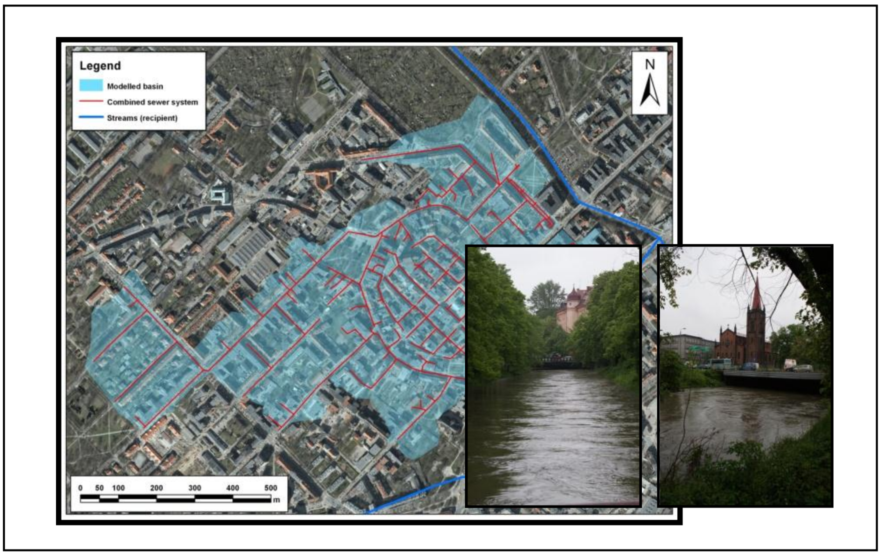
Report on the demonstration in Gliwice of enhanced real-time measuring and forecasting technologies for combined sewer systems (D 1.3.11)



SEVENTH FRAMEWORK PROGRAMME

Report on the demonstration in Gliwice of enhanced real-time measuring and forecasting technologies for combined sewer systems (D 1.3.11) Demonstration Report

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SEVENTH FRAMEWORK PROGRAMME

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Report on the demonstration in Gliwice of enhanced real-time measuring and forecasting technologies for combined sewer systems (IETU) (M48, report, ID)

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Contents

1 INTRODUCTION

Gliwice is a city with 200.000 inhabitants in the densely populated urban area of the Upper Silesia in southern Poland. During the last 20 years the city, with an economy once based on heavy industry, is actively operating on the innovation market.
Climate change has a significant impact on the frequency of extreme weather events in Gliwice (Frei et al., 2000). During the most severe rainfall events, despite the continuous modernisation of the sewer and drainage system, the city centre is flooded regularly approximately once a year. This causes damage to buildings and infrastructure and is a real threat to public safety. The combined sewer-system in the historical part of the city, designed in the beginning of the 20th century, cannot cope with the large amount of storm water. During floods combined sewer overflows into the River Klodnica that runs through the city-centre, thus posing a risk to the river water quality. In the central part of the city the current combined sewer-system cannot be easily separated into a sanitary part and a storm sewer system due to the densely built area. This problem will increase because the city is still developing and new investments are planned in the city centre.
The City of Gliwice (Water Supply and Sanitation Company – PWiK Gliwice) in collaboration with the Institute for Ecology of Industrial Areas (IETU, Katowice) is working on this problem that is top priority for the city, as from the point of safety for inhabitants, concern about the environmental impact as well as for the economic development of Gliwice. The solution demonstrated in Gliwice as a part of the PRREPARED project is an **enhanced real-time measuring and forecasting** system. An example of such system is tested in the medieval Old Town streets and the Market Square in the city centre. The area has a size of approximately 50 hectares and includes mainly combined sewer system.
The first step in solving the problem of combined sewer overflows in Gliwice was the assessment of their frequency and their impact on the receiving waters. At 6 points of the sewer system located in the old city centre several parameters including discharge, flow velocity, depth and temperature of the waste water were continuously monitored. With the data obtained a hydraulic model (Storm Water Management Model – SWMM) was developed that simulates the impact of the heavy rainfall on the waste water flow and points out its most vulnerable sections. Once this model is fed with validated forecasts of precipitation on a local level, it is possible to predict the response of the system to the expected rainfall. As a part of the PREPARED project a meteorological model (Weather Research and Forecasting Model) was run to provide continuous short term rainfall forecasts for Gliwice. The expected, short term outcomes of the demonstration include: test of the real-time forecasting system and provision of short-term forecasts of the combined sewer system performance which can be used as a base for the warning system for treatment plant and receiving waters. On the long term the monitoring and modelling results may lead to redesigning of the sewer system, adding retention tanks at crucial places or the installation of an appropriate control system.

2 FINDINGS

The measuring and forecasting system for combined sewer system in Gliwice is composed of three main parts: 1) flow monitoring system, 2) rainfall monitoring and forecasting system and 3) hydraulic model of the sewer system. Each part provides an extensive amount of useful data separately and each part is combined into one system providing the information on sewer system performance as well for archival rain events as present and forecasted meteorological status.

2.1 Flow monitoring in the sewer system

The monitoring campaign was launched on September 4th 2013. Six flow meters were installed by the NIVUS company (Eppingen, Germany) in manholes selected by the personnel of the Gliwice Utility. The measurements were performed continuously until December 3rd 2013 and included discharge, flow velocity, level and temperature of wastewater / storm water at an interval of 1-5 minutes.

Flow measurements allowed for the assessment of the flows pattern resulting from rain events in the main sub-catchments of the Gliwice's Old Town. The measurements also helped to characterise the sub-catchments' outflows during dry seasons. Thanks to that a set of temporal patterns for wastewater outflows was determined.

2.2 Rainfall monitoring and forecasting system

The Weather Research and Forecasting (WRF) Model is the core of the rainfall forecasting system. WRF is a novel, mesoscale numerical weather prediction system and the data assimilation platform that may be used to both purposes atmospheric research and operational forecasting needs. WRF allows for simulations performed either on real data (observations, analyses) or idealized atmospheric conditions with emphasis on horizontal grids of 1–10 kilometers (Skamarock et al. 2008). For the purpose of the demonstration in Gliwice the WRF model is run continuously based on the Global Forecast System (EMC, 2003) and is continuously being corrected using 1) METAR reports (Meteorological Terminal Aviation Routine Weather Report / Meteorological Aerodrome Report) from Poland, Germany, Czech and Slovak airport weather stations and 2) local meteorological stations of the Upper Silesia Province. The structure of forecasting system can be found in Annex 1. Within the PREPARED project a second level of forecasts correction was tested using a Doppler C-band weather radar data.

Each 6 hours the WRF model provides 35-hours forecast with a spatial resolution of 3 kilometres. 6-hours periods result from the time needed by WRF to complete calculations. Therefore, currently after each 6 hours new time series of rainfall are generated improving the accuracy of forecast for the first 29 hours and adding new 6 hours of rainfall forecast.

It was found that WRF forecasts have some limitations. Application of the model version that does not consider local corrections causes an underestimation of low or very short rain events compared to the closest rain gauge. However, the comparisons of flows in the sewer system and rain monitoring data indicate that the main outflow from the combined sewer system does not reflect perfectly the pattern of rainfall monitored in the catchment. During the very short rain events flow peaks do not occur and it is better to use modelled than monitored data. The most probable reason is the relative position of rain gauge and sewer system sub-catchments. Modelled rainfall represents the area instead of point (like a rain gauge does) and may better characterise the rainfall events for the simulation of combined sewer system.

An example of the comparison of measured rainfall and outflow from the combined sewer system is shown below (Fig. 1), whilst daily comparisons of both measured and simulated rainfall and outflows can be found in Annex 2.

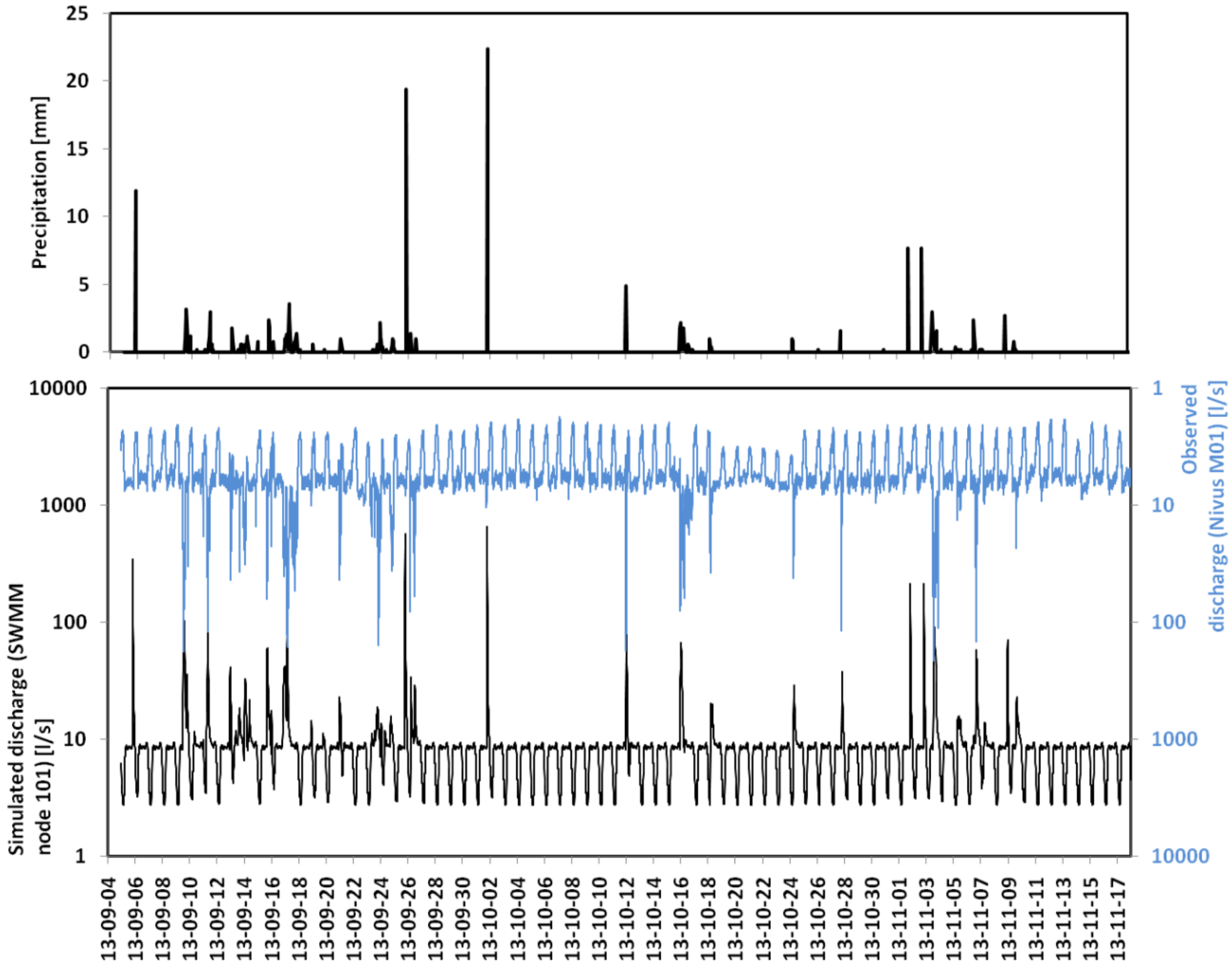

Fig. 1. Comparison of rainfall and modelled (SWMM) vs. monitored (Nivus) main outflow of the combined sewer system

2.3 Combined sewer system model (SWMM)

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that can be used in simulations of single events or long-term (continuous) phenomena. The model is catchment-oriented, which means that the runoff component is calculated within catchment areas specified by the user that receive precipitation and generate runoff and pollutant loads (Rossman, 2000). SWMM has been tested in a multitude of sewer studies. Its main applications that are consistent with aims of the PREPARED project are as follows: (i) designing and changing of the sewer system for flood control, (ii) designing control strategies for mitigating combined sewer overflows. The latter is the primary challenge in the Gliwice demonstration. The performance of solutions aiming to predict and control CSOs includes the construction of SWMM model for the part of the Gliwice sewer system. Demonstration area included the Old Town district of the City of Gliwice, where the sewer system is almost 100% combined. This part of sewer system has no flow inputs from other parts of the city and it contributes directly to the central wastewater treatment plant or overflows to the Klodnica River. The Gliwice Water Supply and Sanitation Company (PWiK) provided data of the sewer network, i.e. the location of manholes, sewer conduits, their geometry, depth etc. Among nearly five thousands of manholes, nearly one thousand were incorporated into the model, because the rest had not sufficiently characterized, and for the same situation only c.a. one-fifth of about five thousands conduits was used in the model, resulting in major simplification. Subsequently catchments were delineated, and thanks to the consultation with the Gliwice Utility twelve main catchments covering 47 hectares were identified. The general spatial structure of sewer system model is shown in Figure 2.

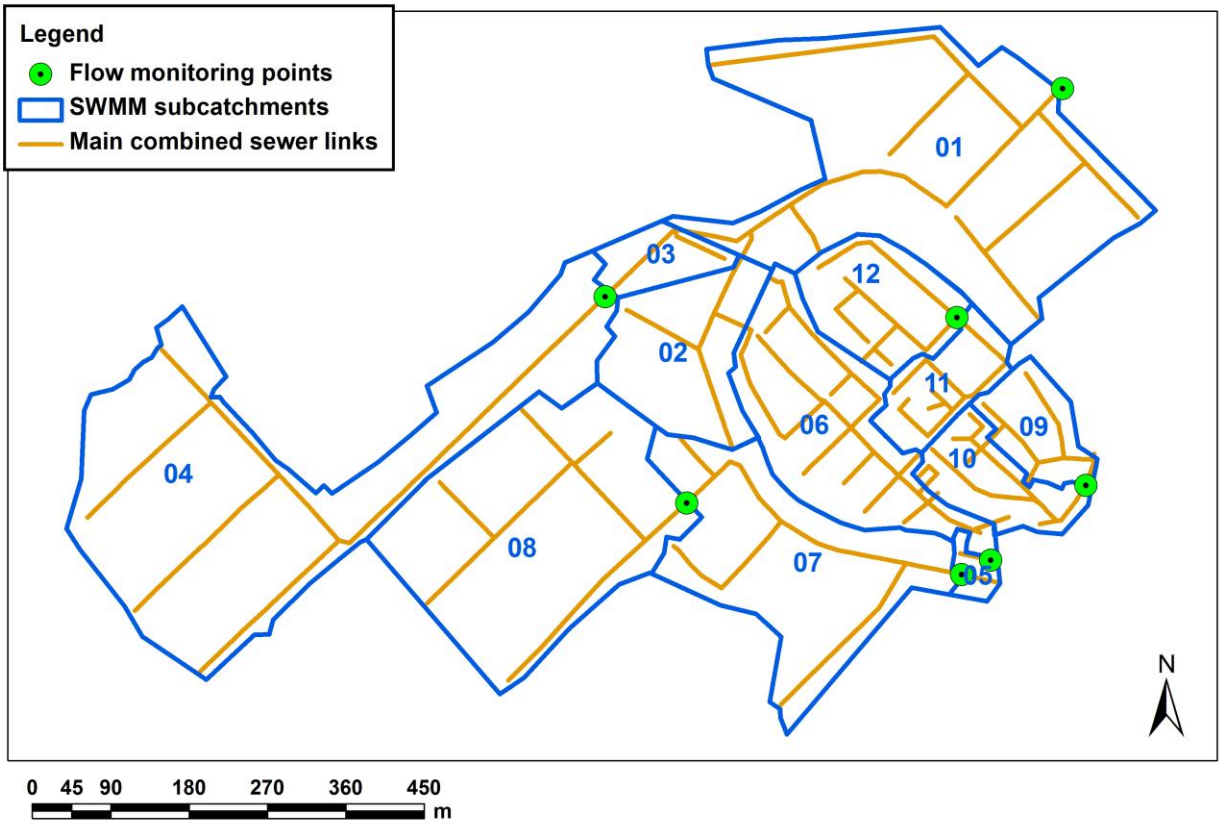

Fig. 2. General spatial structure of the SWMM model of combined sewer system in Gliwice

As an initial weather data source the regional monitoring station (WIOS) was used and later replaced by the WRF model forecasts. Apart of the rainfall information (recalculated into the runoff and then into storm water contribution to the combined system), the model required an input regarding discharges of sanitation sewage into the system. This information was delivered as temporal patterns of wastewater flows measured during dry seasons in several monitoring points in the study area.

The output from the SWMM model includes: wastewater and storm water discharge, flow velocity and water level calculated of each sub-catchment and for each sewage system section in sub-catchment. Information on the combined sewer system performance was calculated each hour with a time step of 5 or 15 minutes for the wet and dry conditions, respectively.

2.4 Coupling

Each of three systems described above cannot provide an information on the past, real-time or forecasted status of the sewer system operation. Monitoring data, rainfall forecasts and hydraulic model had to be coupled into one tool. The idea of such a tool used in Gliwice is described below and depicted in Annex 3.

The central part of the tool (system) is the central database collecting all input and output data. In the forecasting system being currently used in Gliwice each 6 hours the WRF model provides rainfall forecasts, which are stored in the database. Because of the forecasts accuracy only a 24-hour forecast is used to feed the SWMM model. Therefore, each 6 hours the system: 1) updates the rainfall input to the SWMM model (16 hours of forecast are updated and next 6 added), 2) checks the status (SWMM model outputs) of the sewer system calculated in the previous run and uses it as an initial conditions and 3) runs the SWMM model to provide new forecast of the sewer system performance for coming 24 hours.

Apart from the rainfall forecast the SWMM model uses also dry season wastewater flow patterns. These temporal patterns result mainly from the water use in the study area and do not change much in time. The main impact on the sewage system performance are rainfall events causing flow peaks several orders of magnitude greater than the wastewater flow in dry seasons. Simulation outputs are stored back in the database and are available for the system operator in a form of reports, tables and maps.

3 CONCLUSIONS AND RECOMMENDATIONS

The monitoring and modelling system demonstrated in Gliwice allows to:

- predict how future (up to 35 hours) rainfall will affect the combined sewer system in Gliwice and where a risk of flooding and overflows is given;
- collect and analyse long time series of rainfall and flow data.

These functions can be used at the middle stage of the adaptation to effects of climate changes. From the point of view of the urban water / wastewater management the main methods of adaptation include: 1) analysis of climate change effects (changes in precipitation, surface water and groundwater interactions), 2) analysis of flood and other risks resulting from climate change effects, 3) plans and strategies of modifications / upgrades of urban water and wastewater systems and 4) implementation of plans and strategies by changes in legal regulations, water / wastewater management procedures etc. The PREPARED demonstration in Gliwice is a part of the second step mentioned above. Consequences of climate change are already studied in depth and based on global and regional climate models a set of climate (temperature, evaporation, precipitation) scenarios are widely available. These scenarios indicate if our region or city might be at risk of e.g. more severe rainfalls, droughts, larger snow covers and snowmelts etc. If the risk exists (like the flood and sewer overflow risk in Gliwice) we can analyse what parts of storm water or combined sewer system are most vulnerable to the effects of climate change. Monitoring and modelling system demonstrated in Gliwice can be used to simulate effects of future climate scenarios and to then propose appropriate changes in the sewer system structure and assess if they are efficient enough. Results of these analyses are the main input to the next adaptation step which is the creation of adaptation plans and their implementation.

In addition, a second adaptation measure was foreseen as a result of the demonstration in Gliwice. When using short term rainfall forecasts instead of future climate scenarios, the demonstrated tool shows the current sewer system performance indicating the real risk of flooding and of sewer overflows improving emergency plans and flood warning systems. The forecasting system shows the results of extreme rainfall events and gives a basis for developing the sewer control system.

This demonstration can be considered as a first stage of the adaptation of sewer system in Gliwice to expected effects of climate change. After ongoing tests the system should be further developed and finally should include a module assessing the overflows impact on reviving waters. After the finalisation of PREPARED project, the combined sewer system model and database created at IETU will be transferred to the Gliwice Utility (PWiK) and keep working real-time.

In the next stage (not included in the PREPARED task) a series of future climate scenarios should be used as an input to the model to identify if some parts of infrastructure have to be redesigned to prevent adverse effects of changing rainfall patterns. Only then full capabilities of demonstrated system will be utilised. The actions recommended for the utility include: 1) investigation of existing climate (rainfall) scenarios, 2) run the sewer system model using set of rainfall scenarios, 3) identification of potential flooding / sewer overflows and finally 4) testing different solutions (e.g. retention tanks) in model simulations to minimise adverse effects of rainfall events.

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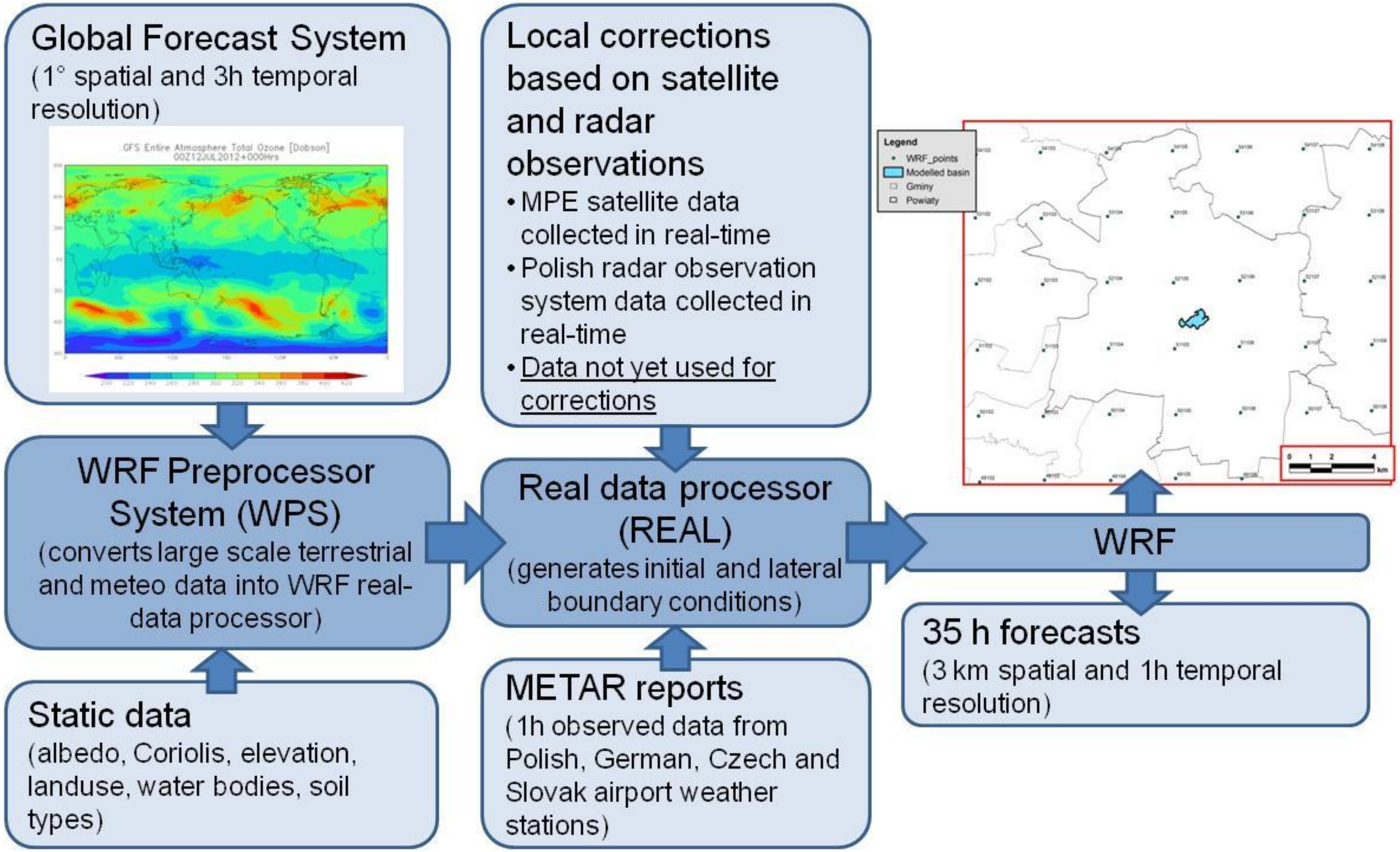
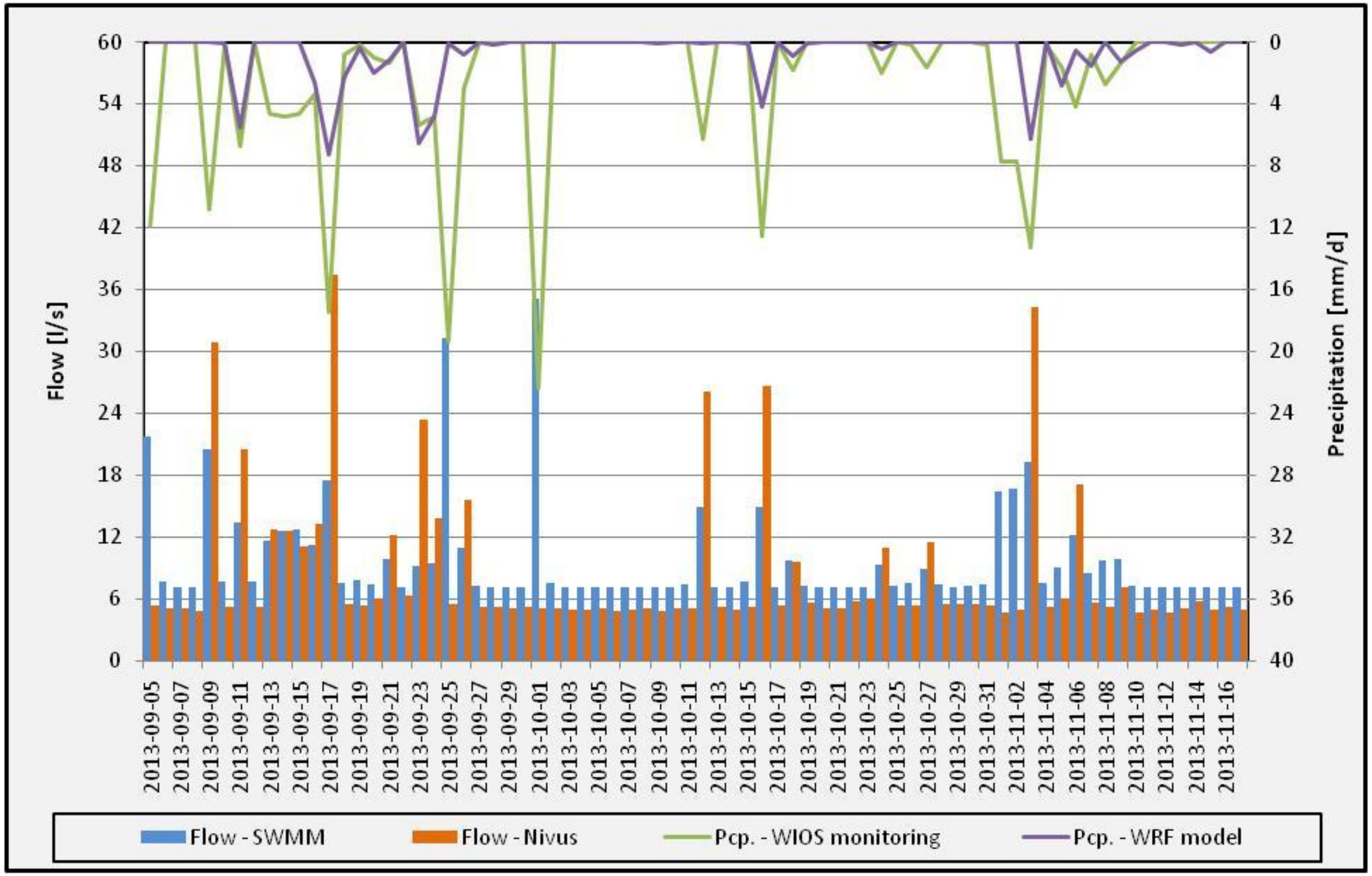
ANNEX 1 - Structure of the WRF-based rainfall forecasting system



ANNEX 2 - Comparison of daily rainfall measurements vs. forecasts and monitored vs. simulated flows in sewer system



ANNEX 3 - Conceptual design of the enhanced real-time measuring and forecasting tool for combined sewer system in Gliwice