SO2016-120-11

Partial Contract concluded on the basis of the Framework Agreement signed on 12 October 2016 with the title:

Utilization of foreign experience in the siting process for a deep geological repository for radioactive waste in the Czech Republic

between

CONTRACTING PARTIES

Client: **Česká republika – Správa úložišť radioaktivních odpadů**

Registered office: Dlážděná 6, 110 00 Praha 1, Czech Republic

Represented by: JUDr. Jan Prachař, Managing Director

ID: 66000769

Banking details:

Name of Bank: ČNB, Na Příkopě 28, Praha 1

Account No.: xxxxx

Not a payer of VAT

(hereinafter referred to as the "**Client**") and

Name of company: **Posiva Oy (lead party) in a consortium with Saanio & Riekkola Oy (from 31 August 2018 onwards, the company name is A-Insinöörit Civil Oy)**

Registered office: Olkiluoto, FI- 27160 Eurajoki, Finland

Represented by: Janne Mokka

ID: 1029258-8,

Tax ID: FI10292588,

Banking details:

Name of Bank: Nordea (NDEAFIHH)

Account No.: xxxxxx

(hereinafter referred to as the "**Supplier**")

(hereinafter both referred to as the "**Contractual Parties**"

The Contractual Parties hereby conclude the following Partial Contract (PC) in accordance with the provisions of Article 5 and in the format of Annex No 4 of the Framework Agreement.

Utilization of foreign experience in the siting process for a deep geological repository for radioactive waste in the Czech Republic

Name of the Partial Contract:	**Utilisation of POSIVA experience in the Application of Posiva Flow Log (PFL)**, Tool for detection of groundwater flows in bedrock in the Melechov site and comparison with previous work.
Area of Services:	iv. the assessment and/or development of specific site characterization methods
ID of Services:	2016-120-04

	Function	Name	Date	Signature
Client approved for chapter 1	Project Manager	xxx	7.6.2019	
Compiled by	Project Manager of the Partial Contract	xxx	7.6.2019	
Partial Contract approved by the Client	Managing Director	Jan Prachař	7.6.2019	
Supplier approved - project manager	Project Manager	xxx	25.6.2019	
Supplier approved - manager of the partial contract	Project Manager of the Partial Contract	xxx	25.6.2019	
Partial Contract approved by the Supplier	Sales Director, Posiva Oy Managing Director, Saanio & Riekkola Oy Managing Director, Posiva Solutions Oy	xxx xxx xxx	28.6.2019 2.7.2019 28.6.2019	

Note: This Partial Contract (PC) has been concluded in compliance with the conditions of a Framework Agreement (FA) signed on 12 October 2016 entitled: "Utilization of foreign experience in the siting process for a deep geological repository for radioactive waste in the Czech Republic".

1 CLIENT'S ASSIGNMENT

1.1 Requirements concerning the scope and technical specifications

The aim of this Partial Contract is application of Posiva flow log system (PFL) in the borehole at Melechov site at borehole MEL-2. The Melechov massif is located approximately in the area between Humpolec, Světla nad Sázavou and Ledčí nad Sázavou and is made of granite massif. This project consists of the creation of basic project of geological works, practical testing and using PFL at Melechov Borehole MEL-2 and water sampling at Borehole Mel -2, database of acquired data and final report. All data will be stored at new SURAO borehole information system (acronym BORIS) which is developed at PC 09. The subject of this partial contract includes a number of activities, the first of which concerns a definition of the borehole data that will be acquired during the testing phase. This project assumes with measure water flow, pressure, electrical conductivity and temperature of the borehole water and single point resistance of borehole wall and water sampling of two features. On Melechov test site, the additional borehole MEL-2 in vicinity to MEL-1 can be used for testing or as an observation point during PFL measurement of MEL-1 (see picture bellow). SÚRAO suggests the borehole MEL-2 for PFL testing due to good condition of borehole for testing and this borehole is situated close to another borehole which can be used as an observation point. During the 2018 TV inspection was made at Mel-2 and the result can be provided for this project.

Parameters of the borehole Mel – 2:

Final depth: 200,0 m

Inclination: vertical

Diameter: NQ = 75,31mm

Locality: Kostelní les, cca 1 000 m east of the village of Kouty and about 700 m to the northwest of the area 708,90 m (Melechov).

Coordinates of the borehole in the S-JTSK coordinate system

Borehole	Y	X	Z
Mel-2	685767.27	1099752.23	600.91

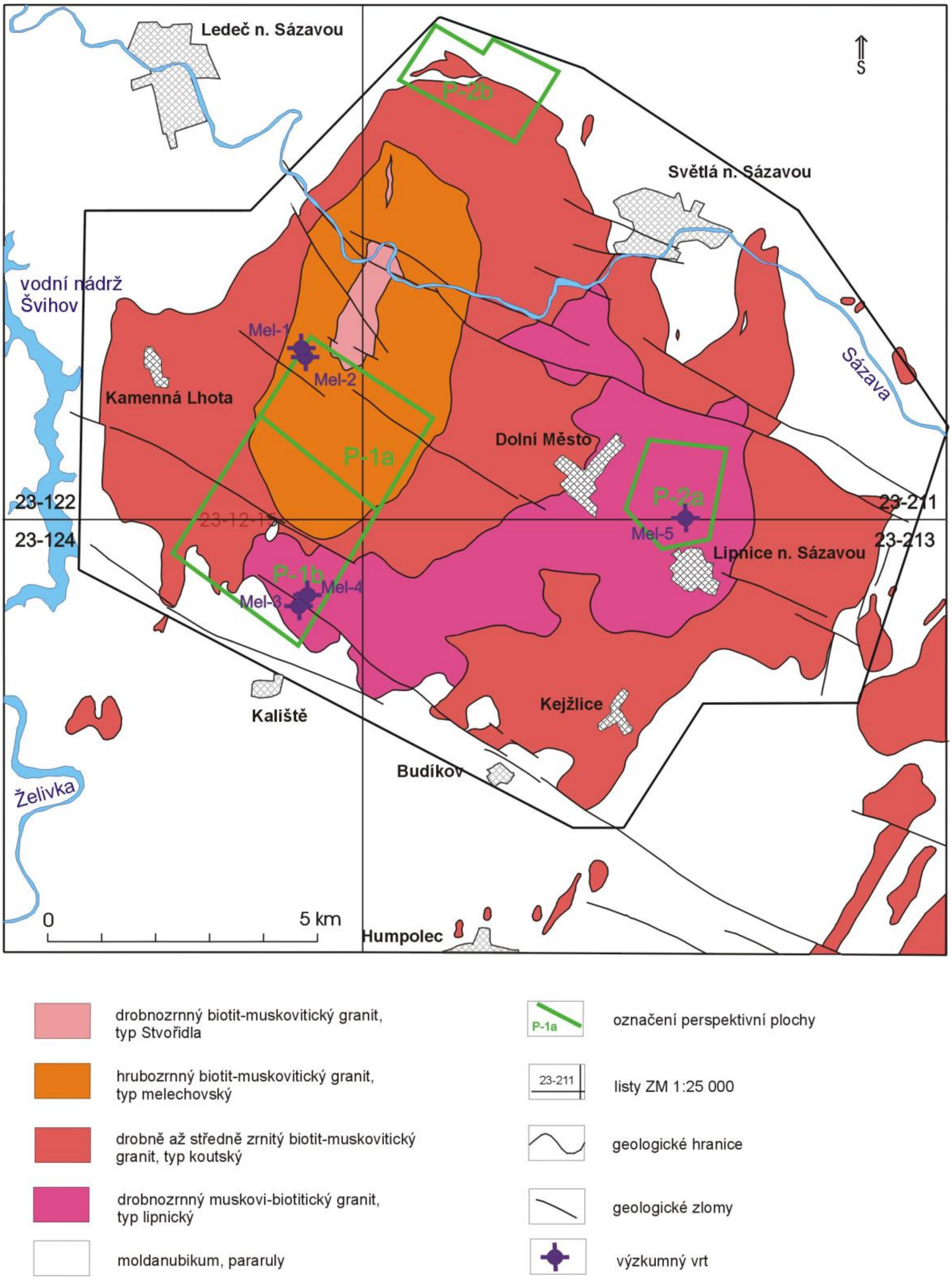

Fig 1. Localization of testing site with boreholes

The Partial Contract includes the following work packages (WP):

WP1: Preparation of technical works

Basic project of technical work includes description of measurements, obtain data and their evaluation, preparation of database and transport PFL to locality. Also it should be including the preparation of monitoring work in another borehole (if it is necessary) which are situated close to MEL-2. Basic plan of situation see the text above at fig. 1.

WP 2: Technical works

IN-situ hydrogeological testing at borehole Mel-2 with using PFL – measure water flow, pressure, electrical conductivity and temperature of the borehole water and single point resistance of borehole wall and water sampling of two features. It means that during first stage of hydraulic testing in borehole Mel-2 two hydraulic active features will be selected and take the sample (interval measurements). The work includes bringing the water sample up to ground level and instructing how to release pressurised water sample from the container but no laboratory analyses. This work package will include the hydrogeological testing of borehole MEL-2 at Melechov site. Testing will focus on the specific hydrogeological condition of the borehole, obtain the data of the hydraulic parameters of rock, selection and testing hydraulic function at least of two features and provide the parameters.

WP3: Data evaluation

This work package will involve preparation of final reports which will describe all new data and their evaluation. Report will also include recommendations for methodology application and advantages and disadvantages of using PFL in this site and proposal for PFL modification in geological characterization during site selection process of DGR in Czech Republic. The part of the works will be depositing knowledge into SÚRAO databases.

The Client nominates the following person as the Project Manager for the Partial Contract (PC): Marek Vencl, e-mail: vencl@surao.cz. The Supplier will communicate directly with this person, with correspondence copied on all occasions to Mr. Lukáš Vondrovic, e-mail: vondrovic@surao.cz

The Client requires the Supplier to nominate those PC participants that will be financed from this Partial Contract.

Changes of persons nominated either by the Client or the Supplier are permitted without the requirement for amending the PC. In case of a change of Project Manager either on the side of the Client or the Supplier, the Project Manager of the one party shall be required to notify his/her counterpart in writing of the change.

1.2 Required Services deadlines

WP1+2	T0+5 Months
– Output: Basic technical project of investigation works, database, hydrogeological testing MEL-2	
WP 3: Final report of description of work, evaluation data, database	T0+7 Months

1.3 Estimated labour intensity and/or its limitation

The Client estimates that the work involved in the PC will amount to 570 hours.

Point in the PC	Activities	Estimated labour intensity [hours]
WP 1	Preparation of technical works	192
WP 2	Technical works	160
WP 3	Data evaluation	180
WP 1-3	Project management	38

Additional cost for transport PFL to locality is preliminary estimated for 11 000 euro.

1.4 Specific requirements concerning the organisation of the Services

The Supplier shall propose the location and timing of those meetings with the Client's experts deemed necessary for the fulfilment of the objectives of the Partial Contract. Communication via telephone, email and videoconferencing will be acceptable provided the security of the information disclosed is ensured.

2 CONFIRMATION / MODIFICATION OF THE ASSIGNMENT OF SERVICES BY THE SUPPLIER

2.1 Scope of the Services and technical specification

The PFL DIFF measurement is used find the locations of the water conductive fractures in boreholes and determine the hydraulic conductivity of borehole sections and fractures.

Method locates hydraulic conductive borehole sections and fractures contributing to water inflows/outflows to/from the borehole and measures their flow rate under natural and/or pumped conditions. From this information, the water balance along the borehole can be deduced under different conditions together with estimations of the conductive fracture frequency along the borehole. In addition, suitable borehole sections/fractures for subsequent water sampling can be identified. Secondly, the hydraulic properties (transmissivity and natural head) of the tested borehole sections and identified single fractures may be determined.

The measurement program is presented below.

1. Dummy logging for borehole stability/risk evaluation. If more than four dummy runs are needed the Client is informed and continuation of the dummy runs is

discussed. Dummy probing resembles moving the PFL probe in a borehole and cannot be replaced by other probing.

2. Electrical conductivity and temperature of borehole water in non-pumped conditions. Continuous measurement run from top of the borehole to bottom of the borehole. Temperature and electrical conductivity profile of borehole water is measured.
3. Flow logging without pumping (section length L=2 m, step length dL=0.25 m). The probe is lowered to the bottom of the borehole. During the automatic measurement probe is moved step length between the measurement points and stopped during the flow measurement. The section length is longer than the step length so the flow from a single fracture is measured more than once.

   Measured parameters:

   - Flow (mL/h)
   - Single point resistance (SPR)
   - Water level in the borehole and pressure
   - Air pressure
   - Electrical conductivity (EC) and Temperature of water

   The measurement gives the location of flowing fractures at the resolution equal to the step length.
4. Flow logging with pumping (section length L=2 m, step length dL=0.25 m). After the measurement of the entire borehole without pumping the PFL probe is lowered to the bottom of the borehole. At the same time the pumping of the borehole is started. The pumping is controlled by a water level sensor in a way that the water level in the borehole remains stable during pumping. Target drawdown is 10 m.
5. Flow logging with pumping (section length L=0.5 m, step length dL=0.1 m). After finding the fractured zones in a borehole the fracture locations can be defined with an accuracy of 0.1 m by measuring the fractured zones again with a shorter section length and step. This measurement will be conducted only at depth intervals where fractures were detected in the previous measurement run.
6. Electrical conductivity and temperature of borehole water in pumped conditions. Drawdown is the same as during flow logging in pumped conditions. Continuous measurement run from top of the borehole to bottom of the borehole. Temperature and electrical conductivity profile of borehole water is measured.
7. Water sample collection from two fractures. Fracture flow rate affects the duration of water sample collection process. If flow rate of a fracture is higher than 1000 mL/h one sample per day can be taken. In field work duration calculation this estimation has been used.

All flow logging measurements, with and without pumping, include a measurement of single point resistance of the bedrock that is used for depth matching between the measurement runs. As the flow measurements are conducted in two different pressure conditions hydraulic conductivity of detected fractures can be calculated. All fractures between two consecutive measurement points are treated as a single fracture in processing of the measurement results.

PFL equipment includes a pump with a capacity of 30 l/min. Therefore achieving a 10 m drawdown might be difficult if the flow of water into the hole is high. Based on experience drawdown of 2 m is still adequate in regards to quality of measurement but it affects the limit how small transmissivities can be determined.

Estimated duration of field work is 8 days.

The interpretation of data is based on Thiem's formula, which describes a steady state and two-dimensional radial flow into the borehole (Marsily, G., 1986. Quantitative Hydrology, Groundwater Hydrology for Engineers. Academic Press, Inc., London.):

$$h_s - h = \frac{Q}{T \cdot a} \qquad \text{3-1}$$

where

h is the hydraulic head in the borehole (at borehole radius r_0),

hS is the hydraulic head at the radius of influence (R),

Q is the flow rate into the borehole,

T is the transmissivity of the test section,

The constant a depends on the assumed flow geometry. For cylindrical flow, the constant a is:

$$a = \frac{2\pi}{\ln(R/r_0)} \qquad \text{3-2}$$

where

r0 is the radius of the borehole and

R is the radius of influence, i.e., distance to a constant head boundary.

When measurements of flow rate are carried out using two levels of hydraulic head in the borehole, i.e. undisturbed and pump-induced heads, then the computational value of head when section flow is zero (hs) and the transmissivity of the borehole sections tested can be calculated. Equation 3-1 can be reformulated in the following two ways:

$$Q_{s0} = T_s \cdot a \cdot (h_s - h_0) \qquad \text{3-3}$$

$$Q_{s1} = T_s \cdot a \cdot (h_s - h_1), \qquad \text{3-4}$$

where

h0 and h1 are the hydraulic heads in the borehole at the test levels,

Qs0 and Qs1 are the measured flow rates in the test section,

Ts is the transmissivity of the test section and

hs is the undisturbed hydraulic head of the section, i.e. head when the section flow is zero.

In general, since very little is known about the flow geometry, cylindrical flow without skin effect is assumed. The measurements are conducted in steady state conditions therefore no skin effect can be assumed and the calculated transmissivity is determined based on the smallest conductivity in the fracture network where the water flow is coming from or going to. Basically in case of positive skin the calculated transmissivity represents only the transmissivity close to the borehole and transmissivity of the fracture or fracture network further away from the borehole wall cannot be estimated. Cylindrical flow geometry is justified because the borehole is at a constant head, and no strong pressure gradients along the borehole exist except at its ends.

The radial distance R to the undisturbed hydraulic head hs is not known and must therefore be assumed. In this case, a value of 500 for the quotient R/r0 is selected. This corresponds a radius of influence of 19 m when the diameter of the borehole is 76 mm.

The hydraulic head hs and the PFL transmissivity TPFL,s in the test section can be deduced from equation 3-5 and 3-6:

$$h_s = \frac{h_0 - bh_1}{1-b} \qquad 3\text{-}5$$

$$T_{PFL,s} = \frac{1}{a}\frac{Q_{s0} - Q_{s1}}{h_1 - h_0}, \qquad 3\text{-}6$$

where $\mathrm{b} = \mathrm{Q}_{s0}/\mathrm{Q}_{s1}$

The PFL transmissivity (TPFL,f) and hydraulic head (hf) of individual fractures can be calculated provided that the flow rates at the individual fractures are known. Similar assumptions to those employed above must be used (a steady-state cylindrical flow regime without skin zones).

$$h_{\mathrm{f}} = \frac{h_0 - bh_1}{1-b} \qquad 3\text{-}7$$

$$T_{\mathrm{f}} = \frac{1}{a}\frac{Q_{\mathrm{f}0} - Q_{\mathrm{f}1}}{h_1 - h_0}, \qquad 3\text{-}8$$

where

Qf0 and Qf1 are the flow rates at a fracture and hf and Tf are the hydraulic head (head when fracture flow is zero) and transmissivity of a fracture, respectively.

2.2 Fulfilment dates

2.3 Price of the Partial Contract

The price of the partial contract has been estimated as presented in table below.

	Price
Preparations	xxx
Field work	xxx
Data processing and reporting	xxx

Project Management	xxx
Equipment rent	xxx
Travel, accommodation, etc.	xxx
Total	109 076,00 €

2.4 Organisation of the Services

Name	Role/position	Knowledge areas relevant to this PC
xxx	Senior expert, Flow logging	PFL flow logging and equipment specialist
xxx	Senior expert, Flow logging	PFL flow logging and interpretation and reporting of the results.
xxx	Project Manager	Project Management

Table 2: Personnel hours by category

Category	Hours	%	Price/€
2	570	100	109 076 €

2.5 Risk identification

Conducting a measurements in borehole includes certain risks that cannot be fully avoided. The risks can be divided at least into two categories; getting jammed into borehole and losing measurement equipment and failing to get representative measurement results due to borehole conditions.

Dummy logging of the borehole is conducted before starting actual measurements in order to assess borehole stability. The dummy logging also cleans the borehole wall from loose rocks. Nevertheless the measurement probe can get stuck in a borehole even though dummy logging was successful. If measurement probe gets stuck in a borehole the contractor is not responsible of opening the borehole.

Borehole conditions can affect the quality of measurement results. Specific borehole conditions that can affect measurement quality have been listed below but other reason may affect as well.

- Rough borehole wall might cause rubber disks in the PFL probe to leak which has significant effect to flow logging quality.
- Gas bubbles coming from a fracture can interfere flow logging by causing erroneous flow rate results.

- Tolerance between probe and borehole wall is very small and therefore if the borehole profile is not round rubber disks might leak or the probe doesn't go into the borehole at all.
- If borehole crosses fractures which have very high hydraulic conductivity it might be impossible to create sufficient drawdown by pumping water out of a borehole. This affects the interpretation of transmissivity and hydraulic head of fractures.

3 CONCLUSION OF THE PARTIAL CONTRACT

The Partial Contract is acceptable. Detail of works, Price of the Partial Contract, organisation and risk identification are describing at Article 2. If the first measurement at borehole Mel-2 is done faster than now estimated Posiva will provide a new estimation for cost of second borehole Mel-1 measurements and then it will be decided about extensional of work.