# SCOREwater

## Smart City Observatories implement REsilient Water Management

## DELIVERABLE D4.18

# EARLY WARNING SYSTEM FOR FLOODING

| | |
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# ABBREVIATIONS

| Abbreviation | Definition |
|---|---|
| CKAN | Comprehensive Kerbal Archive Network |
| FIWARE | Future Internet WARE |
| ICT | Information and Communications Technology |
| IoT | Internet of Things |
| SDG | Sustainable Development Goals |
| COA | City of Amersfoort |
| ML | Machine Learning |
| LSTM | Long Short Term Memory |
| SO | Strategic Objective(s) |



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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

For this deliverable, the city of Amersfoort and HydroLogic have developed, used and refined a flood early warning system in the city of Amersfoort. The system was developed to provide end users such as city officials with early warnings that flooding may occur, thus giving them time to take action to prevent nuisance and damages as much as possible. The system was created using a Machine Learning algorithm and provides warnings via the SCOREwater platform. The report describes in more detail how the system was developed and what actions can be undertaken based upon the warnings provided by the system.



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# 1. INTRODUCTION COA CASE AND FLOOD EARLY WARNING SYSTEM

Due to climate change the City of Amersfoort (hereafter: COA) like many cities is facing more frequently occurring periods of extreme precipitation. Due to these changing weather conditions the city has to take action to prevent flooding. As a result when (re)developing the city, one of the key goals that the city has is to ensure that newly development areas are resilient to climate change. Avoiding nuisance caused by this (such as flooding of basements, streets and other areas) is a key goal of the city's climate adaptation policy goals.

The necessity to take action have been proven both by several examples of extreme flooding and by calculations done to model the city's water systems. Figures 1 and 2 show two examples of flooding in the city: figure 1 shows an example of flooding on the city's streets, whereas figure 2 shows flooding near one of the city's railway stations.

Figures 1 and 2: pictures showing nuisance due to extreme precipitation in Amersfoort

Ideally, the city would ensure that there is no risk of flooding at all. However, preventing all risk of flooding is expensive, time-consuming and extremely difficult to realize, as it is not the only objective the city has that requires space. Among others, the transition of the energy system (requiring space for solar and wind energy) and the building of more houses to deal with the housing shortage also require space and funds. As such, eliminating all risk of flooding in the city is not a realistic goal.

As a result, COA believes that apart from taking action to prevent the risk of flooding as much as possible, it is also important to use and develop techniques and systems that prevent flooding from causing damage and nuisance. The flood early warning system used within the SCOREwater project, has been developed precisely for this purpose. It can assist in gaining insight into what areas are vulnerable to flooding and what preemptive actions can be taken. As such it can be used to prioritize actions.

Moreover, it can ensure that a warning that flooding may occur is identified accurately and sent in time. By doing so it can give city officials time to take action to prevent damage from occurring as much as possible. Examples of actions that can be taken are informing citizens that flooding may occur, thus giving them time to respond, closing down railway stations or redirecting traffic to less vulnerable areas.

This report describes how the flood early warning system was developed and trained, how it is used in practice, what issues are yet to be resolved and what problems it can solve for both COA and other cities in the world.



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# 2. FLOOD EARLY WARNING – HOW IT WORKS

This chapter describes the concept of the early warning system. The system was implemented for one neighborhood in Amersfoort. The second part of this chapter presents the results of the training for this study area.

## 2.1 TECHNICAL CONCEPT

Pluvial flooding can have severe impact in urban environments, causing damage to public and private property. In the case of large-scale precipitation events, pluvial flooding can even cause loss of life. In creating climate resilient cities, adaptive (water) management is a key element to managing extreme precipitation events. Because high intensity precipitation can develop very quickly, especially during summers, the early warning system faces very short lead times. As a consequence, calculation times have to be as short as possible, in order to issue warnings that are timely enough to allow for adequate action to be taken.

Flood analyses in urban environments are usually carried out with the aid of sewer models. These are hydrodynamic (*term explained below*) models of the sewer system. A precipitation load is imposed on the system and the size and location of the flooded area are calculated. Sewer models require relatively large calculation times, due to the high level of detail incorporated in the model, both concerning the physical properties of the sewer system and the flow conditions within this system. This makes hydrodynamic sewer model less suitable for early warning systems.

***Hydrodynamic modelling vs. Machine Learning algorithms***

A sewer system consists of a network of pipes, connected through manholes. Water enters the system through inlets. The water flows through this network by gravity and/or pumps. A hydrodynamic model mathematically describes the movement of water in time in the sewer system, by solving the equations that govern the physics of water flow in pipes. Among others it calculates water and pressure levels, flow velocity, discharge and friction losses. It allows for a very detailed analysis of the system and its components.

A Machine Learning (hereafter: ML) algorithm does not contain any physics. It is designed to find correlations between one or more input signals and one or more output signals. It is purely 'data driven'. Most ML algorithms need a data set to be trained: a combination of input data and 'known' output data. The algorithm uses this data set to 'learn' the correlations between input and output data. Once trained, the algorithm estimates the output data from 'unknown' input data.

There are many types of ML algorithms for different types of applications. When dealing with time series data, like in the case of water flowing through a sewer system, a class of algorithms called 'Recurrent Neural Networks' are widely used. The algorithm used in the flood early warning system, the LSTM-algorithm, is a specific algorithm from this class. A more in-depth explanation of the data drive models used is presented in D2.7.

To overcome the issue of large calculation times, the early warning system is based on a data-driven model. The core of this system is a ML algorithm that is trained on a data set. This data set is generated by a hydrodynamic sewer model. This approach enables the level of detail of the hydrodynamic model, but with very short calculation times offered. ML algorithms are usually trained on data sets based on observations, but in the case of urban flooding, observations are rare and do not contain the same level of detail as the hydrodynamic sewer model. As a result, a different way has been developed to train the ML algorithm. The algorithm used is of the type Long Short Term Memory (hereafter: LSTM). This is a recurrent neural network designed to be used with time series, as is the case for the flood early warning system.


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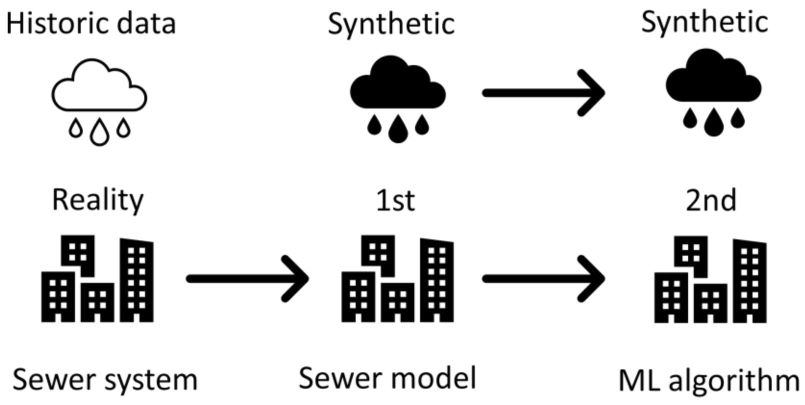


Figure 3: concept of the early warning system. A ML algorithm is trained on a data set created with a hydrodynamic model of the sewer system. The precipitation load is derived from extreme precipitation statistics for the Netherlands.

To create the dataset, the sewer model is trained on a series of 'synthetic' precipitation events: these events have not been recorded but generated, and carry the main characteristics (*duration, pattern/intensity and volume*) of extreme precipitation events in the Netherlands recorded in the period 1990-2010. The characteristics used are listed in table 1 and the precipitation patterns are shown in figure 3. A total of 126 events were generated, each carrying a unique combination of volume, pattern and duration.

Table 1: listing of the characteristics used to generate the synthetic precipitation events. The names of the pattern characteristics refer to the fraction of the volume that is incorporated in the peak.

| Volume | Pattern / intensity | Duration |
|---|---|---|
| 30 mm | uniform | 4 hours |
| 45 mm | 1 peak - 12.5% | 8 hours |
| 60 mm | 1 peak - 37.5% | 12 hours |
| 75 mm | 1 peak - 62.5% | |
| 90 mm | 1 peak - 87.5% | |
| 105 mm | 2 peaks - short | |
| | 2 peaks - long | |


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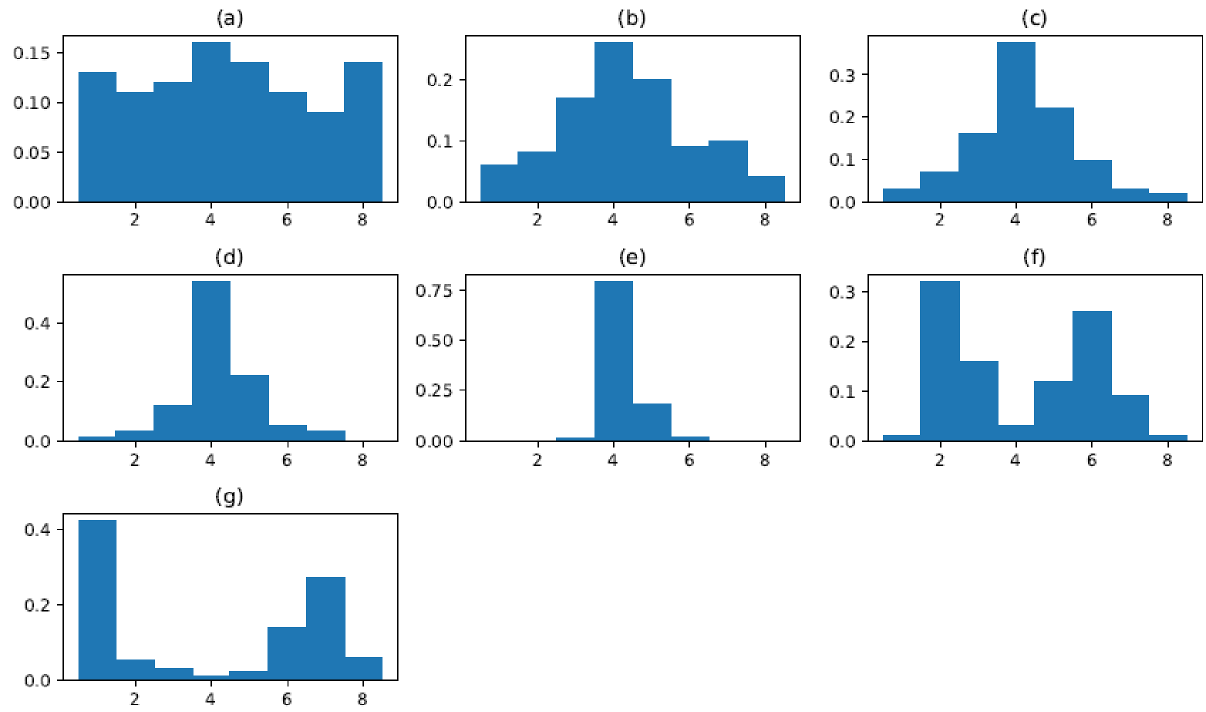


Figure 4: the 7 precipitation patterns for a duration of 8 hours, with (a) Uniform, (b) 1 peak - 12.5%, (c) 1 peak - 37.5%, (d) 1 peak - 62.5%, 1 peak - 87.5%, (e) 2 peaks - short and (f ) 2 peaks - long. The x-axis represents the time in hours and the y-axis the fraction of total mm precipitation.

The algorithm is set up in such a way, that each input event generates a volume curve for each manhole in the sewer system. The volume curve in the manhole is compared to the volume curve calculated by the sewer model for that manhole.

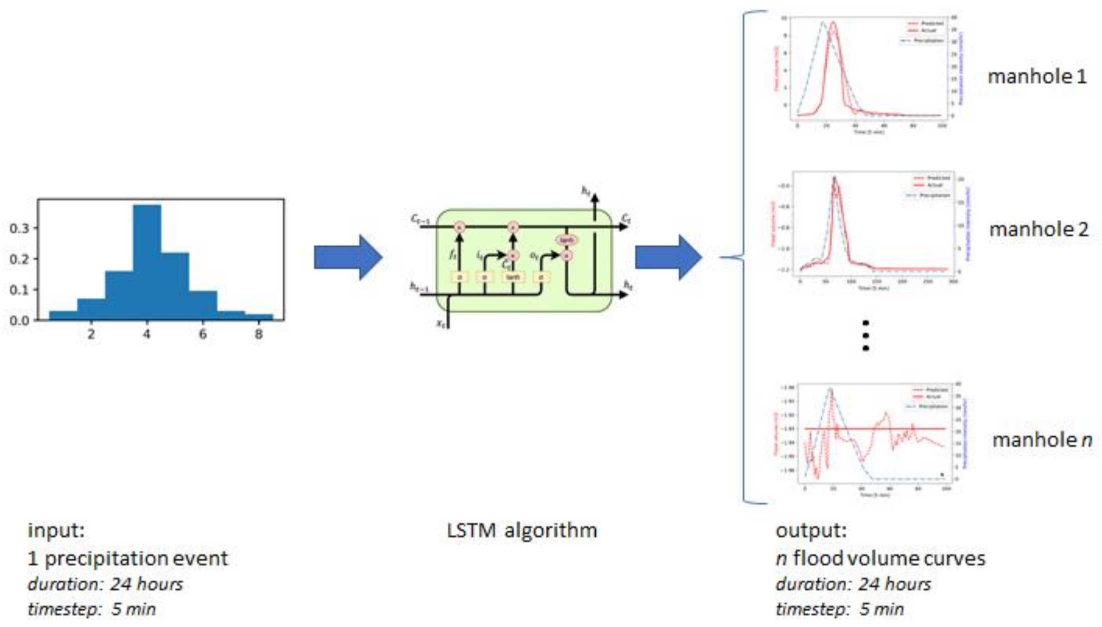


Figure 5: set up of the algorithm. A single precipitation event generates flood volume curves for each manhole in the network.


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## 2.2 STUDY AREA

The study area to test the concept of the early warning system, is a neighborhood called Hooglanderveen. This neighborhood was selected because its sewer system is an isolated, upstream subsystem of the city sewer network, without complicating interactions with adjacent subsystems. The area is also relatively small, containing 230 manholes. The algorithm calculates a 24-hour flood volume time series for every manhole, for every event.

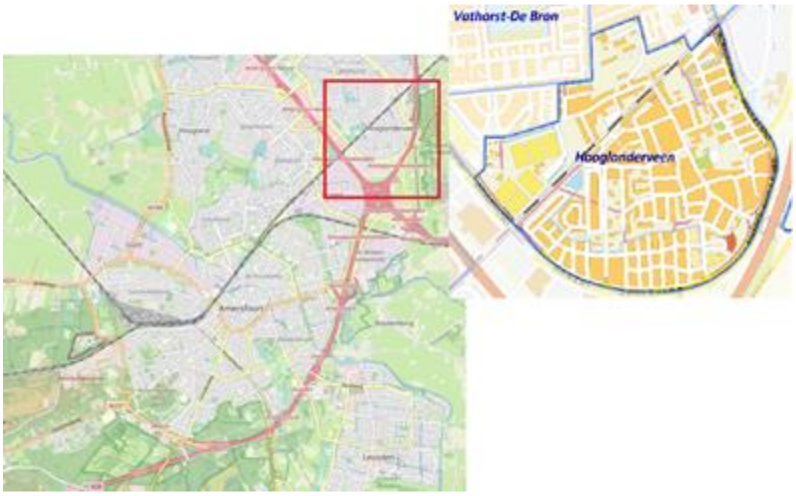


Figure 6: map of the study area Hooglanderveen with its relative location in Amersfoort (left) and the neighbourhood in more detail (right)

The LSTM algorithm trained for this area performed well statistically, with a Mean Absolute Error of 0.06 m3 between the predicted and simulated flood volumes and an $R^2$ of 0.99. This implies that the algorithm accurately describes the output of the flow model for all manholes. The calculation time was recorded at 70 ms per event, simultaneously for all manholes.

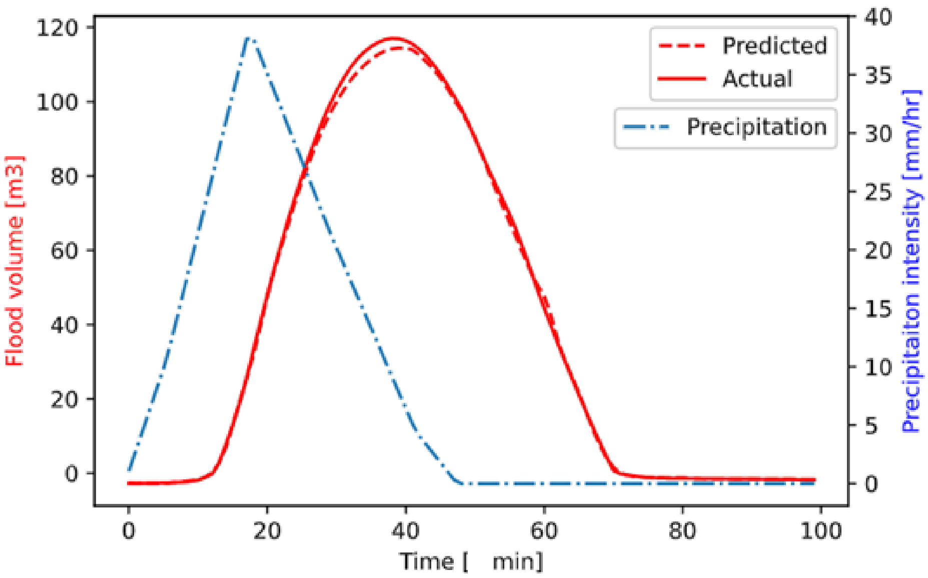


Figure 7: figure showing the relationship between predicted and actual values


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To test the influence of the 'synthetic'/generated precipitation events, the trained algorithm was also tested on a number of precipitation events (see Figure 8), for which flooding in the area had been reported by citizens. The precipitation time series has been obtained from precipitation radar data provided by Hydrologic. The time series start one day prior to the date reported as there can be a delay between flooding and reporting. All events except event 1 and 4 show large peaks in precipitation up to 106 mm/hr. This is higher than the peak precipitation from the synthetic precipitation time series, which have a maximum precipitation of 88 mm/hr. Events 1 and 4 have relatively lower precipitation peaks of 16 mm/hr and 5 mm/hr respectively. Flooding at these dates could be caused by e.g. blockage of the inlets by leaves.

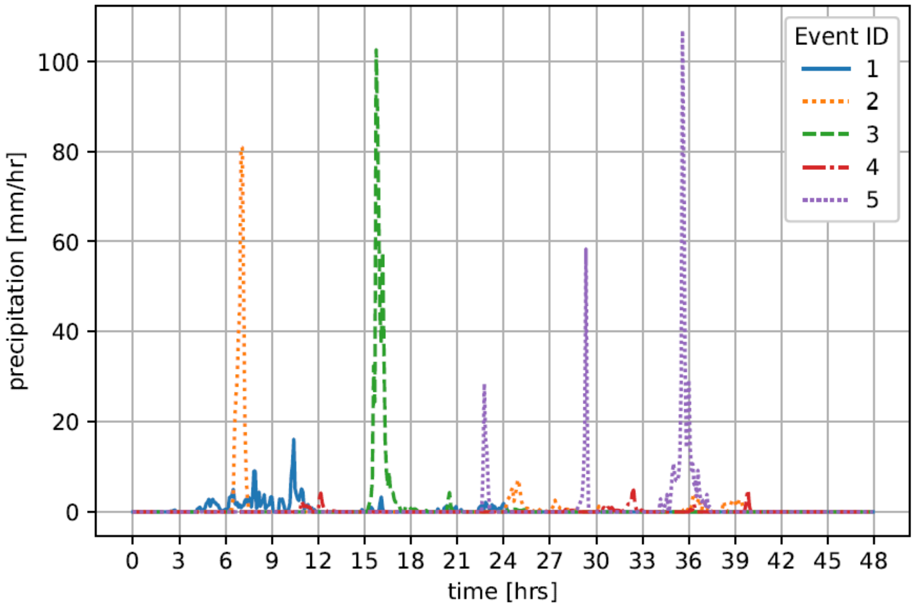


Figure 8. Precipitation time series for historic flood events in Hooglanderveen, used to validate the trained algorithm.

The goodness-of-fit of the algorithm on these events was slightly lower than on the synthetic data, but still satisfactory. The Mean Absolute Error was 0.19 m3 with an unchanged $R^2$ of 0.99. From these results, it was concluded that the performance of the ML algorithm, in terms of flood volume replication and calculation times was satisfactory and fit for use. As a result, the algorithm could be transferred to the SCOREwater platform. This is described in more detail in the following paragraph.


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# 3. LINKING THE SYSTEM TO THE SCOREWATER PLATFORM

The flood early warning system is set up as an operational service within the SCOREwater platform. The flooding algorithms are run every 6 hours, when a new precipitation forecast is available. The time series of flood volumes per manhole are then uploaded to the SCOREwater platform. The information of the latest flood volumes is kept in the database for one month for reference purposes. After a month, all 'negative' flood alarms (*no risk of flooding*) are removed as they are not needed anymore.

Within the SCOREwater platform, for each manhole the calculated flood volumes are compared to warning levels, that can be set per manhole. As such, end users are able to determine threshold values per manhole based upon their goals and knowledge of specific areas. If the volumes in one or more manholes exceed the set warning level, a message is composed containing information about the expected location(s) of the flooding. The message is sent by email to a list of subscribed employees, in this case employees working for COA. With this information they can take action to prevent damage and nuisance. In addition, a list of alerts is kept. The alerts are stored using the "Alert" Smart Data Model which is discussed in deliverable 3.4.

The information on the manholes (*location and identifier*) are uploaded manually to the SCOREwater platform. This information hardly ever changes. A harvester was created to periodically update the address closest to the manhole from the official registration which is kept up to date by the municipality (*reverse geocoding*).

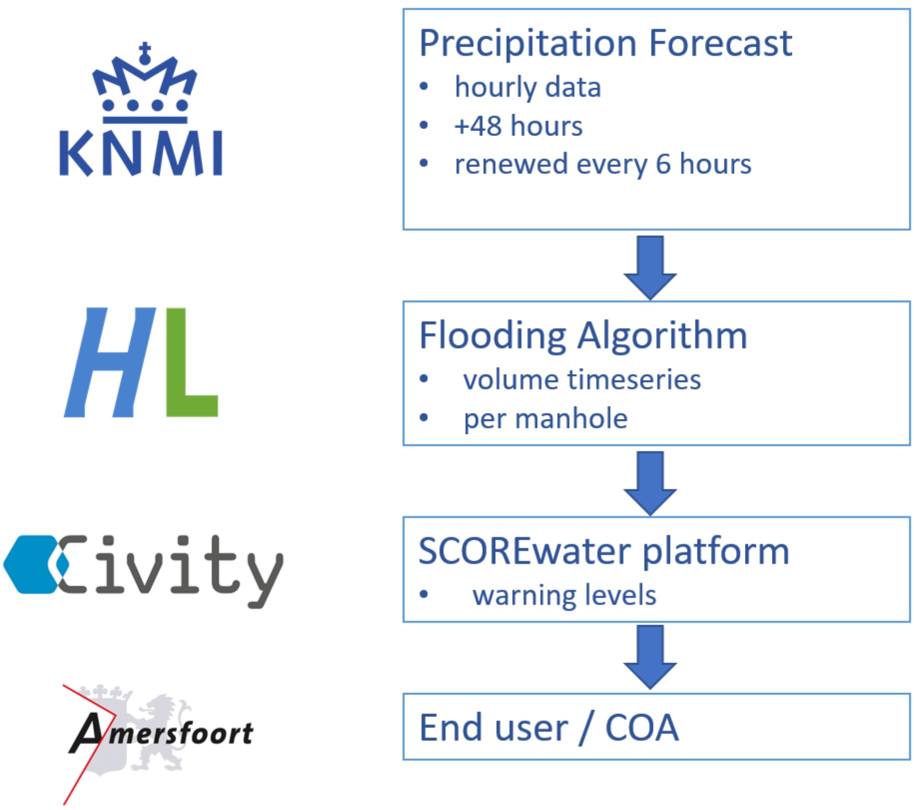


Figure 9: workflow of the flood early warning system, from precipitation forecast to a warning issued to an end user. This workflow is repeated every six hours.


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# 4. USING THE SYSTEM – NOW AND IN THE FUTURE

The first version of the flood early warning system was finished in the summer of 2021.The aim of testing the first version of the system were to:

- Test whether the system would provide accurate and timely notifications that flooding is expected to occur;
- Provide the possibility for end-user COA to test the system and provide feedback;
- By doing so, give input for refinement of the system.

Of course, ultimately the goal of the system is to ensure that when there is a risk of flooding, city officials are timely informed of this and can take action to prevent damages and nuisance from occurring as much as possible. The city has held several meetings together with HydroLogic and Civity to discuss what actions can be taken based upon the information provided by the flood early warning system. It is important to note here that useful actions differ per neighbourhood. For example, for one neighbourhood there may be risk of flooding of basements, while another neighbourhood has tunnels that are vulnerable to flooding.

As stated earlier, the flood early warning system is currently only operational for one neighbourhood. As a result, COA and HydroLogic have not been able to test all potentially useful actions in practice. The model first has to be expanded to include other neighbourhoods to do so, which require the same process as described earlier but with different data (on a different neighbourhood). As a result, the actions described below are hypothetical and have to be tested in practice. COA and HydroLogic are currently looking into the possibility of developing a flood early warning system for other areas in the city, to allow for actual testing of the proposed actions.

Examples of actions that are possible based upon the flood early warning system include:

1. Informing citizens in areas that are vulnerable to flooding that flooding may occur within a considerable time-frame. Within the city, there are neighborhoods where basements are vulnerable to flooding. This is caused by a combination of height differences and the way the water system in these areas function. When flooding is expected, citizens can put up barriers that prevent water from entering their basement, thus preventing damages. The flood early warning system can provide them with accurate and timely information on when this is necessary;

2. Redirecting citizens near the Amersfoort Schothorst railway station. This station is also vulnerable to flooding. When flooding happens, dangerous situations can occur. Figure 10 below shows an example of flooding occurring under the station.


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Figure 10: pictures showing flooding under the Amersfoort Schothorst railway station

In the past, it has occurred that as a result of the flooding people arriving by train could not go from one side of the station to the other side. This led to situations where people have walked over instead of under the railway, which may lead to dangerous situations. Having a flood early warning system that is operational and functional for this area can give city officials the possibility to take mitigating measures. Examples include informing travelers of alternative routes, or preventing travelers from visiting a certain location;

3. Redirect traffic and/or optimize traffic flows. Currently, no flood early warning system is used to optimize traffic in the city. Flooding can cause traffic jams in certain neighborhoods. When developed for vulnerable parts of the traffic system the flood early warning system may provide valuable input to redirect traffic. Specifically, if the risk of flooding for specific areas is known, this information may be used to redirect traffic from areas that are vulnerable to (extreme) flooding to areas that are less vulnerable to flooding. Also, it can give city officials time to decide whether it is necessary to close down certain areas or roads;
4. Lastly, the flood early warning system and the data it provides can be used in the future to analyze the functioning of the sewerage system and the effectiveness of the measures that have been taken to prevent flooding. Specifically, it can provide (historical) data that can be analyzed to look for patterns and changes in dealing with flooding. By analyzing the data, the city can assess the effectiveness of measures taken to prevent flooding from occurring.

From a business perspective, the flood early warning system developed serves as a pilot or first example of an early warning service that can be applied and delivered to other locations and other cities. The business perspective of the system has initially been described in deliverable 6.2 (Value proposition, business model, market and stakeholders analysis, initial version) and will be described in more detail in deliverable 6.3 (Value proposition, business model, market and stakeholders analysis, final version).



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# 5. STAKEHOLDER ANALYSIS

When looking at the potential use and added value of the flood early warning system, several stakeholders have been identified that may benefit from such a system. This chapter shortly describes each of these stakeholders, including how the flood early warning system can benefit them.

## 5.1 CITIZENS

The most important beneficiaries of the flood early warning system are citizens. They live, work and recreate in the city, and flooding can result in immediate damage and/or nuisance during each of these activities. Especially for citizens living in neighborhoods that are vulnerable to flooding, having access to a reliable flood early warning system provides significant benefits to prevent damages. COA and HydroLogic have not yet involved citizens, as they first wanted to ensure that the system was operational and reliable. In the future citizens living in these vulnerable neighborhoods will be asked if they are willing to test the system, to see if it satisfies their needs.

## 5.2 CITY OF AMERSFOORT

Another important end user of the flood early warning system is COA. As a municipality, it has an important role to play in preventing flooding. Currently, COA tries to do so by (*among other activities*) making sure that the sewerage system is capable of dealing with increasing amounts of precipitation, constructing sufficient temporal water storages and making sure that precipitation can enter soil as much as possible. However, as precipitation intensifies due to climate change additional action is necessary.

In the near future, a flood early warning system allows COA to take actions as described in the previous chapter). For the future COA intends to look into the possibility of creating 'flexible' water storage units. The idea behind this is that these flexible storage units store water for as long as possible to prevent draught and allow plants to grow, while at the same time linking it to a precipitation warning system. This is intended to make sure that when precipitation is expected, the storage unit is emptied in the sewerage system before the precipitation occurs, thus creating new room for the incoming precipitation. Although this solution is yet to be developed and tested, this would provide an additional use case for the flood early warning system.

## 5.3 HYDROLOGIC

As stated earlier, HydroLogic has developed the flood early warning system. For HydroLogic, the flood early warning system is an interesting service to add to their portfolio of services. It allows them to offer a more diverse and valuable portfolio to potential customers, thus providing the opportunity of economic benefits. This is described in more detail in work package 6 on business models.

## 5.4 CIVITY / SCOREWATER PLATFORM

The company hosting the SCOREwater platform (the platform provider, Civity) is also a stakeholder in the flood alarm. The system has been developed in such a way that the warnings are sent from the platform. By doing so, end-users gain value from using the SCOREwater platform. As a result, the platform becomes more valuable to them since the alerts and the data used to send out the alert can be combined with other datasets available in the platform and used for other purposes as well. In turn, this also implies that the platform becomes more valuable to the platform provider.


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## 5.5 DUTCH RAILWAY ORGANIZATION

Lastly, COA and Hydrologic intend to contact the Dutch Railway organization because they believe the Dutch Railway organization could also benefit from the flood early warning system. The Dutch Railway organization is responsible for the operation and maintenance of the Dutch railway. Flooding may cause serious hinder to them and their customers, as it can cause trains to be delayed or cancelled. As stated earlier, this may hamper accessibility of train stations and cause dangerous situations. By having access to a flood early warning system, the organization would become able to predict and prevent nuisance and damage as much as possible. However, it is to be investigated whether they are truly interested in the flood early warning system.

# 6. CONCLUSION AND FUTURE DEVELOPMENT

Currently, the flood early warning system has been successfully developed and tested for one area in Amersfoort. Analyses show that the system is both operational and reliable and is able to provide timely and accurate predictions of risk of flooding. However, no severe precipitation has occurred during the period when the system was operational. As a result, no serious warnings of risk of flooding have been sent to city officials. This implies that the system still has to prove itself in practice.

Despite this limitation, city officials are enthusiastic about the system as it provides actionable insights to deal with (risk of) flooding. As stated earlier, preventing all flooding from occurring is not feasible. As extreme precipitation events will occur more frequently within short periods of time, due to climate change, the system provides a good base to prevent nuisance and damages as much as possible. To be able to test the system on its robustness, COA and HydroLogic are currently assessing the possibility of including other neighborhoods in Amersfoort. Doing so would allow city officials to test and refine the system and experiment with more of the potential actions described in chapter four.

There are a number of important future developments that COA and HydroLogic will undertake to further refine the system. Firstly, if the scope can be extended other potential end-users (such as railway organizations and/or citizens) can be asked to use the system and provide feedback, thus giving input for further refinement of the system. Furthermore, the current warnings sent by the system require specific knowledge on the sewerage system to be understood. COA, HydroLogic and Civity are working on making the warnings more accessible, by going from showing risk of flooding near specific manholes to showing risk of flooding near specific streets and locations. Together, these actions should lead to a better and more widely used flood early warning system.

# 7. LESSONS LEARNED

This last chapter describes lessons learned when developing, testing and refining the flood early warning system. The lessons described concern complexity of co-creating such a system, how to deal with the risk of false negatives and false positives, replication in other cities and business models.

**Complexity of co-creating a flood early warning system**

The technical aspects of developing an early warning system are relatively straightforward, at least for the individual components of the service. Testing and training of ML algorithms require in depth knowledge of the techniques applied, but once this knowledge has been developed, it can easily be transferred and extended to other fields of application.



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However, the development of the flood early warning system for the study area Hooglanderveen has shown that for the flood early warning system as a whole, a chain of services has to be set up and maintained: 1. an operational precipitation forecast; 2. the application of the ML algorithm; 3. the transfer to the SCOREwater platform and 4. the warning service output from the platform. Within the SCOREwater project, partners have been able to connect these services by closely working together during the development and use of the system.

When it comes to implementing the system in other cities, it has to be taken into account that the underlying services required to develop a flood early warning system may have to be developed by different parties. The open nature of the SCOREwater platform can facilitate operational services like the flood early warning system to (third) parties that have innovative ideas, but lack the knowledge to set up a service as a whole.

**How to deal with false negatives and false positives**

Although analyses show that the system is reliable, there is always a chance of false positives (1) or false negatives (2). This implies that the system could potentially give a warning that flooding may occur when in fact there is no risk of flooding (*false positive*), or the opposite: that the system does not give a warning when in fact flooding occurs (*false negative*). COA and HydroLogic have discussed both and how to deal with them.

For the first, the risk is that end users will deem the system untrustworthy or will stop using it. For example, as stated earlier, citizens can use the flood early warning system to determine when they have to put up barriers to prevent their basements from flooding. If false positives are to occur more than once, they may stop using the system as they believe their effort was unnecessary. COA intends to prevent this by clearly communicating about the system and its inner workings (*including the risk of false positives*).

For the second, the discussion is more complex as it also deals with roles and responsibilities. In the current situation, citizens themselves are responsible for preventing flooding in their basements. With this new system, this may become less clear. Specifically, it can cause expectations to lead to resentment towards COA when flooding is 'missed' by the system ('you should have warned us'). Again, COA believes that it is important to openly and transparently discuss this with citizens, to ensure that using the system does not cause faulty expectations and resentment.

**Exploitation / replication**

As part of work package six, discussions have been held with representatives of the cities of Barcelona and Gothenburg to discuss whether a flood early warning system is also interesting and useful for their cities to develop and use. Representatives from both cities have confirmed that having access to such a system would be valuable to them. However, it also became clear that contextual factors differ in each of the three cities. This will be explored in depth and described as part of work package six. The same applies to business models surrounding the flood early warning system.


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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 2 lists those strategic objectives (herafter: SO) of SCOREwater 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 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 and use of a flood early warning system, an innovative tool that gives end-users the possibility to anticipate risk of flooding, thus providing the means to prevent damage and nuisance. As such, it contributes to SO1. |
| SO3: Enable the monetization of water cycle data | The flood early warning system is an example of a new business model proposed and tested by the SME consortium partners (in this case: HydroLogic). As such, it contributes to SO3. |
| SO4: Demonstrate benefits of smart water management for increased water-system resilience against climate change and urbanization | As stated, in Amersfoort this SO is focused on reducing risk of flooding due to integrated water management. The flood early warning system has precisely this goal, thus contributing to this SO as well. |
| SO5: Identify and mitigate key barriers to implementation of smart, resilient water management | In chapter seven, several lessons learned have been described. These include lessons learned on potential barriers to implement this system, such as how to include citizens. By identifying and mitigating these barriers the deliverable contributes to SO5. |

## PROJECT KPI'S

Table 3 lists the project KPI's that are relevant for this deliverable and gives a brief explanation on the specific contribution of this Deliverable.



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Table 3: stocktaking on deliverable's contribution to SCOREwater project KPI's.

| Project KPI | Contribution by this deliverable |
|---|---|
| KPI3: Number of innovative tools that illustrate the use and potential of the SCOREwater platform | This deliverable describes the development and use of a flood early warning system. This system is one of the innovative tools developed to illustrate the use and potential of the SCOREwater platform. |
| KPI18: New business models based on value chains proposed and tested by SME consortium partners | As stated earlier, the flood early warning system has been developed by HydroLogic, one of the consortium SME partners. As such, the system provides a new business model based on the value chain described, which is elaborated in more detail in work package 6. |
| KPI 5: In Amersfoort, reduce the risk of flooding risk through integrated water management | The flood early warning has the specific goal of preventing the risk of flooding by providing accurate and timely warnings of risk of flooding |
| KPI 11, 13 and 14: behavioural, organizational and legal barriers identified and mitigating options demonstrated | As stated in chapter seven, there are several key lessons learned from developing and experimenting with the flood early warning system. One of these is that the system can provide value to citizens, by giving them accurate warnings on risk of flooding. However, this may also cause shifting in roles and responsibilities between COA and these citizens, as described in more detail in chapter seven. By identifying and mitigating these behavioural, organizational and potentially legal barriers the deliverable contributes to KPI's 11, 13 and 14. |

## ETHICAL ASPECTS

Table 4 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 4 indicates "N/A" for aspects that are irrelevant for this Deliverable.

Table 4: 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 |



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| | |
|---|---|
| **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 5 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 5: 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. |
| **Other: lack of extreme precipitation** | In the period between now and when the model was finalized, no extreme precipitation or flooding has occurred in the city of Amersfoort. As a result, project partners have not been able to test the system 'in real life'. This is a risk as actual situations are by nature different that simulations and as a result use in actual situation may lead to unexpected issues. COA and HydroLogic have tries to resolve this as much as possible by having several discussions and simulations about the flood early warning system |



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