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1. Management summary

1.1. Aims for the Linz Pilot within SUDPLAN

Urban drainage systems form a valuable backbone of urban infrastructure. On average, it is estimated that the value of the urban wastewater system is about 300 Mio € per 100.000 inhabitants. In many European cities waste water and storm water are drained in one sewerage system ("combined systems"). Thus the urban wastewater system is very vulnerable to potential climate change impacts, particularly to a potential increase of extreme flood events and more spilled out pollution loads to receiving waters. Due to the hydraulic limitation of waste water treatment plants (WWTPs) it is not possible to treat the whole amount of drained water at WWTPs; thus the runoff in combined sewer systems has to be either discharged at combined sewer overflows (CSO) into receiving waters or temporarily stored in reservoirs. CSO facilities can be designed with a retention volume ("CSO tank") in order to mitigate overflow events during heavy rains. CSO tanks also show considerable capacities to hold back the TSS (Total Suspended Solids) and COD (Chemical Oxygen Demand) loads in waste and storm water which are the key parameters to describe and quantify the transported pollution loads in sewer systems.

To limit the spilled out pollution loads from combined sewer systems into receiving waters a new standard, the so called ÖWAV Regelblatt 19 (OEWAV, 2007) was introduced in Austria in 2007 (Kleidorfer and Rauch, 2010). The ÖWAV-Regelblatt 19 (2007) defines the efficiency η of combined sewer overflows (CSO efficiency η) as an indicator for CSO pollution. It distinguishes between two different kinds of CSO efficiency: one for dissolved pollutants (η_d) and one for particulate pollutants (η_p).

The calculation of η should be done as an average over a long-time period of at least 10 years.

Hence this requires long-term simulation by either hydrological or hydrodynamic models. Temporal resolution of rainfall data should be 10 minutes or higher. For the Linz pilot catchment area two models were set up: a hydrological model with the software City (Achleitner et al., 2007) and a hydrodynamic model with the software SWMM 5 (Rossmann, 2007).

In scope of the SUDPLAN project, two main tasks will be carried out within the Linz pilot:

(1) Estimation of the overall CSO efficiency rates η for dissolved pollutants (η_d) and for particulate pollutants (η_p) in the total catchment area of the WWTP of Linz based on long-term simulations and future rain data provided by the common services (Phase 1). By comparing the results of today's and of future scenarios possible effects and changes can be recognised and located and proper strategic adaptions can be developed within the catchment area in time.

(2) Estimation of the sedimentation efficiency rate η_{sed} for the primary clarifiers of the WWTP in Linz by the installation and operation of a novel sensor network in the inflow and outflow of the clarifiers in order to quantify the TSS and COD retention efficiency under different rainwater flow regimes (Phase 2).

1.2. Status summary

The current status of the Linz pilot is the following:

- Decision on historical rainfall data. Version for SOS prepared. Downscaling discussed.
- Decision on the model to be used for evaluation of the efficiency rates.
- Model software tested and ready to be implemented.

2. Preparatory Work

- Screening of available measurement data in the catchment area of the Linz pilot
- Rainfall data
- Discussion on additional measurements
- Workshop on models with Linz AG and University of Innsbruck
- Model check and comparison of available software tools
- Test runs: evaluation of the efficiency rate η_d and model comparison
- Decision on model
- Detailed model check (structures, geometry, boundary conditions etc.)

The Linz Pilot tasks have been defined in the Linz Pilot Definition Plan (Deliverable 7.1.1) in section 5.1. The following tasks have been

Task	**Goal**	**Status**
Assess the current state of the sewer network	• Assess the current state of the sewer network by calculating the required CSO efficiency rates • Calculating the actual CSO efficiency rates	Completed
Calculating actual required CSO efficiency rates	Calculate the actual required CSO efficiency rates based on the available catchment and rainfall data according to the guidelines	Completed
Calculating actual existing CSO efficiency rates	Calculate the actual CSO efficiency rates with the calibrated City Drain model and available historical rainfall time series	Completed
Validate measurement data (rainfall, runoff and pollution concentrations) provided by LINZ AG	Validate the data on rainfall, runoff and pollution concentrations provided by LINZ AG	Completed

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Determine local rainfall data for future scenarios based on climate change models (downscaling) provided by common services	Determine local rainfall data for future scenarios based on climate change models	Different local rainfall data sources where provided to be used by the common services. First success in creating OGC-compliant SOS services and downscaling procedures

The possibilities of sensor data access for V2 of the SUDPLAN product where discussed with Linz AG. First agreements concerning data exchange and data formats where concluded. Parsability and suitability were assured by collection and sighting of already available data.

Due to the nature of available data sources and expected outcome of the sensor system the development of an open source data management system (OpenSDM) was started which should provide the SUDPLAN application with measured data in phase 2. This system will act as connector between the measurement stations and the Time Series Toolbox based OGC Sensor Services developed by AIT. It will provide consistent (meta) data storage and access. It has to be discussed and decided if some relevant parts of the system will be incorporated into the SMS or if it will run standalone as a third party component. First achievements where made by testing the system with a similar measurement station at Graz which is located at a CSO to measure spilled out pollution loads to receiving water. These tests showed that the system is running with high performance and it seems flexible enough to scale. First test data has been delivered to AIT to start the integration process and the results so far are promising.

2.1. Model Component

2.1.1 Software Selection and Procurement

Concerning software selection, two models were available for the Linz catchment in two different software packages: a hydrological model in the software CityDrain (Achleitner et al., 2007) and a hydrodynamic model in the software SWMM 5 (Rossmann, 2007). Both models were set up by University of Innsbruck and represent an aggregation of the real network structure.

Conceptual hydrological models most often use the concept of reservoirs for flow routing. They are based on volume balance calculation. Discharge is the only known value, water levels and velocities can only be deduced by the pipe geometry (linear, without hysteresis). The underlying equations can be solved analytically. The models have relatively low computational costs and are therefore especially suited for long term simulations. Backwater and surface flooding can generally not be assessed (some model approaches, however, allow taking into account static backwater effects based on geometry). Evaluating downstream influence on upstream flow is not possible. In general the models are aggregated and have less data requirements than hydrodynamic models. The processes on the surface and in the sewer are often “blended”.

Hydrodynamic models are based on physical principles, generally solving the full Barré de Saint Venant equations[1]. Therefore, discharge, water level and flow velocities are known values. They

[1] Set of hyperbolic partial differential equations that describe the flow below a pressure surface in a fluid.

are computationally expensive as the underlying equations need to be solved by numeric solvers. As in general the models are more detailed than conceptual hydrological models, the data requirement is higher. In detailed models, a clear distinction between surface and sewer flow is possible and the model geometry is close to nature. They can take into account backwater effects, flooding etc. Pipes under pressure can be modelled.

CityDrain is a conceptual, deterministic, hydrological rainfall runoff model software. It was developed at University of Innsbruck, Austria. It is based on Matlab/Simulink, the code itself is open source.

Figure 1 shows the model representation of the Linz catchment in the CityDrain modelling software, with representations of the subcatchments, main sewer conduits, overflow structures, dividers and pumps.

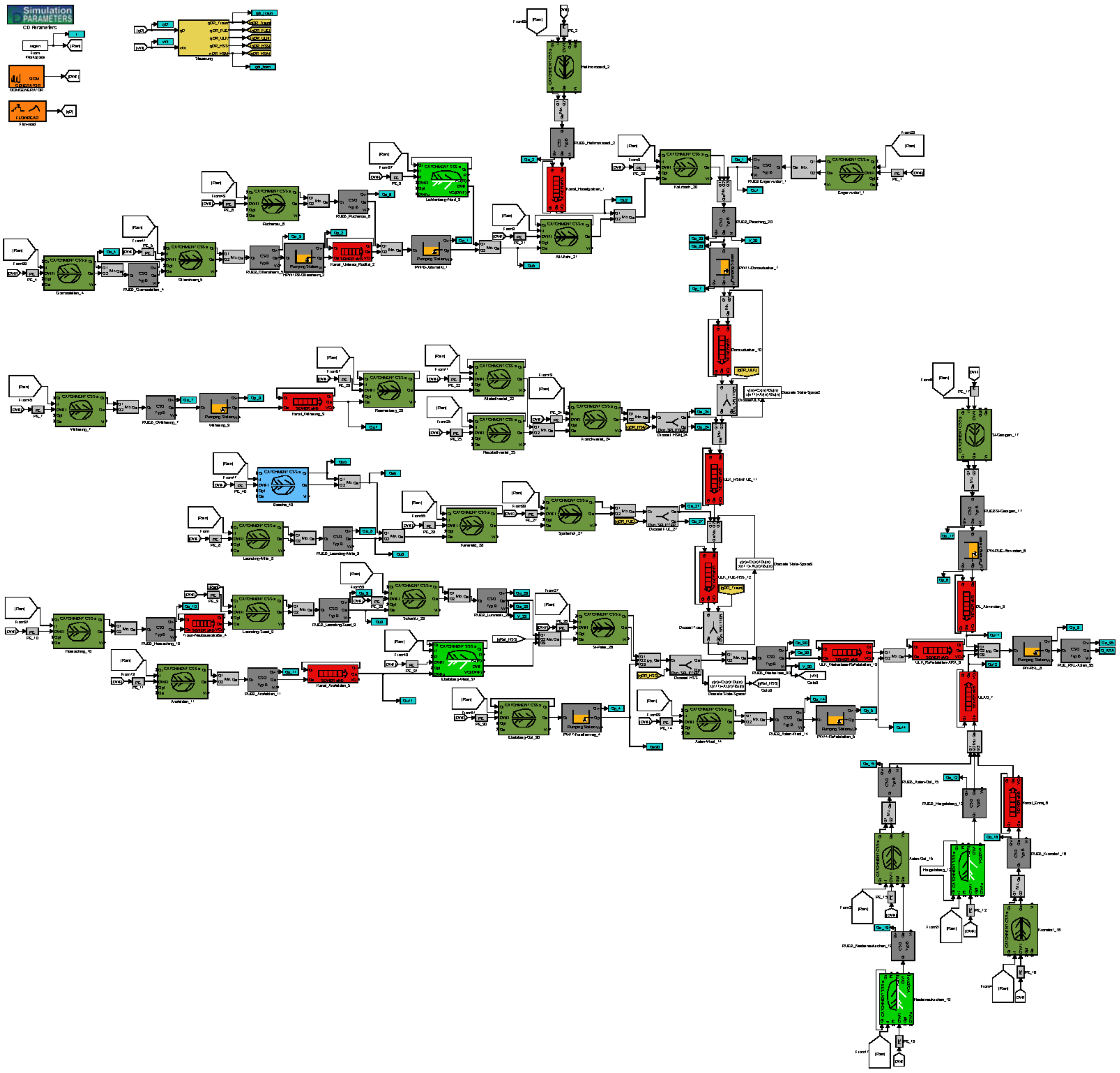

Figure 1: Linz catchment representation in CityDrain

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SWMM (Storm Water Management Model) is a hydrodynamic rainfall-runoff simulation model that was first developed in 1971 in the US and has undergone several major upgrades since then. The latest re-write is version SWMM 5 (Rossmann, 2007) from the US-EPA (United States Environmental Protection Agency). It is available as free software and open source. SWMM 5 and its source code can be obtained from the US-EPA webpages (http://www.epa.gov/ednnrmrl/models/swmm/; on 21-12-2010).

Figure 2 shows the model representation of the Linz catchment in the SWMM modelling software, including subcatchments, manholes, main sewer conduits, overflow weirs and storage tanks. Compared to the CityDrain representation it can be seen that the subcatchments are represented according to their actual geometry.

Figure 2: Linz catchment representation in SWMM 5

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The decision process for the software to be used included the following steps:

- In a workshop with LINZ AG and University of Innsbruck, the two software packages and models were presented and discussed.
- Both models were tested at Graz University of Technology concerning their ability to answer the aims defined in the SUDPLAN project (see chapter 2.1.1.1).

2.1.1.1 Software and model comparison

For model comparison, the following steps were performed for a first analysis.

- Both models were checked on geometric data and aggregation of sewer and catchment geometry.
- Test runs were successfully completed with both models to check their basic operability.

Based on the test run results, minor adaptions were made to the models. This first analysis showed that:

- The sewer network is higher aggregated in the CityDrain model.
- Significant differences in the degree of imperviousness for the subcatchments were identified.
- For both models, additional model calibration is necessary.

After this first analysis, the modified models were compared by simulation and evaluation of a one-year time series (for 2004). Based on these simulations:

Computational time was compared. For SWMM a routing time step of 60 seconds was chosen, in CityDrain routing is generally calculated in 5 minute time steps. As shown in Table 1 computation with SWMM is significantly faster.

Table 1: Comparison of computation times for a one-year time series in SWMM and CityDrain

		SWMM	City Drain
Approximate computation time	Min	25	45

Efficiency rates were calculated and the result for runoff, overflow volume and efficiency rates were compared. The results from the simulation run are given in Table 2. It can be seen that total runoff for both rainfall and dry weather runoff is higher in the SWMM model. For rainfall runoff this can be explained by the higher degree of imperviousness for the subcatchments in the SWMM model. Dry weather runoff still has to be evaluated by data from the wastewater treatment plant.

The obtained CSO efficiency rate η_d is in the same order of magnitude for both models. In both models, the overflow at the primary settling tank is identified as by far the most important.

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About 71% (SWMM) and 78% (CityDrain) of the total spilled volume are spilled at this point. This also shows the importance of assessing the TSS retention efficiency at this point of the system as defined in the aims of the SUDPLAN project.

Table 2: Comparison of calculated runoff, spilled volumes and efficiency rates

		SWMM	**City Drain**
Rainfall runoff	m³	$2.4 * 10^7$	$1.8 * 10^7$
Dry weather runoff	m³	$6.5 * 10^7$	$4.9 * 10^7$
Spilled volume	m³	$7.8 * 10^6$	$5.4 * 10^6$
Spilled volume at primary settling tank	m³	$5.6 * 10^6$	$4.2 * 10^6$
CSO efficiency rate η_d	%	67.0	70.6

2.1.1.2 Software decision

Based on the comparison of the two models it was decided to use SWMM as

- Computation time is slightly shorter in SWMM (based on the simulation of a one-year time series).
- Data for subcatchments, sewer conduits, manholes etc. are geo-referenced in SWMM. This allows a better integration to the planned visualisation activities within the SUDPLAN project.
- Due to the program structure of SWMM (stand-alone program, open-source, can be compiled on any platform), integration in the SUDPLAN Scenario Management System by wrapping the model will be easier than with CityDrain based on Matlab. In addition Matlab is proprietary and a license would have to be acquired.
- SWMM is already being used in other projects by TU GRAZ.
- SWMM can be linked to the optimization framework BlueM.OPT (Bach et al., 2009) that can be used for automated model calibration.

A representation of the results for annual spilled volume as calculated by SWMM for a one-year time series of 2004 is given in Figure 3. After comparing these results with real-world experience from Linz AG several shortcomings were identified that will be treated in the next stage of the Linz pilot activities of the project:

- Some of the spilled volumes at CSOs, especially from the outer subcatchments are not as important as identified by the SWMM model.
- Some CSOs that were identified to have important spill volumes in the field do not show this behaviour in the model.

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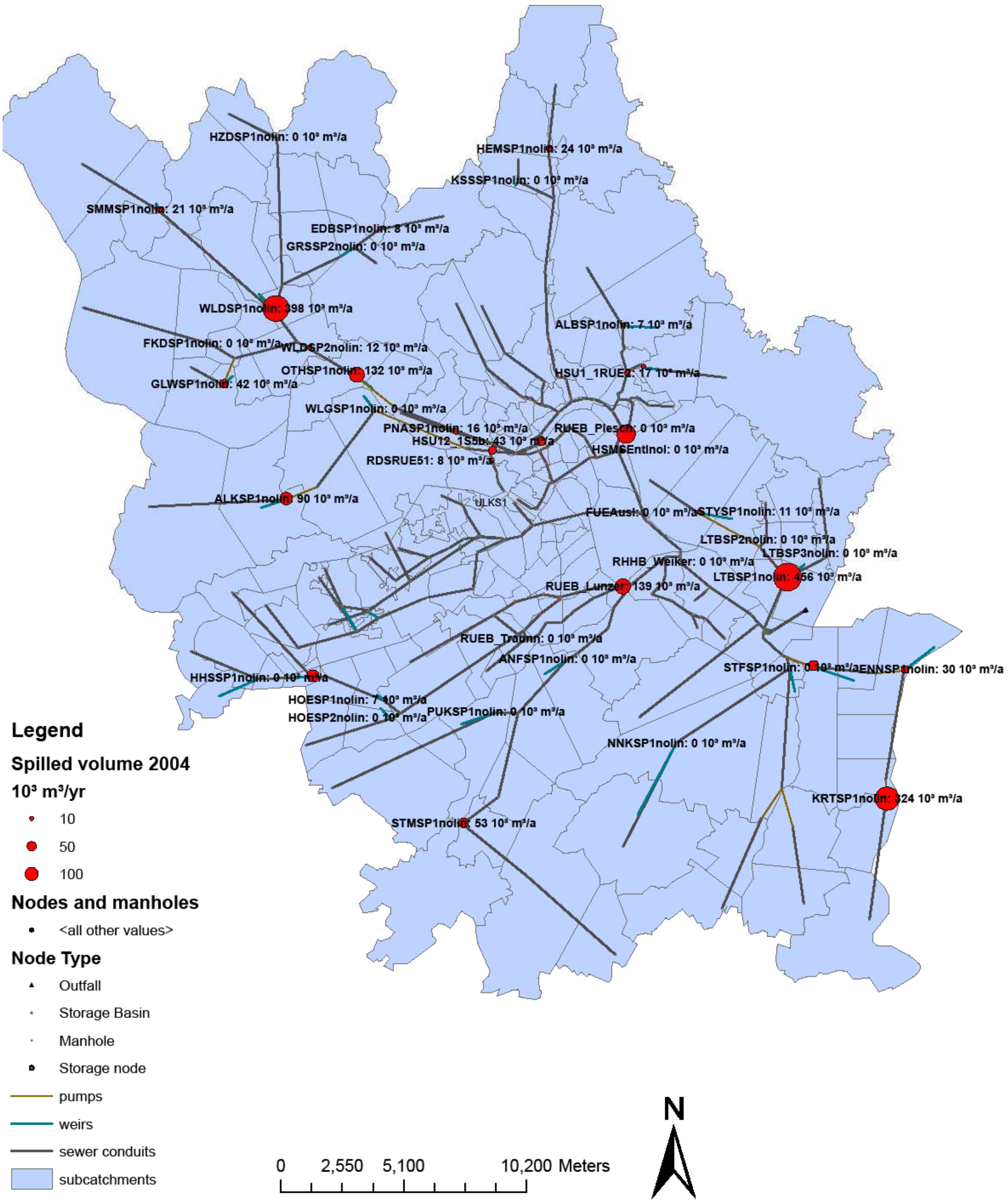

Figure 3: Results from SWMM model for 2004 time series – spilled volumes

2.1.2 Interface

The SWMM model code was tested and the data structure of the model input and output files was analysed. SWMM needs a single input data file that contains all needed information for running the model. It also creates only a single output file from which the efficiency rate can be calculated.

Since the SWMM code is open source and the file formats are well documented it is very easy to create standalone parsers for them. In several test applications the workflow of model execution

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was tested and different local rainfall data sets where used to ensure the stability of the model execution.

An adapted version of the SWMM model was created to deliver status information about the current calculation which makes it easier to create an OGC-compliant SPS for running the model.

2.2. Local Climate Data

2.2.1 Data Acquisition

In the Linz pilot, rainfall data is required as local climate data input to the simulation model.

- Local rainfall data for the rain gauge "Linz Stadt" is obtained from the NIEDA tool (hydro-IT, 2007). The available time series covers 13 years (01.01.1993 to 01.01.2007) with a time resolution of 1, 5 or 10 minutes.
- Additional data will be obtained from the central meteorological service of Austria for the 2007-2010 by LINZ AG and provided for the SUDLAN project.
- In addition rain gauges installed in the Linz area by LINZ AG were provided. They will be used to validate the model but not as historical data or for future scenarios in downscaling as their duration is limited (depending on the rain gauge from 2004 to 2006 onward).

2.2.2 Data Structure and Exchange Formats

The original rain time series (consisting of CSV-Files) will be converted to the netCDF format from http://www.unidata.ucar.edu/software/netcdf/ so that additional metadata can be provided with it. By using the oostethys java toolkit from http://code.google.com/p/oostethys an OGC-compliant Sensor Observation Service (SOS) will be created out of these files, so that it can interact with the Time Series Toolbox based components developed by AIT.

2.3. Other Relevant Input Data

- Geometry data: available from the models & more detailed digital sewer maps. Provided by LINZ AG.
- Geo referenced data: linked to SWMM
- Information on measurement sites provided by LINZ AG.
- Elevation data
- Measurement data of water levels and flow within the system to allow model calibration (adaption of model parameters to fit simulated to measured data). Provided by LINZ AG.

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3. Pilot Design

3.1. Graphical User Interface (GUI)

In total 6 GUI mockups were produced within phase 1 and provided to the mockup blog at http://sudplanwp3.cismet.de/?cat=4. The produced mockups illustrate and describe the functionality and a possible appearance of the developed uses cases within the Linz pilot. Mockups were produced for

- MD-Linz-1: Upload Pilot-Specific Data to Common Services
- MD-Linz-2: Start Downscaling
- MD-Linz-3: Run local model
- MD-Linz-4: Calculate and visualize CSO efficiency rates
- MD-Linz-5: Export Data
- MD-Linz-6: Standard visualizations

Exemplary some mockups for the tasks “Upload Pilot-Specific Data to Common Services (MD-Linz-1)” and the tasks “Calculate and visualize CSO efficiency rates (MD-Linz-4)” are described and illustrated in the following figures.

MD-Linz-1 refers to REQ-USR-2.1.1 (Information source management), REQ-USR-2.3.1 (Initial and boundary conditions), REQ-USR-2.3.2 (Condition sets) and REQ-USR-2.4: (Distributed information sources) and shows how the user can upload pilot-specific data to common services. Of an example Figure 4 shows how the user can update rain time series through an upload or a SOS connection.

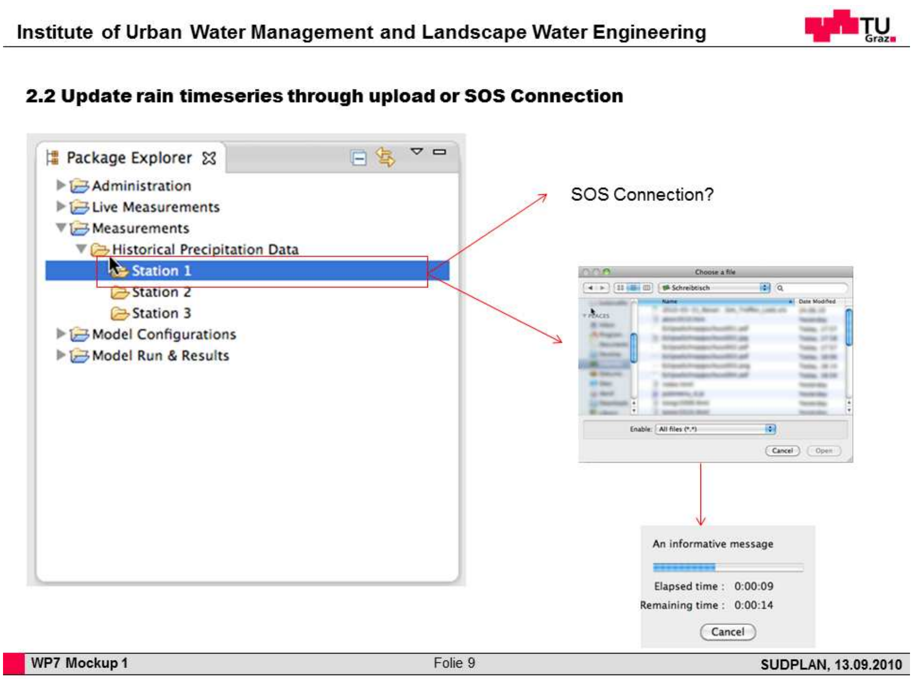

Figure 4: Mockup “Update rain time series through upload or SOS Connection”

MD-Linz-4 refers to REQ-USR-2.6 (Result processing management), REQ-USR-2.31 (Visualization of a model run result) and REQ-USR-2.32 (Comparison of a model run result) and shows how the user can calculate and visualize different CSO efficiency rates. Of an example Figure 4 shows how the user can drop multiple model results to an efficiency rates window to be able to compare the different rates.

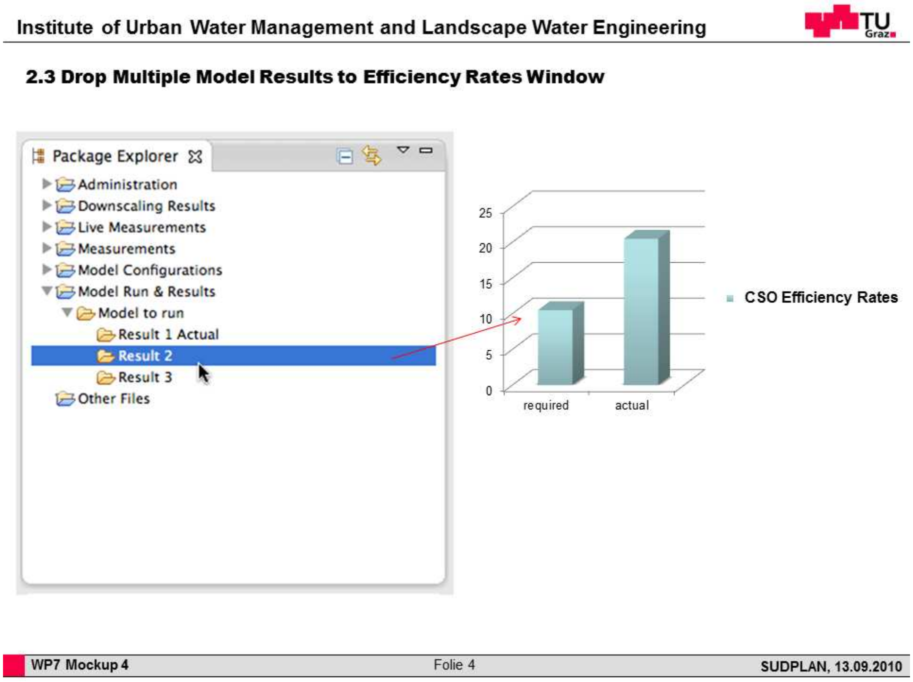

Figure 5: Mockup “Drop multiple model results to efficiency rates window”

3.2. Modification of Use Cases

The only modification on the use cases as described in the respective PDP refers to the used simulation software tool since TU Graz has decided to use the SWMM 5 instead of the CityDrain software.

4. Implemented Use Cases

Since the release of the first version of the integrated SUDPLAN product (Integrated Scenario Management System) is planned for M16 (April 2011) there are no fully implemented use cases using the results of WP3 (Scenario Management System) and WP4 (Common Services) available. However there are non-integrated parts, namely a SOS service offering pilot specific data and a model runtime environment for the pilot-specific models. These parts are planned to be used in all use cases of this pilot and will be described in V2 and V3 of this document.

5. Conclusions

The Linz pilot focuses on the problem of combined sewer overflows into receiving waters. Since it can be assumed that during more frequent and heavier rainfalls the overflow duration of these facilities and the spilled out pollution loads to receiving waters will also increase, possible climate changes might have crucial impacts to the aquatic environment. Within this pilot two main tasks will be carried out:

- Estimation of overall combined sewer overflow (CSO) efficiency rates for dissolved pollutants and for particulate pollutants in the catchment area of the waste water treatment plant of Linz, based on long-term simulations with historical and predicted rain data provided by the common services of the SUDPLAN project (phase 1).
- Estimation of the sedimentation efficiency rate for the primary clarifiers of the treatment plant in Linz by the installation and operation of a novel sensor network in the inflow and outflow of the clarifiers in order to quantify the total suspended solid and chemical oxygen demand retention efficiency under different storm water flow regimes (phase 2).

By comparing the results of today's and of future scenarios possible effects and changes can be recognised and located and proper strategic adaptations can be developed within the catchment area in time.

During phase 1 of the SUDPLAN project preparatory work has been carried out

- to screen all available catchment and measurement data in the area of the Linz pilot,
- to decide on historical rainfall data which are used by Common Services for regional downscaling and for future scenarios and
- to select a proper simulation model for the calculation of CSO efficiency rates based on long term simulation runs.

From the two for the Linz catchment area available simulation models finally the SWMM model was selected since computation time is slightly shorter, all catchment data are geo-referenced in this model and the integration in the SUDPLAN Scenario Management System by wrapping the model will be quite easy.

A full demonstration of how the SUDPLAN platform manages the use-cases specified for the Linz Pilot is not possible at this stage, instead it will be presented in the succeeding documents (V2 and V3).

6. References

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7. Glossary

technical term	*Explanation*
CSO efficiency rate η	Indicator for yearly emitted CSO pollution loads from combined sewerage to receiving waters regarding to the Austrian standard ÖWAV Regelblatt 19 (OEWAV, 2007). It distinguishes between two different kinds of CSO efficiency: one for dissolved pollutants (η_d) and one for particulate pollutants (η_p).
Mockup	A model of a design used for demonstrating the functionality of a system.

8. Acronyms and Abbreviations

acronym / abbreviation	*Definition*
AIT	Austrian Institute of Technology

COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
netCDF	Network Common Data Form
OGC	Open Geospatial Consortium
OpenSDM	Open Scientific Data Management
SMS	Scenario Management System (SUDPLAN functionality)
SOS	Sensor Observation Service
SPS	Sensor Planning Service
SWMM	Storm Water Management Model
TSS	Total Suspended Solid
US-EPA	United States Environmental Protection Agency
WWTP	Waste Water Treatment Plant

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