

# D5.4 Implementation documentation

## How to realize the DIRECTED Data Fabric and bring it into use

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# Report Overview

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# Executive Summary

This deliverable builds upon the high-level architecture of the Data Fabric which was laid out in D5.1. This document, D5.4, describes the implementation plan and forthcoming documentation of the Data Fabric. It is written in conjunction with D5.2, where the low-level design of the Data Fabric is detailed, and D5.3, where data protection and ethical aspects of the Data Fabric are documented. Therefore, several cross-references will be found among D5.1, D5.2, D5.3 and D5.4 all together summarising the preparations necessary to successfully develop, deploy and operate the Data Fabric in DIRECTED.

Based on the architecture design of the Data Fabric and user requirements detailed in D5.2 and D5.3, the prototypical DIRECTED Data Fabric will be developed to showcase the benefit of improved interoperability in our RWLs. This deliverable outlines the agile and sprint-based approach the DIRECTED project will follow to implement, deploy and refine the Data Fabric meeting the real user needs in the RWLs. Smaller sub-teams, so-called *task forces*, will be defined per RWL that integrate one representative per WP. The representative from the RWL hosts will act as product owner. Those small teams will meet on a regular and frequent basis to plan the development based on defined sprints.

As the implementation will also follow the co-design principles, feedback loops are planned in the course of the realization of the Data Fabric. As the core interest of the users is in the information product and its visualization and less on the technical details in the backend, the front-end will be the focus. To start the discussions, mock-ups have been designed, evaluated and refined during the design and implementation phase.

Subsequently, a testing regime has been developed, to ensure a reliable and safe operation of the Data Fabric. Tests need also to be defined by the model developers in DIRECTED to automatically validate model outputs.

Along with the implementation of the Data Fabric, training material is developed. Dedicated training is planned for the user roles defined in D5.3, but also on the ethical aspects and good practices. These trainings will also be linked from inside the Data Fabric, to allow users at any time to revisit the relevant material. Key aspects will crisply be integrated into the user experience of the Data Fabric to maximize awareness and lower the barrier to access the information from the training.

Besides training, user guides will also be provided for the more technical or experienced user who wants to quickly look up functionalities, opposed to receiving detailed training. The user guides will cover all aspects of the Data Fabric and will be developed along with the implementation as lightweight online resources.

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# List of Abbreviations

ACRONYM	DEFINITION
CCA	Climate Change Adaptation
CI/CD	Continuous Integration/Continuous Deployment
CPU	Central Processing Unit
DPI(A)	Data Protection Impact (Assessment)
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EMS	Emergency Management Service
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GUI	Graphical User Interface
MCDM	Multi-Criteria Decision Making
OGC	Open Geospatial Consortium
RWL	Real World Lab
SDI	Spatial Data Infrastructure
WP	Work Package

# 1 Implementation Approach

With the definition of the architecture of the Data Fabric and the collection of relevant user stories in D5.2 and D5.3, the foundation to implement the Data Fabric has been laid out. To further stick to the co-design principles inherent to the entire DIRECTED project, we will combine the Agile development circle with Scrum sprints to realize the Data Fabric. The detailed implementation will be managed within the project's [GitHub organization](#) and respective repositories for the Data Fabric. The components and features identified in D5.2 and D5.3 have therefore been translated into technical components and issues. The data sources providing the information shown in the mock-ups and later front-end are documented in D5.2. These are composed out of external as well as internal resources.

## 1.1 Task forces per RWL

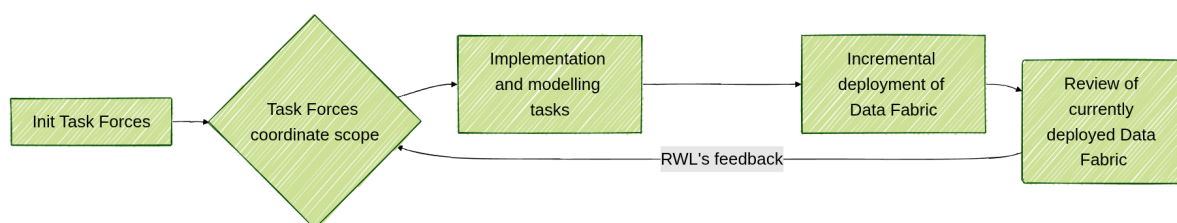
While all RWLs share a common base of the Data Fabric, each RWL has defined its specific interoperability use-case. In order to keep close contact between the RWL hosts and the development team, dedicated *task forces* per RWL are set up that steer the development for their respective RWL. These task forces shall be as small as possible, but also include all relevant Work Packages for the RWL. The central role in this smaller team is the *Product Owner*, who will be filled by a representative from the RWL hosts. The Product Owner is responsible for prioritizing the work on software development, but also thematic, i.e., model related aspects, and managing the product backlog (a list of all desired features and improvements based on the requirement analysis). Team members from WP 2 (i.e., models) and WP 5 (Data Fabric) will focus on the development and modelling tasks prioritized by the product owner. Representatives from WP 3 (governance) and WP 4 (knowledge co-production) support the team in their respective fields to prioritize and scope the product to support improved DRM and CCA through the developed software solutions.

The task forces will also define acceptance criteria (see appendix) for the features and components of the Data Fabric that can be used to evaluate the implementation and to ensure that the system meets end-users' expectations and operational needs.

## 1.2 Agile sprint based development

Borrowing from Scrum, a customer-centric framework that engages stakeholders at the end of each sprint, we foster regular feedback to keep the product aligned with user needs. Through sprint reviews and retrospectives, the development becomes transparent by offering ongoing visibility into team progress, challenges, and dynamics. Short and iterative sprints support adaptability, allowing teams to respond quickly to changes in requirements or scope without disrupting the project. By focusing on delivering directly deployable increments (at <https://directed.dev.52north.org>), we continuously grow and enhance the Data Fabric.

The defined implementation phases, so-called sprints, will start on a bi-weekly basis and can adapt according to needs of the entire team. Sprints are a continuous series of short and very scoped development phases, including a feedback step at the end of every sprint. The scope of each sprint is coordinated by the respective task forces, who also lead the change over meetings from one sprint to the next one. The product owner is responsible to provide feedback (from the RWL host or stakeholders) on the achievements. During the course of the development, different types of feedback will be necessary, e.g., on the integration of back-end components in the modelling chain or on the front-end design.

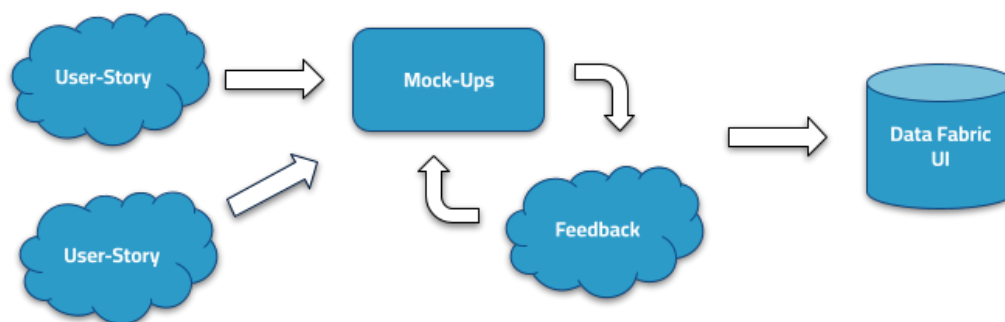


*Figure 1: Sketch of the sprint based development where the RWLs are continuously integrated and integral part of the development.*

Code documentation, guides and training will be developed along the implementation process. End-user feedback will provide an assessment whether the documentation is clear and sufficient, enabling users to understand the system's usage.

## 2 Front-End co-design

During the requirement analysis, the DIRECTED project team has developed personas and user stories together with RWL hosts and stakeholders during extensive joint workshops (see D5.2). In this process, mostly functional requirements and information needs have been identified, but the look and feel of the graphical user interface (GUI) has still to be developed. In order to stick to DIRECTED's co-design principles, this will also be done in close collaboration with our RWL hosts and stakeholders. [Figure 2](#) gives a conceptual process view of the interplay between user stories, mock-ups and the Data Fabric. This section provides an overview of the components of the GUIs and provides first mock-ups that will be used as starting points for the discussion with the future users.



*Figure 2: Sketch of the conceptual interplay between user stories, mock-ups and the Data Fabric in DIRECTED's co-design approach.*

# 2.1 RWL 1 - Capital Region of Denmark

## 2.1.1. Overview

The Capital Region of Denmark, with a focus on the Roskilde Fjord, requires a user-friendly web-GIS GUI for future planning efforts using flood simulations and impact assessments, as well as uncertainty analysis for adaptation measures. In the current status, several different potential GUI design views have been developed and presented to the stakeholder groups, in order to engage with stakeholders in how usable the mock-up interfaces of the Data Fabric could be. The following list gives an overview of the components of the user interface, which will be described in detail below:

- Dashboard
- Layer Control Panel
- Single and Split-Map View
- Split-Map Drop-Down Boxes
- Map pan and zoom
- Latitude Longitude Pin
- Address Search
- Data Catalog Search (for restricted user-access/Data Steward View)

The **Layers Control Panel** is the central control component within the mock-up GUI. It is directly connected to the dashboard, and dictates which layers are displayed in the interactive web-map, and which data are to be displayed and/or compared in the dashboard. The layers control panel for RWL 1 contains simulation outputs from CLIMADA from the Storm Bodil event in terms of damage-cost and impact per sector, future climate projections with impacts, as well as uncertainty analysis comparing between different model outputs ([Figure 4](#), left).

The **Analysis Dashboard** contains the graphical data components displayed from the layers selected in the layers control panel. In the lens of RWL 1, this includes a graph for water discharge per time-step, and building asset damages such as buildings, roads and traffic, critical infrastructure, and people and health. While these asset damage categories could change depending on which assets stakeholders decide they would like to view in the GUI, these damage outputs are all readily available within the DTU Damage-cost model, and can be used as such. Additionally, the layers panel enables the viewing of uncertainty in modelled outputs; these are then also viewable in the dashboard, where users would be able

to view the uncertainty in modelled outputs, i.e., which modelled parameters are driving the uncertainty in simulated outputs through boxplots, a scatterplot, and an uncertainty histogram ([Figure 4](#), right).

The **Single and Split-Map View** functionality enables the user to toggle between two different layers for comparison in the interactive web-map via map **drop-down boxes**. Split map view also dictates whether these data layers are then compared in the dashboard. For example, in [Figure 5](#), the user has selected to view a split map between the original levels of the Storm Bodil event and an increase of 20% precipitation (which could be, for example, RCP2.5). This selection from the layers control is then reflected in the dashboard graphs, as a comparison between these two data layers in the observed vs. predicted water discharge, as well as the original damage to assets vs. the damage incurred at increased levels of precipitation. If split map view is not enabled, the dashboard then reflects only the data for the single layer which was selected, i.e. in [Figure 3](#).

The **Latitude and Longitude Pin** can be placed in the interactive web-map to give the user a sense of where they are. It is not connected to the analysis dashboard, and is seen in the top right corner of [Figure 3](#).

Similar to the latitude and longitude pin, the **Address Search** enables the user to have a better understanding of where they are in the web-map. It is also not connected to the analysis dashboard and does not provide address-specific analysis ([Figure 3](#)).

Within the Layers control, there is a **Data Catalog Search** icon. This can be seen as a potential way for the Data Steward to access and add restricted data to the layers panel. While the architecture of the data catalog is still to be determined within the data scope the RWLs select, this could be one way for data layers to be accessed in the web-GIS view ([Figure 3](#)).

## 2.1.2. Mock-ups

This section presents the Data Fabric GUI mock-ups created in a co-design process with the stakeholders in the Capital Region of Denmark RWL. It showcases functionalities, control panels and options as well as visualizations in plots and maps.

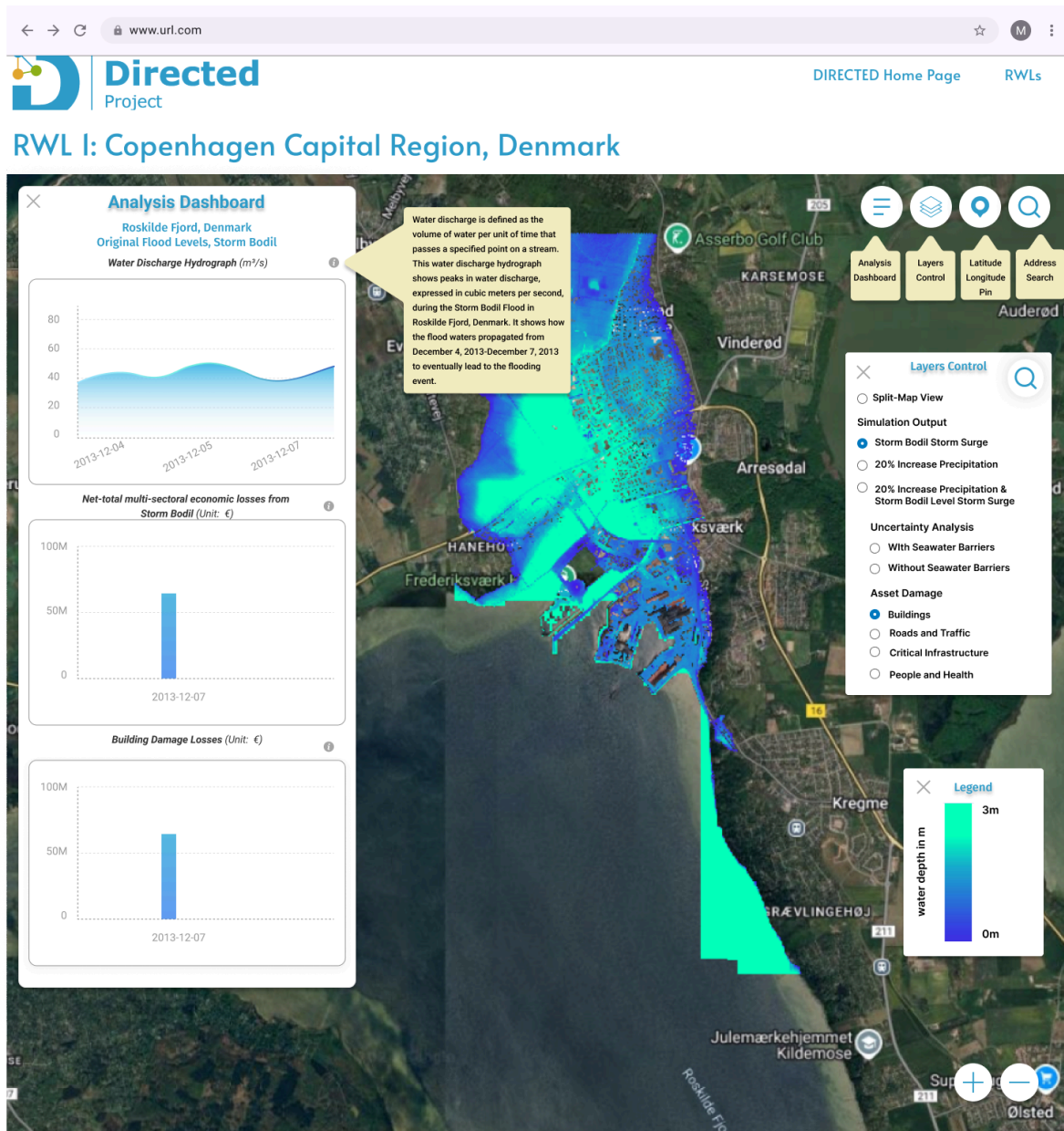


Figure 3: Mock-up of the Data Fabric GUI for RWL 1 for an analysis of flood levels and damages caused by Storm Bodil.



Figure 4: Layer Control Panel (left) and Analysis Dashboard for data visualization (right).

[Figure 3](#) showcases a mock-up where the user has selected to view Storm Bodil level storm surge levels, as well as asset damage in the form of buildings in the Layers Control Panel. The data which is selected in the Layers Control then shows up in the Analysis Dashboard; a close-up view of these selections can be seen in [Figure 4](#). As the user has selected to view building damages, the corresponding graph for building asset damages from the Storm Bodil event, expressed in euros, can be seen in the Analysis Dashboard. While this user has only selected to view building damages, they could also have the ability to select Roads and Traffic, Critical Infrastructure, and People and Health, which are all outputs from the DTU Damage-Cost model. Depending on the continued co-production process as the stakeholders decide which assets they would like included in the GUI, other possibilities

would include agriculture, business, tourism, public services, recreational areas, and ecosystems.

Also viewable in the analysis dashboard is a water discharge hydrograph and the net-total asset losses from the Storm Bodil event; while these figures could also change depending on stakeholder decisions, the water discharge hydrograph shows the volumetric flow rate of water discharge during the Storm Bodil event. This could give stakeholders, for example, a visual representation of how the storm waters propagated at different time stamps during the flood dates, from December 13-17, 2013. A pop-up explaining the graphic can be seen in [Figure 3](#). Net total asset losses could also exemplify the economic losses which were incurred during this event, and, for example, how those losses could compare, and increase, in a future flooding event, such as in the split-map view in [Figure 5](#).

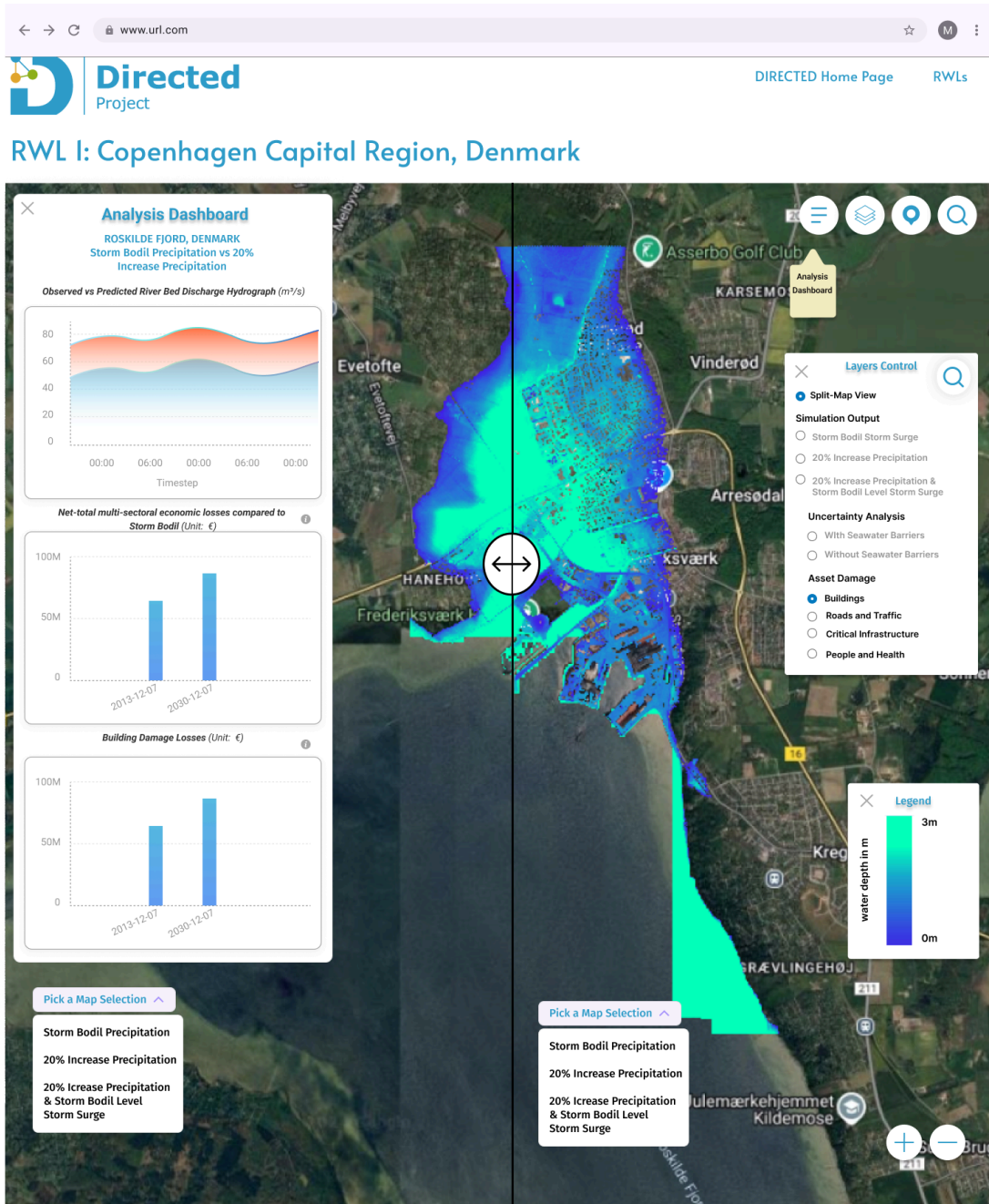


Figure 5: Split map-view for the comparison of two data layers in the map and dashboard.

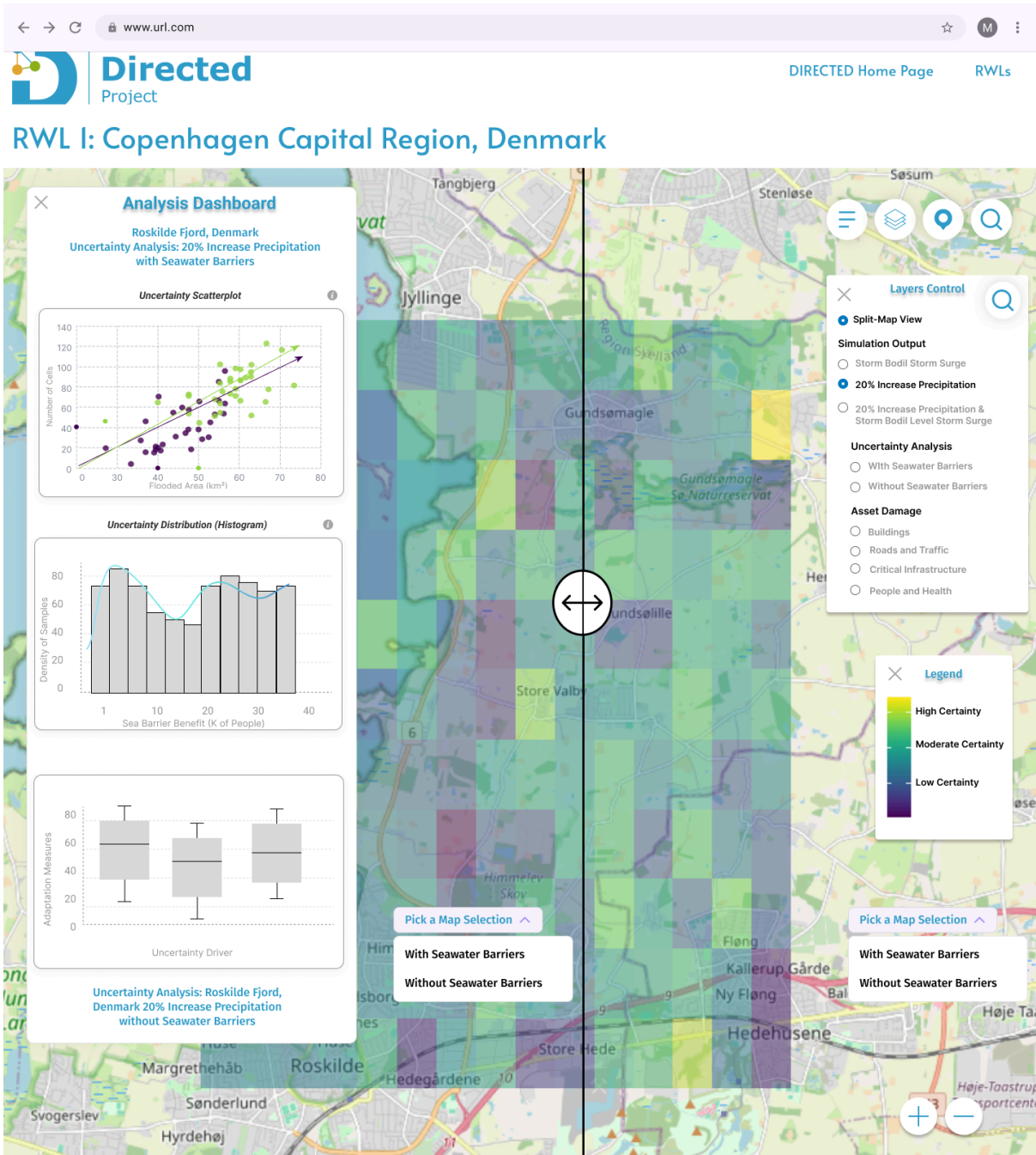


Figure 6: Uncertainty analysis of model output and scenario simulations in Split-Map view with the Analysis Dashboard.

All models are wrong, however some are useful; which is to say, that while we can model a system with certain variables of interest, models outputs will always have a level of uncertainty, as not all data are perfect and it is impossible to capture every single variable within a system. Thus, uncertainty analysis is a powerful tool which can be used to assess model performance and communicate uncertainty to end-users. It allows the visual representation of areas which are “more certain” and “less certain” in modeled outputs and,

in the scope of DIRECTED, guide users to know in which areas they should be more or less certain that adaptation measures, and climate change impacts, could be hazardous.

[Figure 6](#) thus shows a mock-up for how an uncertainty analysis could be visualized in the Roskilde Fjord, Denmark. Within the DIRECTED consortium models, CLIMADA has the capability to communicate uncertainty with different climate drivers and under different climate scenarios, such as SSPs or RCPs. As the DIRECTED project seeks to communicate DRM and CCA within the lens of climate change, utilizing the uncertainty modelling capabilities with CLIMADA has been communicated as a potential way to display these uncertainties in a meaningful way.

In this view ([Figure 6](#)), we can see the uncertainty layer visualized in the Roskilde Fjord in the interactive web-map, where cells containing “high certainty” are coloured in yellow, and “low certainty” coloured in dark purple. As split-map view has been selected to compare uncertainty with seawater barriers versus without seawater barriers in the drop-down boxes, the asset damage layers in the Layers Control Panel have been disabled from selection. The user has also selected a 20% increase in precipitation (which, as mentioned previously, could be an RCP scenario at the stakeholders’ selection). These results are then available in the Analysis Dashboard as a scatterplot showing the flooded area in square kilometers, a histogram showing how many thousands of people could benefit from the presence of a seawater barrier, and a boxplot showing the drivers of uncertainty present in the uncertainty analysis. While these graphs and plots could change depending on what the stakeholders would find the most helpful, they are possibilities within the modelling framework for this RWL.

[Figure 7](#) shows a mock-up of the Multi-Criteria Decision Making (MCDM) process, which is possible with CLIMADA. In this view, the end-user would be able to select different Social Vulnerability Index (SVI) groups that have been identified within the index’s output as data layers. Then, the user can select a climate scenario. Upon selecting these different options, the user is then able to draw boundaries and/or adaptation measures in the interactive web map. Once completed, this output is shown in the analysis dashboard and ready for export. While the full capabilities of developing the MCDM within the Data Fabric are at a lower priority, i.e. the metrics produced in the Data Fabric could then be imported into the CLIMADA MCDM module for further analysis, having this capability could be helpful for the Capital Region of Denmark RWL, and potentially the Rhine-Erft RWL. Thus, for example purposes, this mock-up has been created and visualized below.

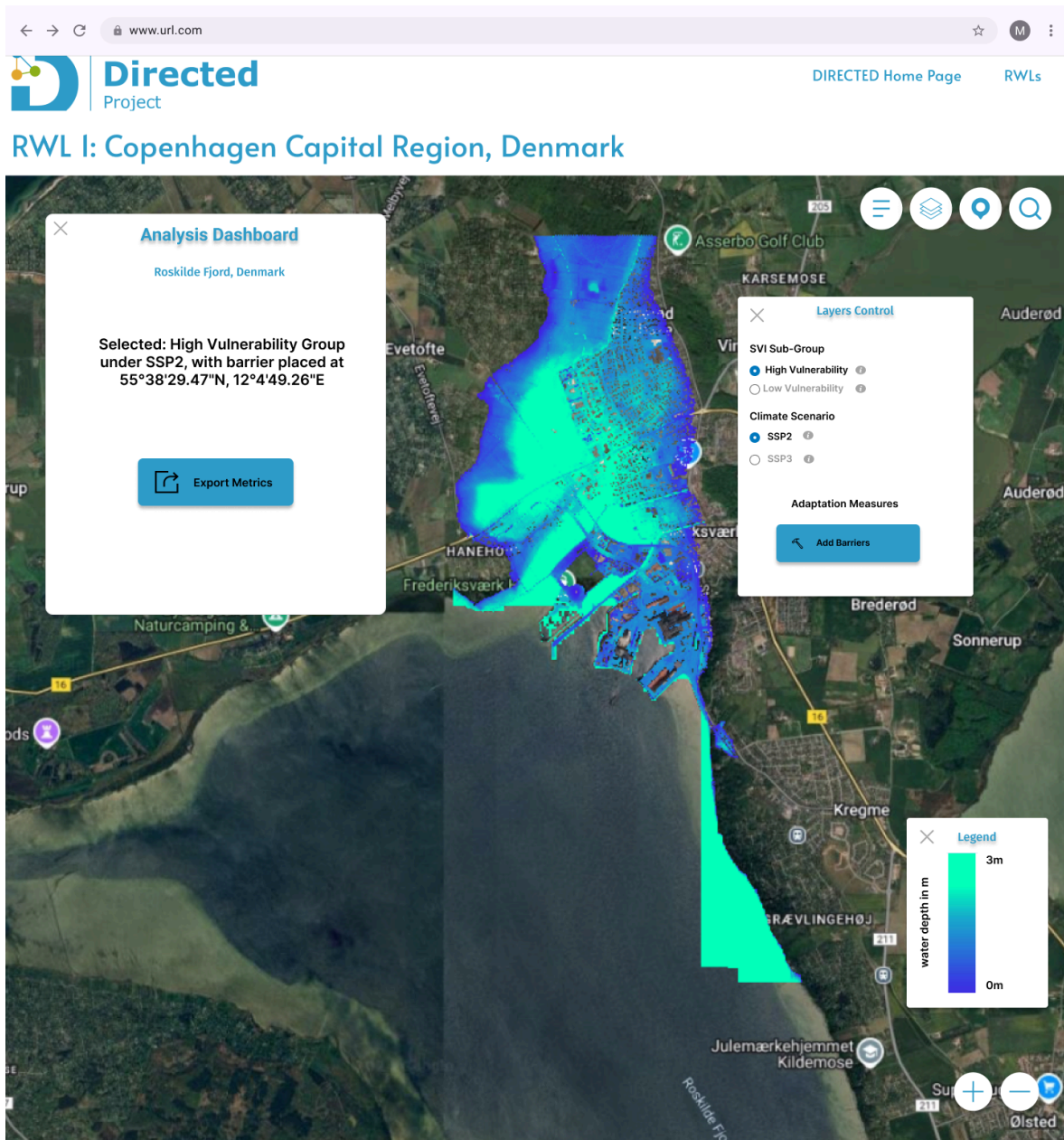


Figure 7: MCDM mock-up for adaptation measures in the Roskilde Fjord.

## Stakeholder Feedback

The presentation with the stakeholders of the Capital Region of Denmark RWL took place on November 11, 2024, in an online meeting format. The presentation consisted of mock-ups for two user-stories (more details in D5.2). Following the co-production process, these user-stories were as follows:

- 1) To aid in the ease and accessibility of viewing geographic information systems (GIS) data through flood simulations and impact assessments toward Climate Change Adaptation (CCA) and Disaster Risk Management (DRM) in the Roskilde Fjord.
- 2) To view the uncertainty of model outputs in the Roskilde Fjord to make better informed decisions toward CCA and DRM.

In response to user-story 1, the Municipality of Halsnæs agreed with the proposition that SSP/RCP scenarios be included in the platform in place of the 20% increase in precipitation; they also added that there could be a series of return periods for different events as a choice rather than the Storm Bodil event. These requests were also in line with comments from the Municipality of Lejre, where they mentioned that the platform could be useful for both the municipality and their respective emergency service (Lejre Brandvæsen), to cater to both climate adaptation needs as well as DRM.

Sentiments shared by the Municipality of Lejre and others present in the online meeting were that the creation of a simplified GIS was welcome, however that it should be intuitive to end-users. While the municipalities welcomed the idea of creating online learning modules accompanying the platform, they did not want end-users to be reliant on going through the learning modules in order to use the platform. Thus, re-designing components and/or adding more pop-ups to describe components within the GUI will be incorporated in future discussion, and has since been updated in the mock-ups so that users with less technical knowledge would be able to use the platform in a more seamless manner (Figures [3](#) and [4](#)).

Another shared sentiment among the municipalities was to have the models used within the platform to be accompanied by uncertainty intervals/ranges for the numerical values viewed in the Analysis Dashboard. Further, they would like to see information on the data source, i.e. where it came from and a date on how old the data retrieved is.

A final remark from the Municipality of Lejre in response to user-story 2 was to include ground water levels in the uncertainty analysis with adaptation measures. It was mentioned that this would be helpful due to the last record wet years (2019, 2023), where there has been political attention to ground water levels in Denmark.

Overall, the stakeholders in the Capital Region of Denmark RWL, with a focus on the Roskilde Fjord, were very thoughtful and insightful with their feedback toward the mock-ups presented in the online meeting. This feedback will help formulate the next stages of the Data Fabric implementation in this RWL, as the co-production and co-design process

continues with the support of the RWL hosts, the stakeholders, and the consortium as a whole.

## 2.2 RWL 2 - Emilia-Romagna Region, Italy

### 2.2.1. Overview

Through stakeholder engagement in workshops and meetings, the Emilia-Romagna RWL has identified the need for improved forecasting capabilities and real-time flood monitoring. These requirements (with more details found in D5.1), then feed into this RWL's overarching goal, which is to provide a platform the civil protection, volunteers, and municipal stakeholders can utilize for centralized climate information, mainly with regard to event-phase DRM and CCA. The following mock-ups were designed in-tandem with the RWL stakeholders in order to fulfil the needs and capabilities outlined in D5.1.

### 2.2.2. Mock-ups

This section presents the Data Fabric GUI mock-ups created in a co-design process with the stakeholders in Emilia-Romagna Region RWL. It showcases functionalities, control panels and options as well as visualizations in plots and maps. The GUI is designed to map and plot rainfall intensity, sea level, and subsequent pluvial/coastal flood hazards; provide real-time nowcasting and forecasting using detailed forcings such as HERA radar data and ICON models for accurate hazard prediction; allowing end-users to interact with high-resolution flood maps and make decisions about mitigation measures, such as installing flood barriers. The key elements shown in the following mock-ups are described below:

#### 1. Sidebar Navigation (Left)

- The sidebar contains categories and submenus organized hierarchically:
  - **Pluvial:** Includes sections like "Realtime," "Radar," "Pluviometers," "Forecast," and "ICON Model."
  - **Coastal:** Includes "Realtime," "Wave Buoys," "Sea Level Meter," "Forecast," and "Sea Forecast."
  - **Account:** Features related to user management, such as "Notifications," "Settings," and "FAQ."
  - A "Log Out" button at the bottom for user session management.
- The sidebar uses clear icons and labels, improving navigation.

#### 2. Central Map and Controls

- The central section displays an interactive map showing predicted flood levels or oceanographic data. The map is colour-coded to indicate different sea levels or flood zones.
- A date and time selector allows users to specify the forecast period.
- Input fields and buttons below the map provide the following functionalities:
  - **Run Map:** Triggers flood simulation.
  - **Draw Barriers:** Allows users to design protective barriers.
  - **Economic Damage Calculator:** Computes potential economic impact.
  - Export and print options for sharing or documenting the results.

### 3. Graphical Data Representation (Top Right)

- Graphs display time-series data:
  - "Sea Level Series of the Past X Hours" (from ADRIAC model).
  - "Wave Time Series" (from SWAN model), showing wave heights and run-ups.
- Checkboxes allow customization of the data displayed (e.g., wave run-up levels).

### 4. GIS Layers and Sensitivity Analysis (Right Panel)

- A "GIS Layers" section provides options to activate various data layers, such as:
  - Flood
  - Damage
  - Critical Infrastructure
  - Other categories like underpasses, parking lots, and underground residences.
- Sensitivity metrics are visualized with progress bars and numerical indicators for:
  - Sensitive receptors
  - Underpasses
  - Parking lots

### 5. Header

- Contains a logo for the "Directed Project" and a search bar for location-based queries.
- Partner logos (e.g., ARPAE, GeoSistema) emphasize collaboration.
- Profile icon and settings are located in the top-right corner.

### 6. Visual Design

- Colour Scheme: Blue shades dominate, reflecting a water-related theme.
- Icons and Charts: Clean, visually distinct icons and charts ensure readability.

- Layout: The interface is modular, with clear separation of navigation, maps, data inputs, and analytics.

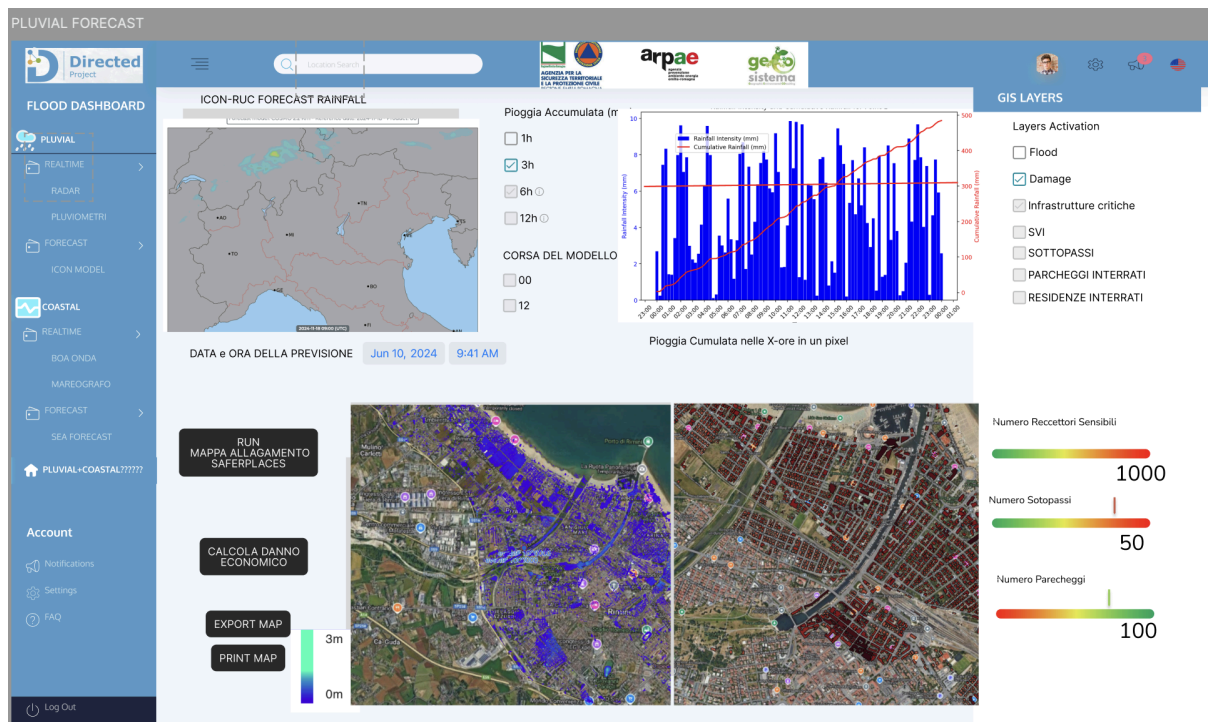


Figure 8: Mock-up GUI dashboard designed for flood forecasting and simulation, tailored for flood disaster management purposes with the overview view.

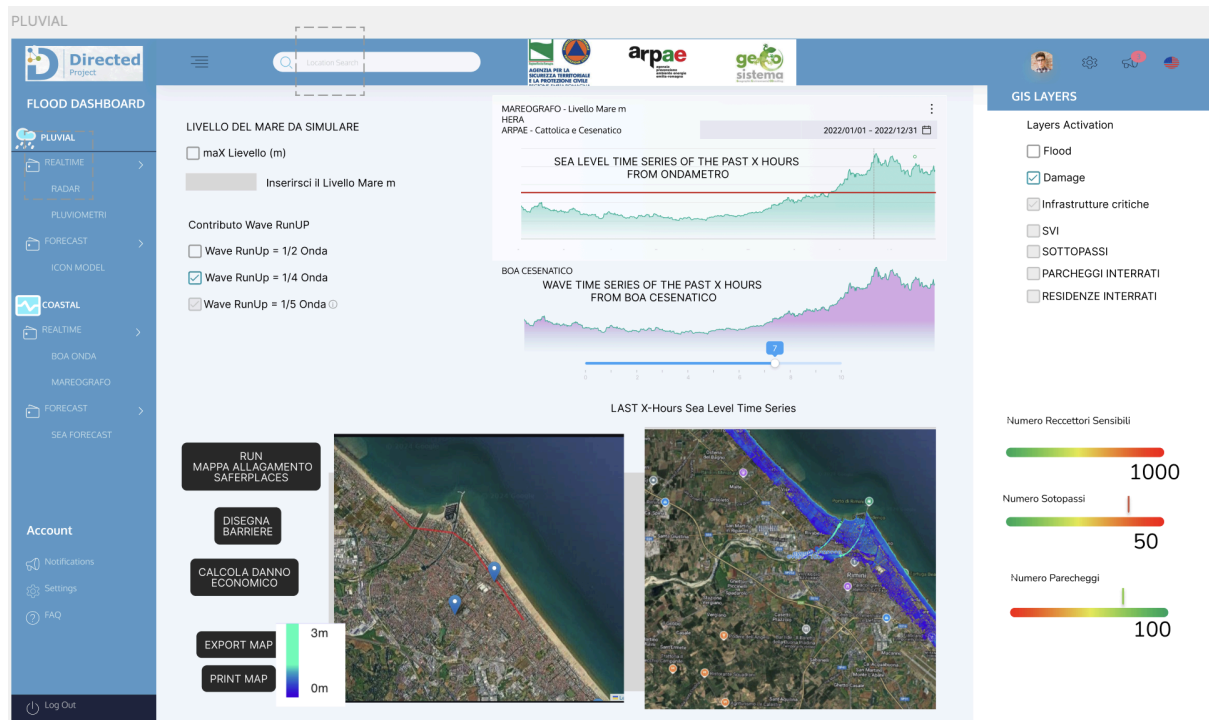


Figure 9: Mock-up GUI dashboard designed for flood forecasting and simulation, tailored for flood disaster management purposes with the time series view.

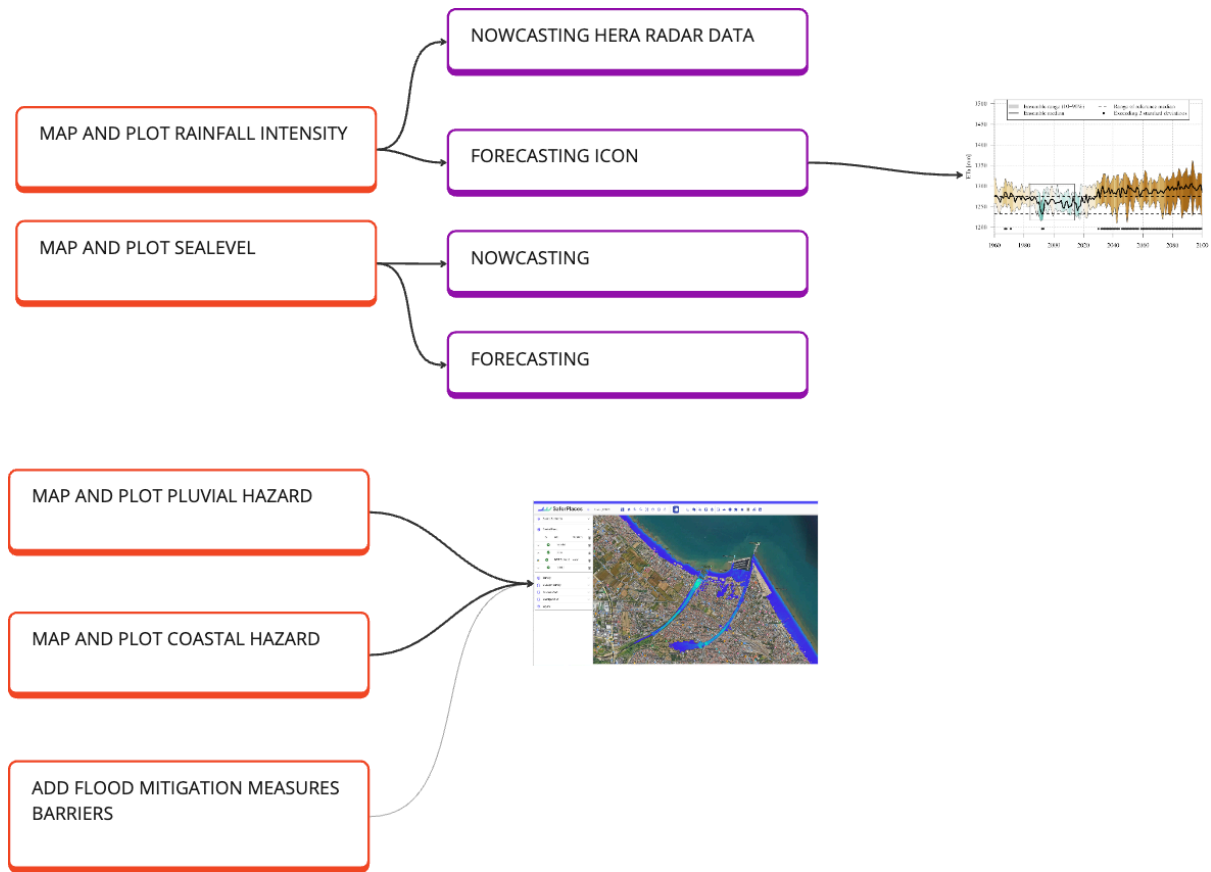


Figure 10: Overview of the different GUI elements and their relation to components.

## 2.3 RWL 3 - Danube Region

### 2.3.1. Vienna, Austria

#### 2.3.1.1 Overview

The Vienna, Austria, part of the Danube RWL, seeks to bridge the gap between the science sector and insurance industry, as has been developed through extensive workshops. The stakeholders in the insurance industry also cross-cut international borders within the Danube RWL, hence this RWL hopes that by leveraging the insurance industry, dissemination to the wider community in the Danube River Basin could be more feasible by the end of the project. This overarching goal is therefore guided by three different user-stories, which have been discussed with this RWL:

- 1) Pluvial flood modelling in urban areas
- 2) Fluvial flood modelling upstream and downstream of Vienna
- 3) Climate projections of flood risk

The following mock-ups are thus targeted at these three user-stories, with a more detailed discussion of the view below.

### 2.3.1.2 Mock-ups

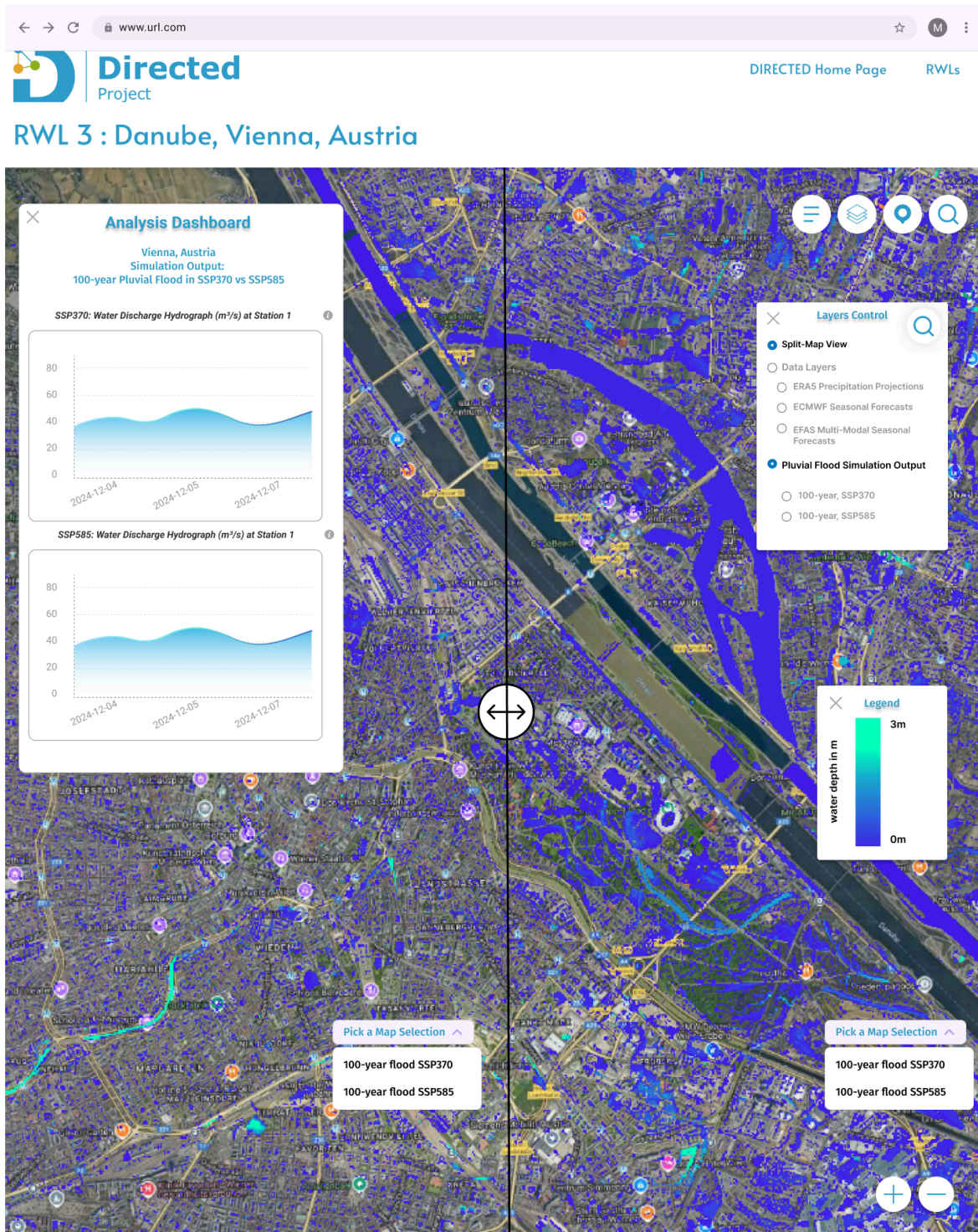


Figure 11: Pluvial Flood simulation mock-up in Vienna, Austria.

In [Figure 11](#), this mock-up demonstrates how climate projections of flood risk could be visualized in the front-end UI of the Data Fabric. In this view, two climate scenarios of SSP370 and SSP585 are available to the end-user, with supporting analysis in the Analysis Dashboard to show how fluvial and pluvial flood risks change with different climate projections. These data views would be supported by outputs from both the Danube Model and CLIMADA. This mock-up has been identified as applicable for all end-users in the Vienna case of the Danube RWL.

### RWL 3 : Danube, Vienna, Austria

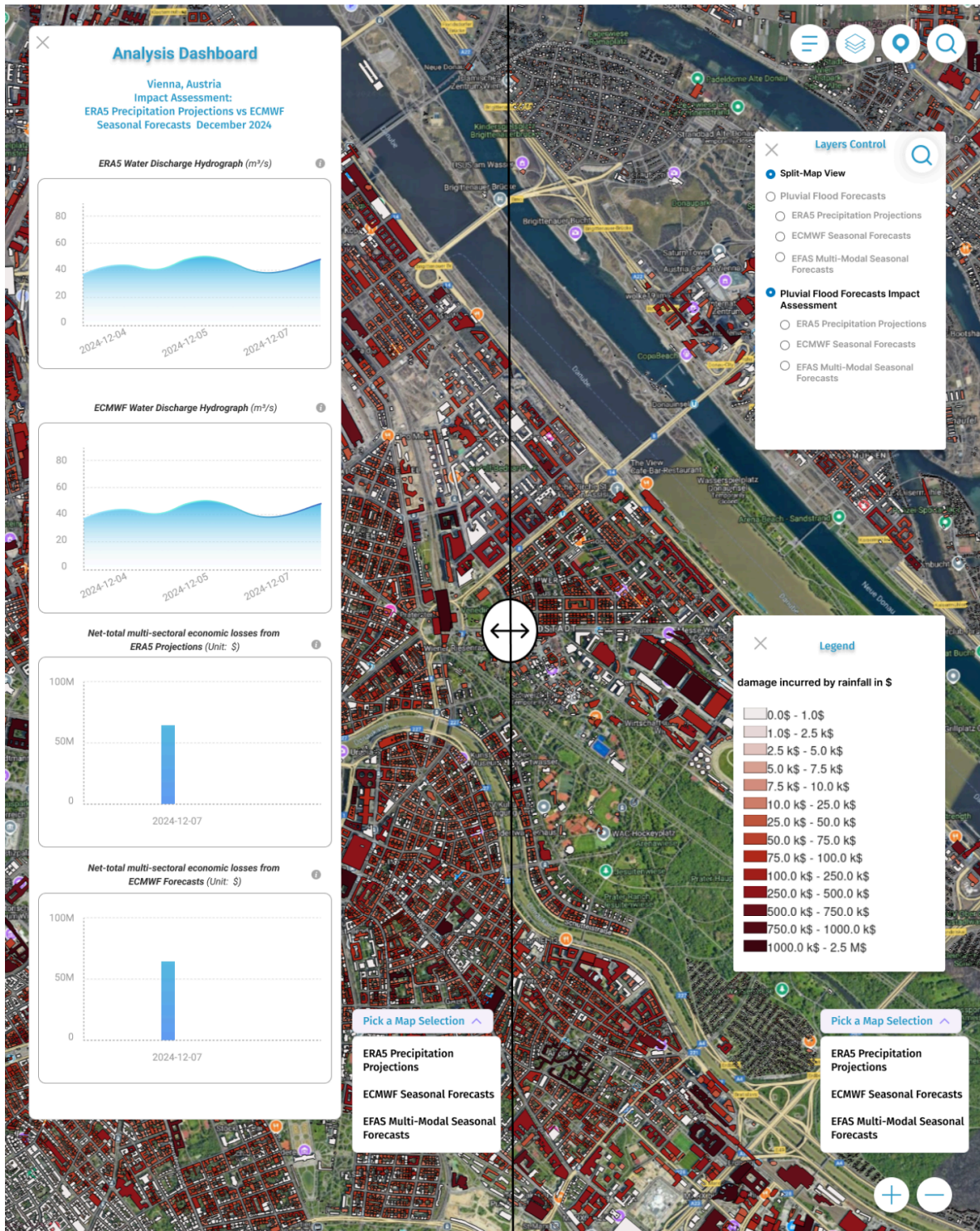


Figure 12: Impact assessment mock-up in Vienna, Austria.

[Figure 12](#) above shows a mock-up of an impact assessment calculated through the SaferPlaces model. It takes input data from ERA5, ECMWF, and EFAS in the form of pluvial flood forecasts, and inputs this data into the model to produce pluvial flood forecast impact assessments. This mock-up has been identified as a low priority for this RWL, as it is only applicable to one stakeholder group. However, given suitable forecast data, it could be a possibility in the Data Fabric.

## 2.3.2. Zala Region, Hungary

### 2.3.2.1 Overview

Another part of the Danube RWL, the Zala Region in Hungary, seeks to bring together citizens, local volunteer organizations, and local governments (namely, in the City of Keszthely) in order to promote climate resilience through future-facing climate scenarios at a city and regional scale. Seven user stories have been developed through workshops with the RWL hosts and stakeholders and are mentioned in D5.2. Amongst these, user stories US3.Z1 and US3.Z2 have during the discussions in the workshops been identified with the highest priority and include to a certain degree many aspects of the remaining user stories:

- 1) US3.Z1: Multi-hazard dashboard for Zala and West Balaton Region
- 2) US3.Z2: Multi-hazard dashboard at Municipal Level in the Western Balaton Region to Support Future Climate/Disaster Resilience

### 2.3.2.2 Mock-ups

Figures [13](#) to [16](#) show mock-ups highlighting the multi-hazard dashboard approach. A central layer controller gives an overview of the available datasets and allows users to choose which datasets they would like to visualize. The mock-ups show examples for flood maps and the visualization of a past disaster event dataset. The key idea of the design is to support a holistic view on hazards in the Zala Region and to make it easier to find suitable adaptation measures to climate change.

Figures [17](#) and [18](#) show mock-ups for the integration of long-term crop yield projections based on a set of different climate scenarios. This should support farmers in choosing the right crops and increase resilience (cf. US3.Z4).

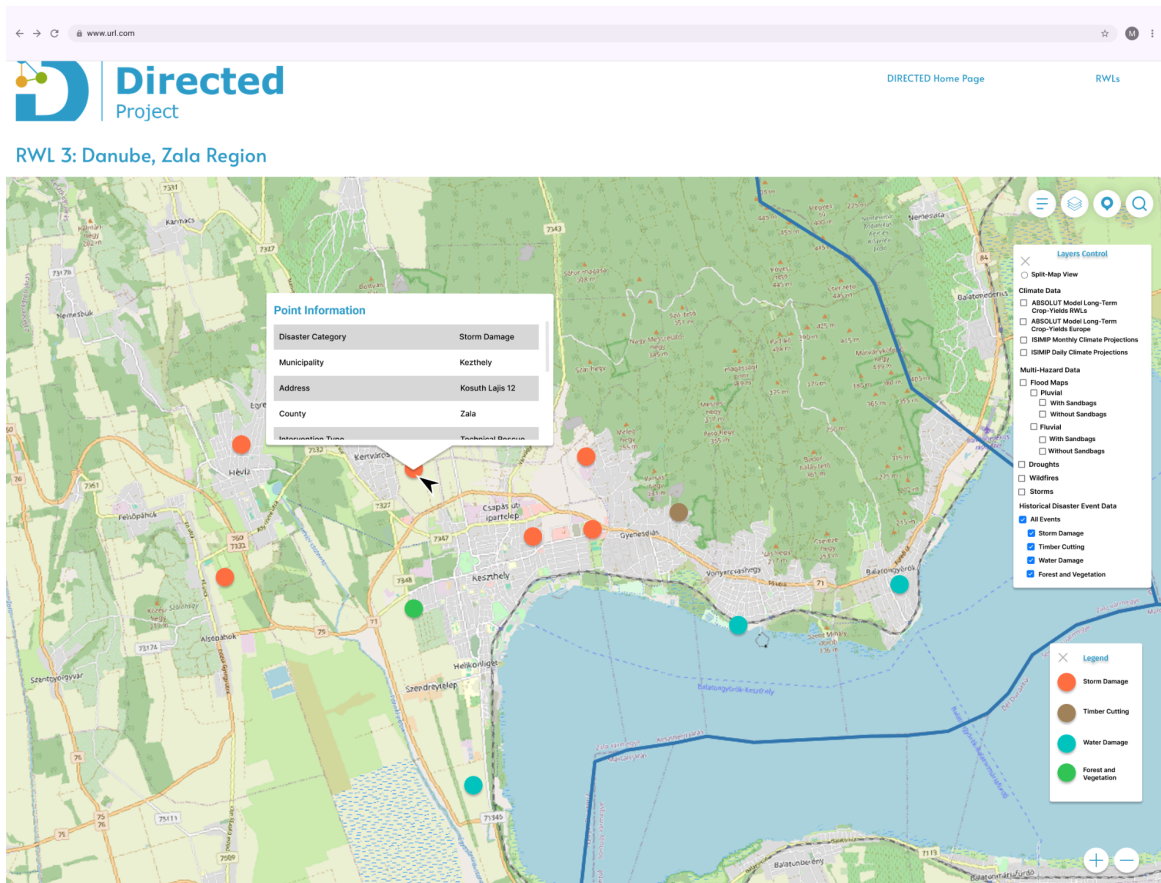


Figure 13: Mock-up GUI for US3.Z1, Multi-Hazard Data, specifically showing mock-up disaster event point data.

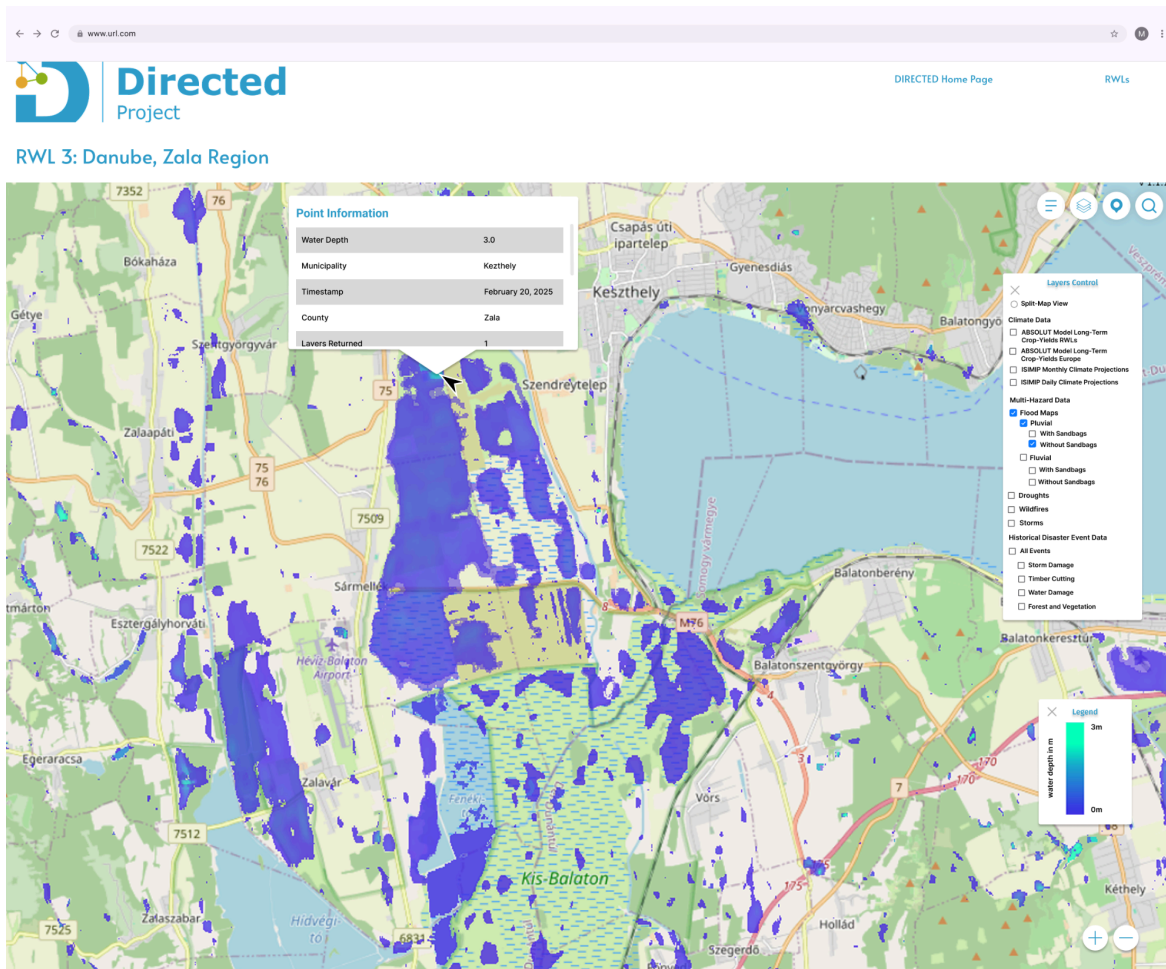


Figure 14: Mock-up GUI for US3.Z1, Multi-Hazard Data, specifically showing how a pluvial flood map data layer without sandbags could be visualized.

✕ **Layers Control**

Split-Map View

**Climate Data**

ABSOLUT Model Long-Term Crop-Yields RWLs

ABSOLUT Model Long-Term Crop-Yields Europe

ISIMIP Monthly Climate Projections

ISIMIP Daily Climate Projections

**Multi-Hazard Data**

Flood Maps

Pluvial

With Sandbags

Without Sandbags

Fluvial

With Sandbags

Without Sandbags

Droughts

Wildfires

Storms

**Historical Disaster Event Data**

All Events

Storm Damage

Timber Cutting

Water Damage

Forest and Vegetation

Figure 15: Layers Control panel for all mock-ups in the Zala Region.

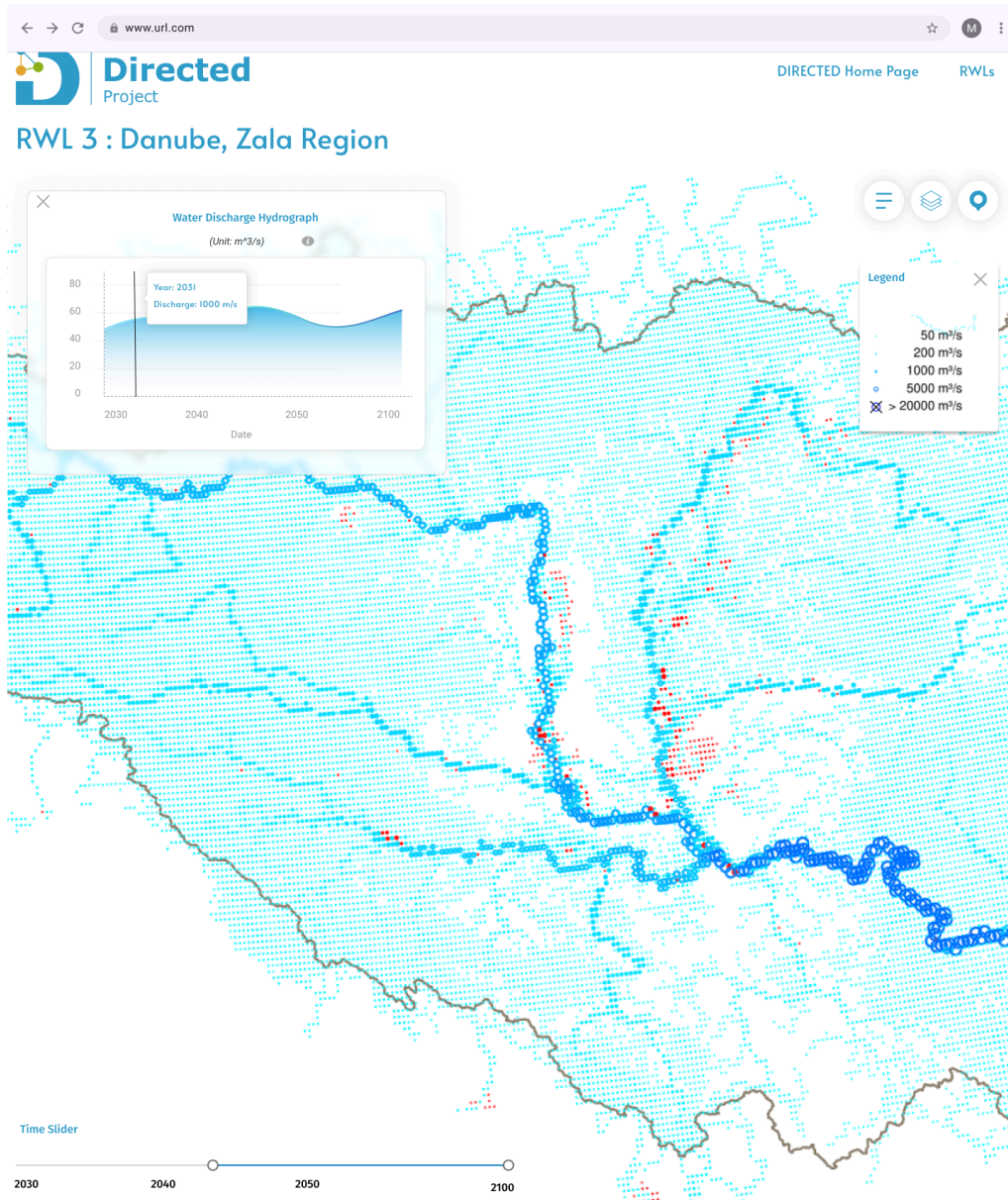


Figure 16: Mock-up GUI for US3.Z1, showing how a fluvial flood map data layer could be visualized.

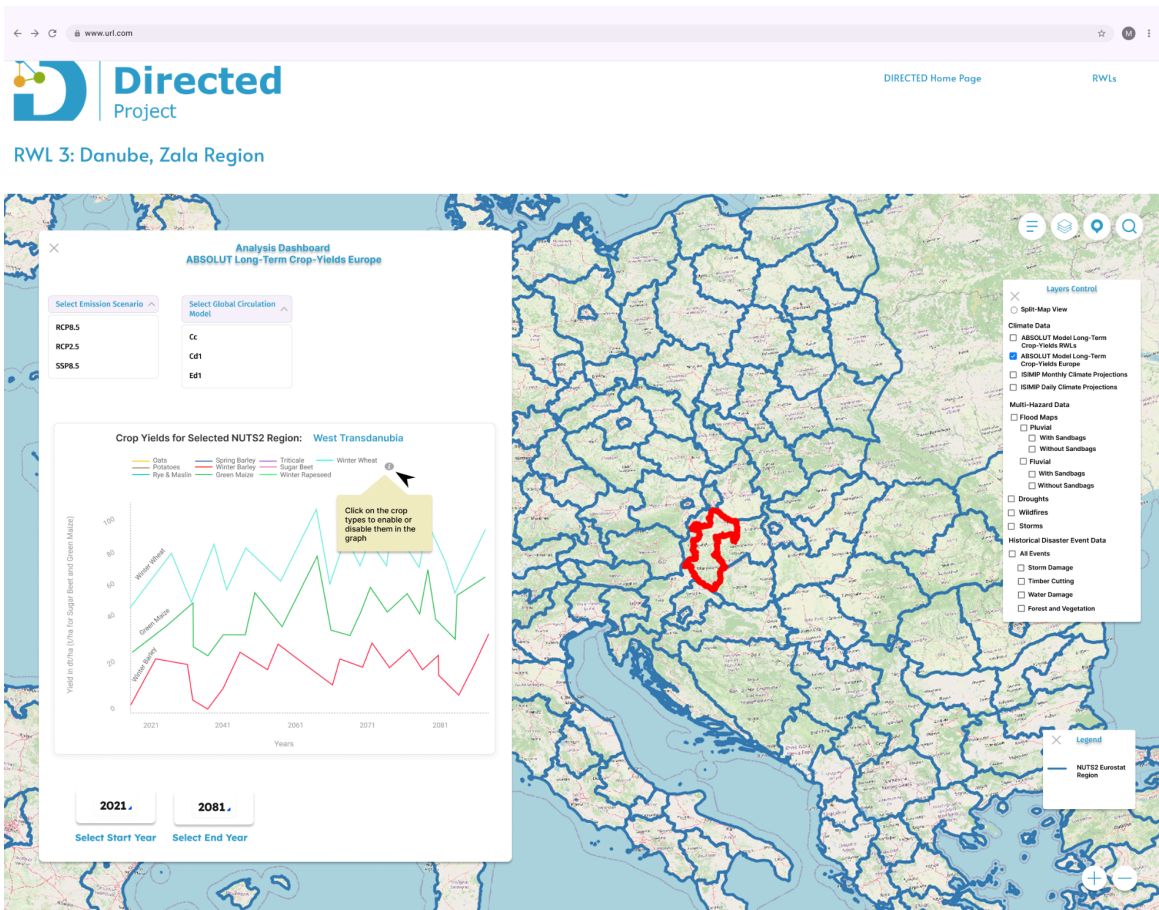


Figure 17: Mock-up GUI for US3.Z4, showing long-term crop yield data for Europe.

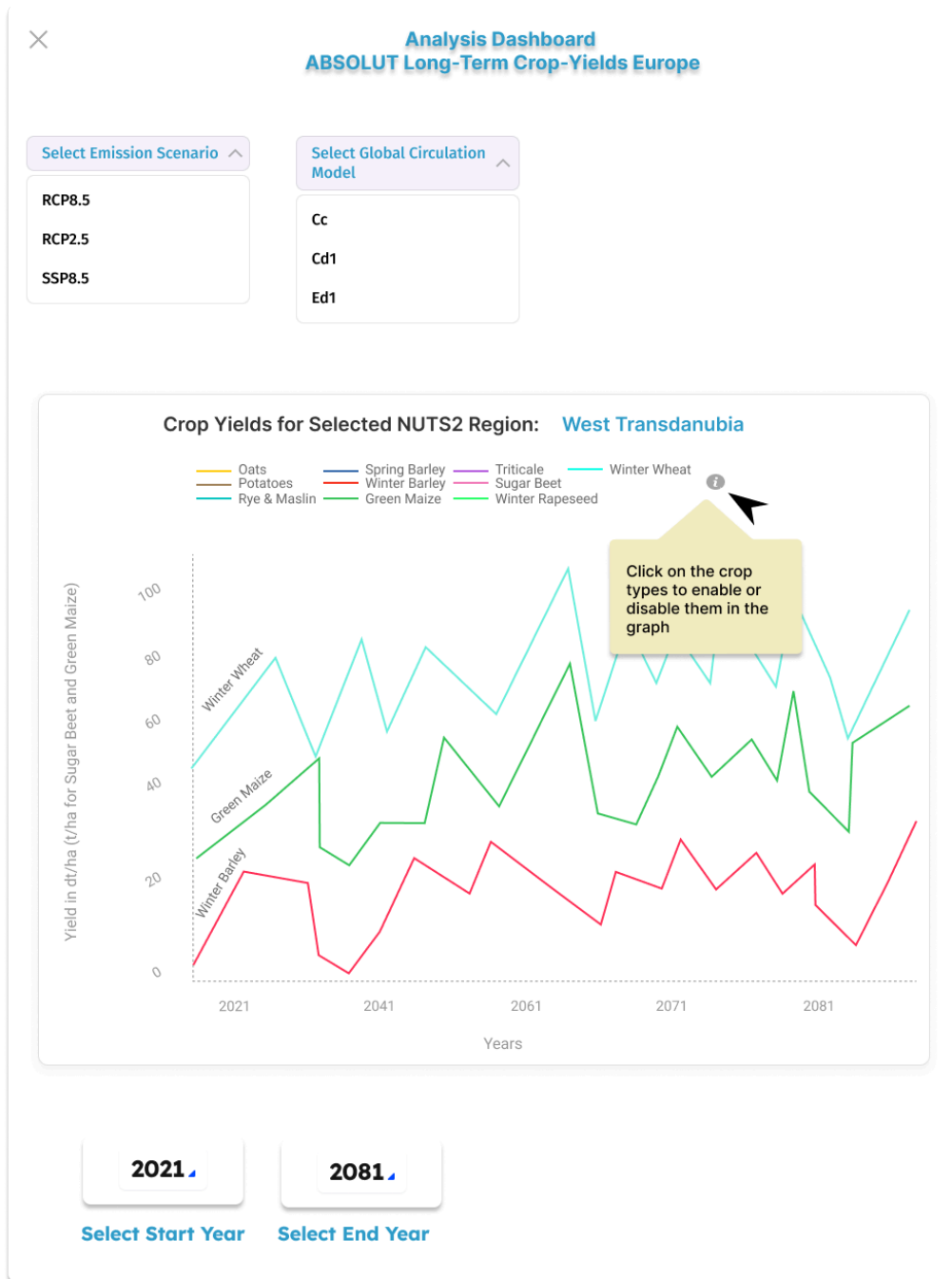


Figure 18: Larger view of the interactive graph from the mock-up of US3.Z4

## 2.4 RWL 4 - Rhine-Erft Region, Germany

### 2.4.1. Overview

In order to aid the Erftverband's efforts to strengthen the water management expertise for the region, the workshops in the RWL have revealed that it requires a user-friendly platform capable of making data and model outputs easier to understand, and interactive, for future planning efforts in the lens of CCA and DRM.

The following mock-ups were thus designed towards two priority user-stories based on D5.2 and subsequent discussions with the RWL hosts.:

- 1) A user-friendly interface to showcase adaptation measures (such as e.g. green roofs and water tanks) in the lens of climate change to communicate with EMS personnel and citizens/stakeholders under the Rhine-Erft Region jurisdiction.
- 2) The simulation of dam break scenarios with the possibility of a cost-benefit analysis to showcase potential effects of the failure of technical flood protection measures in the Rhine-Erft Region.

Further requirements within the scope of these user-stories which are to be continued to be explored in this RWL include:

- 1) Allowing the user to place adaptation measures within the GUI to show how it affects risk in urban areas in the Rhine-Erft Region under different climate scenarios.
- 2) Integrating the Social Vulnerability Index as an additional layer with the cost-benefit analysis, given that qualified census data will become available.
- 3) Allowing the user to run a simulation "event test," whereby the user can simulate flooding levels of 2021 with the added adaptation measures.
- 4) Allowing the user to input different values of buildings in the cost-benefit analysis.

## 2.4.2. Mock-ups

The following mock-up view in [Figure 19](#) shows a static implementation of the cost-benefit analysis output from the CLIMADA, SaferPlaces, and RIM2D models within the modelling chain framework developed for this RWL. In this view, the user has selected the Split-Map View to compare the implementation of water tanks in the Rhine-Erft Region in the year 2021 (the flooding event which greatly impacted this region) with the year 2080 (a future climate scenario which could be, for example, an RCP scenario). The layer in the interactive web-map shows the exposure value, an output from the CLIMADA model in the cost-benefit analysis; this layer indicates areas which are greatly exposed, and at-risk, in these different climate scenarios. Further description of the analysis dashboard can be found below in [Figure 20](#).

It should be noted that this is just one feasible mock-up that could be developed for the Rhine-Erft Region; as discussions for which visualizations and components this RWL would like to see are still on-going (mentioned above), this mock-up view was shown to the Rhine-Erft RWL as an example of what a cost-benefit analysis in the context of the adaptation measures could look like.

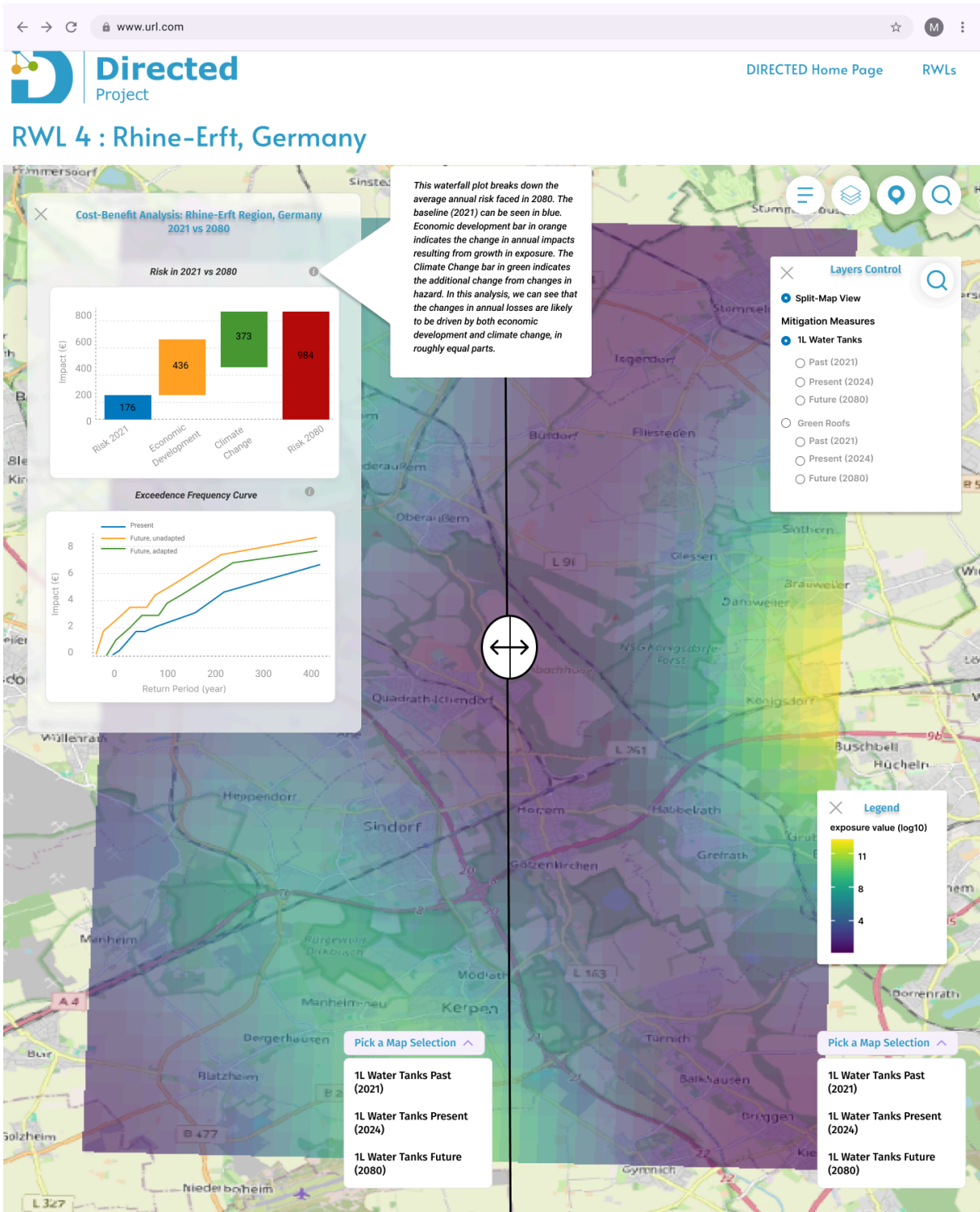


Figure 19: Mock-up GUI for the Rhine-Erft RWL, showing a cost-benefit analysis with mitigation measures of water tanks and green roofs.



Figure 20: Analysis Dashboard for the cost-benefit analysis in the Rhine-Erft Region.

In the analysis dashboard, a waterfall plot shows the average annual risk with regard to 2021, the baseline measure in blue, and 2080, in red. The drivers of risk over the time period, economic development and climate change, are also shown in the waterfall plot. The economic development bar seen in orange indicates the change in annual impacts resulting from growth in exposure. The climate change bar in green indicates the additional change from changes in hazard. In this plot, we can see that the changes in annual losses are likely to be driven by both economic development and climate change, in roughly equal parts. Below the waterfall plot, an exceedance frequency curve can also be seen in the analysis

dashboard, as a means to show the impact in euros for the present, an adapted future, and an unadapted future.

This example of a cost-benefit analysis was derived from CLIMADA, with other data sources supporting this mock-up via SaferPlaces and RIM2D.

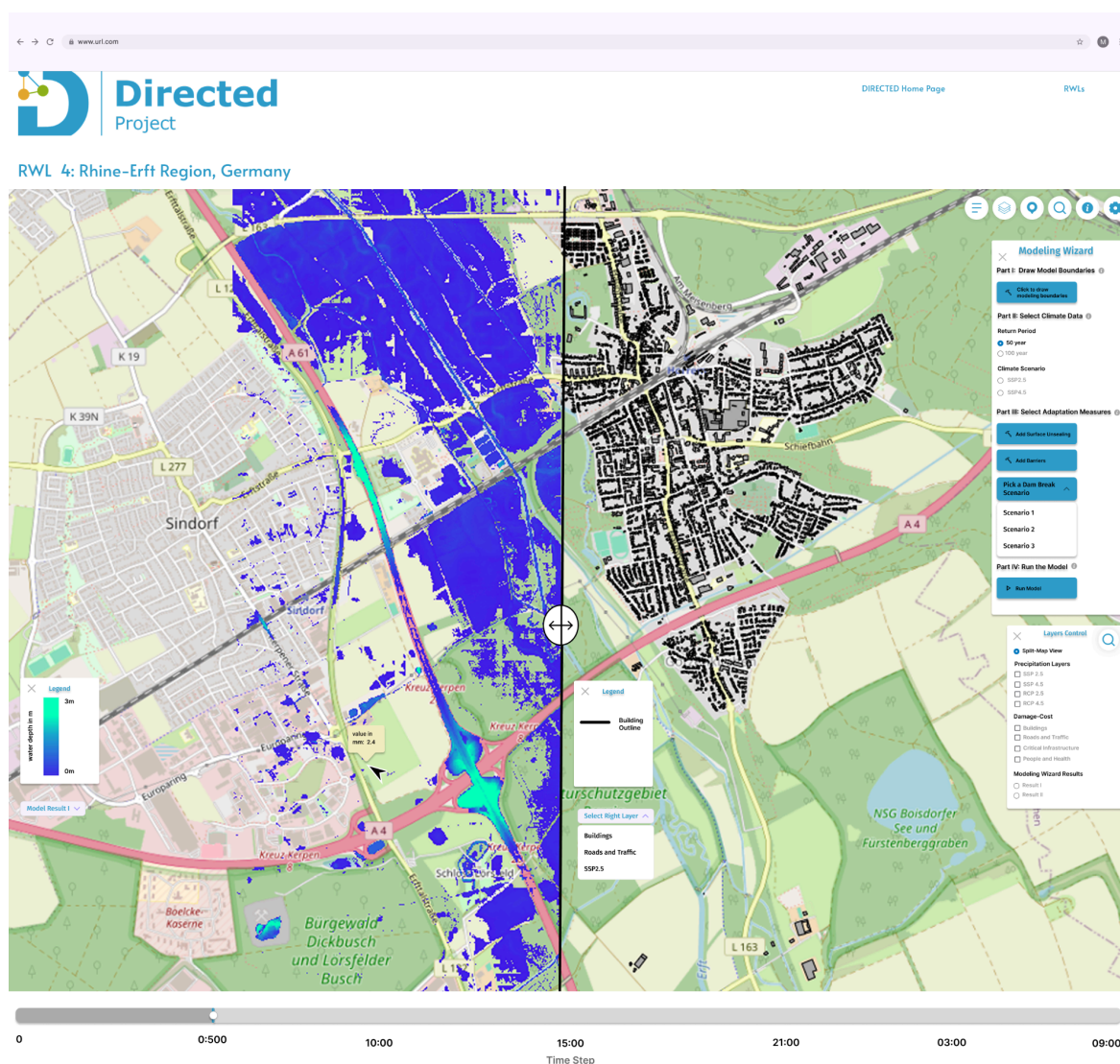
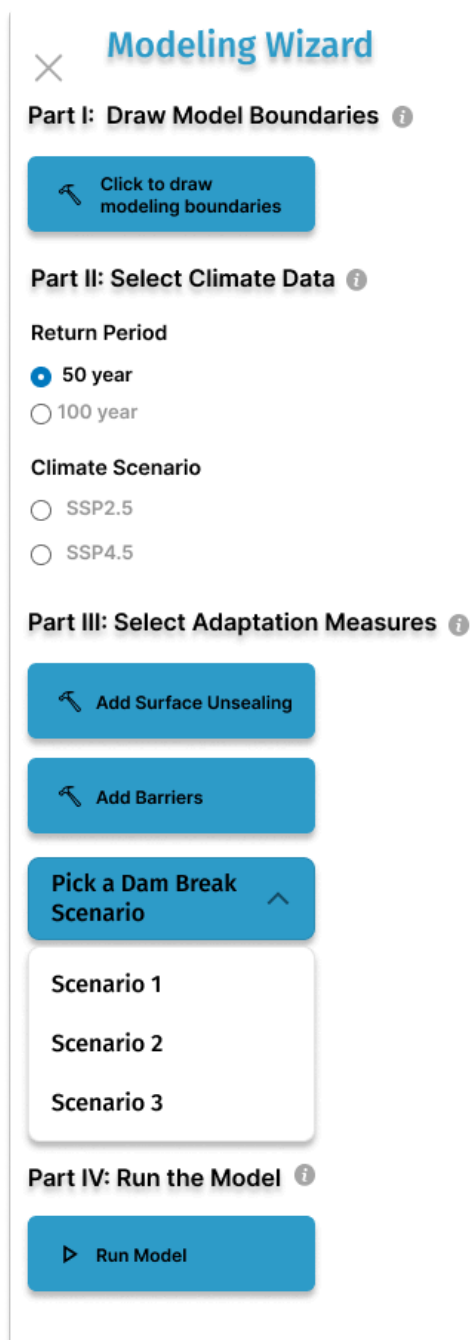


Figure 21: Mock-up GUI for US4.7, showing options for Dam Break scenarios in the model execution module.

In [Figure 21](#) above, this mock-up is in line with US4.7, to show how dam break simulations could be achieved through the “Modelling Wizard.” This mock-up shows the end result of when a user has already run the model simulation, and has produced two results which can be seen in the Layers Control Panel as “Result I” and “Result II.” The model outputs then have a button for the user to select if they would like to download modelled results locally, also located in the Layers Control Panel. The split-map view has also been selected, with a comparison between a dam break scenario model output, and a building damage layer, for

example purposes. A larger view of the “Modelling Wizard” model execution module can be seen below, with further detailed description.



The screenshot shows the 'Modelling Wizard' interface, which is divided into four parts:

- Part I: Draw Model Boundaries** (with an information icon): A blue button with a pencil icon and the text 'Click to draw modeling boundaries'.
- Part II: Select Climate Data** (with an information icon):
  - Return Period:** Radio buttons for '50 year' (selected) and '100 year'.
  - Climate Scenario:** Radio buttons for 'SSP2.5' and 'SSP4.5'.
- Part III: Select Adaptation Measures** (with an information icon):
  - A blue button with a pencil icon and the text 'Add Surface Unsealing'.
  - A blue button with a pencil icon and the text 'Add Barriers'.
  - A blue button with the text 'Pick a Dam Break Scenario' and an upward arrow icon.
  - A white dropdown menu with the following options: 'Scenario 1', 'Scenario 2', and 'Scenario 3'.
- Part IV: Run the Model** (with an information icon): A blue button with a play icon and the text 'Run Model'.

Figure 22: The Modelling Wizard module, to address US4.5 and US4.7.

The Modelling Wizard in [Figure 22](#) is a graphical component that would guide the user through a series of steps in order to run the modelling chain requirements for the Rhine-Erft RWL. It is divided up into four parts; part I, the ability to draw model boundaries, part II, the ability to select different climate scenarios, part III, the ability to add surface unsealing, barriers, and select different dam break scenarios, and part IV, running the model execution. The Modelling Wizard is thus a way to ensure that the user does not skip any steps that are

necessary to run the model simulations, and also gives them interactive capabilities/the flexibility to view outputs based on their specific needs or interests.

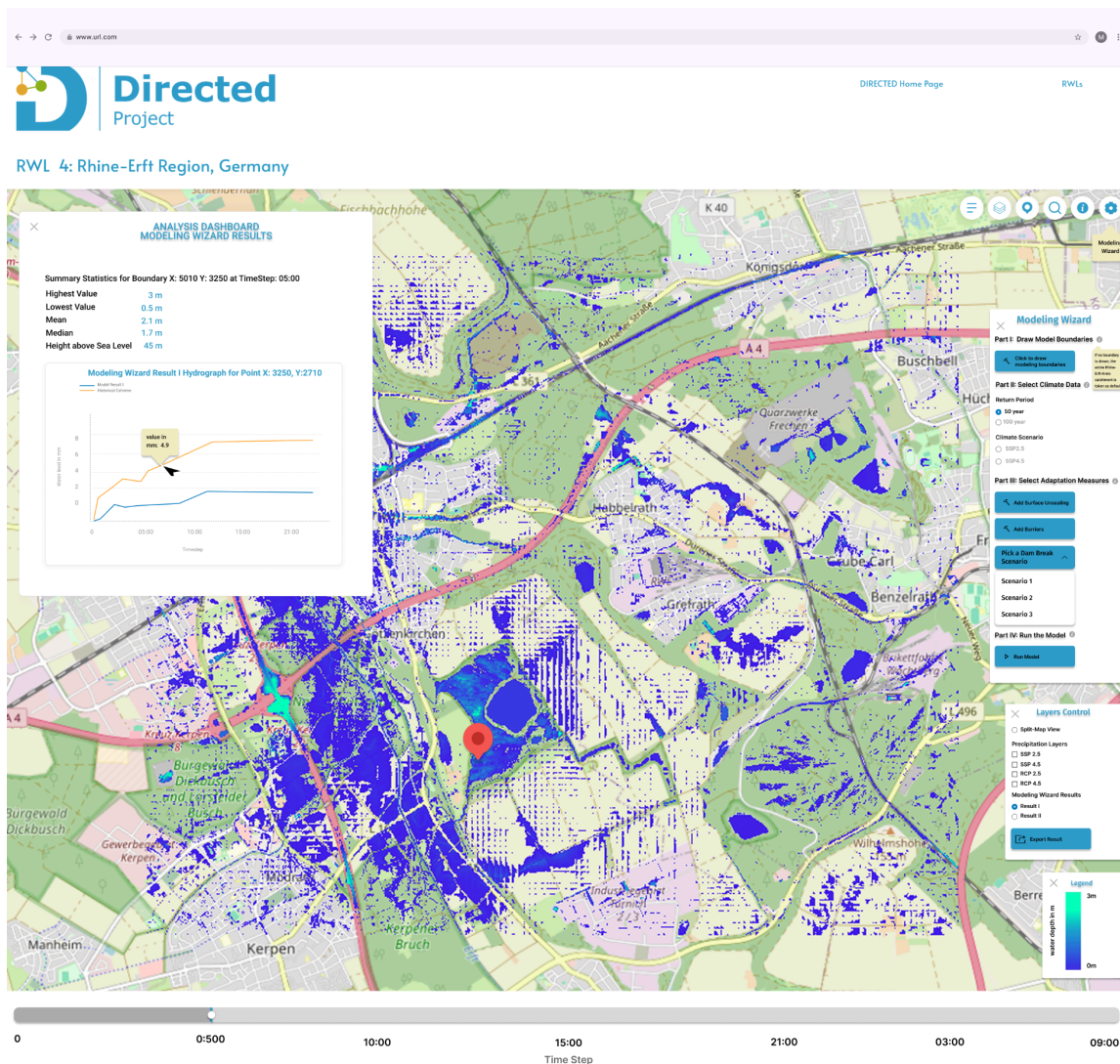


Figure 23: Mock-up GUI for US4.5, to showcase the “Simulation Sandbox,” a hydrodynamic modelling interface utilizing the Modelling Wizard.

Figure 23 above showcases a mock-up toward US4.5, the “Simulation Sandbox. In order to show how RIM2D and SaferPlaces could be utilized in a user-friendly way, the Modelling Wizard (Figure 22) has been used in this mock-up as well. At the bottom of the screen, a time-slider is shown so that the user can view the timesteps of the output hydrodynamic flood simulations. Additionally, the pin displayed in the map has been placed at the user’s discretion, and information for this pin then shows up in the Analysis Dashboard in the form of a time series for that point. An info tooltip has also been added, so the user can view specific flood depth values, as well as compare between historical highs. The Analysis Dashboard also shows summary statistics for the entire modelled region, so that the user can get an overall sense of the state of the selected region from the flood simulation.

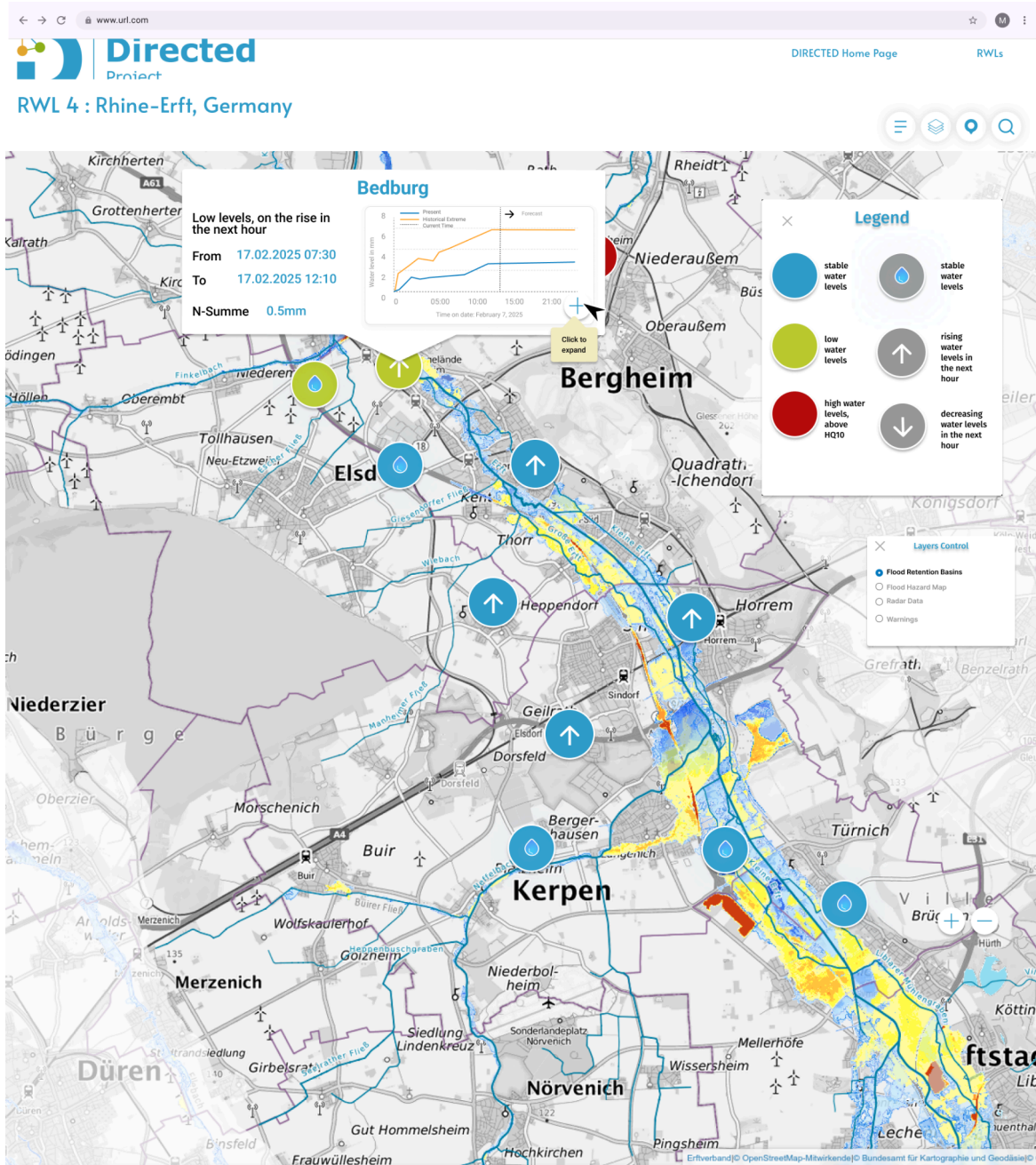


Figure 24: Mock-up GUI for US4.4, for the visualization of HOWIS platform data in the Data Fabric.

In Figure 24 above, this mock-up depicts an improvement of HOWIS platform data visualized in the Data Fabric. As the original HOWIS platform icons, particularly for flood retention basins, currently do not indicate the status of the water levels at each basin, icon colourization and arrow markings for indication of the water level gives the end-user a quick snapshot view of the overall water status in the Rhine-Erft Region. In this view, stable water levels are coloured in blue, low water levels, in green, and high water levels, above HQ100, in red. Additionally, the icons within the coloured icons give the user information about the water trend in the next hour; a water droplet indicates stable water levels/unchanging in the next hour, an upward arrow indicating rising water levels in the next hour, and a downward arrow indicating decreasing water levels in the next hour. Other data layers which are used in

the HOWIS platform but not visualized in this mock-up include radar data and further information about the hydrological situation. The basemap is a flood hazard map, included in the Erfverband's webGIS platform.

In [Figure 25](#) below, a larger view of the popup can be seen. This pop-up would be enabled when the user clicks on the icons in the map. Thus, an example station, Bedburg, has been clicked on. In the pop-up, a small analysis of the station can be viewed in terms of the date, water levels in the next hour, a sum of the water levels recorded in the day to the current timestamp, as well as a small water hydrograph showing water levels recorded at the Bedburg flood retention basin. A forecast summary can also be seen on the right of this popup for the next 5 hours. When the user clicks on the "plus" icon, they are taken to the view in the following mock-up, in [Figure 26](#) and as zoom in [Figure 27](#) below.

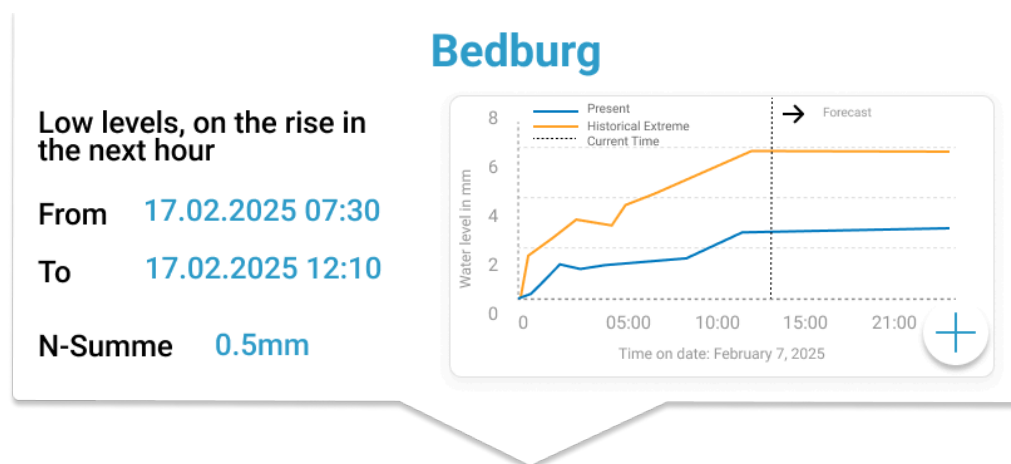


Figure 25: A larger view of the popup when the user clicks on the icons in the flood basin retention map.

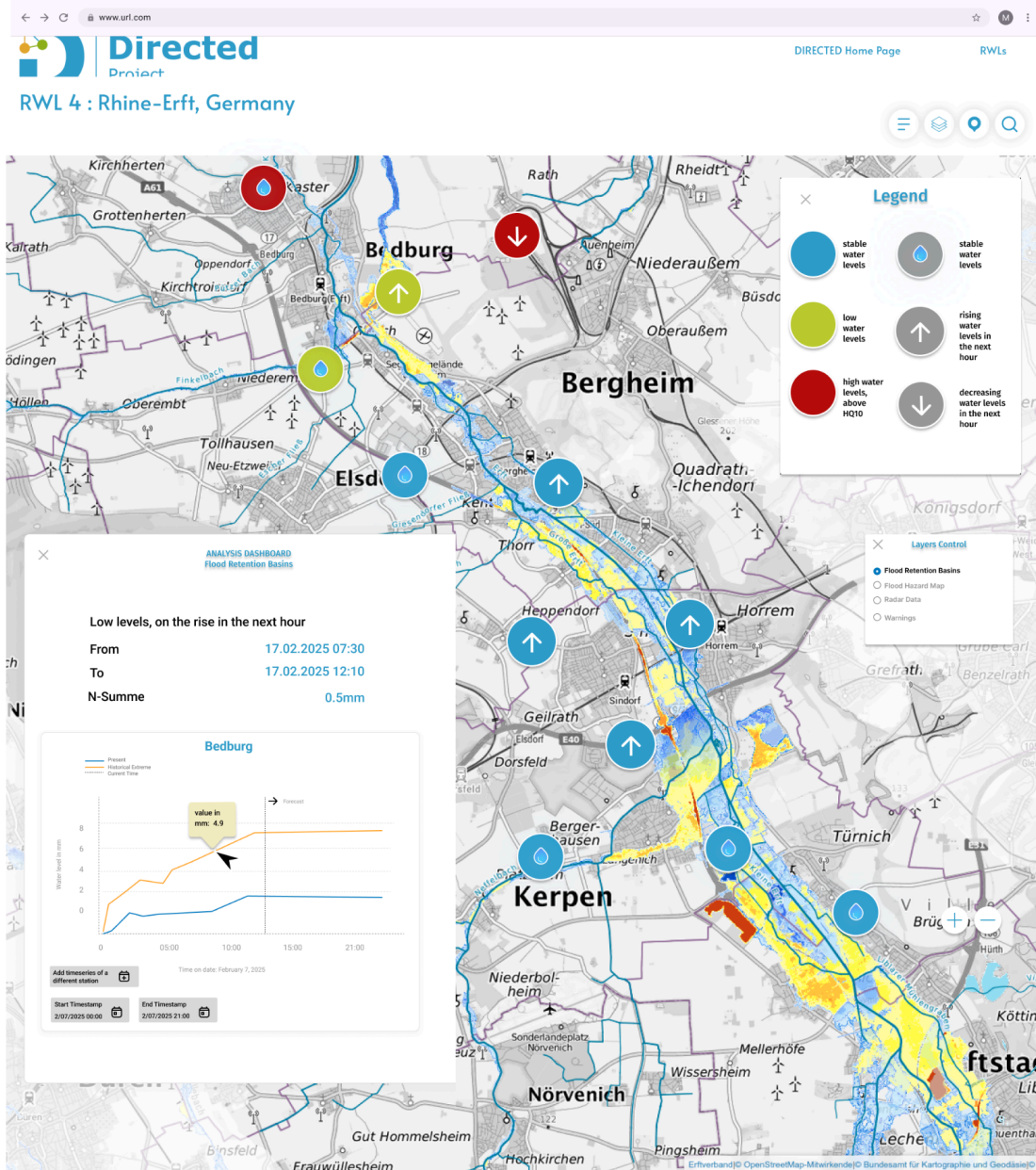


Figure 26: Mock-up GUI for US4.4, of the flood retention basin map, with an expanded view of the graph popup in the Analysis Dashboard.

In [Figure 26](#) above, the expanded view of the popup can be seen in the Analysis Dashboard. Here, the user has a few more capabilities in the graph for data viewing; in the bottom lefthand corner of the hydrograph, the user can select to add a time series from another flood retention basin of their choosing. They can also toggle for the start and end timestamps, if they wish to see historical data, for example. There is also an info tooltip when hovering in the hydrograph, so that the user is able to see the exact values per timestamp. A larger view of the Analysis Dashboard with the expanded view of the pop-up in the Analysis dashboard can be seen in [Figure 27](#) below. Due to later decisions of the HOWIS development team, this User story will not be implemented within DIRECTED.



ANALYSIS DASHBOARD  
Flood Retention Basins

Low levels, on the rise in the next hour

From 17.02.2025 07:30

To 17.02.2025 12:10

N-Summe 0.5mm

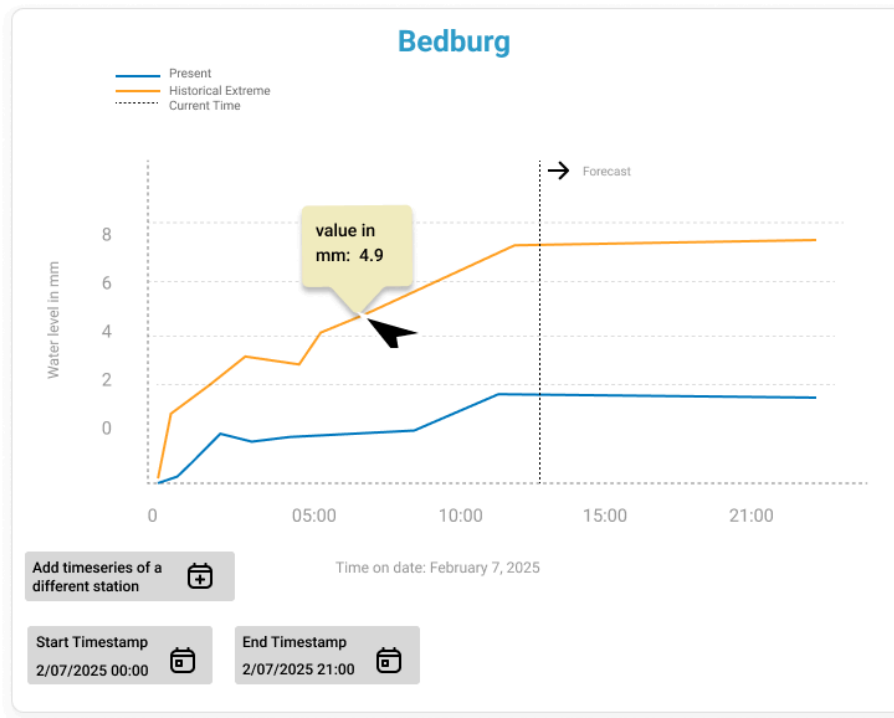


Figure 27: Mock-up GUI for US4.4, zoom in to the pop-up in the Analysis dashboard from [Figure 26](#).

## 3 Testing Regime

A comprehensive testing regime for the federated Data Fabric ensures that the system is reliable, secure, and performs well across its distributed components. The testing regime works across different levels. Starting from single and specific software implementations up to validating the output results of the Data Fabric. Where applicable, tests will be performed automatically, but testing interactions in the user interface will, e.g., remain a manual effort. The Data Fabric follows consistent error handling and logging across its components, enabling troubleshooting across different systems during the development and testing. The described tests are composed for a Data Fabric implementation that is entering the production phase. Within the DIRECTED project, only a prototypical implementation is planned to showcase the benefit of it in the RWLs. Testing is factored in from the beginning, but some tests described below go beyond the scope of the project.

### 3.1 Testing during development

Different types of test will be exploited to mature the software during development and under CI/CD pipelines:

**Unit Testing** verifies the functionality of individual components and modules. It will be applied to test APIs for each federated node and within the DIRECTED Data Fabric to ensure they correctly handle requests, return accurate data, and fail gracefully when errors occur. The Data Fabric will contain a rich metadata catalogue that also needs to be tested for accurate tagging, searchability, and retrieval of metadata associated with datasets. For the user and access control components, unit tests need to verify that role-based access control and user authentication mechanisms enforce permissions correctly at a granular level. Furthermore, the processing components are tested for integrity and reasonableness based on pre-calculated results that can be compared against the test outputs.

**Integration Testing** ensures that different system components work together as expected. This is crucial for the Data Fabric as it is composed out of several modular components. The data ingestion workflow needs to be tested whether that data is properly retrieved and integrated without duplications or inconsistencies. As the Data Fabric allows a federal set-up, particular queries will reach out to different nodes and results need to be sensibly aggregated to a single response. This interplay will also be tested by federated query execution. Interoperability is a key property in DIRECTED. Even though the Data Fabric is based on open standards, the interoperability across different implementations of the standard and instances of the service are tested by specifically designed queries.

**Performance and Load Testing** assess the system's performance under various load conditions. Different indicators are measured and monitored as the development of the Data Fabric progresses. Query response times across nodes are tested to assess their performance. Data Transfer Speed and model processing times are evaluated between models, components and nodes, particularly when dealing with large datasets. Throughout these tests, the resources in the DIRECTED cloud infrastructure are monitored, i.e., CPU, memory, and storage usage to identify inefficiencies or excessive resource consumption.

**Security Testing** ensures the system is secure, compliant, and resistant to potential threats. Security measures in the Data Fabric will be rigorously tested across several key areas to ensure compliance and safeguard user data. Authentication and authorization testing will confirm that only authorized users can access data and policies are enforced. Penetration testing (comp. Sec 3.3.3 In D5.3), or ethical hacking, will identify vulnerabilities in network configurations, APIs, and access controls. Finally, audit and logging tests will confirm that all access, queries, and data-sharing actions are correctly recorded for audit trails and compliance tracking.

**Compliance and Data Governance Testing** verifies adherence to data governance policies, industry standards, and regulatory requirements. We will test that data retention and deletion policies are enforced across components and nodes, especially for sensitive or regulated data. Also, proper enforcement of data access policies by users and model chains are tested

## 3.2 Monitoring and Continuous Testing in Production

We will implement monitoring and continuous testing for operation of the Data Fabric to catch issues early and maintain stability. Lightweight monitoring systems record system health and reachability of the services. The logs collected during operation will allow assessing unexpected behaviors or security events. Automated alerts for key events will be established. The components are regularly tested for known vulnerabilities by Trivy Vulnerability Scanner and the Trivy-Operator in the deployed system (comp. Sec. 3.3.2 in D5.3). Test workflows for data and model integrity will be performed to ensure accuracy and data availability across the Data Fabric.

# 4 Training and User Guides

In order to exploit the developed Data Fabric to its full potential by all users, training material and user guides will be developed after the Data Fabric has been released. These will also contribute to the knowledge transfer outlined in Deliverable D6.3. The training material will be tailored by role and mostly compiled as online learning material. User guides will document the functionality of features and components in the Data Fabric. Both, training and user guides, will be developed once the Data Fabric has taken shape as screenshots and screencasts will be a central element and can only be taken with a deployed version of the Data Fabric.

## 4.1 Training by role

Different roles in the Data Fabric will have different duties and options when using the Data Fabric. We stick to the roles defined in Section 2.1 in Deliverable D5.3 and give a first overview of the training aspects. A detailed description of the training by role will follow in Deliverable D5.7.

The **Infrastructure Administrator** is operating the entire Data Fabric. Therefore, training needs to start with the deployment and configuration of the system. This includes security, safety and ethical aspects (comp. D5.3). Furthermore, the set-up of user groups, roles and the interplay between the authorization and Spatial data Infrastructure (SDI) parts of the Data Fabric need to be explained. Common explanation material tailored to IT administrators is often predominantly technical and may root in annotated docker compose files accompanied by a quick start tutorial to initially deploy and configure the Data Fabric.

**Data Stewards** run the Data Fabric from a thematic point of view. They manage data, processes and results. The training material will cover the technical basics on, e.g., the OGC APIs that are used to integrate remote data sets, but also to provide results of the Data Fabric to external clients like a web or desktop GIS. Further training addresses the import process of data sources, including the DPI assessment (comp. D5.3) and the registration of metadata. Training is also needed to explain the set-up of models and model chains in the Data Fabric and the ethical and DPI assessment of the model outputs and results. Training material will heavily build upon screenshots and -casts.

A **User Administrator** will assign roles and as such rights to individual users of the system. Besides the technical training of how to manage users, training on the impacts regarding GDPR and ethical considerations will be necessary. Training material will be based on screenshots for the technical parts and use-case and example based discussing GDPR and ethical aspects.

An **Anonymous User** is unknown to the system and can only exploit a limited set of features. General training will be developed explaining in a “quick start guide” how to use and responsibly use and interpret the information products presented in the Data Fabric. This guide will be linked in the Data Fabric’s front-ends. The material will be based on annotated screenshots.

**Logged-In users** have elevated rights and a richer feature set as anonymous users. They will also take benefit from the training material, i.e. quick start guides, provided for the anonymous users. However, those users are known to the Data Fabric and will receive additional training on the specific features they have access to (this may vary between RWLs). Typically, the added features allow access to more sensitive data and results, stressing the importance of a training on responsible use and interpretation of the information products provided in the Data Fabric.

## 4.2 User Guides

The Data Fabric user guides will serve as a reference book to look up details about the available features and components. The guides will range from simple user interactions in the front-end like the selection of layers, up to explanation how to control embedded processes in the OGC based processing component or even adding new processes. Based on the intended target audience from novice users over Data Stewards, modellers and IT-staff, the explanation will vary in wording. The target audience will be clearly mentioned at the beginning of each described feature.

The user guides will be developed in a simple and lightweight yet appealing way, that also allows searching for topics and features, to quickly guide the users. The front-ends developed within DIRECTED will also reference specific sections in the user guides, in order to provide seamless guidance as part of the user experience.

Stubs of the user guides will already be defined during the development phase of the Data Fabric as part of the code documentation. These rather technical stubs will be further detailed and, where deemed necessary, rephrased to be tailored for the anticipated audience. During the evaluation phase of the Data Fabric, feedback will also be collected on the quality of the explanations in the user guide and improved where appropriate.

## 4.3 Ethics

General ethical dimensions of the Data Fabric have already been addressed in Section 4 in D5.3. Here, we address issues linked to training activities for the Data Fabric. As mentioned for several roles in Section 4.1, information products derived from the Data Fabric can be sensitive and decisions taken based upon them will potentially impact many people. Therefore, the training of users needs to pay special attention to limitations. While the users with elevated rights can e.g. re-run model chains to better understand the effect of inputs and parameters, anonymous users, i.e. citizens, will not be able to replicate the model chain and need to trust in the information products made available. Therefore, it is important to provide the training for anonymous users in a way, such that it also enables citizens to understand the type of data and models (hydrological, economic, cost-benefit analysis) and associated constraints.

Expert users can access detailed scientific papers that are linked in the metadata of the integrated models to learn about their mechanics and constraints. Novice users from the general public will have access to references from the metadata, but typically no means to access the paper and will most likely lack the necessary background knowledge. Therefore, simplified explanations targeting general end users of the models should also be part of the system's metadata and training.

The Data Fabric itself should provide mechanisms for reporting issues or questioning results. This possibility and the process behind it will also be contained in the training material, in order to raise awareness and encourage users to critically question data and results.

## 5 Conclusion

This document, D5.4, serves as a comprehensive overview of the implementation plan for the DIRECTED Data Fabric, building upon the foundational architectural design detailed in D5.1 and the user requirements from D5.2 and D5.3. By embracing a user-centered, agile and sprint-based development methodology, the DIRECTED project is committed to a co-design approach, ensuring that the Data Fabric evolves in direct response to the real-world needs of its users in the RWLs.

The detailed mock-ups presented for each RWL - Capital Region of Denmark, Emilia-Romagna Region, Danube Region (Vienna and Zala), and Rhine-Erft Region - demonstrate the tangible progress in translating user needs into intuitive graphical user interfaces. These mock-ups are critical starting points for ongoing discussions with stakeholders, facilitating continuous feedback loops that are integral to our iterative development process. The insights gained from initial stakeholder feedback of all RWLs, highlight the importance of user-friendliness, data source transparency (also use of Open Data and following FAIR principles), and the inclusion of relevant climate scenarios and uncertainty analysis. This continuous user feedback has further shaped the refinement of the Data Fabric's features and visualizations.

Furthermore, this deliverable outlines a robust testing regime, emphasizing both testing during development through unit testing and continuous monitoring in a production environment. This ensures the Data Fabric's reliability, security, and performance across its federated components. While the project focuses on a prototypical implementation, the testing framework is designed to support future scalability and operational readiness.

Finally, the document addresses the critical aspects of training and user guides. By developing dedicated training modules for defined user roles and providing lightweight online resources, the project aims to maximize user awareness and to lower barriers to accessing the Data Fabric's functionalities. The continuous integration of ethical considerations and good practices, as further detailed in D5.3, underpins the entire implementation process, fostering responsible usage of the Data Fabric.

This deliverable detailed the implementation, design, and co-design approach of the Data Fabric in its ongoing development. Preliminary mock-up user-interfaces have been discussed and visualized together with the RWLs, modellers, and Data Fabric team. These mock-ups are being continuously tailored to the needs of the stakeholders, as workshops and discussions with RWL hosts and end-users continue. By prioritizing user engagement, iterative development, rigorous testing, and comprehensive support, the project is well-positioned to deliver a prototype of a robust, interoperable, and user-friendly platform that significantly contributes to improved Disaster Risk Management and Climate Change Adaptation within the participating RWLs and beyond.

The Data Fabric helps overcome silos and improves communication among disaster risk reduction and climate change adaptation actors through its interoperable, co-designed, and feedback-driven development. It leverages synergies by integrating various models and data sources, promoting multi-risk thinking with multi-hazard dashboards and uncertainty analysis. The Data Fabric breaks down technical barriers between stakeholders, and improves cooperation and exchange of data and information for operational, research and strategic purposes. This approach also builds capacity and lasting partnerships through tailored training and continuous collaboration with stakeholders. In order to also support the RWLs beyond the project lifetime, a business development plan (D6.5) will be created.

# Annex - Tables of acceptance criteria of the RWL interoperability use-cases

From the user stories, mock-ups and continuous discussions with RWL hosts and users throughout the project, checklists have been derived that will serve as means of verification for Milestone 24 in project month 36. The checklists will allow us to assess whether the interoperability use cases have been achieved per RWL.

## Capital Region of Denmark RWL

Gap Identified	Requirements to Address the Gap	User-Story Target	Fulfillment Status
Lack of real-time data displayed in an understandable manner (i.e., in a UI)	Real-time data via DMI displayed in the Data Fabric	US1.4	
Lack of real-time modelling to view potential impacts and coastal and pluvial flood propagation	Real-time modelling with SaferPlaces and the DTU Damage-Cost Model, surrounding pluvial and coastal flooding events (and their co-occurrence)	US1.4, US1.2	
Static, long-term, open source climate change scenarios that couple between persistent rainfall and high water levels in the Roskilde Fjord	Coastal and Pluvial Flooding event climate change scenario model outputs, from the DTU Damage-Cost model, SaferPlaces, and Scalgo models	US1.2	
WebGIS floodmap layers available in an easy to understand UI as well as available for download	Coastal and Pluvial Flooding event climate change scenario model outputs, from the DTU Damage-Cost model, SaferPlaces, and Scalgo models	US1.1	
Lack of storm surge model outputs with adaptation measures	Model outputs from the DTU Damage-Cost model as well as the SaferPlaces model, with input barriers and water tubes for future planning efforts and potential damages mitigated	US1.3	

Ability to compare different adaptation measures based on criteria input	GUI and back-end integration of the CLIMADA MCDM (Multi-Criteria Decision-Making Assessment)	US1.3	
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## Emilia-Romagna Region RWL

Gap Identified	Requirements to Address the Gap	User-Story Target	Fulfillment Status
Rapid flood modelling tool for early warning and Disaster Risk Management	Real-time modelling with SaferPlaces using weather nowcast and forecast data	US2.1	
Platform to map flood hazards and damage for historical and projected climate data	Web platform to view and generate flood and damage maps for historical and potential future scenarios	US2.2	
Rapid wildfire modelling tool for early warning and Disaster Risk Management	Real-time modelling with ForeFire using weather nowcast and forecast data	US2.3	

## Danube, Vienna RWL

Gap Identified	Requirements to Address the Gap	User-Story Target	Fulfillment Status
Lack of pluvial flood modelling in urban areas	Pluvial flood maps with SaferPlaces and/or RIM2D and damage cost assessment with SaferPlaces and/or CLIMADA	US3.V1	
Lack of climate projections of flood risk	Pluvial and fluvial flood maps for climate scenarios	US3.V1, US3.V2, US3.V3	
Change of annularity of flood events (e.g., will a 100-year flood be a 50-year flood in 2050?)		US3.V3	

## Danube, Zala RWL

Gap Identified	Requirements to Address the Gap	User-Story Target	Fulfillment Status
Lack of a multi-hazard platform	Multi-hazard maps	US3.Z1, US3.Z2, US3.Z7	
Impact of climate change on agriculture and forestry	Modelling of crop yields for climate scenarios with ABSOLUT model and/or CLIMADA  Climate projections (especially temperature, rainfall, droughts) for the region	US3.Z3, US3.Z4, US3.Z5	

# Rhine-Erft Region RWL

Gap Identified	Requirements to Address the Gap	User-Story Target	Fulfillment Status
Impact of dam breaks on flooding	Simulation of dam break scenarios with RIM2D	US4.7	
A platform which allows to test the impact of different measures in flood protection	On-demand modelling with SaferPlaces and/or RIM2D	US4.1, US4.2, US4.3, US4.5, US4.8	
Impact of climate change on agriculture	Modelling of crop yields for climate scenarios with ABSOLUT model and/or CLIMADA	US4.6	

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