WaterJPI project

SMARTControl

Smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge (MAR) applications

Deliverable D5.1

Real-time observation system at pilot scheme in Pirna, Germany
Testing of the newly developed real-time monitoring tool of the web-based INOWAS platform

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Short summary

The present report provides a brief description of the hydrogeological conditions underlaying the research test field in Pirna, Germany, and introduces the existing monitoring system that was updated to meet the project objectives. The specific aim of deliverable 5.1 is to demonstrate the integration of the local groundwater monitoring system into the INOWAS simulation platform and to validate the functionality of the web-based tool "T02. Real-time monitoring".

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ABSTRACT

The monitoring tool developed within the frame of SMART-Control allows an easy observation of real-time data collected from MAR facilities under consideration of various data sources and processing algorithms. One of the six MAR case studies considered by the project is located in Pirna, Germany, on the premises of Technische Universität Dresden. The test field consists of a small-scale groundwater monioring network constructed over the past 15 years for teaching and research purposes. In the frame of SMART-Control, the experimental site is used to validate the research concept and to test the MAR simulation tools developed by the project. The present report provides a brief description of the hydrogeological conditions underlaying the test field and introduces the existing monitoring system that was updated to meet the project objectives. The specific aim of deliverable D5.1 is to demonstrate the integration of the local monitoring system into the INOWAS simulation platform and to validate the functionality of the real-time monitoring tool.

CONTENT

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1. INTRODUCTION

1.1 BACKGROUND

Managed aquifer recharge (MAR) is used worldwide for sustainable management of water resources. MAR implies the storage of surface water in the underground and its utilisation for different purposes such as domestic and agricultural use, or for ecological benefits. What differentiates MAR from other groundwater recharge practices (i.e. leakage from sewerage networks) is the intentional recharge of the aquifers by injecting water under controlled conditions. In order to safeguard and protect the good status of the aquifers, a monitoring system provides qualitative and quantitative data necessary for the safe operation of the MAR scheme. Depending on site-specific requirements, the monitoring system contributes to the optimisation of the operational scheme in order to reduce the MAR-associated risks. The role of monitoring systems consists in assessing the water quality parameters of the influent water, native groundwater and recovered water in respect to existing regulations. This can be done by manually sampling the water at regular time intervals and analyzing the water samples in the laboratory.

Considering the relatively high costs of the analyses and the rather long time interval between two sampling campaigns, automatic monitoring systems consisting in multi-parameter probes can deliver continuous measurements of most relevant parameters and deliver the values in near-real time conditions. The systems can be equipped with additional control functionalities that have the capability to intervene in the operational management and, for example, to stop the water inflow when the water quality does not meet the desired quality thresholds.

1.2 ABOUT THIS REPORT

"SMART-Control" is an international research project funded through the Water Joint Programming Initiative (WaterJPI) and implemented by nine institutions from Germany, France, Cyprus and Brazil. The main objective of the project is to reduce the risks associated to MAR by the development of an innovative web-based real-time monitoring and control system (RCMS) in combination with risk assessment and management tools. The SMART-Control approach relies on coupling a real-time in-situ observation system consisting of state-of-the-art online sensors and a web-based groundwater monitoring and modelling platform. The resulting system shall provide operators and managers of MAR schemes with automatic decision support tools for monitoring, controlling and prediction of processes occurring during MAR. The approach will be tested and validated at six MAR sites under different environmental and operating conditions. More information about SMART-Control is available on the project website: https://www.smart-control.inowas.com.

One of the six MAR sites is located in Pirna on the premises of Technische Universität Dresden. The site is activelly embedded in the teaching and reasearch curriculum of the university and was constructed over the past 15 years within several research projects. In SMART-Control, the experimental MAR test field is used for the development and testing of MAR simulation tools developed by the project. The present report provides a brief description of the hydrogeological conditions underlaying the test field and introduces the existing monitoring system that was updated to meet the objectives of the project. The aim of the deliverable 5.1 is to demonstrate the integration of the monitoring sensors installed at test site to the web-based INOWAS platform. The software infrastructure that enabled the connection of the monitoring system to the INOWAS platform is described in the report D3.1 and the real-time monitoring tool that is used in this document is described in detail in the report D4.2 (see project website).

2. MAR TEST SITE IN PIRNA, GERMANY

The experimental MAR test site is located about 15 km southeast of Dresden, in the city of Pirna, Germany, on the nothern riverbank of the Elbe river (Figure 1). The test field belongs to Technische Universität Dresden (TUD) and has been used for groundwater-related investigations for over 15 years. In addition, the Research Group INOWAS at TUD uses the test field for specific MAR-related investigations (Barquero, 2020).

Figure 1. Location of the case study site in Pirna, Germany (left) and satellite view of the university test field (right) (Barquero, 2020)

Pirna is characterized by a temperate climate with warm summers and cold winters. Annual precipitation is about 800 mm and falls throughout the year. The average annual air temperature is 9 °C, with January being mostly the coldest and July the hottest month of the year (Li, 2014).

The Elbe river originates in Czech Republic and flows northwest through Germany into the North Sea, having almost 100,000 km^2 catchment area in Germany (Barquero, 2020). The Elbe riverbanks are only about 150 m south of the wellfield in Pirna. The average flow rate of the Elbe river is 332 m^3/s at a 1.84 m stage in the city of Dresden (Barquero, 2020). Depending on the season, the discharge varies between 110 m^3/s (low flow, frequently in summer) and 1700 m^3/s (high flow, spring) (Barquero, 2020). Previous investigations showed that the Elbe river is strongly connected to the local groundwater and causes groundwater table fluctuations within short time periods (Barquero, 2020; Händel et al., 2016).

2.1 HYDROGEOLOGY

The unconsolidated sediments in the upper 15 m below surface until the Quaternary bedrock of the test field were hydrogeologically characterized in detail by (Dietze and Dietrich, 2012) using common and Direct-Push-based exploration methods. The investigations covered soil sampling and sieve analysis at 9 locations with 177 samples, Direct-Push-Injection-Logger (DPIL) at 10 locations and Direct-Push-Slug-Tests (DPST) at 4 locations (G11, G13, G15, G17) with a total of 51 tests to gain in depth knowledge about the vertical heterogeneity of the test field (Händel et al., 2016).

The aquifer is characterised by interbedded strata of medium sand to coarse gravel followed by fine sands of varying thickness (Dietze and Dietrich, 2012). Due to the fluvial formation, a high variability in lithology and hydraulic parameters are present (Händel et al., 2016).

The upper layer with a thickness of about 2-4 m consists of anthropogenic fillings mixed with fine materials from flood events of the Elbe river (Händel et al., 2016). At a depth of 4 m until 7.5 m below surface, a low conductivity layer with silty sediments and a hydraulic conductivity of approximately $5*10^{-4}$ m/s exists (Dietze and Dietrich, 2012; Händel et al., 2016). Underneath follow highly heterogeneous but in general highly conductive sands and gravels with a thickness of approximately 4-5 m (Händel et al., 2016). The impervious basement in about 15 m below surface is formed of marine sediment rocks which consist mainly of sand- and mudstone of Upper Cretaceous age (Dietze and Dietrich, 2012). In general, the lithological units as well as the aquifer dip slightly towards the riverbank of the Elbe river (Li, 2014).

2.2 MONITORING NETWORK

The test field including the monitoring system in Pirna has developed over about 10 years and consists of numerous wells with varying diameters (Figure 2):

- 1" Direct-push wells (G)
- 1" Multi-level Direct-push wells (M)
- 5" wells (I)

Figure 2. Overview of monitoring system in Pirna, Germany

In 2008, the G- und M-wells were drilled using the Direct-Push method. Since then, the groundwater levels in G-wells are frequently monitored: at first manually at irregular time intervals, then from June 2014 almost daily. In

January 2015, UIT sensors were installed that record the groundwater levels hourly (ongoing measurements). Due to some maintenance issues, the time series are not continuous. In comparison to the G-wells, the multi-level M-wells are mainly used to investigate small-scale transport processes in the subsurface using e.g. tracer tests.

The 5” I-wells were drilled in June 2016 to investigate the pilot MAR infiltration basin system in detail (Figure 3). Multi-parameter sensors were installed which measure groundwater level, groundwater temperature, electrical conductivity, oxygen saturation and pH.

Figure 3. Detailed view of current system setup of the infiltration basin pilot site and the surrounding 5”-wells in Pirna, Germany

In February 2019, four of the multi-parameter sensors were upgraded to transmit data in real-time via the GSM mobile network to UIT´s SENSOweb platform (Figure 3, Chapter 4). For this, a SIM-card with a mobile internet flatrate of 50 MB per month was purchased for each sensor and installed using the sensor manual.

3. TESTING OF THE WEB-BASED REAL-TIME MONITORING TOOL ON INOWAS PLATFORM

The implementation of tool “T02. Real-time monitoring” was tested using the following monitoring data:

- I-wells connected via GSM, SensoWeb and FTP
- Elbe river stage connected via public WebServer and Prometheus
- Historical data uploaded via CSV

3.1 SENSOR SETUP

The I-wells were integrated by setting up the sensor including its location. As a second step, the parameters were defined. These include for the multi-parameter sensors electrical conductivity, water level, pH, temperature, and dissolved oxygen. For each parameter, the data source was defined as shown in Figure 4 by specifying the server (uit-sensors.inowas.com), the project (DEU1), the sensor name (I-6) and the parameter (h for water level). In addition, a filter for the lower limit of 1 m was added as due to maintenance some time steps had missing values (0 m).

Figure 4. Screenshot of the definition of an UIT sensor as data source on the web-based INOWAS platform

The Elbe river stage data was added by choosing "prometheus" as data source (Figure 5). The public available data was before added to the prometheus INOWAS server (more details about the technical infrastruture for data acquisition in report D3.1). In the query field, the station, type and simple calculations such as the conversion of unit needs to be defined (pegel_online_wsv_sensors{station="PIRNA", type="waterlevel"}/100). By ticking the field "auto update", new data is automatically added to the platform.

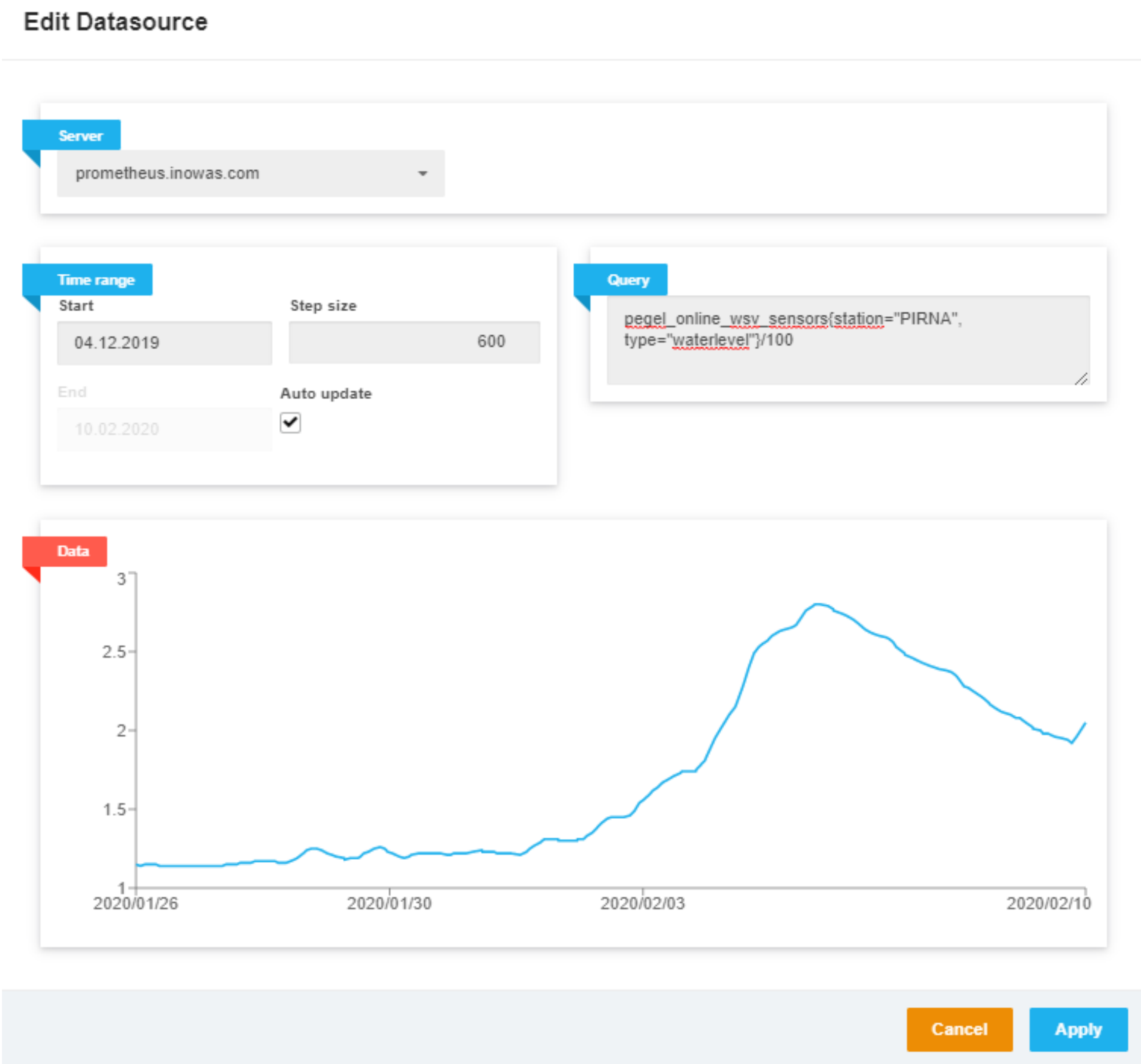

Figure 5. Screenshot of the definition of an external sensor as data source on the web-based INOWAS platform

As a second data source, historical data of the Elbe river water stage was added using the CSV upload function. In total, four I-wells and the Elbe river stage with three different data sources were successfully added to the web-based INOWAS tool (Figure 6).

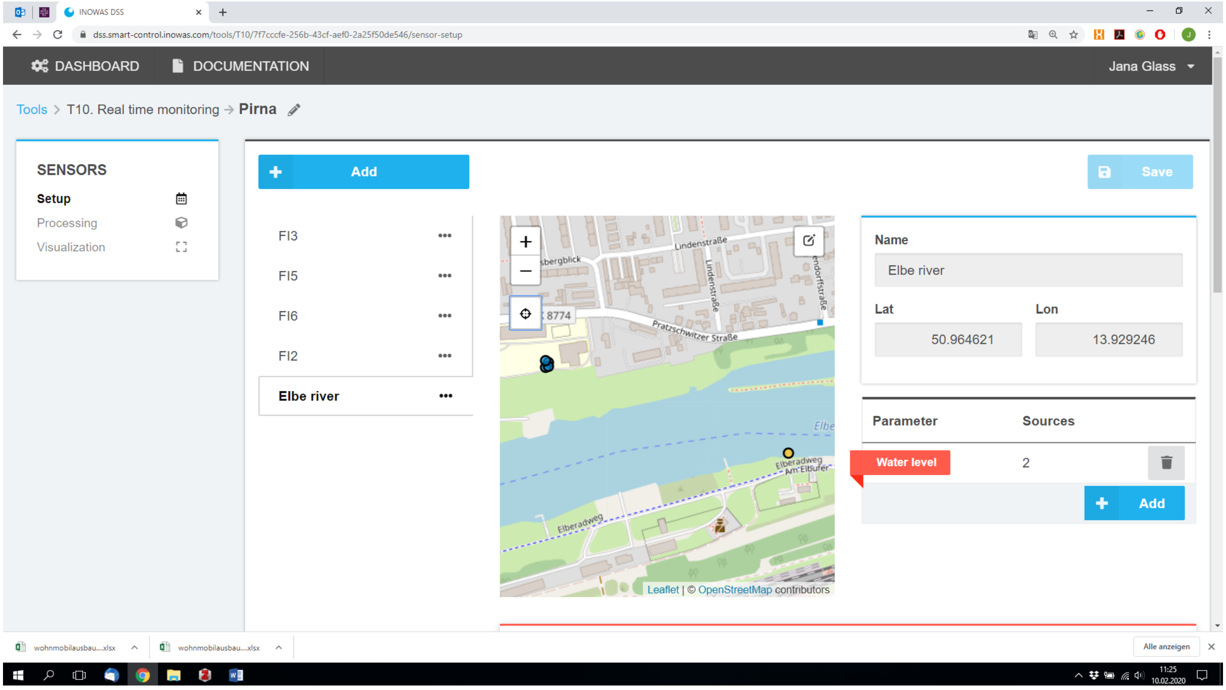

Figure 6. Screenshot of the implemented online sensors on the web-based INOWAS platform

3.2 PROCESSING

The raw data of the four connected sensors were processed to exclude missing values and outliers. For this, the processing functions of the real-time monitoring tool were utilized such as filtering. The time processing algorithms were applied to prepare the data for later use e.g. in a (real-time) groundwater model of the test site. The hourly data was resampled to daily data (Figure 7).

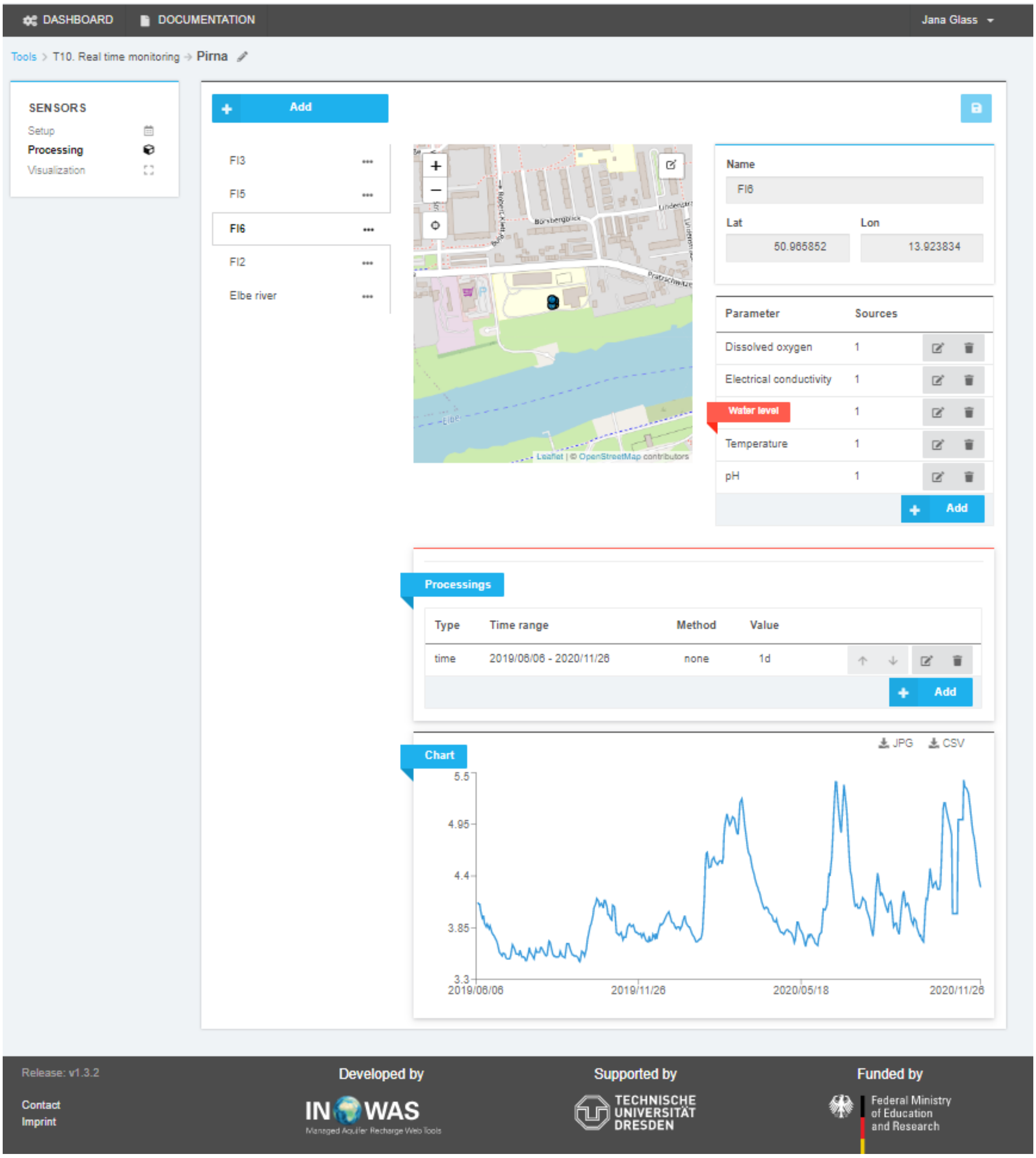

Figure 7. **Screenshot of the time processing of sensor data on the web-based INOWAS platform**

3.3 VISUALISATION

The visualisation section of the real-time monitoring tool can be used to compare various time series, e.g. the groundwater level at the monitoring wells in Pirna (Figure 8). Due to the low distance to the Elbe river, the groundwater levels at the Pirna test site follow the Elbe river water level. The water level of the various monitoring wells show only slight differences which could be caused by local heterogeneities of the inhomogeneous aquifer.

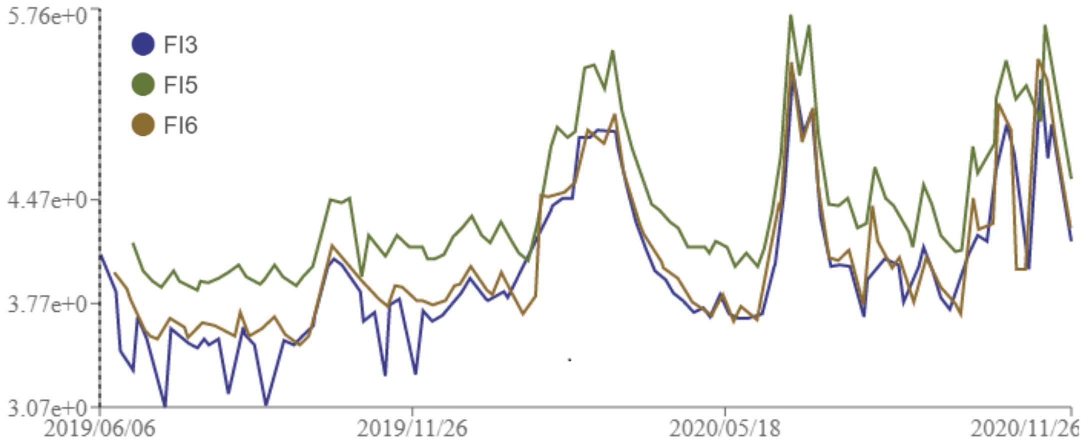

Figure 8. **Time series of water level at sensors in Pirna, Germany**

4. SUMMARY AND OUTLOOK

The successful testing of newly developed real-time monitoring tool was conducted at the Pirna case study site. For this, various sensors which are installed in different monitoring wells were connected to the web-based platform by GSM. In addition, the publicy available water level of the closeby Elbe river was connected via a public WebServer and Prometheus. Also, historic data was uploaded via CSV. The sensor processing tools were tested by eliminating outliers and missing values or resampling of the time series to other time resolutions. In the visualisation section of the real-time monitoring tool, the data of the various sensors were compared.

As next steps in SMART-Control, the online monitoring system at Pirna will be expanded by the installation of additional sensors at the test field. This will help to set up the real-time model and to better describe the local groundwater processes. In addition, a numerical groundwater flow model of the Pirna test site will be implemented on the INOWAS platform. After integration of new monitoring data and recalibration, the model will be used to test the real-time modelling tool which is currently under development.

5. REFERENCES

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