# AQUACLEW case study progress report

## Urban Flash Floods, City of Hagen (Germany)

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## Water management issue

The Hagen case study focuses on local heavy rainfall events and how the negative impacts on the city's urban areas can be mitigated. So far the effects of climate change on rainfall events in Hagen have not really been dealt with adequately (see next section). But for investigating which areas of the city would be flooded in the event of e.g. a 100-year return period event, it would be necessary to make use of the latest climate projections. On this basis storm water run-off simulations could be carried out that more accurately calculate the flood depths and flow velocities of storm water in Hagen. The results could then be used as a basis for developing adaptation strategies at neighbourhood and city level by integrating other information e.g. on land use, population distribution etc.

Better rainfall projections and storm water run-off simulations would in particular benefit Hagen's long-term urban development plans and the emergency and response plans for extreme rainfall events.

## Use of Climate Data

The City of Hagen in general uses climate data from Germany's National Meteorological Service (DWD) and data of twelve local weather stations that are run by the city. In addition, the municipal Civil Protection department also uses DWD's weather forecasts and extreme weather warnings. For planning purposes some municipal department (including the Fire and Disaster Prevention department) currently apply a flat 10% 'climate change surcharge' in heavy rainfall precipitation, which is based on an extrapolation of the precipitation data of the last 15 years.

Currently there are two municipal planning processes that would particularly benefit from better climate data on extreme rainfall events:

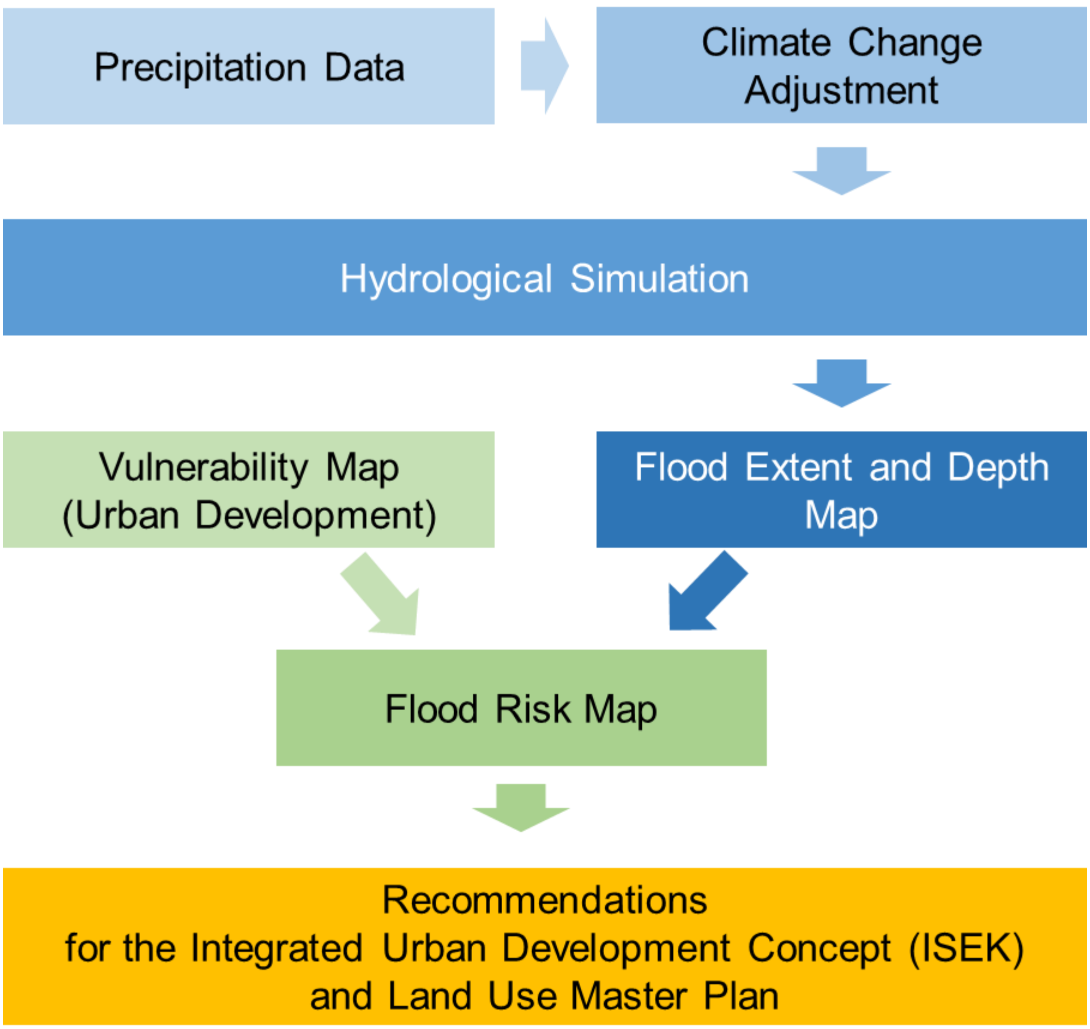
Hagen's **Urban Development** department is in the process of developing an 'Integrated Development Concept' (German abbreviation: ISEK). The ISEK is a non-mandatory planning process that the City of Hagen started because the current Land Use Master Plan is very outdated and a previous attempt to develop and approve a new land use master plan failed in 2004. A new master plan is urgently needed, but the city decided it would be best to have an open discussion with all stakeholders and the public about trends and possible strategies that could later on be integrated into a new master plan. Based on broad strategic goals adopted by the local council and a series of public hearings 'climate change adaptation' was defined as a cross-cutting issue for the ISEK. However, despite Hagen's mountainous terrain the ISEK process has not specifically dealt with extreme rainfall events and flash floods. In this regard the ISEK's spatially explicit urban planning recommendations (which are due to be politically approved shortly) could be counter-checked with storm water run-off simulations based on the latest climate change projections and thus be an important input for the later development of the new land use master plan.

Hagen's **Fire and Disaster Prevention** department (which includes the fire brigades and emergency services) are in the process of developing emergency response plans for flash floods and other extreme weather events. Apart from identifying flash flood prone areas and facilities such plans would determine which vehicles and equipment and which emergency routes to use in case of a flash flood event. A preliminary internal study indicated that more than 100 road segments (e.g. intersections) might not be passable for police cars and ambulances in the event of extreme rainfall due to expected flood depths. But this analysis is based on the flat 10% 'climate change surcharge' mentioned above. Otherwise the department uses the weather forecasts and weather warnings issued by the national meteorological service as well as historical data of past emergency operations, e.g. which roads or intersections were flooded in the past. Storm water run-off simulations based on different climate change projections would greatly improve the quality of the new emergency plans of the Fire and Disaster Prevention department.

The staff of the Fire and Disaster Prevention department and the Urban Development department have not had any training in using climate services – apart from how to use continuous weather forecasts and extreme weather warnings.

## Preliminary Workflow Results

**A – Urban Development**



**Precipitation Data**

For the case study of Hagen, values for very heavy rainfall events (that will increase in the context of climate change) are relevant. The data provide modeled rain quantities for a specific annuality of an event (e.g. 100-year event) for different time periods (e.g. one hour). In Germany, KOSTRA data from the 'Deutschen Wetterdienst' (German Meteorological Service) usually provide these data at raster cell level. Additionally, rain gauge data for eleven relevant locations are available.

**Climate Change Adjustments**

As a more sophisticated approach compared to the current 10% 'climate change surcharge' (see Use of Climate Data section above) rainfall data for the city of Hagen are adjusted based on a statistical scaling technique that analyses historical rainfall data on heavy rainfall days in relation to air temperature. Based on this relationship, the future precipitation intensities on heavy rainfall days are estimated based on the temperature projections of different representative concentration pathways (RCPs) for Hagen (cf. Leidinger et al. forthcoming).

**Hydrological Simulation**

In consultation with Hagen's Urban Development and Planning Department the most critical areas from the perspective the Integrated Urban Development Concept and the future Land Use Master Plan are identified. With the ArcGIS extension FloodArea, runoff simulations are conducted for these areas in order to determine flood areas, flood depths and storm water flow velocities. The simulations incorporate data on elevation, land use and existing buildings as well as precipitation data: Simulations are run for 100-year return events based on historical data and using the new climate change adjustment method described above based on RCP 2.6 and 8.5. In addition, the simulations are also run for extreme events based on the new rainstorm severity index (Schmitt et al. 2018).

**Flood Extent and Depth Maps**

Based on the simulations, maps are produced for the selected critical areas and flood events described above. These maps show the flooded areas and corresponding flood depths.

**Vulnerability Map**

The vulnerability map shows areas and facilities within the city, which are especially sensitive to flooding, e.g. residential, commercial and industrial areas, roads, railways, hospitals, fire stations, day care facilities, retirement homes etc. Geographical concentrations of particularly vulnerable population groups are also identified. In addition, the map shows priority areas and measures of the Integrated Urban Development Concept that is currently being developed by the City of Hagen.

**Flood Risk Maps**

Flood risk maps are created for each of the identified critical areas by integrating the results of the flood extent and depth maps with the vulnerability map. Differentiated by the various flood events (and climate scenarios) these maps show areas, facilities and urban development measures that are particularly at risk in the event of heavy rainfall and corresponding flash floods.

**Recommendations for the Integrated Urban Development Concept and Land Use Master Plan**

Based on the flood risk maps for various flash flood events specific recommendations are made that address the flood risk and possible adaptation strategies for areas, facilities and planned urban development measures that are particularly at risk in the event of heavy rainfall and corresponding flash floods.

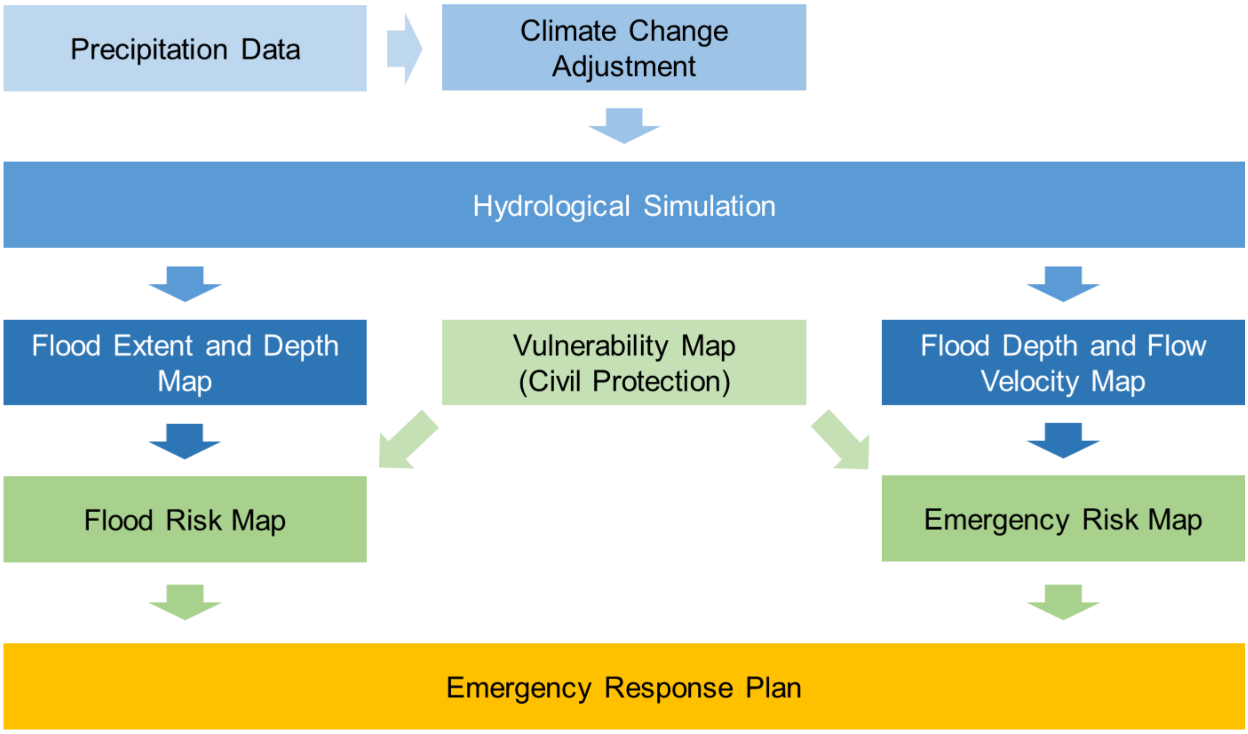
**Comparison of existing and new methods**

Finally, two comparisons are conducted:

a) a comparison of the new flood simulation results for a 100-year return event based on two RCPs and two time periods with the old results for a 100-year return event based on historical data (i.e. without consideration of climate change) and

b) a comparison of the new flood simulation results for a 100-year return event based on two RCPs and two time periods with the old results based on the method currently used by the city, i.e. adding a flat 10% 'climate change surcharge' (as described above).

**B – Disaster Emergency Response**



**Precipitation Data**

For the case study of Hagen, values for very heavy rainfall events (that will increase in the context of climate change) are relevant. The data provide modeled rain quantities for a specific annuality of an event (e.g. 100-year event) for different time periods (e.g. one hour). In Germany, KOSTRA data from the 'Deutschen Wetterdienst' (German Meteorological Service) usually provide these data at raster cell level. Additionally, rain gauge data for eleven relevant locations are available.

**Climate Change Adjustments**

Rainfall data for the city of Hagen are adjusted based on a statistical scaling technique that analyses historical rainfall data on heavy rainfall days in relation to air temperature. Based on this relationship, the future precipitation intensities on heavy rainfall days are estimated based on the temperature projections of different representative concentration pathways (RCPs) for Hagen (cf. Leidinger et al. forthcoming).

**Hydrological Simulation**

In consultation with Hagen's Fire and Disaster Prevention Department the most critical areas from an emergency response perspective are identified. With the ArcGIS extension FloodArea, runoff simulations are conducted for these areas in order to determine flood areas, flood depths and storm water flow velocities. The simulations incorporate data on elevation, land use and existing buildings as well as precipitation data: Simulations are run for 100-year return events based on historical data and, using the climate change adjustments described above, based on RCP 2.6 and 8.5. In addition, the simulations are also run for extreme events based on the rainstorm severity index (Schmitt et al. 2018).

**Flood Extent and Depth Map**

Based on the simulations, maps are produced for the selected critical areas and flood events described above. These maps show the flooded areas and corresponding flood depths.

**Flood Depth and Flow Velocity Maps**

A second set of maps is produced that show the flow paths, flow velocities and flood depths for each of the flood events described above.

**Vulnerability Map**

The vulnerability map shows areas and facilities within the city, which are especially sensitive to flooding, e.g. residential, commercial and industrial areas, roads, railways, hospitals, fire stations, day care facilities, retirement homes etc. In addition, concentrations of particularly vulnerable population groups are identified.

**Flood Risk Maps**

Flood risk maps are created for each of the identified most critical areas by integrating the results of the flood extent and depth maps with the vulnerability map. Differentiated by the various flood events (and climate scenarios) these maps show areas and facilities that are particularly at risk in the event of heavy rainfall and corresponding flash floods.

**Emergency Risk Map**

Emergency risk maps are created for each critical area by integrating the flood depth and flow velocity maps with the transport infrastructure data of the vulnerability map. Again, there are maps for the different flood events and underlying climate scenarios. The maps show which road segments, underpasses and road junctions that are critical for emergency and rescue vehicles are likely to be impassable due to the depth and flow speeds of flood waters.

**Emergency Response Plan**

The emergency risk maps are in the end used as an input for informing, evaluating and adjusting the Fire and Disaster Prevention Department's emergency response plans for extreme rainfall events. Most importantly, the routes for emergency response vehicles are assessed and possibly modified.

**Comparison of existing and new methods**

Finally, two comparisons are conducted:

a) a comparison of the new flood simulation results for a 100-year return event based on two RCPs and two time periods with the old results for a 100-year return event based on historical data (i.e. without consideration of climate change) and

b) a comparison of the new flood simulation results for a 100-year return event based on two RCPs and two time periods with the old results based on the method currently used by the city, i.e. adding a flat 10% 'climate change surcharge' (as described above).

## Client perspective

Basically the clients (fire and disaster prevention department and urban development department) are looking forward to receiving urban flash flood simulations based on more sophisticated methods for incorporating the effects of climate change. Up to now only a simple 10 % 'climate change surcharge' on the 100-year return event precipitation levels has been used, which is simply based on an extrapolation of precipitation measurements of the last 15 years.

Due to technical restrictions detailed flash flood simulations can only be conducted for 10 areas within the city of Hagen using the new climate change adjustment method based on RCP projections. These areas have been determined in collaboration with the Fire and Disaster Prevention Department and the Urban Development Department.

## Task list

| Completion date | Task |
|---|---|
| Sept 17 | • Identification of focus areas for flood simulations<br>• Set-up of flood simulation model<br>• Decisions on RCPs and projection time periods to be used for simulations<br>• First simulation runs for focus area 1 |
| Sept 19-20 | General Assembly |
| Oct 25 | • Simulation runs for focus areas 2-5<br>• Interpretation of results |
| Nov 29 | • Simulation runs for focus areas 6-10<br>• Interpretation of results |
| Dec 20 | • Vulnerability and risk mapping<br>• Interpretation of results |
| Jan 17 | • Preparation of presentation for case study partners |
| Jan 29 | • Presentation and discussion of results with case study partners |