CP/03

# CCI-HYDR – Results

## Climate change impact on hydrological extremes along rivers and urban drainage systems

DURATION OF THE PROJECT
15/12/2005 – 30/04/2008

BUDGET
521.343 €

KEYWORDS
Climate change, floods, hydrology, low flows, precipitation, rivers, urban drainage

### CONTEXT

Flood risk is in Belgium as well as in other European countries of considerable importance. This is due to dense populations and high industrialization along river banks. Since last decades, sewer systems are being built at a large scale. Drought risks are less significant in the country, due to the humid climate and the limited length of the dry spells in summer. However, extreme low flows may occur along rivers, causing severe problems of water shortage for drinking water supply, for agriculture, for industrial water use and for the environment.

There is strong evidence that due to global change, the risks of inundations and low flows are changing. The consequences of these changes in potential hazards are to be assessed in a perspective of sustainable development. Water managers have to anticipate these changes, as to limit the flood and drought risks of the inhabitants to acceptable risk levels. In addition to the water administrations, the insurance industry needs quantification of their related risks, as well as the different water users and policy makers so as to develop and adapt policies (e.g. $CO_2$ emission reduction).

The concerns about the impact of climate change on the hydrological water cycle (including floods and droughts) have triggered specific studies since the 80s. The Royal Meteorological Institute of Belgium (RMI) has been pioneering in putting into evidence differences in the sensitivity of catchments with contrasted characteristics to a $2xCO_2$ scenario. They extended their study to a larger set of catchments (whole Scheldt and Meuse basins), using a new set of climate scenarios based on transient experiments, for instance based on the results of Global Circulation Models (GCMs) forced with an increasing greenhouse gas content. However, the GCMs have since improved, and high resolution regional climate models (RCMs) have been nested within to downscale the climate variables to regional scale. This has sparked new research related to regional impacts relevant at local scales. Hydrological impact assessments can now be performed with increased confidence.

### OBJECTIVES

The CCI-HYDR research project investigated in a detailed objective way and based on the most recent data and climate modelling results, the climate change impact on the risk of hydrological extremes along rivers and urban drainage systems in Belgium. For rivers, the risk of both floods and low flows has been considered. For urban drainage systems, only the impact on flood risks has been studied. The study required the simulation results from GCMs and RCMs to be downscaled to the time and space scale necessary for the hydrological impact analysis. The modelling approach was based on ensemble modelling and probabilistic analysis of simulation results, enabling the uncertainty on the climate model-based results to be taken into account. The climate change scenarios furthermore were to be compared / verified with the results from a statistical analysis on the present and past climate and flow records. This subtask aimed to bring together the two separate science domains of physically-based climate modelling and statistical hydrology.

The project consisted of two main phases. In Phase 1, the climate change scenarios were being developed after statistical analysis of trends and cycles in long-term series of historical rainfall, evapotranspiration and river flow, and after the analysis and statistical downscaling of climate model simulation results. Phase 2 focused on the impact modelling towards flood risks and low flows risk along rivers, and flood risks along urban drainage systems, making use of hydrological and hydrodynamic models.

### CONCLUSIONS

**Development of climate change scenarios**

Historical trends and oscillations in rainfall extremes and evapotranspiration (ETo) and river flow patterns showed deviant behaviour from the long term average. There is a reason to be concerned as the recent significant trends in rainfall and ETo suggest. In particular, winter showed pronounced changes during the most recent decade: positively significant rainfall and ETo amounts. The future predictions (2071-2100) also point to a continuation of the same trends; the winters generally get wetter and the summers get drier. ETo will increase for all the seasons.

The future predictions were based on a set of about 30 simulations derived from 10 RCMs nested in two main GCMs. The experiments were run for the IPCC regional A2 and B2 future greenhouse gas emission scenarios. Since the PRUDENCE RCM models were based on only the A2 and B2 scenarios, scaling factors were required to make the scenarios more exhaustive (reducing the emissions uncertainty) by including changes from extra scenarios (notably the A1B and B1). These were derived from GCM simulations considered for the 4th Assessment Report of IPCC.

The selected RCM simulations exhibited both negative and positive changes (-40% to +10%) in rainfall during the hydrological summer, and positive changes during the hydrological winter (+5% to +50%). There were no significant regional differences in the climate change signals over Belgium; with the exception of the coastal region. The rainfall increases are for the main Belgian lands around 10% lower than the ones over the coastal area.

From the large set of climate model projections, three probabilistic scenarios were extracted to allow end users to investigate the range of changes. The scenarios were appropriately named high, mean and low.

The climate change scenarios were to be translated to changes in the historical rainfall and ETo input series of hydrological models. To support this task, a Perturbation Tool has been developed. The tool applies perturbations to the rainfall and ETo series. For the rainfall series, the perturbations involve both changes in the frequency of rain storms and changes in the rainfall intensity. The changes are being made in a variable way, depending on the month in the year, and on the return period or storm frequency. For the ETo series, only intensities are perturbed, but also depending on the month and the return period. The series to be perturbed can be daily or hourly and can have any length (typical lengths vary from a few years to 100 years). The perturbations can be made for time horizons till 2100 (e.g., for 2020, 2030, …, 2100).

**Hydrological impact analysis**

Hydrological impacts of the rainfall and ETo change scenarios were investigated at large scale in the Meuse and Scheldt basins (SCHEME hydrological model of RMI) and at local scale for the river basins of Dender and Grote Nete – Grote Laak (VHM, NAM and MIKE-SHE hydrological models and MIKE11 river hydrodynamic model by K.U.Leuven). In cooperation with the Flanders Hydraulics authority, also the impacts in 67 other subbasins of the Scheldt basin have been studied. In order to separate in the river flow trends the contributions from climate change and the non-meteorological trends (i.e. land use trends), the impact of recent land use trends also has been investigated. It has been concluded that river total and overland runoff volumes linearly increase with the increase in urban paved (impermeable) areas, while the number of extreme low flow or flood days depend in a quadratic way on the urban land use area in the basins.

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Climate change impacts on hydrological extremes (floods and low flows) (scenario period 2071-2100 versus control period 1961-1990) indicated that this impact weakly depends on the topographical and soil type characteristics of the catchments. In general, low flows significantly decrease in all studied catchments and reaches up to 80 till 90% reduction in the low scenario where almost all decreases are more then 50%. The increase in hourly river peak flow extremes is less strong, and limited to around 35%. Results indicate that low flow or drought problems will increase and might become more severe in comparison with flood risk problems induced by extreme precipitation.
Uncertainties in the results are, however, still very high. Depending on the ratio between the increase in rainfall versus the increase in ETo, and the ratio between the increase in winter rainfall versus the decrease in summer rainfall, the hydrological impact results for high flows might turn over from a positive trend into a negative trend.
While the climate change impacts tend towards wetter winters and drier summers, the hydrological response appears similar throughout the entire area. The findings show that the intensity of the impacts is only slightly dependent on the location.
The implications of the changes in flood and drought risks continued to be investigated through a collaboration with the ADAPT project. The implications to society, water mangers and policy makers were assessed.

For urban drainage systems, it has been found that systems designed for a 2 years return period of flooding would flood twice that frequent for the most pessimistic climate scenario (scenario period 2071-2100 versus control period 1961-1990). Regarding the design of local source control measures (storage facilities, rainwater tanks, infiltration reservoirs, etc), 15% to 35% increase in the storage capacity would be needed for the same climate scenario if one wants to limit the overflow frequency of the facility to the current level. Correspondingly, storage facilities with a current overflow return period of 2 years would overflow approx. twice per year; facilities with an overflow return period of 5 years would (for the same scenario) overflow approx. once per 1 - 1.5 years. The latter results indicate that there is a need for more and larger local stormwater storage. In case this storage is built by means of infiltration ponds, the stormwater stored in the ponds will enhance the groundwater infiltration and consequently will help to solve the enhanced low flow problems expected for river catchments.

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## MORE INFORMATION

More detailed technical information about the CCI-HYDR project, the methodologies and results can be found in the five technical reports, uploaded together with all other documents produced as part of the CCI-HYDR project on the project website*:* http://www.kuleuven.be/hydr/CCI-HYDR.htm.

## CONTRIBUTION OF THE PROJECT TO A SUSTAINABLE DEVELOPMENT POLICY

The project results provided important support to sustainable policy development especially related to sustainable water management and planning, risk and risk insurance management, the Kyoto Protocol and its successor to be discussed in December 2009 in Copenhagen.

The CCI-HYDR climate change scenarios developed in the project (incl. the statistical downscaling technique and CCI-HYDR Perturbation Tool) are currently being applied by several national water and environmental authorities. They investigate impacts of projected climate changes on flood and low flow risks, water availability, environmental conditions, needs for adaptation measures, etc. This shows that there was a great need for the results obtained within the scope of the CCI-HYDR project. The CCI-HYDR project consequently almost immediately supported policy implementation and related sustainable development of the region..

## CONTACT INFORMATION

Website of the project:
http://www.kuleuven.be/hydr/CCI-HYDR


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