Activity report about field measurements in the pilot area Bratislava - Hainburg

Deliverable D.T3.2.2 Updated database of existing and additionally measured data at the pilot areas

Final Report

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Content

1. Introduction ... 3

1.1. Aim and scope of this report ... 3

1.2. Overview of the chosen strategy for field measurements ... 3

2. Documentation of field measurements ... 4

2.1. Groundwater temperature and level measurements ... 4

2.1.1. Methods ... 4

2.1.2. Documentation ... 7

2.2. Grounwater chemistry investigations ... 8

2.2.1. Sampling and methods ... 8

2.2.2. Documentation ... 11

2.3. Thermal rock properties ... 14

2.3.1. Sampling and methods ... 14

2.3.2. Documentation ... 16

3. Data processing ... 20

3.1. Groundwater temperature measurements ... 20

3.2. Groundwater chemistry analysis ... 20

3.3. Transfer of field data to the joint databases ... 20

4. Results ... 21

4.1. Groundwater temperature measurements ... 21

4.2. Groundwater chemistry analysis ... 22

4.3. Isotope composition ... 23

4.4. Thermal rock property measurements ... 23

5. Summary and conlusions ... 24

1. Introduction

1.1. Aim and scope of this report

This report describes the field measurements performed in the pilot area PA Bratislava - Hainburg, which have been performed within the frame of Activity A.T2.3.2. It aims at a full documentation of the assessed field data, which will be published at the GeoPLASMA-CE web portal (www.geoplasma-ce.eu).

This report contains:

- An overview of parameters measured in the pilot areas for creating the aimed project outputs
- A brief description of the methods applied for measurement and data processing
- A documentation of the field measurements performed in the PA area.
- A short description of the results achieved and how these results contribute to the generation of thematic outputs.

1.2. Overview of the chosen strategy for field measurements

The temperature measurements feed into the numerical model of the pilot area Bratislava-Hainburg (D.T3.3.3), which provides groundwater temperature maps. These maps are important input data for the potential calculations for open loop systems, namely the output parameters (OP) “Thermal capacity – peak load” (OP07), “Thermal capacity – base load” (OP08), “Energy content” (OP09), “Thermal productivity” (OP11). The potential maps will be included in the GeoPLASMA-CE web portal.

Chemical analysis of groundwater samples (at the sampling location and in the laboratory) reveal possible risks for open loop and closed loop systems. The output parameter “Problematic groundwater zones” (OP29) will rely on this information and additional existing data from external sources. A map showing the problematic groundwater zones will become part of the location query on the GeoPLASMA-CE web portal.

The goal of the isotope research was to assess the relationships between groundwater and its potential sources. Two potential sources are considered:

> local precipitations

> water flows – bank recharge (infiltration)

Investigations intend as well to assess the relationships between individual sources of groundwater to each other.

In addition to groundwater analyses, in situ measurements of thermal properties in the pilot area Bratislava-Hainburg were performed. Those analyses will feed into a look up table of thermal conductivities of different rocks in all pilot areas of GeoPLASMA-CE. Analyses will also feed into the numerical model (D.T3.3.3) and in the bulk thermal conductivity map (OP02) for the pilot area Bratislava-Hainburg.

2. Documentation of field measurements

2.1. Groundwater temperature and level measurements

2.1.1. Methods

Continuous groundwater level and temperature monitoring

To obtain groundwater level and temperature data, continuous measurements with submergible dataloggers were utilized at several boreholes in the Slovak part of the pilot area. The selected boreholes are from 11.5 to 19.0 m deep, all penetrating the topmost quaternary fluvial aquifer. The boreholes were equipped with either a Solinst "Model 3001 LTC Levelogger Edge" or "Levelogger Junior Edge" diver, installed in depths from 6.3 to 11.9 meters. An overview of the used dataloggers and the measured parameters is in Table 1. Three boreholes (VN6-2, VN48-8 and VN138-1) were equipped with dataloggers and maintained by our team, the rest (VN4-2, VN5-7, VN6-12, VN6-18, VN46-5 and VN138-3) are monitored within another running project. For barometric compensation of the measured pressure readings a Solinst "Barologger Edge" was deployed in a vented and shaded box at the premises of SGIDS in Bratislava.

Table 1: Boreholes employed with dataloggers. Dataloggers installed previously within different project are marked with italics.

Borehole name	UTM Easting [m]	UTM Northing [m]	Ref. point elevation [m Baltic]	Borehole depth [m]	Screen depth - top [m]	Screen depth - bottom [m]	Monitoring start	Parameters
VN6-2	659753.88	5339676.46	135.89	15.0	2.0	8.0	25/7/2016	Level, T, EC
VN48-8	655619.91	5331291.3	136.47	18.0	3.0	15.0	9/10/2015	Level, T
VN138-1	660061.71	5332712.96	136.85	19.0	4.0	18.0	25/7/2016	Level, T, EC
VN4-2	*658269.24*	*5334536.42*	*136.95*	*15.5*	*3.0*	*13.5*	*24/7/2015*	*Level, T*
VN5-7	*658741.48*	*5334451.27*	*136.28*	*15.0*	*3.0*	*13.0*	*9/7/2015*	*Level, T*
VN6-12	*659718.67*	*5337677.96*	*138.43*	*19.0*	*2.0*	*17.0*	*24/7/2015*	*Level, T*
VN6-18	*661185.23*	*5338361.68*	*132.03*	*11.5*	*1.5*	*7.5*	*24/7/2015*	*Level, T*
VN46-5	*659373.59*	*5334249.62*	*137.28*	*17.0*	*3.0*	*15.0*	*24/7/2015*	*Level, T*
VN138-3	*660305.33*	*5332759.99*	*136.68*	*15.0*	*3.5*	*14.0*	*9/7/2015*	*Level, T*

Figure 1: Types of used submersible groundwater level, temperature and EC probes (left) and barometric pressure datalogger (right).

Manual groundwater level, temperature and conductivity measurements

Additional manual measurements of groundwater level, temperature and conductivity at boreholes were performed occasionally during each visit at the nine monitored sites by SGIDS. Altogether five measurements were made at each site. The purpose of those measurements was mainly to obtain reference values of groundwater table elevation, subsequently used for adjusting groundwater table height measurements made by installed dataloggers.

Figure 2: Left and middle: Solinst groundwater table depth meter with temperature and EC measurement probe used for manual measurements in the Slovak part of the pilot area. Right: Equipment for manual groundwater temperature and water level measurements in the Austrian part of the pilot area.

Measurements from SGIDS were performed using Solinst Model 107 TLC flat tape water level, temperature and conductivity meter (Figure 2). Measurements of depth had the zero reference point usually at the end of the borehole casing.

The equipment underwent regular maintenance including cleaning of iron- or manganese fouling and repair of corroded fittings.

LP-GBA conducted only manual groundwater temperature measurements in 11 observation wells (10 in the topmost quaternary aquifer and one in a tertiary aquifer) and three surface water bodies in the Austrian part of the pilot area. Two different well dippers (50 m and 150 m length) from *"HT- Hydrotechnik GMBH"* with temperature sensors were used to measure the groundwater temperatures every three month. Figure 2 shows the equipment for manual groundwater temperature and water level measurements. The measurements include depth of the water level and groundwater temperatures in fixed depths of a 50 cm interval. LP-GBA calibrated all used devices at the beginning of the measuring period.

The position of all monitoring wells within the pilot area Bratislava-Hainburg is displayed in the map in Figure 3.

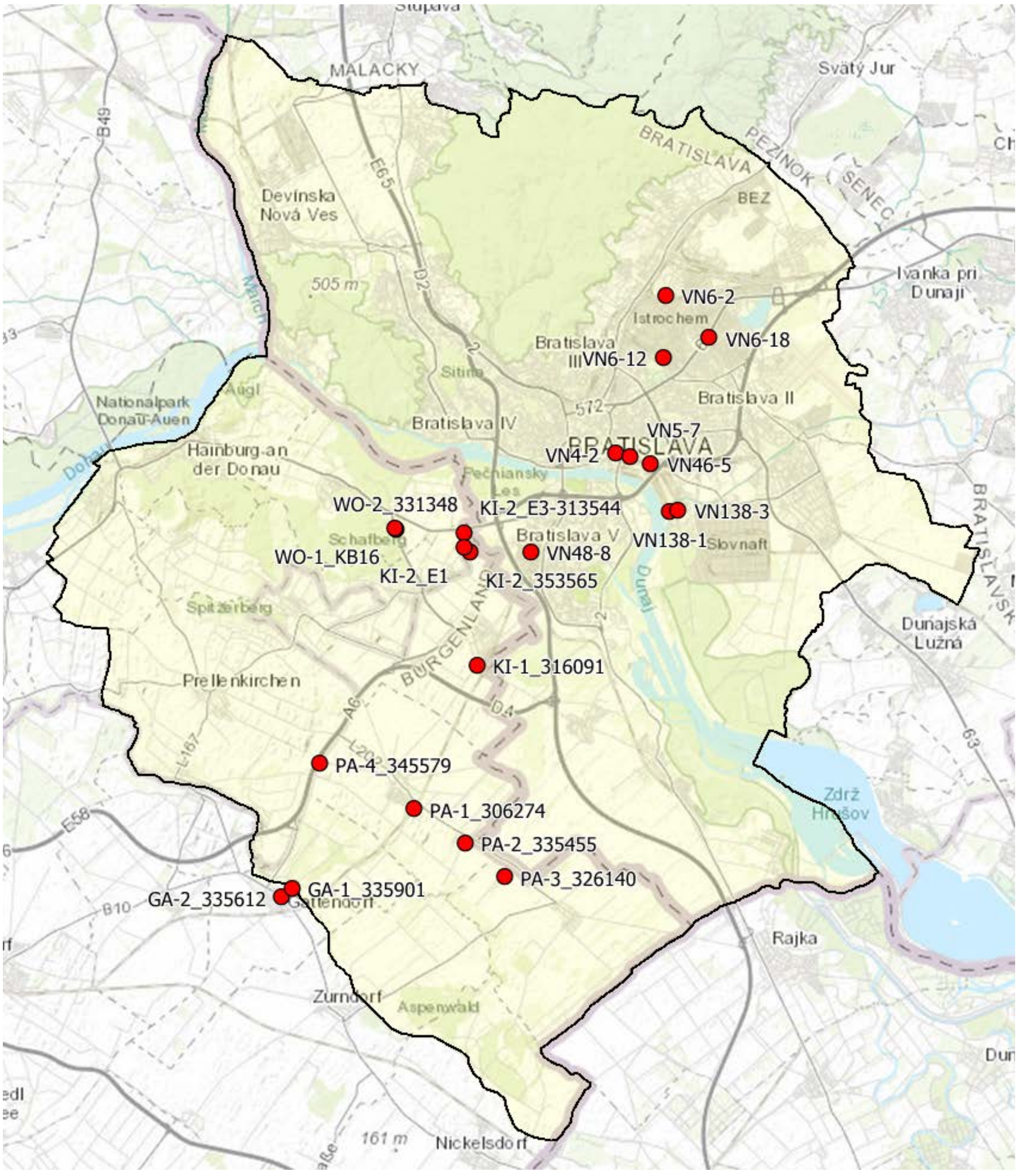

Figure 3: Localization of boreholes for groundwater temperature and level measurements.

2.1.2. Documentation

SGIDS monitored nine and LP-GBA 11 observation wells in the pilot area Bratislava-Hainburg. Single groundwater measurements were performed in five different climatological periods (November 2017, February 2018, May 2018, July 2018 and October 2018) to perceive a seasonal variability.

During visits at sites all data stored in dataloggers were downloaded in form of *.lev and *.xle files, which were later processed using Solinst "Levelogger 4.4.0" software for barometric compensation of level measurements. Data from manual measurements were recorded on paper and transferred to a digital database in the post-processing phase. In addition to the temperature and water level, the team also recorded information about weather, well dipper used, date and time of the measurements and the names of the technicians in the field. The information which well dipper was used is crucial for the post-processing phase, where the corresponding calibration equation had to be applied.

Due to accessibility reasons and device availability, not all wells and surface water bodies could have been investigated at all five field campaigns. Table 4 gives an overview of the temperature and water level measurement history.

2.2. Grounwater chemistry investigations

2.2.1. Sampling and methods

Water sampling

The type of water sampling is depending on the type of water sampling point. For observation wells, the sampling was executed using a submersible pump (Figure 4). Sampling depth for all observation wells was the middle of the saturated aquifer. The depth was calculated from data from the level measurements. Before testing, the pump removed the standing water column in the wells to get fresh groundwater for sampling. An angular beaker with a holding rod was used for sampling surface water bodies like rivers and quarry ponds.

Sampling bottles, measuring cups and the surface water sampler were rinsed three times before being filled with sampling water. Sampling water was injected into the bottles using a syringe and a membrane filter with a porous space of 0.45 µm. At each sampling location, plastic bottles with 250 ml and respectively 50 ml and one 25 ml glass bottle for isotope samples were filled. After the filling of the 50 ml bottle with sampling water, 1 ml of nitric acid was added to preserve the sample. Lids were placed carefully on the brimming bottles to ensure no air bubbles inside. A cooling box stored the filled sample bottles during the field trips. After field work, all filled sample bottles were stored in a refrigerator until the department Geochemistry at LP-GBA performed the chemical analysis.

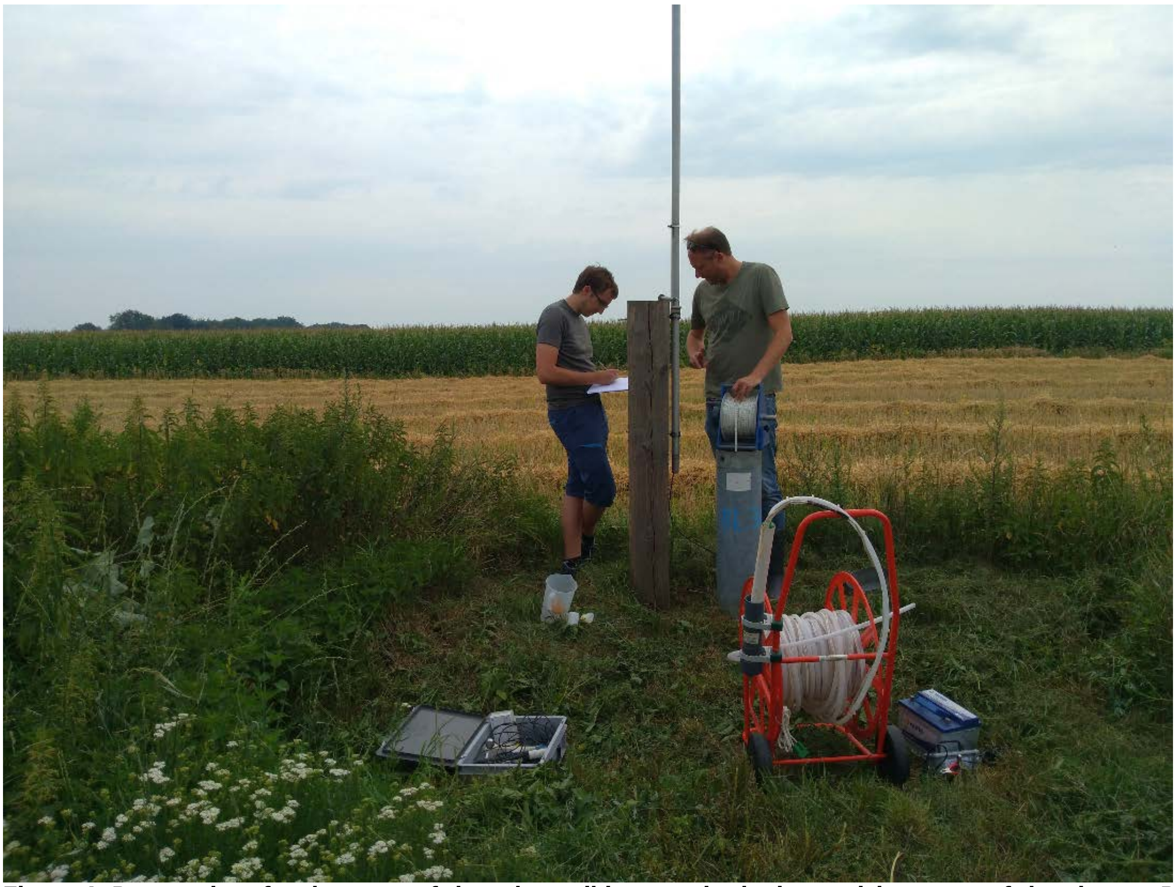

Figure 4: Preparations for the setup of the submersible pump in the lower right corner of the picture. Picture was taken at sampling site KI-2_353565.

Groundwater chemistry analysis

Groundwater chemistry analysis for the PA Bratislava-Hainburg contained measurements directly in the field and laboratory investigations. On-site parameters are described in Table 2 and were analysed with a WTW multi-parameter probe with various sensors (see also Figure 6 and Figure 7). For sampling sites where only electric conductivity data are existing, the measurement was executed with a well dipper (Figure 5). The execution of the measurements was either in beakers or in case of surface water bodies directly. Before the field trips, the department of Geochemistry of LP-GBA calibrated all WTW sensors.

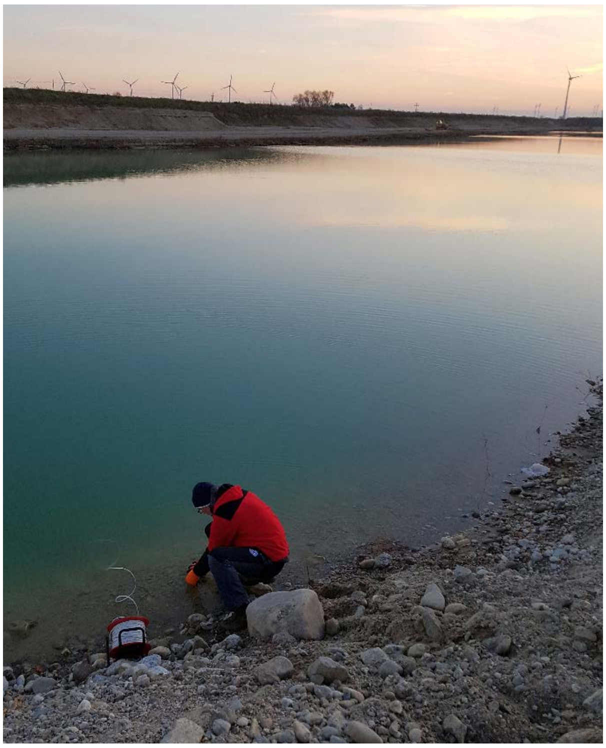

Figure 5: Measurement of temperature and electric conductivity directly in the quarry pond Kittsee.

Figure 6: Measurement with the WTW logger in beaker.

Table 2: On-site parameters of groundwater chemistry analysis.

On-site parameter	Unit	WTW Sensor
Temperature	°C	TetraCon 925
Electric conductivity	µS/cm	TetraCon 925
pH	-	SenTix 940
Reduction potential	mV	SenTix ORP
Oxygen	Mg/l and %	FDO 925

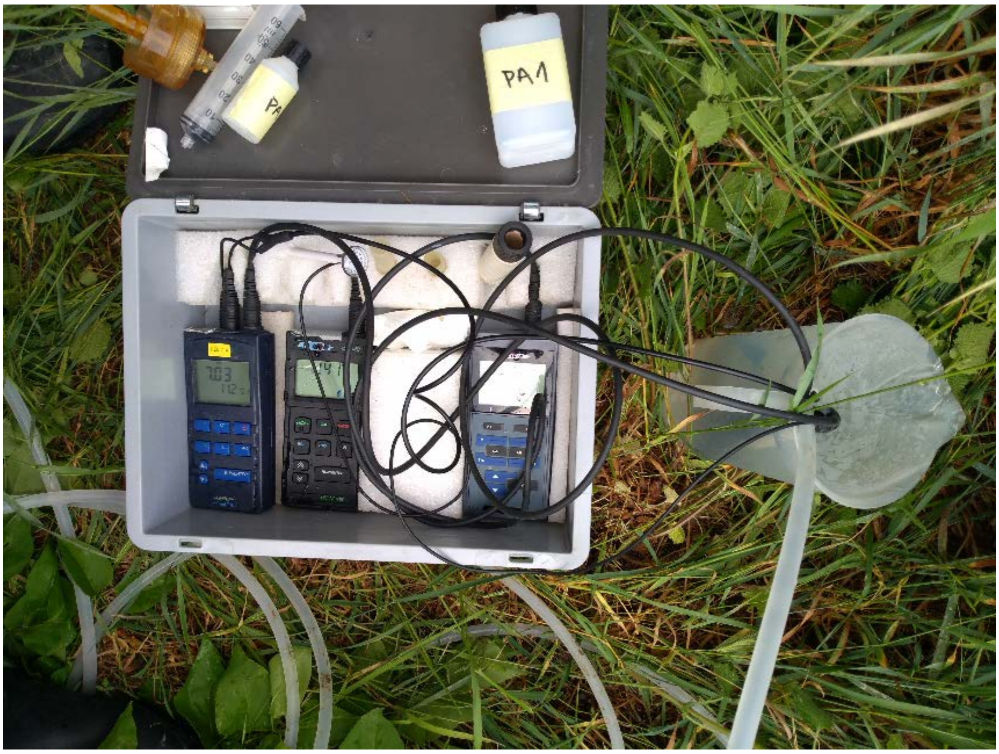

Figure 7: Setup of the WTW multimeter tools with four different sensors for groundwater on-site analysis.

Table 3: Laboratory parameters of groundwater chemistry analysis

Laboratory parameter												
Cations [mg/l]												
Ca	Na	Sr	Li	Cs	Mn	Fe	Mg	K	Ba	Rb		
Anions [mg/l]												
HCO3	SO4	F	Cl	NO3								
Special parameters [mg/l]												
Cu	Pb	Cd	Al	As	Cr	Ni	Zn	U	Co	Mo	V	Si
Isotopes												
$\delta^{2}H$	$\delta^{18}O$											
Calculations												
Total hardness [°dH]												
Carbonate hardness [°dH]												
Non-carbonate hardness [°dH]												

Parameters derived by laboratory measurements are listed in Table 3. Measurements were performed in accordance with the routine of the laboratory and the requirements of the workflow for problematic groundwater bodies in the department of geochemistry of LP-GBA.

Isotopes

Isotope composition H and O was measured in the laboratory of isotope geology of department of special methods of SGIDŠ in Bratislava at LWIA instrument (Los Gatos). After delivery to laboratory samples were immediately filtered, marked by laboratory number and stored in fridge at 4 °C until the analyses. An aliquot sample was taken during the filtration and preserved for possible control measurements. Results are referred to as $\delta^{2}H$ resp. $\delta^{18}O$ against the VSMOW standard. Reproducibility of measurement is better than 2‰ for $\delta^{2}H$ resp. better than 0.2‰ for $\delta^{18}O$. The authors of analyses are Bilohuščin J. and Čech P.

2.2.2. Documentation

LP-GBA sampled 11 observation wells, one river and one quarry pond in the pilot area Bratislava-Hainburg. An overview of the locations, where LP-GBA took groundwater samples for chemical analysis including isotopes, is available in Table 4 and Figure 8. Groundwater samples were taken during five field campaigns, representing different seasons (15.11.2017, 21.02.2018, 15.05.2018, 11.07.2018 and 16.10.2018). Due to accessibility reasons and device availability, not all wells and surface water bodies could have been sampled at all five field campaigns. Table 4 gives an overview of the sampling history.

For isotope investigations, 140 samples were measured, including monthly cumulative precipitations of 29 samples, surface water of 63 samples and groundwater of 48 samples.

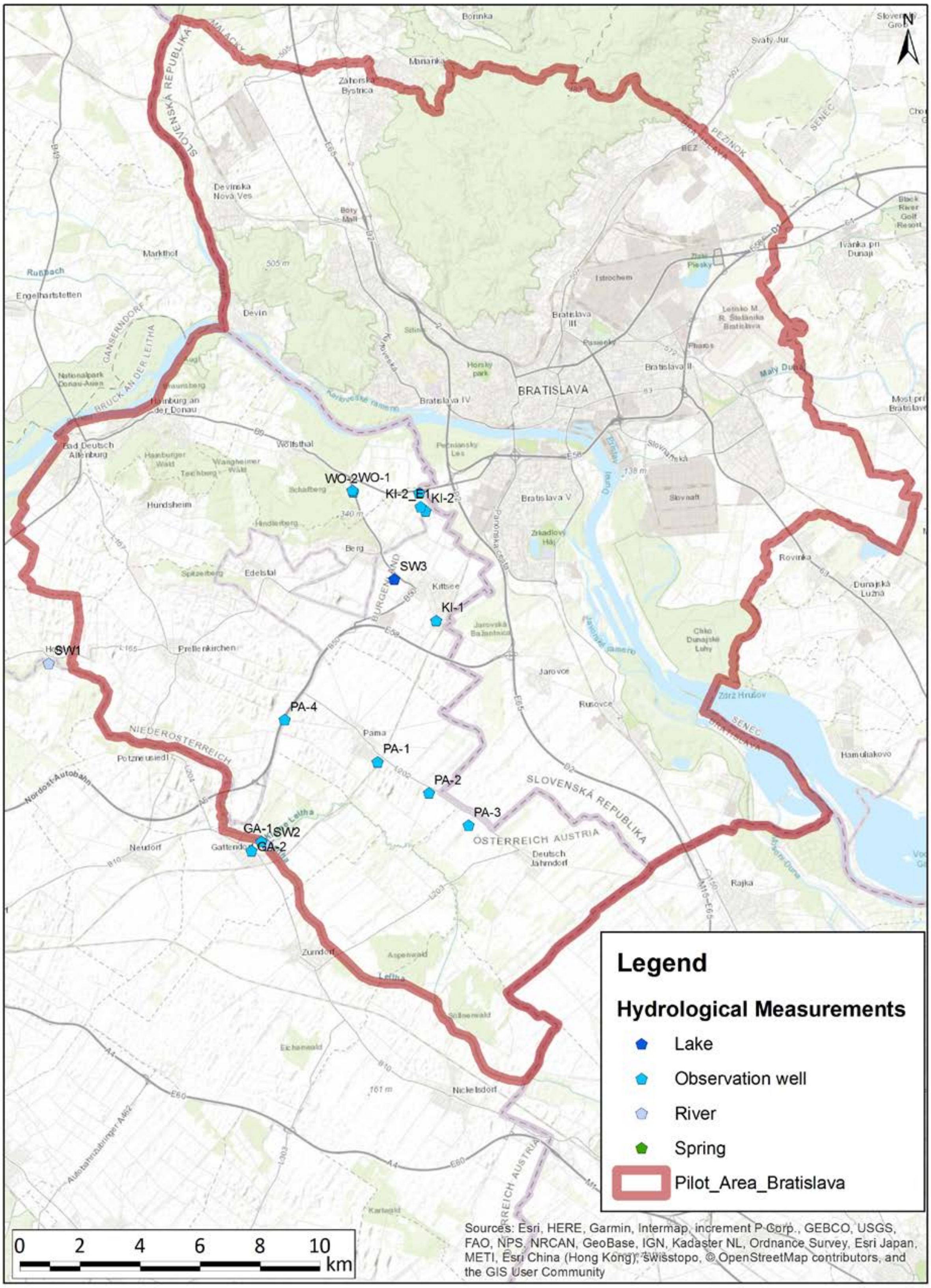

Figure 8: Sites of hydrogeological measurements performed by LP-GBA in the Austrian part of the pilot area Bratislava-Hainburg.

Table 4: Sampling history and history of temperature and level measurements for the wells in the Austrian part of the pilot area Bratislava-Hainburg executed by LP-GBA.
Abbreviations:
Chemistry: O… On-site measurements; L… Laboratory measurements and sampling for isotope measurements; T… Temperature and water level measurement;

Well or surface water body	15.11.2017			21.02.2018			15.05.2018			11.07.2018			16.10.2018		
	Chemistry		T	Chemistry		T	Chemistry		T	Chemistry		T	Chemistry		T
	O	L		O	L		O	L		O	L		O	L	
E305-18								x							
GA-1_335901	x		x	x	x	x				x	x	x	x	x	x
GA-2_335612	x		x			x			x			x			x
KI-1_316091	x		x			x	x	x	x	x	x	x	x	x	x
KI-2_353565	x		x	x	x	x				x	x	x			
PA-1_306274	x		x	x	x	x	x	x	x			x			x
PA-2_335455	x		x	x	x	x	x	x	x	x	x	x	x	x	x
PA-3_326140	x		x			x	x	x	x			x			x
PA-4_345579	x		x			x			x						
WO-1_KB16	x		x	x	x	x	x	x	x	x	x	x	x	x	x
WO-2_331348	x		x			x			x			x			x
SW1_Leitha-Hollern				x		x	x	x	x				x		x
SW2_Leitha Gattendorf	x		x			x	x		x	x		x	x		x
SW3_Quarry pond Kittsee	x		x	x		x	x	x	x	x		x	x		x
KI-2_E1									x			x			
KI-2_E3-313544							x		x			x			

2.3. Thermal rock properties

2.3.1. Sampling and methods

Thermal rock property measurements compiled data for:

> Thermal conductivity (λ) [W/mK]

> Thermal diffusivity (a) [m^2/s]

> Volume heat capacity (cp) [J/m^3K]

> Soil moisture [m^3/m^3]

> Temperature [° C]

Measurement device for the first three parameters was the ISOMET-"Heat transfer Analyser – Model 2104". This is a portable instrument for the measurement of thermophysical properties. The instrument measures the temperature response of a material to heat flow impulses. Electrical heating excites a resistor heater, which is in direct contact with the sample. Thermal conductivity and volume heat capacity are evaluated from sampled temperature records as a function of time. The instrument then calculates thermal diffusivity. The device is equipped with two types of probes. A needle-probe measurement kit for soft materials and a surface probe kit for hard materials (Figure 9). Each of this probe kits has two different measurements probes with different measurement ranges (see Table 5).

Table 5: Overview of uses probes for the ISOMET 2104

Needle probe for soft materials	*Probe 1*	0.20 – 1.00 W/mK
	Probe 2	1.00 – 2.00 W/mK
Surface probe for hard materials	*Probe 1*	0.30 – 2.00 W/mK
	Probe 2	2.00 – 6.00 W/mK

Soil moisture and temperature result from measurements with an Em50 data logger in combination with its soil moisture and temperature sensor (5TM) from Decagon Devices' ECH2O System (Figure 10). The sensor determines the water content by measuring the dielectric constant of the material. Methods behind is the capacitance/frequency domain technology. An on-board thermistor measures the temperature.

Figure 9: Measurement devices for the determination of thermophysical properties in the PA Bratislava. On top: Left: The Isomet 2104 during measurement. Right: Needle probes used for the investigation of soft rocks. Bottom: Left: The Isomet 2104 during a measurement in the laboratory for hard rock investigations. Right: Surface probes for the investigation of hard rocks.

Figure 10: Measurement device for the determination of soil moisture and temperature in the PA Bratislava. Left: Measurement arrangement of the senor in the field. Right: The Em50 data logger and used soil moisture and temperature sensor (5TM).

The ISOMET 2104 needle probe kit and the soil moisture sensor were used in-situ in the outcrops without the application of thermal conductivity pastes. Additionally, some samples from selected sediment beds were taken for laboratory investigations at the raw materials department at the GBA. Those additional investigations include screening curves and the mineralogy of the sediments derived with XRD (X-ray diffraction). Executing the measurements in sediments, both sensors, the ISOMET needle probe and the 5TM sensor, are carefully pricked into the sediment. Whenever possible, both sensors were placed at the same spot. The 5TM sensor is much more fragile compared to the ISOMET needle probe and could not be used in densely bedded sediments. For according test-sites are no temperature data available.

The use of surface probes is only possible in the laboratory since samples need a flat surface for the measurement. The optimal surface has a diameter of at least 60 mm and a minimal thickness of 15 mm. Those minimum size requirements must be considered while the sampling as well. Sample preparation then included cutting of the samples with a rock-cutting machine. After cutting, the samples were dried for 24 hours at 40° C to guarantee a similar condition for the measurement. The measurement was performed when the rock temperature was equal to the room temperature.

Measurement durations for all measurement arrangements are then up to 20 minutes in total. Technicians noted the results in the field or laboratory and transferred them to the GeoPLASMA-CE database.

2.3.2. Documentation

An overview of the locations, where GBA performed thermal rock property measurements in the pilot area Bratislava - Hainburg is available in Figure 11 and Table 7.

For the performance of thermophysical property measurements the GBA investigated eleven sites in the PA Bratislava-Hainburg. The aim was to cover most of the occurring sediments and rocks in the area. The decision for outcrops was then depending on their availability. All measurements were performed as described in chapter 4.4.1. The first measurement was always executed with the respective probe of higher measurement range. In case values were lower, the measurement was repeated with the low range probe.

The raw materials department of the GBA additionally investigated the mineralogy and provided screening curves for selected samples.

All data and pictures are available via the database of the PA Bratislava-Hainburg (Deliverable D.T3.2.1, more information see chapter 5).

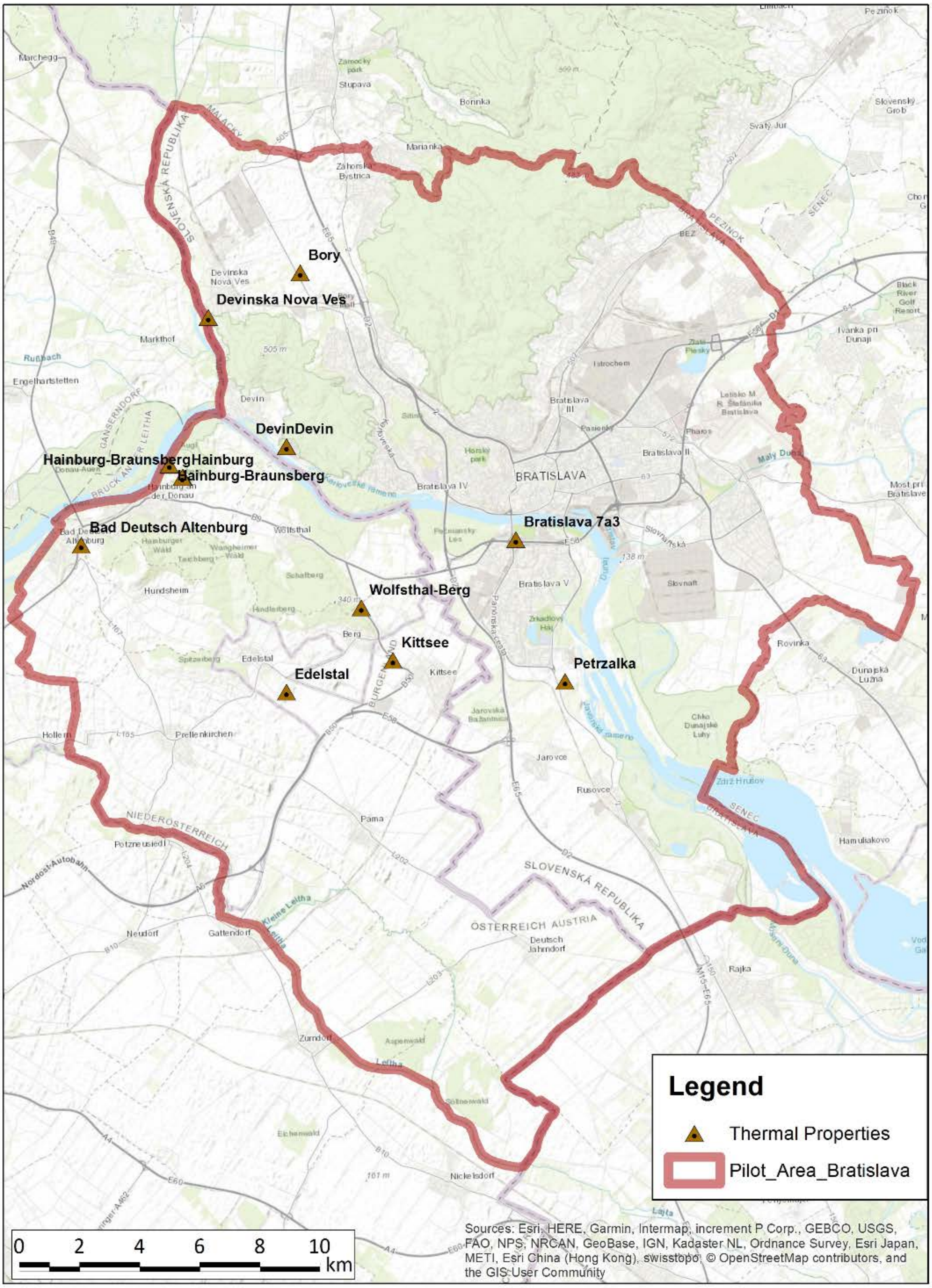

Figure 9: Location of thermophysical properties measurements and sampling points in the pilot area Bratislava - Hainburg.

Table 7: Overview of the measurements of thermophysical properties in the PA Bratislava-Hainburg.

Outcrop PA Bratislava	Sample	Measurements		
		Thermal conductivity	Soil moisture	Additional investigations
Devin_Granite	G1 - Granite	x		
	G2 – Granite	x		Mineralogy
	G3 - Granite	x		
	PA_Brat_Phylitt			Mineralogy
Devinska Nova Ves	L1 - Limestone	x		
Edelstal Outcrop “Raubwald”; Sand;	Layer 1	x	x	Screening curve and mineralogy
	Layer 2	x	x	
Kittsee Sand pit	KIT 1	x		Screening curve and mineralogy
	KIT 2	x		
Bad Deutsch Altenburg Quarry “Rohrdorfer”; Carbonates;	BDA 1	x		
	BDA2	x		Mineralogy
	BDA3	x		Mineralogy
	BDA4	x		
	BDA5	x		Mineralogy
	BDA6	x		Mineralogy
	BDA7	x		
	BDA8	x		Mineralogy
	BDA10	x		
Hainburg-Braunsberg Outcrop; Sediments; Quartzite and Carbonates;	BB1 - Sediment	x		Screening curve and mineralogy
	BB2 - Carbonate	x		Mineralogy
	BB3 - Quartzite	x		Mineralogy
	BB4 – Quartzite	x		

	BB5 - Quartzite	x		
Devin_Sediments Outcrop; Sand;	D1	x		Screening curve and mineralogy
	D2	x		
	D3	x		
Petrzalka_Sediments Construction pit; Sand;	Pz1	x	x	
	Pz2	x	x	Screening curve and mineralogy
Bory_Sediments Outcrop; Sand;	Bory 1	x		
	Bory 2	x		
	Bory 3	x	x	Screening curve and mineralogy
	Bory 4	x		
Bratislava_7a3 Drill core; Sand and clay;	15.8 – 16 m	x		
	17.4 – 17.8 m	x		
	20 m	x		
Wolfsthal Outcrop; Granite;	Wolfsthal	x		Mineralogy

3. Data processing

3.1. Groundwater temperature measurements

For quality management, LP-GBA calibrates new equipment using a highly precise temperature sensor Testo “Hochpräziser Tauch-/Einstechfühler” and the handheld instrument Testo 735-2. All well dippers had been calibrated previously to GeoPLASMA-CE. The procedure was a 4-point-calibration with temperature steps 5 °C, 10 °C, 15 °C and 20 °C in a water bath. Based on temperature measurements of one of the calibration devices, a calibration equation for each temperature sensor was determined. The calibration equations for each sensor were applied to the temperatures measured in the field and only the calibrated temperatures were entered in the joint database. Further, all measurements were evaluated applying a sinusoidal fit.

3.2. Groundwater chemistry analysis

The department of Geochemistry of LP-GBA analysed all water samples and delivered the results as Excel-Sheets. Project team members of GeoPLASMA-CE afterwards compiled the data in one MS Excel database for further data analysis. Before the assessment of the data regarding possible risks for shallow geothermal energy applications, the cation anion balance was checked. The ion balance was below 1.9 % for all measurements and therefore stayed in the threshold of ±2 % for 3.0 – 10.0 meq/L stated in the workflow.

3.3. Transfer of field data to the joint databases

In a last step, the processed field data have been summarized and documented for transferring them to the following databases:

- Metadata database of relevant input data (D.T3.1.2) for a full documentation of the achieved datasets.
- Key value database for publishing the achieved results (D.T3.2.1).

The metadata description of the produced datasets follows the joint concept on geodata management, which is described in Deliverable D.T2.3.1.

The summarized datasets, shown in the key value database are characterized by:

- Number of individual measurements (≥1)
- Presentation of either alpha-numeric (e.g. <0,01 mg/l) or numeric values
- The dataset is characterized by a single or mean-, minimum- and maximum value as well as by the standard deviation (in case of at least three single datum points).
- All presented values are allocated to a measurement period, a surface location and a depth interval of the measurements.

4. Results

4.1. Groundwater temperature measurements

Sinusoidal fitted data (Figure 12) are used for numerical models and diverse maps like “Thermal capacity – peak load” (OP07), “Thermal capacity – base load” (OP08), “Energy content” (OP09), “Thermal productivity” (OP11). For further information to the potential maps, we refer to the GeoPLASMA-CE web portal.

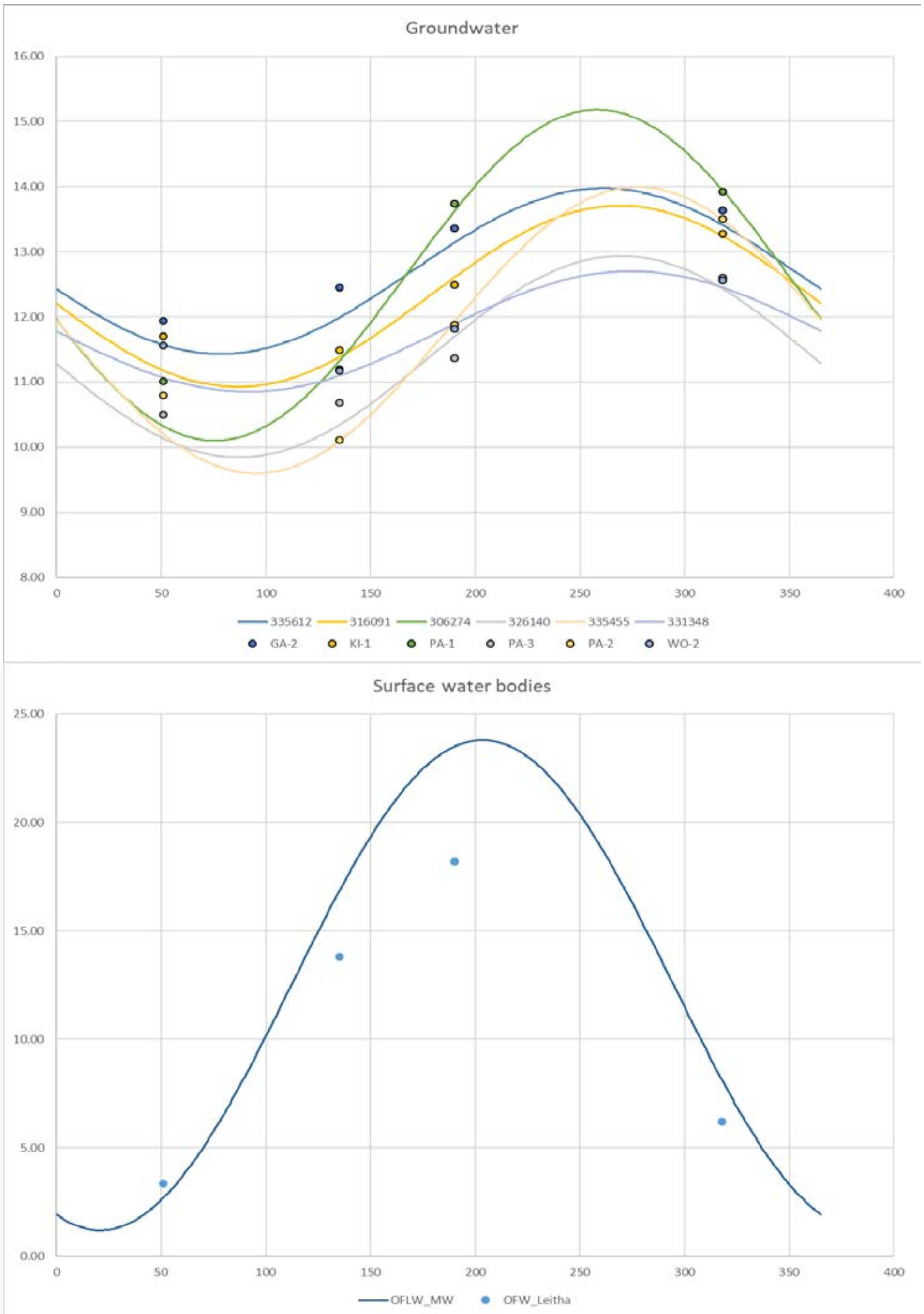

Figure 10: Sinusoidal fit for temperature measurements of groundwater wells and surface water bodies.

4.2. Groundwater chemistry analysis

Data derived from goundwater chemistry analysis, togehter with data from national hydrographic services were combined and evaluated for the generation of a groundwater-risk-zone map. Figure 13 presents the result of this calculation according to the GeoPLASMA-CE workflow for problematic groundwater bodies in the GeoPLASMA-CE deliverable D.T2.3.2 .

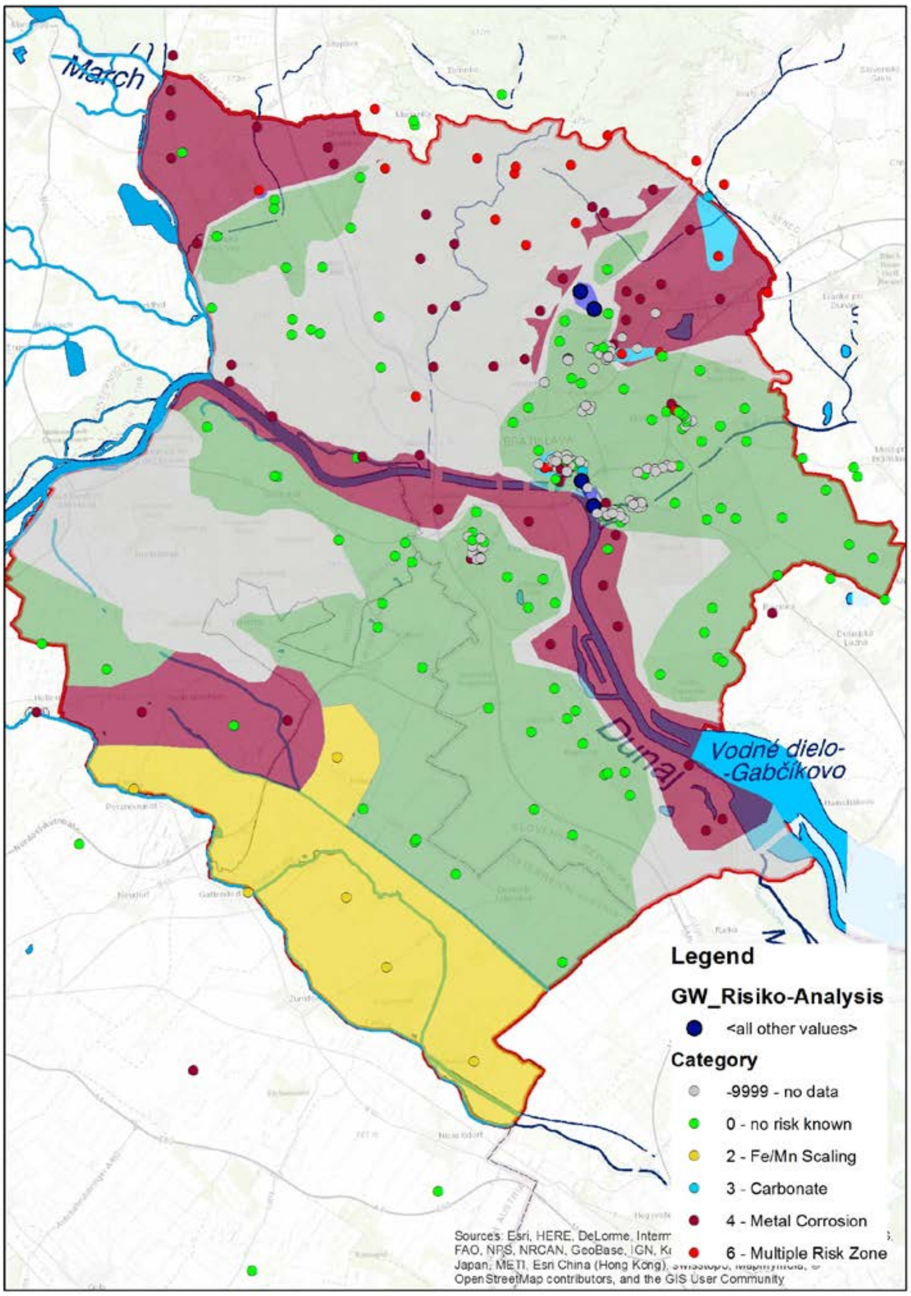

Figure 11: Groundwater risk-analysis map for the PA Bratislava-Hainburg. The map based on field- and laboratory measurements by GeoPLASMA-CE and compiled with data of national hydrographic services.

4.3. Isotope composition

All monitored samples are clearly meteoric, they spread along GMWL (Global Meteoric Water Line) defined by equation δ2H = 8·δ18O + 10 (Figure 13). The largest range of δ values show precipitations as expected, they form Local Meteoric Water Line (LMWL), which is only slightly different form the GMWL. The deviation from the global line for part of surface and groundwater is apparently due to evaporation. It is clear from the results that a substantial part of the groundwater needs to be deduced from the Danube, similarity in heavier waters with Moravia is rather non-genetic and is probably due to evaporation.

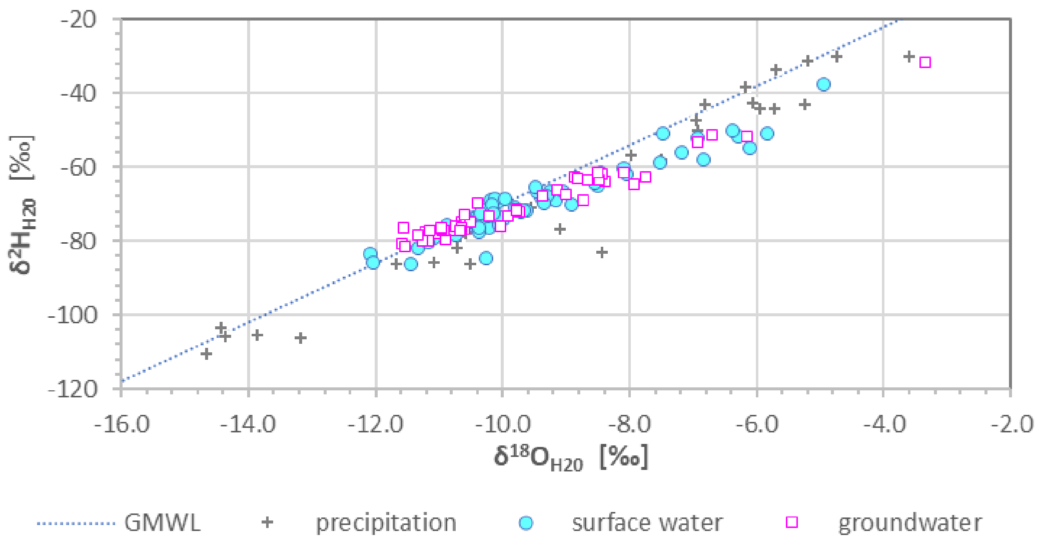

Figure 12: General view of isotope composition of the different water types

4.4. Thermal rock property measurements

Thermal conductivity measurements lie in the expected range of values and are comparable with values from look up tables like those of the German VDI-standards. Compared with look-up tables the GeoPLASMA-CE investigations allow a more precise calculation with the measured thermophysical rock properties. Further investigations at different seasons would improve the data quality and would enable a correlation with soil moisture results.

5. Summary and conlusions

During the GeoPLASMA-CE project, field measurements in the pilot area Bratislava-Hainburg focused on isotope investigations, chemical groundwater properties, thermal rock properties, and temperature measurements of groundwater and surface water.

The key value database includes a total of 714 measurements and links to raw data. Table 8 provides a short summary of field measurements included in the database.

Table 8: Short summary of filed measurements in the PA Bratislava-Hainburg

Input parameter	Number of measurements
Thermal conductivity of dry rock sample	19
Thermal conductivity of saturated rock sample	18
Groundwater temperature (single measurement, time series)	235
Groundwater level	73
Groundwater: pH value	27
Groundwater: Content of O2	22
Groundwater: Electrical conductivity of water sample	209
Heat Capacity	37
Thermal diffusivity	37
Groundwater: Eh	26
Soil temperature °C	5
Electrical conductivity (soil) mS/cm	1
Water content m^3/m^3	5
Total	**714**

The field measurements not only led to a better understanding of the groundwater and thermal properties of the sediments, but also revealed a few small shortcomings in the used methods.

Outcomes of the isotopes measurements reveal that a combination of knowledge about hydraulic properties, chemical and isotope composition could bring deeper look in the distribution and movement of the groundwater in this area, but where beyond the focus of GeoPLASMA-CE investigations.

Thermal conductivity measurements with the used hand-held measuring device are favourable for sediments. The advantage of this method is the in-situ measurement, where the original storage density of the sediments remains the same. Comparable values result from a consistent measuring arrangement. For the PA Bratislava-Hainburg all sites had the same measuring arrangement to provide this consistency. Nevertheless, the quality of some measurements is suboptimal since the placing of the needle probe can create air inclusions between the sample and the probe. This problem also occurs for the measurement of hard rock samples. The cut surfaces often reveal small bumps, which also cause air pockets between the sample and the probe. Same problem occurs with heterogeneities in the rock structure, like small karstic structures or fractures.

For future measurements, it would be favourable for both probes to improve measurements with the use of a thermal conductivity paste. Before application, a validation of the use of a thermal conductivity paste is recommendable. For hard rock samples, also the use of polished surfaces could be a future method.