminars and congresses, and various institutional and educational visits were attended. Among the visits received, it's worth mentioning that of the Brazilian delegation chaired by the Minister of Regional Development, who was accompanied, among others, by the Brazilian ambassador to Spain and the president of the National Water and Basic Sanitation Agency.

Finally, within the framework of **institutional collaboration**, CEH has continued to participate in the Central Commission for the Exploitation of the Tajo-Segura Aqueduct, of which it's been a member since its establishment in 1978, having prepared monthly reports on the situation and application of the exploitation rule, from which the decisions of the volumes to be transferred are adopted. This year the new rule has come into force, the update of which has been based on the technical studies carried out at CEH.

Participation in the Large Dams Standards Commission has also continued, which, after the approval in 2021 of the Technical Safety Standards for dams and their reservoirs, now focuses on the safety of rafts, and participation in the Hydrology Section of the Spanish Commission of Geodesy and Geophysics has been formalized.

Visit of the minister of Regional Development of Brazil.

As a singular fact, it should be noted that in 2021 an agreement was signed between CEDEX and Francisco Javier Puerta Arrúe for the transfer and conservation of part of the legacy of the agricultural engineer Ángel Arrúe Astiazarán, who was part of the team of the CEH in its early days (1933-1936), and was one of the redactors of the National Hydraulic Works Plan.

RAILWAY INTEROPERABILITY LABORATORY

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"2021: The European Year of Rail"

2021 can be considered as a year of transition regarding the activities of the CEDEX Railway Interoperability Laboratory (RILLIF). Indeed, the activity of the laboratory has begun to move from the previous stage, focused on the execution of many interoperability tests of the complete ERTMS system on Spanish high-speed lines on which it's been installed, to a new stage much more aimed at railway R&D. This is mainly due to the high degree of participation of the LIF in the European railway R&D partnership ERJU (Europe's Rail Joint Undertaking) to which we will refer later.

With completion in December 2020 of the interoperability tests of the Valladolid-Burgos line for Adif, a stage was closed in which a multitude of ERTMS lines and almost 2,300 km of track length have been tested in the laboratory (table 1).

The growing maturity of the ERTMS system, as well as the decrease in the rate of opening of new high-speed lines in Spain, gives rise to a decrease in commissioning tests and, therefore, in laboratory tests.

That's why in 2021 the LIF began a transition process towards a use of its laboratories directed to new R&D projects, in accordance with the provisions of the CEDEX 2020-2022 Strategic Plan, one of whose main vectors was the promotion of R&D. Fortunately, this process has coincided with the creation of the European joint venture ERJU (Europe's Rail Joint Undertaking) in 2021, which will jointly manage and direct European railway R&D during the 2022-2031 period.

CEDEX, with Adif, Renfe Operadora and Ineco, presented a candidacy to become a founding member of ERJU, being chosen by the European Commission as one of the 25 founding members in July 2021. Unlike what happened in the precursor program of ERJU, Shift2Rail, in which the MITMA consortium was not selected. In the

← A high-speed train in Europe (Source: Shutterstock).

Table 1. List of ERTMS lines tested at CEDEX-LIF

Line	Length (Km)	Rail Supplier	Supplier of ETCS on-board	Year
Madrid-Lleida HSL	470	ANS (L1 and L2)	ANS, ALS, BTS, SIE	2004-2005
Barcelona Port- Mollet-Figueres	160	THA (L1)	BTS, SIE	2009-2010
Madrid-Valencia-Albacete	450	SIE (L1 and L2)	BTS, SIE	2009-2010
Cercanías de Madrid (C4)	70	SIE, THA (L1 and L2)	ALS	2012-2013
Olmedo- Zamora	110	THA (L2)	BTS, ALS and SIE	2016
Valladolid-León. L2	270	ALS (L2)	BTS, ALS, CAF	2016-2017
Hand Over RBCs Venta de Baños	-	ALS and BTS(L2)	BTS, ALS, CAF	2017
Brussels- Airport L1	50	ALS (L1)	BTS and ANS (BL3)	2017
Haramain HSL (Meca-Medina)	460	SIE (L2)	ALS	2017-2018
Corredor Atlantico (Vigo-Coruña)	180	SIE, ALS, CAF (L1)	BTS, ALS, SIE	2018-2019
Antequera-Granada	100	SIE (L2)	ALS	2019
Dakar (Senegal)	90	THA (L2)	ALS (BL3)	2019
Valladolid-Burgos-León. L2	270	BTS (L2)	ALS, CAF	2020
Cercanías de Barcelona	80	ALS (L2)	ALS (BL3)	2020-

former, it successfully became a founding member, which ensures the participation of CEDEX (not only of LIF, but also of LG and LCEYM) in the most relevant European railway R&D projects in the next decade.

2021 began with the delivery of an ERTMS course to the Finnish company Proxion by the LIF staff. This course, held entirely online and in English, opens a very interesting way of working due to the need throughout Europe, and in all those countries outside of Europe that're installing ERTMS, for the training of specialized ERTMS personnel. The course was very well evaluated by the student body, 28 people, and will be repeated in the future for new applicants.

The year also began with the closing of the European project GATE4RAIL, in whose final conference CEDEX carried out a very interesting demonstration in which an ERTMS train equipped with a real eurocab at the LIF lab circulated virtually on a line in Sardinia equipped with virtual beacons georeferenced by Galileo. This demonstration was highly praised by the representatives of the European Space Program Agency, EUSPA (European Union Space Program Agency), who attended the conference.

Almost in parallel with the completion of GATE 4RAIL, the LIF started the next European project related to the use of Galileo on the railway, the RAILGAP project in which it participates with Adif and Ineco, and whose kick-off meeting was held on January 20, 2021. This project consists of using multi-sensor systems for the precise location of the train, and carrying out an inventory of railway signalling assets, in which it will be used, in addition to Galileo (GNSS), inertial sensors (IMU), cameras of high precision, and laser technology (LIDAR).

The most relevant project in terms of its projection as a European certification laboratory was

Equipment of an Adif railcar for the European project RAILGAP (financed by the EUSPA).

the completion of the complete test campaign for the ERTMS on-board equipment of the French company Hitachi (formerly Ansaldo), which will equip most French high-speed trains. Indeed, between February and May 2021, the execution of all the test sequences of Subset-076 (V3.1.0) that applied to the Hitachi on-board equipment (BI-STANDARD ERTMS/TVM V9.3B) was carried out. The execution of more than 80 % of these sequences with the robot developed by the LIF development team during the period of pandemic confinement, made it possible to meet the deadlines established with the client and finish the work in the record time of 4 months. For comparison, if 10 daily sequences were manually executed or, what's the same, 100 in two weeks, the first time a playlist of sequences to be executed with the robot was launched, 100 sequences were automatically executed during a night session from 0:00 to 8:00 in the morning.

In the second part of the year, the ERTMS specifications specialist work team was used to design the test cases for the compatibility tests of the ESC system (ETCS Compatibility Tests), requested by the Italian branch of the Hitachi company, responsible for equipping the ERTMS trains of the new Italian operator (ILSA) that has been authorized to circulate on the Spanish high-speed network. This type of test was designed for this operator, whose initial intention was to run it in the CEDEX laboratory. However, Adif's decision was that they should be executed on the track and, consequently, the LIF restricted its collaboration to the definition of the SSC test cases, their

Photograph of the French TGV equipped with the certified ERTMS Eurocab at the LIF.

Photograph of the Zefiro train of the Italian operator ILSA, which the LIF has supported in the compatibility tests of the system (ESC) on track.

location on each of the lines for which they want to obtain the circulation permit, and attendance at the first on-track tests on the Madrid-Barcelona HSL.

One of the most important activities of the second part of the year was the celebration at CEDEX, organized by the LIF, of the *Conference on the Interoperable and Sustainable Railway as the Backbone of the Future Europe*. This conference, framed within the celebration of the **European Year of the Railway,** was attended by, among others, the Secretary of State for Transports, Mobility and Urban Agenda, the presidents of Adif and Ineco, the executive director of the ERA, the general director of UNISIG (an entity that brings together the entire signaling industry), and the CEDEX director. The entire Spanish public railway sector participated in the morning session (Adif, Renfe, Cedex, Ineco, AESF and the Directorate-General of Railway Planning of MITMA), and the European and private sector in the afternoon session (ERA, RFI, German laboratory DLR and the entire European and Spanish industry, Ansaldo-Hitachi, Alstom, Bombardier, CAF, Thales, Siemens, Enyse, Indra, and Talgo).

The conference had a notable success in terms of participation, as it was held in a mixed face-to-face/remote format, thus constituting one of the first face-to-face railway events after the pandemic and highlighting the excellent health of the Spanish railway system, and how Spain has been and continues to be one of the countries that's contributing the most to the construction of the single European railway area.

Other activities carried out by the LIF in 2021 are those listed below:

- Execution in the Traffic Simulation Laboratory of the LIF of the ERTMS tests of Barcelona's Commuter lines by Alstom company.
- Participation in the National Technical Committee for Standardization on Hyperloop, exercising the presidency of the UNE CTN-326.
- Participation in the European Committee for Hyperloop Standardization JTC-20 of CEN/CENELEC as head of the Spanish representation of UNE.
- Participation at the request of MITMA, as a Spanish representative, in the meetings of the ERGO group which, led by the EUSPA (European Space Program Agency), promotes the use of Galileo in the railway.
- Technical advice to the company ENYSE for the development of an RBC (Radio Blocking Center) for level 2 of ERTMS.
- Preparation of the test offer for the Maya line (more than 1,600 km) that will be equipped with the ERTMS in the Yucatán Peninsula, in México.
- Continuation of the work of the European group for the definition of ERTMS tests (Subset-076) for the new version of the ERTMS that will be published in the 2022 TSI update.

- Participation in the meetings of the European Association of ERTMS Accredited Laboratories (EAL: ERTMS Accredited Labs), together with five other accredited European laboratories (DLR in Germany, Multitel in Belgium, RINA, and ItalCertifer in Italy and LEF in France).
- Continuation of the preparatory work with Adif, the Spanish Railway Safety Agency, Renfe Operadora and Ineco for the creation of the ERTMS National Laboratory at the LIF.
- Renewal in September 2021 of the ENAC Accreditation.
- Evaluation, together with other CEDEX centres/laboratories, of projects on sustainable mobility for financing through the PRTR (Recovery, Transformation and Resilience Plan).
- Holding various meetings with the CDTI for the construction, through the Innovative Public Purchase procedure, of the Hyperloop Test Track between the Castilla-La Mancha towns of Argamasilla de Alba and Alcázar de San Juan.
- Participation in the European project Eulinx for normalization and standardization of the interfaces of railway signalling systems.
- Preparation with ADIF of the ERT MS Regional project which, financed with European funds from the PRTR (15 M€), will allow the deployment of low-cost ERTMS and with Galileo in a pilot line of ADIF's conventional network.
- Collaboration with the Finnish railways for the project of Digitalization of the Railway and Deployment of the ERTMS in Finland.

Railway conference held at CEDEX in November 2021.

CENTRE FOR STUDIES ON PORTS AND COASTS

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"In 2021, the Centre for Studies on Ports and Coasts has maintained a high level of activity despite unprecedented difficulties"

Within CEDEX, the Centre for Studies on Ports and Coasts (CEPYC) is responsible for the compliance of statutory functions in coasts and seas, ports, and navigation. During 2021, CEPYC has continued to work with the main goal of providing services based on science and technology to the MITMA and MITERD units with competencies in these environments and activities.

The centre aims to make available to the sector, with the active involvement of its clients, advanced, complementary, and integrated capabilities, based on competent specialized human teams and top-level facilities.

Sharing the common difficulties derived from the extension of the Covid-19 pandemic throughout 2021 with different intensities and limitations, the centre has also suffered a disruptive catastrophe: the collapse of the roof of the Maritime Experimentation Laboratory (LEM) during the snowstorm Filomena. The exceptional snow load caused the structure's two main lattice girders with a span of 115 m to break, causing large deformations and irrecoverable destruction of the roof itself. This situation has led to the complete closure of the Laboratory and the almost total limitation, recommended by our technical services, of the use of the office building until the end of September 2021. In these circumstances the priorities from the very beginning have been to promote the procedure to ensure external security against possible developments of the failure, and to recover the experimental capabilities of the centre by repairing the damaged facilities. And simultaneously, make it possible the continuity of the work with a minimum impact on the undergoing activities and new demands. The best disposition has been provided by all the staff, delivering creative solutions to move resources and units to other CEDEX's centres, such as CETA and CEH, whose collaboration has been essential to maintain some experimental and analytical activity.

The experience acquired during the previous period of confinement in teleworking has allowed

← Wave breaking.

to maintain a high level of activity supporting the different entities and through them society in general, which's objectively reflected in the 78 reports issued in the year in response to various requests for collaboration under different instruments.

For the **Directorate-General of the Coast and the Sea (DGCM),** and within the framework of the current Technical Service Assignment, work has been done on the different stipulated lines of activity.

One of the most noteworthy is the chapter "Coastal Engineering Studies" including technical notes on issues raised, analysis of situations, proposals for action in coastal zones of different morphologies and complexity, as well as experimental work oriented to specific problems and the evaluation of solutions for typified situations. The technical notes related to the "consequences of not executing the actions proposed in the Strategic Plan in the Maresme in the Ocata Beach of the Municipality of Masnou (Barcelona)", on the "effect of the Filomena Storm on the coastal edge of the Ebro Delta (Tarragona)", to the "Analysis of the possibility of sand filling a cell in Cubelles Beach (Barcelona)", to the "Analysis of the actions to be undertaken on the beaches of Barcelona", and on the "effect of the Hotel Riu in the Corralejo Dunes field (Fuerteventura, Canary Islands)". A study has been carried out on the costal management in the Albufereta cove (Alicante). Two regional plans completed in 2021 should also be mentioned: the Plan for the protection of the coastline of the Mar Menor (Murcia), and the Plan for the protection of the coastline of the Ebro Delta; the activity has included in both cases analysis of allegations received in public consultations and re-elaboration, where appropriate, of the Plan. With the experimental activity using reduced-scale physical models temporarily interrupted at the centre, the experimental study carried out in 2020 on the overtopping caused by the waves on the promenade of the second Sardinero beach (Santander), has been completed. And reports have been finished on the experimental tests of the effects of short groynes in a physical model with a mobile bottom in the multidirectional wave tank, and of the works in a large-scale 2D physical model of sand beach reprofiling operations for temporary protection against coastal floods due to storm waves, 2nd phase. These lines of research, with the aim of generating design guidelines for actions to combat erosion and protect against coastal flooding, will be continued when the experimental capabilities of the centre are recovered.

Measurements in nature are another essential component of studies of the coastal environment. In 2021, field work carried out to monitor various beaches through topo-bathymetric surveys: Costa Ballena (Cádiz), various beaches in the province of Huelva, Salinas beach (Asturias), Laredo and Sardinero beaches (Santander), Santa Cristina and the inner edge of the barrier beach of the Burgo estuary (A Coruña), and the Maresme coast between the Arenys de Mar and El Balís marinas (Barcelona). The comparative analysis of successive surveys allows to evaluate the evolutionary dynamics of the coast. In addition to direct measurements, employ of remote sensors is potentially useful in the coastal and marine environment: throughout 2021, a research project on remote measurement techniques and monito-

Image of the Ebro Delta after the Gloria storm.

ring of coastal areas continued to be developed, reporting to the DGCM on its applications to coastal management.

Within the support to the actions of the DGCM, mention should be made of the proposal of guidelines for acceptance of sediments for beach nourishment and, associated with this, the identification in collaboration with the Spanish Geologic Institute (IGME), of coastal areas affected by geochemical anomalies. In relation to the acceptability of materials for sediment supply to beaches. Further, in support of the actions, the analysis of sand extraction activities in underwater deposits of the Barcelona and Gerona coastlines, and its possible interaction with the fishing activity.

A relevant aspect of CEDEX's collaboration with the DGCM is devoted to the implementation of European directives on environmental protection. In 2021, diagnostics on sectors, uses and activities in the five marine demarcations (Levantino - Balear, Estrecho - Alborán, South Atlantic, North and Canary Islands) was completed, analyzing the current situation, forecasts and interactions for the preparation of the proposals for plans associated with the Marine Spatial Planning Directive. Similarly, support has been provided in the public consultation and participation process of the corresponding Maritime Spatial Plans (POEM) for each of the Demarcations. The application of the Marine Strategies in their second cycle (2018-2024), in development of European and national legislation, is another noteworthy aspect in this section: In 2021 the reports related to the evaluation of underwater noise associated with navigation have been presented in the marine demarcations; the monitoring program for micro-plastics on beaches has been reported for the elaboration of the corresponding indicator; and an investigation has been carried out on the procedures to estimate the contributions of microplastics discharged into the sea by rivers, as well as the updating of the monitoring programs of human activities and pressures. And in application of the Water Framework Directive in its aspects related to coastal and transitional

waters, collaboration has also been made in the review and implementation of river basin plans with the analysis of documents in the third cycle of hydrological planning, and in relation to marine strategies.

Besides the implementation of directives, it has to be mentioned the development, for the DGCM, of the INFOMAR system, a geographic information system of the marine environment that has been made available to the general public, and that integrates a large number of layers of information related to the three directives cited plus the one on flood risks, and including cartographic support from entities such as the Marine Hydrographic Institute (IHM) and the National Geographic Institute (IGN). Work has also been undertaken on updating the Ribera Application to support the State Plan for the Protection of the shoreline 'Ribera del Mar' against accidental marine pollution. And finally, work has been undertaken on the unification of marine and coastal data notification processes for different European plans.

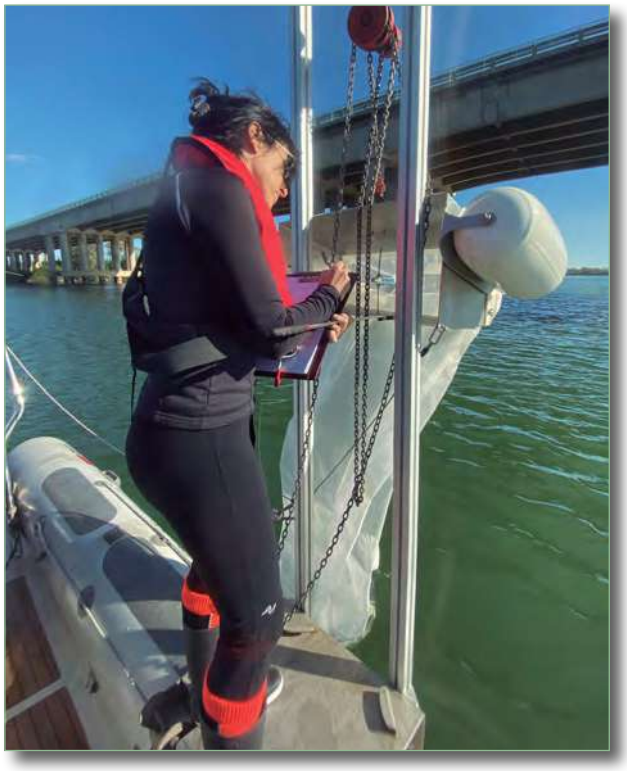
The centre supports participation in international conventions for the protection of the coast and the sea by preparing periodical national reports, such as those corresponding to the dumping of dredged materials into the sea for London and OSPAR Conventions, carrying out other activities for OSPAR (report of contaminant inputs from rivers and direct discharges), and for the Barcelona Convention, as well as monitoring and evaluation of marine litter.

In relation to the state-managed marine Special Conservation Areas (ZEC), documentation has been prepared on the uses and activities of nine Sites of Community Interest (SCI), and an analysis of maritime traffic and the risk of collisions with cetaceans has been carried out in the Mediterranean cetacean migration corridor. This work will continue in 2022 in the context of the proposal to the International Maritime Organization (IMO) of a Particularly Sensitive Marine Area (PSSA) of the North-Western Mediterranean by Italy, Monaco, France, and Spain.

For the **Spanish Office for Climate Change, OECC**, work is going on within the Plan to Promote the Adaptation to Climate Change in coastal areas of Spain, Plan PIMA ADAPTA – Costas, reporting about the tasks accomplished on the first part of the work that involves Spanish Regional Governments.

For the entity **Aguas de las Cuencas del Mediterráneo (ACUAMED)**, work has continued through the current assignment in relation to discharges from desalination plants in operation, making a report on the Environmental Monitoring Plan of the Torrevieja plant and a proposal for its revision, considering the experience accumulated in the period 2015-2018. Likewise, the necessary pre-dilution has been evaluated to avoid adverse effects of the brines from the Carboneras WWTP (Almería), where this discharge is mixed with the cooling water of a thermal power plant.

The service to **State Ports and State-Run Port Authorities** is one of the main activities of the centre since its inception as the Ports Laboratory of the Special School of Civil Engineers in the 1940s. Throughout 2021, work has been done on the topics of the current assignment with State Ports, collaborating also with other CEDEX's centres and laboratories: CETA, LCEYM and LG. And on other specific works commissioned by Port



Field work near the mouth of the Ebro river for the estimation of the contribution of microplastics from rivers to the sea.

Authorities and State Ports. In the topic of continued experimentation, the annual inventory of dredged materials in Spanish ports has been drawn up. A broader topic, Research, Development and Innovation (R&D&I), includes three subsections: Infrastructures, Exploitation and Sustainability. In the first, a partial report on the study of the evolution of damages in breakwaters on slopes has been presented, with the activity suspended at the end of 2021. The second R&D&I subsection, Exploitation, has suffered the impact of the centre's operating mode in 2021, in particular the study of operating criteria for ships docked in the port of Las Palmas; A partial report has been issued and the activity is expected to continue in 2022. In addition, work has continued on the risk analysis associated with traffic and maneuvers using AIS data, and maneuvering simulation with the aim of proposing revisions to the ROM 3.1-99 instruction, in the general study of anchoring on non-sheltered waters, and activity has begun as well in the development of the National Plan for Adaptation to Climate Change for the port subsector. In the Sustainability subsection, intense work has been done in the development of a methodology for real-time estimation of greenhouse gas (GHG) emissions in port environments, collaborating with State Ports in its implementation in the information system of the Public Body. Progress has also been made in the identification of geochemical anomalies from the perspective of the management of dredged materials, producing a partial report that has detected the ports of Avilés, Cartagena, Almería, Málaga, and Arrecife as being susceptible to these effects.

Among the works for Port Authorities, those aimed at Balearic Ports stand out: Climate and

Main simulation bridge. Access of a 330 m cruise ship to the port of Ibiza.

wave driven harbor agitation using numerical modeling, study of environmental conditions limitations for entry and departure of large ships – cruise ships, ferries, oil tankers - in the Botafoch quay of the port of Ibiza, and for port of Palma, the study of safety and operability for a new configuration of the SW dock and the landscape impact of the Master Plan of the Port of interest in the port-city relationship. Likewise, work has been done in the port of Alcudia on sedimentation and interaction with the coastal environment. For the port of Avilés, a set of works related to the sustainable management of its dredging has been developed, issuing reports on hydrodynamics, sediment dynamics and characterization, including their public presentation to the national and local stakeholders in Avilés. The study in a large-scale physical model of the beacon of the port of Pasajes damaged by a storm was reported in 2021. This study is being complemented with a numerical research activity by CEDEX. In the port of San Cibrao (Ferrol), the operating conditions in its anchorage have been studied, and in Ceuta a study has been carried out for the remodeling of the auxiliary boat dock. Work has been carried out for the Huelva Port Authority, through physical and numerical experimentation aimed at the practical development of the technique for Subaqueous contaminated dredged material capping with clean materials

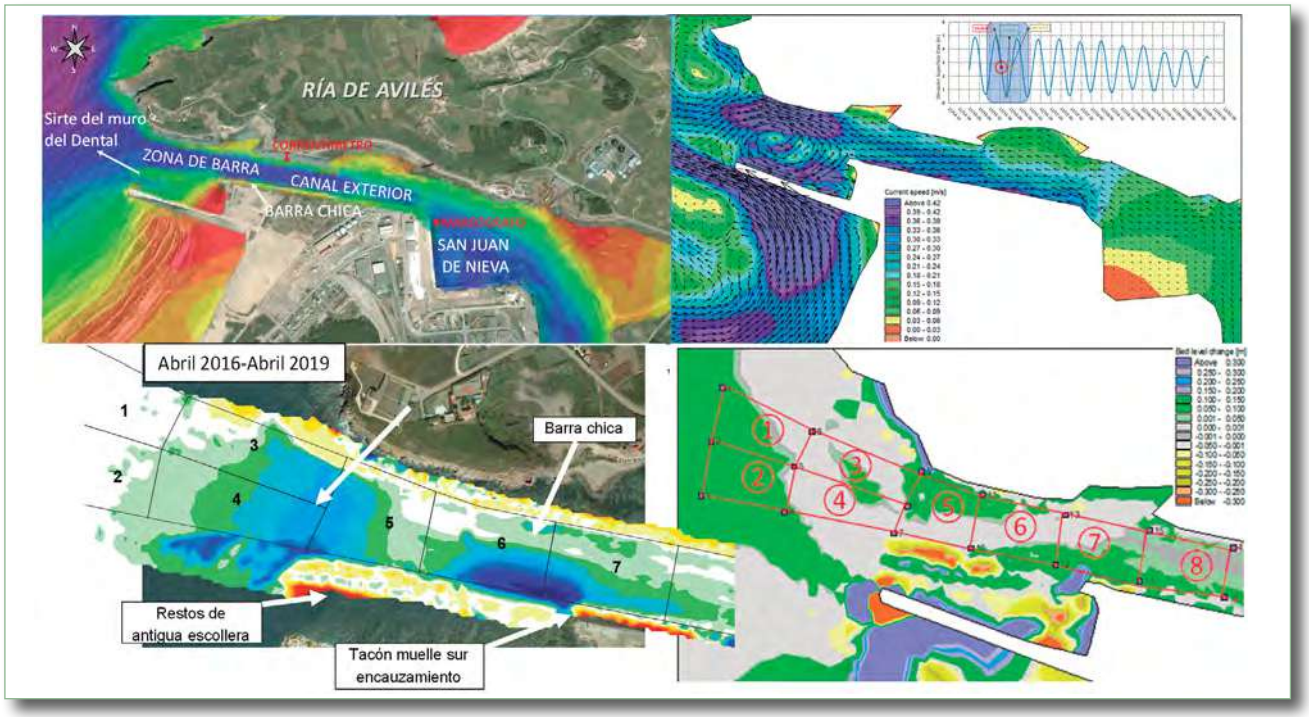
In 2021, **the Directorate-General of the Merchant Marine** (DGMM) has made a new assignment to CEDEX for activities to be carried out by CEPYC in the 2021-2023 period, including work on the safety of nautical operations and bulk goods, the applicability of pollution control products, and quantitative assessment of GHG emissions from commercial shipping in the Spanish territorial and jurisdictional waters of more than 1,000,000 sq. km. This year, two reports have already been issued on the safety of two types of unclassified cargo, two on requests for homologation of absorbent products and one on an emulsion breaker. At the same time, work has begun on the operating conditions at the Sanlúcar anchorage

and on fine-tuning the procedures for evaluating emissions.

The centre also provides support to the **Commission for the Investigation of Maritime Accidents and Incidents (CIAIM)** through studies of marine and atmospheric meteorology conditions, and maneuverability during the occurrence of accidents, in support of the work of the Commission's researchers. In 2021, through an agreed commission, a simulation study of the undocking maneuver of the 23,000 TEU container ship *MSC Mia* in the port of Valencia on September 13, 2020, as well as the analysis accident of the fishing vessel *Sempregueto,* has been carried out.

The special circumstances of the activity throughout the year have given great importance to the internal meetings for the presentation of works that began to take place in the last quarter of 2020. During 2021, seventeen meetings have been held that have served to share knowledge and discuss the centre's activities, also including presentation sessions by Puertos del Estado, DGCM, DGMM, and CIAIM, which helps us to stay in tune and guide shared strategies with their needs in the medium term.

Finally, it should be noted that the contribution and activity of the centre activity depends on a constant learning process in contact with mainstream sources of knowledge on our subjects. This process requires participation in forums, working groups, scientific organizations, and conferences on matters of the expertise. In the last months of 2021, more intense face-to-face participation in these meetings has begun to be recovered, and it's expected that throughout 2022 progress will be made towards normality, while preserving everything learned and the full opportunities offered by remote work.



Sedimentary dynamics of the Avilés estuary. Comparison with field measurements.

CENTRE FOR STUDIES ON APPLIED TECHNIQUES

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"We care about our shared home by taking actions to tackle the greatest environmental challenges"

In 2021, the Centre for Studies on Applied Techniques (CSAT-CETA) has developed a remarkable activity in the study and characterization of the effects and natural risks posed by human activities.

The extensive typology of infrastructures and the complexity and multiplicity of the impacts they generate, leads CETA to focus on three main lines: **(i) the response to major environmental challenges**, mainly the fight against climate change and the efficient use of resources through the application of the circular economy, **(ii) the analysis of specific impacts** such as noise and air pollution, impacts on surface water and groundwater, fragmentation of habitats and civil engineering works both in riparian ecosystems and on the shoreline, and **iii), the proposal of measures for the mitigation of impacts and the monitoring of the quality of ecosystems**, defining policies for the reduction of greenhouse gases in different fields, the ecological restoration of ecosystems, including the procedures regulated in the environmental evaluation of projects and strategies, and the monitoring of the state of ecosystems, with special emphasis on the analysis of their radiological quality.

A significant part of the actions has been focused on providing support to the Ministry of Transports, Mobility and Urban Agenda (MITMA), and the Ministry for Ecological Transition and the Demographic Challenge (MITERD), thus complying with one of the main functions of CEDEX. Likewise, the stress has been placed on the fulfillment of the objectives of CEDEX's 2020-2022 Strategic Plan (PEC 2020-2022), by giving technical assistance to the sector at large.

Among the actions in response to the major environmental challenges, those related to the fight against climate change, based on new tools to optimize the management of port infrastructures, stand out. These projects are part of

← Drone image of an island in the Douro River as part of the DRAINAGE project.

a request from *Puertos del Estado,* and propose methodologies that facilitate the management of port areas by the competent administrations. In this line, SAMOA2, where Port Authorities are directly involved trough surveys, and the monitoring of ship emissions in real time stand out. Both projects are aimed at optimizing the management of operations likely to generate pollutants or GHG emissions in each port, mainly in ship loading and unloading, and in other ship operations. Methodologies such as EMEP/EEA (European Monitoring and Evaluation Programme of the European Environment Agency), and others developed at CEDEX are being applied in these projects. CEDEX's Centre for the Studies on Ports and Coasts (CEPYC) and other entities are collaborating in this work. In parallel to these projects, and for Puertos del Estado, a project is being developed for the estimation and management of the carbon footprint. In 2021, two actions have been taken, one to collect public procurement criteria with the concept of carbon footprint, and another with the calculation of the carbon footprint of the port of Seville.

These tools have a positive impact to society by contributing decisively to the reduction of pollution and the emissions of greenhouse gases generated in the ports and, therefore, to the improvement of air quality in nearby urban areas.

CETA have also contributed to the achievement of strategies for the adaptation of land transport infrastructures to climate change. Thus, in the field of roads, CEDEX is participating in a working group within the framework of the Technical Road Association (ATC). With this participation, one of the main objectives of the CEDEX Strategic Plan 2020-2022 is achiveded, facilitating the transfer of knowledge in collaboration with other public and private agents.

Continuing with the actions in response to the major environmental challenges, those related

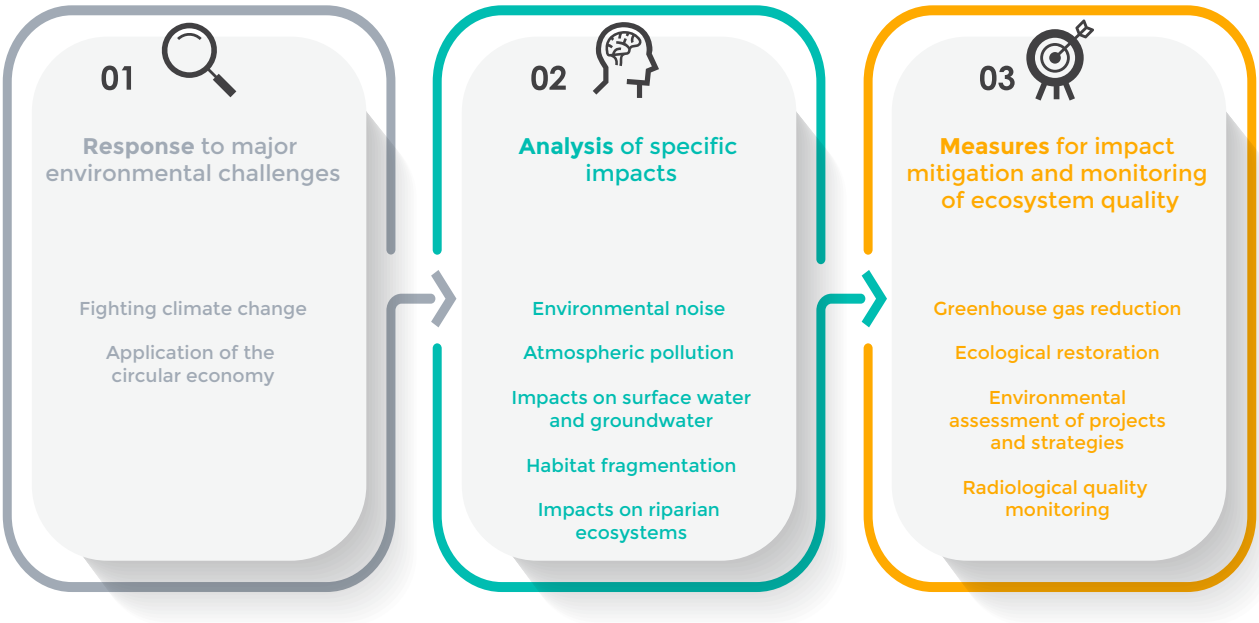


Table of measures to address environmental challenges.

to the Circular Economy stand out, where the establishment of indicators to measure circularity is being addressed.

The Circular Economy is a system whose objective is to maximize available resources, making them remain as long as possible in the production and consumption cycle, extending the life of the product, reusing it, and finally using the waste generated as primary material in order to reduce the generation of waste. To this end, it's necessary to foster the durability and product substitution, and these must be designed for recycling and a longer useful life, encouraging their repair.

The benefits of the Circular Economy for society have an impact on all market-related actors, whose participation is essential to carry out the transition. Therefore, both official and social involvement are necessary at all levels: citizens, public administration and the private sector.

In order to know that the actions being developed are in line with the essence of the new paradigm, it's necessary to have indicators that can quantify the measure of circularity, so that the implementation of the different measures and their results can be monitored, thus preventing the transition from being blocked in ineffective routes.

To achieve this, in 2020, the European Commission developed the Circular Economy Action Plan, which includes initiatives throughout the entire life cycle of products, starting from their design, aiming to bolster the generalization of circular economy processes.

The circularity approach is embedded in the sustainability paradigm, which has an integrating vision of the dynamic relationships among nature, economy, and society. Thus, the first step towards sustainability is to implement a Circular Economy model to achieve the decoupling between economic growth and environmental impact.

Schematic representation of the

Circular Economy concept.

At the national level, the Spanish Circular Economy Strategy (EEEC), Spain Circular 2030, lays the foundations for promoting the new production and consumption model. To carry it out, the First Circular Economy Action Plan has been developed as an organizing tool for the measures in place.

This work falls within the lines of achieving a sustainable, innovative and efficient industry. In terms of the SDGs, the Circular Economy is directly related to Goals 6, for sustainable water management; 8, for promoting sustainable economic growth; 9, by furthering sustainable industrialization and fostering innovation; and 12, by encouraging sustainable consumption and production patterns. Indirectly, it allows for the

achievement of Goals 13, 14 and 15 by being part of the measures to combat climate change and promote the sustainable use and management of marine and terrestrial ecosystems.

Among the works aimed at the analysis of specific impacts, those focused on environmental noise stand out. The environmental noise assessments, in line with CEDEX's 2020-2022 Strategic Plan, contribute to improvement of health and well-being of citizens (SDG 3) in the face of noise pollution, reducing the impact of noise in cities and that caused by large transport infrastructures.

Moreover, it facilitates the development of contracted R&D&I personnel and trainees, who participate in noise assessment and management activities related to land use planning, and transportation infrastructure planning and management.

A large part of the work is oriented towards the development of methodologies for the evaluation and communication of environmental data in compliance with the Noise (END) and Spatial Data Information Infrastructure (INSPIRE) Directives, with CEDEX acting as a national reference agency for the National Administration, Regional Governments and Local Entities, and participating in working groups of the European Commission.

The actions that have been developed throughout 2021 in the field of Environmental Noise are numerous, and have as a central aim to provide service to the sector, reinforcing the strategies and plans of both MITMA and MITERD. Among these actions, it's worth mentioning the support to the Ministry for Ecological Transition and the Demographic Challenge (MITERD) in the creation of the Panel of Competent Authorities (AACC) of the Kingdom of Spain on Noise, in compliance with the END Directive by the AACC, in the meetings of the Noise Expert Group and Noise Regulatory Committee and in the meetings with the AACC.

Noise map for Madrid-city.

Similarly, the National Information System on Noise Pollution (SICA) has been improved, promoting its evolution towards a national infrastructure of spatial data on environmental noise, in compliance with the INSPIRE Directive.

Support has also been provided to the European Commission in the design of guidelines for the preparation and communication of Strategic Noise Maps (SNM) and Noise Action Plans (NAP), the preparation of instructions for the application of the Common European Noise Assessment Method (CNOSSOS-EU), the participation in the technical workshop on noise for the adaptation to CNOSSOS-EU organized by the Spanish Society of Acoustics, and, finally, in the design and implementation of the common repository Repornet 3.0 in the field of environmental noise.

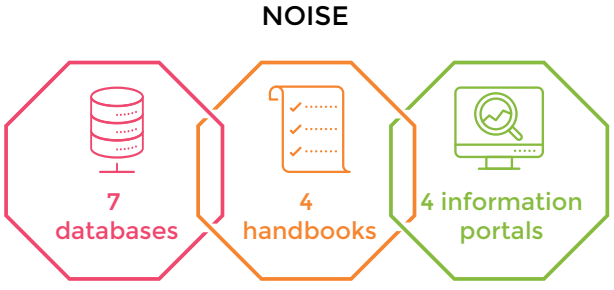
R&D&I work is also beginning in relation to the development of the Noise Law and the evaluation of noise in natural ecosystems.

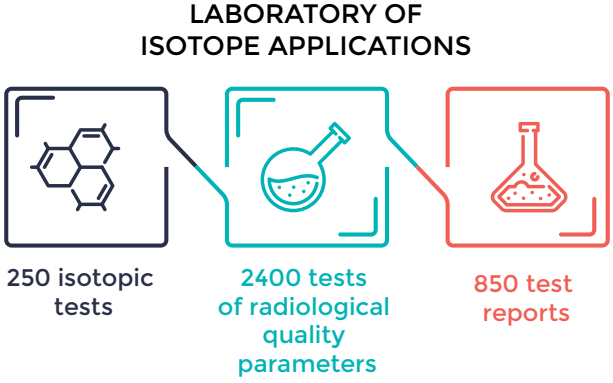
This work on environmental Noise has a deep impact on Society, since it's the basis for the evaluation of the noise that affects a large part of the population, and for the establishment of corrective measures in the different modes of transport, the main acoustic emitters.

An essential aspect of environmental monitoring applies to the radiological parameters of water quality. In 2021, the Nuclear Safety Council commissioned CEDEX to continue radiological monitoring of the aquatic environment through the Laboratory of Isotope Applications. This assignment applies to the National Network of Inland Waters and Transitional, Coastal and Marine Waters in compliance with the EURATOM international treaty.

This laboratory, in collaboration with the Geotechnical Laboratory of CEDEX, has also evaluated and diagnosed waste sites, through studies on their stability and the confinement and transport of contaminants, thus contributing to the water resource protection strategies carried out by the river basin authorities, and the integration of efforts by environmental departments of regional governments for waste management.

In support of the management of hydraulic infrastructures, which's required by river basin authorities, possible solutions to reservoir sealing problems are sought through the application of tracing techniques with environmental isotopes. These techniques make it possible to evaluate the residence time of water in the aquifers around the dams, identify its origin and connection with the water in the reservoirs and improve

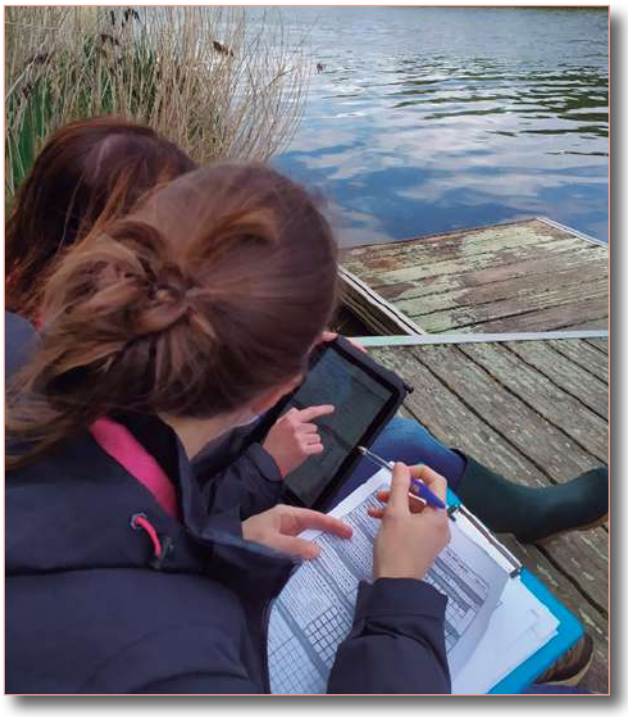




the evaluation of water resources and the protection of their quality.

In this field, and in collaboration with the Centre for Hydrographic Studies, a study of persistent and emerging organic pollutants has been developed to improve tracing techniques in the assessment of surface water and groundwater interactions. In the near future, these methodologies will be consolidated in the consultancy work of units and laboratories specialized in groundwater quality studies, providing a service to the sector and to the hydraulic administrations.

Equally, in 2021 work has been promoted to **propose measures to mitigate impacts. Work aimed at increasing knowledge of the impact of road traffic on insects in general, and pollinators in particular, can be highlighted.** At the beginning of the spring, new tests were carried out to assess the performance of the insect collector designed by CEDEX.



Data collection in the Duero River, upstream of Zamora.

With this work, knowledge is gained on the emerging problem of insect decline, and references are provided to MITERD to respond to the objectives set out in the National Strategy for the Conservation of Pollinators, among whose measures in relation to the impacts of infrastructures, *B.2.2* stands out*: Develop technical guidelines for the conservation of pollinators and their habitats in the environment of communication, transport, energy, and other services infrastructures*. These works are also aimed at the development of people and teams, contributing to the undertaking of Master's and Degree Final Projects by students from different universities who seek to complete their university experience with experimental work studying highly topical environmental issues.

Environmental Restoration represents a further step in the proposal of measures to mitigate the impacts derived from human activity. In this line, one of the main activities has consisted of monitoring the effects of the ecological flow regimes established in the river basin management plans and their relationship with the ecosystems. This work has been carried out for the Directorate-General for Water (DGA) within the framework of the work program being developed by CEDEX. Firstly, it contributes to the rational and sustainable management of water resources, fulfilling the strategic objective of service to society. Secondly, to the application of the DPSIR (Drivers, Pressures, State, Impacts and Responses) study model based on the cause-effect relationship, which's one of the current challen-

ges of MITERD regarding the interactions between human activity and the environment.

In the same vein, support tasks have begun for the DGA in monitoring the effects of climate change on the Natural River Reserves (NRR) through advice on the implementation of a Monitoring Network. This activity is included in the PIMA Adapta Agua Plan, which in turn is part of the MITERD's National Plan for Adaptation to Climate Change (PNACC) to adopt managerial and adaptation measures in NRR in the face of the potential effects of climate change, thereby advancing to SDGs 6, 13 and 15.

Finally, this year saw the completion of the Drainage Project for integrated flood risk management. This project, in line with the targets of SDGs 6.5, 9.1, 11.4, 11.5, and 11.B, aims to improve the resilience of urban and peri-urban areas to flooding through the design of green infrastructures compatible with the sustainable management of water resources, and the good status of water bodies. In this way, progress is made in improving the know-how that will help MITERD and the river basin authorities in the revision of the next Flood Risk Management Plans (PGRI).

Natural fluvial reserve of the Iregua River.

This activity has been complemented by the attendance to different conferences and seminars of national and international relevance, and by the publication of an article in one of the most prestigious journals in the field of environmental restoration, accomplishing another of the objectives of CEDEX's Strategic Plan, the development of people and teams, especially R&D&I personnel.

CENTRAL LABORATORY FOR STRUCTURES AND MATERIALS

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"At the Central Laboratory for Structures and Materials we work to improve the safety and durability of structures, as well as in the use of more sustainable materials"

During 2021, the Central Laboratory for Structures and Materials (CLSM-LCEYM) has completed an intense activity in the field of of dykes, dams, and bridges. All this work has been aimed to contribute to the sustainability and resilience of infrastructures, increasing their useful life as established by the Sustainable Development Goals (SDGs), section 9.A.

A significant part of the actions has been focused on the needs of MITMA and MITERD, thus fulfilling one of the main functions of CEDEX, laid out in its 2020-2022 Strategic Plan, and contributing to its role as public service in the construction sector in the broadest sense.

A specialised technical assessment has been conducted to resolve the inconsistencies of criteria in the design of some of the viaducts for the Mediterranean Corridor high-speed rail. The assignment was carried out by a specialised technical team from LCEYM and LG, coordinated by the Structure Studies and Evaluation Area. The work consisted of reviewing the design criteria in the structural project, of the structures, related mainly to the dynamic interaction, due to the seismic action, between the structure, its foundations, and the soil on which it's located.

Intensive work has been undertaken in the field of dam concrete pathologies for the Directorate-General for Water (DGA). This work is meeting SDG 6 (Clean Water and Sanitation). This way, the study on the Tajera dam has been concluded. In this study, it's been developed specific research on phenomena of delayed ettringite formation and alkali carbonate reaction, leading to concrete degradation processes that can produce expansions. Significant progress was also made in the analysis of the concrete for the Atance dam in Guadalajara. The study of the concrete for the Tentudía dam in Badajoz was also initiated.

← Metallic bridge O Braqueire over the river Sor (Source: Shutterstock).

Analysis of the concrete for the Atance Dam.

Research of corrosion in the reinforced concrete of the Reina Sofía Dock (port of Las Palmas).

By the same token, in accordance with the Goal 9 (Industry, Innovation and Infrastructure), the study requested by the National Port Authorities about concrete corrosion processes in port structures has continued. Therefore, the research of corrosion in the reinforced concrete of the Escombreras Southwest Dock (port of Cartagena) has been completed, and a similar study has been initiated at the Reina Sofía Dock (port of Las Palmas). Both structures are exposed to a harsh marine environment and suffer from corrosion problems.

Equally, and at the request the National Port Authorities, it's been carried out a study in scope of prevention of the appearance of pathologies in future constructions. In this respect, it's been studied the development of a field test to control concrete durability on site.

On the other hand, research has gone on regarding the influence of the manufacture of caissons employing floating platform caisson technology, which is widely used in our country. To this end, cores have been extracted from the ports of Tenerife and Barcelona, which will complete the work previously done at the laboratory.

The conclusions drawn from this work requested by the Directorate-General for Water and the National Port Authorities have allowed to introduce improvements in current regulations (*Structural Code*) to avoid the appearance of problems in future works. Thus, the objective of the CEDEX in its strategy of providing service to sector and society, while improving the resilience and sustainability of hydraulic and port structures, has been accomplished.

In the innovation field, a state of the art on very high durability concretes for port applications is being produced. In the Construction Products Department, a work line has been initiated on high corrosion resistance concrete reinforcement, as an alternative to traditional carbon steel concrete reinforcement. Galvanized steels, stainless steels and fibre reinforcement polymers have been considered as possible options.

The resulting studies point to increased durability and greater resilience to aggressive chemical agents of the reinforcement concrete structures.

The focus of the works tries to promote the sustainability of materials, considering not only their production but also their complete life cycle and the extension of the service life of the structures. Likewise, this line of action falls within the possible strategies to reduce both the carbon footprint and the emission of greenhouse gases, meeting several targets of SDGs 9, 11, 12, and 13.

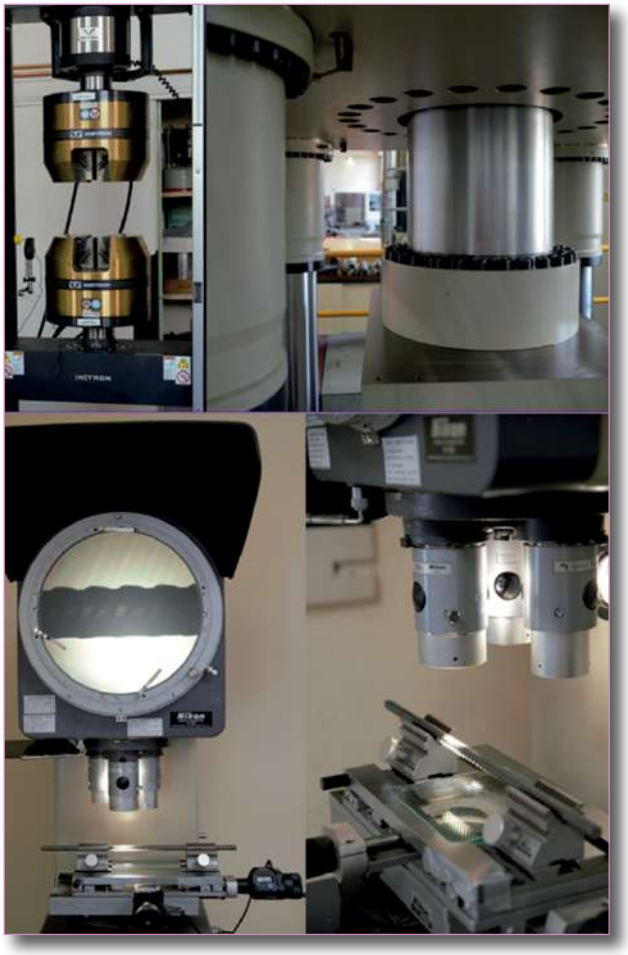
As for the reservoir waterproofing field, the collaboration with the DGA, for the preparation of the "Practical Guide for the inspection and monitoring of the geosynthetic barriers used in the waterproofing of reservoirs", has carried on. Works corresponding to the study and monitoring of the performance of waterproofing geomembranes used in reservoirs have also continued, within the collaboration agreements with Balsas de Tenerife and the Insular Water Council of La Palma, as well as with the Taibilla Canals Community. These studies will contribute to the improvement of our water resources, one of our most precious and scarce assets, optimizing its management by the Public Administrations (SDGs 6.4, 6.5 and 5.A).

Requested by Naturgy, the study of the state of the Castrelo Dam concrete, in Orense, has also been carried out, developing a deep analysis of pathologies, and of the physical and mechanical characterization of the dam concrete, which has allowed the knowledge transfer acquired in previous assignments by the DGA, concerning dams affected by alkali-silica, to the private company.

The LCEYM has maintained its activity as a testing laboratory for construction steel: structural steel, and reinforced and prestressed concrete reinforcement steel, in the field of product approval for the Ministry of Industry, Trade and Tourism, and for the product certification within the framework of various technical committees of the AENOR Certification Commission. These works permit to verify compliance with the specifications and requirements for steel materials and products, guaranteeing their technical competence and durability in a sector of great economic importance for the country such as the steel industry.

In the field of technological development, the implementation of the BIM methodology for existing structures has kept on. The results of the monitoring of different parameters, the structural assessment analysis, and the information about materials, have been incorporated into digital models. This implementation methodology allows to integrate the results of the studies carried out at CEDEX into the BIM infrastructure

One of the activities of LCEYM's Materials Area is the technical inspection of reservoirs.



Construction Products Department Laboratory.

management models, which are increasingly being used in the engineering sector.

The Structure Studies and Evaluation Area has been coordinating the CEDEX drone service, adapting it to the new regulations, developing and increasing its capacity to provide different services. It's also been internally provided to the organisation for technical support, in structures matters, in different interventions of its own building stock. This working line, along with the implementation of the BIM methodology, contributes to the digital transformation process within both LCEYM and CEDEX. As a result, both lines, applicable to different works in the field of construction, are promoting collaboration between CEDEX's different centres and laboratories.

On the other hand, a specific technological survey has started to identify the proper equipment to assess the condition of bridge stay cables and post-tensioning tendons. It's been motivated by the uncertainties about the real durability of this critical elements in the capacity of structures.

Concerning road signals and marks, 458 km of highways have been monitored, and numerous reports have been issued corresponding to the verification of the indicators related to the retroreflection of road markings and vertical signals, commissioned by the Directorate-General of Roads (DGC). This work will entail improving road safety, minimizing traffic accidents, and increasing the perception of well-being by facilitating driving (SDG 3.6).

At the Photometry Laboratory, an outstanding facility belonging to the LCEYM, studies have been conducted on the performance of different retroreflective materials used in vertical signals, commissioned by the companies T2S and 3M Spain. This activity has been complemented with an internal R&D&I line.

The knowledge transfer from the works in progress is reflected through participation in national and international conferences, thus reinforcing the international presence of CEDEX. In this regard, it could be highlighted the participation in the first EUROSTRUCT international congress of the European Association for Quality Control of Bridges and Structures, held in Padua (Italy), with a presentation on a methodological proposal for the study of post-tensioned con-

Point cloud of the 3D scan (above) and its geolocation in the BIM environment (below).

crete bridge decks affected by alkali aggregate reactions.

The availability of a unique facility such as the Seismic Simulator has enabled the development of new technologies in both public and private sectors. In the public sector we highlight the case of the National Geographic Institute (IGN), which is being supported by the LCEYM with the calibration of accelerograph-type sensors, called

SILEX. These sensors are developed by this entity for their implementation in the seismic detection network distributed throughout the Spanish territory, allowing a better study and detection of seismic activity. In relation to the private sector, seismic qualification tests have been carried out for companies such as Ormazabal-Veletia. For companies INDRA Sistemas and SEPSA-MEDHA, frequency or vibration sweep tests have been performed. Shock test to radar equipment and auxiliary converter will be on board submarines or trains to verify their response to the actions imposed by the applicable standards according to their nature. These works are to meet SDGs 9 and 12.

Standing out as one of CEDEX'x priorities, and to maintain and improve this unique facility, actions have been carried out to ensure the control of the cooling system of the hydraulic units. These actions allow for the optimization of its operation, stability, and response during the tests by controlling the temperature of the oil cooling water during the tests. Undoubtedly, all this will provide a higher quality and reliability service while increasing the efficiency of the cooling installation with a consequent lower environmental impact.

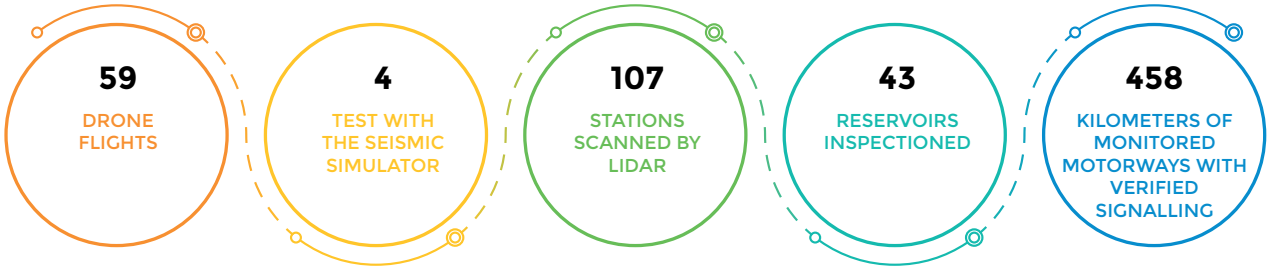
The participation of the LCEYM in several standardization and certification committees has continued, having to underline the active involvement in a working group in charge of studying new cements, with a lower carbon footprint, to include them in Spanish regulations. This will involve the development of more sustainable infrastructures (SDG 9.1, 9.4).

The activity of the LCEYM linked to experimentation requires the performance of numerous laboratory tests to evaluate physical, chemical, and mechanical properties, as well as the maintenance of the ENAC accreditation and the Quality Management System (QMS), according to UNE-EN ISO/IEC17025:2017.

In October 2021, the ENAC accreditation as a Testing Laboratory has been renewed. To ensure the validity results, calibrations and continuous training of personnel have been carried out, with ongoing improvement in quality procedures.

Moreover, the LCEYM is integrated into the CEDEX Multisite Certification of the Environmental Management System (EMS), according to UNE-EN ISO 14001:2015, for the observance of the Sustainable Development Goals (SDGs) and the Green Deal. In 2021, the certification was renewed by the external entity SGS.

The planned environmental objectives have been met by identifying and evaluating environmental aspects, legal requirements, risks, and opportunities for improvement. Trends in consumption



of natural and energy resources have been analyzed, seeking their efficient management. Improvements in facilities, such as boilers, air conditioning equipment, etc., are being addressed to reduce the environmental impact on the city (SDG 12.6). Staff awareness in environmental matters (SDG 12.8), in the recycling of waste and the maintenance of the Recycling Point, and in energy saving, continues.

The creation and implementation of Server M, computerized support for archiving the EMS documentation and the use of the Excel Book to record the EMS data, has begun.

All the lines of action aforementioned show that the current activity by the LCEYM is aligned with the sustainability and resilience of infrastructures, as well as with the reduction of the consumption of natural resources (underscoring SDGs 6.A, 9.4, 9A, 11.6, 12.2, 12.5, 12.6, and 12.8), thus favouring compliance with the 2030 Agenda, especially when it comes to innovation and infrastructure.

Seismic qualification test prototype .

GEOTECHNICAL LABORATORY

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"The Geotechnical Laboratory, for the safety and sustainability of works about the ground"

The work of the Geotechnical Laboratory (GL-LG) during 2021 has been focused on serving MITMA and MITERD, fulfilling one of CEDEX's main functions included in its 2020-2022 Strategic Plan.

Among the works carried out, those concerning the commitments of our participation in the research programmes on **railway geotechnics** stand out. In particular, CEDEX's participation in the European project GEOLAB, which began its work in February 2021. The first face-to-face meeting of this consortium was organised at CEDEX in the last week of November, with more than 50 participants.

At CEDEX Track Box, the most important input is the maintenance of hydraulic and mechanical equipment necessary for this facility, which was inaugurated 17 years ago. Two very complete studies have been carried out on the influence of train speed on rail deflections, and the use of the Panda as a tool for the correct assessment of the state of compaction and degradation of the ballast. The availability of a unique facility such as the CEDEX Track Box makes it possible to incorporate new technological innovations into the railway infrastructure, resulting in greater safety and resilience.

The drafting of standardization has continued in the UIC (International Union of Railways), updating the document UIC-IRS 70722 (Maintenance and Improvement of Earthworks and Track Bed of Existing Railway Lines), and on the future Eurocode EC-7 "Geotechnical Project". The results of these standardisation activities contribute to the sustainability and resilience of infrastructures by increasing their service life

For the **Directorate-General of Roads** (DGC), of MITMA, the LG has signed a contract for the execution of the performance of "Technical Assistance in geotechnical issues within the

← Image of El Cáliz, in La Pedriza (Source: Spanish Society of Soil Mechanics).

Table 1. Monitoring of pathologies on the State Road Network

Road Department	Road	Province/City/Km	Pathology under study
Andalucía Oriental	A-7	Granada/Carchuna	Cutting
		Granada/Polopos-Albuñol	Cutting and tunnel of Ramoncillos
	A-44	Córdoba/Jabalquinto	Pavement
	A-32	Jaén/Enlace de Canena	Pavement
Andalucía Occidental	N-432	Córdoba	Pavement
	A-45		
	CO-32		
Aragón	A-22	Huesca	Erossion
	A-2	Huesca/Fraga	Pavement
	N-420	Teruel/Escucha	Earthwork
Cantabria	N-621	Cantabria/Bores	Cutting and pavement
	A-8	Cantabria/Reocín	Pavement
	A-67	Cantabria/Corrales de Buelna	Pavement
Castilla-La Mancha	N-420	Ciudad Real/Fuencaliente	Cutting and eathwork
Castilla y León Oriental	BU-30	Burgos	Reinforced earth wall
Cataluña	N-420	Tarragona/Coll de Teixeta	Earthwork and false tunnel
Comunidad Valenciana	A-7	Alicante/Variante de Alcoy	Deformations and instabilities in several embankments
	A-33	Valencia/Fuente de la Higuera	Stabilisation by means of pile wall of abutment deformations

scope of the DGC", with an amount exceeding 6 million (€) and with a duration of 3 years. The aim of the work is to provide technical assistance studies, installation and measurement of the instrumentation installed for monitoring pathologies at various points of the State Road Network. All these works will enable the State Road Network to provide a higher quality and more reliable service, which will result in improved mobility in the transport sector.

N-420, in La Escucha.

As part of the R&D&I programmes developed this year by the LG, it's worth mentioning that new methodologies are being implemented, in collaboration with other CEDEX centres for monitoring the evolution of geotechnical pathologies such as those described, based on the new technologies available, such as laser scanning and photogrammetry, complemented by the use of drones in some cases.

With regard to the advice to the **Directorate-General for Coasts,** the most relevant projects were the analysis of the slope stabilisation to prevent the effect of the landslides in the parking

area of the Interlimen urbanisation in Hondarribia (Guipúzcoa); the review of the documentation submitted by Euskadi Trenbide Sarea to the Guipúzcoa Provincial Coastal Service of Guipúzcoa, in relation to getting back to the work on the Donostia metro system on the Miraconcha-Easo metro section; and the initial approach to the measures to be taken on the beach at Alojera beach (La Gomera) to minimise the risk of landslides. These actions can be framed within the activities carried out by CEDEX in the field of resilience and sustainability of the natural environment.

At the request of ADIF, a report has been drawn up on the discrepancies in structural design criteria in the project for sixteen viaducts of the Níjar-Río Andarax section of the high-speed line of the Mediterranean. This work was performed in collaboration with the Central Laboratory for Structures and Materials (LCEYM).

For the **National Port Authorities,** and within the framework of the current assignment in force, different technical assistance tasks have been executed for the evaluation of studies of alternatives, preliminary projects and projects, as well as reports on works already underway, in the following ports:

- Avilés, on the extension of the Raíces dock by sheet piling. Reports on the feasibility of the project and guidelines for an alternative design with stabilisation of the current dock by micropiles;
- Barcelona, on the foundations of the new fish market. Assessment of the geotechnical information and the design of the foundations, prescriptions for the proposed typology and alternative design with driven piles;

Alojera beach (La Gomera).

- Huelva, on the north extension of the south dock by sheet piling, a compilation of the work carried out since the spring of 2019;
- Cartagena, evaluation of the geotechnical information and foundation typology on the project for the border control building and the office building of the Port Authority;
- Pasajes, analysis of the results of a test embankment and assessment of secondary settlements on the preloading on the surface of the former the old esplanade. Including *in situ* measurements and laboratory test; and
- Cádiz, on the increased dredging of the channel and extension of the terminal: ongoing compilation report on the work carried out by this laboratory since 2019.

In addition to the aforementioned technical assistance tasks, we have also carried out R&D&I studies, which have been focused on new technologies for data processing applied to port preload prediction, and to automatic learning, which has led to the publication of an article for the occasion in the 50th anniversary of the journal *Geotecnia*.

Geophysical tests in the port of Huelva.

The work carried out in the port area combines activities related to mobility and natural environment, in terms of both the resilience of port infrastructures and the sustainability of the marine-port environment.

The works carried out in 2021 for the **Directorate-General for Water** is focused on the analysis and improvement of the safety of hydraulic infrastructures through the study of pathologies of a set of dams that are in service.

They're as follows:

- Study on the pathology of the foundations of the El Atance dam (CH Tajo);
- Study on the stability of the slopes of the Arenós reservoir (CH Júcar); and
- Study of the seepage and interstitial pressures in the embankment downstream of the Mairaga dam (CH Ebro).

In addition, the Confederación Hidrográfica del Guadalquivir has asked LG for the assessment of seepage on a hill of the Breña II dam. This work was performed not only by desk but by in situ tests.

In line with one of the main functions of the CEDEX, and linked to experimentation, the Basic and Experimental Geotechnics Area has carried out numerous laboratory works. It can be highlighted the reports of the Almudévar reservoir; the report of permeability tests on

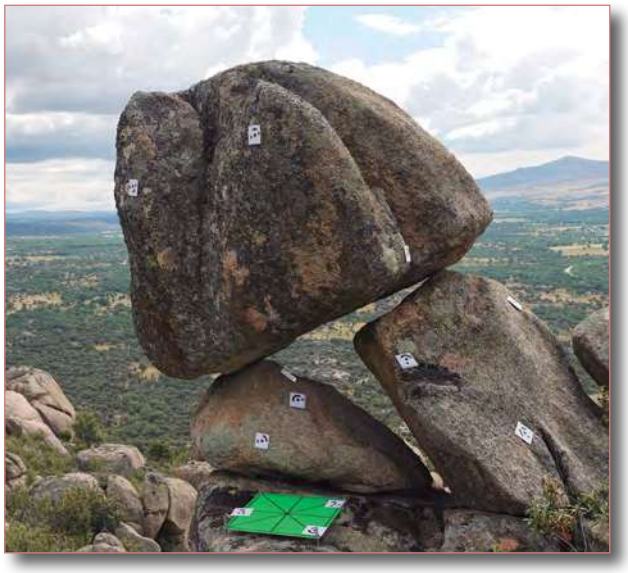
La Breña dam.

6" bentonite-cement test specimens for Terratest Chile; the report for the port of Pasajes; and the collaboration in the activities carried out for the DGC on the N-420 and the A-7. The dynamic tests, requested by the University of Córdoba, the Ascó nuclear power plant and CIEMAT, have included the application of different techniques of cyclic triaxial tests, cyclic single shear test, Bender tests, and resonant column tests.

In R&D&I, work has been done on updating the ISRM method for the characterisation, testing and monitoring of rocks; on the characterisation of the granite of La Pedriza, and on the study "Analysis of the impact of lindane contamination of the Sardas landfill in the Gállego river", in collaboration with the Centre for Studies and Applied Techniques (CETA), of CEDEX, contributing to CEDEX in the field of environmental sustainability of the natural environment.

As part of this collaboration between CEDEX centres, it should be highlighted the technical assistance tasks for the foundations of the shoring for the dismantling of the main structure of the roof of the Centre for Studies on Ports and Coasts (CEPYC), of CEDEX, which was badly damaged by the Filomena snowfall.

In the field of knowledge transfer, the *Master's Degree in Soil Mechanics and Geotechnical Engineering,* offered by CEDEX and UNED, was carried out. In 2021, for the first time, with a telematic format for the teaching phase, between February and June, as well as in the tutoring of the dissertations, from July to September, and with a face-to-face module in Madrid in October, where it was organized laboratory and field practicals, visits to CEDEX worksites and to the different CEDEX centres, and, also, the participation in technical conferences and the defence of dissertations. The new format led to a notable increase in the demand for the Master, so a rigorous selection process had to be carried out for candidates until there were 25 students enrolled from different countries.



3D modelling by photogrammetry of granite boulders in La Pedriza.

An important effort has been made to maintain the presence of CEDEX in national geotechnical forums: the Spanish geotechnical societies and the AENOR standardisation committees. As well as in the international counterparts, adopting, in general, the form of telematic participation: Participation in the committees and working groups of geotechnical standardisation (the European Committee for Standardisation, CEN), the ELGIP platform, the organisation of face-to-face technical conferences (SEMSIG-AETESS Technical Workshop in October), and participation in virtual congresses.

CENTRE FOR HISTORICAL STUDIES OF PUBLIC WORKS AND URBAN PLANNING

CENTRE FOR HISTORICAL STUDIES OF PUBLIC WORKS AND URBAN PLANNING
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"At present, the Centre for Historical Studies of Public Works and Urban Planning is making an effort to reach out to all geographical areas, with special dedication to the so-called depopulated or low-density Spain, maintaining close cooperation with various local institutions"

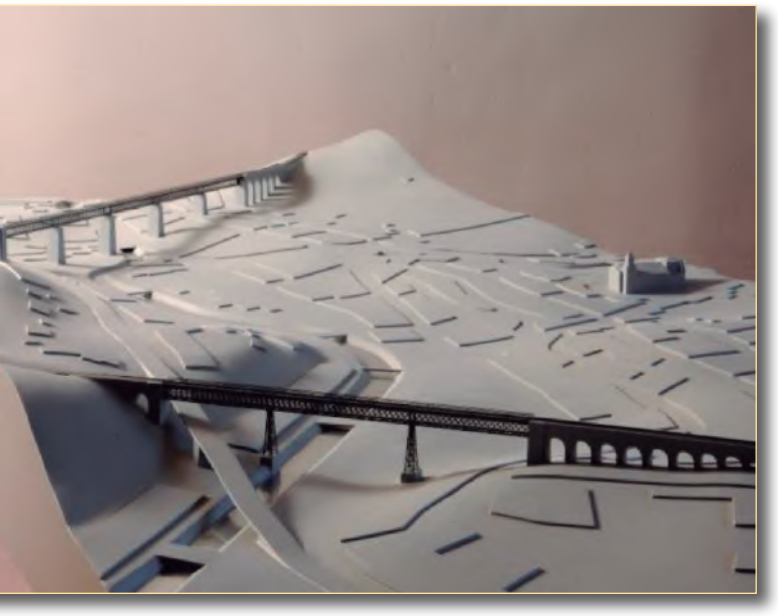
Within the competencies of CEDEX, as defined in its statutes, the Centre for Historical Studies of Public Works and Urban Planning (CHSPWUP-CEHOPU) is responsible for the research, study, and knowledge transfer of the important historical heritage of public works in Spain.

Since its foundation, more than 35 years ago, the centre has deployed an important activity in three major fields:

1. Historical research
2. Knowledge transfer
3. Management of historical archives and documentary sources of its own

The dissemination effort has been reflected in the organization of new exhibitions and their subsequent itinerant version, in addition to their respective catalogues, traveling around our country and beyond our borders. Throughout its trajectory the centre has developed its activities through the organization of exhibitions, publications, participation in congresses, conferences, meetings, etc. During this long period of activity, CEHOPU has made important efforts in terms of economic investment, not only by the setting-up of exhibitions, but also in the making of the *Collection of Models of the History of Public Works,* on show at CEDEX website. A unique collection of elements which, with a marked plastic and formal imprint, is the most important represen-

← Engraving of the city of Odessa, 1850.



Scale model of the city of Redondela with the metallic viacucts called Madrid and Pontevedra that cross it. CEHOPU's Collection of Models of the History of Public Works.

tation of the evolution of the history of engineering, urban planning, and public works heritage in our country.

Thus, during 2021, CEHOPU has consolidated the aforementioned lines of work with horizontal and collaborative dedication, optimizing available human resources and assisting CEDEX Management in its participation in cultural and informative events, among which it's worth mentioning:

- Summer course, in collaboration with the Engineering and Society Foundation, *San Blas Hill and Its Surroundings, A Spot for Knowledge and Innovation*, with the presentation of the paper "The activity of CEDEX. Impregnation in the Civil Society", by Áurea Perucho Martínez, director of CEDEX.
- "A new strategy for the recovery of depopulated Spain, the recovery of the public works heritage as an economic engine", in *Renowable Energy, Digital Networks and Cultural Heritage,* conference organized by the Caminos Foundation at the College of Civil Engineers, 3 June 2021.
- Meetings for support and collaboration with ministerial departments in charge of the implementation of the *Recovery, Transformation and Resilience Plan* in matters of its activity regarding the enhancement of the historical heritage of public works.
- Support to the Management for the elaboration of articles with an informative profile within the framework of public works heritage: Promoting Engineering Heritage from CEDEX. *Revista de Obras Públicas,* extraordinary issue, José Antonio Torroja 1933-2021, nº 3630, pp. 138-141. Madrid: College of Civil Engineers, 2021.

HISTORICAL RESEARCH

The lines of research, based on the study of original sources and historiography, are the foundations of CEHOPU's activity. During 2021 it has been its most important activity, the one that most enriches the contents of the centre and the traveling exhibition program, being also the most relevant in terms of its enormous projection towards civil society through the organization of exhibitions in well-known venues. An activity that blends originality of themes with the excellence in its approaches. In this regard, we're currently working on several lines that strengthen the exhibition catalogue.

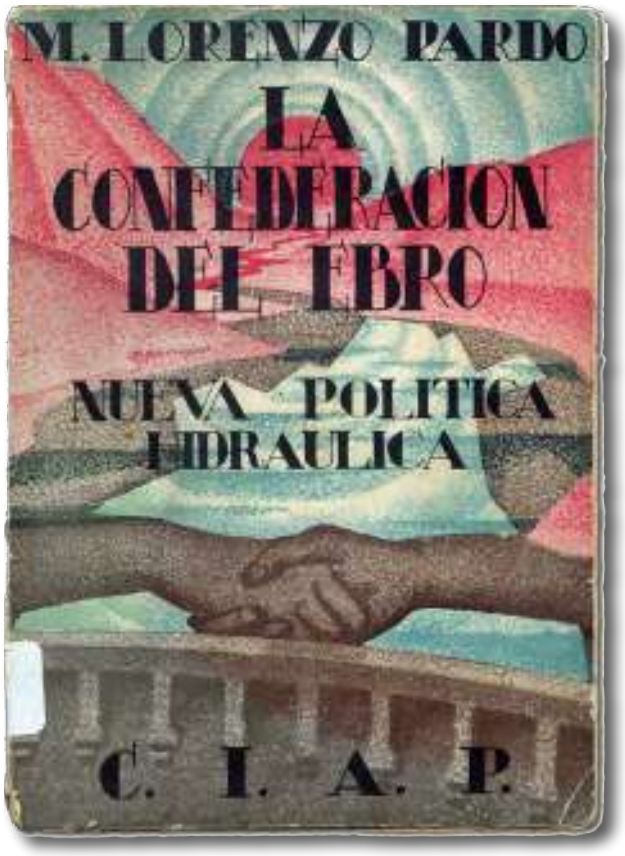
The first of of them has continued with the study and dissemination of great figures of Spanish

engineering, especially those linked to CEDEX. The second is the continuation of a theme that proved successful in the 1980s. We're referring to the history of urban planning, in our country and those close to it in the period of the remarkable initiatives of the 18th century.

The first exhibition is devoted to Manuel Lorenzo Pardo, providing for most of the ongoing exhibition project, and which's due to open its doors in January of 2023 at the Villanueva Pavilion of Royal Botanical Garden in Madrid. A institution that encompasses, among its areas of interest, the uses of water and science.

This display, *Science and Water. Manuel Lorenzo Pardo: A Hydraulic Engineer,* addresses the dimension and profesional recognition of this engineer in the execution of major engineering works, such as the regulating reservoir at the headwaters of the Ebro river, designed in 1916; the conception and development of the current organizational model of hydrographic confederations by river basins (1926); and the drafting of the National Plan of Hydraulic Works (1933) which, together with the creation of the Centre for Hydrographic Studies of CEDEX, meant the main programmatic basis for the planning and management of the country's water resources and, as a result, the significant physical, socioeconomic and environmental transformation that a large part of the national territory would thereafter undergo.

The second major exhibition, scheduled to open in the second half of 2024, addresses urbanism in continuity with another CEHOPU exhibition, *The Hispanic American City. The Dream of An Order.* This new project, in which research is progressing with remarkable results, addresses the founding of new cities in the 18th century, linking it to the history of Spain.



Cover image of La Confederación del Ebro. Nueva política hidráulica, a work written in 1930 by Manuel Lorenzo Pardo during his tenure as head of this entity.

In addition to the best known, such as those created for the repopulation of Sierra Morena, the foundations of Ferrol and San Fernando de Cádiz, among others, are discussed. It will also include the Ukrainian city of Odessa, known as the pearl of the Black Sea, whose establishment was laid out by the Spanish admiral José de Rivas.

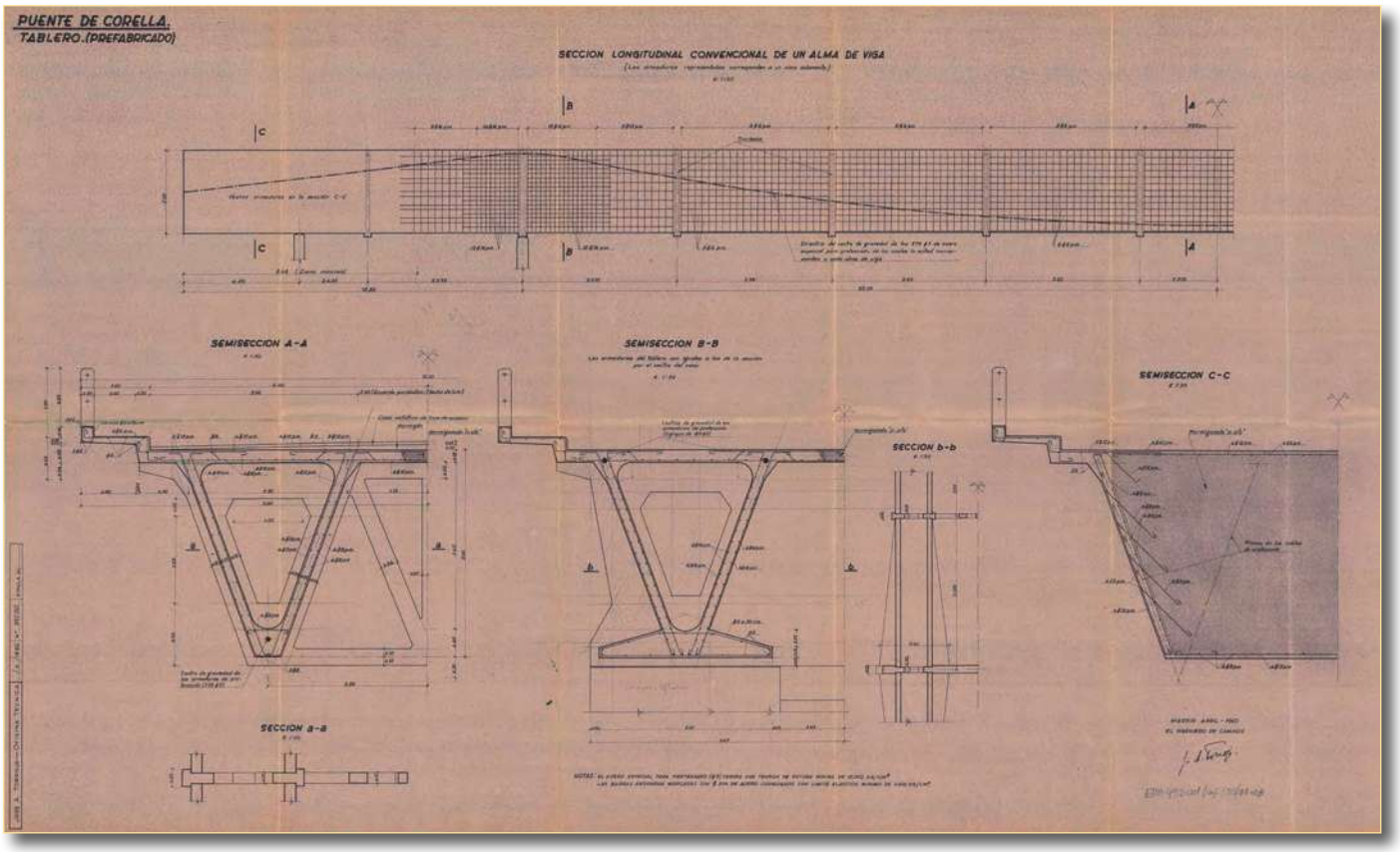
A third exhibition will explore the unknown work of the engineer Eduardo Torroja, and his professional relationship with another engineer and

scholar of reinforced concrete, Jaroslav Josef Polivka. Given the importance of the documentation, a thorough study is being carried out in order to analyze the exchange, both professional and personal, between the two engineers, and how this relationship, running for over a decade, influenced the contents of the book *Philosophy of Structures,* published in 1958.

Research into the original sources of both engineers will enhance the planned panoramic exposition of the hitherto unknown work of Eduardo Torroja Miret, which's being organized in collaboration with the Torroja Foundation through a joint curatorship, and is due to open in the first quarter of 2024. The exhibition will contain unpublished material, mainly original plans uncatalogued until now in the Torroja archive, and documentation donated by the Jaroslav Josef Polivka's family.

When it comes to the research project being developed under the title *Study and Research of Public Works Funds in the General Archive of the Administration,* we've continued making progress in the examination of the existing bibliography. However, and as a result of the pandemic, many archives and libraries have maintained restricted access conditions during 2021, which's why priority has again been given to the study of CEDEX's own archives, mainly of the Eduardo Torroja Miret one, with an exhaustive analysis of the uncatalogued funds.

Looking into the documentation has made it possible to create a database divided into four



Corella bridge deck, designed by Eduardo and José Antonio Torroja. Torroja Archive, CEHOPU.

four large blocks encompassing Eduardo Torroja Miret's profesional and personal work: [1] Technical Office, [2] Research Technical, [2] Research, [3] Teaching, and [4], Personal.

This research work is being developed in parallel with the tasks of expansion and improvement of the existing cataloguing in the archive, placing greater stress on the research, teaching and personnel blocks, where most of the work has been done. Further, in the Technical Office block, which's still being catalogued, numerous original plans have been incorporated.

Within the research activity of CEHOPU, its scientific staff is currently involved in R&D&I projects related to the historical study of public works heritage, within the framework of public works heritage, and in collaboration with leading agents in the sector:

·Research project *Analysis and Definition of Strategies for the Characterization, Recovery and Enhancement of Public Works Heritage. An Approach from Territorial Scale* (PID2019-105877RA-I00), led by the Technical College of Civil Engineers, within the State Program for R&D&I Oriented to the Challenges of Society, of the *State Plan for Scientific and Technological Research, and Innovation 2017-2020*.

·Research project *Water and Lights. Treatises Spanish Treatises on Hydraulic Architecture in the Enlightenment,* according to the Resolution of the Presidency of the State Research Agency for R&D&I Projects, within the framework of the *State Program for Generation of Knowledge, and Scientific and Technological Strengthening of the R&D&I System Oriented to the Challenges of Society.*

KNOWLEDGE TRANSFER

In the field of dissemination of engineering heritage in the civil society, one of the centre's most emblematic programs is that of the traveling exhibitions, which is fed by new ones.

Currently, CEHOPU is making an effort to reach all geographic areas of the country, with special dedication to the so-called 'unpopulated or low-density Spain', maintaining close cooperation with various local institutions. In this respect, we're collaborating with various institutions of La Rioja in order to to promote activities in places of great symbolism, such as Santo Domingo de la Calzada.

The general aim is that an itinerant exhibition should be running every year, with a duration of six months.

Also, this program contemplates in its nearest horizon the presence of CEHOPU exhibitions in regions, such as Castilla y León and Castilla-La Mancha, inland regions particularly vulnerable due to current demographic trends.

Broadly speaking, the activity of this program could be specified in the following initiatives:

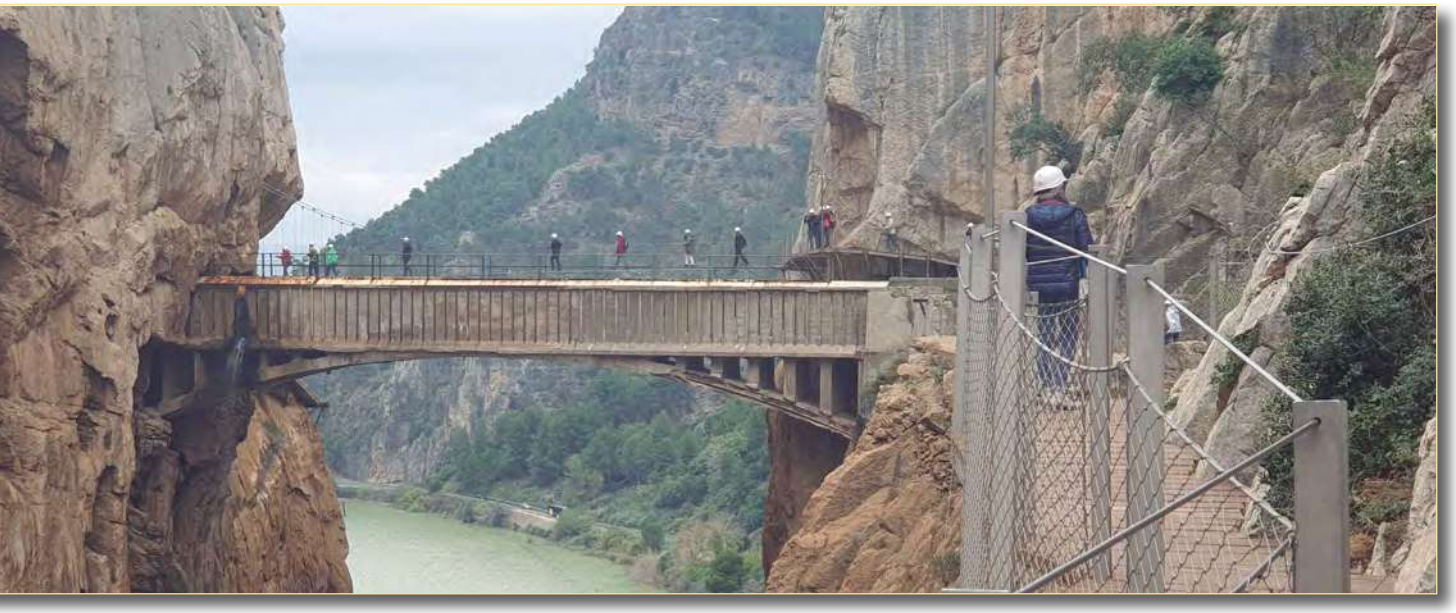
- Traveling exhibition *Artefacts and Machines: Engineering and Public Works During the Times of Philip II*, Casa de las Ciencias, Logroño, 22 April-29 August.
- Preparation of a plan for the inaugurations of the exhibition *Santo Domingo de la Calzada. The Engineer of the Road*, with the Demarcations of the Colleges of Civil Engineers and the Colleges of Technical Engineers of Public Works.

- Temporary loan for the presentation of the exhibition *Santo Domingo de la Calzada. The Engineer of the Road*, at the headquarters of the Demarcation of Castilla-La Mancha of the College of Civil Engineers, March 2022.
- Collaboration with the Demarcation of Castilla-La Mancha of the College of Civil Engineers, for the organization of the exhibition *Engineering in Castilla-La Mancha*.
- Collaboration with the Royal Academy of Letters and Arts, and the Council of Culture, Tourism and Sports, of the Regional Government of Extremadura, for the organization of the display *The Legacy of Rome: The Alcántara Bridge Before the Third Millennium*.
- Collaboration agreement for the organization, conservation and dissemination of the aforementioned and other works of common interest between the Juanelo Turriano Foundation and CEDEX. Within the framework of knowledge transfer concerning engineering heritage, another relevant activity in CEHOPU is the publication of monographs, as well as the participation in collective books or journals by the the centre's personnel.

In this respect, it took place the institutional presentation of the facsimile edition of the book *Main Reinforced Concrete Works by Eduardo Torroja (1926-1936),* published by CEHOPU, in collaboration with the with the Eduardo Torroja Foundation, in 2020. This event, chaired by the director of CEDEX, was hosted at the Agustín de Betancourt Room, of the Colllege of Civil Engineers of Madrid, 29 November 2021. The large turnout served as a posthumous and well-deserved tribute to José Antonio Torroja, who donated the last existing copy for this new edition.

MANAGEMENT OF HISTORICAL ARCHIVES AND DOCUMENTARY SOURCES

CEHOPU, in the exercise of its competencies and as part of its activities, is committed to conserving, studying and disseminating the documentary heritage of of public works. As a result, it



The King's Little Path (Málaga). In the background, the aqueduct bridge by José Eugenio Ribera.

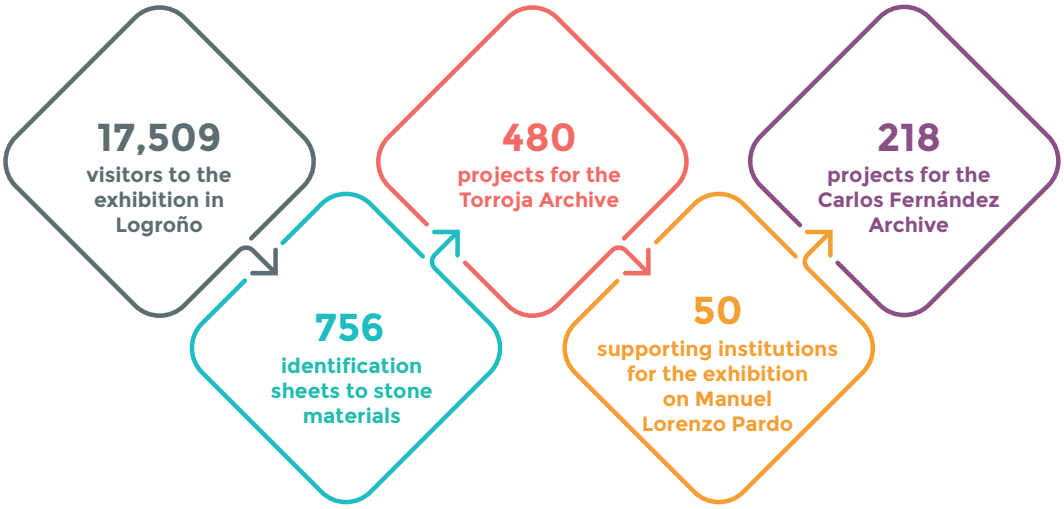
houses the archives of engineers Eduardo Torroja Miret and Carlos Fernández Casado.

The centre is responsible for the management, cataloguing and attention to the general public in relation to the websites of the Torroja and Carlos Fernández Casado archives, and the collections donated by the families of the both engineers. In both archives, a continuous digitization of documents has been carried out in order to increase the contents of the web with the electronic material obtained.

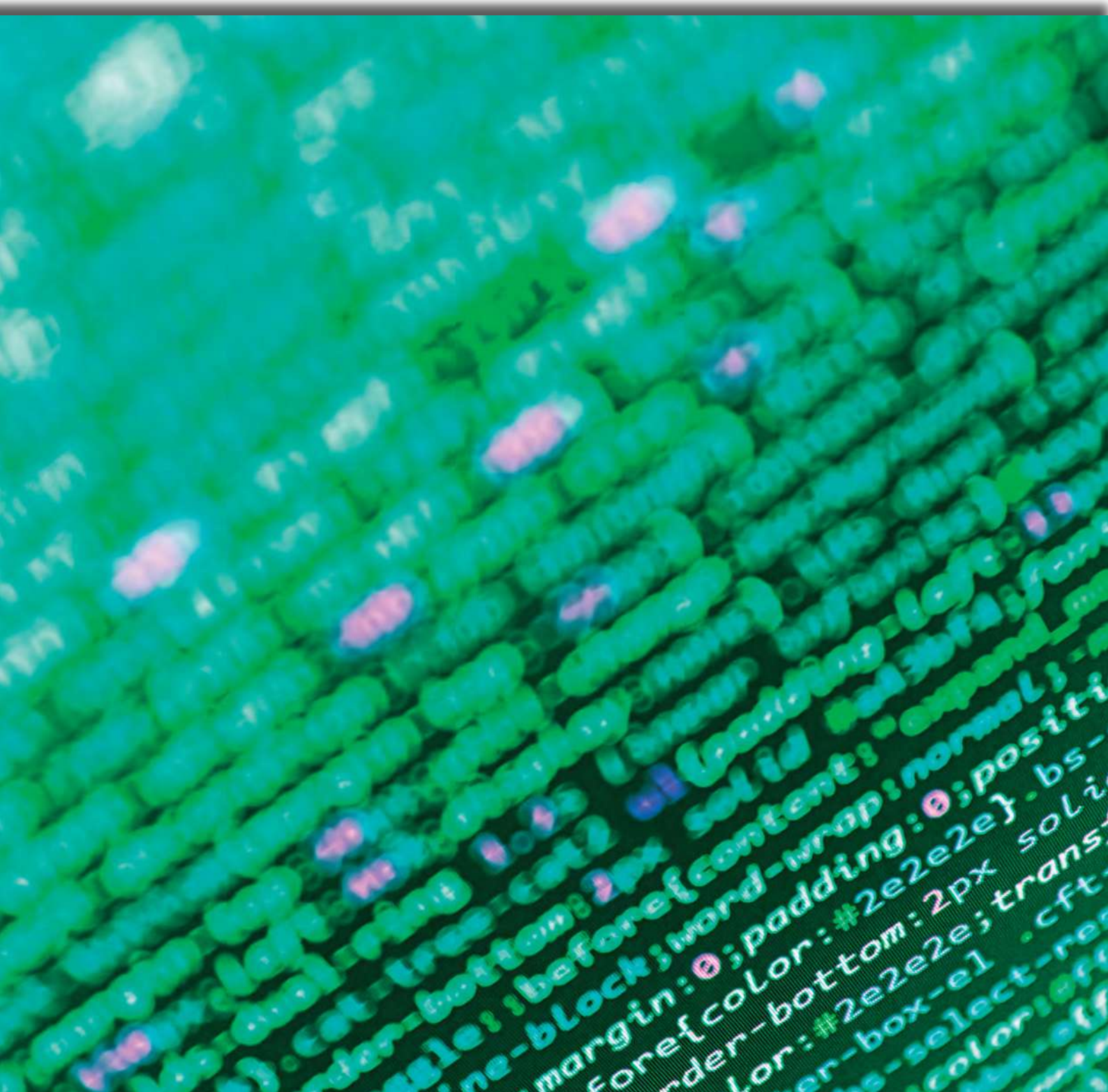
In this line of activity, there has been a significant number of requests for information through the web from scholars and institutions with the purpose of consultation and reproduction of items of these collections. A success, with no doubt, by making this collection of undeniable interest accesible online to researchers.

With regard to Carlos Fernández Casado archive, we're working with the family of the engineer to facilitate the handing over of other documentation related to him so as to augment the archive's holdings.

Last but not least, the management of the archive of Professor Francisco Hernández-Pacheco allows research on his work as head of the Geological Service of the Transport and Soil Mechanics Laboratory of the Transport and Soil Mechanics Laboratory of CEDEX -later called Laboratorio de Geotecnia- from 1958 to 1970.



KNOWLEDGE TRANSFER



"Now as ever, knowledge transfer is part of CEDEX's DNA"

The CEDEX Training and Documentation Unit is a structural element of CEDEX for training, dissemination, and transfer of technology generated in the organization. Its activity has always been a hallmark of CEDEX abroad and fundamental in the performance of public-private collaboration.

The functions it carries out routinely fit very well with various goals of the Sustainable Development Goals (SDGs), among which it's worth highlighting goal 4, Quality Education, specifically contributing to the increase of skills to access to employment (4.4) with the improvement of the training by students; by particularly influencing aspects related to the elimination of gender disparity and vulnerable groups (4.5); and by promoting global education for sustainable development (4.7). In relation to SDG 5, Gender Equality, it should be noted that its activity sets the objective of ensuring the full participation of women and equal opportunities (5.5) and improving the use of technology and ICTs (5.B). Finally, it's important to mention the contribution of this unit towards the achievement of the goals included in SDGs 9, 11, 12, 13, 14, and 15 through training and information dissemination activities.

← AI Tensorflow concept.
(Fuente: Shutterstock).

Similarly, it contributes in a basic way to the priorities set in CEDEX 2020-2022 Strategic Plan (PEC 2020-2022) through the transfer of knowledge in collaboration with other public and private agents, providing training and first-level technical-scientific information to companies in the economic activity sector related to the activities developed by MITMA and MITERD, as well as to the management centres of these departments, through national and international training programs and its extensive catalog of publications.

EDUCATIONAL COOPERATION PROGRAMS

Universities

The CEDEX has established educational cooperation agreements with 9 Spanish universities to bring university education closer to the social and professional reality of our environment, allowing students to complete their training process. Putting into practice the theoretical knowledge through internships that facilitate their subsequent incorporation into the workforce is considered an opportunity of great value in general by the university system. And in the case of CEDEX,

they may well gain access, through these agreements, to facilities and personnel with a high degree of specialization in the different disciplines of civil engineering and their environment-related issues.

As a result, throughout the first semester of 2021 a total of 11 students from various universities have carried out academic internships in different CEDEX centres and laboratories. The teaching load of each practice varies between 150 and 500 hours, and the training is completed with the undertaking of a final project directed by tutors assigned by CEDEX.

Learning internships of a student from the University of Alcalá during the sampling work of CEDEX in a reservoir for the activities of the Albufeira project.

Institutes

The CEDEX also has agreements with five secondary education institutes for the development of training programs in workplaces, aimed at students who're enrolled in professional training.

Under these agreements, from March to June 2021, a total of 11 internships were carried out with a duration of 370 hours each.

INTERNAL TRAINING

The 2021 Internal Training Plan has aimed to enhance the skills, knowledge and abilities of CEDEX professionals. To this end, new training actions have been developed to meet the needs detected in the agency's centres and laboratories. Thus, such a plan has been outlined as an important element to ensure the highest quality of CEDEX's operations, not only in bureaucratic aspects, but also, and especially, in the various specialized technical lines, in which a research and experimentation body like CEDEX has a clear driving for innovation. All this without neglecting the right of public employees to training and professional and personal improvement.

Based on these premises, a total of 51 courses have been carried out, partially subsidized by the INAP, with a course load of 1,072 hours and 395 students. The training activity has been distributed in a balanced way among all CEDEX centres, and the overall evaluation by attendees has been very positive.

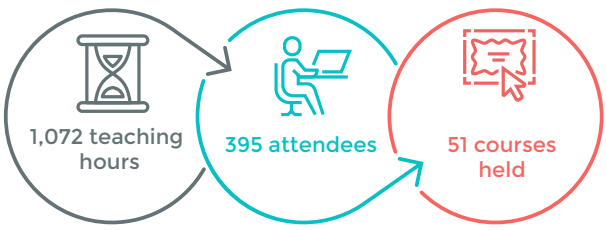
CEDEX INTERNAL TRAINING COURSES

INFORMATION AND COMMUNICATIONS TECHNOLOGIES	LANGUAGES	SPECIFIC AND ENVIRONMENTAL POSITIONS	OCCUPATIONAL HEALTH
N° OF COURSES = 6	N° OF COURSES = 11	N° OF COURSES = 26	N° OF COURSES = 8
N° OF ATTENDEES = 84	N° OF ATTENDEES = 81	N° OF ATTENDEES = 148	N° OF ATTENDEES = 82
TEACHING HOURS = 188	TEACHING HOURS = 440	TEACHING HOURS = 349	TEACHING HOURS = 95

For all courses, it's necessary to highlight the continuous adaptation, driven by the difficulty of face-to-face engagement, to new training technologies with the development of remote training activities, having used different platforms, from both CEDEX and the contracted firms, to run the courses.

An important aspect is the development of a learning platform using *Moodle,* which has facilitated the management of courses, and the use of the SIGP application (Integrated System for Personnel Management) of the Public Administration.

In addition to internal training, CEDEX personnel have benefited from training provided by MITMA, INAP and other agencies of the Public Administration.



COURSES

Among the external training activities of CEDEX, the running of courses, seminars and conferences aimed at specialized national and international public stands out.

With regard to long-term courses, CEDEX **Master's Degree in Soil Mechanics and Geotechnical Engineering** has been held, in its 39th edition, as a title of the National University of Distance Education (UNED), having an equivalence of 60 ECTS credits (European Credit Transfer and Accumulation System). This master's degree has been running without interruption since the 1980s. In 2021, 25 students participated: 5 from Spain, 2 from the Netherlands, and the rest from Latin American countries (Perú, Costa Rica, Chile, Honduras, México, Argentina, and Uruguay). 560 teaching hours have been completed, including the preparation of the Final Master's Thesis. The master's degree has been carried out remotely during its teaching portion and has ended with face-to-face training to carry out the internships.

As part of international training, the online **ERTMS Course** has been carried out, lasting 25 hours, for the staff of the company PROXION (Finland).

One of the most prestigious courses held by CEDEX in the field of civil engineering and the environment is the **Course on Wastewater Treatment and Operation of Treatment Plants**, which has been running since 1983, and whose 38th edition has been held face to face in November 2021. 55 students have participated in the course, and it has consisted of 80 hours, including two visits to treatment plants.

Lastly, for 25 workers from the Junta de Castilla y León, the **Pavement Auscultation Course** has been carried out, online, with a teaching load of 15 hours.

CONFERENCES

The different services offered by the CEDEX in 2021 have involve the organization of 24 events, including meetings, platforms, conferences, and exams, in which CEDEX facilities have been chosen as the venue for the celebration by different institutions, both public and private, and with a notable turnout of public.

Presentation covers for the brochures of the Master's Degree in Soil Mechanics (right), and the Water Treatment Course (left).

National Civil Engineering Award

The National Civil Engineering Award (PNIC) was established in 2001 and is given annually, as a reward and recognition, for a meritorious professional career developed mainly in Spain in the field of civil engineering. CEDEX promotes and manages the tasks associated with the granting of this prestigious award. In its 2021 edition, it went to the civil engineer Carmen de Andrés Conde.

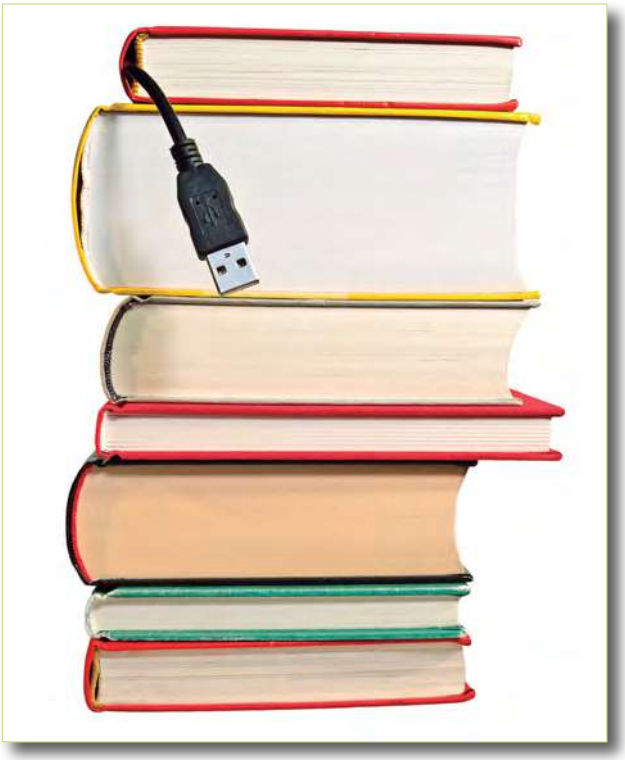
In the image, the civil engineer Carmen de Andrés, National Civil Engineering Award 2021.

DOCUMENTATION AND LIBRARY NETWORK

CEDEX provides bibliographic and documentary information service through its Network of Libraries, specialized in civil engineering and environmental matters. Throughout different centres, and coordinated from its Central Library, it operates as an information and knowledge management system, supplying national and international technical documentation with the aim of giving support to CEDEX technical staff in the tests and works undertaken in the different centres and laboratories.

CEDEX Library Network has made new acquisitions in 2021, both specialized monographs and technical standards of a diverse nature (UNE, ISO, ASTM, DIN, AFNOR, ACI, NEN, CEN-TS, etc.), which has allowed to satisfy all requests for books and other documentary resources, thereby enriching the bibliographic collections of the Library Network. CEDEX libraries keep on adapting to new technologies, which is why many of the new documents that have been acquired are in electronic format. Thus, most of the technical standards and magazine articles are acquired in PDF format, having begun to include digital books.

The collective catalog of the Library Network has increased by 806 records, reaching 132,448 titles and 166,908 volumes. The catalog includes the titles of monographs, magazines, maps, electronic resources, and technical reports prepared by



Stack of books with a USB cable (Source: Shutterstock).

CEDEX. Access to the catalog is public and is available for consultation on CEDEX website: http://vopac.cedex.es/opac

Libraries have access to the WOS (Web of Science) database, whose subscription has been renewed through the FECYT. This database, consisting of multidisciplinary bibliographic references, offers technicians and researchers the bibliography published in their respective areas of interest, the impact obtained from the articles they have published in international journals, and the citations of those articles. In turn, the libraries have been used as another tool to look for articles and find information of interest to CEDEX technicians.

With regard to customer service, in 2021 telematic attention has predominated, thanks to the potential to send documents by email or other computer file transfer services over the internet such as WeTransfer. Service has been provided, both face to face and online, to CEDEX staff and to external users, mostly university students.

Further, the libraries have been enriched with the works and publications that have been generated from the consultation and cataloging of the documents housed in the archives of Eduardo Torroja and Carlos Fernández-Casado, archives managed by the Centre for Historical Studies of Works Public and Urban Planning (CEHOPU) in coordination with the Central Library.

PUBLICATIONS

CEDEX, in its capacity as Editorial Unit of the Ministry of Transports, Mobility and Urban Agenda, and within the General Plan for Publications of the General State Administration (AGE), has continued to promote the transfer of knowledge through the technical publications of the agency and the *Civil Engineering* journal in the fields of public works, civil engineering, environment and mobility.

This editorial program is a means of communication and dissemination of the activities carried out in the organization, generating a benefit for citizens and social agents. All CEDEX's official publications can be found in the *Catalog of Publications*, accessible at https://catalogue.cedex.es/

In 2021, various publications were edited, both on paper and electronically, which are detailed below:

- *History of the Spirit and Culture of Water: Anthropology and Ethnography.* Volume III (2 v.)
- *Ports in Antiquity* (3 v.)
- *Coastal Engineering and Marine and Coastal Environment Course*
- *Paleofloods and Historical Floods and Their Application to the Hydrological Safety of Dams* (Monograph M-143)
- *Characterization of the Ecohydromorphological State and the Cultural Ecosystem Services of the Water Masses of the River Duero Section included between Toro and Zamora.* CEDEX contribution to the DRAINAGE project (Research Notebook C-55)
- *Methodological Guide for the Cost-Benefit Analysis of Structural Defense Actions Against Floods* (Manuals and Recommendations R-24)
- *2018-2019 Digital Gauging Yearbook*
- *XXXVIII Course on Wastewater Treatment and Operation of Treatment Plants*

- *Digital Catalog of CEDEX Publications for 2021*
- *CEDEX: Technical and Scientific Activities, 2020*

Finally, in 2021 two issues of the *Civil Engineering* journal (198 and 199) have been edited and published on paper and digitally, with free access through the official CEDEX website http://ingenieriacivil.cedex.es/index.php/civil-engineering/index

RELEVANT PROJECTS

FULL-SCALE TEST AND LABORATORY CHARACTERIZATION OF NEW BITUMINOUS MIXTURES

Contact: jorge.carnerero@cedex.es

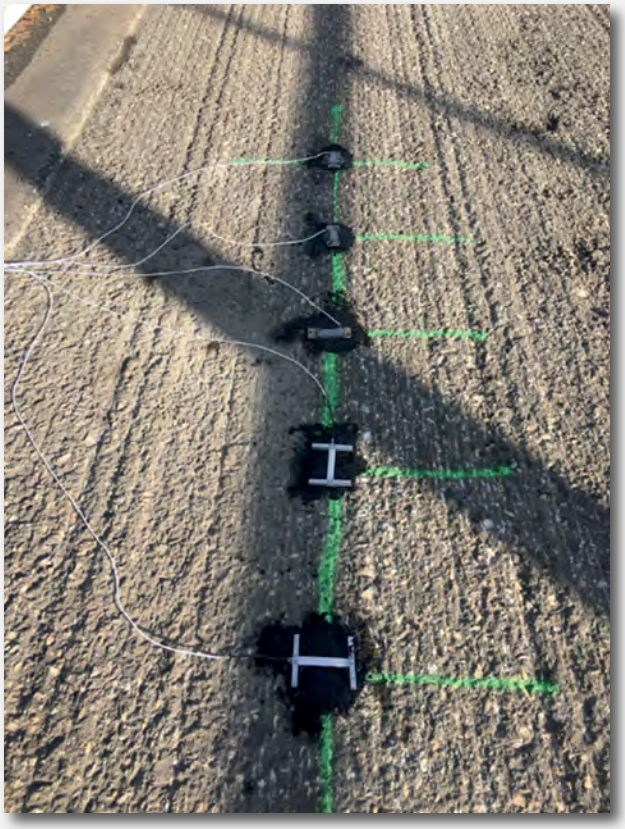
The test consists of the study and comparison of the evolution of the behaviour of two types of bituminous mixtures: one with aggregates obtained from construction and demolition waste; and other, a conventional bituminous mixture. This experimentation has been carried out by means of testing the Full-Scale Accelerated Pavement Test Track of the Centre for Transport Studies (CET) of CEDEX.

The trial, which at the end of the year was still underway, deals only with the characterization of the mixtures in the wearing course, which's about 6 cm thick. Each of the two sections has a built length of 25 m. The test mixtures have been placed on the east straight section of CET'S pavement test track.

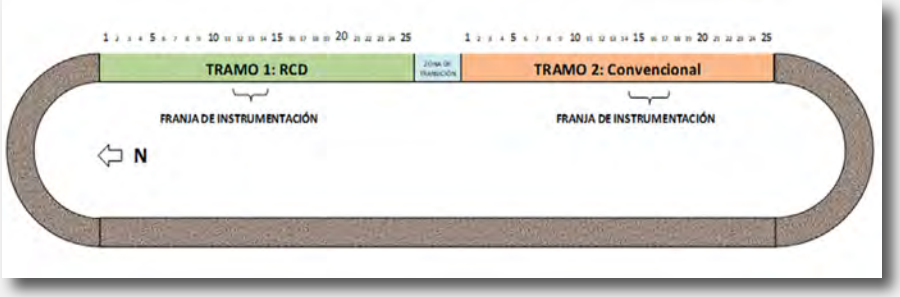
The study consists, on the one hand, of taking samples of the two mixtures, which was carried out during the paving on the test track of the CET, and the conducting of the pertinent tests in laboratory; and, on the other, in the execution of the full-scale dynamic test on the CET track, in which the passage of vehicles is simulated with the application of a total of 25,000 load cycles with two heavy vehices with a standardized semi-axle of 6.5 tons.

The necessary instrumentation equipment has been placed in both sections to comparatively characterize the structural behavior of the mixtures, by measuring strains, stresses, and temperatures in real time.

Likewise, the bearing capacity of the pavement is being evaluated by measuring deflections every 7,500 load cycles, approximately.



↑ Instrumentation equipment.



← Diagram in ground plan of the test sections.

ASSIGNMENT FROM THE DIRECTORATE-GENERAL FOR WATER TO CEDEX TO PROVIDE TECHNICAL ASSISTANCE, RESEARCH AND TECHNOLOGICAL DEVELOPMENT IN THE FIELD OF CONTINENTAL HYDRAULICS

Contact: luis.balairon@cedex.es

In 2021, the Hydraulics Laboratory has started the works included in an order that the Directorate-General for Water entrusted to CEDEX in December 2020. The focus of this commission is to carry out technical assistance, research and technological development in the field of continental hydraulics for over 3 years.

The objective of this assignment is to carry out a series of hydraulic studies through physical and numerical modelling (a total of 11 studies) of the spillway devices of various dams across different River Basin Authorities (RBA) in which problems have been identified for the fulfillment of their functions with the safety that these infrastructures require.

During 2021, work has begun on the Yesa (Ebro RBA), Terroba (Ebro RBA), Pálmaces (Tajo RBA), Rumblar (Guadalquivir RBA) and Amadorio (Júcar RBA) dams. In addition to these 5 dams, the commission foresees work during 2002 and 2023 on the dams of Jándula (Guadalquivir RBA), Tranco de Beas (Guadalquivir RBA), Aguilar de Campoo (Duero RBA), El Regajo (Júcar RBA), La Fuensanta (Segura RBA), and Vega del Jabalón (Guadiana RBA).

The studies carried out in 2021 have been undertaken using physical and numerical models (2D and 3D) all of them are aimed at improving and/or enlarging the surface spillways of the respective dams (except the Terroba dam, where the aim is to improve its bottom outlet).

Regarding the physical models, the hydrodynamic behaviour of the flow in the hydraulic structures

↑ Physical modelling of the new spillway of the Yesa dam (Ebro RBA).

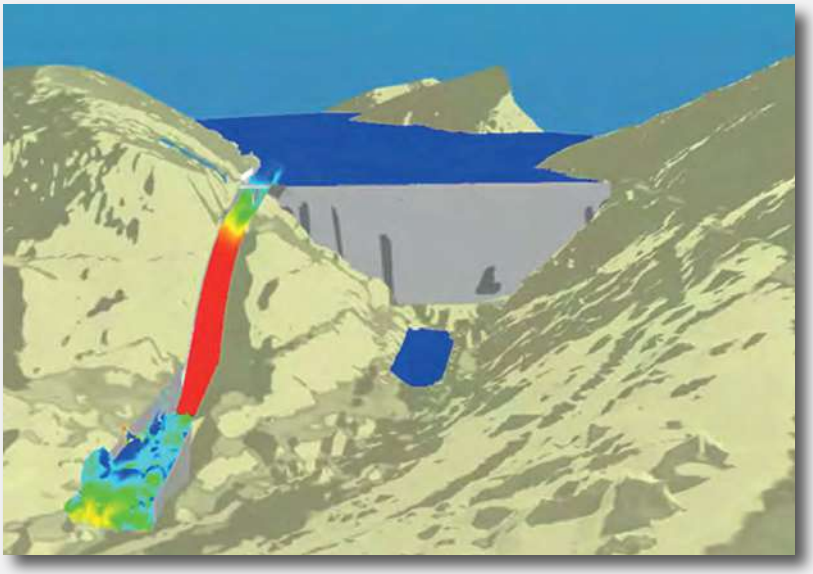
under study is analysed, recording the main hydraulic variables for their characterization. In particular, in several of the studies dynamic pressure measurements are being carried out with highly sensitive piezoresistive dynamic pressure transducers, for whose digital acquisition a Scanivalve is used, which represents an innovation in the process of electronic scanning of pressures at multiple points.

Of all these works, the new Yesa dam´s spillway can be highlighted due to its special relevance, which's currently being enlarged by means of a new breakwater dam where a concrete screen supported on the face downstream of the current dam. This ongoing action is currently one of the most important in terms of dams across Spain and, for the correct definition of the raised spillway, the conclusions of the study carried out at CEDEX are decisive.

To monitor the assignment from the DGA to CEDEX, a monitoring commission was set up (chaired by the General Director for Water and of which the director of CEDEX is also a member) that met twice during 2021 (in June and December).

This assignment is complemented by two other orders also formalized in 2021 to carry out two hydraulic studies, one of the spillways of the Arenós dam (Júcar RBA) and another of the general interceptor of the North Zone of Murcia (Segura RBA), which have also started during this year.

- In 2021, the Hydraulic Laboratory began the work included in a commission that the DGA entrusted to CEDEX in December 2020 to carry out various hydraulic studies on dams with a term of 3 years
- This year, work began on the Yesa (Ebro RBA), Terroba (Ebro RBA), Pálmaces (Tajo RBA), Rumblar (Guadalquivir RBA) and Amadorio (Júcar RBA) dams



↑ 3D modelling of the Rumblar dam spillway (Guadalquivir RBA).

IMPACT OF CLIMATE CHANGE ON MAXIMUM PRECIPITATION IN SPAIN

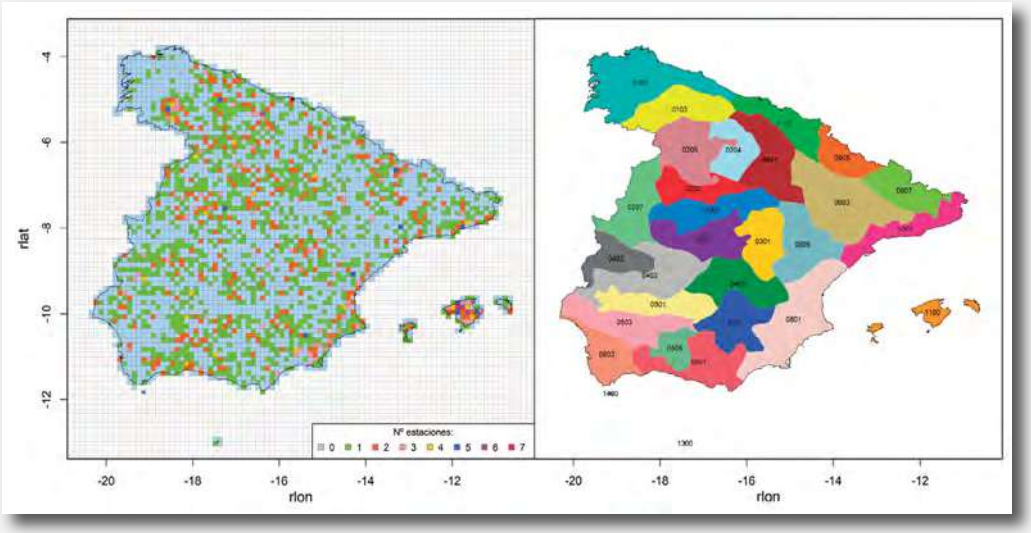
Contact: celia.garcia@cedex.es

The Centre for Hydrographic Studies has concluded the evaluation of the impact of climate change on maximum precipitation in Spain, whose results facilitate the incorporation of the possible repercussions of climate change on the incidence of floods in the revision of the Flood Risk Management Plans (2021).

The CEH has been working for years on the evaluation of the impact of climate change on different aspects of inland waters such as the hydrological cycle, exploitation systems, demands or the ecological status of water bodies. In this context, and included in the "Program that defines the lines of work to be developed by CEDEX for the Directorate-General for Water in relation to research and development in hydraulic resources and infrastructure" (2018), this work has been completed in 2021.

The work consists of the evaluation of the impact of climate change on maximum precipitation in Spain, considering different time intervals, and can be considered as the update and extension of work previously carried out or supervised by CEDEX, such as the "Assessment of the Impact of climate change in water resources in natural regime" (2010), and the "Incorporation of climate change in the preliminary assessment of flood risk (EPRI) in the second cycle of implementation of the flood directive (2007/60/CE)" (2018).

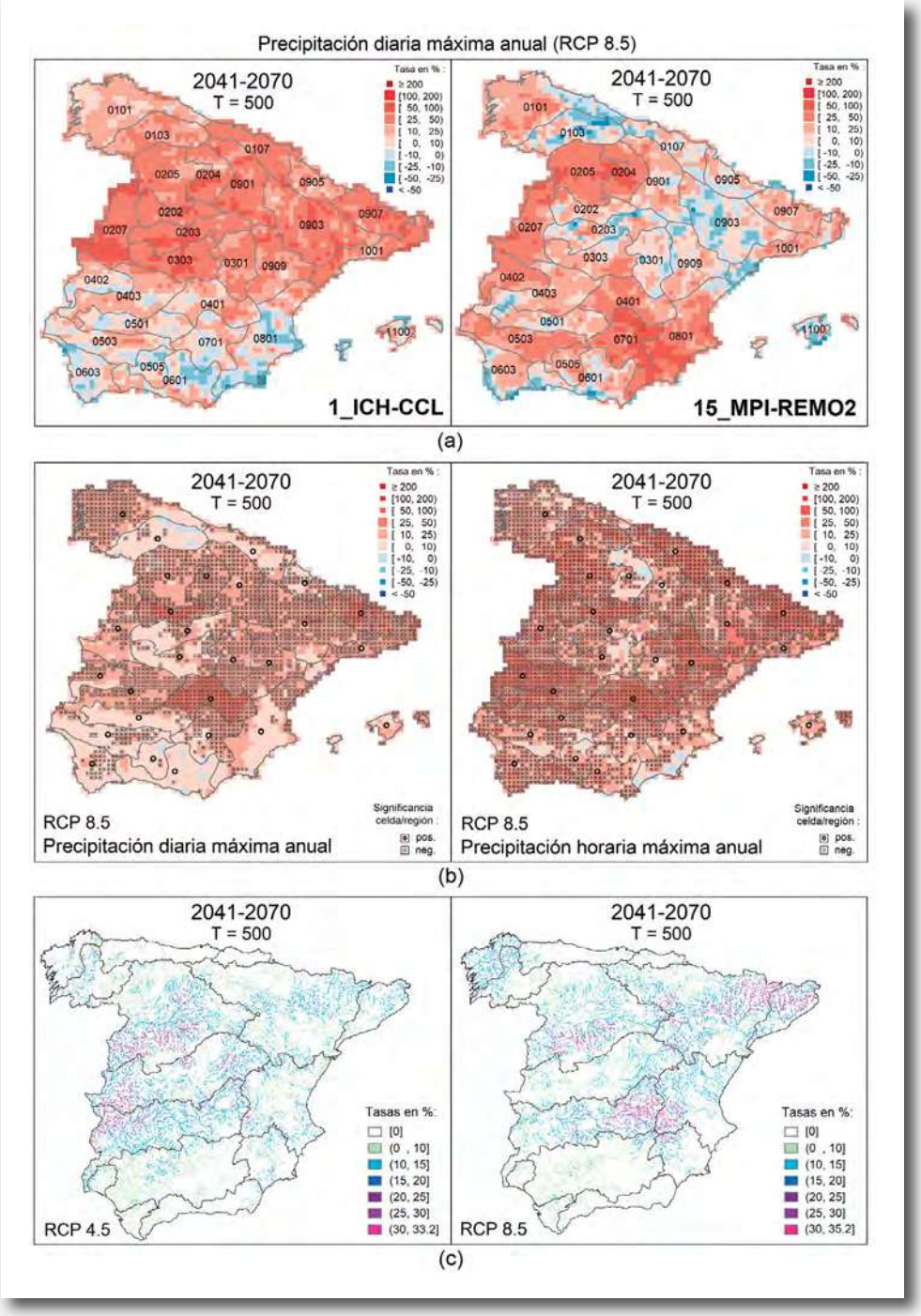
For its elaboration, simulations of 15 EURO-CORDEX regional climate models were used for two emission scenarios (RCP 4.5 and 8.5), as well as the daily precipitation recorded from 2079 AEMET stations. The study undertakes improvements with respect to previous studies, such as the analysis of the behaviour of six variables of maximum annual precipitation associated with different time intervals (daily, daily convective, hourly and accumulated precipitation in 3, 6 and 12 hours maximum to annual), both at a cell and at regional level, as well as a greater number of climate models, impact periods (2011-2040, 2041-2070, and 2071-2100), statistical models (regional adjustment of



↑ Cells and regions in the study area.

the SQRT-ET$_{max}$ distribution , and local adjustment of the GEV distribution), return periods (10, 100 and 500 years) and representative values of the rates of change resulting from the set of climate models (mean and percentiles 10 and 90).

The work has consisted of the following stages: (i) analysis of the behaviour of the annual maximum precipitation series from climate models with respect to observed series, (ii) analysis of trends, and changes in the median, variance and seasonality of annual maximum precipitation series from climate models during impact periods, (iii) estimation of average quantile change rates (and associated with percentiles to assess their uncertainty) of the series of maximum annual precipitation from



↑ (a) Variability in quantile rates of change from climate models, (b) mean quantile rates of change, and (c), preliminary identification of river reaches affected by climate change.

climate models, evaluation of the statistical significance, as well as an estimation of changes in the torrentiality factor, and (iv), analysis of changes in the quantile of annual maximum daily precipitation accumulated in the river network.

A high variability of results from climate models and the various sources of uncertainty has been identified; caution is therefore recommended in its application. It's important to evaluate the significance of quantile rates of change to identify changes due to climate change. Significant trends and changes have been observed that intensify with shorter precipitation duration, being more marked for RCP 8.5 and the last impact period, as well as significant rates of change of greater extent and magnitude for hourly precipitation than daily, indicating greater torrentiality. Rates of change in maximum accumulated precipitation in the river network of up to 35 % have been obtained.

Use of exchange rate maps is recommended (https://ceh.cedex.es/web_ceh_2018/Imp_CClimatico_Pmax.htm) associated with the adjustment model of the current maximum precipitation study that is currently under review.

- Results used in the incorporation of the effect of climate change in the revision of the Flood Risk Management Plans
- There's high variability of results between climate models: caution in their application
- An increase in torrentiality has been observed, and rates of change in maximum accumulated precipitation in the river network of up to 35 %

ALBUFEIRA PROJECT: JOINT ASSESSMENT PROGRAM OF THE WATER BODIES OF THE SPANISH-PORTUGUESE HYDROGRAPHIC BASINS

Contact: manuel.toro@cedex.es

The Albufeira project aims to improve the coordination of actions to promote and protect the good status of shared water bodies, for their protection and sustainable use.

It regards the harmonization of methodologies for evaluating the state or ecological potential, and the definition of the necessary measures to achieve the environmental objectives.

It proposes the improvement of the management of the protected areas linked to these water bodies, by means of methodologies that integrate the requirements of the WFD and the Natura 2000 Network, improving the coordinated protection of the species and habitats of great value that they house.

The Albufeira project is co-financed by the European Regional Development Fund (ERDF) through the Interreg VA Spain-Portugal Program (POCTEP) 2014-2020. CEDEX is one of the main partners of the Albufeira project together with the Ministry for Ecological Transition and the Demographic Challenge, Agência Portuguesa do Ambiente (APA), the Higher Institute of Agronomy of the University of Lisbon (ISA) and the Polytechnic Institute of Leiria.

The Centre for Hydrographic Studies has participated in the work scheduled for the Albufeira project, carrying out joint sampling campaigns in border and cross-border water bodies in 2019, 2020 and 2021: 7 in reservoirs (Alqueva, Chanza, Cedillo, Saucelle and Salas), 5 in estuaries (Miño and Guadiana) and 47 in rivers (Miño, Duero, Tajo and Guadiana basins). With the data obtained in the field and in the laboratory analysis for chemical and biological indicators (phytoplankton, phytobenthos, macrophytes, macroinvertebrates and fish fauna), both countries have simultaneously evaluated the ecological status of these waterbodies applying their protocols. To detect possible discrepancies, intercalibration exercises have been carried out on the field sampling methodologies and on the application of the indices and metrics for status assessment.

↑ Joint sampling campaign in the border reservoir of Chanza (Huelva).

One of the main objectives of the project is to propose and validate a joint methodology for monitoring the ecological status or ecological potential of shared water bodies. In addition, a cross-border inventory of habitat types and flora and fauna species linked to the aquatic environment present in the Natura 2000 Network areas will be carried out, with the specific requirements for each species.

The Albufeira project was born at the 3rd Conference of the Parties to the Agreement on Cooperation for the Protection and Sustainable Use of Water in Spanish-Portuguese Hydrographic Basins (Albufeira Agreement), to take on the challenges of managing shared water bodies, and to meet any regulatory requirements set out by the European Commission in monitoring the Water Framework Directive (WFD).
https://poctepalbufeira.org/

↑ Physical-chemical data collection in the Salareja River (Guadiana basin).

ADVANCES IN 2D NUMERICAL MODELLING OF FLOW IN CHANNELS AND RIVERS: IBER 3.0

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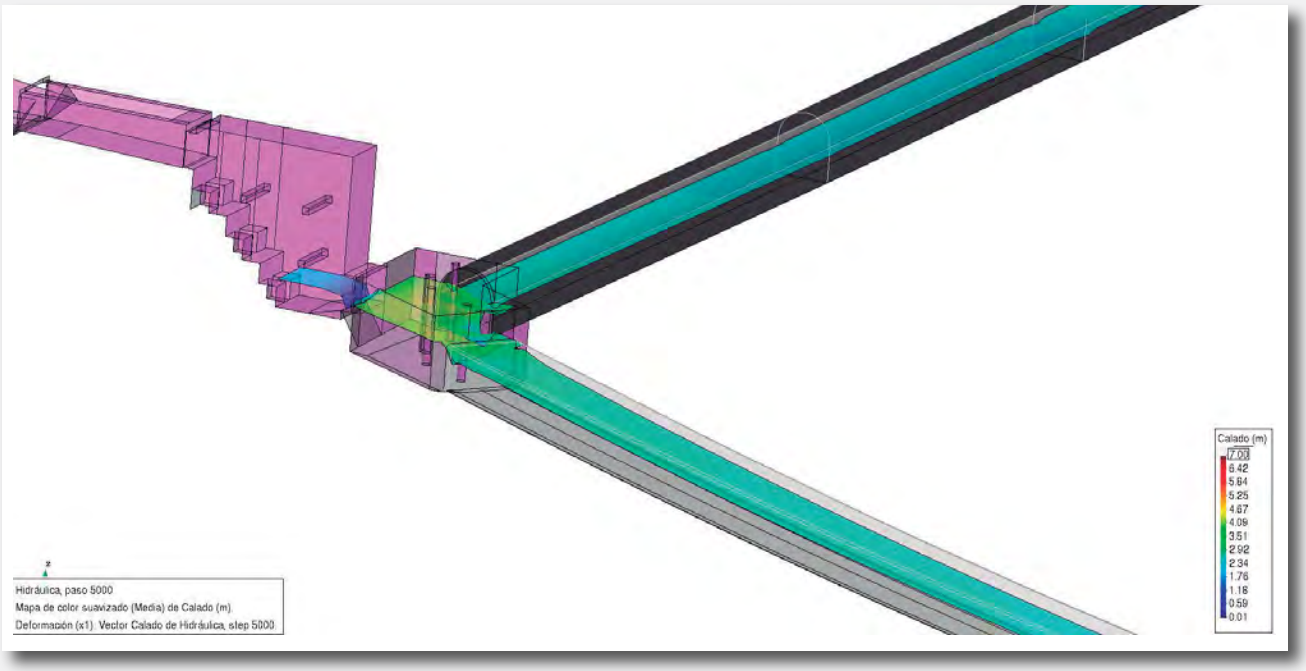
Iber is a two-dimensional numerical model for simulating turbulent flow in a free layer in a variable regime for the hydromorphological study of riverbeds that was developed in 2010 within the framework of an agreement signed between CEDEX and the Directorate-General for Water (and in collaboration with the Water Engineering Group of the Universidade da Coruña, and the Flumen Group of the Universitat Politècnica de Catalunya).

Version 1.0 of Iber (2010) consisted of 3 main calculation modules: a hydrodynamic module, a turbulence module, and a sediment transport module. Later (in 2016), and within the framework of another management assignment between CEDEX and the DGA, a series of improvements were made to Iber that resulted in the version 2.0 of the model (which involved improvements to the interface, introducing important advances in the hydrodynamic module, and in which new hydraulic habitat modules and of water quality were generated).

The collaboration between the DGA, CEDEX and previous university groups has remained constant throughout this time and has been consolidated by introducing further improvements to the Iber model that have given rise to version 3.0, which was completed in 2021 and presented at a conference held at the Centre for Hydrographic Studies in November 2021. Among the advances included in this version 3.0 of the Iber model, the incorporation and improvement of the following thematic modules can be highlighted:

- Dual drain Integration of flow simulation in underground drainage networks with surface flow.
- Progress in the hydrological simulation module considering both surface flow and soil erosion.

↑ Modelling with Iber of the mouth of the Guadalhorce River in Málaga.



↑ Modelling with Iber of the North Interceptor in Murcia.

- Improvement of the bedload sediment transport module including the capacity to work with non-uniform granulometries (sediment mixtures).

In addition, supercomputing techniques on GPUs have been incorporated that allow addressing broader fields of study and reducing calculation times. Finally, an effort has been made to simplify the working environment with the development of a new Iber 3.0 interface.

On the other hand, Iber is a free downloadable model that has made it much easier to carry out two-dimensional river studies necessary for the work carried out in this field by the Directorate-General for Water, in particular those related to Flood Risk Management Plans.

The promotion, coordination and development of the Iber model is part of a very relevant strategic line in the Centre for Hydrographic Studies of CEDEX in terms of technological innovation in the field of numerical modelling in hydraulics, which to date has been very productive.

It has also meant a very an important strengthening of CEDEX's capabilities, which has allowed a relevant technological leap in the scope of the studies carried out. Thanks to this tool (in addition to other 3D mathematical models developed entirely at CEDEX), the Hydraulics Laboratory now carries out its hydraulic studies with hybrid modelling techniques, greatly improving the capacity and scope of the work.

Iber is also part of CEDEX's knowledge transfer activity in the areas in which we work. In fact, the model has many users in different countries, particularly in Latin America.

- Iber is a 2D numerical model for simulating turbulent flow in a free layer in a variable regime for the hydromorphological study of riverbeds that was developed in 2010 on behalf of the DGA (and in collaboration with the Universidade da Coruña, and the Universitat Politècnica de Catalunya)
- In addition to version 1.0 of 2010, the version 2.0 of the model was presented in 2016, and in 2021 the version 3.0 has been completed, again commissioned by the DGA

THE JOINT COMPANY ERJU (EUROPE'S RAIL JOINT UNDERTAKING): RAILWAY R&D FOR THE NEXT DECADE

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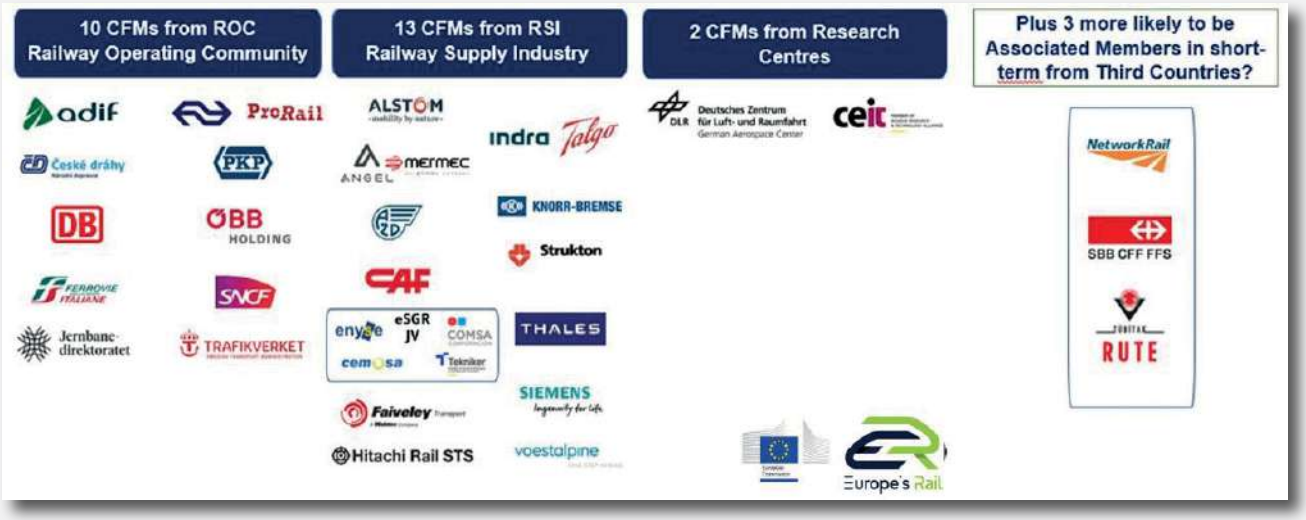
CEDEX, with ADIF, Renfe Operadora and Ineco, has become a founding member of the Europe's Rail Joint Undertaking (ERJU) venture, which brings together the European Commission and all its 25 founding members. ERJU will be the channel for participation in European railway R&D in the 2022-2031 decade.

2021 has been the launch of the common European railway R&D undertaking called Europe's Rail Joint Undertaking (ERJU), which has been configured as a continuation of the previous initiative that covered the five-year period 2017-2022, called Shift2Rail (S2R). This new joint venture will launch R&D projects over the next 7 years and thus cover railway R&D over the decade 2022-2031. The big difference is that while in S2R the Spanish public railway sector wasn't admitted as a founding member of the joint venture, in this new initiative the MITMA railway group has been able to participate as a founding member of ERJU.

MITMA's candidacy is headed by Adif, and is made up of Renfe Operadora, Cedex and Ineco as affiliated entities. During 2021, negotiations were held both between the members of this candidacy, and with the European Commission, to obtain its admission as a ERJU founding member. Its final admission in July 2021 can be considered a great success for the Spanish public railway sector, for its membership of ERJU ensures a front-line position in railway R&D for the next 10 years.

Figure 1 shows the 25 ERJU founding members: 10 European railways, which in most cases include the Infrastructure Manager and the Public Operator, 13 European railway material companies, both rolling stock and track and signalling, and, finally, two European railway research centres. ERJU is, therefore, configured as a common company in which 50 % of the budget is provided by the founding members and the remaining 50 % by the European Commission.

ERJU's initial budget was around €1,200 million, which, divided among the 20 initially estimated



↑ **Figure 1.** List of founding members of the ERJU (Europe's Rail Joint Undertaking).

founding members, yielded a project participation figure for each founding member of around €60 million. As the final number of founding members has been higher, the budget of each founding member is slightly less. In the case of the MITMA candidacy, the final budget is shown in figure 2, with a total of just over €53 million in R&D projects, of which €6.6 million must be developed by CEDEX. Of this amount, about 50 % will be financed by the European Commission.

This budget for CEDEX means that throughout one decade a very notable effort must be made to participate in R&D projects. Although the LIF will be the CEDEX laboratory that participates the most in ERJU, the Geotechnical Laboratory (LG) and the Central Laboratory for Structures and Materials (LCEYM) will also take part.

ERJU has already published on its website both the Framework Program (Master Plan) and the Multi-annual Working Plan, in which the objectives of this joint R&D undertaking are listed in detail.

	TOTALS	R&D COSTS	COSTS ADM.	%
ADIF	27.038.500,00	26.428.000,00	610.500,00	49,65%
ADIF-AV	2.455.500,00	2.400.000,00	55.500,00	4,51%
RENFE	13.614.500,00	13.307.000,00	307.500,00	25,00%
CEDEX	6.807.000,00	6.653.000,00	154.000,00	12,50%
INECO	4.544.500,00	4.442.000,00	102.500,00	8,34%
TOTALS	54.460.000,00	53.230.000,00	1.230.000,00	100,00%

↑ **Figure 2.** Budget breakdown of the MITMA consortium at the ERJU.

CERTIFICATION TEST OF A NEW EVC SOFTWARE (ERTMS ON-BOARD EQUIPMENT) FROM HITACHI, USING THE NEW TEST AUTOMATION SYSTEM OF THE EUROCAB LABORATORY

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The Hitachi company's ETCS on-board equipment, with its different software versions, has been technically validated at the CEDEX Railway Interoperability Laboratory (LIF), through several test campaigns that culminated in the final campaign carried out in 2021. This on-board equipment is the one that equips the French high-speed TGV trains, and the performance of these certification tests at the LIF constitutes a milestone of great relevance.

The test specifications, or tests to which an ETCS on-board equipment must be subjected, are defined in Subset-076 of Annex A of the Technical Specifications for Interoperability (TSI).

Subset-076 defines the test cases where all the requirements of the specifications linked to the on-board equipment or EVC (European Vital Computer) are verified. It also defines the test sequences that refer to the chaining of a set of different test cases so as to simulate them correctly in the test benches. The number of sequences defined in Subset-076 to complete the validation of on-board equipment is made up of more than 700 different sequences, and with the simulation of each sequence, the reaction of the EVC to different actions is checked in accordance with the system specifications ERTMS.

The LIF has carried out 4 Subset-076 certification campaigns on this Hitachi ETCS on-board equipment since April 2017.

Eurocab test automation system developed and implemented in the laboratory throughout 2020 has been used to undertake the fourth campaign.

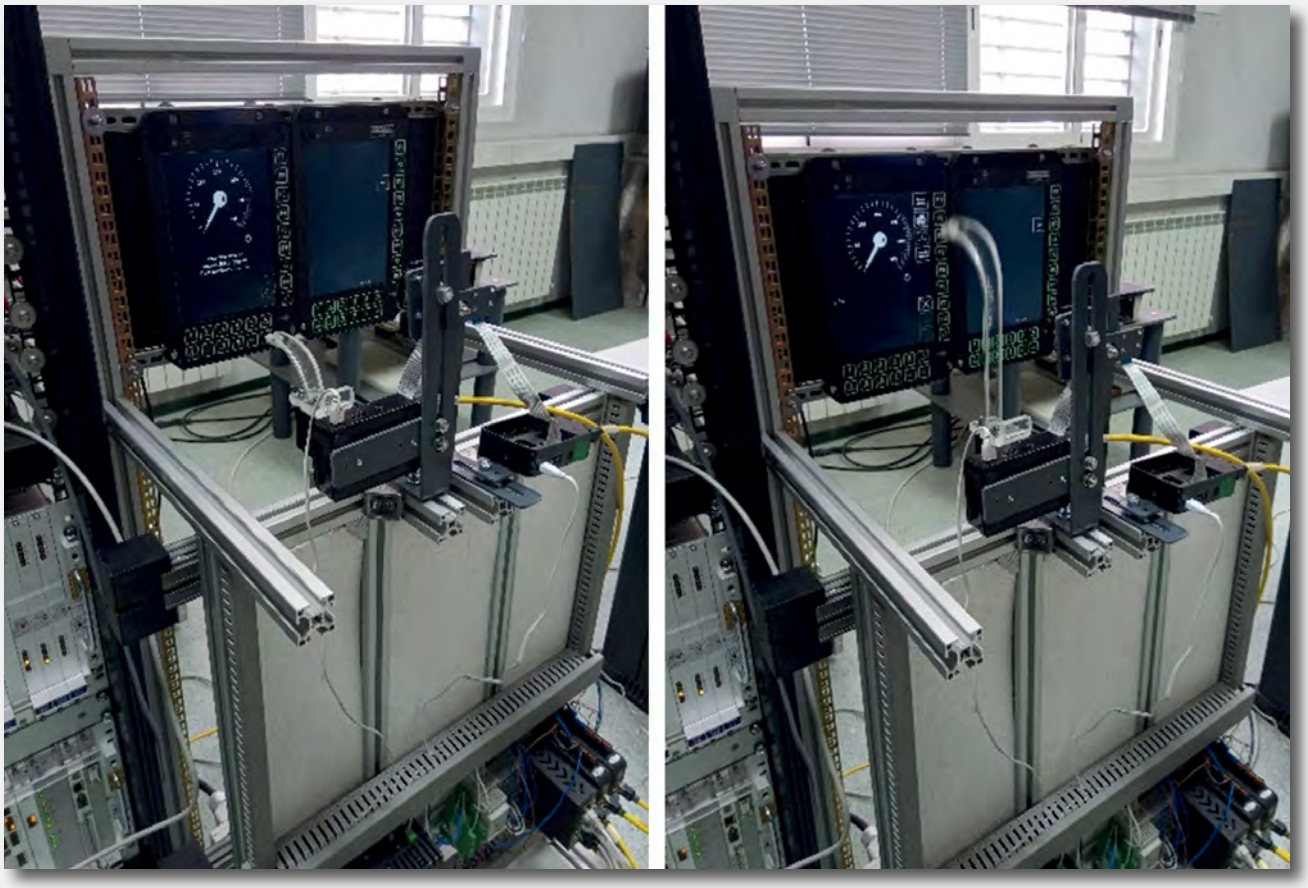
This system allows tests to be conducted at the laboratory automatically during execution. It consists, roughly, of an automatic control and verification of the process, a push-button robot as a driver to execute the sequences, as well as carrying out a first analysis, called pre-analysis, of the data obtained after having completed the Subset-076 tests on a specific on-board equipment.

For this, test sequences were prepared by introducing the actions that must be executed by the push-button robot that performs the tasks of the on-board equipment machinist, as shown in figures 1 and 2.

With this system, it was possible to achieve an automation of the sequences of 80 % of Subset-076, which allowed to increase the pace of execution with respect to previous campaigns, because, to date, the execution of previous campaigns was completely manual. By automating the sequences, more than 100 sequences per day can be executed, while manually it's reduced to an average of 20 sequences per day.

In addition to the use of a push-button robot for the execution, the image recognition software developed within the automation system has been used, with the aim of turning the video of the recording of the execution of the sequence into a text document with the events that have occurred, thereby allowing to automate the analysis of the events.

This project, in addition to improving the validation process, has made it possible to evaluate the Eurocab test automation system, developed in 2020,



↑ **Figures 1-2.** Different moments when the robot is pressed throughout the test.

detecting possible improvements for the following versions. In this way, the laboratory is constantly evolving, with an increasing level of automation and making it increasingly efficient.

PARTICIPATION IN THE ERTMS TEST SPECIFICATIONS DEVELOPMENT WORK GROUP – SUBSET-076

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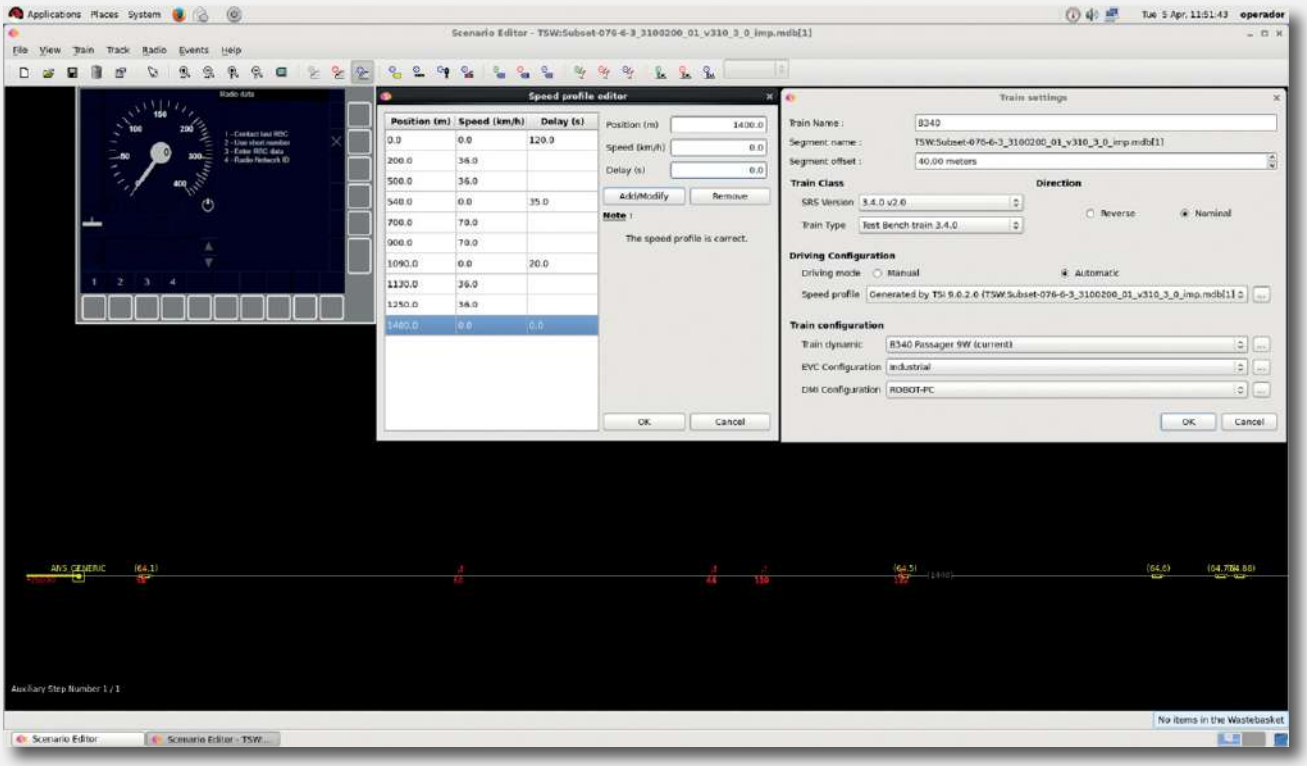
Throughout 2021, CEDEX's Railway Interoperability Laboratory (LIF) participated in the European working group in charge of drafting the standard that defines the Test specification of ERTMS on-board equipment (Subset-076).

With the aim of establishing a European standardization of the railway Control, Command and Signalling system, the ERTMS/ETCS (European Traffic Management System/European Train Control System) emerged in the first years of this century, which, currently and soon will gradually replacing the multitude of national systems still in service in Europe.

The most important document in the set of documentation that makes up the ERTMS is commonly known as Subset-026 or SRS, which specifies the requirements of this system from a technical point of view, both for the on-board subsystem and for the track subsystem.

Of these two subsystems, the one that implements most of the ERTMS functionality is the on-board system, for this equipment must comply with all requirements of the specification, with the only exceptions and conditions explicitly detailed in the ETI CMS specification and in the own SRS. An on-board team must be able to circulate on any ERTMS line regardless of its level (1, 2 or 3), or the specific engineering and functionality rules of such a line.

ERTMS Test specifications (Subset-076), in which the LIF team has participated since its first draft in 2006, leading the working group for more than a



↑ Execution of a test sequence of the SS-076 in the LIF.

decade, are based on the strategy of grouping the requirements by functionalities.

Subset-076 is made up of the following mandatory documents for the certification of an ERTMS on-board equipment: Subset-076-5-2, Subset-076-6-3, and Subset-076-7. The magnitude of work involved in drafting these regulatory documents is reflected in the latest version of SS-076, published in 2019, in which the number of test cases included is 1,801, grouped into 194 functionalities and subsequently concatenated into 775 sequences. of tests that must be executed later in the laboratory. The time required for a complete test campaign of the SS-076, in an accredited laboratory such as the LIF, is 4 months, having a robot that automatically executes the sequences.

All these documents are published on the website of the European Union Railway Agency: https://www.era.europa.eu/content/set-specifications-3-etcs-b3-r2-gsm-r-b.

LIF, together with five other accredited European laboratories, has participated in the development and maintenance of Subset-076.

During 2021, work has been done to evolve from version 3.6.0 to version 3.7.0. This process fixes bugs from previous versions and implements industry-approved change requests. In 2022 and 2023, the rest of the work planned for the preparation and updating of the different documents included in SS-076 will continue.

CEDEX CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS	Centro de Estudios y Experimentación de Obras Públicas
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. Institute of Transportation Systems
ITALCERTIFER GRUPPO FERROVIE DELLO STATO ITALIANE	ITALCERTIFER
Multitel INNOVATION CENTRE	Multitel ASBL
#LEF	SNCF Voyageurs - Direction du Matériel Centre d'ingénierie du Materiel (CIM) - Laboratoire ERTMS France
RINA	RINA SERVICES S.P.A.

↑ European accredited laboratories in charge of drafting the ERTMS test specification (SS-076).

TEST CASES FOR NEW ITALIAN OPERATORS

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During the last quarter of 2021, CEDEX's Railway Interoperability Laboratory (LIF) has completed the formalization of the necessary tests for the commissioning of trains equipped with ERTMS level 1 and 2, for the new Italian railway operators.

The liberalization of the railway sector has meant the access of new operators to the high-speed railway network. For this access, it's necessary for the new companies to carry out a series of rail-train interoperability tests that guarantee the uninterrupted circulation of trains through any section of the railway network equipped with ERTMS level 1 and level 2.

One of the new operators that obtained the authorization to operate on the Spanish lines is ILSA, owned by Air Nostrum and Trenitalia (the Italian public railway operator), which will operate with Zefiro V300 high-speed trains manufactured by the Swedish Canadian company Bombardier, whose railway division was acquired by Alstom.

This train is equipped with the ERTMS system of the Hitachi-Italy company, equipment different from that of Hitachi-France, also tested at LIF for its certification. This new railway operator contacted the LIF to request support for the compatibility tests of its on-board equipment with the Spanish lines, tests called ESC (ETCS System Compatibility) in the latest TSI (Interoperability Technical Specification) of 2019.

During the last quarter of 2021, LIF has developed a database that contains all the information related to the interoperability tests that must be carried out during an on-track test campaign. These interoperability tests are divided into test cases, where a functionality to be tested is defined in initial conditions and with final conditions, as well as the mode and level in which it must be executed. From this database, all this information can be accessed, allowing it to be filtered as appropriate and thus to develop test protocols with scenarios according to the line to be tested and the functionality of the tested equipment to be tested. This guarantees the complete execution of the tests and their correct location on the track.

From this database, and by executing the different scripts developed, it's also possible to obtain a table format that allows to control of the result of each test and to generate the deliverable for the company.

Once all the test cases have been developed, completing the list defined by Adif in the Spanish ESC document, the LIF has undertaken the work of concatenating said test cases on the Madrid-Lleida line in test scenarios which, by decision of ADIF, had to be carried out on the track. In December 2021, the LIF staff participated in the execution of such tests for the Zefiro V300 train along the aforementioned AV line.

Finally, LIF, given its knowledge of Spanish high-speed lines, is designing these test scenarios for the rest of the lines on which this new rail operator will initially operate Lleida-Barcelona to complete the Madrid-Barcelona axis, Córdoba -Malaga, Madrid-Valencia-Albacete, and Albacete-Alicante.

↑ Zefiro train in track tests.

HISTORICAL AIS DATABASE: DEVELOPMENT AND APPLICATIONS

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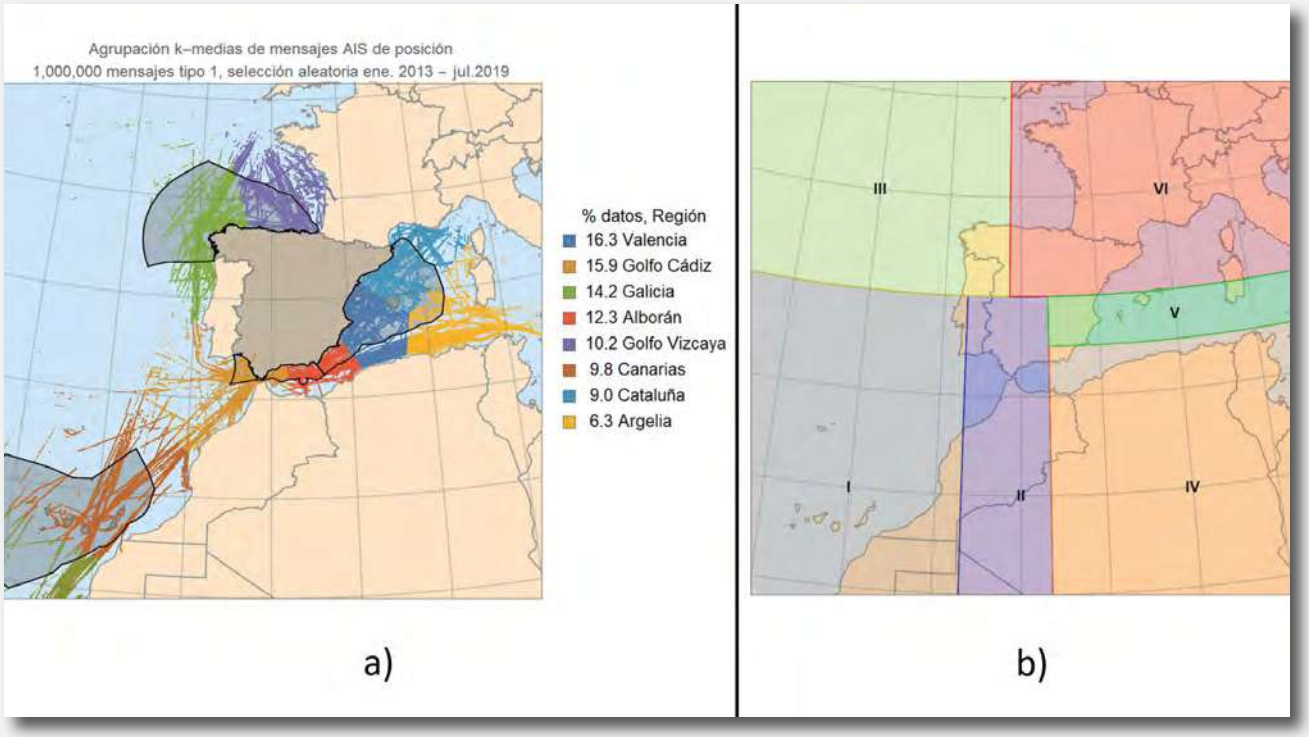
AIS is a source of Maritime Big Data with many applications in marine transport and environment. Within the framework of MITMA's Digital Transformation Plan, CEDEX has performed this action with the support of SASEMAR to provide service to several units of MITMA and MITERD.

The purpose of this work has been to optimize the historical database of messages from the Automatic Identification System of ships (AIS), which contains data from 2012 up to now. The exploitation of this database has allowed CEDEX to carry out multiple applications, such as the characterisation of maritime traffic in waters under Spanish jurisdictional waters and the use of the maritime zone of ports, the evaluation of fishing activity and the estimation of various environmental effects linked to navigation: underwater noise, greenhouse gases emissions, effects on biodiversity. These applications are completed with the study of risks derived from traffic and accidents, the operation of traffic separation systems, and the characterisation of special activities at sea such as dredging and maritime towing.

The high frequency of messages builds up a very high volume of data: there are currently some 50,000 million messages stored, and to speed up queries, a partitioned structure of the information has been established in the time domain (up to one partition/month for the most frequent position messages) and spatial (defining 6 homogeneous regions around the Spanish coasts), and a linkage between related position and static/travel messages through external keys. To keep the database updated, routine processes have been established.



↑ a) Automatic classification of messages. b) Defined geographical partitions.

The Database is complemented by additional tables of geographic and vessel information: marine demarcations, port areas, vessel characteristics, and others. The types of queries that can be made are instantaneous; most recent messages available for each ship at a given time, evolution sets, and messages emitted in a time interval. To facilitate the application to different fields of study, a set of more than 100, still growing, specialized SQL query procedures have been developed and integrated into the PostgreSQL Database Management System.

Among the growing number of applications of this source of information in ongoing studies or to start soon are the study of maritime traffic in the Mediterranean cetacean migration corridor (RD 699/2018), the estimation of greenhouse gas emissions (GHGs) and other pollutants from ships sailing in waters under Spanish jurisdiction, and the expansion of the operational study for the future configuration of the SW basin of the port of Palma, Mallorca.

← Annual maritime traffic density (ships per km-1) during 2019 in the Mediterranean cetacean migration corridor.

WORKS FOR THE RECOVERY OF MARITIME EXPERIMENTATION LABORATORY AFTER THE COLLAPSE CAUSED BY THE FILOMENA SNOWSTORM

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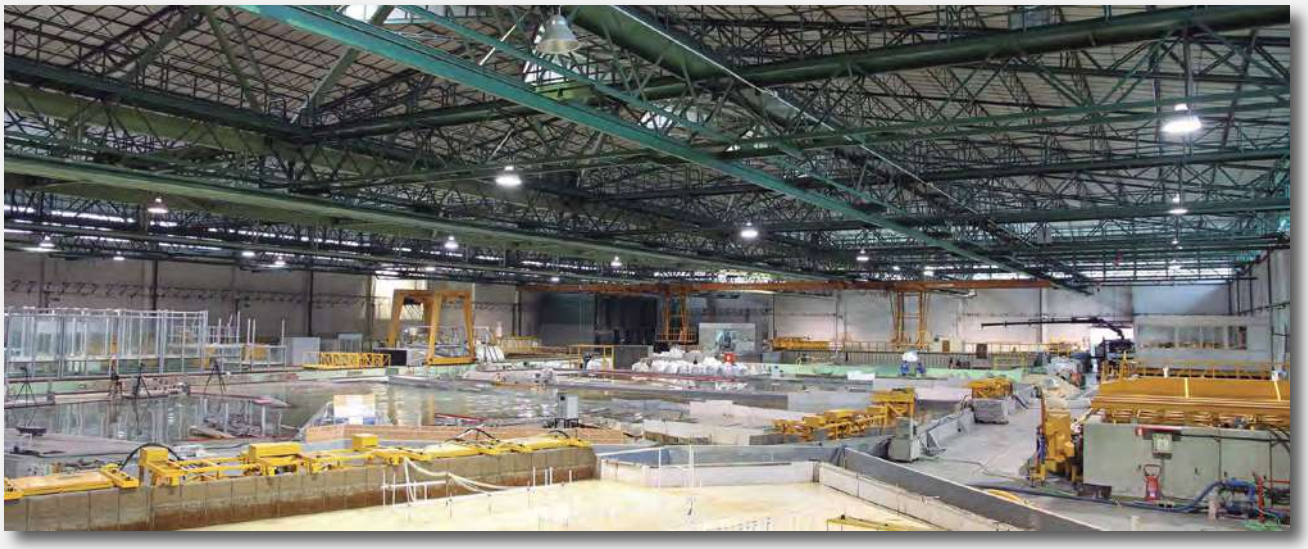
The Maritime Experimentation Laboratory of the Centre for Studies on Ports and Coasts of CEDEX, with floor plan dimensions of 115 x 71 m, was built in 1980. The structure of the original roof was built to a very unique design, consisting of a metal structure with two large Warren-type lattice beams, parallel to each other, arranged in the central part of the building and oriented along the longest side. The roof formation consisted of ribbed sheet metal plates with an expanded polystyrene sheet as insulation.

On January 9, 2021, between 2:00 p.m. and 3:00 p.m., during the Filomena snowstorm, the Laboratory's roof partially collapsed. Fortunately, the collapse occurred without people inside the building.

The state of the roof after the collapse was classified as highly unstable, with a serious risk of collapse progression. The first concern focused on securing the outside of the building. Urgently, the protection of the facade and the roof of the warehouse was carried out to prevent possible damage to the outside of the building. For safety reasons, the usual use of the offices was temporarily closed for several months, until sufficiently safe conditions were achieved. With the exception of the physical models, the rest of the areas were able to continue to operate by teleworking.

The Council of Ministers, on May 18, 2021, approved the Agreement by which the Emergency Declaration was taken for the necessary actions to repair the damage caused by the collapse of Laboratory building. The complexity of the situation due to the dimensions of the structure, as well as the importance and value of the existing facilities, was high-



↑ Laboratory hall before collapsing.

lighted, justifying the need to propose an emergency procedure to develop the following actions:

- Safety and health coordination in the execution of works
- Preliminary study of damage, identification of risks, and determination of actions to be carried out
- External securing of the Laboratory building, and specific actions in the office building
- Emergency shoring to strengthen the roof structure and prevent further collapse
- Controlled demolition of the damaged structure
- Project and emergency works for reconstruction
- Replacement of facilities and equipment that have been affected
- Compensation for damages caused in neighborhood homes.

Specialized companies were selected both in dismantling actions and in the design and construction of structures of these characteristics. Engineering companies with experience in project management tasks and technical advice on this type of works were also selected, and health and safety coordination work were contracted for the different phases. The advice of the Central Laboratory for Structures and Materials (LCEYM), as well as CEDEX's Secretariat for administrative tasks, was also available.

Within CEPYC's activity in 2021, a special place was given to the monitoring and implementation of all the actions: Provide to the companies involved the necessary information and documentation on the characteristics of the Laboratory: facilities and equipment, as well as functional needs.

- Continuous monitoring of the situation and the progress of works
- Review and assessment of possible damage to facilities and equipment, as well as verification and recovery of existing instrumentation and equipment
- Preparation and processing of administrative documentation for development of the actions

← Laboratory hall's collapsed structure.

STUDY OF MARITIME WEATHER CONDITIONS OVER THE COURSE OF SHIP ACCIDENTS. SHIP MANOEUVRING SIMULATION: MSC MIA

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The Spanish Commission for Maritime Accident and Incident Investigations (CIAIM) commissioned CEDEX to carry out a ship manoeuvrability study to analyse the accident of the container ship MSC MIA in the south basin of the port of Valencia on 13 September 2020.

This study aims at carrying out a detailed analysis of the accident, indicating its possible causes, as well as assessing the appropriate actions to avoid it or minimise its consequences based on simulations of the manoeuvres in real time. Inbound and outbound harbour manoeuvres under different meteorological conditions were also studied, exploring the suitability of the adopted tug formation and its operation strategy.

The results and conclusions of the study were set out in the document entitled «Estudio de condiciones de clima marítimo en el transcurso de accidentes de buques. Simulación de la maniobra del buque MSC MIA» (Study of maritime weather conditions over the course of ship accidents. A manoeuvrability simulation on the MSC MIA ship, self-translation), December 2021, with the following code CEDEX: 20-420-0-002.

This study was commissioned by MITMA to CEDEX for the provision of technical assistance in matters related to the technical investigation of maritime accidents and incidents.

The study was carried out using the navigation and manoeuvring system of CEDEX's Centre for Studies on Ports and Coasts, which's a unique facility. For this purpose, a 3D model of the port of Valencia was built, including the bathymetry.

The ship under study was the MSC MIA, 400 m long, 61.5 m beam, and 13.5 m draught. The manoeuvres were simulated in such a way that the ship was berthed with the bow in.

The meteorological conditions studied, according to the CIAIM, were those specific to the accident (SW wind of 6 knots, no swell) and, in addition, a prevailing wind (NNE) of 20 knots maximum, to-

← Accident simulation. Previous moments. View from the bridge aft.

gether with the provision of an external swell of 1.5 m significant height at deep waters and 9 seconds of peak period. Manoeuvres were also simulated in calm conditions.

The access manoeuvres simulations were carried out employing 3 V.S. tugs: 2 with a pull of 80 t, and 1 with a pull of 50 t. Simulations of the exit manoeuvres were carried out with 2 V.S. tugs, of 80 t each.

The simulations were analysed on an «expert judgement» basis, looking at the judgements of engineers, masters, and pilots.

A simplified analysis of the area occupied by the ship in both inbound and outbound harbour manoeuvres was also carried out, based on the study of the envelope of the area covered by the ship in the simulations as a whole.

In both the inbound and outbound simulations, it was possible to navigate with the ship and tugs at a sufficient and safe distance from other berthed vessels, cranes and port structures.

A thorough control of the ship's stern by the designated tug would have prevented this accident from happening.

← The navigation simulator's main bridge in operation.

METHODOLOGY FOR ESTIMATING SHIP EMISSIONS BASED ON AIS DATA

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To help reduce environmental impacts from maritime transport, such as greenhouse gases, air and water pollutants or underwater noise, increasing knowledge of ship emissions is needed, paying special attention to port environments.

Therefore, to better quantify the atmospheric emissions from sea-going vessels, CEDEX has developed a methodology for real-time estimation of ship emissions, on behalf of the Spanish State Ports Authority. Significant methodological developments will be applied to the study requested by the Directorate-General for Merchant Shipping, aimed at carrying out the systematic assessment of vessel atmospheric emissions in Spanish jurisdictional waters.

Given the existing great diversity in terms of vessel types, engines on board, operations conducted, etc., ships carrying out similar operations have been grouped together. For each vessel group, a specific methodology for estimating polluting gas emissions has been developed.

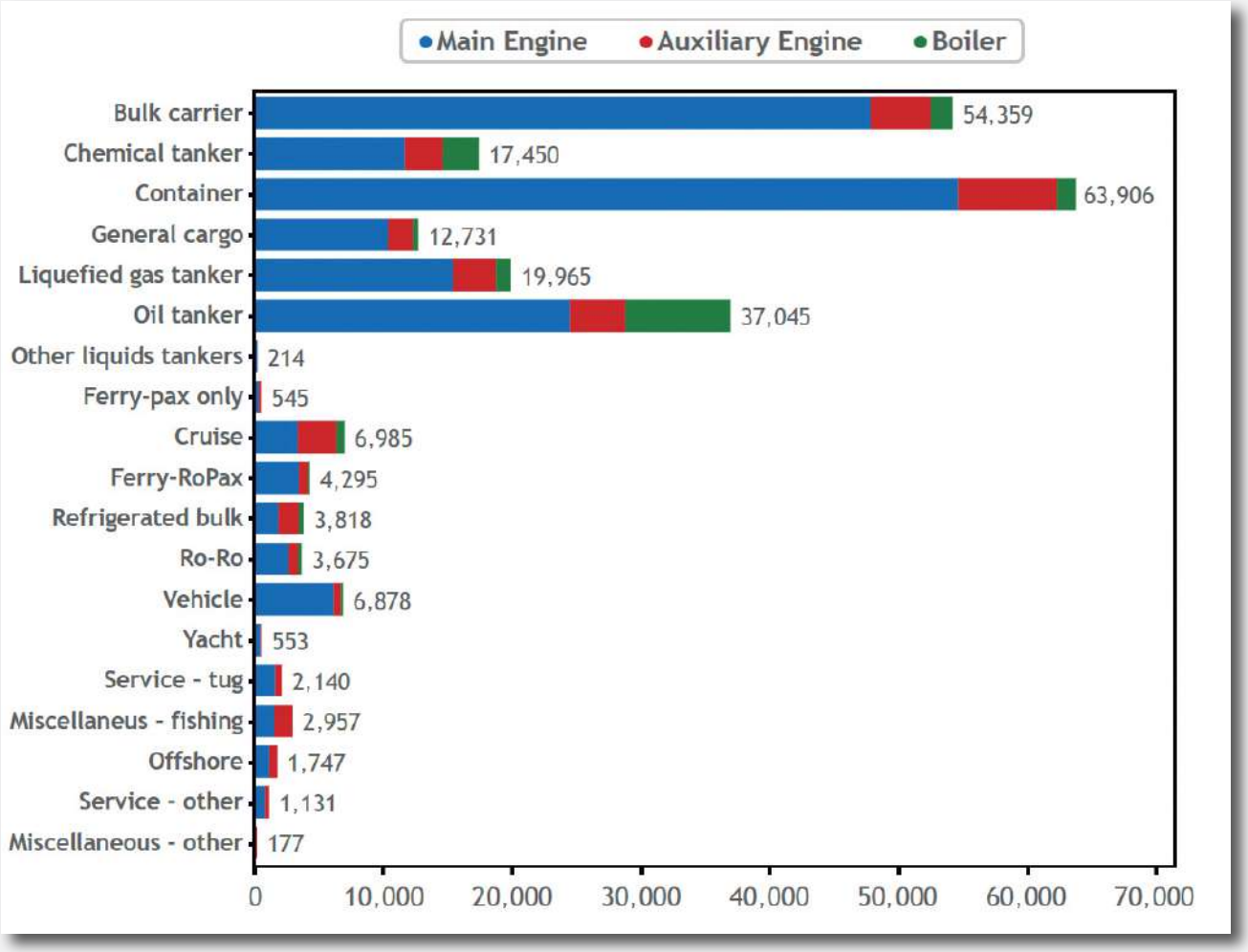
This methodology is based on the calculation of real-time vessel fuel consumption, which's estimated from the instantaneous power demand of the vessel obtained from its geographical location and instantaneous navigation speed. Both data are provided by the AIS network as well as by the data included in the IHSMarkit database and/or in the European Fishing Fleet Register.

Instantaneous vessel fuel consumption depends on a variety of factors, including ship type, year of construction, size and loading condition, engine type, fuel type, navigation phase, and instantaneous speed. Once the instantaneous amount of fuel consumed has been estimated, a series of emission factors are applied to each pollutant to quantify the total amount of pollutants emitted by each vessel into the atmosphere.

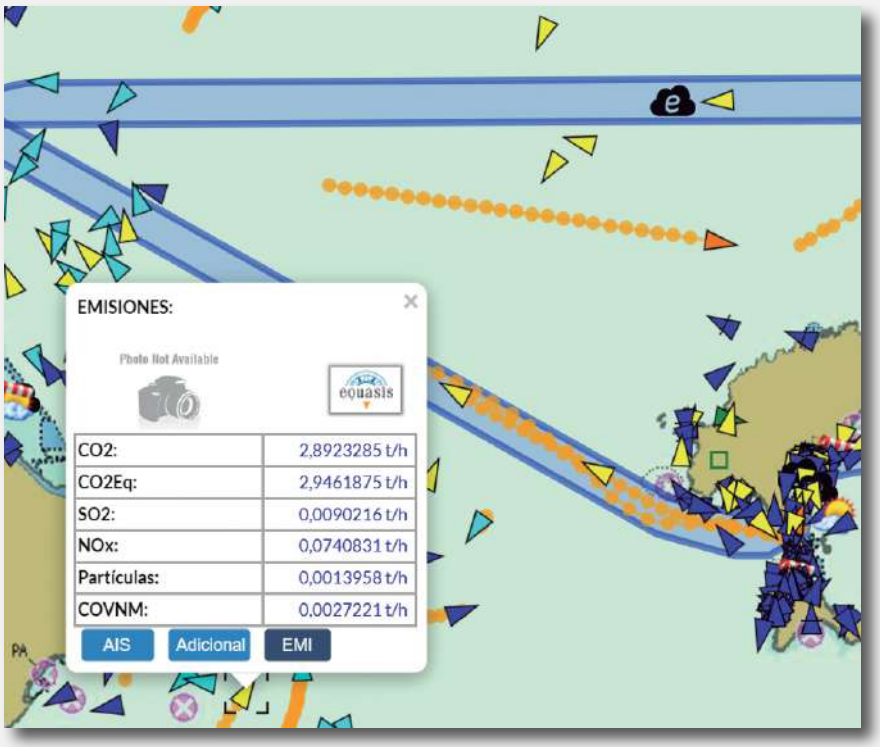
The main air pollutants associated with maritime transport are: SO2 (sulfur dioxide), nitrogen oxides (NO/NO2 and NOx), particulate matter (PM-10 and PM 2.5), NMVOCs (non-methane volatile organic compounds), CO2 (carbon dioxide), and CO2eq (carbon dioxide equivalent units). Real-time estimations of vessel emissions, or their aggregation in a given area, are displayed in the SHIPLOCUS tool, of the Spanish State Ports Authority, which has been improved to incorporate this new feature.

The Centre for Studies on Applied Techniques (CETA) has collaborated with the Centre for Studies on Ports and Coasts (CEPYC) in the determination of emission factors for each pollutant.

This real-time calculation methodology, developed for the Spanish State Ports Authority, has been applied to the study of the Directorate-General for Merchant Shipping, aggregating fifteen-minute interval gas emission values into periods of six months. A spatial grid covering the whole of the Spanish jurisdictional waters has been designed to allow the cumulative estimation of vessel emissions in predefined time intervals and geographical areas.



↑ Overall estimate of fuel consumption associated with maritime transport, in kilotonnes, by vessel type and engine (main, auxiliary and boiler) (Source: Fourth IMO Greenhouse Gas Study 2020).



← SHIPLOCUS application (Spanish State Ports Authority). Estimates of greenhouse gases and other pollutants emitted by a ship. Values in t/h aggregates in the 7 days prior to the query.

STUDY OF LAND-SEA INTERACTIONS

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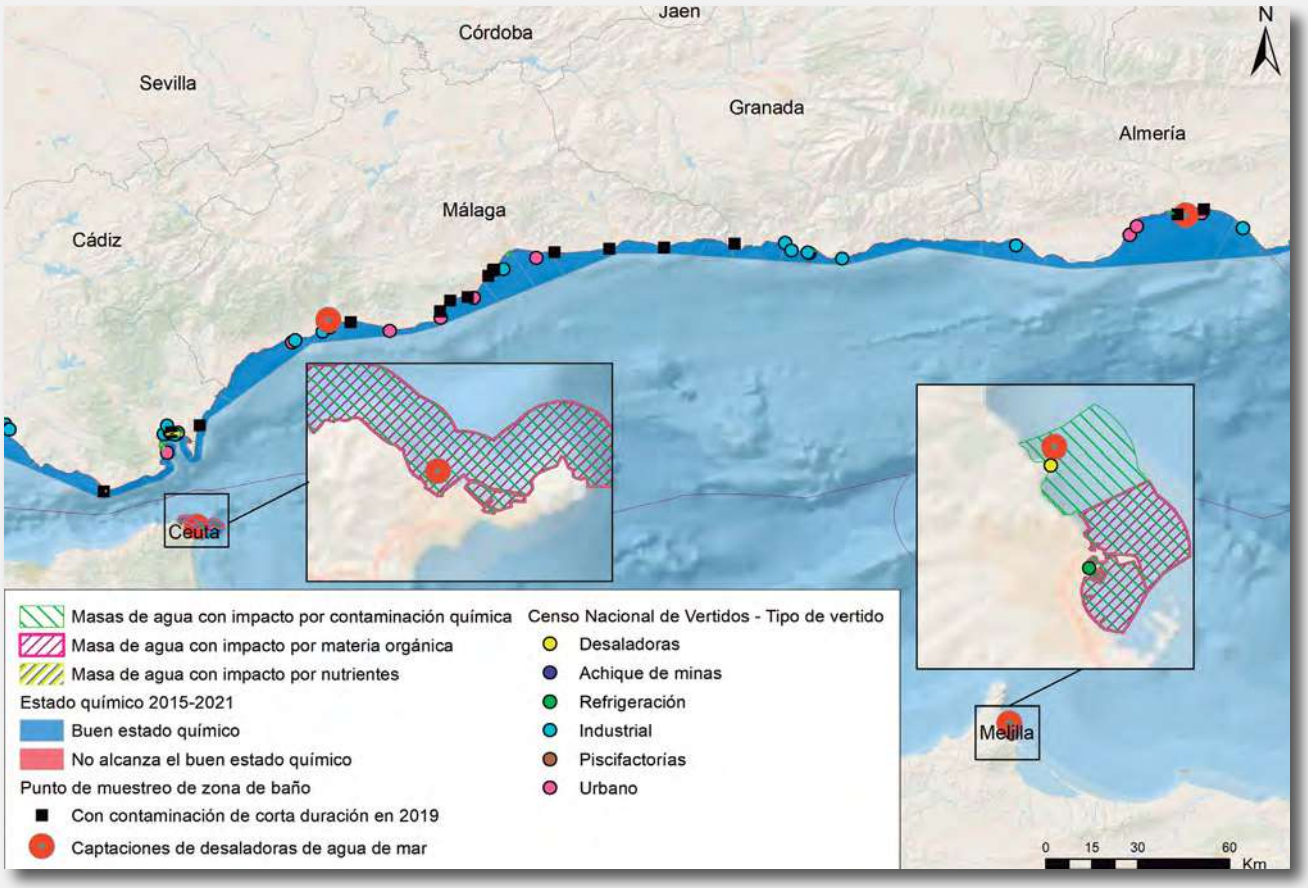
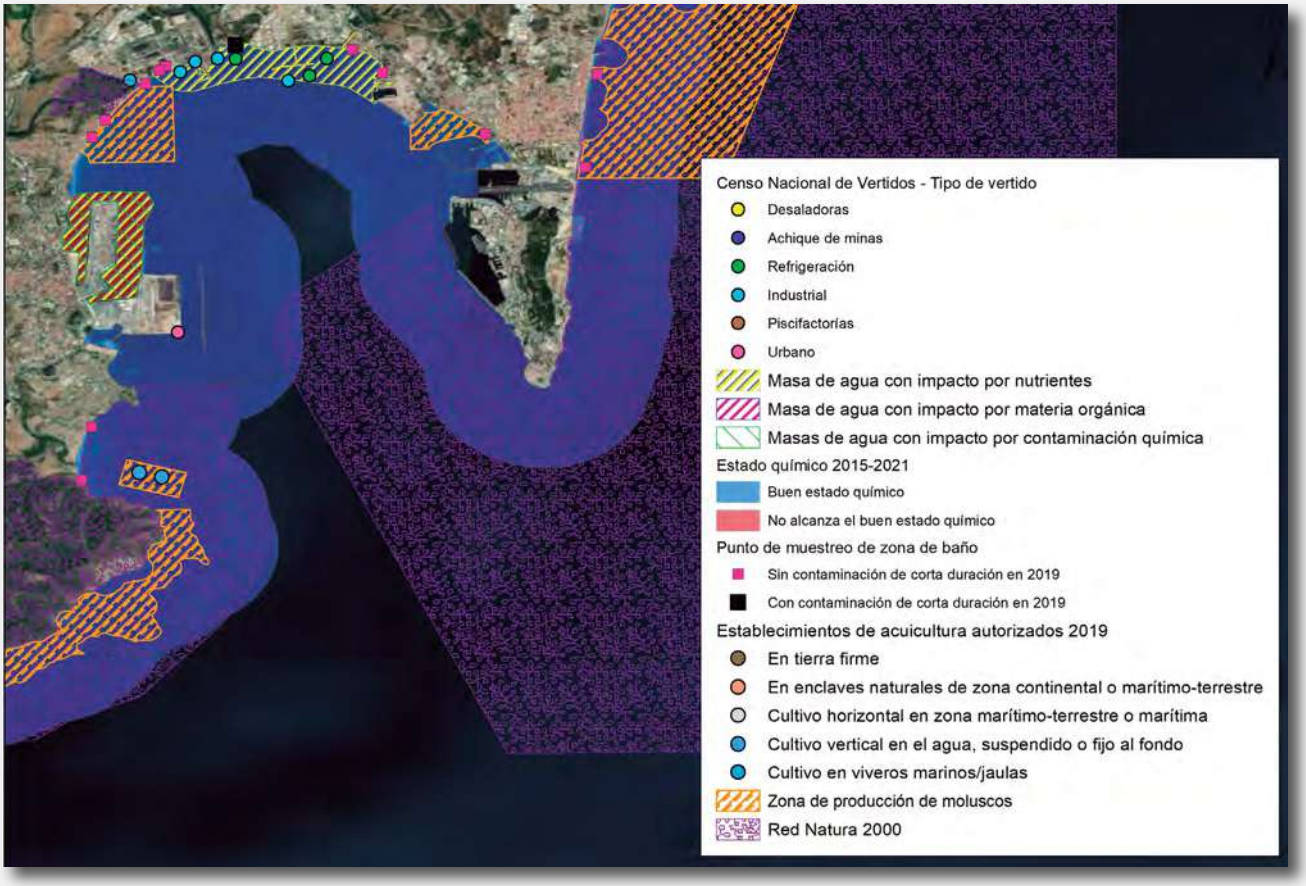
Within the Maritime Spatial Planning (MSP) process, an analysis of the interactions between human activities that take place in the vicinity of the coast has been carried out, also considering natural processes. Land-Sea Interactions (LSI) related to pollution, landscape, infrastructure and climate change have been analyzed, in order to identify those that are not currently being addressed by other management tools, to integrate them during the planning process.

More and more human activities are seeking to establish themselves in the marine environment, thus resulting in the need to achieve an orderly and sustainable development of the blue economy that contemplates the protection of resources and biodiversity. In this context, the coast constitutes the interface between land and sea, i.e. the coast is the place where the interrelations between both environments and the activities that take place in them are most evident. To highlight and translate them into the Maritime Spatial Planning Plans of the five Spanish Sea



↑ Land-sea discharges, human activities that require good water quality, Natura 2000 Network and coastal water bodies with various impacts in the second cycle of hydrological planning (2015-2021) in the province of Huelva (Source: Own elaboration based on information from MITERD, SGP-MAPA and Junta de Andalucía).

Districts that are being prepared by the MITERD, an analysis of how the activities developed in one of the environments influence what happens in the other has been carried out. The main issues addressed are pollution (accidental or not), by various substances such as hydrocarbons, gases from ship emissions or garbage; and the construction of new infrastructures which demand space both at sea and on land (ports, coastal defence structures, wind farms, etc.), generating hydrodynamic, sedimentary and landscape modifications, conditioning other activities such as tourism. All this is framed in a global context of uncertainty considering the consequences of climate change. This study establishes the areas where LSI are more relevant, identifies the management instruments that address them and, if possibilities for improvement are detected, evaluates how management plans could provide solutions and recommendations.



↑ Land-sea discharges, human activities that require good water quality, Natura 2000 Network and coastal water bodies with various impacts in the second cycle of hydrological planning (2015-2021) in the bay of Algeciras.

ENVIRONMENTAL MANAGEMENT OF DREDGED SEDIMENTS IN THE ENTRANCE CHANNEL TO THE PORT OF AVILÉS

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The study will serve as a basis for evaluating the alternatives for the management of dredged material and will draw up an action plan to manage the most polluted fraction in a sustainable way. Its results will also have an impact on the protection actions of Salinas beach, located in the same coastal system, and which has suffered erosion processes for years.

The port of Avilés is located at the mouth of the Avilés estuary, which forces the Port Authority (APA) to carry out a yearly maintenance dredging, mostly in the so-called "bar area", the channel outer part, and less frequently in the inner areas. The Salinas beach is located in the same coastal system of the estuary (figure 1), on which recent actions have been carried out to protect the coast against erosion, which must be taken into account as a determining factor of some alternatives for the management of dredged material.

To help the decision-making process and select the best alternatives for the management of dredged material, the APA asked CEDEX to carry out a study divided into several tasks. Among them there's the detailed study of the bar area and the sediment environmental quality of it, and the sedimentary dynamics. These two tasks were developed in parallel by various units of the Centre for Studies on Ports and Coasts.

Regarding the study on the quality of the sediments in the area of the bar, the suitability of using category 'A' materials for their possible contribution to the Salinas beach was evaluated, and possible geochemical influences of the geological environment of Avilés were explored. The main conclusion is that it's necessary the application of a precautionary principle, and that the use of these materials for their contribution to the beach of Salinas is discouraged.

In addition to the aforementioned study, a simplified characterization of the materials to be dredged in the channel was undertaken to verify the validity of the original characterization carried out in 2016, which resulted in the need to complete a new characterization of the sediments to be dredged.

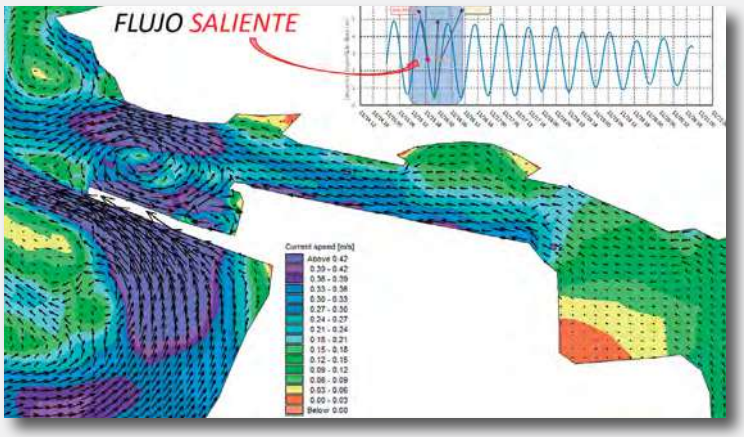
The analysis of the sedimentary dynamics in the surroundings of the mouth of the Avilés estuary was based on the application of the Mike 21 numerical model that simulated the wave fields (i.e. the currents associated to wave breaking), the wind, and the tidal currents in the estuary. This simulation allowed to analyze the sedimentary patterns in the bar area and in the mouth of the Avilés estuary, thus allowing the identification of sediment deposit areas and mechanisms in the navigation channel. The numerical simulation works entailed a field survey including sea currents and sea level measurements using tide sensors, along with fixed and mobile current meters to calibrate the numerical model and validate its results (figure 3).

Hydrodynamic simulations show how circulation patterns are strongly conditioned by wave breaking currents in storm conditions (figure 2). Similarly, the data of the bathymetric surveys carried out in the area from 2005 to now points to the deposited sand coming mostly from the beach, as a result of the discontinuity generated by the jettie

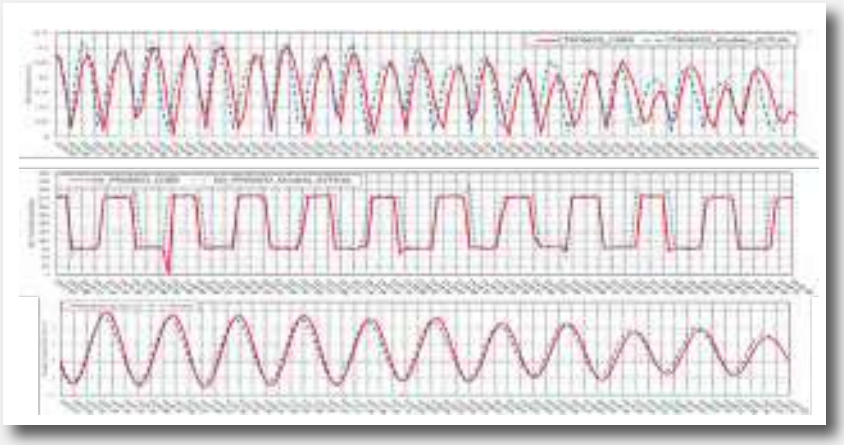
and the ruins of a former breakwater built in the bar area in the first decades of the 20th century (figure 4). This contribution of material from the outside was also observed in the numerical modelling of sediment transport.

The results of the study were presented in Avilés in November and have set the basis for proposing and discussing viable technical solutions, both in order to reduce dredging in the bar area, and for the management of the material in the bar area.

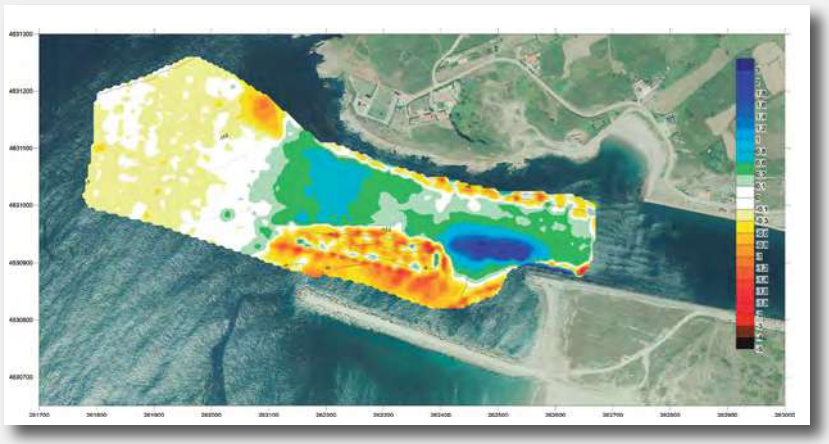
↑ **Figura 1.** Main elements of the coastal system of the mouth of the Avilés estuary and the beach of Salinas/ Espartal.



↑ **Figura 2.** Circulation pattern in ebb tide, under storm conditions of Hs ≈ 4 m.



← **Figura 3.** Results of the calibration of the numerical model. Comparison of numerical model results – field measurements.



← **Figura 4.** Sedimentation patterns in the winter from 2013 to 2014 in the bar area.

LANDSCAPE IMPACT STUDY OF THE FUTURE CONFIGURATION AND REORGANIZATION OF THE PORT OF PALMA

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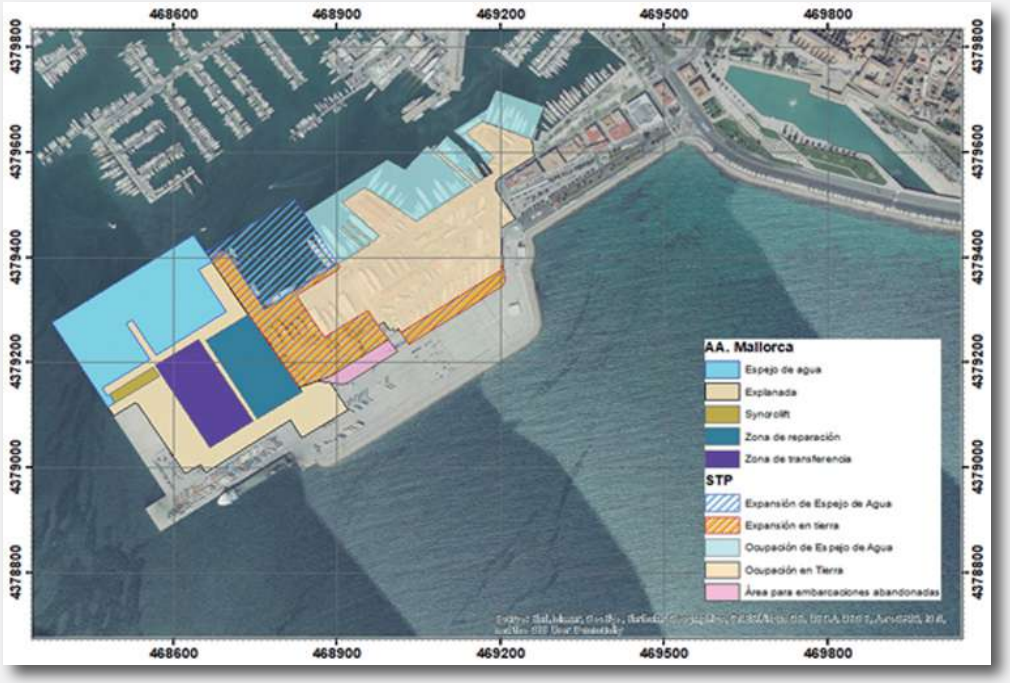
The island of Mallorca is a first-class Mediterranean natural environment. The coastal side of its capital has been historically cared, to present itself to the observer as attractive as possible. While taking care of the Spanish historical and cultural heritage, we try to maintain and favor one of the main assets of our country: tourism. It includes first-rate spots such as the Cathedral and its surroundings, the Bellver Castle, whose memories were glossed by Jovellanos, and other highlights. Others, which involve areas of channeling of movements, as well as recreation, such as the promenade (Gabriel Roca Avenue) surrounds the port and offers an area for both stay and circulation, which allows for the sightseeing of the port and the bay of Palma.

In this context, the Port Authority of the Balearic Islands is interested in collaborating in the conservation of the landscape, without reducing the service to users and, by extension, to society as a whole.

CEDEX has carried out several studies involving the works which had been foreseen in the Port Master Plan, trying to analyze the impact they may have on the surrounding landscape. These studies have been based on the facilities offered by technologies supported by Geographic Information Systems.

The contribution of this project to the concept of R&D&I, consists of the development of simple parameters that allow the result of the study to be not only qualitative, proposing assessments that allow the quantification of the impact, so

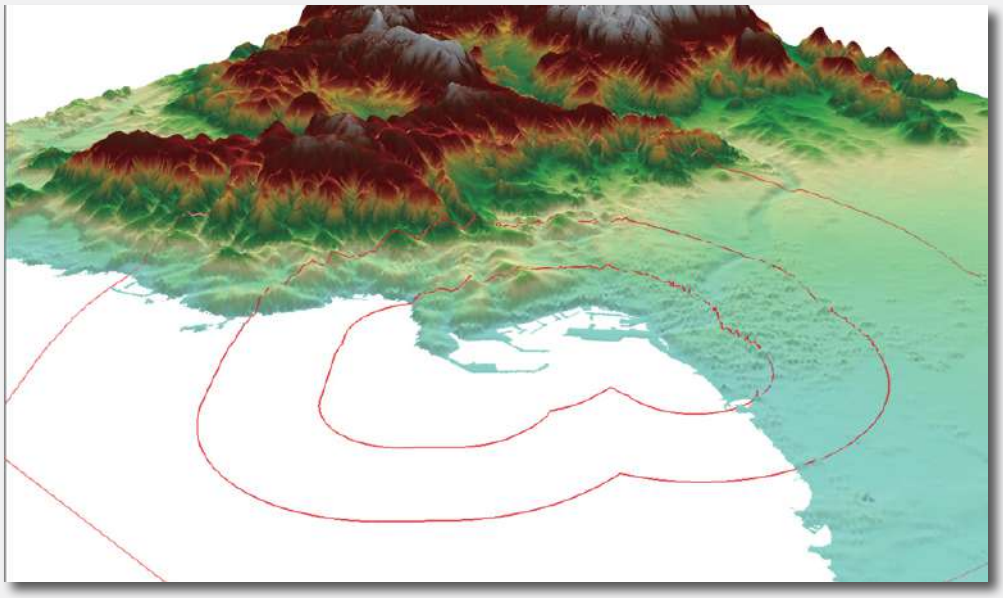


↑ Facilities of Astilleros de Mallorca and STP.

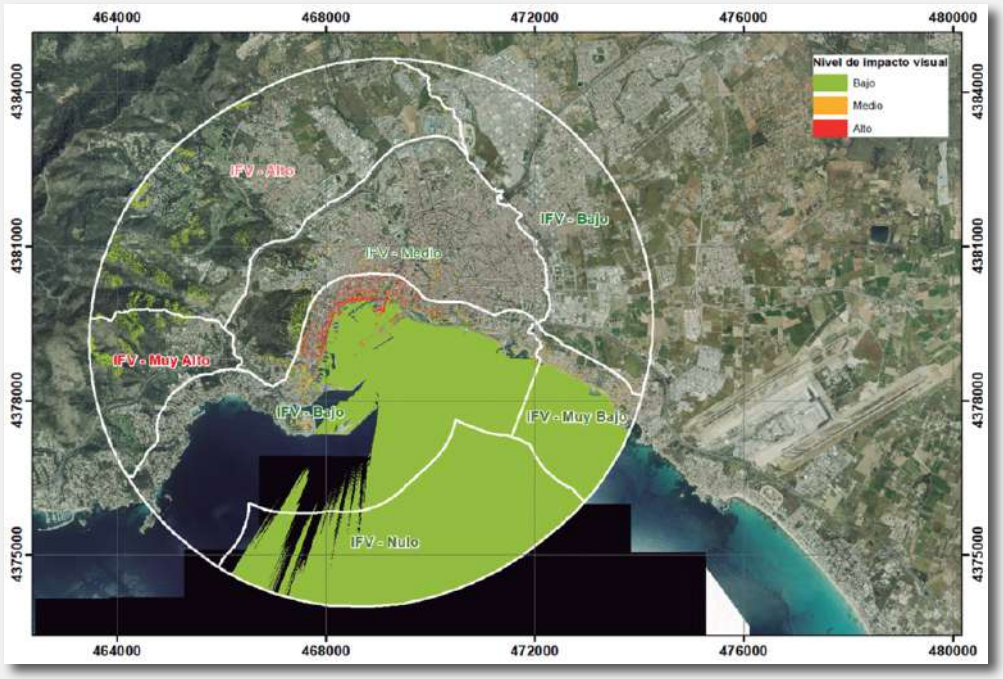
that it contributes directly to the analysis of alternatives, using synthetic systems such as ELECTRE, or similar.

This is intended to facilitate and synthesize the decision-making process, helping a more effective management of natural heritage and guiding the enjoyment of the environment in a sustainable way.

An attempt has also been made to assess the impact that the masts of the sailboats produce on the landscape, which do not constitute a direct barrier to the visual but do make it significantly difficult. This is an effect which's common to most recreational nautical facilities that has not been fully resolved.



↑ Digital model of elevations and areas of visual incidence.



↑ Example of visual impact according to the Visual Fragility Index of the landscape.

OPERATIONAL MODELLING OF AIR-POLLUTANT-EMISSION DISPERSION BASED ON SAMOA

Contact: laura.crespo@cedex.es

CEDEX, commissioned by Puertos del Estado (PE) and in collaboration with the wind engineering company Oritia & Boreas and 16 Port Authorities, is working on the implementation of an operational modelling of air pollutant dispersion within the SAMOA project in each of the ports managed by the aforementioned authorities.

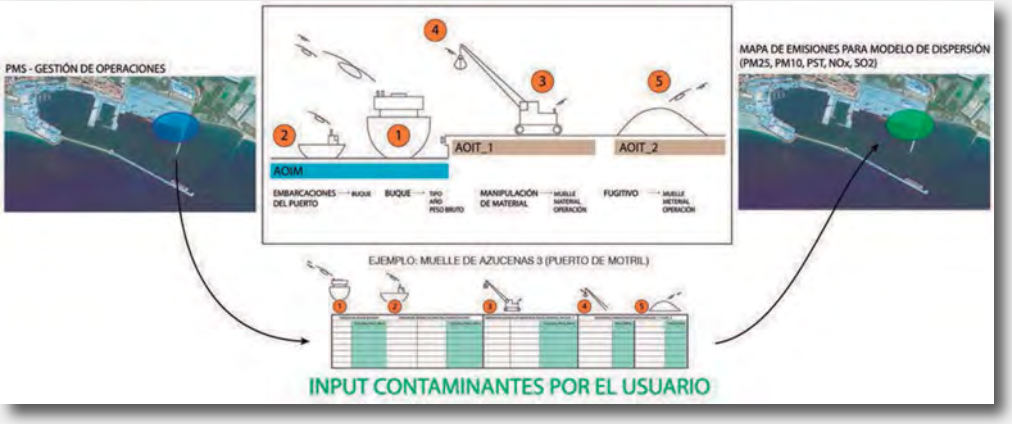
The project begins with the modelling of the physical port environment, which incorporates information on pollutant emissions into the atmosphere, both typical port activities and others that are located in the vicinity for logistical reasons. The atmospheric dispersion model becomes into a tool that allows to know in advance the contribution to atmospheric pollution of port activities in cities near port environments.

The use of these types of models helps to optimize port management operations, berthing/ manoeuvring of ships, and loading/unloading of goods. It's a further advance in the objective of improving the efficiency of the port system, with the consequence saving in operating times, which results in a reduction in the consumption of energy-carbon footprint and pollutant emissions into the atmosphere of different pollutants such as SO2, NOx, PM-10, PM-2,5 (particulate matter), etc. The use of these tools results in the improvement of air quality and, thereby, in the public health of port cities.

This work is complemented with a survey that's distributed and filled out by each Port Authority, and serves as a script to address air pollution problems reported through on-site visits to each port, and the response of environmental authorities, public health and citizens to this reality.

Working group participating in the project of dispersion of atmospheric pollutants affecting the port environment, based on SAMOA:

- National Port Authorities
- Port Authorities (16 ports participate in the exercise, which includes a visit to the ports, with analysis of responses to a form on environmental problems related to atmospheric pollution.)
- Company specialized in Wind engineering (Oritia & Boreas)
- CEDEX



← Diagram of the Port Authority decision-making process resulting from air pollutant dispersion modelling.

SUPPORT TO THE MITERD FOR COMPLIANCE WITH ENVIRONMENTAL NOISE LEGISLATION

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NATIONAL NOISE POLLUTION INFORMATION SYSTEM WEBSITE

The Environmental Noise Area, within the technical assistance to support the Ministry for Ecological Transition and the Demographic Challenge (MITERD), in application of the END Directive, develops, maintains, and continuously provides new data to the website of the Basic Information System on Noise Pollution (SICA) (https://sicaweb.cedex.es/).

SICA shows:

- Noise maps, exposed population and action plans with their corrective measures, noise sources constituted by cities, highways, railway lines and airports.
- Communications sent to the European Commission according to Directive 2002/49/EC on the assessment and management of environmental noise.
- Instructions, guides, recommendations, and other type of documentation needed for the evaluation of environmental noise.

SICA, in accordance with Royal Decree 1513/2005 of 16 December, which develops Law 37/2003 of November 17 on noise, forms the basis of data necessary to transmit directly to general public , information on environmental noise

During 2021, a completely new SICA website has been developed to comply with website navigation protocols. In addition, work has been incorporated into the 4th phase of the implementation of the environmental noise Directive, which includes changes in calculation methods and data delivery. This new methodology has involved the creation of a national spatial data infrastructure for Environmental Noise (idesica.cedex.es) complying with the INSPIRE Directive. Similarly, to facilitate the task of information management and massive data feed, it has been necessary to develop another web application (gestionsica.cedex.es).

← SICA web portal.

INSECT COLLECTOR PERFORMANCE EVALUATION TESTS

Contact: manuel.colomer@cedex.es

The goal of the project Roads and Pollinizers is to assess the impact of highway traffic on insect populations. To this effect, an insect collector was designed to capture insects directly on the road. One way to assess the impact of highways is to estimate how many insects are killed in the road. Therefore, a thorough understanding is needed of how the collector works. To this end, various tests were carried out which are summarized in this sheet.

	Issues addressed and tests performed	Test results
1	Do we lose sample during sampling in 10 km stretches? **Test 1:** 60 cardboards of 6 different sizes and shapes are added to the collector, a distance of 10 km is covered and at the end the remaining cardboards are counted.	In the five repetitions performed 100% of the card are recovered s => no loss of sample.
2	Do we catch the same number of insects by installing the collector on the roof of the vehicle as at engine level? **Test 2:** a collector is installed in each position, a distance of 10 km is covered and at the end the number of insects captured in each collector is counted.	After five repetitions no significant differences were found in the total number of insects or by order (Diptera, Hymenoptera, Coleoptera, etc.).
3	Can we estimate the number of insects killed in the road by a car from those captured by the collector? **Test 3:** Given that the ratio of the collector to the front end of an average vehicle is 1:10, if with two collectors we capture approximately twice as many insects as with a single collector, then with one car we hit l 10 times as many insects.	After five repetitions, the number of insects hit in a vehicle is 10 times higher than those captured with a collector.

← Installation of two collectors at different levels for 2 and 3. A webcam has been installed at the front end for recording the tests.

ANALYSIS OF THE IMPACT OF LINDANE CONTAMINATION IN THE GÁLLEGO RIVER FROM THE SARDAS LANDFILL (SABIÑÁNIGO)

Contact: javier.rodriguez@cedex.es

The study of the lindane contamination observed in the Gállego River from the Sabiñánigo Reservoir, commissioned to CEDEX by the Ebro River Basin Authority, finished in 2021. It has been performed through the collaboration of the Centre of Studies on Applied Techniques (CETA) and the Laboratory of Geotechnics (LG), at CEDEX.

This work has consisted in the compilation and analysis of information generated during decades by several centres of the Central Administration, the Regional Government of Aragón, and experts in multiple disciplines. This information has been integrated into a cartographic database to support this and future works. The assessment performed deepens the knowledge of the system formed by the Sabiñanigo Reservoir, the Sardas facilities located in the left riverbank and the geological substratum. As a result, the most plausible hypotheses about the performance of the system that could explain the episodes of water contamination have been identified, and future tasks for the additional characterization of key aspects in these hypotheses have been proposed to correct or limit the impacts observed.

Among the achievements of the study there must be emphasized: a better definition of the role of the substratum of low permeability underlying the landfill of Sardas; the assessment of the watertightness and stability of the landfill; the new information produced about the mass balance and contaminant distribution during the episodes analysed; and the proposal to optimize the monitoring network, based on a deeper understanding of the residence time of water in the reservoir, as well as of the interaction between surface and groundwater from the underlaying aquifer (gravels and silts from a fluvioglacial terrace).

The results of this work help to know the origin and fate of persistent organic contaminants in the water and to minimize the impact of lindane contamination in the Gállego River. These results contribute to SDG 3, Good Health and Well-being, by reducing illness associated to dangerous chemicals and air, water and soil contamination; 6, Clean Water and Sanitation; and 15, Terrestrial Ecosystems Life, by protecting and restoring aquatic ecosystems, and looking after the conservation and sustainable use of interior fresh-water ecosystems and the services they provide.

Summary of the information analysed during the project

Area and water bodies	Number of documents revised	Number of measurements
8 km of the Gállego River. Five surface water bodies, the Sabiñánigo Reservoir included	More than 100 documents (annual reports from 1990 to 2020, and research papers)	Millions of records about meteorology, hydrology and water quality

RADIOLOGICAL QUALITY MONITORING OF DRINKING WATER (TRITIUM ACTIVITY)

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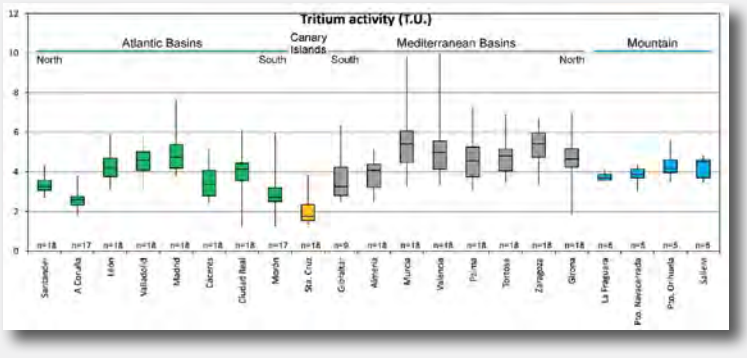
The Laboratory of Isotope Hidrology, of CETA (accredited according to the UNE-EN ISO/IEC 17025:2017 standard) has been working in radiological environmental monitoring since its creation in the 1970s, in order to meet the needs of measuring radiological parameters in water derived from the first nuclear power plants in Spain. Among other parameters, Tritium activity in continental and marine waters is measured by the "direct" method (Minimum Detectable Activity MDA: >3,0 Bq/l) in support of compliance with International Treaties and European Union Directives, in the framework of radiological monitoring of the aquatic environment for the Nuclear Safety Council and water management for the Directorate General for Water of the Ministry for Ecological Transition and the Demographic Challenge.

During 2021, this laboratory has analysed tritium activity, prior electrolytic concentration (MDA: > 0,05 Bq/l), in drinking water samples from the water supply system of Tenerife (Canary Islands). This work is performed in collaboration with the University of La Laguna to verify that the activity values detected are lower than the limit defined for tritium in the Royal Decree 314/2016, of July 29th which establishes the sanitary criteria of water for human consumption (100.00 Bq/L). The values measured in all samples are close to the MDA, three orders of magnitude bellow than this limit, and equivalent correspond to the activity of tritium in precipitation samples taken from underground galleries after the decay time elapsed during its infiltration through the soil (see Figure).



In addition to these tasks, CEDEX participates in the Spanish Network of Isotope Monitoring in Precipitation (REVIP) and in the Global Networks, the first one managed in collaboration with the National Meteorological Agency, and the second one managed jointly by the World Meteorological Organization and the International Atomic Energy Agency. This highly sensitive network, in addition to supporting water resource management and studies of isotope hydrology, climate and ecosystem functioning, provides information on the natural background of this radionuclide in precipitation in the Iberian Peninsula, and in Balearic and Canary Islands. The data are available through the CEDEX website: http://www.cedex.es/CEDEX/LANG_CASTELLANO/ORGANISMO/CENTYLAB/CETA/LINEAS/07_REVIP.htm

Radiological monitoring of continental and marine waters and monitoring of radionuclides (Tritium) in drinking waters performed at CEDEX contribute directly to health risk management, one of the targets of SDG 3, Good Health and Well-Being. On the other hand, the use of environmental isotopes such as Tritium to trace and date the water cycle in REVIP is used to determine the renewal time of groundwater in aquifers, providing basic information to ensure the sustainability of freshwater abstraction and supply, within SDG 6, Clean Water and Sanitation.

Area	Number of analyses in drinking water	Number of analyses in precipitation	Number of analyses of continental and marine surface water
Iberian Peninsula, the Balearic, and the Canary Islands	12	44	560 (500 of continental waters, and 60 of marine waters)

← Variability of tritium activity in precipitation for the period 2000-2017 in the sampling stations of REVIP.

ANALYSIS OF THE ECOLOGICAL FLOW REGIMES STABLISHED IN THE RIVER BASIN MANAGEMENT PLANS OF THE SECOND PLANNING CYCLE (2015-2021)

Contact: beatriz.molina@cedex.es

In 2021, the analysis of the ecological flow regimes established in the river basin management plans of the second planning cycle (2015-2021) has been carried out in a collaborative project between CETA's Environmental Restoration Area and CEH's Hydrological Planning Area, to meet the needs of the Directorate-General for Water (DGA), of the Ministry for Ecological Transition and the Demographic Challenge (MITERD).

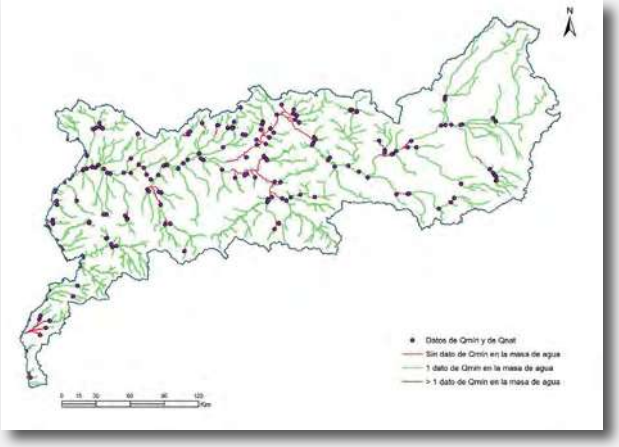
The aim of the project is to obtain a national overview of the degree of progress in the implementation and compliance with ecological flows in the second planning cycle, to update the analysis carried out by CEDEX in 2014. To this purpose, in collaboration with the river basin authorities, an exhaustive compilation of all available information on environmental flow regimes was carried out. Based on the information collected, the minimum ecological flows were compared with natural flows gauged or calculated with the SIMPA3 model to determine the relationship between the two.

The results of this analysis will enable the necessary adjustments to be made, where appropriate, in the ecological flows of the following hydrological planning cycles, with the aim of improving their efficiency in achieving good surface water status, in compliance with the Water Framework Directive (WFD). All this contributes to rational planning and sustainable use of water resources, as well as to the maintenance and conservation of water-related ecosystems (SDG 6 targets 6.4, 6.5 and 6.6).

In this way, the objective of CEDEX's 2020-2022 Strategic Plan of service to the sector has been met: on one hand, by collaborating with the river basin authorities; and on the other, by providing assistance to MITERD and contributing to its responsibilities with the European Commission.

The following results were obtained from the analysis of the water bodies which must have an ecological flow regime:

- 65.33 % have some component of the ecological flow regime defined (minimum flows, maximum flows, flood flows, rates of change)
- The ecological minimum flow has been established for 62.33 % of the water bodies
- 3,439 river stretches have been analysed where minimum ecological flow has been defined
- The minimum ecological flow generally represents 11 % of the natural flow



↑ Water bodies and spots with data on natural flow and minimum ecological flow in the Guadiana River Basin District.

SEAWATER CURING STUDY

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The floating caissons, used in the construction of wharves and breakwaters, are reinforced concrete structures in premature contact with seawater during their fabrication on floating platforms. The study to evaluate their durability has been completed in 2021.

Floating caissons are large reinforced concrete structures that are built with sliding formwork on the sea, transported floating and, anchored for the formation of port structures, such as wharves and breakwaters.

The construction process of these elements forces the reinforced concrete to be in contact with seawater during the curing period, for the lower part of the caisson is submerged in the sea as the caisson gains height.

The Materials Science Area of the Central Laboratory for Structures and Materials has carried out, requested by the National Port Authorities, the study on the extent to which the premature contact of the concrete with sea water has on the subsequent durability of the floating caissons.

For this purpose, seven different dosages have been tested, with and without pozzolanic additions, which meet the requirements of the Structural Code for the most aggressive marine environment. The laboratory study, which has lasted 3 years, has allowed to know the behavior of concretes that are initially cured in salt or fresh water, and then completely submerged in seawater.

This laboratory work has been completed with the field study on real caissons, comparing the upper zone, which doesn't have any contact with seawater until days after its manufacture, with the lower zone of the caisson, which comes into contact immediately after its execution.

The work carried out has concluded that the differences found in the advance of chlorides are manifested in the first ages and limited to the outer 10 mm of the coating, but their long-term repercussion is not important. Neither physical nor mechanical properties of the concrete are altered. Therefore, no significant risk of increased corrosion of the reinforcement in the caissons has been observed due to the construction method used.

← Floating caisson fabrication.

This study has also made it possible to modify Article 29 of the Structural Code to allow elements that will be exposed to an XS2 environment to be cured by immersion in seawater, giving greater regulatory coverage to a construction method that places Spain among the most advanced countries in the construction of reinforced concrete caissons.

- Laboratory study of concretes with CEM I, CEM II/B-V and CEM III/B cements, meeting the requirements for XS3 environment
- 12 boreholes were drilled in 6 caissons of 3 different structures to carry out tests on floating caissons in service
- The study evaluated: compressive strength, resistivity, water penetration, chloride profiles, open porosity, capillary absorption and oxygen permeability

← Location of drill holes for the study of caissons.

AN ANALYSIS OF THE DESIGN CRITERIA FOR THE SOIL-STRUCTURE INTERACTION OF HIGH-SPEED RAIL BRIDGES

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In the summer of 2021, CEDEX was commissioned to assess the design criteria of 16 high-speed rail viaducts, related mainly to the structural analytical modelling and to the soil-structure interaction.

The Central Laboratory, collaboratively with the Geotechnical Laboratory, issued a specialised evaluation report about the structural design criteria to be adopted in the design of sixteen viaducts belonging to a new high-speed railway line. These criteria referred mainly to specific aspects such as soil-structure interaction, both static and dynamic, and to parameters and particularities to be considered in the structural analytical modelling and in the earthquake resistant analysis.

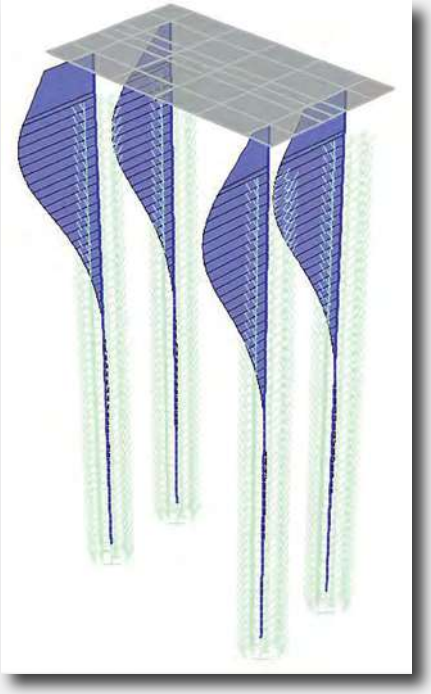
Soil-structure interaction can be defined as the difference between the real response of a structure when subjected to a seismic action and its response assuming that it's ideally founded on rigid ground (fixed base). In case of dynamic actions, such as earthquakes, the interaction phenomenon reflects a set of kinematic and inertial effects that are caused by the compatibility of displacement and velocity fields between the foundation and the ground.

Although it's true that in most of the national territory the seismic design situation isn't the conditioning one, in certain geographical areas, such as the southeast of the Iberian Peninsula, where these viaducts are located, seismicity already has a preponderant character.

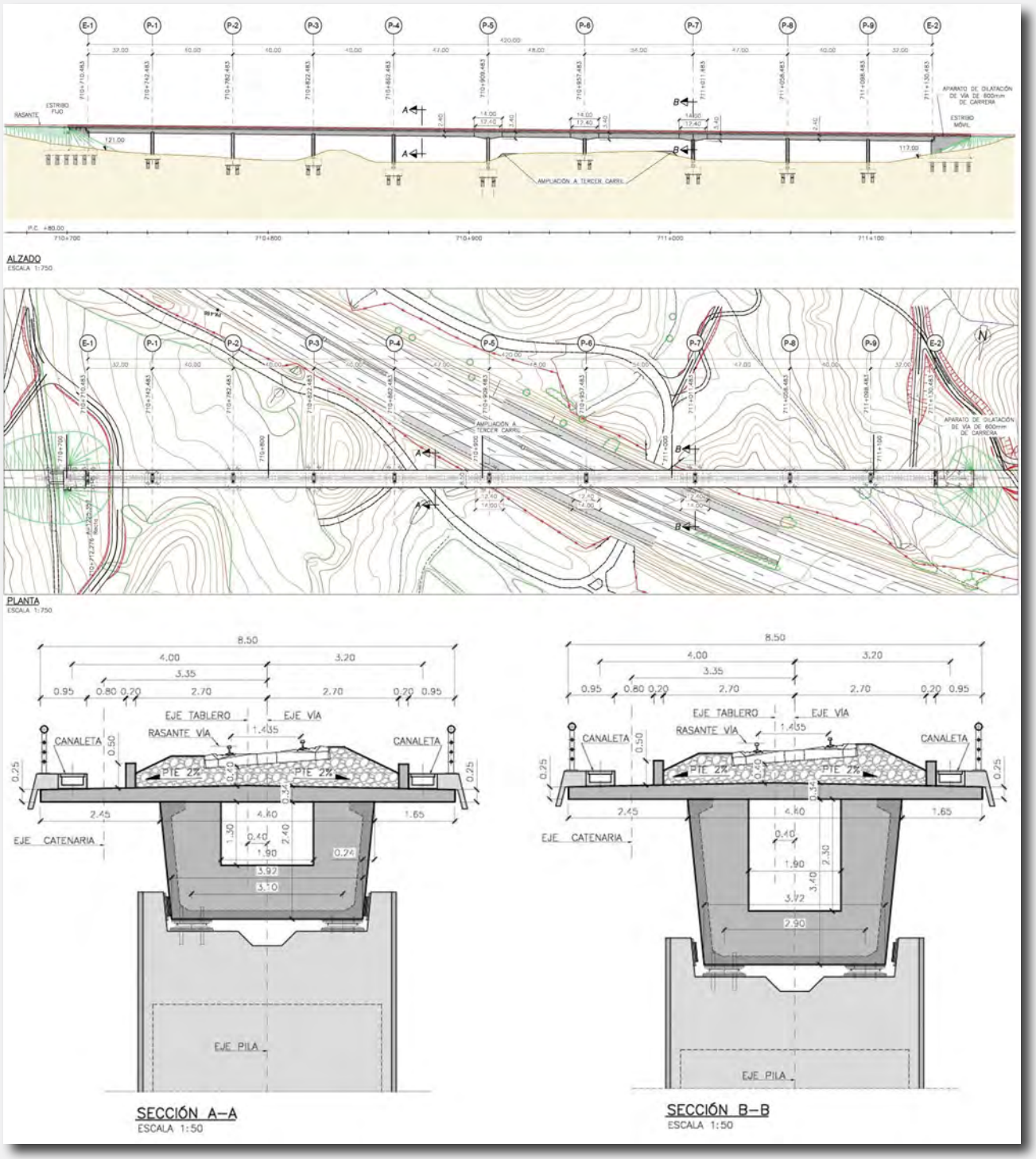
In this case, the consideration of certain design criteria, related to the modelling of the connections or the mass, and stiffness parameters to be considered in each element, decisively conditioned the structural solution. And this not only regarding the resulting stresses, but also the system of connections to be considered between the deck and the substructure, a system that must be properly implemented in the calculation models, and subsequently materialised in the built structure.

It should be noted that all the above considerations had a strong implication on the budget and timeframe of the work.

- In Spain, it's unusual that dynamic interaction conditions the design of the bridge structure
- Specific design criteria were studied for the sixteen high-speed rail viaducts located in an area of high seismicity
- The hypotheses considered conditioned the structural design of the viaducts and their links between elements and with the soil



← Bending forces in piles in seismic design situation.



↑ Plan, elevation, and cross sections of one of the bridges.

CHEMICAL CHARACTERIZATION OF GEOMATERIALS AND WASTES IN THE GEOTECHNICAL FIELD

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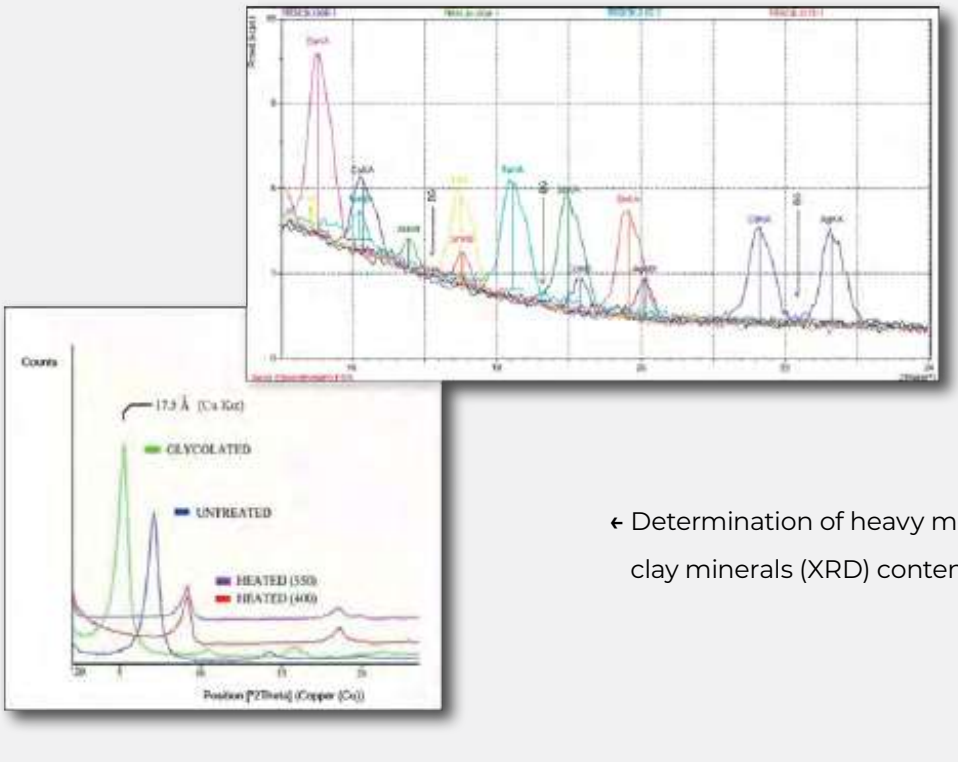
The Laboratory of Geotechnics has a Chemistry Laboratory for the chemical and environmental characterization of soils, rocks, and other geomaterials and their associated waters, as well as recyclable wastes in geotechnical works.

The procedures used for this purpose are developed in the CEDEX Monograph M-141 *Ensayos de Análisis Químico en Geotecnia. Empleo de Técnicas Instrumentales* (2019). They can be used to determine conventional chemical parameters such as loss on ignition, soluble sulphates, gypsum, soluble salts, organic matter, carbonates, pH and redox potential in samples of soils, rocks, construction materials and waste (solid samples), or pH, electrical conductivity, alkalinity and organic matter in water and associated leachates (liquid samples).

Testing protocols based on advanced analytical instrumentation can also be used to determine the mineralogical composition, cation exchange capacity and content of major elements in solid samples, soluble ions in liquid samples, or trace metals and mercury in all of them.

The analysis of these chemical parameters allows the study of geotechnical problems related to contaminated soils and rocks, underground hydrogeology, seepage in material dams, soil identification, classification of waste for landfills and its possible use as fill or embankment material, soil dispersion, soil treatment with cement and mobility of contaminants in landfills. Such is the case of the work carried out during 2021 for the CH Ebro in the Sardas landfill, Sabiñánigo (Huesca).

Main instrumental techniques of chemical-mineralogical analysis of the Geotechnical Laboratory



← Determination of heavy metal (WD-XRF) and clay minerals (XRD) content in a soil sample.

PROPOSAL OF REEVALUATION AND REPLACEMENT OF THE MONITORING SYSTEM AT THE SLOPES OF THE ARENÓS RESERVOIR (CASTELLÓN)

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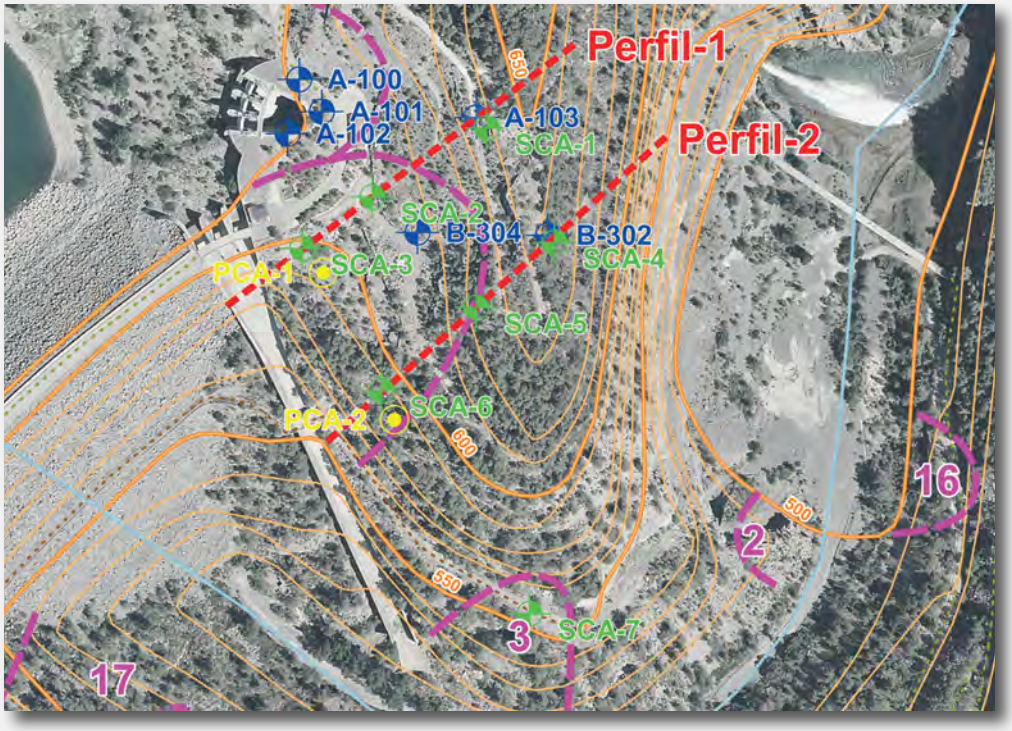
This work is an example of the assistance provided by the Geotechnical Laboratory of CEDEX to the Directorate-General for Water. Specifically, the aim is to provide support for the re-evaluation of the stability of the slopes of the Arenós reservoir, at the headwaters of the Mijares, a tributary of the Júcar, in the province of Castellón.

Prior to its construction, the stability of the slopes of the reservoir basin, as well as those of the dam itself, had given rise to some uncertainty. In this regard, the exploitation of the reservoir has been limited, and over the 45 years of its existence it has been prevented from being filled in its entirety, with two episodes of landslides. One affected the spillway in 1987 through a planar landslide between Jurassic limestone strata, which collapsed the wall of the spillway and disabled one of the sluice gates and the access road on its top; and the other occurred in 1989, when part of the hillside opposite Puebla de Arenoso slid into the reservoir.

The aim of this geotechnical work is to put into practice the Administration's plans to complete the impoundment of the reservoir. It means that the historical ground movement records from the monitoring system must be revised.

In view of this demand, the work was divided into two parts: One of re-evaluation of the installed instrumentation, and other on the applicability of the most modern remote sensing techniques.

A review of the *in situ* instrumentation, basically inclinometers, piezometers and displacement control, has been undertaken, arriving at the conclusion that much of this instrumentation is obsolete, has ceased to function or no longer meets the initial requirements, which is the case of some in-



← Proposal of the monitoring system near the dam and spillway.

clinometers that have been cut, or of the monitoring system itself that failed to provide data for some years.

Therefore, a proposal of an updated monitoring system at the purportedly unstable slopes of the reservoir has been drawn up, consisting of the execution of 26 new inclinometers and 13 vibrating-wire piezometers along 13 sections, divided into the three areas deemed most critical, namely, the area of the dam's downstream boundary, the area of the town centre of Puebla de Arenoso, and the slope opposite this town. Such system is complemented by the installation of new differential GNSS surveillance monitoring equipment with two reference stations and 37 control points distributed mainly in Puebla de Arenoso and the hillside opposite. Besides, an automatic system capable of detecting movements in real time and alert has been recommended for the area of the dam and the spillway, for the spillway, damaged in 1987 by a local slope instability, will undergo refurbishment.

In terms of remote sensing techniques, the key issue is to single out the most suitable for this purpose.

Within the range of alternatives, interferometry with synthetic aperture radar images, InSAR, seems most appropriate. It allows the large extension of the reservoir to be covered with fair accuracy, being cost-effective in terms of expenses on field work. Thus, InSAR proves to be a sound complement to the *in situ* measurements of inclinometers.

← INSAR analysis of the Arenós dam. Areas with movements are displayed with yellow dots.

EUROPEAN GEOLAB PROJECT
WORKING DAYS AND COURSES FOR YOUNG RESEARCHERS

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CEDEX participates in the European GEOLAB project through the CEDEX Track Box (CTB), belonging to the Geotechnical Laboratory.

The project involves 10 European institutions operating 11 unique test facilities in the field of Geotechnical Engineering. In these facilities, it is possible to study the behaviour of the ground, its interaction with structures, and its effect on the environment. These studies are carried out by physical models.

The project aims to integrate these national facilities to advance innovative studies to meet the new challenges facing Critical Infrastructures in Europe.

Among the tasks of the GEOLAB project is also the knowledge transfer. In this framework, CEDEX has organised the first workshop of the project, in a hybrid format. It included working meetings of the project members, open days with private companies, and a training course for young researchers.

Proyecto europeo GEOLAB

https://project-geolab.eu/

Project funded by the Horizon 2020 research and development programme, under Grant Agreement No. 101006512

Details of the single installations included in the GEOLAB project.

Singular Facility	Country/City	Owner	Physical model size
Large-scale triaxial apparatus	Slovenia/Ljubljana	UM/ZAG	Small
TU Delft Geotechnical centrifuge	The Netherlands/ Delft	TU Delft	Small
Beam and Drum Centrifuge	Switzerland/ Zurich	ETHZ	Small
Uni-Eiffel Geo-Centrifuge	France/ Bouguenais	Uni Eiffel	Small
Geo-Centrifuge	The Netherlands/ Delft	Deltares	Small
Schofield Centre	United Kingdom/ Cambridge	UCAM	Small
TU Delft Large Scale Geotechnical Physical Modelling Facility	The Netherlands/ Delft	TU Delft	Medium
GeoModel Container	The Netherlands/ Delft	Deltares	Medium
TUDa Geotechnical Test Pit	Germany/Darmstadt	TUDa	Large
CEDEX Track Box	Spain/Madrid	CEDEX	Large
Geo-Test Sites	Norway/Onsøy, Tiller, Halden, Øysand and Svalbard	NGI	Full size

TECHNICAL ASSISTANCE TO THE DIRECTORATE GENERAL OF ROADS ON THE PATHOLOGY OBSERVED IN THE N-420 ROAD, ESCUCHA (TERUEL)

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The Geotechnical Laboratory of CEDEX gives support to the Directorate-General of Roads, of MITMA, for different geological-geotechnical problems observed in various sections of the N-420 road nearby Escucha (Teruel).

The section affected by the pathologies is located between km 648+290 and 649+260. In this area, the road runs over an embankment.

The existing problems are related to the deformations observed in the road platform, which are reflected in the formation of cracks, ondulations and irregularities in the pavement. This has caused road safety and traffic problems, and an increase in the cost of road maintenance.

To determine the origin of the pathologies and to propose appropriate corrective measures, CEDEX, in collaboration with the Road Demarcation, has carried out the following tasks:

- Monitoring movement and deformations by inclinometer and micrometric sensors located in the boreholes.
- Monitoring the piezometric level by open piezometers.
- Monitoring the surface movements by total stations.
- Performing Dynamic penetration tests (DPSH).
- Performing laboratory tests over undisturbed samples.

The most relevant geotechnical aspect related to the road construction phase, and the results of the new geotechnical prospection carried out for this purpose (15 boreholes) were also analysed.

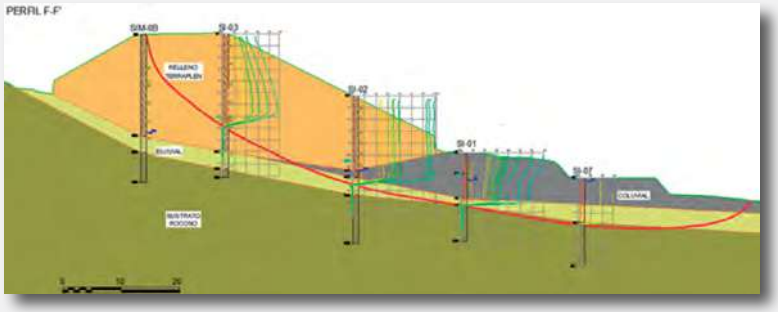
Based on the information provided by the monitoring and the analysis of the available documentation, possible causes of the observed pathology have been identified.

For their correction, various alternatives have been proposed, which have been compared with each other using technical, economic and functional criteria, always bearing in mind the sustainability and resilience of the action.

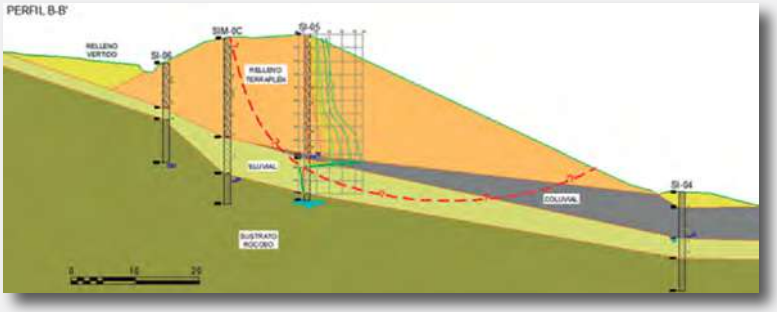
↑ Cracks in the pavement.

↑ Deformation of the road surface.

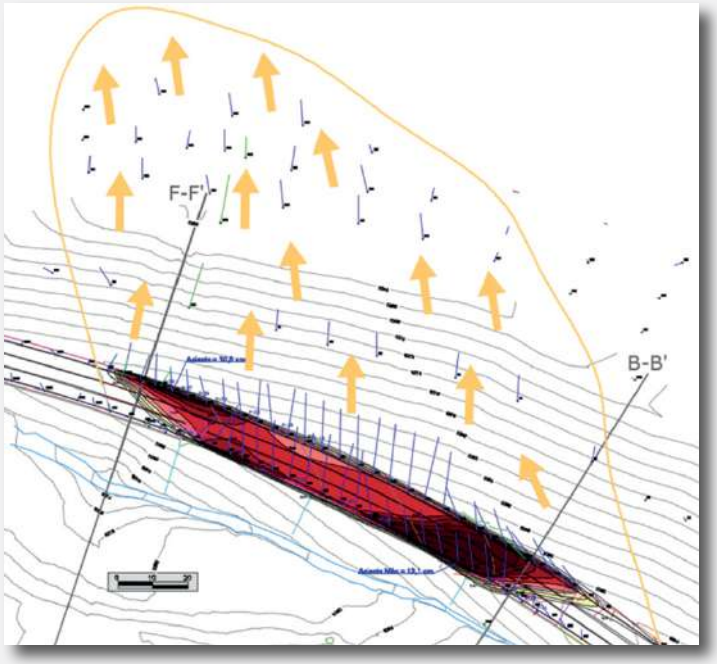
Finally, a report of conclusions has been drawn up recommending the implementation of the corrective alternative that's considered optimal. Subsequently, technical support will continue to be provided during the corresponding work.



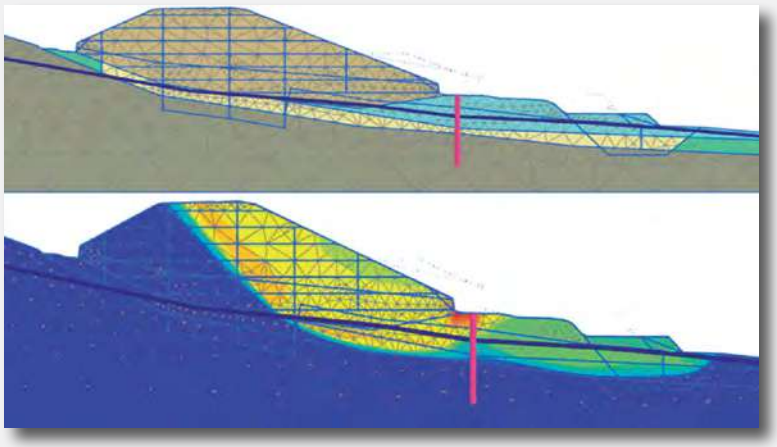
↑ Cross-section F-F'. Lithological scheme, inclinometers and instability surface.



↑ Cross-section B-B'. Lithological scheme, inclinometers and instability surface.



↑ Floor plan with slip interpretation.



↑ Finite element models (FEM) for the technical analysis of the different action alternatives.

EXHIBITION 'SCIENCE AND WATER. MANUEL LORENZO PARDO: A HYDRAULIC ENGINEER'

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Since its foundation, the Centre for Historical Studies of Public Works and Urban Planning (CEHOPU) has always stressed the need for research and knowledge dissemination on engineering heritage. One of the lines of work carried out by the centre involves promoting the work of Spanish engineers who have been closely linked to the Centre for Studies and Experimentation in Public Works (CEDEX). Given this background, it comes as timely the organization of the temporary exhibition *Science and Water. Manuel Lorenzo Pardo: A Hydraulic Engineer is underway*, being scheduled to open at the Villanueva Pavilion of the Royal Botanical Garden in Madrid, in January 2023.

Manuel Lorenzo Pardo (1881-1953) was one of the most outstanding civil engineers of the first half of the 20th century. He specialised in the field of hydraulics, his most remarkable merits and works include those relating to the promotion, planning, and execution of hydraulic projects of paramount importance: From the reservoir project in Reinosa, to the conception and creation of the current Hydrographic Confederations and CEDEX's Centre for Hydrographic Studies, to the drafting of the National Plan of Hydraulic Works (1933), the first to contemplate an integrated vision of the country's hydrological problems, based on the different realities of the hydrographic basins, and taking into consideration not only hydrological, but also geographical, climatic, forestry geographical, climatic, forestry, and economic issues. The model for the division of the Spanish territory in hydrographic basins with greater autonomy for better planning and management of the country's water resources, proposed by Lorenzo Pardo, would serve as example and inspiration for other countries.

Not only is the figure of Manuel Lorenzo Pardo interesting for his work in the field of hydraulic engineering, but also for his role in the management of institutional bodies. He was a truly charismatic man for the features of his personality and the quality of his relationships and extra-professional activities, strongly connected with the scientific and cultural environment of his time. It should also be underscored his work as a populariser of science, where he achieved a notable recognition, stemming from his participation in national and international events of great importance. The work and writings of Manuel Lorenzo Pardo have outlived him, to the extent that a large part of the of the hydraulic policies developed in the second half of the 20th century draws on his national plan.

This exhibition will make it possible to carry out an in-depth and necessary research into the life and works of Manuel Lorenzo Pardo, showing unpublished documentation linked to the engineer and the related institutions. Furthermore, it will offer a unique opportunity to assess the intellectual dimension of his work and complex legacy.

↑ Manuel Lorenzo Pardo explains the *National Plan of Hydraulic Works* of 1933 during the exhibition dedicated to it a year later at the Palacio de la Música in Madrid.

↑ *The Traveler,* by Pelayo Ortega (Work belonging to the Spanish Ministry for Transports, Mobility and Urban Agenda).

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES, MOVILIDAD Y AGENDA URBANA
VICEPRESIDENCIA TERCERA DE GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
CEDEX CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS