SCOREwater

Smart City Observatories implement REsilient Water Management

DELIVERABLE D4.15
INTEGRATION OF HYDROLOGICAL AND GROUNDWATER MODELS IN THE SCOREWATER PLATFORM

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Author(s)	Meijer, U; Kooistra, T
Reviewed by	Filip Moldan (IVL), Lluis Corominas (ICRA), Edgar Rubion Soler (Eurecat)
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ABBREVIATIONS

Abbreviation	Definition
CKAN	Comprehensive Kerbal Archive Network
COA	City of Amersfoort
ICT	Information and Communications Technology
IoT	Internet of Things
SDG	Sustainable Development Goals
SME	Small and Medium-sized Enterprise

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PROJECT ABSTRACT

SCOREwater focuses on enhancing the resilience of cities against climate change and urbanization by enabling a water smart society that fulfils SDGs 3, 6, 11, 12 and 13 and secures future ecosystem services. We introduce digital services to improve management of wastewater, stormwater and flooding events. These services are provided by an adaptive digital platform, developed and verified by relevant stakeholders (communities, municipalities, businesses, and civil society) in iterative collaboration with developers, thus tailoring to stakeholders' needs. Existing technical platforms and services (e.g. FIWARE, CKAN) are extended to the water domain by integrating relevant standards, ontologies and vocabularies, and provide an interoperable open-source platform for smart water management. Emerging digital technologies such as IoT, Artificial Intelligence, and Big Data is used to provide accurate real-time predictions and refined information.

We implement three large-scale, cross-cutting innovation demonstrators and enable transfer and upscale by providing harmonized data and services. We initiate a new domain "sewage sociology" mining biomarkers of community-wide lifestyle habits from sewage. We develop new water monitoring techniques and data-adaptive storm water treatment and apply to water resource protection and legal compliance for construction projects. We enhance resilience against flooding by sensing and hydrological modelling coupled to urban water engineering. We will identify best practices for developing and using the digital services, thus addressing water stakeholders beyond the project partners. The project will also develop technologies to increase public engagement in water management.

Moreover, SCOREwater will deliver an innovation ecosystem driven by the financial savings in both maintenance and operation of water systems that are offered using the SCOREwater digital services, providing new business opportunities for water and ICT SMEs.

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EXECUTIVE SUMMARY

The City of Amersfoort has developed a hydrological (sewerage-)model that provides insight in the sewerage system, potential issues and the expected effect of mitigating measures. These mitigating measures are intended to prevent flooding in the city. Due to climate change the risk of flooding is increasing, thus raising the necessity to build and use such a model. Both the input-data used to construct the model and the outcomes it delivers are integrated in the SCOREwater platform. This document describes how the model was developed, how it will be used by the City of Amersfoort and how it is integrated in the SCOREwater platform.

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1. INTRODUCTION COA CASE AND HYDROLOGICAL MODEL

In the City of Amersfoort (hereafter: COA) case the overall goal is to contribute to the redevelopment of the city, in such a way that it becomes more resilient to climate change. One of the ways to do so is by using hydrological models to gain insight in potential hydrological issues and the expected effect of mitigating measures. If we look at the definition of a hydrological model, Wikipedia says that "a hydrologic model is a simplification of a real-world system (e.g., surface water, soil water, wetland, groundwater, estuary) that aids in understanding, predicting, and managing water resources[1]". In the Amersfoort Case, the hydrological model that we talk about focuses on the sewerage system. As such, it is a digital representation of the sewerage system.

The remainder of this report will focus on the sewerage model. As this differs from what was described in the Grant Agreement, why this differs will be addressed in the following chapter. Chapter 3 describes how an external company was contracted to build the model. Chapter 4 describes the sewerage model in more detail. Chapter 5 describes integration on the SCOREwater platform, and lastly chapter 6 describes lessons learned.

2. GRANT AGREEMENT AND DELIVERABLES

In the Grant Agreement section on D4.15, we have written that the hydrological model will be integrated on the SCOREwater platform. More specifically, we have written that doing so 'includes integrating existing data on monitoring networks, precipitation and flood alarms'. This, however, only partially describes a hydrological model. The data can be used to show historical trends and investigate the actual situation, but is not sufficient in answering all our questions. Specifically, the data described provides input that is used to build a model that is also able to predict the risk of flooding. As such the model is much more: it is a representation of the sewerage system, that allows for calculations of expected flooding. The model is described in more detail in chapter 4. This chapter describes how existing monitoring networks are integrated on the SCOREwater platform.

2.1 EXISTING MONITORING NETWORKS ON WEATHER

The City of Amersfoort owns its own network of weather monitoring, which includes 5 precipitation sensors. The locations of these sensors can be found in figure 1. The data collected by these sensors will be published as open data on the SCOREwater platform. This includes both metadata (location, type of measurement and type of sensors) and actual precipitation data. The latter is collected once every 5 minutes. The precipitation data is used as input to construct the hydrological model.

[1] https://en.wikipedia.org/wiki/Hydrological_model

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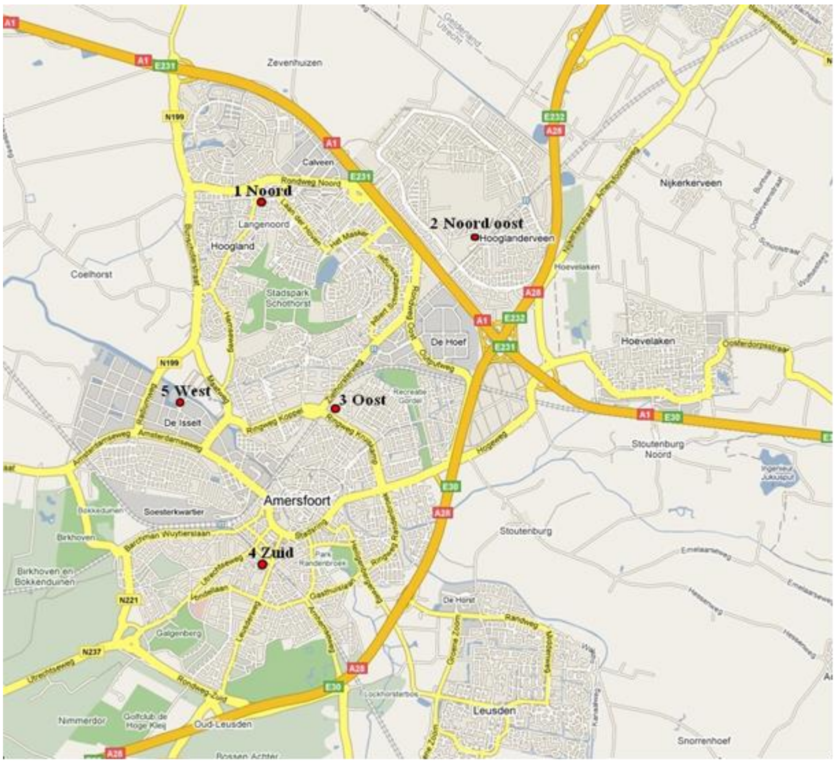

Figure 1: Locations of the precipitation sensors owned by the City of Amersfoort

Besides the precipitation sensors, the City of Amersfoort owns sensors measuring groundwater levels (200 locations), soil moisture, temperature and humidity (12 locations). The latter were installed as part of D4.17. All data gathered by these sensors will be published as open data on the SCOREwater platform.

2.2 FLOOD ALARMS

As stated earlier, the Grant Agreement also states that flood alarms will be integrated as part of this deliverable. However, while working on the deliverable this has proven to be impossible. More specifically, the data that is needed to build a flood alarm is not yet available because it is produced by the hydrological model. More detailed information about what data the model provides will be given in chapter 3. By using this data we will built a flood alarm aimed at predicting flooding before it occurs. This work will be done as part of D4.18, which will be finalized in M30.

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3. MARKET SCREENING

The municipality does not have all the required knowledge in-house to develop a hydrological model. As such, a tender was required. The following paragraph describes how COA organized this process.

Several external suppliers were approached in search of a party most suited to build the hydrological model. The market is characterized by a large number of companies offering similar products. As such, a so-called national public tender was used to obtain tenders from several companies. The choice was based on both price and quality offered. The quality of the tenders was measured using different criteria. All tenders that were received were scored on these criteria, which included criteria on how the model was to be built, the proposed manner of collaboration, planning and validation of the model. Based upon this, the company Arcadis[2] (https://www.arcadis.com/en/global/) was selected as having offered the best proposal.

The hydrological (sewerage-)model is being built as part of the establishment of a municipality-wide sewerage plan. All municipalities in the Netherlands are required to have such a plan. It describes water management within the municipality, including assets that are owned and used, current status of these assets and future maintenance plans. The sewerage model that is described in this deliverable is part of this plan. It is important because it shows potential issues and describes which measures are necessary to mitigate potential flooding issues.

The following chapter describes the sewerage model in more detail, including goals, data used and data and insights provided by the model.

4. SEWERAGE MODEL

Like in all cities, the city of Amersfoort has a sewerage system that has grown as the city has grown. This implies that different neighborhoods have different sewerage-subsystems with different characteristics. A digital representation of this system aids in understanding both how the system functions and in the necessity to alter it. Important to note here is that as we are being confronted with more extreme precipitation, we are required to take action to prevent flooding in the city. But before being able to take mitigating measures, it is important to know exactly how the sewerage system works, what happens with differing amounts of precipitation, what variables can be adjusted and what the expected effect of taking these mitigating measures is.

4.1. GOALS

Before focusing on the data that is included in the model, it is important to state how the sewerage model adds value. The sewerage model is developed for various goals:

- Firstly, it shows the working of the sewerage system, including interaction with the surface water system at normal and extreme precipitation;
- Secondly, it allows COA to develop and use so-called ‘stress-tests’ focused on specific neighborhoods. A stress-test shows the consequences of climate change in specific areas, in this case related to extreme precipitation. They are often used to engage in dialogues about climate-related risks together with external stakeholders (such as residents, companies or educational institutions);
- Thirdly, the model shows the expected effect of proposed mitigating measures. This allows COA to prioritize measures.

[2] Arcadis is a global Design & Consultancy firm for natural and built assets. Applying deep market sector insights and collective design, consultancy, engineering, project and management services they work in partnership with their clients to deliver exceptional and sustainable outcomes throughout the lifecycle of their natural and built assets. The company has 28,000 employees, is active in over 70 countries and it generates €3.5 billion in revenues.

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The most important objective of the model is to assess the effectiveness of proposed measures that are intended to prevent flooding. An example of where this can be used is the Soesterkwartier-area, which is located closely to the Amersfoort Central Railway area. The sewerage model will be used here to assess the effects and necessity of proposed measures to prevent flooding caused by extreme precipitation. The insights from the model will be used in redeveloping the area. Another example includes the tunnel near the Schothorst station, which is periodically flooded due to extreme precipitation. By analyzing the effect of extreme precipitation, the sewerage model can make a similar assessment of the necessity and expected effectiveness of measures near this tunnel.

4.2. INPUT AND CONSTRUCTION

The sewerage model is built using the municipality's data on characteristics from the sewerage system. These include sewerage objects such as inspection wells, weirs, pumping stations and conduits. Relevant characteristics are recorded per object. For inspection wells, these include the X- and Y-coordinates, ground levels, form and shape of the well and internal measurements. For weirs, in addition to these characteristics crest level and weir width are also catalogued. For pumping stations, capacity as well as switch on and switch off levels are included. Lastly, when it comes to conduits that are located in the sewerage system, a number of characteristics is used: the wells that it is connected to, length, shape, diameter, material, height and the type of system. All this data is static data.

Besides using the above described characteristics, model parameters are used to be able to calculate expected effects. An example includes the Roughness Coefficient, which differs based upon the material that is used in constructing the pipes. As this is not known for all the pipes, predefined model parameters (in accordance with the Dutch national guideline for sewer modelling) are used. Furthermore, several parameters are used to assess the hydraulic load of the sewerage system. These include calculations based on both number of inhabitants and average discharge quantities. When known, these are combined with data on discharge quantities of companies. The way this discharge 'flows' through the system can be simulated with the model. Lastly, paved surface areas that function as sub catchments are included. The paved surface areas consist of roads, squares and roofs. This is necessary to allow for more precise calculations.

To perform these calculations, all the above is added to a digital model. The model is an integral model consisting of sewerage, surface water and ground level. Paved surface areas are included in the model. Then, a certain type of precipitation (length x intensity) is simulated to assess the effect on the model. Model calculations show what happens in different parts of the sewerage system, and which potential issues may arise related to flooding. Different scenarios of precipitation are imputed to ensure that all possible scenarios are known.

Afterwards, the model is validated by comparing calculated water levels in the sewerage system (as given by the hydrological model) with actual measurements in the sewerage system. When necessary, the model (parameters) will be adjusted based upon this validation. By doing so, COA ensures that the (results of the) model are as accurate as possible. The model is almost ready and the first calculations have been made. After the model is validated the model will be shared on the SCORE water platform. This is expected to be finalized in the first quarter of 2021.

Lastly, it is important to note which software is used to construct the model. The sewerage model is being built using InfoWorks® ICM (Integrated Catchment Modelling). This is a software platform for hydrodynamic modelling of both rivers and sewer systems. With the program, it is possible to thoroughly study complex catchment areas, including all the elements of the drainage infrastructure and natural river systems and the interactions between them in qualitative and quantitative level as a single work flow. InfoWorks® ICM (https://www.innovyze.com/en-us/products/infoworks-icm) provides a wide range of internationally approved theoretical and empirical computational models for detailed simulation of runoff volume formation and routing over complex catchments, while taking into account various hydrological processes such as interaction with ground waters, snow melting, evaporation, formation and transport dynamics of surface contaminants.

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4.3. OUTPUT – DATA AND MAPS

If we look at the output of the model, we can distinguish two different types:

1. The first are data. As stated, the model calculates the effect of mitigating measures in specific areas. The outcome is a data-set that shows which effect can be expected at certain locations given certain predefined amounts of precipitation. These include data on different scenario's, which can be used to assess the effect of different type of measurements.
2. The second are digitally accessible maps, which show both the sewerage system as it is today, and the expected effect that occurs when certain amounts of precipitation occur. Figure 2 shows an example of what this looks like. These maps can be used to engage in dialogues with citizens about climate-change related risks.

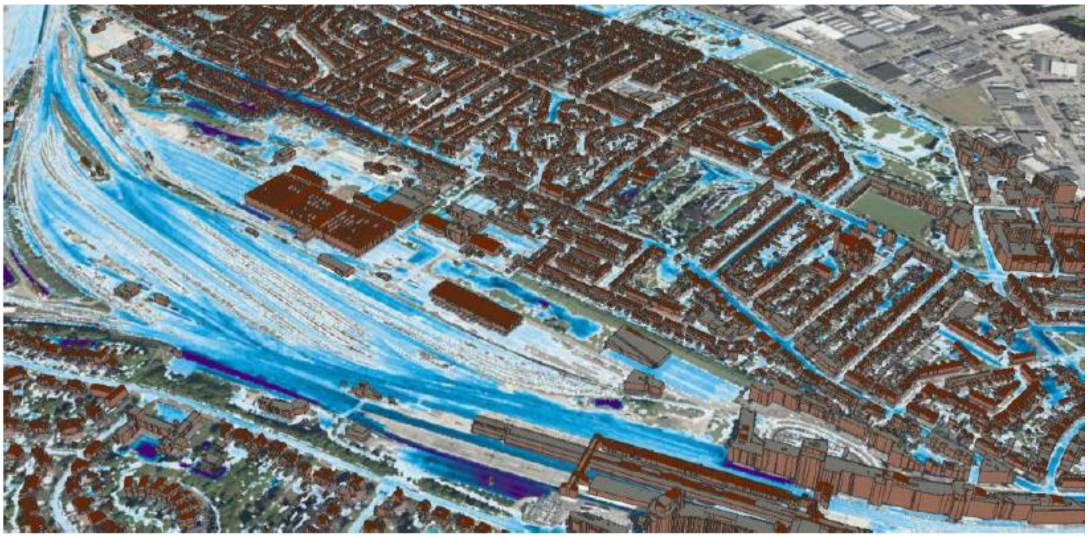

Figure 2: Visualisation provided by the hydrological model displaying the expected flooding resulting from a certain amount of precipitation (160mm in 2 hours) occurring in the Soesterkwartier-neighbourhood [3]

4.4. GROUND WATER MODEL

Besides the sewerage system, COA is also working on a hydrological model that focuses on the groundwater system. For this model, the city works together with the local water authority and the nearby municipalities of Soest and Baarn. The goal of the groundwater system model is to gain insight in the effect of avoiding precipitation from entering the sewerage system. By doing so, less water has to be processed in the sewerage system, as more water is infiltrated in the ground. However, this causes other less desirable effects, which is why a balance has to be sought between the two. These less desirable effects are caused by ground water nuisance. More specifically, high levels of ground water caused by infiltration of precipitation in the ground can cause flooding, for example in basements.

[3] The model calculates the effect of certain types of precipitation on expected flooding in the city. In the white locations minor flooding occurs, in the light blue locations medium flooding occurs and in the dark blue locations major flooding occurs. Buildings are shown in grey and brown.

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Currently, the City of Amersfoort is considering whether or not the groundwater model will be built. A market orientation has been organized to assess which possibilities are offered by companies operating in the market to construct a groundwater model. However, this market orientation has led to the conclusion that many different programs exist, each with their own limitations. Furthermore, the most promising program is still in its development phase. As such, COA has not yet decided on how it will proceed with this model. Important questions that need to be answered include whether the costs that are necessary to do so outweigh the benefits and which software turns out to be most suited. If the city chooses to build the model and the timeline allows for it, the model will also be integrated in the SCOREwater platform to allow interested parties to use the knowledge and data provided by the model for their own interests.

As the hydrological model is part of SCOREwater, an important aspect of the process is integrating it in the SCOREwater platform. Chapter 5 describes this integration in more detail.

5. INTEGRATION ON THE SCOREWATER PLATFORM

To allow interested parties to use the data and insights gained from the model, the model will be integrated on the SCOREwater platform. How was discussed together with project partner Civity. Three 'parts' of the model will be included:

1. As stated in chapter 2, the data gathered by the different sensors that are used by the municipality to measure the environment (e.g. groundwater, soil moisture, precipitation, temperature and humidity) will all be integrated in the SCOREwater platform. As a result, the data gathered by these sensors will be published as open data, to allow all interested parties to use it.
2. Secondly, the input-data that is used to build the model will be shared on the platform, as well as the results from the calculations. This was described in more detail in chapter 4. Interested parties can than download and use this data for their own purposes. Figure 3 shows the open data platform as it is today, to which the data will be added.

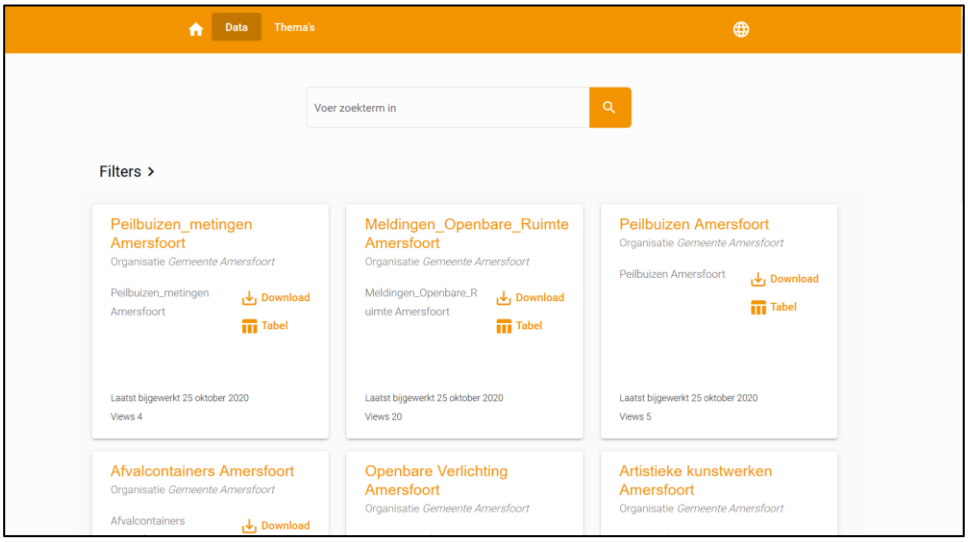

Figure 3: Screenshot of the Amersfoort's open-data platform, to which both the input-data and the output-data will be added.

3. Thirdly, the results from the model will be made accessible using a geographical map-type display. This shows what effects are expected with different types of precipitation. This is a more-user friendly and accessible result. Figure 4 shows a visualization of what this looks like.

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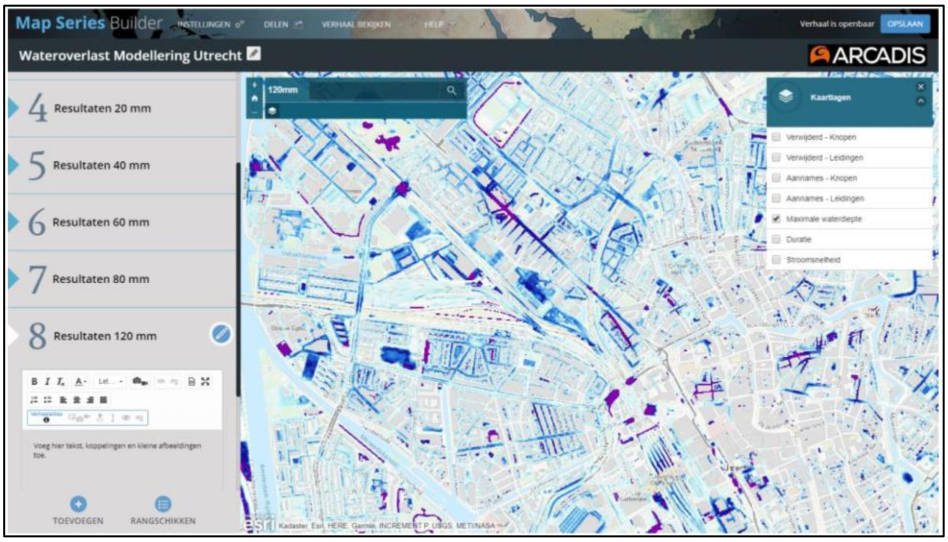

Figure 4: Visualisation provided by the hydrological model displaying the expected flooding resulting from a certain amount of precipitation occurring in the city of Amersfoort[4].

6. LESSONS LEARNED

During the project one of the most important issues to be solved was that not all the data that was necessary to build the model was available. Part of this was caused by the fact that some of the data needed is owned by an external organization (the local water authority). As a result, a delay was inevitable because this data had to be made available. This took some time and was not anticipated upfront. As such, an important lesson learned is that it is important to assess data quality for these types of projects early on when the data is owned by an external organization, to contact them as soon as possible.

Furthermore, a lot of local knowledge on the sewerage system (e.g. certain characteristics) has never been published or integrated in the data. As such, it is only known by specific people (who work for COA). This makes building a model a labor-intensive process, because a lot of interaction between those with the knowledge and those building the sewerage model was required. It is important to take this into account when determining planning of such a process.

[4] The model calculates the effect of certain types of precipitation on the expected flooding in the city. In the white locations minor floodings occur, in the light blue locations medium flooding occurs and in the dark blue locations major flooding occurs. Buildings are shown in grey

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ANNEX 1 – STOCKTAKING

A final Annex of stocktaking was included in all Deliverables of SCOREwater produced after the first half-year of the project. It provides an easy follow-up of how the work leading up to the Deliverable has addressed and contributed to four important project aspects:

1. Strategic Objectives
2. Project KPI
3. Ethical aspects
4. Risk management

STRATEGIC OBJECTIVES

Table 1 lists those strategic objectives of SCOREwater that are relevant for this Deliverable and gives a brief explanation on the specific contribution of this Deliverable.

Table 1. Stocktaking on Deliverable's contribution to reaching the SCOREwater strategic objectives.

Project goal	Contribution by this Deliverable
SO1: Deploy and demonstrate a smart water management approach, which is people-centred, inclusive, interoperable, flexible and safe.	The deliverable describes the deployment of the hydrological (sewerage) model, which is key to assessing smart water management measures. By integrating it on the SCOREwater platform, interested parties can make use of these results.
SO4: Demonstrate benefits of smart water management for increased water-system resilience against climate change and urbanisation	With the hydrological (sewerage) model, COA will be able to more accurately assess the effectiveness of proposed measures. As a result, it becomes possible to more effectively mitigate the effects of climate change.

PROJECT KPI

Table 2 lists the project KPI that are relevant for this Deliverable and gives a brief explanation on the specific contribution of this Deliverable.

Table 2. Stocktaking on Deliverable's contribution to SCOREwater project KPI's.

Project KPI	Contribution by this deliverable
KPI2: Number of input data-sources connected and consumed	As part of the deliverable, three data-sources were connected to the SCOREwater-platform: the input-data used to build the hydrological (sewerage) model, the output produced by the model and the precipitation data from the 5 precipitation sensors.
KPI 5: In Amersfoort, reduce the flooding risk through integrated water management	The hydrological (sewerage) model is used specifically to reduce the risk of flooding in Amersfoort.

ETHICAL ASPECTS

Table 3 lists the project's Ethical aspects and gives a brief explanation on the specific treatment in the work leading up to this Deliverable. Ethical aspects are not relevant for all Deliverables. Table 3 indicates "N/A" for aspects that are irrelevant for this Deliverable.

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Table 3. Stocktaking on Deliverable's treatment of Ethical aspects.

Ethical aspect	Treatment in the work on this Deliverable
Justification of ethics data used in project	N/A
Procedures and criteria for identifying research participants	N/A
Informed consent procedures	N/A
Informed consent procedure in case of legal guardians	N/A
Filing of ethics committee's opinions/approval	N/A
Technical and organizational measures taken to safeguard data subjects' rights and freedoms	N/A
Implemented security measures to prevent unauthorized access to ethics data	N/A
Describe anonymization techniques	N/A
Interaction with the SCOREwater Ethics Advisor	N/A

RISK MANAGEMENT

Table 4 lists the risks, from the project's risk log, that have been identified as relevant for the work on this Deliverable and gives a brief explanation on the specific treatment in the work leading up to this Deliverable.

Table 4. Stocktaking on Deliverable's treatment of Risks.

Associated risk	Treatment in the work on this Deliverable
1. Risk of delay	Due to the Covid-19-crisis, it has proven to be difficult to perform the work as planned. This is due to a variety of reasons, such as having to organize work differently due to the lockdown in March and illness of team members. Where possible, partners have collaborated closely to prevent delay.
2. Loss of Key Staff	As stated above, team members have temporarily fallen ill. Where possible, work was performed by other staff members and was organized in collaboration to prevent delay.

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