ASSIGNMENT DESCRIPTION

Changes from version 3.0 are marked in yellow.

Content

1. Introduction

Introduction project Einstein Telescope
The Einstein Telescope will be an advanced observatory for gravitational waves. The border region of the Netherlands, Belgium and Germany is in the picture as a possible location. This is because of its tranquillity, stable soil, and strong ecosystem of knowledge institutions and high-tech companies. Researchers, companies and governments in the Netherlands, Belgium and Germany are jointly exploring the possibilities. The ultimate goal is to build the Einstein Telescope in the Meuse-Rhine Euroregion. For more info see https://www.einsteintelescope.nl/.

Project office ET
The Project Office ET, based in Maastricht, is carrying out a feasibility study, resulting in a contribution to the bid book, on the basis of which a final choice of location for the Einstein Telescope will be made. This phase includes activities within various disciplines (project management, contract management, technical management, environmental management, project control).

2. Assignment

The assignment is divided into 2 plots:
- Boreholes, borehole testing and logging Plot A – 6 locations (Chapter 4.1)
- Boreholes, borehole testing and logging Plot B – 3 locations (Chapter 4.2)

The work is described in Chapter 3, the locations (indicative, for pricing purposes) and quantities in Chapter 4. Chapter 5 contains the Annexes.

3. Work

3.1. General

- The bidder must provide a list of subcontractors;
- The Contractor must cooperate with inspections by or on behalf of the Client.

3.2. Communications

3.2.1. Client – Contractor

Client will appoint a manager (Operations manager) who will be in charge of the day-to-day management of this campaign on behalf of Client and will be the first point of contact for all operational matters (organisation, implementation, accompaniment, quality control and enforcement, communication and reporting). Under the guidance of this Operations manager, Client specialists will monitor the daily progress of the work on site. The borehole will be logged by experienced geologists at the time as drilling proceeds, in order to be able to discuss with the driller any doubts about the condition of the cores, whether they are the result of the drilling or extraction process (damaged during coring, retrieving from core barrel and or during core handling) or whether they correspond to the natural state of the extracted material. The Contractor shall cooperate fully at the drilling site with the work of the Client's specialists.

Adjustments or operational changes, <u>without</u> financial implications, can only be made after approval by the Operations manager.

The Operations manager may define Hold points to ensure the respect of the works procedures, and quality of results.

Frequency and content of consultation moments should be coordinated between the Operations manager and the Contractor prior to the start of the work. The Contractor takes the initiative for a proposal.

The Client shall also appoint a Contract Manager. Adjustments or changes <u>with</u> financial implications, can only be made after written approval by the Contract Manager.

3.2.2. Communication with the environment

- Client is responsible for external communication. Any questions from press or members of the public have to be passed on to the Operations manager.
- Publication of articles about or videos of the drilling are allowed only after explicit review and permission from the Client.

3.2.3. HSE

- The personnel to be deployed should hold safety certificates and apply the relevant personal protective equipment.
- All work conducted in elevated areas, such as platforms, must adhere to the following safety requirements:
    - The elevated area must be fully enclosed with appropriate fencing or barriers to prevent falls.
    - Workers operating at heights must wear suitable safety gear, including but not limited to safety harnesses securely attached to anchor points and appropriate safety ropes.

- Rotating parts of a rig must be safeguarded by an installation designed to prevent access during operation. This protection system must include, but is not limited to, a manually or automatically closing cage or equivalent mechanism that effectively restricts access to rotating components.
- A rig must be equipped with a gas detection system capable of measuring the concentrations of at least carbon monoxide (CO), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). The system must provide both acoustic and optical alarms in the event of hazardous gas levels being detected.
- All machines used on-site must be equipped with integrated drip trays to prevent spillage and minimize environmental contamination.
- Drilling operations must comply with the applicable noise regulations in South Limburg (Netherlands) and Wallonia (Belgium). The noise levels produced by the drilling rig and associated equipment must not exceed the locally permitted thresholds and should be minimized to avoid disturbance to surrounding areas. The Contractor must implement noise mitigation measures as necessary and provide documentation demonstrating compliance with these regulations.
- A site must be equipped with mandatory safety equipment to effectively respond to gas alerts.

3.3. Boreholes

3.3.1. Site preparation / utility provision / site restoration

- Site Preparation: Before the start of drilling, the Contractor must prepare the site to ensure it is suitable for the placement of the drilling rig. Sites should be properly sealed with foil against leaks. With regard to soil protection, the requirements of BRL 2100 must be met.
- A site should be duly protected to prevent unwanted access by third parties.
- Utility Provision: The Contractor must ensure the availability of water and electricity at the site for the duration of the works. To protect the aquifers in the soil, water from a stream is not permitted. Contractor must provide a standpipe / hydrant (in the Netherlands via WML, in Wallonia via SWDE/CILE).
- Site Restoration: Upon completion of the works, the Contractor must restore the site to its original condition.
- Verification: The Contractor must provide evidence of the site's condition before and after the works through recorded documentation (e.g., photographs, videos). This verification must be signed by the landowner to confirm agreement on the site's pre- and post-work condition.
- Each site should include a suitable facility where the Client and its specialists can carry out their work as described in this document.
- Annex 6.3 contains a list of subcontractors who assisted with site preparations in phase 1 of the project.

3.3.2. Borehole specifications and operations

- Plot A: Drilling of boreholes of maximum 350 m depth in areas of information gaps.
- Plot B: Drilling of boreholes of maximum 500 m depth in areas of information gaps.
- Boreholes generally to be drilled with continues core recovery with an emphasis on soil and rock core recovery.
- For soft overburden, the material must be fully retrieved during drilling operations. Washing away of the material is not permitted.
- The borehole diameter must be sufficiently wide to accommodate all programmed tests, measurements, and finalization activities.
- The deviation of the borehole from the vertical axis must not exceed 2°.
- The maximum inclination of the borehole must be demonstrated to meet the specifications, through measurements by the Contractor.

- All operations at a single site, including borehole measurements (logging and testing) and casing installation, must be fully completed before the rig is relocated to the next site. If interim relocation is desirable in an exceptional situation, this must be approved by the Client.
- If a borehole fails or appears to fail, the Contractor shall consult with the Client by return. A borehole has failed if:
    - A well does not reach final depth because of the chosen method versus geological situation, or:
    - The drilling breaks down prematurely and equipment cannot be brought to the surface with fishing action,or:
    - The borehole for a seismometer hole is found to have a tilt (inclination) greater than 2 degrees, or:
    - The sensor borehole turns out not to be leak-proof after finishing.
- The responsibility for the success of a borehole lies with the Contractor. Costs for additional drilling in case of failure of a well shall be borne by the Contractor.

3.3.3. Core recovery and handling

- Core Diameter for Hard Rock:
    - Preferred Core Diameter: PQ.
    - Accepted Core Diameter Range: SQ to HQ.
    - HQ is acceptable only if technical reasons necessitate a reduction from PQ to HQ diameter.
- Coring operations must use at least a double core barrel with a length of 3 meters. Alternatives, such as a triple barrel or barrels of different lengths, are acceptable; however, bidders must provide a clear justification for the proposed alternative.
- The core handling process for a double barrel system must adhere to the following procedures:
    - Core retrieval from the inner barrel must be performed using water.
    - The core must be pushed out with water from the inner core barrel into a metal gutter (Annex 6.2).
- If the bidder proposes coring with a triple core barrel, a detailed suggestion for the core retrieval process must be included as part of the proposal.
- Contract shall properly photograph the cores.
- Recovered soil and rock cores are to be deposited in core boxes.
- Contractor shall deliver the core boxes with recovered soil and rock cores to the core shed in Aubel (Rue de Merckhof 48/52).

3.3.4. Core box specifications and labelling

The Contractor is responsible for core handling, labelling and deposition of samples in core boxes according to international standards and their transport to a shed for storage and analysis. Specific attention is to be given to:

- The recovered soil and rock cores are to be recovered and deposited in core boxes (plastic core boxes with lids, each designed to hold two 1-meter core sections (Annex 6.2)). Induced breaks due to core retrieving from core barrel and manoeuvring or fitting in the core boxes are to be marked on the cores, the logger is to be informed on the labelling and recorded.
- Core loss and no-core sections are to be labelled in the core box.
- The labelling of cores will be determined by the Client, and the company must strictly adhere to the specified labelling system.

3.3.5. Photographing the cores

The Contractor should properly photograph the cores:

- Photographs of the cores before (just after retrieving from core barrel) and after boxing with project name, date, borehole id, borehole depth interval, metric scale.
- The core photographs have to be delivered as a single pdf document for each borehole and individual core box photographs in high quality (e.g. jpg, png) in a zipped archive for each borehole.

3.3.6. Drilling report

A sample daily report should be submitted as an annex to the project plan, which is part of the tender phase. Information on the loss of drilling fluid should be part of the report.

3.3.7. Equipment and rig requirements

- Client assumes multiple rigs operating in parallel.
- Rigs must be capable of holding and pulling a drill string, including a core barrel filled with hard rock material, with a PQ diameter at a depth of 600 meters.
- The installation must effectively reduce nitrogen oxides (NOx) in exhaust gases using a proven and efficient emission reduction technology that complies with the current state of the art (see annex 6.5).
- All aggregates used must meet at least Stage 5 emission standards, ensuring compliance with the latest environmental regulations and minimizing environmental impact.

3.3.8. Permits and administrative requirements

- Permits to carry out the work shall be applied for by the Client. The Contractor may assume that the permits will be available in time.
- Upon request from the Client, the Contractor must provide all necessary information and documentation required for the application of the necessary permits.
- All work must fully comply with the requirements specified in the permits.

3.3.9. Seismometer-borehole (Se)

- The proposed method for drilling and casing installation must follow these steps:
  - Drilling and coring of soft material and hard rock;
  - Testing / Measuring;
    - Geophysical logging (3.4.1)
    - Permeability testing (3.4.2)
    - In-situ stress testing (3.4.3)
    - Dilatometer testing (3.4.4)
  - Widening of the borehole to facilitate the installation of casing;
  - Installation of glassfibre casing and DAS (digital acoustic sensor) cable.
- Widening Method:
  - Use a roller bit with drilling mud.
  - Preferred bit size: 9⅞ inches.
  - Minimum bit size: 8½ inches.
  - Prohibited Equipment and Methods:
    - Down-the-hole hammer is not allowed.
    - Air-lift roller bits are not permitted.

    - Perform a check trip before the installation of the casing.
- Delivery and installation of Glassfibre casing is part of the scope.
- Installation of DAS-cable (cable provided by Client). Client shall provide guidance for this installation.
- Delivery of the seismometer and installation of the seismometer is **not** part of the scope. For information: The sensor to be placed has a diameter of approximately 120 mm.
- The internal diameter of the support tube through the overburden should be such that a support tube with an internal diameter of 146 mm can be placed and the cored hole reamed.
- Due to hydrotesting, pressiometer tests and borehole logging, you should apply standard diameters for core drilling in the Devonian and Carboniferous at least HQ [internal 78 mm; external 96 mm] In other words, core drilling ends at minimum HQ [internal 78 mm; external 96 mm]. >300 m1 minimum diameter PQ;
- The widened borehole must be fitted with a permanent glass fibre casing. Specifications of the tubes (Glass fiber casing 140 mm Tubing 725 psi 6-5/8 4Rd G/C D) and centralisers (model HD30) are included in Annex 6.4. The required borehole diameter is ~ 222 mm (Norm O.D. of the casing is 181.1mm (ignoring drift) plus ~20mm space around the casing for the DAS-fiber);
- The casing should be cemented to the rock and provide a watertight, dry hole for the installation of a dry deep seismometer station.
- The borehole should be finished with a solid manhole cover (e.g. sewer inspection manhole cover with an axle load of 2,500 kg).

3.3.10. Piezometer-borehole (Pi)

- The proposed method for drilling and casing installation must follow these steps:
    - Drilling and coring of soft material and hard rock;
    - Testing / Measuring;
        - Geophysical logging (3.4.1)
        - Permeability testing (3.4.2)
        - In-situ stress testing (3.4.3)
        - Dilatometer testing (3.4.4)
    - Installation of casing and Piezometer (3.4.5).
- Delivery of the piezometer and installation of the piezometer is part of the scope (see H3.4.5)
- A pressure meter has to be delivered and installed between PVC pipe and borehole at a depth to be decided after logging and consultation with Client (see Annex 6.6).
- The internal diameter of the support pipe through the overburden should be large enough to allow core drilling in the rocks below.
- Due to hydro tests, pressiometer tests and borehole logging, you should apply standard diameters for core drilling in the Devonian and Carboniferous minimum HQ D[external] = 96 mm to maximum D [external]= 146 mm;
- The borehole should be finished with a 70 mm PVC pipe with filters with a solid lid or sleeve on top, this may vary per location. The level filter should be backfilled with filter gravel, clay sealing above it so that there is no exchange between the different soil layers.

3.3.11. Borehole for pumping test (Pu)

See section 3.4.7

3.4. Borehole testing / logging

3.4.1. Geophysical logging

Borehole geophysical logging involves measuring the physical properties of the surrounding medium with a sensor lowered along the path of a borehole. The following sections describe the various methods that may be used in the various boreholes. The contractor shall document the capability to perform such logging by its own or by a separate contractor. So far, the following geophysical logs may be requested and are described in more detail below:

- Acoustic/optical televiewer
- Temperature log and electrical conductivity log
- Full wave sonic log
- Dipole Sonic log (OPTIONAL)
- Natural gamma log
- Caliper log

3.4.1.1 Acoustic/optical televiewer

The acoustic or optical televiewer scan (ATV, OTV) scanning is to be typically undertaken on completion of the coring to generate an acoustic or optical image of the borehole walls. Whereas the optical scan gives additional info on the encountered geology, the acoustic scan identifies better material contrast, such as voids. The imaging is then to be processed using a software such as WellCAD and inferred geological defects are to be identified.

These geological structures are to be interpreted into a plane and the dip and dip direction is determined and reported. The inferred structures are oriented to true north and the correction for magnetic declination is to be applied. The types of discontinuities are to be identified with depth, orientation and aperture (i.e. width), and delivered in terms of a graphical log (containing typically a depth view of registered graphic, interpreted structures, 3D view), and a digital format delivery (MS Excel file or text file containing data as: depth [m], type of structure, dip direction [°], dip [°], aperture of structure [mm]).

The contractor shall use the same set of defects and symbol legend in all boreholes in order to facilitate cross-comparison. It is suggested to use the following legend: Parting (Pt), Joint (Jt), Sheared surface (SS), Sheared zone (SZ), Sheard seam (SSm), Crushed Seam (CSm), Infilled Seam (ISm), Extremely weathered Seam (WSm), Vein (Ve). The orientation of the structures is to be given in terms of Dip direction and Dip, in degrees, with three-digit numbers and two-digit numbers, in order to avoid confusion, e.g. 030/65.

3.4.1.2 Temperature and electrical conductivity log

A continuous log of temperature and electrical conductivity is carried out in groundwater-filled boreholes. The log is useful to identify thermal anomalies along the boreholes which may indicate groundwater flow. The temperature is logged ensuring sufficient time for the probe to reach downhole ambient temperatures. The output is a file which gives the measured temperature and electrical conductivity at a sufficiently detailed depth interval.

3.4.1.3 Full wave sonic log

A full-waveform sonic log is used to measure the acoustic properties of subsurface formations. It records the entire sonic wave train, including compressional (P-wave), shear (S-wave), and boundary waves, as they travel through the formation. This data helps determine rock properties such as porosity, permeability, and mechanical strength and is also used in seismic calibration and formation evaluation.

3.4.1.4 Dipole Sonic Log (OPTIONAL)

The Dipole Sonic Log is optional and will not be considered in the evaluation of the tender submission.

A dipole sonic log is used to measure the acoustic properties of subsurface formations, specifically in environments where shear (S-wave) velocity is difficult to obtain using conventional sonic tools. It generates both compressional (P-wave) and shear (S-wave) waves, as well as flexural and Stoneley waves, allowing for accurate measurement of shear wave velocity in soft or unconsolidated formations. This data is essential for evaluating rock mechanical properties, stress conditions, and anisotropy, and is widely used in geomechanics, seismic calibration, and formation evaluation.

3.4.1.5 Natural gamma log

Natural gamma is primarily a lithology tool that measures gamma radiation in the borehole naturally emanating from the rocks. The natural gamma logs are applicable to investigations in both sedimentary and crystalline rocks, particularly for stratigraphic correlation.

3.4.1.6 Caliper log

A caliper log is used to measure the diameter/geometry of a borehole along its depth. It may be used to identify geometry variations caused by factors like borehole wall erosion, fractures, collapses or changes in lithology, or borehole deformation/outbreaks caused by excessive horizontal stress. For caliper logging, a 16 arm caliper is preferred.

3.4.1.7 Additional geophysical logging

Geophysical logging is often done with devices that have several sensors that can log a number of parameters. Additional properties may be identified and requested, such as:

- Magnetic susceptibility
- NMR (Nuclear Magnetic Resonance)
- Resistivity (normal and focused)
- Neutron and gamma-gamma density log (limited to boreholes in Wallonia)

3.4.2. Permeability testing

3.4.2.1 Flowmeter testing

Flowmeters are to be realized in each borehole, in open hole, before packer testing and before equipment of the borehole if needed. The aim is to identify the locations of water venues and to select the best sections to be submitted to packer testing and/or equipped in piezometers.
Flowmeter readings are performed while the tool is being raised (in some case lowered). Logs have to be performed under static (no flow) and dynamic conditions, in which the well is pumped at constant rate keeping the drawdown as short as possible but sufficient to induce different velocities between the static and the dynamic conditions and to identify location of water ingresses in the borehole.
The flowmeter logging in dynamic conditions has to be done once a steady regime is installed by pumping. The pump is installed outside the tested section, in the upper part of the saturated zone.
The contractor describes in its tender the type of equipment that he proposes to use: either spinner flow meter, or electromagnetic borehole flowmeter (EBF).
The contractor must be able to run the test in different conditions supposed to be met on site (i.e. for different range of flow and hydraulic conductivities). For this, he is likely to adapt either the type of pump to be used (capacity vs manometric height) and the type of equipment to measure the water velocities (for instance different spinner flowmeter could be used from borehole to borehole). The contractor must perform the test with the most suited equipment to guarantee sufficient sensitivity of the measurement.

The results must at least:
- Identify any possible internal circulations in the borehole (in case of communication between different aquifer level before equipment).
- Identify locations of saturated sections contributing to water ingresses in the boreholes and quantify the proportion of each of them to the total water ingress in the borehole.

3.4.2.2 Packer testing

Packer tests are to be made, at least, in accordance with the following standards or equivalent:
- EN ISO 22282-1: Geotechnical investigation and testing - Geohydraulic testing - Part 1: General rules
- EN ISO 22282-3: Geotechnical investigation and testing - Geohydraulic testing - Part 3: Water pressure tests in rock
- EN ISO 22282-6: Geotechnical investigation and testing - Geohydraulic testing - Part 6: Water permeability tests in a borehole using closed systems

Permeability water pressure testing (packer tests **Fout! Verwijzingsbron niet gevonden.**) is to be carried out in boreholes at the frequencies and depths nominated in the scope of work. Either single and more frequently double (straddle) packers are used to obtain a measurement of the rock mass permeability characteristics in corresponding conductivity (m/s) and Lugeon (UL) if relevant. The applied Lugeon-conductivity conversion is to be supplied.
The packer testing program will be designed in order to test both the more permeable and less permeable portions of the borehole. Selection of intervals to be tested will be made according to the following principles coupling different approaches during the campaign and before equipment of the boreholes:

1) **Systematic packer testing on discrete sections**: Double packer tests executed on a succession of distinct discrete sections between 3 and 10 m length. This testing will be systematically organised alongside the saturated section of the borehole in the rocky formations. This will not necessarily be executed in order to cover the complete section of the saturated rock; the requested frequency will be communicated by the client and is likely to be adjusted during the campaign; this systematic approach will be organized in order to a have a representative characterization of each type of formations (Namurian, Dinantian, Famennian) and each type of lithology inside each formation.

2) **Targeted packer testing on discrete sections**: Targeted double packer tests executed on selected sections (between 3 and 10 m) likely to be positioned in zones of interest (E.g. faulted sections, fractured sections, sections identified as productive by the flow meter test, location of water ingresses observed during drilling, …). This will complete the previous systematic approach in some selected sections chosen during the field survey.

3) **Packer testing on integrated larger sections**: A limited number of single packer tests will be executed on longer distinguished sections (e.g. from bottom of the borehole up to the single packer). The number of test will be adjusted during the field survey.

The first and second type of approach will be privileged as much as possible. It is not foreseen to perform a great number of tests of the third type which usually give less specific results.
Interval length of the double packers must be adaptable depending on the logging results. The location of tests will be defined in accordance with the client after evaluation of the results of the geophysical logging and the “on site” survey.
During packer testing, hydrogeological tests may need to be conducted for hydrogeological characterisations of the subsurface. The contractor shall declare which methods can be conducted or which alternatives can be offered.

For each test the following approaches may be conducted:
- Slug testing (build-up/drawdown)
- Constant rate (injection-/pumping tests with constant rate)
- Pressure recovery after constant head/rate testing

If judged relevant the testing will be completed by the following phases:
- Constant head (injection-/pumping tests with constant pressure)
- Pulse testing (positive/negative pressure pulse)

The contractor will present its methodology in the tender.
The report will involve an explanation of the methods of analysis and a discussion about the most representative value of hydraulic conductivities and if relevant the possible trends of overestimation or underestimation of the proposed results.
The duration of the test will be sufficient until IARF (DP derivative analysis) conditions or sufficient steady conditions will be reached.

Among others the following points need to be paid attention to:
- Flexibility and capability to adjust the testing approach to the existing context
- Identify anomalous behaviour (bridging, packer contourning, …) and repeat the process up to get acceptable testing conditions
- Identify any deviation / potential bias to target the more representative value of hydraulic conductivity (i.e. identify if wellbore storage effect, skin effect, head losses, etc. are suspicious and select the more appropriate data to be interpreted) and give explanations in the report of the selected values

Multi-rate or multi-stage test (Lugeon) is not foreseen to be requested approach if a single rate approach is proved to give relevant results. Anyway, a multi-rate approach must be performed in, accordance with the client, in case a single rate doesn't give relevant results or the level of flow rate must be adjusted during the testing.
The contractor has to check the compatibility between the side of its equipment (packer lines, …) and the diameter of the boreholes.
In addition of the reports and discussion, results have to be provided in an exploitable shape (xls files) and under a summary table for all the survey.

3.4.3. In-situ stress testing

Two methods are requested for in-situ stress measuring, Overcoring (OC) or Hydrofracturing (HF)/Hydraulic Testing of Preexisting Fractures (HTPF). These methods are outlined in ISRM recommendations and have intrinsic advantages and disadvantages, so a complementary mix of both may be needed.
- OC measures the observable strain of an induced stress relief of a relatively small rock volume, in 2D or 3D, depending on the used device. It is thus representative for a smaller rock volume (~1 litre) and more prone to preexisting rock structure.
- The contractor must specify which type of test (2D/3D) is offered (or subcontracted), to a maximum borehole depth of 500 m.
- HF and HTPF work with water pressures. HF induces a new fracture in the rock mass, which aligns with the in-situ stress, whereas HTPF tests existing fractures. Being representative for a larger rock volume (~1 m3), it is also subject to preexisting rock weaknesses and the method relies on the fact that the borehole is drilled parallel to one of the major stresses. The methods give an additional hydrogeological characterisation of permeability at higher injection pressures (compared to packer tests), which may be useful for grout design.
- The orientation of the induced or existing fracture is preferably read by an impression packer (or ATV recordings) and is used to determine the orientation of the principal stresses. The contractor is to specify if they use impression packer or ATV/OTV.

3.4.4. Dilatometer testing

Dilatometer tests are treated in norm ISO 22476-5:2023. It is used to measure the deformability and stiffness of rock formations in a borehole. Different variants can be used based on the stiffness of the rock: flexible radial dilatometer or with a flat, expandable blade. The contractor is to specify instrumentation suitable to cover testing in softer and harder rock. The correct operation of the device is to be proven (laboratory certificate, test against material of known deformability). Boreholes, testing depths and load cases will be supplied by the client.

3.4.5. Piezometer installations

Upon completion of the borehole and corresponding testing, boreholes may be used for piezometer installation. Generally, 2 types of piezometer installation may be requested:

- Piezometers equipped with an inner tubing involving screened section(s), gravel pack, bentonite sealing and cementing (keeping open holes is not allowed in order not to cause any circulation between different aquifer levels).
- In addition, vibrating wire piezometers of water pressure sensors (locally positioned). It measures groundwater pressure using a sensor with a tensioned wire that vibrates at a frequency proportional to applied pressure or another appropriate system. It's highly accurate, durable, and suitable for long-term monitoring. Also multiple piezometer installations may be necessary. In this case single piezometers reach individual borehole depths, hydrogeologically isolated, in order to possibly identify multiple groundwater bodies or layers.

The decision if a piezometer is to be installed in a borehole and of which type is done based on the borehole and testing evidence. It is foreseen to equip 2 boreholes but this quantity could be adjusted later on.

- One borehole will be drilled and equipped as a pumping well: The pumping is to be designed in such a way to allow implementation of a well screen with a minimum internal diameter of 152 mm (6 ") (in order to allow the use of a pump with a diameter as high as 142 mm).
- One borehole will be drilled and equipped as a piezometer or observation well: The piezometer is to be designed in such a way to allow implementation of a well screen with a minimum internal diameter of 101 mm (4") (in order to allow sampling in good conditions or any ulterior testing).

As a first approach it would be taken advantage of these 2 boreholes (dedicated to pumping well & piezometer) to use the same approach as for the other boreholes i.e. for the first phase wireline coring, … with the requested diameter for geotechnical investigation and in a second phase reaming with a destructive tool to adjust the borehole to the diameter requested for a proper equipment as described in the present section (downhole hammer is allowed only for these operation of reaming). Here after a summary of the minimum requirements that are proposed concerning the equipment of the pumping well and the piezometer (s).

The equipment (internal tube) will be made of PVC or HDPE and composed of screened section(s) and a blind section(s). Thickness of the tube will be selected to offer a SDR of max 17 (SDR Standard Dimension Ratio = Ratio of the outside diameter of the pipe to the minimum wall thickness).

- The aperture ratio of the screened section of the internal tube will be at least 10%.
- The internal tube has to be centred (use of centralizers).
- The diameter of the boreholes before equipment will be selected to offer a minimum thickness of the gravel pack of 50 mm, between the outer diameter of the tube and the walls of the borehole, this on the entire periphery of the borehole.
- The type of drilling method is to be proposed by the contractor. The use of a mud drilling technique is forbidden in order not to disturb the results of the future pumping tests and sampling.
- The section(s) to be screened will be selected by the client and its field representative, on basis of the field monitoring and/or the geophysical and flowmeter loggings. This selection will be done in

order to monitor the hydraulic head on a limited section inside a targeted formation. The way of equipment has to avoid any communication between different aquifer units.

- The gravel pack will be a clean siliceous gravel, round shaped. As a first assessment, the grain size distribution would be in the range 5/8 mm (it could nevertheless be adjusted depending on the context and the lithologies met during drilling operation). The slot width of the screened section (apertures) will be selected between D5 and D20 of the gravel pack in order to retain between 80 and 95% of the pack.
- The top of the gravel pack will be placed to an elevation corresponding to the top of the screened section + minimum 2 meters after settlement. After placement of the gravel pack an airlift will be achieved up to obtain stabilisation (settlement) of the gravel pack and to extract a sufficient water free of fines and suspended solids. If necessary, the top level of the gravel pack to be adjusted after settlement.
- The gravel pack is sealed by a bentonite sealing on a thickness of minimum 3 meters. The outer space between the top of the bentonite sealing and the ground level will be cemented by an appropriate grouting material (cement /water + a low proportion of bentonite if necessary). The grouting material will be injected from bottom to top. The cementing must be completed (no void in the outer space) and the cementing material must perfectly stuck to the walls of the formation and of the internal tube. The client reserves the right to have the quality of the cementing checked by an appropriate method.
- After completion of the pumping well and the piezometer(s), they must be developed in a proper way as long as to remove any fines and suspended solids. The method shall be proposed by the contractor.
- All the methods have to be described in the tender. During execution the contractor will propose a method statement for each steps, they have to be validated by the client.
- In addition to the screened sections of the pumping well and the piezometer(s), some water pressure sensors will be set up in some other targeted locations composed by a limited length of gravel pack isolated by 2 bentonites sealing and located in targeted places at different levels in the cemented section. This will allow to observe the impact of pumping at different aquifer level and their level of connectivity.
- The choice and sensitivity of the sensors will have to fit to the hydraulic head expected and the range of variation expected at different levels. The selection of the section equipped with the sensor will be done by the client on basis of the field survey observations and the results of geophysical and/or flowmeter logging. As a first assessment, the pumping well and piezometer(s) will be equipped with 2 levels of sensor in complement of the screening sections; the number can be adjusted depending of observations.
- The sensors are to be calibrated before placement and acquisition of data is made at the surface via an appropriate system to be proposed by the contractor.

3.4.6. Borehole standards and norms

Table 1 lists the standards for borehole execution and borehole testing used in the previous sections.

Table 1: Relevant standards for boreholes and borehole testing.

Test	Standard, Method
Overcoring test	ISRM (2003), Part 2
Hydrofracture test	ISRM (2003), Part 3
Lugeon test	ISRM (2019)
Dilatometer test	ISO 22476-5:2023

3.4.7. Well pumping test

3.4.7.1 Borehole used for the pumping test

The construction of 1 well with a larger diameter than that of the geotechnical boreholes and a piezometer is planned for this campaign. The minimal requirements of the pumping well and piezometer are described in this chapter. The pair will be used to carry out (1) a **step-drawdown test** (short steps) and (2) a **constant rate pumping test** for a longer duration.

The pumping well will be drilled next to a borehole equipped with a piezometer, in order to be located in the expected influence area of the pumping well. The location of the pair of boreholes (pumping well and piezometer(s)) will be selected to test, as much as possible, the hydraulic behaviour of an area identified as faulted / fractured (either, for instance, on each side of a fault if it appears to be subvertical, or connecting what it is supposed to be a subhorizontal or tilted fault, this aspect will be discussed later on, on basis of available data and field monitoring).
This will guide the design of the well, which must be carried out by the Contractor and approved by the Owner and his consultants before drilling begins. The depth and length for the installation of the screen and filter gravel pack, and the submersible pump will be indicated to the Contractor by the Owner with his consultants.

The piezometer aside will be used as secondary control point during pumping tests. Location of well and piezometer(s) will be instructed by the Employer. If some other piezometers or wells are identified in the vicinity of the pumping well (i.e. in the area supposed to be theoretically influenced by it) it will be involved, as well, in the testing program (water level monitoring) to add complementary data.
Wells drilled to intersect different aquifers can disturb these aquifers and can provide an undesired vertical connection between aquifers of different head or groundwater qualities inside the borehole. Drilling methodology and design of the wells (pumping well & piezo) have to consider the protection of the groundwater resource and the absence of such connections.
The following parameters, but not only, have to be included in the well design by the Contractor: casing size, based on the desired yield and pump size that will be instructed by the Employer and its consultants, screen diameter and length, entrance velocities, screen slots size and gravel pack size, based on analysis of the gradation of the aquifer materials.
A simplified and schematic well construction scheme is shown in **Figure 1** as an example (bentonite sealing is not symbolized here).

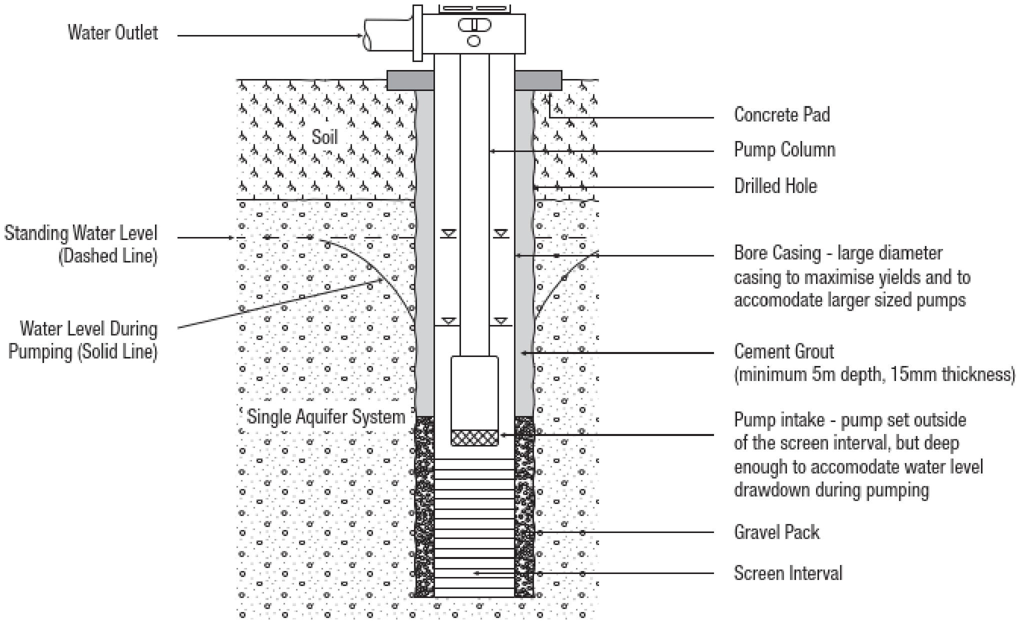


Figure 1: Well construction scheme.

The Contractor driller should keep a record of drilling observations in a field book while drilling progresses. These observations should include:

- the accurate location of the bore site (X,Y,Z in absolute coordinate system)
- start and finish dates
- the bore identification number (a unique identification of the bore site by number or name will be instructed by the Employer)
- drill string inventory
- bit types and sizes
- strata details
- details of the aquifer, yield, and water quality
- casing lengths, sizes, and types
- the penetration log
- the drilling method over any particular zone
- the decommissioning method used
- cement grouting details
- hole behaviour
- observed drilling fluid changes and depth.

The client will communicate the type of headwork (cover) to be implemented at the surface either underground chamber or aerial head. The headworks have be closed with a system of padlock or equivalent.

3.4.7.2 Hydraulic testing program

The hydraulic testing will be accordance at least with the following standards:

- EN ISO 22282-1: 2012 - Geotechnical investigation and testing - Geohydraulic testing - part 1: general rules
- EN ISO 22282-4: 2012 - Geotechnical investigation and testing - Geohydraulic testing - part 4: pumping test

(3.4.7.2.1) Short Step-Drawdown Test

Also referred to as a variable-rate test, the step-drawdown test is a short-term test to determine the pumping rate for the constant-rate test. Specific capacity (defined as the ratio of the production rate or yield of a well to the drawdown required to produce that yield), well efficiency and critical flow rate will also be determined by this test. Any short step can also be interpreted in transient regime to have a first evaluation of the hydraulic conductivity around the borehole (borehole testing). Recovery is also interpreted in transient regime.
The test procedure requires to pump the well at minimum 4 discharge rates (i.e. 4 steps or more) over a period of 6 to 8 hours (or longer); beginning at the lowest discharge rate as the first step, the well is pumped and measurements of the pumping water level are made in the borehole.
The steps duration are generally about 2 hours in length and are designed to reach a steady state or a quasi-steady state. Ideally the schedule of flow rate is designed to slightly exceed the critical flow and inducing appearance of turbulent headlosses.

The results of the short step drawdown will be:

- to establish a characteristic curve of the well (flow rate vs drawdown);
- to determine the critical flow rate;
- to assess the character confined or unconfined of the tested aquifer;
- to quantify the hydraulic conductivity in the surrounding of the borehole

The contractor will deliver factual data and a complete interpretation of the test. Factual data will be provided, included under the shape of exploitable data (.xls file).

(3.4.7.2.2) Constant-rate pumping test

The constant-rate test, a long-term pumping test, will last a minimum of 72 hours and could be extended to take into account the distance between the pumping well and the piezometer. The aim is to record a sufficient drawdown also at the location of the piezometer and for a sufficient duration to be interpreted. The selection of the minimum duration of the drawdown phase could be made on basis of the result of the short step test and the distance between pumping well and piezometer(s). As mentioned hereabove any piezometers supposed to be in the influence area of the pumping deserve to be involved in the water level monitoring.

The period of drawdown is followed by a period of recovery recorded at the pumping well and at the piezometer(s).

The constant rate pumped discharge is selected slightly inferior to the critical flow rate, identified by the Step-Drawdown Test results. The contractor has to maintain the flow rate as constant as possible during the drawdown to allow a proper interpretation.

An adjustment of the valves could be necessary during the first period of pumping to take into account headlosses and variation of the manometric height. The system of pumping must be equipped of adjustment valve allowing an accurate regulation of the flow rate.

The test targets to reach a steady regime (sufficient stabilising of water level) during a sufficient duration. If a steady regime could not be reached due to too much headlosses, overexploitation of the aquifer, or if the selection of the flow rate generates a drawdown that exceed 30% of the saturated height above the bottom of the pumping well the test is operated again, after a complete recovery and with a lower flow rate. The selection of flow rate has to be made in order not to desaturate any confined hydrogeological unit (any change of regime from confined to unconfined conditions is prohibited during the test).

Any unexpected interruption of the flow rate or shift / deviation of the flow rate will lead to an interruption of the test, pursuing the monitoring of water level up to complete recovery and the performing of new test properly executed.

Groundwater level will be measured using automatic measurement devices. This is to be completed by a series of manual measurement, appropriately spaced in time, in order to control the trend of drawdown and recovery. Flow rate will be manually measured and completed by an automatic recording of values. The sensitivity of the flow meter have to be adapted to the range of flow rates supposed to be tested. As a first assessment, the sensitivity of the flow meter has to be suited to a range of flow ranging from 0,1 m^3/hr up to 30 m^3/h.

The monitoring of data is operated with a suited and variable frequency to be adjusted to the aquifer behavior: for instance at least every 30 second the first 5 minutes, followed by every minutes during 15 minutes, followed by every 5 minutes during 1 hour, followed by every 15 minutes during 3 hours, followed by every hours during the remaining period.

To obtain accurate estimates of aquifer characteristics, variation in water level at the pumping well and at all the piezometer(s) in the influence area of the pumping well are to be monitored. A monitoring of the hydraulic head is also to be made for the local water pressure sensors that are installed at different levels in the borehole. This monitoring is also to be interpreted regarding the connection between different aquifer levels.

The schedule of flow rate is proposed by the contractor and validated by the client on basis of the results of the short step drawdown test.

If judged relevant, the client can ask the realization of several constant rate pumping tests in order to get relevant values and a validation of the results.

The results of the constant rate pumping test will be at least:

- Interpretation and assessment of the hydraulic conductivity in transient and steady regime.
- Evaluation of the storage coefficient, specific yield.
- Evaluation of the influence radius.
- Identification of any effects useful for the interpretation: headlosses, barrier effects, recharge effects, leakage during testing, identification of wellbore storage phase, etc.

The contractor will deliver factual data and a complete interpretation of the tests. Factual data will be provided, included under the shape of exploitable data (Excel file).

(3.4.7.2.3) Points of attention

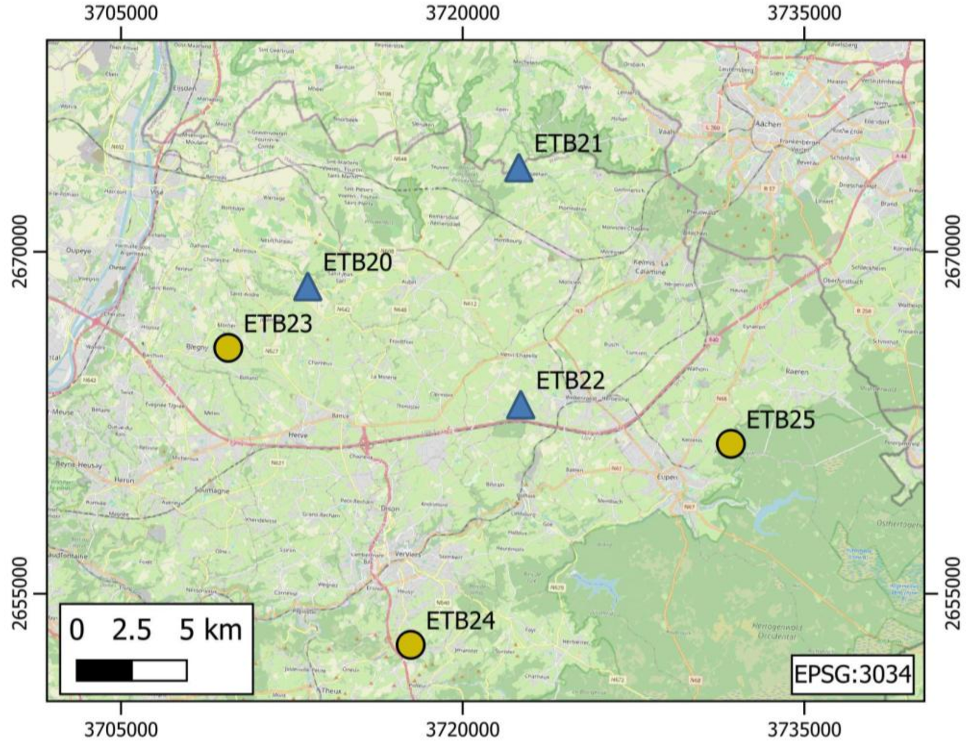
A non-exhaustive list of points of attention is identified here after:

- During the pumping tests a monitoring of water level outside the influence radius has to be done in order to identify any groundwater change not due to the pumping during the test and (identification of the background); if necessary and in case of significant change the data dedicated to the interpretation have to be corrected in a proper way. The contractor will ensure that no other pumping action in the vicinity, other that the one dedicated to the pumping test will disturb the program and the acquisition of relevant data. There must not be any simultaneous pumping in the vicinity.

- Any new testing, if necessary, have to be made after a complete recovery of the water level (i.e. reaching the static level) and occurrence of a steady situation.
- The discharge of the extracted water has to be made outside the influence area of the pumping to avoid any shortcut or recirculation of extracted water in the pumping (situation uninterpretable).
- The pumping line will be equipped with a sampling valve allowing any sampling in proper conditions.
- The selection of the pump (characteristic curve) and of the regulation valves will have the required sensitivity to allow a fine regulation of flow rates.
- The selection of automatic loggers, their sensitivity and their position will be in line with the expected range of water level variations.
- If necessary, the testing program has to take account of the permitting constraints.
- The contractor is autonomous for its power supply during the testing program. Any precaution are to be taken regarding the use of fuels.

4. Locations

Below are indications of the drilling locations. The final locations will be announced upon award. <u>The locations included are for pricing purposes only.</u>



No	Finish	Location	Region
PLOT A			
ETB20 (SE)	Seismometer-DAS	Val-Dieu	B - Wallonia
ETB21 (SE)	Seismometer-DAS	Kuttingen	NL-Limburg
ETB22 (SE)	Seismometer-DAS	Hoof	B – Wallonia
ETB26 (PI)	Piezometer	Henri Chapelle	B - Wallonia
ETB27 (PU)	Pumping test	Henri Chapelle	B - Wallonia
ETB07 (PI)	Piezometer	Vijlenerbos	NL-Limburg
PLOT B			
ETB23 (SE)	Seismometer-DAS	Blegny	B - Wallonia
ETB24 (SE)	Seismometer-DAS	Jonkeu	B - Wallonia
ETB25 (SE)	Seismometer-DAS	Osthertogenwald	B - Wallonia

4.1. Plot A

Plot A consists of:

- 3 boreholes (Seismometer and DAS, packer test, measurements), ETB20, ETB21, ETB22;
- 2 boreholes (1 Piezometer, 1 pumping tests, packer test, measurements), ETB26, ETB27;
- 1 borehole (deepening, piezometer, packer test, measurements), ETB07 .

4.1.1. ETB20 (Se) Val-Dieu

- Location : exact location to be determined, see sketch for an indication
- Depth : 300 m

This site is located near the Val-Dieu Abbey. The primary geological units present at ground level consist of sedimentary rocks dating from the Upper Famennian to the Upper Carboniferous. Notably, Lower Carboniferous limestones (Dinantian) are absent in this region. Cretaceous sediments cover the upper parts of the hills, while Palaeozoic rocks dominate the slopes of the landscape.

Site location (EPSG:3034)

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2668488	3713195	182

A published cross-section from the regional geological map offers a general overview of the subsurface composition and structure. The planned drilling site is located 400 meters southwest of this cross-section. Figure 2 illustrates the projection of the proposed borehole onto the cross-section. The first unit depicted in the figure consists of Quaternary sediments, which are unlikely to be present at the selected site, as it is situated on the upper part of the slope.
Beneath a thin colluvium layer, probably only a few meters thick, the borehole is expected to encounter dark shales and sandstones from the Upper Carboniferous, specifically the Namurian formations, which correspond to the lower part of the Houiller Group (HOU in Figure 2). This unit is likely to be observed along the full length of the borehole.
These layers underwent intense folding and faulting, particularly in the footwall of the Asse Fault, where beds are often steeply dipping or even overturned.

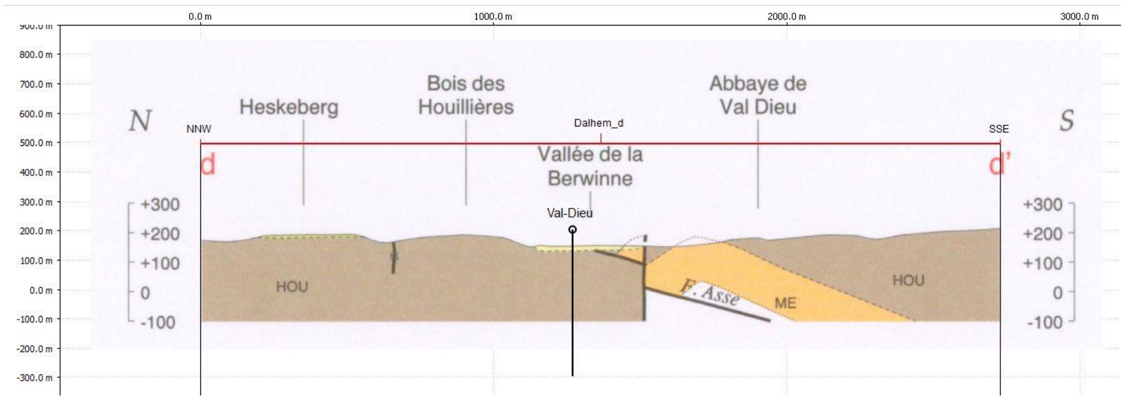


Figure 2 – Published cross-section near the Val-Dieu abbey. The foreseen borehole has been projected on this section down to a depth of 500 m.

4.1.2. ETB21 (Se) Kuttingen

- Location : exact location to be determined, see sketch for an indication

- Depth : 280 m

This site is located near the border between the Netherlands and Belgium, approximately 0.6 km south of the locality of Kuttingen. The surface geology is primarily composed of Cretaceous sediments.
The region has previously been investigated through two boreholes in Terziet and one in Cottessen. The Terziet boreholes indicate that the sedimentary cover has a thickness of approximately 12 meters, whereas no Cretaceous cover was observed in Cottessen. At greater depths, all sites reveal the same geological sequence, consisting of Namurian shales and sandstones, followed by sandstones and siltstones of the Montfort-Evieux Group (Upper Famennian). Notably, Dinantian limestones are absent in this sequence.

Site location (EPSG:3034):

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2673695	3722391	165

To illustrate the local subsurface composition the key observations observed in the borehole of Terziet-2 is presented in the following table:

	Depth						
Unit	From	To	Elevation (m)	Lithologies	Structural features	Interpretation	Symbol
1	0	3	218	Loam and weathered sediments		Mix of colluvium and weathered rocks	
2	3	13	208	Chalk, sand, clay		Cretaceous cover	
3	13	42	179	Dark shales, siltstone and sandstone		Houiller Group	
4	42	249	-28	Sandstone, siltstone		Montfort-Evieux Group	

4.1.3. ETB22 (Se) Hoof

- Location : exact location to be determined, see sketch for an indication
- Depth : 400 m

The Hoof site is situated 2.3 km south of the village of Henri-Chapelle. To the North, the Upper-Carboniferous formations are largely covered by Cretaceous sediments. Beneath this sedimentary cover, the first unit to appear consists of Namurian sedimentary rocks, primarily shales and sandstones.
The descriptions of small boreholes to the North indicate the presence of Dinantian limestones under the Namurian detrital rocks. The contact between these two units is mainly unknown due to the intense folding and faulting. This site remains largely as an area to be investigated.

Site location (EPSG:3034)

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2663304	3722546	290

4.1.4. ETB26 (Pi)

- Location : Henri Chapelle
- Depth : 260m.
- After installing the PVC casing (inner diameter 4 inch), at least a 1-inch space around the casing should be left free for installation of a filter pack.

4.1.5. ETB27 (Pu)

- Location : Henri Chapelle
- Depth : 260m.
- The pumping test is part of the scope.
- After installing the PVC casing (inner diameter 6 inch), at least a 1-inch space around the casing should be left free for installation of a filter pack. Based on this, the appropriate drill diameter should be chosen.

4.1.6. ETB07 (Pi) Vijlenerbos

- Location : existing borehole at the Epenerbaan car park
    - Depth : Deepening the borehole at Vijlenerbos for approx. 50 m;
    - Work to be carried out outside the breeding season.

4.2. Plot B

Plot B consists of:

- 3 boreholes (Seismometer and DAS, packer test, measurements), ETB25, ETB26, ETB27

4.2.1. ETB23 (Se) Blegny

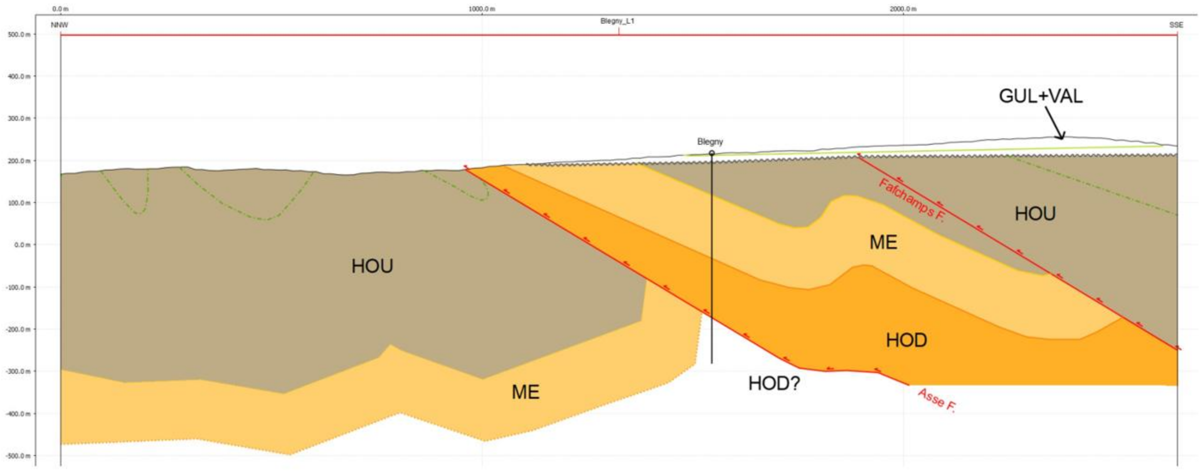
- Location : exact location to be determined, see sketch for an indication
- Depth : 300 m

The currently selected site is located 1.4 km East to the locality of Blegny. The main units observed at the ground level are mainly Cretaceous sediments covering a basement composed by shales, siltstones and sandstone from either the Upper Carboniferous (Namurian + Westphalian) and from the Middle and Upper parts of the Famennian.
In order to evaluate the underground composition and structure of the region a geological cross-section has been established from the existing geological map and other available data.

Site location (EPSG:3034)

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2665790	3709706	221

	Depth [m]						
Unit	From	To	Elevation (m)	Lithologies	Structural features	Interpretation	Symbol
1	0	2	219	Loam		Colluvium or weathered horizon (Quaternary)	
2	2	4	217	White chalk rich in glauconite at its base. Presence of flint		Gulpen Formation (Cretaceous)	GUL
3	4	20	201	Glauconiferous clay, sand. Carbonate clay and siltstone		Vaals Formation (Cretaceous)	VAA
4	20	20	201		Unconformity between Cretaceous/Paleozoic		
5	20	98	123	Interbedding of dark shales-siltstone, sandstone, quartzite		Lower part of Houiller Group (Namurian)	HOU
6	98	250	-29	Sandstone in some cases presence of mica, feldspar		Montfort-Evieux Group (Famennina)	ME
7	250	391	-170	Greenish to purplish shales, micaceous siltstone		Hodimont Formation (Famennian)	HOD
8	391	391	-170		Fault zone (SE-dipping)	Asse Fault	
9	391	500	-279	Possible presence of shales and siltstones		Hodimont Formation (Famennian)?	HOD?



4.2.2. ETB24 (Se) Jonkeu

- Location : exact location to be determined, see sketch for an indication
- Depth : 430 m.

This site is located 3.5 km south of the city of Verviers. The main geological units observed at the ground level are Lower Devonian sedimentary rocks folded and thrusted along a NE-SW direction. According to the existing geological information and especially with the field observations conducted in the region for the establishment of the geological map at the scale 1/25.000 the follow composition

Site location (EPSG:3034)

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2652767	3717728	356

Unit	Depth [m] From	Depth [m] To	Elevation (m)	Lithologies	Structural features	Interpretation	Symbol
1	0	6	350	Loam, sand, clay with rock fragments		Colluvium	
2	6	150	206	Interlayered red shales, siltstone and sandstone and green siltstone. Associated with carbonate nodules		Marteau formation (L. Devonian)	MAR
3	130	130	226		Possible fault zone (S-dipping thrust)	Jonkeu Fault	
4	150	330	26	Interlayered red shales, siltstone and sandstone and green siltstone. Associated with carbonate nodules		Marteau formation (L. Devonian)	MAR
5	330	390	-34	Possible presence of shales and slates of Low Paleozoic	Angular unconformity	Undifferenciated Lower Paleozoic	X
6	390	390	-34		Major fault zone dipping NW	Theux Fault	
7	390	500	-144	Dolomite and limestone	Overturned geological formations	Dolhain, Bay-Bonnet group (Top Devonian and Dinantian)	DOL/BBN

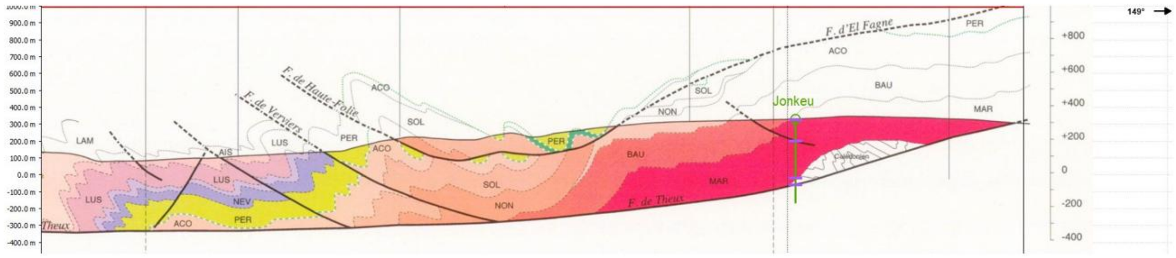


Figure XXX – Cross-section near the selected site in Jonkeu. The projected borehole is represented in green (see table for details) – Modified from Laloux et al., 1996.

4.2.3. ETB25 (Se) Osthertogenwald

- Location : exact location to be determined, see sketch for an indication
- Depth : 460 m.

This site is located 2.5 km north-east of the city of Eupen. The main geological units observed at the ground level near the selected site are Mid-Devonian of age separating the Lower Devonian formations to the SE and Upper Devonian rocks to the NW. The main Variscan structures are oriented NE-SW.

A published cross-section is located at 1.5 km to the NE of the selected site. The hypothetical composition and structure is as follow:

Site location (EPSG:3034)

X [m]	Y [m]	Z [m] – LIDAR of Wallonia
2661581	3731769	325

Unit	Depth From	Depth To	Elevation (m)	Lithologies	Structural features	Interpretation	Symbol
1	0	3	322	Weathered bedrocks (rock sub cropping)		Mix of colluvium and weathered rocks	
2	3	210	115	Red and/or green siltstone with clayey sandstone. Possible conglomerate lenses	Secondary folds. Mainly NW steeply-dipping bedding	Lower part of Pepinster formation	PER
3	210	230	95	Conglomerate composed by quartz vein and quartzite 5-10 cm size elements		Vicht conglomerate	VCH
4	230	500	-175	Shales, siltstone and clayey sandstone of dark red colour	Steeply-dipping bedding	Upper part of Acoz formation	ACO

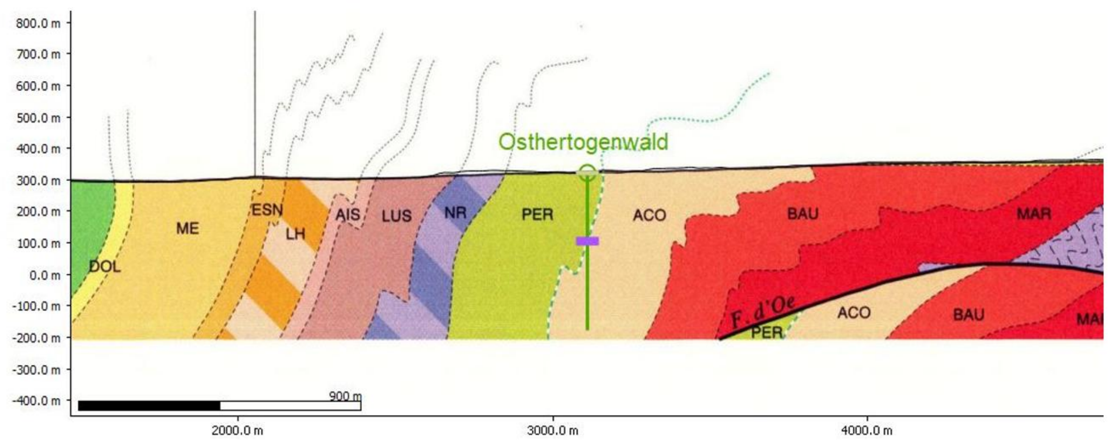


Figure XXX – Cross-section near the selected site of Osthertogenwald. The projected borehole is represented in green (see table for details) – (Modified from Laloux et al., 2000).

5. Planning

5.1. Plot A

- ETB20, ETB21 & ETB22 to be completed no later than 1 September 2025. ETB20, ETB21 & ETB22 are completed once the casings are in place and the DAS cables are installed.
- ETB26, ETB27 to be completed no later than 1 November 2025. ETB26 borehole is completed once the casing is in place and the Piezometer is installed. ETB27 is completed once the pumping test is completed.
- ETB07 to be completed no later than 1 December 2025. ETB07 is completed once the Piezometer is installed.

5.2. Plot B

- ETB23, ETB24, ETB25 to be completed no later than 31 December 2025. ETB23, ETB24 and ETB25 are completed once the casing is in place and the DAS cable is installed.

6. Annexes

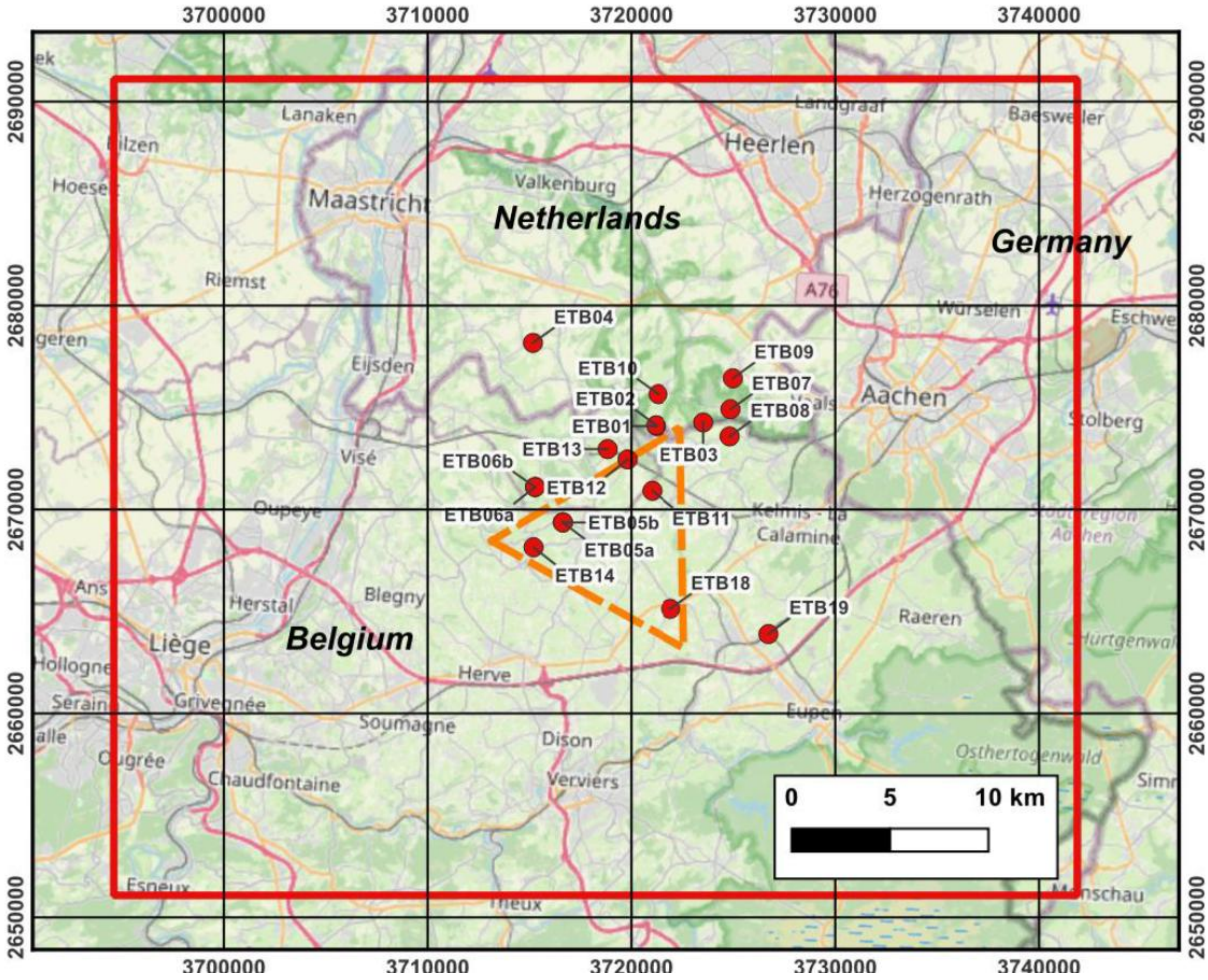
6.1. Geological information

6.1.1. Information phase 0 - 1 investigations

The so far performed investigation campaigns consisted in 11 boreholes and can be summarized as (see Figure below for borehole locations):

Phase 0 investigations: The investigation campaign consisted in 5 boreholes: ETB01 (Terziet-1, NL), ETB02 (Terziet-2, NL), ETB03 (Cottessen, NL), ETB05 (Aubel-1, B), and ETB05a (Aubel-2, B).

Phase 1 investigations: The investigation campaign consisted in 11 boreholes, all performed in 2024: ETB-06 (S. Pieters Voeren, B), ETB07 (Vijenerbos, NL), ETB08 (Gemmenich, B), ETB09 (Vijlen, NL), ETB10 (Epen, NL), ETB11 (Hombourg, B), ETB12 (Obsinnich, B), ETB13 (Teuven, B), ETB14 (Aubel-3, B), ETB18 (Henri Chapelle, B), ETB19 (Herbesthal, B).



Preliminary reports of phase 1 drilling locations (PDFs available in Tender Documents):

- P3.1_045 ETB14 Aubel
- P3.1_046 ETB18 Henri Chappelle
- P3.1_047 ETB13 Teuven
- P3.1_048 ETB08 Gemmenich
- P3.1_049 ETB06 St. Pietersvoeren
- P3.1_050 ETB11 Hombourg

6.1.2. Description of expected rocks and structures

Lithology

Chalk, chalk

A layer of flint eluvium may be present on the plateau near drilling, especially at Vijlenerbos ETB07. The stacked flint chunks (flint) may reach a size of 50 x 50 x 20 cm or larger. Below this are charred Cretaceous Chalk, these are soft, however these still contain flint nodules or flint plates up to ~15 cm thick. Both layers are well permeable and gradually blend together. Execution experience from several borings in this region has shown that pulse drilling <50 cm and the roller bit method do not work in the flint eluvium from 5 m thickness onwards.

Cretaceous sands, glauconitic

The underlying Cretaceous glauconitic sands (Vaals and Aachen formations) are moderately coarse to fine. They are mainly poorly permeable and some layers can be well permeable [0.5-7m/day]. These glauconitic sands contain many clay layers and zones of calcified banks. Clogging may occur when applying a down-the-hole hammer (DTH).

The overburden consisting of eluvium, loam, Cretaceous calcareous and Glauconitic sands should be separately support-cased to several metres into the weathered zone of the Carboniferous or Devonian rocks. The other underlying layers, consisting of rocks as named below, should be cored for strength testing (UCS etc.) in the laboratory. Layers may be abrasive.

Upper Carboniferous: Namurian/Westphalian 'Houillier'

These consist mainly of soft shales with sandstone in between with occasional hard quartzite banks. Mainly Siltstones, Sandstones and Claystones possible

Under-Carbon: Visean

Limestone, soft to very hard with chert in it and possibly highly charred with hollows at the top. Furthermore, layers with shales are present. This layer may be abrasive.

Lower Carboniferous: Tournaisian

Limestone, shales and dolomites, karst may also occur on the upper side of this formation.

Upper Devonian: Famennian

Hard micaceous shales with sandstone and quartzite beds where parts can be porous and have a permeability of 10 m/d. The inclination can vary greatly in depth and even overlie. Hardness can vary by decimetres, making this layer abrasive. Sandstones and Sand-/Siltstones, can be very hard (low penetration rate), individual limestone layers possible.

Middle Devonian Frasnian and Givetian

Charred limestone, shales and dolomites.

Schists and quartzite from the Lower Devonian or Silurian are not expected but cannot be ruled out.

In addition to the above info, you will find further information on the regional geological setting in the attached document.

6.1.2. Expected
Borehole Compositi

6.2. Core Boxes / Core retrieval

The core boxes must comply with the specifications outlined in the product sheet. The attached sheet serves as an example; the Contractor is free to propose an alternative product, provided it meets or exceeds the minimum specifications detailed in the product sheet.

6.2 Core Boxes.pdf

Core Orientation:

Top

Bottom

Core Retrieval:

6.3. List of Subcontractors for site preparation phase 1

Company	Contactperson	Phone/E-mail	Notes
Beckers Joël BV Schietekamer 29 3798 VOEREN (B)	Joël Beckers	+32 496 893704 beckers_joel@hotmail.com	Site preparation
Mertens Grondverzet,- Transport- en Loonbedrijf B.V. Hilleshagerweg 45 6281 AD Mechelen (NL)	Jo Mertens	+31 43 4551305 +31 6 53110783 j.mertens@12move.nl	Site preparation / water supply

6.4. Glass fiber casing

The glass fiber casing must comply with the specifications outlined in the product sheet (Glass fiber casing 140 mm Tubing 725 psi 6-5/8 4Rd G/C D). The attached sheet serves as an example; the Contractor is free to propose an alternative product, provided it meets or exceeds the minimum specifications detailed in the product sheet.

6.4 Glass fiber casing - datasheet.pdf

The centralizers to be used must comply with the specifications outlined in the product sheet (Centralizer HD Series Vertical - HD 30) provided in the annex. The attached sheet serves as an example; the Contractor is free to propose an alternative product, provided it meets or exceeds the minimum specifications detailed in the product sheet.

6.4 centraliser HD30.pdf

6.5. Emission reduction installation

The emission reduction installation must comply with the specifications outlined in the product sheet. The attached sheet serves as an example; the Contractor is free to propose an alternative product, provided it meets or exceeds the minimum specifications detailed in the product sheet.

6.5 Factsheet VWML NoNOx 200.pdf

6.6. Piezo meter

The piezometer must comply with the specifications outlined in the product sheet. The attached sheet serves as an example; the Contractor is free to propose an alternative product, provided it meets or exceeds the minimum specifications detailed in the product sheet.

6.6 4500S Piezometer.pdf