



IDEATION

D2.3: MSF results and functional and non-functional requirements (KER1) V1

Deliverable 2.3

WP2

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ABSTRACT	<p>The IDEATION project develops a roadmap, including a reference architecture and knowledge base, for a European Digital Twin (DT) inland waters, interoperable with the Digital Twin Ocean (DTO), creating a comprehensive DT of Europe's hydrosphere.</p> <p>As part of WP2, between August 2024 and February 2025, the project engaged 348 stakeholders (SHs) across 15 reference scenario (RS) countries, including two newly added in Portugal and Norway. Leveraging Water-Oriented Living Labs (WOLLS) and project partners' networks, a variety of engagement activities were conducted, including Multi-Stakeholder Forums (MSFs), bilateral discussions, networking events, and surveys. The collected data were analyzed and structured into functional and non-functional DT requirements. Additionally, SHs validated priority types of water for each RS, refining the initial classification presented in D2.1, and provided additional insights on potential DT applications and general DT characteristics. This information contributes to the work of T2.3, WP4, and WP5. The first round of MSFs will finish in May 2025, providing additional SH input for refinements of the DT requirements and use cases.</p>		



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EXECUTIVE SUMMARY

The IDEATION project aims to provide a roadmap, including a reference architecture and knowledge base, for the future development of a European Digital Twin (DT) inland waters, interoperable with the Digital Twin Ocean (DTO) under development, creating a comprehensive DT for Europe's hydrosphere. This initiative supports the EU's "Restore our Ocean and Waters" mission by enhancing water management through digital innovation.

Work Package (WP) 2 focuses on stakeholder engagement (SHE) to identify the DT requirements and validate the DT reference architecture and roadmap (WP4 and WP5). Through Multi-Stakeholder Forums (MSFs), bilateral discussions, and surveys, WP2 collected insights on functional and non-functional DT requirements. Between August 2024 and February 2025, the project engaged 348 stakeholders (SH) across 15 reference scenarios (RS) countries, leveraging Water-Oriented Living Labs (WOLLs) and project partners' networks. The number of RSs was increased from 13 to 15, with Portugal and Norway newly added.

MSFs yielded a wealth of information that was organized in this deliverable as DT functional and non-functional requirements presented in Section 4. Additional insights from SHs, in particular on potential uses of the DT such as for supporting early warning systems, legal evidence, education, infrastructure planning, and risk assessment will be used to develop the project use cases in T2.3 that has just started. Finally, SHs validated priority water types for each RS, refining the initial classification presented in Deliverable (D2.1). Based on the prioritization, Task 2.3 has preliminarily identified one RS per each type of water for which it will develop a use case, i.e. rivers and estuaries, lakes, reservoirs, wetlands, snow and ice, urban water, groundwater, and coastal water.

The first round of MSFs will finish in May 2025, with further engagements planned at international events as well with follow up MSFs in the RS countries targeting the prioritized water types.

List of acronyms

Short name / Acronym	Full name / Description
DT	Digital Twin
DTO	Digital Twin Ocean
D	Deliverable
EU	European Union
IoT	Internet of Things
KoM	Kick-off Meeting
MSF	Multi-Stakeholder Forum
QH	Quintuple Helix
RS	Reference Scenario
SH	Stakeholder
SHE	Stakeholder engagement
WOLL	Water-Oriented Living Lab
WP	Work Package
WPE	Water Projects Europe
Open KIWAS	Open Knowledge Inventory for Inland Water Systems

1.0 Introduction

Digital innovation is crucial to transform the European Union (EU) into a modern, resource-efficient, and competitive economy considered essential to achieve climate neutrality by 2050. In this context, the EU Mission “Restore our Ocean and Waters” aims, among other things, to create a comprehensive and cohesive approach to managing Europe's aquatic environments, leveraging regional strengths, and addressing local challenges to achieve broader environmental, social, and economic benefits. Cross-cutting enabling actions will support this objective, broad public mobilization and engagement, and a digital ocean and water knowledge system, known as Digital Twin Ocean (DTO) currently under development.

In this context, the IDEATION project delivers a roadmap, including a reference architecture and knowledge base, for the integration of inland waters into the DTO in an interoperable way, for a comprehensive digital representation of the hydrosphere as a whole in Europe. This integrated Digital Twin (DT) will facilitate efficient integrated water management by addressing both inland and ocean waters.

Within IDEATION, Work Package (WP) 2 focuses on stakeholder engagement (SHE) for the co-creation of the roadmap, including reference architecture and knowledge base, for the DT inland waters. WP2 fosters cooperation and commitment of stakeholders (SHs) by leveraging the European Water-Oriented Living Labs¹ (WOLLS) and the project partners' national and international networks. SHs are engaged via Multi-Stakeholder Forums (MSFs) and other activities such as bilateral talks, networking activities, and surveys as needed across reference scenario countries. These engagement activities aim to collect SH functional and non-functional requirements (first round of SHE) and to refine the reference architecture, roadmap, and to prioritize solutions and formulate policy recommendations (second round of SHE).

This report (Deliverable D2.3) presents the results of the first round of MSFs, bilateral talks, surveys and networking activities conducted between August 2024 and February 2025. The initial list of reference scenario (RS) countries, including the respective WOLLS, project partners' countries, and related stakeholders provided in D2.1, was used as the entry point for organizing the MSFs and bilateral talks. Using a snowballing approach and the network of the project partners, the list was expanded, allowing it to reach a broader audience. This resulted in engaging SHs across 15 reference scenario (RS) countries for a total of 348

¹ WOLLS are real-world environments where diverse stakeholders, including scientists, innovators, local communities, businesses, and policymakers collaborate to develop, test, and validate innovative solutions to water-related challenges. The WOLLS are designed to address issues related to climate change, water management, biodiversity, and sustainable development by fostering continuous innovation and practical problem-solving. Overall, WOLLS represent a dynamic approach to water management and policy development, promoting a Water-Smart Society that is secure, resilient, sustainable, and adaptive to future challenges.

stakeholders engaged. An updated stakeholder register will be reported in D2.2 due by M18 (November 2025).

The results of the MSFs, bilateral talks, and surveys, documented via the project meeting reports and survey (internal documents; templates in Annex 1 and Annex 2), were analyzed by all technical project partners and compiled into a set of functional and non-functional DT requirements presented in Section 4. The DT requirements, together with the Open KIWAS (D3.1, that will be submitted on M8, as this deliverable), will be used by WP4 and WP5 to design the DT reference architecture and the SWOT, first, and the roadmap, next. The first round of MSFs will end in M12 (end of May 2025) continuously informing the activities of WP4 and WP5 via the bi-weekly WP2 meetings.

This report is organized as follows: Section 2 presents the SHE methodology; Section 3 presents the results of the engagement, including an overview of the activities conducted and the SHs engaged across RSs, and a revised version of the water types of interest to the RS according to the SHs. Section 4 presents the DT requirements. Conclusions and next steps are presented in Section 5.

2.0 Methodology

WP2 developed the SHE plan for the first round of MSFs (overview in Figure 1) and accompanying materials including consent forms, templates, and guidance documents, to be used by the RS coordinators in their own SHE activities throughout the project.

During WP2 bi-weekly meetings, which started in July 2024, the plans and progress of the SHE activities in each of the RS were discussed and KWR provided support to the RS coordinators where necessary. The meetings were also used to keep track of the MSFs and bilateral and networking meetings that were being organized and for group discussions about the data collected.

Data collection for the DT requirements took place via SHE meetings in each of the RS, starting with bilateral talks and a Kick-off Meeting (KoM). Each of these meetings was reported in a SHE report according to the templates provided by WP2 (template in Annex 1). These reports were used to collect the information from the SHE activities. The collected information was analyzed by all technical project partners over four meetings (29/01/2025, 06/02/2025, 12/02/2025, and 17/02/2025) and aggregated into functional and non-functional DT requirements presented in Section 4.

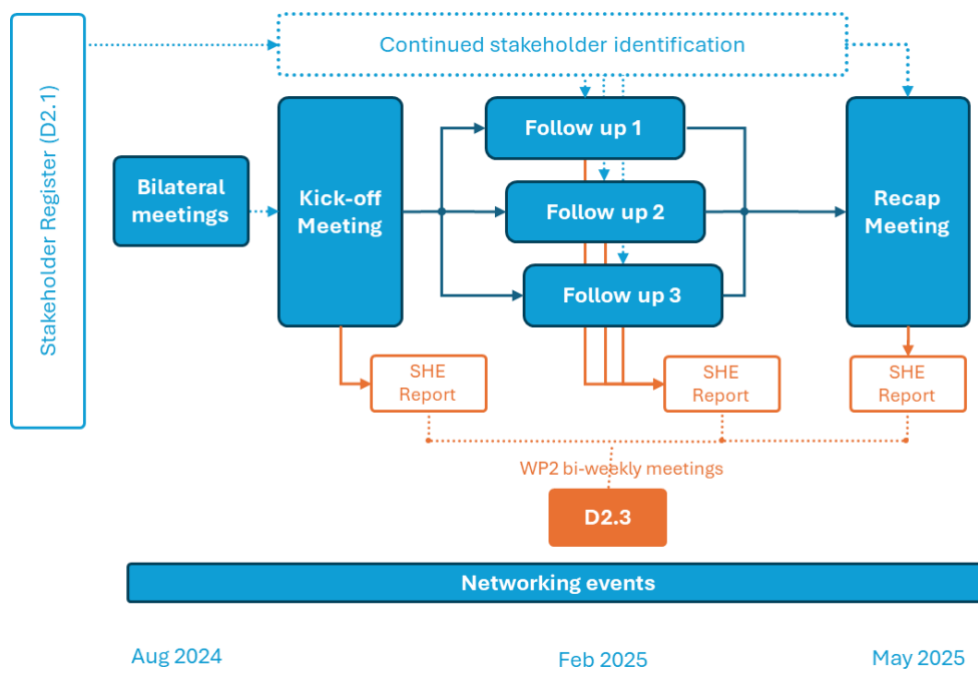


Figure 1 - Stakeholder engagement plan for the first round of MSFs

Starting in August 2024, RSs undertook to organize a KoM, often preceded by bilateral, introductory meetings. The aims of the KoMs were to:

- Introduce the IDEATION project, the DTO, and the ideas for the future DT for inland waters to SHs. For this, a presentation was prepared by the project coordinator. In

some KoMs the coordinator was present to deliver this presentation, while in others the RS coordinator gave the presentation in the local language.

- Validate the types of water the RS will focus on. While the types of water had tentatively been distributed between the RS, the KoM was used to discuss the most relevant types of water with SHs and to see if the distribution matched their perception. In some RSs, the types of water were adjusted accordingly (see Table 4).
- Identify the value of a DT for inland waters. Together with SHs, the types of activities and problems were identified for which a DT for inland waters would have added value.
- Discuss the requirements for a DT for inland waters. This included discussion about the application of the DT (how SHs envisioned they would use the DT), and identifying some of the preconditions (requirements) that should be met in order for the DT to be relevant and useful.

These goals were translated into questions to be discussed during the meeting and answered by the SHs in writing via a survey (see template in Annex 2) at the meeting or post-meeting. Different survey options were available depending on how it was administered (printouts, google form, and Word documents). The Swiss reference scenario opted for one-on-one interviews instead of a group meeting. An MSF will be planned as a follow-up.

Follow-up meetings for this first round of MSFs (until M12; end of May 2025) are currently being planned (the UK and the Spanish RS already hosted one) with specific groups of SHs, aiming particularly at different types of users, e.g., technical users, strategic users, researchers, etc., to allow for more targeted discussions with these groups. Follow-up meetings will focus on the types of waters selected per RS. A final recap meeting across RS will also be planned to allow SHs across countries to exchange on key issues emerged during the MSFs.

Furthermore, additional MSFs will take place at specific national or international events such as the the Aquatech International Conference in Amsterdam (The Netherlands) on March 12th, the World Water Day on March 21st in Helsinki (Finland), jointly organized with the Digital Waters Flagship (DIWA/SYKE), and the *Waterinfodag* on March 27th in 's-Hertogenbosch (The Netherlands).

The additional information collected via follow-up meetings and additional MSFs until M12 will be shared with WP4 and WP5 for their activities via WP2 bi-weekly meetings and recorded via meeting reports and meeting logs.

3.0 Overview of stakeholder engagement activities

3.1 Overview of stakeholder engagement activities

An overview of the SHE activities conducted between August 2024 and February 2025 per RS is provided in Table 1. SHE activities included: bilateral meetings, usually organized to familiarize with the core group of SHs, such as WOLLs coordinators, and introduce the project and the objectives of the MSFs; MSF KoM which could take place in person, online, or hybrid; one-on-one interviews; networking events including participation to existing events or setting up of networking events to develop new RS or align activities between projects; and follow-up MSFs. The table reports the total number of participants to the activities including project partners, who take different roles in the activities depending on their expertise, from facilitators to technical experts contributing to content discussion.

From the very beginning, networking activities with organizations, networks and relevant EU and other projects have been performed. These activities range from bilateral talks to align activities and events to the organization of cross-project events, and specific collaboration activities with related projects. Such activities will continue throughout the lifetime of the IDEATION project.

Being coordinated by CERTH and participated by CETAQUA, KWR, UNEXE, FIWARE, ENG, WE (all partners of IDEATION), MSF organized under the umbrella of WATERVERSE (ID: 101070262) have been used to also co-organize some of the MSF of IDEATION (KoM in Germany and Cyprus, and follow-up meeting in Spain). Moreover, WATERVERSE and IDEATION are the organizers of the Water Projects Europe (WPE)² event that will take place in conjunction with the Aquatech International Conference in Amsterdam on March 12th.

A meeting with the Aqualnra (ID: 101094434) consortium was held in Barcelona on November 6th, 2024, during a project board of Aqualnra. The two projects identified similarity and points of contact and are planning further meetings and initiatives in the future.

Following the suggestion by the Project Officer of IDEATION, in order to cover the Danube and Black Sea Lighthouse, the coordinators of EcoDaLLi (ID: 101093908) and DALIA (101094070) have been contacted and a meeting organized with them. They will both participate in the WPE at Aquatech. Similarly, the Danube4All (ID: 101093985) project was contacted and a meeting will be organized in the following months. An online meeting was also held with the coordinator and a partner of the SUNDANSE (ID: 101156533) project, they participated in the Romanian MSF, and will present the project during the WPE at Aquatech.

To reach more stakeholders in Malta, thanks to the participation of UNEXE in the consortium, the coordinator of WATERLINE (ID: 101071306) was also contacted and an online meeting was held.

² <https://watereurope.eu/event/water-projects-europe-at-aquatech/>

In addition, the coordinator of FERRO (ID: 101157743) reached out to IDEATION asking for an online meeting. Considering the interests of the projects on the lakes, as a type of inland water, FERRO will participate in the WPE at Aquatech. Moreover, a meeting with the FERRO's sister projects (ProCleanLakes, ID: 101157886; EuroLakes, ID: 101157482; and FutureLakes, ID: 101156425) and IDEATION has been scheduled on March 3rd, 2025 during the Mission Ocean and Waters Forum.

Finally, in December 2024, during the plenary meeting of the ARC Alliance, the Aqua Research Collaboration to which the research organizations CETAQUA (Spain), KWR (Netherlands), LNEC (Portugal), IWW (Germany), NTNU (Norway), and SINTEF (Norway) belong, IDEATION was presented and feedback was used for this report. This initiative led to add 2 new RSs, Portugal and Norway. The KoM MSF of the Portuguese RS took place already (thanks to the support by LNEC; Table 1) and the one in Norway by NTNU and SINTEF is planned for the following months.

Table 1 - SHE meetings per RS and exchanges with other projects and initiatives. KoM = Kick-off meeting; Bilateral = Bilateral meetings between project partners and WOLL representatives or particular stakeholders; Follow-up = meeting with a particular group; Networking = meetings with other projects' consortium.

RS	Type of meeting	Format	Date	# participants ³	Comments
Finland	KoM	Online	14-11-2024	6	WOLL representatives
Malta	Bilateral	Online	07-10-2024	6	WOLL representatives
	Networking	Online	21-01-2025	5	WATERLINE - IDEATION project alignment
Spain	Bilateral	Online	30-07-2024	3	First meeting with the Catalan Water Partnership (owners of the WOLL)
	Bilateral	Online	1-10-2024	6	Presentation of the project to the Agbar partner Aquatec
	Bilateral	Online	10-10-2024	3	Spain MSF organization with the Catalan Water Partnership
	Bilateral	In person	22-10-2024	5	Preparation of the MSF in Andalusia together with the WATERVERSE one
	KoM	In person	12-11-2024	14	Spanish MSF
	Bilateral	Online	15-11-2024	2	Catalan Water Agency (Agència Catalana de l'Aigua)
	Bilateral	Online	18-12-2024	4	Ebro Observatory (Observatori de l'Ebre)
	Follow-up	In person	30-01-2025	22	MSF WATERVERSE and follow-up of IDEATION

³ The number of participants includes partners of IDEATION in charge of leading or supporting the meeting.



France	Bilateral	Online	08-11-2024	3	Introduction of IDEATION to Veolia
	KoM	Online	14-01-2025	7	French MSF
Italy	Bilateral	Online	24-10-2024	6	WOLL representatives
	KoM	Online	30-01-2025	19	Italian MSF
Belgium	Bilateral	Online	21-11-2024	6	WOLL representatives
Switzerland	Bilateral	Mix	01-2025	5	Interviews
Netherlands	KoM	Hybrid	12-09-2024	13	DT, data technical experts meeting
Germany	Bilateral	Online	20-08-2024	5	Present IDEATION and first SH contact
	Bilateral	Online	18-11-2024	5	Meeting to align IDEATION-WATERVERSE MSF in Germany
	Bilateral	In person	20-11-2024	3	Meeting with partners of FIWARE during the SmartCityExpo in Barcelona
	KoM	Hybrid	20-01-2025	19	18 participants in person + 1 online
Cyprus	KoM	In person	31-10-2024	40	Joint IDEATION and WATERVERSE MSF
UK	KoM	Online	15-10-2024	8	-
	Follow-up	Online	24-01-2025	6	-
	Networking	Online	21-02-2025	5	Meeting with ESA DT-Coastal Processes and Extremes
Greece	KoM	In person	03-12-2024	17	-
Romania	KoM	Online	03-02-2025	13	-
	Bilateral	Online	14-11-2024	3	With Romanian advisory board member
	Networking	Online	22-01-2025	4	SUNDANSE - IDEATION project alignment
Portugal	KoM	Online	29-01-2025	12	Portuguese MSF
—	Networking	In person	06-11-2024	15	Aqualnra - IDEATION project alignment
	Networking	Online	14-11-2024	4	EcoDaLLi - IDEATION project alignment
	Networking	Online	29-11-2024	3	DALIA - IDEATION project alignment

	Networking	In person	04-12-2024	8	ARC Alliance meeting
	Networking	Online	22-01-2025	3	FERRO - IDEATION project alignment
	Networking	Online	19-02-2025	5	FERRO - IDEATION and the Helmholtz-Centre for Environmental Research
	Networking	Online	21-01-2025	12	Meeting with VLIZ regarding the DTO
	Networking	Online	21-02-2025	17	Meeting with Mercator regarding the EDITO-INFRA project

An overview of the type of SHs engaged is presented in Table 2. The table reports the overall number of SHs organized per quintuple helix (QH) type that are in the SH register as per February 2025. These include:

- SHs who were engaged via different means of communication, including MSFs, bilateral meetings, networking activities, email exchanges and informal talks.
- SHs who were invited to project activities, could not join but expressed interest in follow up activities.
- SHs who did not reply to a first invitation but are deemed important, and with which the project will make another attempt to engage.
- SHs that the project has mapped but not engaged yet.

Table 2 also provides the total number of SHs engaged per RS and overall (via MSFs, bilateral meetings, networking activities, informal talks and email exchanges) as per February 2025.

Cross-cutting SHs are SHs whose contribution is relevant to the entire project as well as, when pertinent, also to a specific RS. This category also includes IDEATION project partners with technical expertise, who contribute to the content discussion with SHs during engagement activities. Project partners that act as support or facilitators are not included in the SH register and therefore also not in Table 2. Therefore, the numbers in Table 2 are higher than the numbers in Table 1.

Overall, both technical DT/data experts and potential DT users were engaged across different organizations, covering the QH spectrum, with the prevalence of SHs in the academic system. The category media, citizen, culture which includes NGOs, foundations, art, culture and citizen groups as well as media is the least represented with only 17 SHs due to the highly technical nature of the project. More representatives of this category will likely be engaged in the second round of MSF, in particular potential users, when the reference architecture and roadmap will be validated.

Table 2 - Overview of stakeholders identified and engaged in IDEATION updated to February 2025. M = male; F = female; X= only an organization was identified, not a specific individual yet; QH type: environmental representatives (the fifth type of the Quadruple

RS	# SHs in the IDEATION SH register per QH SH type					# SHs engaged as per February 2025	Gender		
	Research	Industry	Governments/agencies	Media, citizen, culture	Total #		M	F	X
Finland	9	0	33	6	48	45	30	18	0
Malta	1	0	6	0	7	7	6	1	0
Spain	14	12	11	0	37	36	29	8	0
France	2	4	1	0	7	7	5	2	0
Italy	20	9	9	0	38	38	26	11	1
Belgium	0	4	4	0	8	8	4	3	1
Switzerland	6	1	0	0	7	7	6	1	0
Netherlands	15	2	0	0	17	17	14	3	0
Germany	3	9	13	2	27	27	19	8	0
Cyprus	10	4	26	0	40	40	28	12	0
UK	2	9	2	5	18	18	9	6	3
Greece	3	9	12	0	24	15	13	11	0
Romania	8	2	9	0	19	19	11	8	0
Norway	2	0	0	0	2	2	1	1	0
Portugal	17	2	14	0	33	24	16	17	0
Cross-cutting SHs* ⁴	47	2	0	4	53	38	35	18	0
Total	159	69	140	17	385	348	252	128	5

3.2 Updated list of reference scenarios and WOLLS

The bilateral meetings, KoMs, and networking meetings were used to identify any additional SHs to be involved in follow-up IDEATION activities. This led to identifying 2 new RS and 2 new WOLLS, which have already been engaged. Furthermore, Water Europe has identified additional WOLLS in other countries beyond the current RS that will be contacted in the coming months to contribute to the project.

At the same time, 3 WOLLS initially contacted opted out, being the focus of their work not aligned with the objectives of the IDEATION project. Table 3 illustrates the changes that occurred. The initial stakeholder register (D2.1 submitted at M6) was updated with

⁴ Cross-cutting SHs include SHs who are relevant for the project across all RS, including project partners with technical expertise who contribute to content discussion with SHs;

additional names and organizations throughout the process and will continue to be updated as the IDEATION project progresses (the update will be presented in D2.2 due by M18).

Table 3 - Changes occurred in the list of reference scenarios and WOLLS

D2.1 submitted in August 2024		Updates as per February 2025		
Reference scenario	WOLL	New reference scenarios	WOLL	Changes occurred
Finland	Yes	--	Yes	Unchanged; via the project advisory board in addition to the WOLL new stakeholders have been contacted and an in person.
Malta	Yes	--	Opted out	Additional SHs in government agencies and university contacted via WATERLINE project; bilateral meeting held.
Spain	Yes	--	Yes	Unchanged
France	Yes	--	Opted out	Additional SHs in government agencies and university contacted via Veolia (to which CETAQUA belongs); bilateral meeting and MSF held.
Italy	Yes	--	Yes	Unchanged
Belgium	Yes	--	Yes	Unchanged; the WOLL has provided additional SHs beyond the WOLL to engage; they have been contacted; MSF will be planned.
Switzerland	Yes	--	Opted out	Additional SHs in government agencies and university contacted via project partner; 5 interviews conducted.
Netherlands	No	--	No	Unchanged
Germany	No	--	No	Unchanged
Cyprus	No	--	No	Unchanged
UK	No	--	No	Unchanged
Greece	No	--	Yes	A new WOLL called VesperX has been contacted and showed interest.
Romania	No	--	No	As part of the Danube lighthouse; multiple projects have been contacted (see networking activities in Table 1 and Section 3.1).
--	--	Norway	No	New reference scenario added via ARC Alliance; there is no WOLL in Norway.

				Networking event took place; MSF will be planned.
--	--	Portugal	Yes	New reference scenario added via ARC Alliance; there is also a WOLL in Lisbon called Lisbon Water Smart Living Lab. Networking event took place; MSF held (Table 1).

3.3 Stakeholder validated water types for each reference scenario

During the SHE activities, SHs across all RS were consulted on the availability and demand for DTs for different water types, as well as what should be the project's water type focus in each RS. They also reviewed the initial water type prioritization from August 2024 (D2.1). Their feedback helped validate and refine these priorities, improving the classification presented in D2.1. Table 4 presents the updated list of prioritized water types based on these discussions. In **Blue**, those validated and changed from initial proposal in D2.1; in **Green**, those validated and unchanged; in **Red** those not validated yet. Using this prioritization, Task 2.3 has preliminarily selected one RS per water type for developing a use case, highlighted in bold in Table 4.

Table 4 - Stakeholder validated types of waters

Reference Scenario	Rivers and estuaries	Lakes	Reser-voirs	Wet-lands	Snow and ice	Urban water	Ground water	Coastal water
Finland	1	3					2	
Malta			3			1	2	
Spain	2					1	3	
France	1	2	3					
Italy	3	2	1					
Belgium	2		3			1		
Switzerland	1	2 (lakes and reservoirs)			3			
Netherlands	1 (rivers and lakes)					3	2	
Germany	1					3	2	
Cyprus	1		2					3
UK	1					3		2
Greece	1	2	3	4				
Romania	1	3	2					
Portugal	x		x				x	
Norway (new RS; no type of water yet)	/	/	/	/	/	/	/	/

4.0 Digital Twin functional and non-functional requirements

During the MSFs, functional (F) and non-functional (NF) requirements of the DT were identified by the participating SHs. An overview of the requirements is provided in Table 5 (non-functional) and Table 6 (functional). Both types of requirements are crucial for building a robust, efficient, and user-friendly DT.

IDEATION adopts the following definition for DT requirements:

- **Non-Functional Requirements.** Non-functional requirements define quality attributes, constraints, and system performance characteristics. They describe how the system should operate rather than what it should do. Examples include performance, scalability, security, reliability, and usability.
- **Functional Requirements.** Functional requirements define the specific capabilities, behaviors, and operations a DT must perform. They describe what the system should do to achieve its intended purpose. Examples include real-time data acquisition from Internet of Things (IoT) sensors; simulations of different operational scenarios; predictive analytics for asset maintenance; integration with external systems; user interaction through dashboards, and visualization tools.

4.1 Non-Functional Requirements

Table 5 -Non-functional requirements for the future DT inland waters as identified by stakeholders

Category	Subcategory	#	Non-functional requirement	Proposed by RS
Scale	Temporal	1	The DT should cover short, medium and longer timescales and appropriate time resolutions of data, depending on the given data (e.g., data from a glacier or from a river).	CH, FR, NL, RO
		2	There should be clarity on which temporal scales the DT can cover	UK
	Spatial	3	The DT should be able to operate at a large, international scale connecting various existing digital systems, as well as be useful to local decision-making. The DT should cover different levels of geographic detail and appropriate spatial resolutions of the data.	CH, ES, FR, IT, NL, RO
Data	Data types	4	The DT should use data from real-world observations. Physical system understanding must be incorporated into data-driven techniques. (Physical based and empirical model).	CH, FR, NL
		5	The DT should be able to incorporate synthetic data, i.e., artificially generated data not produced by real-world events.	NL



	Data sharing	6	The DT should be based on a common structure for collecting and processing data (data lake). Data should be publicly available on a well-documented platform.	CY, IT, NL
	Data management	7	The DT should be based on standardized data management. (Open) data should be organized uniformly to account for different formats and scales). See also: Interoperability – Semantic.	FR, IT, Project entry
Interoperability	Technical	8	The DT should be easily accessible, intuitive, updated, visual, and provide simple indicators.	FR, IT, UK
		9	The DT should support system thinking. It should be able to systematically solve multiple problems.	FR, IT, UK
		10	The DT should be designed as a modular system. Modules should be interoperable with one another. The DT should provide a well-documented infrastructure to build new models upon.	GR, IT, NL, PT, RO
		11	Guidelines should be provided for the integration of new models.	NL
		12	The DT should be compatible with and/or integrate existing DTs.	CH, NL
		13	The DT should integrate different models and tools and should allow for consistent scaling of data formats.	NL
		Semantic	14	The DT should involve standardization of data models and adapters that can match different types of data.
		15	The DT should follow data standards and Open Science principles.	NL, Project entry
		16	The DT should enable connection with ML/AI predictive systems.	IT
	Viability of the DT	Uptake	17	The DT should be designed taking into account possible future exploitation modes of the DT.
18			The DT should have demonstrable added value relative to existing datasets and models	CH
Maintenance		19	The DT should be actively maintained over time. Responsibility of maintenance (including management of data sources) should be allocated.	FR, IT
Operating capacity		20	The DT should be able to manage (future) increased workload without compromising performance.	IT
		21	The DT should have appropriate capacity. For real-time use fast processing is needed while 'slower' uses (e.g., research), require less capacity.	FR, IT, NL, UK
Governance	Policy and legislation	22	Appropriate EU and national legislation should enable data sharing, security, and collaboration.	NL
		23	Environmental policies should stimulate the quality of data through comprehensive reporting.	NL



Cross-sector collaboration	24	The DT should foster collaboration between organisations on data exchange. Involvement at different levels of administration for data sharing along with private actors is required. See also: Interoperability - Semantic.	CY, IT
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4.2 Functional Requirements

Table 6 - Functional requirements for the DT inland waters as identified by stakeholders

Category	#	Functional requirement	Proposed by RS
Back-casting, monitoring, and forecasting	25	The DT should be able to predict and analyse possible cascading effects from events that happen within a water system.	CY
	26	The DT should provide models of past events to enable analysis and to develop predictive models.	IT
	27	The DT should allow for continuous updating of model parameters.	CY, IT
Extreme events	28	The DT should enable early warning to inform emergency responses.	CH, IT, ES, NL, RO, UK
	29	The DT should enable the evaluation of extreme weather scenarios.	CH, ES, NL, UK
	30	The DT should be able to include conditions for scenario development and prediction that go beyond those that are currently being monitored so as to account for extremes.	CH, ES, FR, IT, NL
Cross-domain linkages	31	The DT should enable linkage between atmospheric and hydrological data.	CH
	32	The DT should enable understanding of cross-ecosystem linkages. Modules should reflect biodiversity.	CH, NL
	33	The DT should enable scenario analyses of cross-domain future conditions, including climate, socio-economic, ecological, and land cover changes.	CH, ES, IT, NL, RO, UK
Assessment, monitoring, and forecasting of:	34	Sediment quality.	GR, RO, UK
	35	Algal blooms and nutrient and pollution retention and transport.	FR, GR, NL, UK
	36	Water quality and quantity.	CH, ES, FR, GR, IT, NL, PT, RO, UK
Decision-making	37	The DT should enable hierarchization of problems.	IT
Interoperability (technical)	38	The DT should be configurable (resolutions, model parameters, modules, etc.), automatically depending on incoming data or manually according to user needs.	CH
	39	The DT should enable use of existing as well as user-specific or non-public datasets. The DT should enable testing of these datasets and models. Related to data management as well.	CH, RO

4.3 *Additional stakeholder insights on the digital twin*

In addition to the DT requirements presented in Tables 5 and 6, SHs provided general insights on the future DT. These include:

- **Continuous Operation:** the DT models should run continuously to ensure real-time monitoring and analysis.
- **SH collaboration:** the DT should serve as a collaborative framework, enabling individuals and organizations (even across countries) to work together and benefit from shared activities in design, planning, and decision-making.
- **Documentation & Disclaimers:** clear documentation and disclaimers should address data accuracy and reliability concerns.
- **Data Reliability:** ensuring both data accuracy and reliable access to data is critical.
- **IoT Sensor Integration:** the DT should incorporate real-time IoT input data.
- **Historical Data & Meteorological Interactions:** the DT should integrate past behaviors and deterministic models while considering meteorological interactions to refine a global water model.
- **Standardization & Governance:** A committee of experts should oversee the development and maintenance of standards to guide future DT improvements.
- **User Responsibility & Communication:** Designated personnel should be responsible for using the DT, interpreting its outputs, and effectively communicating alerts and insights.
- **Phased Development Approach:** The DT should be developed iteratively, starting with core functionalities, followed by testing and incremental feature additions.
- **Economic sustainability and viability:** long-term financial sustainability including funds for administration, maintenance, update and upgrade should be ensured.

Furthermore, SHs suggested some potential applications of the DT inland waters. In particular, the DT should support:

- Assessing the effectiveness of potential interventions when predicting imminent issues (early warning and intervention assessment).
- Educational applications at various levels, including higher education, Massive Open Online Courses (MOOCs), and lifelong learning.
- Emerging legal applications, such as use in court as forensic or evidentiary support.
- Infrastructure planning to enhance water resilience and assess investments.



- Water availability planning.
- Risk prevention, management, and contaminant propagation simulation in urban water systems.
- A weather/climate module providing data on precipitation, temperatures, wind fields, solar/longwave radiation, evapotranspiration, and runoff.

These insights will help shape the DT architecture and roadmap (WP4 and WP5) to better meet SH needs and enhance the DT overall effectiveness. The envisioned applications will be particularly valuable for developing the project use cases (T2.3).

5.0 Conclusions and next steps

The IDEATION project establishes a foundation for a comprehensive and cohesive approach to managing Europe's aquatic environments as part of the European Mission "Restore our Ocean and Waters". In particular, it focuses on developing a roadmap, including a reference architecture and knowledge base, for a European Digital Twin (DT) for inland waters. The DT will be integrable and interoperable with the Digital Twin Ocean (DTO) under development, ensuring a holistic digital representation of Europe's hydrosphere.

Within the project, Work Package (WP) 2 is central to stakeholder engagement (SHE), fostering collaboration through European Water-Oriented Living Labs (WOLLS) and extensive national and international networks. Using an initial list of reference scenario (RS) countries, the project applied a snowballing approach to expand outreach, ultimately engaging 348 stakeholders across 15 RS countries, including two new RS in Norway and Portugal. Through Multi-Stakeholder Forums (MSFs), bilateral talks, networking activities, and surveys conducted by project partners between August 2024 and February 2025, WP2 has gathered valuable insights from SHs across the quintuple helix (QH). The collected data have been analyzed and compiled into functional and non-functional DT requirements and used for refining the priority water types in each RS (Section 3). These requirements, along with the Open KIWAS (D3.1 and D3.2), will guide T2.3, WP4 and WP5 activities.

Next steps

The first round of MSFs will finish in M12 (end of May 2025) and continue informing T2.3, WP4 and WP5 through bi-weekly WP2 meetings.

Further MSFs will be held in RS countries and at national or international events, including: Aquatech International Conference (March 12th, Amsterdam, The Netherlands); *Waterinfodag* (March 27th, 's-Hertogenbosch, The Netherlands); World Water Day (March 21st, Helsinki, Finland) jointly organized with the Digital Waters Flagship (DIWA/SYKE).

Follow-up meetings in the RSs are being planned with different SHs groups, including technical users, strategic users, and researchers, to facilitate targeted discussions. These meetings will focus on the water types selected by each RS. Additionally, a final recap meeting will enable cross-country exchange on key issues identified during the MSFs.

Over the past eight months, IDEATION has effectively mobilized and engaged a diverse network of QH SH across Europe. Moving forward, the project will sustain and expand this network, ensuring SHs' contributions will continue to inform the project activities.

ANNEX 1: Meeting report template

Meeting report for multi-stakeholder forums

This meeting report is to be filled out by the Reference Scenario coordinators, reflecting the information that was gathered during the meeting. Please note that it should be written in English for project purposes.

Reference Scenario	All / FI / MT / ES / FR / IT / BE / CH / NL / DE / CY / UK / GR / RO
Meeting date	dd/mm/yyyy
Meeting duration	X hours
Meeting type	In-person / Hybrid / Online
Language in which the meeting was held	

List of participants

List the participants that were present during the meeting

Name	Organisation	In person / online
Meeting organizer(s)		
Participants		

Total number of participants (including organizers):

Meeting agenda

Please copy-paste the meeting agenda here. Please include only items that were actually discussed during the meeting.



The value of a DT for inland waters

For whom did participants consider that a DT for inland waters would have value? In relation to what activity or problem?

In terms of functionality, what did stakeholders envisage or expect that this digital twin should do?

What preconditions were recognized for this digital twin to be relevant, useful, and viable?

Verifying the types of water

Following discussion with the participants, which types of water were selected for the remainder of the IDEATION stakeholder engagement process in your Reference Scenario?

Type of Water 1	Type of Water 2	Type of Water 3
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What were the main reasons for this decision?

If specific people were identified to co-lead the discussion for a type of water, please note their names here.

Type of Water	(possible) discussion (co)leaders

Identifying Stakeholders

Were specific 'types' of stakeholders identified that would need to be involved in the stakeholder engagement process?

Please list below the stakeholders that were identified.

Name (if available)	(type of) organization	Role, function, or level; user, developer, data provider (if known)	Type of Water (if applicable)





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Final remarks

Please provide any final remarks or comments that could not be included in the questions above.

ANNEX 2: Survey questionnaire

This survey was administered in person or via Google form.

1. Basic details

Name and last name

Organization

Email address

2. The value of a digital twin for inland waters

- a. For whom do you see that a digital twin of inland waters would have value? In relation to what activity or problem?
- b. What do you envisage or expect that this digital twin should do?
- c. What are the preconditions for this digital twin to be relevant, useful, and viable?

3. Types of Water

- d. In what types of water are digital twins available and/or most needed? Please specify the need or availability.
- e. Which types of water should we focus on? Tic the appropriate box

<input type="checkbox"/>	Rivers and estuaries
<input type="checkbox"/>	Lakes
<input type="checkbox"/>	Reservoirs
<input type="checkbox"/>	Wetlands
<input type="checkbox"/>	Snow and ice
<input type="checkbox"/>	Urban water
<input type="checkbox"/>	Groundwater
<input type="checkbox"/>	Coastal water
<input type="checkbox"/>	Transitional water

- f. Would you like to take the lead in discussing about a type of water? (or do you know anyone who might be interested in this?)

4. Stakeholders

- g. Who should be involved in this process as potential developers and/or users of the digital twin?




Name	Organisation / project	Type of water expertise (if applicable)	Developer, user or both

5. Your contribution

- h. In what ways would you like to be involved in this stakeholder process? E.g. as ambassador of IDEATION; discussion leader; participant; validator; etc. Please specify.
- i. Do you see yourself as a potential developer or user of the digital twin, or both/neither?
- j. What types of water are you specializing in, if any?

6. Do you have any final comments or additions?



IDEATION to prepare the development of the digital twin of the inland waters (rivers, lakes, reservoirs, wetlands, snow, and ice) addressing activities to be developed and to make it integrated and interoperable with the DTO for a unified digital twin of ocean and waters.



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