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THE SELECTION OF POTENTIAL SITES FOR THE CZECH DEEP GEOLOGICAL REPOSITORY IN THE NEXT STAGE OF RESEARCH FROM 2020

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SÚRAO

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Abreviations:

BP	Březový potok site
CE	Čertovka site
CI	Čihadlo site
ČEZ	Czech power company
DFN	Discrete fracture network
DGR	Deep geological repository
E	East
EDU	Dukovany nuclear power plant
EIA	Environmental impact assessment
ENE	East north east
ERT	Electrical resistivity tomography
ESE	East south east
ETE	Temelín nuclear power plant
EU	European Union
GRAV	gravimetry
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH
HC	Hot chamber
HLW	High-level waste
HO	Horka site
HR	Hrádek site
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate-level waste
JA	Janoch (ETE-south) site
KH	Kraví hora site
MA	Magdaléna site
MC	Migration corridor
N	North
NE	North east
NNE	North north east
NNS	New nuclear sources
NNW	North north west
NPP	Nuclear power plant
NS	Na Skalním (EDU-west) site
NW	North west
POSIVA	Finnish nuclear waste management organisation
RAW	Radioactive waste
S	South
SE	South east
SKB	Swedish nuclear fuel and waste management company
SNF	Spent nuclear fuel

SSE	South south east
SSW	South south west
SÚJB	State Office for Nuclear Safety
SÚRAO	Czech radioactive waste management authority
SW	South west
TDEM	Time Domain Electromagnetic
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VVER	Water-water energetic reactor
W	West
WDP	Waste disposal package
WNW	West north west
WSW	West south west

Abstract

This report describes the process of the assessment of potential sites for the construction of a deep geological repository in the Czech Republic and the reduction in their number from nine to four. This assessment duly fulfils the requirements of assignment no. 464 of 18 July 2018 set by the Government of the Czech Republic. The report describes the assessment of the potential sites for the construction of the deep geological repository according to both exclusion and comparison criteria as identified by methodology applied by (Vondrovic et al. 2019). The assessment is based on the study of surface geological data, which will have to be further verified and completed based on the various legislative requirements set for the siting of nuclear installations. The first step of the assessment process (a comparison with excluding criteria) resulted in the recommendation of all the sites in terms of their mutual comparison. The result of this comparison, as based on the identified key criteria, consisted of the recommendation of the Březový potok, Horka, Hrádek and Janoch sites for the next stage of research and development. The other sites, Čertovka, Čihadlo, Kraví hora, Na Skalním and Magdaléna, will continue to serve as backup sites.

Keywords

Deep geological repository, site selection process, site evaluation, Březový potok, Čertovka, Čihadlo, Horka, Hrádek, Janoch, Kraví hora, Na Skalním, Magdaléna.

1 Introduction

1.1 Objectives of the report

The main objective of this report is to assess the nine candidate sites for the construction of the Czech deep geological repository (DGR) for SNF and RAW (Březový potok, Čihadlo, Čertovka, Hrádek, Horka, Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west) and to reduce the number thereof. The assessment presented in the report was performed via the use of key and exclusion criteria that addressed the technical feasibility, long-term and operational safety and impact on the environment of the DGR. The assessment process was based on the application of the criteria described in the SÚRAO MP.22 document (Vokál et al. 2017) and the site assessment methodology described in detail in Vondrovic et al. 2019.

This report fulfils the assignment set out in Resolution of the Government of the Czech Republic No. 464 of 18 July 2018 based on the SÚRAO Annual Report of 2017, which set out the requirement to reduce the number of candidate DGR sites from nine to four preferred sites. The results of the technical assessment outlined in this report were subsequently submitted to the Government of the Czech Republic for consideration. The next stage of the research will comprise field geological and other research and exploration activities at the four recommended sites aimed at obtaining data for the next stage of the assessment process that will result in the selection of the final and backup DGR sites.

The assessment process commenced in June 2019 with the compilation of a basic geological descriptive report (Mixa et al. 2019). Hydraulic models of the sites were then created based on this initial report for assessment purposes and for the determination of the preliminary technical designs of the DGR underground complex. The results of previous research on the preliminary siting of the surface areas of the DGR, stability and other relevant issues were also used in the assessment process. Based on a summary of all the data on the various sites and the evaluation of the applicability of the data for assessment purposes, a methodology for the comprehensive assessment of the DGR candidate sites (Vondrovic et al. 2019) was developed, see appendix no. 4 to this report. The assessment of various aspects (excluding and key criteria, see appendices 5 to 17 to this report) was then conducted based on this methodology and a comprehensive assessment report was subsequently compiled.

The assessment methodology, partial assessment and selected background reports, and the final assessment report were then discussed and presented to the so-called expert advisory panel, an advisory body set up by the Managing Director of SÚRAO aimed at guaranteeing the objectivity, transparency, independence and expertise of the assessment process. The expert advisory panel was composed of representatives of the state administration system (Ministry of Industry and Trade, Ministry of the Environment), academic institutions (Masaryk University, Czech Technical University), public research institutions, supervision and administrative organisations involved in radiation protection and nuclear safety (the SÚJB, the State Institute for Radiation Protection), SÚRAO as the managing organisation and experts appointed by the affected municipalities. Elected representatives of the municipalities and representatives of the regulator were invited to meetings of the panel as observers. The expert advisory panel discussed and commented on the assessment criteria, the partial assessment reports and the final assessment report (appendix 18 to this report).

1.2 The deep geological repository concept in the Czech Republic

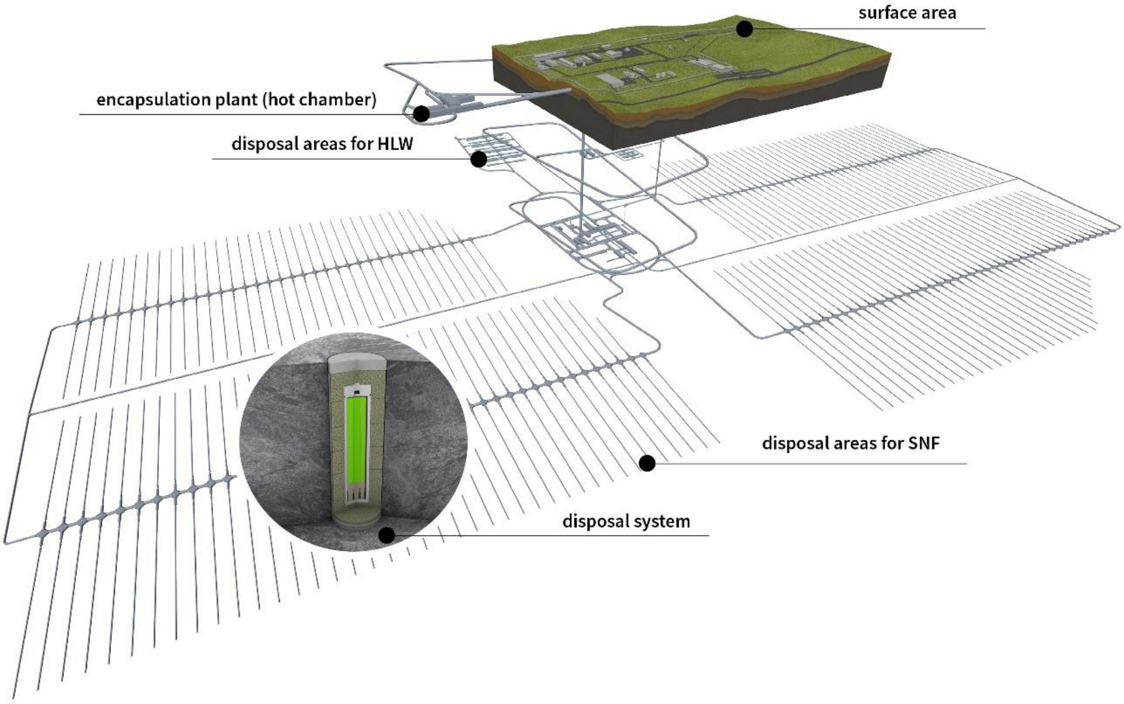


Fig. 1 The deep geological repository concept

The construction of a DGR for radioactive waste is planned in the Czech Republic for the safe and permanent disposal of that radioactive waste that cannot be disposed of in surface or near-surface repositories, i.e. spent fuel from nuclear reactors and, to a lesser extent, high-level waste from the nuclear energy, industry, research and health sectors. The planned capacity of the DGR takes into account the current and anticipated future generation of the relevant types of waste. According to the Spent Nuclear Fuel and Radioactive Waste Management Concept, the operation of the DGR is expected to commence in 2065.

The most important factor in the design of the DGR concerns its long-term safety, which will be ensured by a system of geological and engineered barriers that complement each other and ensure the protection of the biosphere from the penetration of radionuclides from the disposed of waste. The most important barrier will comprise a stable rock block at a depth of around 500 metres below the surface. The other (artificially-created, so-called engineered) barriers will consist of the steel disposal containers and sealing and backfill components based on clay materials (bentonite). The proposed multi-barrier system is based on the Swedish KBS-3 concept. This combination of artificial and natural barriers is required so as to fulfil the legislative requirements of the Atomic Act No. 263/2016 Coll. and its implementing regulations.

These requirements must be met not only during the operational phase of the repository (operational safety) but, especially, following the closure of the facility (long-term safety).

2 Follow-up on previous research studies

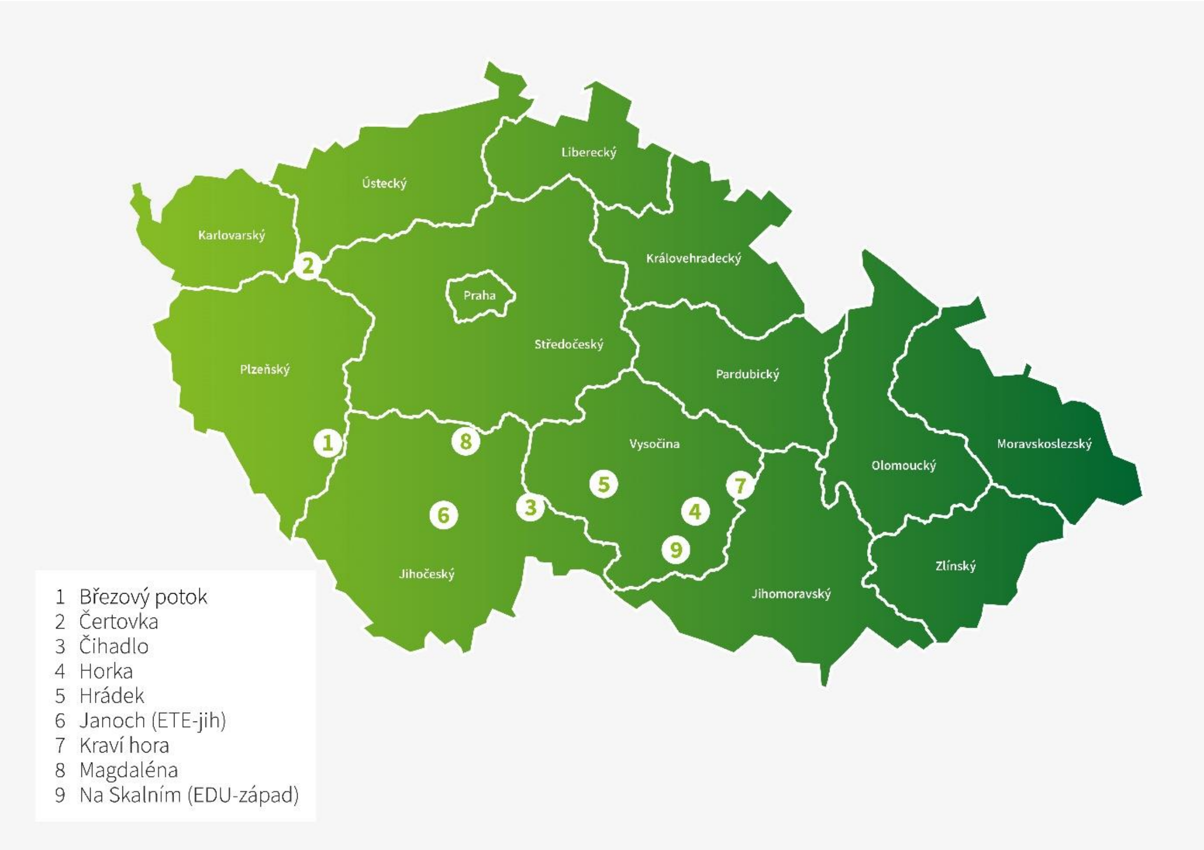


Fig. 2 Potential sites for the DGR in 2014-2020

The first assessment of the whole of the Czech Republic in terms of suitable geological conditions for the construction of the DGR was conducted by the Czech Geological Institute in the early 1990s; the majority of the research was commissioned by the Ministry of the Environment, while part of the research was also commissioned by ČEZ and the Ministry of the Economy. The basic report comprised the study (Novotný et al. 1991): Geological research for the safe disposal of highly radioactive waste, phase I - the selection of promising areas in the Bohemian Massif. The research focused on the geological and tectonic aspects of the assessed areas and the overall potential of the rocks of the Bohemian Massif. The result was the proposal of 32 potential areas. A further study comprised (Novotný-Kříž 1993): The geological research of the safe disposal of spent fuel rods from nuclear power plants, which resulted in the selection and subsequent recommendation for further research of 27 crystalline and sedimentary rock bodies based on existing knowledge of the geological structure of the Czech Republic and the country's mineral deposits, and data obtained from remote sensing research and the study of the hydrogeology, seismicity, recent movements of the earth's crust, geophysics and engineering geology of the areas. The final study conducted in the initial phase of the research comprised (Woller et al. 1998): The critical research of archived geological information, which resulted in the addition of two more granitoid areas. Subsequently, 13 sites were selected from the areas identified above for critical research. Finally, based on several phases of assessment, eight sites were defined in five of the above selected areas.

In 1997, the Czech Radioactive Waste Repository Authority (SÚRAO) was established to assume responsibility for SNF and RAW issues. In 2002-2003 Energoprůzkum Praha Ltd updated the research based on the Atomic Act No. 18/1997 Coll. and subsequent SÚJB decrees and IAEA recommendations. The result comprised a report entitled: The selection of a site for, and the construction of, a DGR for RAW in the Czech Republic - the analysis of the whole of the Czech Republic - regional mapping phase (Šimůnek et al. 2003). The assessment of the Czech Republic and the subsequent selection of sites for the construction of the DGR involved several consecutive stages. The first stage comprised the exclusion of unsuitable areas due both to the natural conditions of the area (tectonic disturbances and tectonic activity, seismic loading, volcanism and post-volcanic activity, etc.) and the consideration of societal and legal issues and commitments set out in international treaties. The second stage consisted of the selection of areas with suitable geological conditions via the thorough assessment of the geological structure of the Czech Republic, and the definition of the types of rock suitable for the disposal of radioactive waste. The third stage comprised the rejection of those areas subject to exclusion criteria (according to Act No. 114/1992 Coll., SÚJB Decree No. 215/1997 Coll. and from the point of view of protected interests). The fourth stage involved the application of a ranking system (population density, land cover, the dose rate of the gamma radiation of the rock environment, radon risk, conditions for the construction and operation of the DGR, etc.). Finally, eleven potential sites and a reference site were selected. Based on the results of the Šimůnek et al. 2003 project, SÚRAO decided that the next stage of the research would commence at six sites, all of which were situated in similar rock environments, i.e. granitoids (crystalline rock environments).

Subsequently, the GeoBariéra consortium (AQUATEST Ltd, Stavební geologie – GEOTECHNIKA Ltd and Atelier T-plan; Černý et al. 2005) conducted geological research in 2003–2005 as part of the Performance of geological and other research for the evaluation of, and reduction in, the number of sites for the DGR project (sites: Blatno, Pačejov, Božejovice, Lodhéřov, Rohozná and Budišov). The project included the collection of information on the geology of the areas and the petrography, geophysics, geochemistry, hydrogeology, hydrology and engineering geology conditions. In addition, new research was conducted via aerial photography and field work methods (remote sensing of the Earth, aerial geophysics, field geological reconnaissance research); moreover, conflicts of interest were defined and feasibility studies compiled. Based on the research and multi-criteria analysis, the spatial areas of the sites were reduced for the conducting of further research and survey work. With respect to all the defined sites, it was concluded that no natural, environmental or socio-economic conditions had been determined that served to exclude the sites from further consideration. It was recommended that prior to the commencement of further research, decisions should be obtained from the Ministry of the Environment on the designation of exploration areas for special intervention into the earth's crust. It was also decided to rename the sites: Březový potok (Pačejov-Nádraží), Čertovka (Blatno), Čihadlo (Lodhéřov), Horka (Budišov), Hrádek (Rohozná) and Magdaléna (Božejovice-Vlksice).

In 2008-2009, the geological research of designated military areas in the Czech Republic was conducted. A study was compiled on this issue entitled: The critical research of geological information on current military areas of the Czech Republic in terms of defining a potentially suitable area for the siting of the DGR (Hrkalová et al. 2009). The study assessed the potential for the use of the following military areas: Boletice, Brdy, Březina, Hradiště and Libavá. Subsequently, only the Boletice area (crystalline rocks) was recommended for further consideration. Although the geological conditions were deemed favourable, the area was not added to the list of potentially suitable sites at this stage due to the number and complexity of conflicts of interest; while it was assumed that all these issues could be resolved technically and administratively, it was decided that the costs of doing so would be too high. However, the site is still considered a backup option should it not be possible to find a more suitable site from the other areas being considered.

Based on the results of a study by Navrátilová et al. 2011, the Kraví hora site was added to the six original sites in 2011. The site is located in a crystalline environment, i.e. highly-metamorphic rocks (granulite, migmatite). This decision took into account the potential connection of the site to the planned Skalka central interim spent fuel storage facility, which has a valid permit for the siting of a nuclear facility (Fiedler 2010), (Šimůnek et al. 2005).

Although, according to studies carried out in 2003-2004, the areas of nuclear power plants (NPP) were not considered due to ‘further burdening such areas’, the idea of siting the DGR in the vicinity of such facilities, as in Sweden and Finland, was subsequently reconsidered (Vojtěchová 2019). SÚRAO then addressed this option in the Evaluation of geological and other information on selected parts of the Czech Moldanubian in terms of the potential suitability for the siting of the DGR (EDU-west and ETE-south) project. In 2015, based on a preliminary expert geological assessment of the areas, two rock polygons were selected near to the Czech Republic’s two nuclear power plants, subsequently referred to as ETE-south (near the Temelín NPP) and EDU-west (near the Dukovany NPP). The main aim of the research was to determine potentially suitable geological blocks for the siting of the DGR, and resulted in the identification of potentially suitable areas near to both of the NPPs, i.e. EDU-west, referred to as "Na Skalním", and ETE-south, referred to as “Janoch”. The addition of these sites to the list of potentially suitable DGR locations increased the total number of considered sites to nine (Hanžl et al. 2018), (Navrátilová et al. 2018). In 2017-2019, extensive surface-based geophysical research was conducted at all nine candidate sites, which yielded a large amount of data on the geological structures of the areas which, in turn, served as the basis for the assessment of the candidate DGR sites described in this report (Beneš et al. 2019, Duras and Bláha 2019, Hrutka et al. 2019, Jirků et al. 2019, Karous et al. 2019, Kašpar et al. 2019, Levá et al. 2019, Levý et al. 2019, Nikl et al. 2019).

Tab. 1 The selection of areas of interest for the siting of the DGR for radioactive waste (the most important studies).

Year	Study	Site
1991	Novotný, P. et al.: Geological research for the safe disposal of highly radioactive waste, phase I - the selection of promising areas in the Bohemian Massif.	32 potential areas
1993	Novotný, P. and Kříž, J: Evaluation of promising areas selected by the Czech Geological Institute for the permanent disposal of spent nuclear fuel with regard to the construction of a central interim storage facility in the Czech Republic. Czech Geological Institute, Prague 1993.	27 selected geological bodies and areas

Year	Study	Site
1998	Woller, F. et al.: The critical research of archived geological information. MS SÚRAO TZ 1/1998.	13 potentially suitable areas
2003	Šimůnek, P. et al.: The selection of a site for, and the construction of, a DGR for RAW in the Czech Republic - the analysis of the whole of the Czech Republic - regional mapping phase.	11 selected sites and a reference site
2003	Selection of a crystalline environment for the siting of the deep geological repository	6 sites
2003-2005	Černý et al. (2005): GEOBariéra project – geological research at the Blatno, Pačejov, Božejovice, Lodhéřov, Rohozná and Budišov sites	6 sites
2009	Hrkalová, M. et al.: The research of military areas - Boletice, Brdy, Březina, Hradiště and Libavá	Recommendation of the Boletice area. Later excluded due to conflicts of interest
2011	Navrátilová, V. et al.: Evaluation of existing geological and other information from the area between the Rožná and Olší deposits in terms of defining a rock mass potentially suitable for the construction of the deep geological repository.	The Kraví hora site was added to the six original sites
2015-2018	Hanžl, P. et al.: Evaluation of geological and other information on selected parts of the Czech Moldanubian in terms of potential suitability for the siting of the DGR – EDU-west; DGR site EDU-west - summary final report, MS SÚRAO TZ 219/2018.	EDU-west (Na Skalním)
	Navrátilová et al.: Evaluation of geological and other information on selected parts of the Czech Moldanubian in terms of potential suitability for the siting of the DGR - ETE-south. Summary final report on ETE-south. Evaluation of intervention into the Earth's crust and proposals for follow-up geological research, MS SÚRAO TZ 222/2018.	ETE-south (Janoch)
2017-2019	Description of the geological structure of potential DGR sites in the Czech Republic using geophysical methods (Beneš et al. 2019, Duras and Bláha 2019, Hrutka et al. 2019, Jirků et al. 2019, Karous et al. 2019, Kašpar et al. 2019, Levá et al. 2019, Levý et al. 2019, Nikl et al. 2019).	9 sites

3 Background reports for the proposal of recommended sites

3.1 Background reports

The evaluation and comparison of the candidate DGR sites was performed on the basis of data obtained by SÚRAO from projects conducted in the period 2000 to 2019 with an emphasis on the synthesis of the data in the form of descriptive models of the sites and preliminary project designs (reviews of Vokál et al. 2018a-i, Marek et al. 2018a-g, Krajíček et al. 2018, Bureš et al. 2018a-d, Špinka et al. 2018a-c, Navrátilová et al. 2018, Hanžl et al. 2018, Martinčík et al. 2018a-i). The geological data, which constitutes a substantial part of the information on the sites used in the assessment process, was obtained on the basis of the extensive study of the near-surface parts of the candidate sites and the research of archived data. The assessment process was based on the assumption that all the significant rock interfaces (higher order faults, contacts between lithological units, etc.) have been identified from the geological research and the results of previous projects commissioned by SÚRAO (summarisation of Franěk et al. 2018, Mixa et al. 2019, Beneš et al. 2019, Duras and Bláha 2019, Hrutka et al. 2019, Jirků et al. 2019, Karous et al. 2019, Kašpar et al. 2019, Levá et al. 2019, Levý et al. 2019, Nikl et al. 2019) and follow-up research that served to refine this information. A further set of data used for assessment purposes comprised descriptive models of the sites (geological, hydrogeological, transport - for an overview see Franěk et al. 2018, Havlová et al. 2020a-i, Vokál et al. 2018a-i) and updates thereof based on geophysical measurement results (Mixa et al. 2019, Baier et al. 2020a,b, Černý et al. 2020a,b, Jankovec et al. 2020a,b, Polák et al. 2020, Uhlík et al. 2020a,b). The data that allowed for the description of long-term predictions of the development of the sites (erosion, seismic, vertical stability) was taken from reports by Hroch-Pačes 2015 and Málek et al. 2018.

With respect to technical issues, the outputs from preliminary DGR design projects for the various sites were used for assessment purposes (according to the results of reports by Bureš et al. 2018a-d, Špinka et al. 2018a-c, Navrátilová et al. 2018, Hanžl et al. 2018) in Zahradník et al. 2020. In the case of environmental impact issues, data based on the preliminary siting of the DGR surface area and environmental impact studies (Bureš et al. 2018a-d, Špinka et al.2018a-c Hanžl et al. 2018, Navrátilová et al. 2018, Marek et al. 2018a-g, Krajíček et al. 2018,) were used in the assessment of the sites, taking into account current knowledge obtained via the geophysical research (Beneš et al. 2019, Duras and Bláha 2019, Hrutka et al. 2019, Jirků et al. 2019, Karous et al. 2019, Kašpar et al. 2019, Levá et al. 2019, Levý et al. 2019, Mixa et. al. 2019, Nikl et al. 2019). The assessment process itself was performed on the basis of the application of key (comparative) and exclusion criteria according to the assessment methodology devised by Vondrovic et al. 2019, taking into account the methodological guidelines set out in the SÚRAO MP.22 document (Vokál et al. 2017). The following studies, which form background reports to the submitted assessment, were compiled for evaluation purposes:

Pertoldová et al. 2019: The localisation of promising areas for geological characterisation research and promising areas for project design work for the purposes of the evaluation of the potential sites for the DGR (explanatory report); the determination of rock polygons for promising areas for geological characterisation research and promising areas for project design work (Appendix 5 to this report).

Butovič et al. 2020: The evaluation of the potential DGR sites in terms of key technical feasibility criteria; the evaluation of the technical aspects of the preliminary designs of the DGR at the specific sites (Appendix 6 to this report).

Havlová et al 2020a-i: The evaluation of the potential DGR sites in terms of key long-term safety criteria, the evaluation of long-term safety issues, especially with respect to geological, hydrogeological, stability and other criteria (Appendices 7-15 to this report).

Lahodová and Popelová 2020: The evaluation of the potential DGR sites in terms of key operational safety criteria, the evaluation of key components in terms of the future operation of the repository (Appendix 16 to this report).

Krajíček et al. 2020: The evaluation of the potential DGR sites according to key environmental criteria; the evaluation of the environmental aspects of, particularly, the siting of the surface area at the specific sites (Appendix 17 to this report).

The findings from the above studies were synthesised in this summary assessment report. The above-mentioned reports form electronic appendices to the assessment report (Appendices 5-17 to this report).

3.2 Validation of the inputs to the candidate DGR site assessment process

The input data for the assessment process was validated at several levels. The basic guarantee of the accuracy of the information received for the assessment process comprised the qualifications of the various research organisations as proven by the relevant tenders accompanied by lists of the respective significant projects and the specialists who led them, and the fulfilment of set technical and qualification requirements, including proof of professional competence.

The next stage of the quality assurance (QA) procedure comprised the compilation of detailed plans for the various projects. The inspection of the fulfilment of these plans throughout the course of the projects was ensured via the ongoing auditing of the projects involving the contracting parties and SÚRAO experts. With respect to major projects, SÚRAO inspected the fulfilment of the project objectives and the data obtained on a continuous basis via inspection days that were held once per month.

In the case of multi-organisational (consortium) contracts, all the project interim and final technical reports were subjected to a comments procedure involving representatives of the main suppliers. Subsequently, the submitted results were checked and commented on by SÚRAO experts, who were entitled to submit the results to an external audit in case of doubt. In the case of the provision of background data, all the reports submitted by experts in the supply chain were assessed via an internal SÚRAO review process.

SÚRAO obtained the data, models, arguments and methodologies needed for the evaluation of the candidate DGR sites on a continuous basis, including via international cooperation. The tools for the assessment of radionuclide transport in the rock environment were validated using international benchmarking with the Task Force on Groundwater Flow and Transport of Solutes group and in cooperation with the German organisation GRS (Noseck et al. 2020). Moreover, the procedures used for the creation of hydraulic models and the transport of radionuclides were addressed via a pilot safety report compiled on the Kraví hora site (Trpkošová et al. 2018) in cooperation with the Finnish company POSIVA (Vuorio 2018).

The background reports that were used for the purposes of the assessment of the candidate DGR sites described herein, were verified as follows:

Proposals for the project design options for the DGR were assessed by the Finnish company POSIVA (Ikonen-O Carrol 2019). Furthermore, a comparative calculation mechanism was prepared (Hasal et al. 2017) for the purposes of the verification of the thermo-technical calculations of the sites (Kobylka et al. 2018).

The geological models (Franěk et al. 2018) were critically appraised by Dr. Radomír Grygar, CSc. (VŠB, Technical University of Ostrava, Grygar R. 2018). These 3D structural geological models were then updated based on the results of the DGR Geofyzika project (Beneš et al. 2019, Duras and Bláha 2019, Hrutka et al. 2019, Jirků et al. 2019, Karous et al. 2019, Kašpar et al. 2019, Levá et al. 2019, Levý et al. 2019a,b, Nikl et al. 2019). The supervision of the geophysical project from the technical and expert points of view was provided by the Czech Geological Survey. The use and applicability of the results of this project with concern to the evaluation of faults at the various sites were assessed by Dr. Ivan Prachar, CSc. (Prachař 2020a). The updated tectonic networks, as well as all the geological maps and geological sections used in the evaluation of the candidate DGR sites and the creation of the updated 3D structural-geological models (Mixa et al. 2019), were then critically appraised by the Czech Geological Survey according to certified geological mapping methodology (Hanžl et al. 2009).

The accuracy of the application of the hydraulic models of the candidate DGR sites (Uhlík et al. 2018, Baier et al. 2018, Jankovec et al. 2018, Černý et al. 2018) was ensured on a continuous basis via the parallel processing of the site models by three different modelling teams (Technical University of Liberec, ÚJV Řež Ltd, PROGEO Ltd) using three different software applications. Furthermore, the benchmarking comparison was performed of the results of the hydraulic model of the Čihadlo site with a model developed by the German company GRS (Noseck et al. 2020). A report on the methodology used for the application of the hydrogeological models and the flow models of the candidate DGR sites in 2018 was prepared by Prof. Naďa Rapantová, CSc. (Rapantová 2020). Model updates based on changes to the geometry of the fault network were applied for the purposes of the assessment of the sites presented herein, whereas the other model assumptions remained unchanged.

The background studies of environmental impacts as well as the assessment of the sites according to environmental criteria were in all cases based on current data on the values and limits of the areas as provided in regional and municipal territorial analytical documentation. The second source of background data comprised the continuously updated public databases of the Ministries of the Environment, Agriculture, Transport, etc. In the case of the territorial analytical documentation, the guarantors of the completeness and timeliness of the information were considered to be the various providers of data on the respective areas; with respect to public databases, the guarantors were considered to be the operators thereof.

With concern to the assessment methodology and the actual evaluation of the sites (Vondrovic et al. 2019), the mathematical approach was critically assessed by Dr. František Staňek, Ph.D. (University of Mining, Staněk 2020).

The assessment of the sites both individually and in terms of the overall assessment process was critically appraised by the Expert Advisory Panel (Appendix 18 to this report). In addition, a critical assessment of the environmental criteria was provided by Mgr. Tomáš Šikula (Šikula 2020).

Statements on the site assessment process were provided by the Finnish company POSIVA and two leading Czech experts with IAEA experience, i.e. Ing. Jiří Faltejsk (IAEA, overall evaluation) and Dr. Ivan Prachař, CSc. (overall evaluation and evaluation of the methodology).

A summary of the various safety reports (Vokál et al. 2018 a-i) was assessed by the State Office for Nuclear Safety from the point of view of the future fulfilment of the requirements of the Atomic Act No. 263/2016 Coll. and decree on the siting of nuclear facilities no. 378/2016 Coll. Assessment of the sites

4 Areas of assessment

The assessment of the candidate DGR sites was performed with respect to a number of spatial extents and distances from the considered homogeneous rock blocks (polygons). These various levels of detail are described in the assessment methodology (Vondrovic et al. 2019). Based on the results of research in various areas (e.g. Havlová et al. 2020a-i, Vokál et al. 2018a-i, Bureš et al. 2018a-d, Špinka et al. 2018a-c, Marek et al 2017a-g, Navrátilová et al. 2018, Málek et al. 2018, Zahradník et al. 2020, Butovič et al. 2020) the following polygons were defined for assessment purposes (Fig. 3):

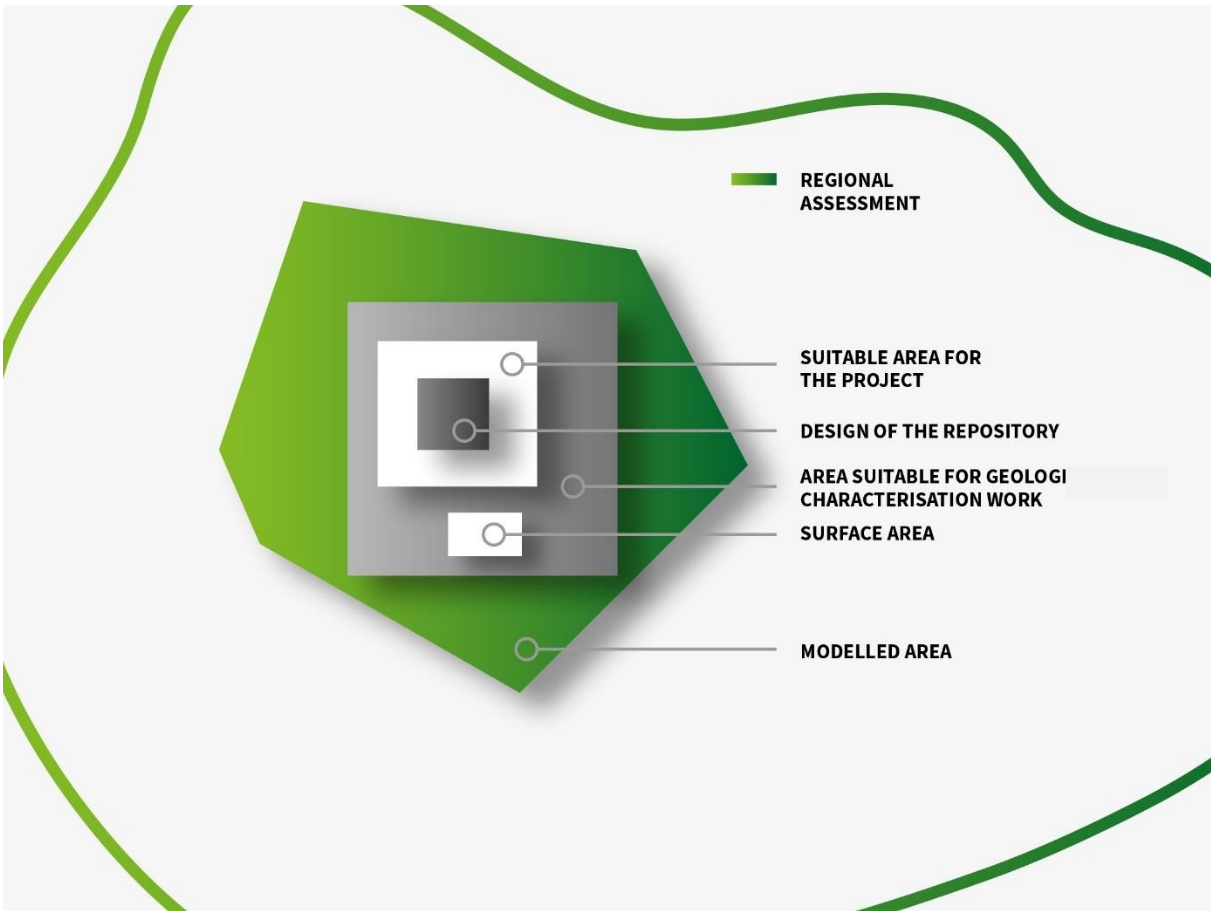


Fig. 3 Scope of the description of the sites for the purposes of the assessment process - main components

a) **DGR underground area:** the minimum extent of the disposal space at the specific site defined on the basis of the preliminary design project for each site applying the vertical disposal method. Only those polygons that allow for the defining of areas for the disposal of both SNF and RAW were included in the assessment process.
b) **Surface area:** surface areas with a minimum of conflicts of interest at the sites that are considered preliminarily suitable for the siting of the DGR surface complex.
c) **Promising area for the project design work:** a rock block that makes up the so-called isolation part of the repository for the disposal of the waste (i.e. a rock area that is considered preliminarily suitable for the disposal wells) at the anticipated depth of the

repository. The promising area for the project design work is located within the polygon of the promising area for the geological research work.

d) **Homogeneous rock block:** a promising area for the project design work without the presence of category II faults, with a reserve and without the occurrence of so-called unusable fragments (see below) in the promising area for the project design work.

e) **Unusable fragments in the project design area:** defined as an area that is potentially suitable for waste disposal, but which has such dimensions that, for future project reasons (especially in terms of size), the area cannot be practically used for disposal purposes.

f) **Promising area for the geological characterisation work (promising area for the geological research work):** an area in which geological research can be performed in the future in order to define the promising area for the project design work, i.e. an area in which it is highly probable that geological research will be conducted in order to determine a rock environment that fulfils the requirements for the isolation part of the DGR.

g) **Modelled area:** the area that will need to be characterised in order to create descriptive models of the sites and to be able to gain an understanding of the broader context (for the various modelled simulations - geological, hydrogeological and transport models; the size of the evaluated modelled polygons may differ according to the subject of modelling). It comprises the area in the wider vicinity of the promising area for the project design work, which must be assessed so as to determine the extent of the fulfilment of the assessment criteria and indicators. It concerns the assessment process via modelled simulations in cases where the inclusion of regional boundary conditions is required so as to obtain the data needed for modelling purposes. Furthermore, it concerns indicators that are dependent on, or consider, only data from the wider region (e.g. the evaluation of territorial stability).

h) **Regional area:** the larger-scale area that must be described in order to meet the requirements of Decree No. 378/2016 Coll. (e.g. seismicity).

The text below provides a description of the locations of the surface areas, the promising areas for the geological research, the promising areas for the project design work, the planned repository (disposal spaces) and the areas defined for the 3D structural-geological modelling for all the candidate DGR sites.

4.1 Březový potok

The Březový potok site is located in western Bohemia, in the Plzeň region, Klatovy district (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work, as defined for the purposes of the site assessment process (Pertoldová et al. 2019), are located in the municipalities of Břežany, Horažďovice, Chanovice, Kovčín, Kvášňovice, Malý Bor, Maňovice, Olšany, Pačejov and Velký Bor. The promising area for the geological characterisation research has an area of 37.874 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). Two polygons were defined for the promising areas for project design work within the defined promising area for the geological characterisation research. The total area of these two polygons is 13.374 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 12.315 km^2. The polygon of the promising area for the project design work defined in the northern part of the area (Březový potok - S) for the geological characterisation research has an area of 6.462 km^2 (at the repository depth: 5.845 km^2), while that of the second defined polygon in the southern part of the area (Březový potok - J) for the geological characterisation research has a surface area of 6.912 km^2 (at the repository depth: 6.470 km^2). The assessed surface area has an area of 17.092 ha (Špinka et al. 2018c) and is located SW of the village of Maňovice. The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the Březový potok-S polygon and has an area of 2.94 km^2 (Zahradník.et al. 2020).

Fig. 4 Map of the assessed areas of the Březový potok site

4.2 Čertovka

The Čertovka site is located in western Bohemia in the Ústí nad Labem region, Louny district and in the Plzeň region, Plzeň - north district. The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work (Pertoldová et al. 2019) are located in the municipalities of Blatno, Lubenec, Pastuchovice, Tis u Blatna and Žihle. The promising area for the geological characterisation research has an area of 40.029 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). Two polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research. The total area of these two polygons is 10.31 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 10.017 km^2. The polygon of the promising area for the project design work defined in the northern part of the area (Čertovka - S) for the geological characterisation research has an area of 5.472 km^2 (at the repository depth: 5.190 km^2), while that of the second defined polygon in the southern part of the area (Čertovka - J) has a surface area of 4.834 km^2 (at the repository depth: 4.827 km^2). The assessed surface area has an area of 17.44 ha (Bureš et al. 2018c) and is located south of the village Lubenec. The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the Čertovka - S polygon and has an area of 1.53 km^2 (Zahradník et al. 2020).

Fig. 5 Map of the assessed areas of the Čertovka site

4.3 Čihadlo

The Čihadlo site is located in the South Bohemia region, Jindřichův Hradec district (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work, as defined for the purposes of the site assessment process (Pertoldová et al. 2019), are located in the municipalities of Deštná, Lodhéřov, Pluhův Žďár, Světce and Velký Ratmírov. The promising area for the geological characterisation research has an area of 38.144 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). Two polygons were defined for the promising areas for the project design work (Pertoldová et al. 2019) within the defined promising area for the geological characterisation research. The total area of these two polygons both on the surface and at repository depth is 14.051 km^2. The polygon of the promising area for the project design work defined in the western part of the area (Čihadlo - Z) for the geological characterisation research has an area of 11.827 km^2, while that of the second defined polygon in the eastern part of the area (Čihadlo - V) has an area of 2.224 km^2. The assessed surface area has an area of 16.61 ha (Bureš et al. 2018b) and is located southeast of the village Lodhéřov. The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the Čihadlo - Z polygon and has an area of 2.03 km^2 (Zahradník et al. 2020).

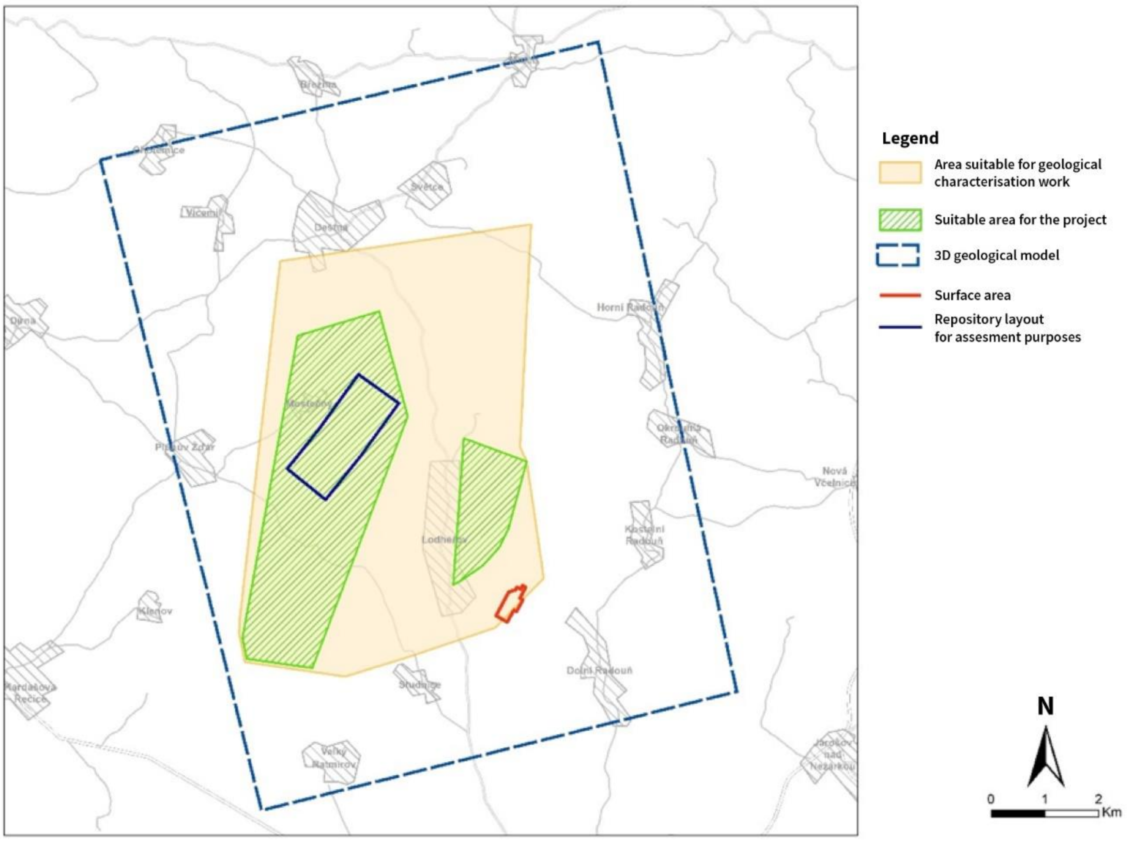


Fig. 6 Map of the assessed areas of the Čihadlo site

4.4 Horka

The Horka site is located in the Vysočina region, Třebíč and Žďár nad Sázavou districts (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work (Pertoldová et al. 2019) are located in the municipalities of Budišov, Hodov, Nárameč, Oslavice, Oslavička, Osové, Rohy, Rudíkov and Vlčatín. The promising area for the geological characterisation research has an area of 28.268 km^2 and was described by Franěk et al. 2018. Three polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research. The total area of these three polygons is 14.52 km^2 on the surface and 14.908 km^2 at repository depth. The polygon of the promising area for the project design work defined in the north-western part of the area (Horka - SZ) for the geological characterisation research has an area of 9.291 km^2 (9.679 km^2 at repository depth), that of the second defined polygon in the north-eastern part of the area 2.949 km^2 (also at repository depth) and that of the third defined polygon in the southern part of the area (Horka - J) an area of 2.28 km^2 on the surface and at repository depth. The assessed surface area has an area of 17.01 ha (Bureš et al. 2018a) and is located north of the village of Náraměč. The preliminary siting of the DGR for assessment purposes was chosen for the Horka - SZ polygon and has an area of 2.5 km^2 (Zahradník et al. 2020).

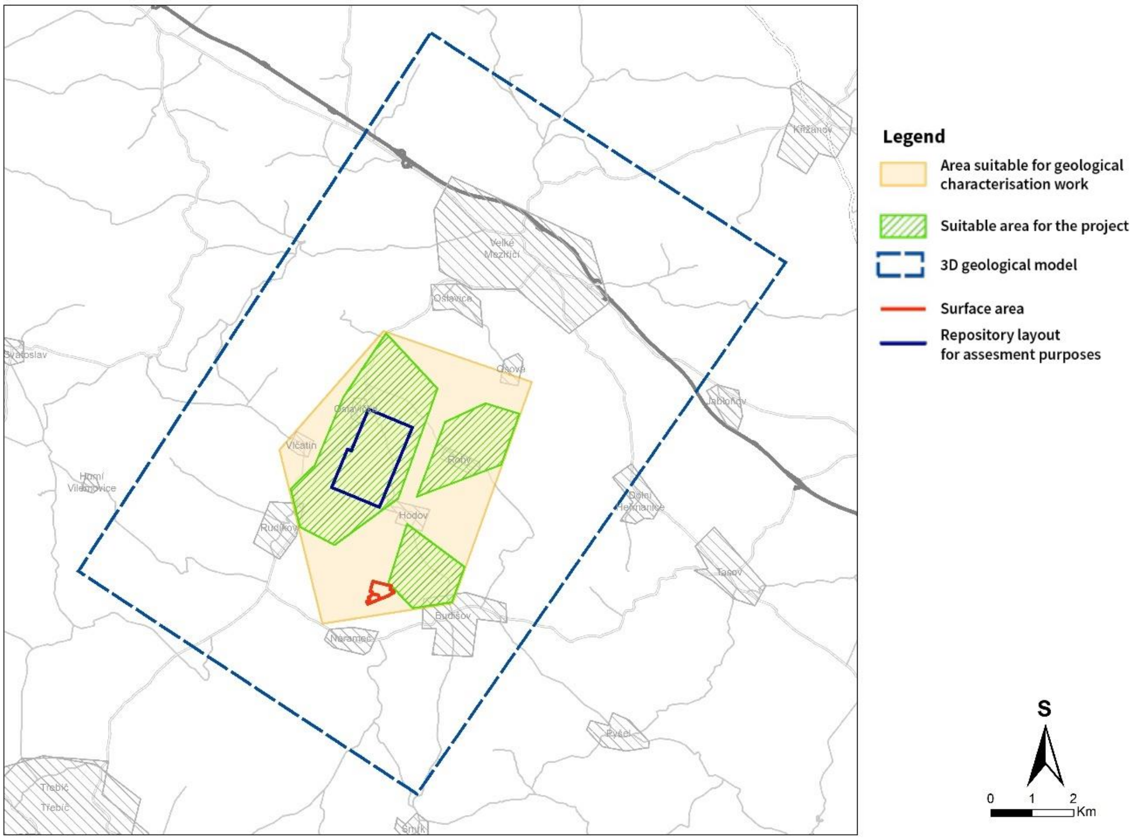


Fig. 7 Map of the assessed areas of the Horka site

4.5 Hrádek

The Hrádek site is located in the Vysočina region, Jihlava and Pelhřimov districts (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work, as defined for the purposes of the site assessment process (Pertoldová et al. 2019), are located in the municipalities of Boršov, Cejle, Dolní Cerekev, Hojkov, Milíčov, Mirošov, Nový Rychnov and Rohozná. The promising area for the geological characterisation research has an area of 35.077 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by

Mixa et al. 2019). Two polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research. The total area of these two polygons is 10.263 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 9.861 km^2. The polygon of the promising area for the project design work defined in the north-western part of the area (Hrádek - SZ) for the geological characterisation research has an area of 3.4 km^2 (at the repository depth: 3.096 km^2), while that of the second defined polygon in the south-eastern part of the area (Hrádek - JV) has a surface area of 6.863 km^2 (at the repository depth: 6.765 km^2). The assessed surface area has an area of 14.59 ha (Špinka et al. 2018b) and is located west of the village of Dolní Cerekev. The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the Hrádek - JV polygon and has an area of 2.67 km^2 (Zahradník et al. 2020).

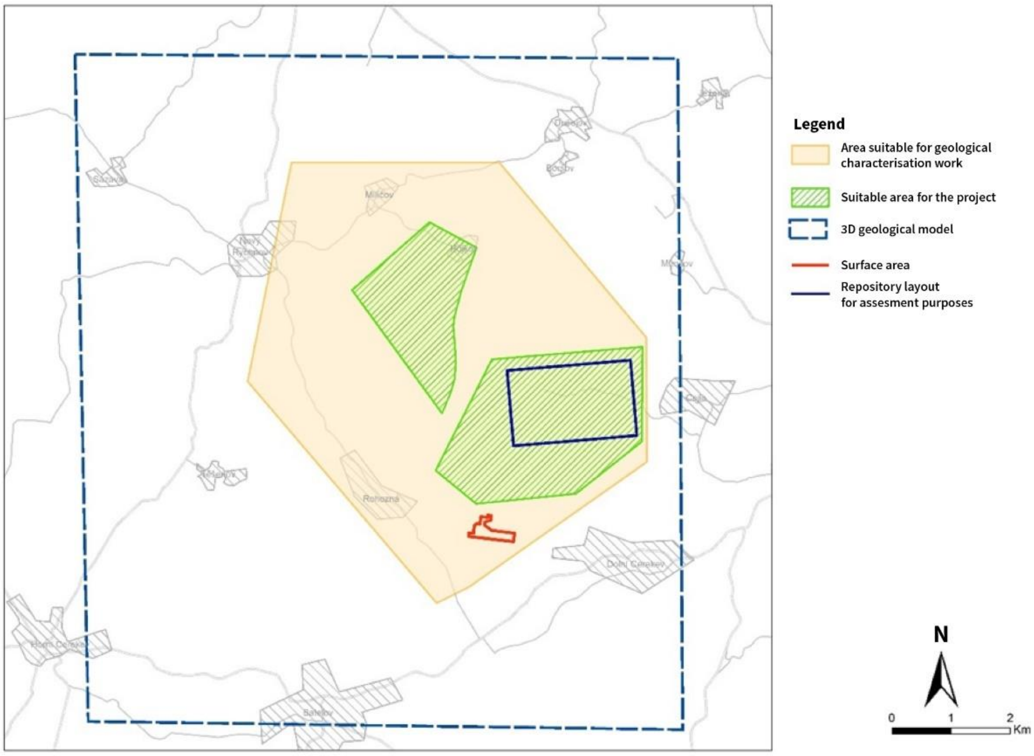


Fig. 8 Map of the assessed areas of the Hrádek site

4.6 Janoch (ETE-south)

The Janoch site is located in the South Bohemia region, České Budějovice district (for more detailed information, see e.g. Navrátilová et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work, as defined for the purposes of the site assessment process (Pertoldová et al. 2019), are located in the municipalities of Dříteň, Hluboká nad Vltavou, Olešník and Temelín. The promising area for the geological characterisation research has an area of 22.742 km^2. Two polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research. The total area of these two polygons both on the surface and at repository depth is 10.169 km^2. The polygon of the promising area for the project design work defined in the eastern part of the area (ETE-south-V) for the geological characterisation research has an area of 4.676 km^2, while that of the second defined polygon in the southern part of the area (ETE-south - Z) has an area of 5.493 km^2. The assessed surface area has an area of 26.5 ha (Navrátilová et al. 2018) and is located east of the village of Dřiteň (Navrátilová et al. 2018). The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the ETE-south-V polygon and has an area of 2.37 km^2 (Zahradník et al. 2020).

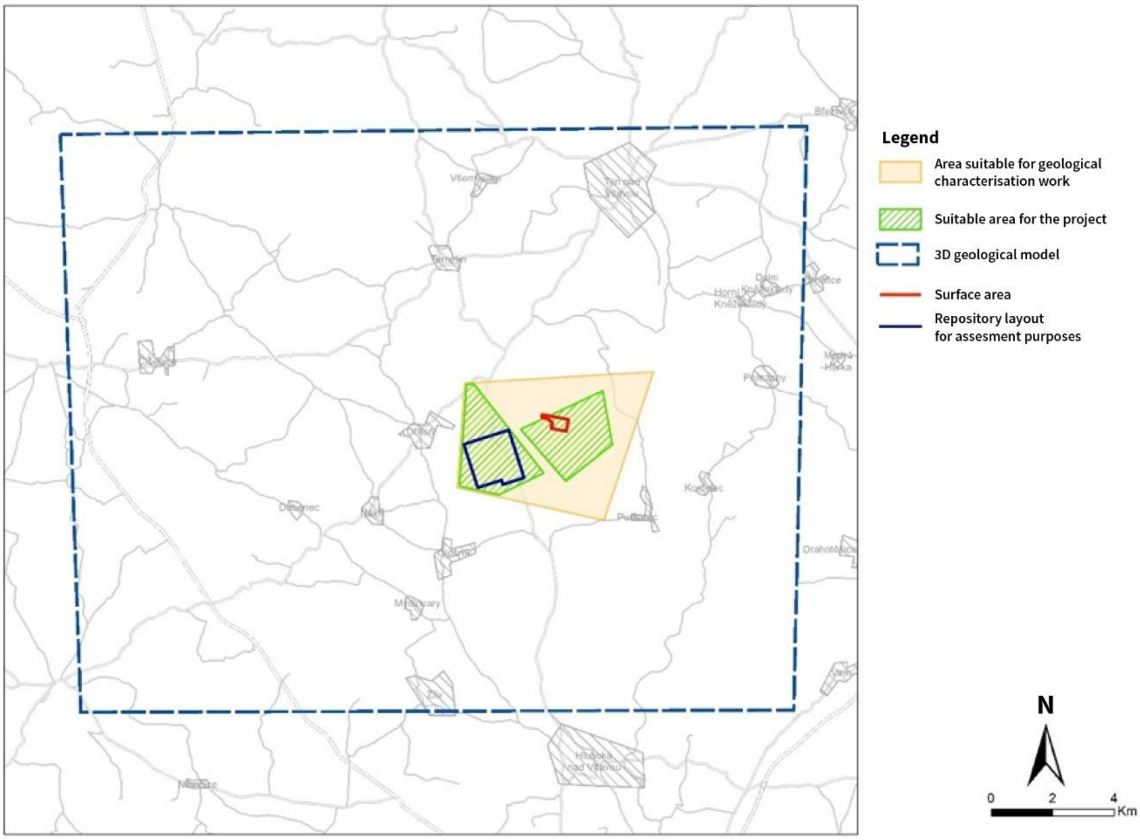


Fig. 9 Map of the assessed areas of the Janoch (ETE-south) site

4.7 Kraví hora

The Kraví hora site is located in the Vysočina and South Moravia regions, Žďár nad Sázavou and Brno-venkov districts (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work (Pertoldová et al. 2019) are located in the municipalities of Bukov, Dolní Rožínka, Drahonín, Milasín, Moravecké Pavlovice, Olší, Rodkov, Rožná, Sejřek, Strážek, Střítež and Věžná. The promising area for the geological characterisation research has an area of 27.763 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). One polygon was defined for the promising area for the project design work within the defined promising area for the geological characterisation research. The total surface area of this polygon is 7.301 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 5.463 km^2. The assessed surface area has an area of 10.92 ha (Špinka et al. 2018a) and is located north of the village of Střítež. The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, has an area of 3.054 km^2 (Zahradník et al. 2020).

Fig. 10 Map of the assessed areas of the Kraví hora site

4.8 Magdaléna

The Magdaléna site is located in the South Bohemia region, Písek and Tábor districts (for more detailed information, see e.g. Franěk et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work (Pertoldová et al. 2019) are located in the municipalities of Božetice, Jistebnice and Nadějkov. The promising area for the geological characterisation research has an area of 26.823 km^2 and includes both previously described areas (Franěk et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). Two polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research. The total surface area of these two polygons is 6.345 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 5.406 km^2. The polygon of the promising area for the project design work defined in the northern part of the area (Magdalena – S) for the geological characterisation research has an area of 4.219 km^2 on the surface and, at repository depth, 3.671 km^2, while that of the second defined polygon in the southern part of the area (Magdalena-J) has a surface area of 2.126 km^2 on the surface and 1.735 km^2 at repository depth. The assessed surface area has an area of 17.498 ha (Bureš et al. 2018d) and is located south of the village Božejovice. The preliminary siting of the DGR for assessment purposes was chosen for the Magdaléna - S polygon and has an area of 2.134 km^2 (Zahradník et al. 2020).

Fig. 11 Map of the assessed areas of the Magdaléna site

4.9 Na Skalním (EDU-west)

The Na Skalním (EDU-west) site is located in the Vysočina region, Třebíč district (for more detailed information, see e.g. Hanžl et al. 2018). The polygons assessed for the promising area for the geological characterisation research and the promising area for the project design work (Pertoldová et al. 2019) are located in the municipalities of Dolní Vilémovice, Jaroměřice nad Rokytnou, Lipník, Myslibořice, Ostašov and Zárubice. The promising area for the geological characterisation research has an area of 27.13 km^2 and includes both previously described areas (Hanžl et al. 2018) and newly-characterised areas based on recently attained SÚRAO geophysical data (summary by Mixa et al. 2019). Three polygons were defined for the promising areas for the project design work within the defined promising area for the geological characterisation research: EDU-west - Z with an area of 4.16 km^2 (at repository depth: 3.709 km^2), EDU-west - SV with an area of 2.693 km^2 (at repository depth: 2.479 km^2) and EDU-west - J with an area of 3.102 km^2 (at repository depth: 2.937 km^2). The total area of these three polygons is 9.955 km^2. Following the approximation of the geological structure to the expected depth of the repository, including the assumed slopes of the various geological interfaces, the promising area for the project design work has an area of 9.125 km^2. The assessed surface area has an area of 12.29 ha (Krajíček et al. 2018) and is located north-west of the village of Myslibořice (Hanžl et al. 2018). The preliminary siting of the DGR for assessment purposes, i.e. the area designated for the disposal of SNF, was chosen for the EDU-west-J polygon and has an area of 2.62 km^2 (Zahradník et al. 2020).

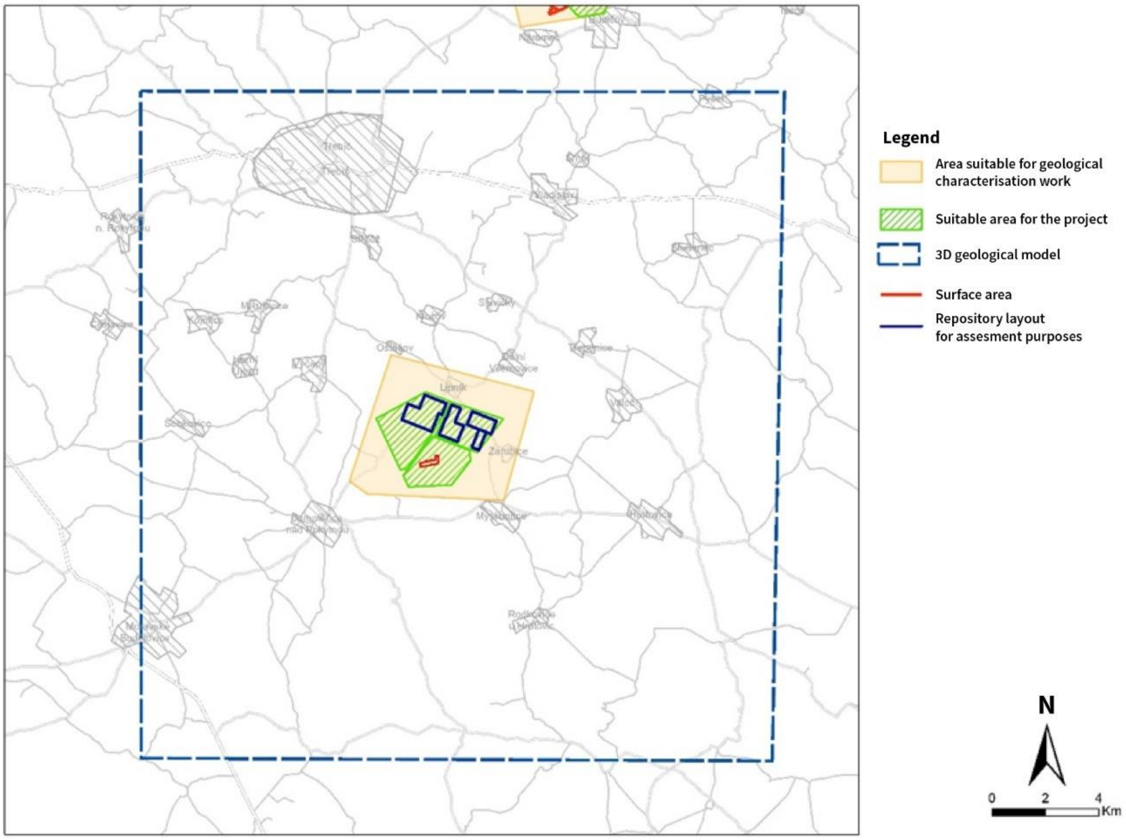


Fig. 12 Map of the assessed areas of the Na Skalním (EDU-west) site

5 Assessment of the sites

5.1 Assessment procedure

The MP.22 methodical guidelines (Vokál et al. 2017), that set out the requirements, suitability indicators and criteria for the DGR site selection process, as well as the site assessment methodology, as determined by Vondrovic et al. 2019, set out the requirements and procedures to be applied when comparing the suitability of the sites in terms of the location of the DGR. The site assessment process covered the following criteria areas:

- technical feasibility;
- safety
    - operational;
    - long-term;
- environmental impacts.

The assessment of the suitability of the sites was conducted in two stages:

1. first assessment stage - risk exclusion (the assessment of exclusion criteria in all the evaluation areas according to the MP.22 document and Vondrovic et al. 2019);
2. second assessment stage - benefits analysis (the comparison of the sites using key criteria according to the assessment methodology of Vondrovic et al. 2019).

Fig 13 Site assessment process

The first stage comprised the assessment of the criteria that served for excluding the sites should there be no appropriate technical or administrative measures available to remedy the deficiencies. If the site was in conflict with any of the exclusion requirements or criteria and no such measures were considered feasible, it was no longer considered for further research and was included in the excluded site category (Fig. 13). If it was considered possible to solve the various conflicts, the site proceeded to the second assessment stage.

The results of the assessment of each of the exclusion criteria were classified as follows:

1. The information available on the assessed properties of the site leads to the conclusion that the requirement will be met (the opportunity outweighs the risk), i.e. no property has been identified at the site that leads to it being excluded in terms of the location of the repository.

2. The information obtained on the assessed properties indicates an obstacle or problem in terms of meeting the respective requirement, or potential problems with the demonstration thereof (the risk outweighs the opportunity).

3. Insufficient data is available to assess the respective criterion at the given stage of the site selection process.

The second assessment stage compared the sites that passed the exclusion criteria evaluation by means of the defined key criteria (Vondrovic et al. 2019), which comprised those site characteristics according to which the sites could be compared at the given stage of DGR development. The assumption was that they comprised both characteristics that can be determined/estimated from current knowledge and characteristics according to which the sites differed based on the evaluation of available information. A further assumption was that these characteristics did not correlate with each other (for example, they were not based on the recalculation of the same basic information). The key criteria were further divided into indicators, i.e. the various characteristics of the sites considered in the key criteria (Vondrovic et al. 2019).

At this stage, the assessment of the suitability of the sites was conducted on the basis of the reduction of the number of sites based on those criteria that had the highest information relevance and were founded on a sufficient amount of input information. In accordance with the adopted methodology (Vondrovic et al. 2019), the values of the indicators were converted into a grade in the range of 1-5 (1 – relatively the best site, 5 – relatively the worst site). The conversion was performed by the assessment teams who were responsible for providing and analysing the input data of the relevant criteria and indicators. According to the multicriteria assessment of the suitability of the sites as per the methodology (Vondrovic et al. 2019), the values of the grades of the various indicators were multiplied by the weightings of the relevant indicators in order to obtain an overall grade for the respective criterion. The grades of the criteria were then multiplied by the weightings accorded to the individual key criteria defined on the basis of the expert Saaty pairwise assessment of the significance of the various criteria (see Chapter 6.2). The final grade for the site was thus the sum of the products of the weightings of the relevant criteria and the grades thereof. The relatively more suitable candidate DGR sites had lower overall grades. In order to verify the multicriteria assessment procedure applied to the sites, a comparison was performed of the various mathematical approaches that influenced the calculation of the weightings of the key criteria and other calculation procedures (standardisation).

5.2 Assessment of the exclusion criteria

An exclusion criterion comprised a property of the site that excluded the siting of the DGR in the absence of the appropriate technical or administrative remedial measures. The exclusion criteria are listed and described in Tab. 2, classified in accordance with the assessment methodology (Vondrovic et al. 2019). The description of the assessment of the various exclusion criteria (chapters 5.3 to 4.7**Chyba! Nenalezen zdroj odkazů.**) is arranged according to the content of Tab. 2, either collectively for all the sites or for each site separately. With respect to the assessed exclusion criterion, the final decision is always provided, whether the criterion was fulfilled or not, either collectively for all the sites per criterion or for each site separately.

Tab. 2 Overview of the exclusion criteria according to Vondrovic et al. (2019) and MP.22

ID	Criterion designation	Criterion description/value
1	**Project exclusion criteria**	
1.1	Size of the usable rock mass	The usable rock mass must be of such dimensions that, in compliance with technical and safety requirements, it is able to host the expected amount of waste to be disposed of with a reserve.
1.2	Hydrogeological conditions	Very unfavourable hydrogeological conditions for the siting of the DGR may lead to the exclusion of some parts of the repository area; however, as a rule, most unfavourable conditions can be remedied via technical or administrative measures. The preliminary criterion is the value of water flow into the disposal wells (0.1 l/min) and the disposal tunnels (0.25 l/min).
1.3	Ensuring stability for construction	Occurrence of: a) volcanic rocks of the Pliocene to Holocene eras or indications of post-volcanic activity, in particular the outflow of gases or mineral waters associated with past volcanic activity; to a distance of 5 km. b) phenomena according to para. 2 c) of Decree No. 378/2016, 1. caverns and karst formations, 2. deep mines, underground gas storage facilities and other facilities constructed in underground spaces, and indications of previous mining activities,

ID	Criterion designation	Criterion description/value
		3. pumping wells and other infrastructure for the extraction of minerals and groundwater, including the subsidence or deformation of the surface, And that: 1. on the land of the nuclear facility or 2. outside the land of the nuclear facility if there is the risk of the subsidence or deformation of the surface of the area for the siting of the nuclear facility with a potential impact on nuclear safety. c) slope movements that reduce nuclear safety d) persistently unsuitable foundation soil properties, namely 1. unsuitability of the foundation soils for the foundations of components important from the point of view of nuclear safety; in the case that the average speed of transverse waves in the foundation soil is lower than 360 m/s, 2. occurrence of foundation soil with a loading capacity of less than 0.2 MPa, 3. occurrence of sedimentary or strongly swellable foundation soils, 4. the presence of a foundation soil classified as moderately organic or highly organic, or 5. occurrence of soil liquefaction.

ID	Criterion designation	Criterion description/value
1.4	Number and complexity of conflicts of interest	Characteristics that are in conflict with a protection or safety zone shall result in the exclusion of the consideration of the construction of a nuclear facility. This constitutes the interference of the land of the nuclear facility in a protection zone pursuant to Section 15, para. 1 a) and b) of Decree No. 378/2016 Coll., i.e.: a) road protection zone, b) railway protection zone
2	**Long-term safety exclusion criteria**	
2.1	**Geological characteristics**	
2.1.1	Describability and predictability of the homogeneous rock blocks	The geological conditions of the repository must allow for the creation of a credible complex, spatial geological model. The depth extent of the rock mass must be sufficient with regard to the maximum expected depth of the repository (minimum of 400 m). An unacceptable degree of uncertainty in the identification and description of regional and local fault zones and other geological structures may preclude the siting of the repository. In the first phase of surface geological research, however, this factor is not necessarily excluding and can be used to compare the sites.
2.1.2	Variability of the properties	If the variability of the properties is such that it does not allow for the preparation of a reliable 3D geological, hydrogeological, geomechanical and geochemical model, the site shall be excluded. In the first phase of surface geological research, however, this factor is not necessarily excluding and can be used to compare the sites.
2.2	**Hydraulic characteristics**	
2.2.1	Presence of aquifers in the isolation part of the repository	The presence of aquifers in the isolation part of the repository constitutes an exclusion criterion for the siting of the repository.

ID	Criterion designation	Criterion description/value
2.2.2	Difficulty of creating hydrogeological models and predicting the development of hydrogeological conditions at the site	Unacceptable uncertainties due to the difficulty of determining the influence of fault zones and other structures when creating hydrogeological models of the sites. In the first phase of surface geological research, however, this factor is not necessarily excluding and can be used to compare the sites.
2.3	**Site stability**	
2.3.1	Earthquakes and the presence of potentially active faults over the next hundreds of thousands of years (seismic stability)	The site of a nuclear facility, and at a distance of up to 5 km from the boundary thereof, must not feature any faults potentially capable of shifting with manifestations on or near the surface. Maximum potential magnitude and soil vibration acceleration values, however, may be used for site comparison purposes.
2.3.2	Subsidence or uplift of the surface of the area (vertical movements of the earth's crust)	The siting of the repository is excluded at sites at which movements of the earth's crust are greater than 1 mm/year.
2.3.3	Post-volcanic phenomena	Sites with post-volcanic phenomena (gas outflows, thermal water, etc.) will be excluded.
2.4	**Characteristics that could lead to the disturbance of the repository via future human activities**	
2.4.1	The presence of old mine workings	No old mine workings must be present on the proposed site of a nuclear facility.
2.4.2	The presence of mineral resources	There must be no mineral resource reserves at depths greater than 100 m.
2.4.3	The presence of underground water or geothermal energy sources	The rock environment must not contain significant water sources or have the potential for the use of geothermal energy.
3	**Excluding operational safety criteria**	
3.1	**Natural phenomena**	

ID	Criterion designation	Criterion description/value
3.1.1	The occurrence of faults	a) Occurrence of a zone with a physically or seismically active fault or other movement of the earth's crust that could result in damage to the nuclear installation, thus negatively affecting nuclear safety; up to a distance of 5 km, or
		b) Occurrence of an accompanying fault at the site of the nuclear installation. This criterion will be combined with the criterion for assessing seismicity in terms of long-term safety
3.1.2	Flooding	Regular flooding of the site of the nuclear installation due to extreme meteorological situations with a probability of occurrence of once every 100 years or higher.
3.2	**Factors influencing the management of exceptional situations**	
3.2.1	Proximity to an international border	Proximity to an international border or settlements that negatively influence the feasibility of the emergency plan.
3.2.2	Ensuring access for rescue units	The lack of access for fire, mining rescue and ambulance services.
3.2.3	Ensuring information and evacuation	The impossibility of communicating timely information to, and the evacuation of, the population.
3.2.4	Ensuring measures against sabotage	The inability to secure the facility against sabotage precludes the siting of the DGR.
4.	**Exclusion criteria in terms of environmental impacts**	
4.1	**Occurrence of specially protected natural areas**	
4.1.1	Occurrence of UNESCO biosphere reserves	The area designated for the surface area must not feature a UNESCO biosphere reserve (Article 1 of Ministry of Foreign Affairs communication No. 159/1991, Coll. Convention Concerning the Protection of the World Cultural Heritage).
4.1.2	Occurrence of national parks	The area intended for the surface area of the DGR must not be situated in a national park. Definition: Appendices Nos. 1 - 4 of Act No. 114/1992, Coll.

ID	Criterion designation	Criterion description/value
4.1.3	Occurrence of a protected landscape area	The area intended for the surface area of the DGR must not be situated in a protected landscape area.
4.1.4	Occurrence of national natural monuments and national nature reservations	The area intended for the surface area of the DGR must not be situated in areas with the occurrence of national natural monuments and national nature reservations (in all cases this refers to so-called specially protected natural area categories).
4.1.5	Occurrence of a Natura 2000 site (Area of European Importance, Bird Protection Areas)	The area intended for the surface area of the DGR must not be situated in Areas of European Importance and must not interfere with Bird Protection Areas.
4.1.6	Occurrence of nature reserves and natural monuments	The area intended for the surface area of the DGR must not be situated in nature reserves or at sites with natural monuments

5.3 Excluding technical feasibility criteria (ID1)

5.3.1 Size of the usable rock mass (ID 1.1)

Description of the exclusion criterion

The usable rock mass must be of such dimensions that, while complying with all the technical and safety requirements, it is able to host the expected amount of waste to be disposed of with a reserve.

Assessment results

The size of the usable rock mass comprised an exclusion criterion for the site if the dimensions of the homogeneous rock block were deemed insufficient for the disposal of the expected amount of SNF in waste disposal packages (WDP) for all three types of fuel considered (VVER 440, VVER 1000 and SNF from new nuclear sources (NNS)). The criterion included the assessment of the extent of the area reserve for the disposal of the expected amount of waste (9500 tonnes of SNF and 4500 m^3 of HLW/ILW according to (Vokál et al. 2017)) in the promising area for the project design work.

For the purposes of the assessment, all faults and fragments were excluded from the usable rock mass, i.e. the polygons for the promising area for project design work; such features render the rock environment unusable in terms of SNF disposal and accessibility with concern to the technical feasibility of the access corridors (Butovič et al. 2020 and Zahradník et al. 2020). Furthermore, thermo-technical calculations were made of each of the sites, which determined the spacing required between the disposal corridors and the WDPs (Kobylka 2018). Based on this data, disposal sections were designed for each site with respect to the expected number of WDPs with SNF. The areas of the disposal sections determined in this way were then compared to the size of the defined rock blocks at the sites (Butovič et al. 2020).

Tab. 3 Summary of reserves with respect to the usability of the rock blocks according to Butovič et al. (2020)

Site	**Disposal area**	**Area of the rock blocks at a depth of around 500 m below the surface**	**Reserve for the siting of the underground part of the DGR**
	[m²]	[m²]	[%]
Březový potok	2 944 729	11 812 154	75.07
Čertovka	1 530 000	9 417 447	83.75
Čihadlo	2 030 466	13 332 558	84.77
Horka	2 497 119	14 236 292	82.46
Hrádek	2 671 020	9 861 730	72.92
Janoch (ETE-south)	2 368 963	9 892 677	76.05
Kraví hora	3 053 775	4 648 195	34.30
Magdaléna	2 134 212	5 041 756	57.67
Na Skalním (EDU-west)	2 623 746	8 031 870	67.33

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.3.2 Hydrogeological conditions (ID 1.2)

Description of the exclusion criterion

Very unfavourable hydrogeological conditions for the siting of the DGR were considered an exclusion criterion with respect to certain parts of the repository; however, as a rule, such unfavourable conditions can be remedied via the application of technical or administrative measures. The preliminary criterion considered values of water flow into the disposal wells of 0.1 $l.min^{-1}$, and into the disposal tunnels of 0.25 $l.min^{-1}$.

Assessment results

The assessment of the criterion was performed for all the candidate sites according to (Butovič et al. 2020). At the present stage of the assessment process, it is not possible to unambiguously assess this criterion due to the lack of data from the disposal depth. The criterion refers to the hydrogeological characteristics that will be known only after the excavation of the underground part of the DGR. Currently, the hydrogeological models of the sites (a summary of the results used to assess the suitability of the sites is provided in Havlová et al. 2020a-i) do not describe the flow conditions at the time of the commissioning of the repository.

Hydrogeological models were created for all the sites that included the calculation of selected hydrogeological characteristics (Havlová et al. 2020a-i). However, with the current level of knowledge of the rock mass at the assumed SNF disposal depth, there is not enough information available for the evaluation of the value of the flow of underground water into the disposal wells. However, international experience, e.g. (Riekkola et al. 2003) indicates that such unfavourable conditions can usually be remedied via the application of technical or administrative measures.

However, generally accepted assumptions on the development of permeability in crystalline and Moldanubian rock masses led to the expert opinion that at all the sites:

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.3.3 Ensuring stability for construction (ID 1.3)

The evaluation of this exclusion criterion refers to the siting of the surface area. Therefore, in the following text, the land of the nuclear facility is considered to be identical to that of the DGR surface area.

Description of the exclusion criterion

According to Section 9 of Decree No. 378/2016 Coll. (SÚJB Decree No. 378/2016 on the siting of a nuclear facility, 2016), the following comprise exclusion characteristics in terms of the siting of a nuclear facility:

a) the occurrence of volcanic rocks of the Pliocene to Holocene eras or indications of post-volcanic activity, in particular the outflow of gases or mineral waters associated with past volcanic activity; to a distance of 5 km.

b) the occurrence of phenomena referred to in paragraph 2 c) (i.e. caverns and karst formations, deep mines, underground gas reservoirs and other structures constructed in underground spaces, the remnants of previous extraction activities, pumping boreholes and dissolution technologies for the extraction of minerals and groundwater, including the subsidence or deformation of the surface) on the land of a nuclear facility, or outside the land of a nuclear facility, if there is the risk of the subsidence or deformation of the surface of the area selected for the siting of the nuclear facility that exerts a potential impact on nuclear safety,

c) the occurrence of slope movements that reduce nuclear safety, or

d) the occurrence of persistently unsuitable foundation soil properties, namely:

- unsuitability of the foundation soils for the foundations of components important from the point of view of nuclear safety; in the case that the average speed of transverse waves in the foundation soil is lower than 360 m/s,
- occurrence of foundation soil with a loading capacity of less than 0.2 MPa,
- occurrence of sedimentary or strongly swellable foundation soils,
- the presence of a foundation soil classified as moderately organic or highly organic, or
- occurrence of soil liquefaction.

Assessment results

The sites were assessed on the basis of a report by Butovič et al. 2020; appendix 6 to this report.

Březový potok

Based on the geological data on the Březový potok site, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered. There is no risk of conflict of interest with mined areas or the instability of the area in terms of mining burdens nor the occurrence of underground anthropogenic weakened zones. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Březový potok site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čertovka

Based on the geological data on the Čertovka site, it was found that the volcanic rocks present within 5 km of the assessed site are from the tertiary era. Remnants are evident of the volcanic complex of the Doupov mountains, which were volcanically active 34–20 million years ago. Post-volcanic events (e.g. the hydrothermal alteration of rocks) may have occurred in the area as recently as 10 million years ago. However, there are no known indications of post-volcanic activity from the Quaternary. Around 4 km from the assessed site, Vladař, the remnant of a separate smaller volcano, is characterised by dispersed remnants from the isolated Tepelská and Slavkov volcanic bodies. The age of the activity of this volcanic field is stated to be 22 to 6 million years. Throughout the Tepelská and Slavkov areas, the volcanic activity took the form of separate eruptions, without the prolonged subsequent post-volcanic manifestations related to the degassing of cooling magma. From the point of view of post-volcanic phenomena, no exclusion criteria were determined for the site. No karst phenomena or old or abandoned mine workings have been recorded at the site and no occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Čertovka site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čihadlo

Based on the geological data on the Čihadlo locality, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Čihadlo site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Horka

Based on the geological data on the Horka site, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Horka site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Hrádek

Based on the geological data on the Hrádek site, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered (in the surface area). No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Hrádek site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Janoch (ETE-south)

Based on the geological data on the Janoch site (ETE-south), it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered in the surface area. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Janoch site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Kraví hora

Based on the geological data on the Kraví hora site, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. There are 79 mine workings registered for the site in the mine workings database of the Czech Geological Survey, which can be divided into two categories according to Section 35 of Act No. 44/1988 Coll. (the Mining Act), i.e. 78 abandoned mines from which radioactive raw materials were extracted and one exploratory mine for asbestos rocks. Older maps record the conducting of geophysical and exploratory research at the site, involving the drilling of 52 boreholes of more than 300 m deep. However, none of these workings are located on the site defined for the potential construction of the DGR nuclear facility, and the land is not affected by any potential consequences of former mining activities, i.e. so-called mined areas. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Kraví hora site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Magdaléna

Based on the geological data on the Magdaléna site, it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. No old or abandoned mine workings are registered for the Magdaléna site, nor is there any evidence of the undermining of the area. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Magdaléna site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Na Skalním (EDU-west)

Based on the geological data on the Na Skalním site (EDU-west), it was determined that the site is located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif or the Carpathian arch. Within a radius of 5 km of the assessed area, there are no known manifestations of the volcanic or post-volcanic activity of the Pliocene to Holocene eras. In terms of post-volcanic phenomena, no exclusion criteria were determined for this site. Furthermore, there are no karst phenomena, nor have any old or abandoned mine workings been registered in the database of mine workings of the Czech Geological Survey nor is there any evidence of the undermining of the area. No occurrences of slope movements that would reduce nuclear safety in the vicinity of the surface area have been registered at the site. No indications of the presence of foundation soils with unsuitable properties were determined in the presumed surface area of the Na Skalním (EDU-west) site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.3.4 Number and complexity of conflicts of interest (ID 1.4)

Description of the exclusion criterion

Characteristics that are in conflict with a protection or safety zone shall result in the exclusion of the consideration of the construction of a nuclear facility. This constitutes the interference of the land of the nuclear facility in a protection zone pursuant to Section 15, para. 1 a) and b) of Decree No. 378/2016 Coll. on the siting of nuclear facilities (i.e. road and railway protection zones).

Assessment results

The sites were assessed on the basis of a report by Butovič et al. 2020; appendix 6 to this report.

The surface areas of all the sites were determined with a view to minimising conflicts of interest and avoiding the exclusion criteria. Therefore, at none of the sites does the land of the nuclear facility impinge upon railway or road protection zones.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.4 Long-term safety exclusion criteria (ID 2)

Geological characteristics (ID 2.1)

The assessment of both of the exclusion criteria in this category was based on the description of the geological structure, which is described in studies by Havlová et al. 2020a-i in a summary study concerning both the exclusion and comparison criteria. The text below presents the main findings in terms of the ID 2.1 exclusion criteria.

5.4.1 Describability and predictability of the homogeneous blocks (ID 2.1.1)

Description of the exclusion criterion

The impossibility of creating a complex spatial model of the geological structure of an area determined for the siting of a nuclear installation due to the complex geological structure and tectonic conditions precludes the siting of the DGR.

The geological conditions of the repository must allow for the creation of a credible complex, spatial geological model. The depth extent of the rock mass must be sufficient with regard to the maximum expected depth of the repository (minimum of 400 m). An unacceptable degree of uncertainty in the identification and description of regional and local fault zones and other geological structures may preclude the siting of the repository. In the first phase of surface geological research, however, this factor is not necessarily excluding and can be used to compare the sites.

5.4.2 Variability of the properties (ID 2.1.2)

Description of the exclusion criterion

If the variability of the properties is such that it does not allow for the preparation of a reliable 3D geological, hydrogeological, geomechanical and geochemical model, the site shall be excluded. In the first phase of surface geological research, however, this factor is not necessarily excluding and can be used to compare the sites.

Assessment of the results for both exclusion criteria (ID 2.1.1 and 2.1.2)

The sites were assessed in reports by Havlová et al. 2020a-i.

Březový potok

The main rock body for the siting of the DGR at the Březový potok site is made up of blatenský and červen granodiorite, which comprise deep-seated rock masses with a depth range of at least 2.5 km. The contacts between these two types of granodiorites are intrusive, as are the contacts with the surrounding metamorphic Moldanubian rocks. The veined rocks in the E-W direction comprise less dominant rock bodies of up to several hundred metres long. From the point of view of the variability of the rock environment, the petrological and geochemical variability of the rock bodies and various lithologies is insignificant. Both magmatic and metamorphic ductile deformation structures (Franěk et al. 2018) (Mixa et al. 2019) have been identified to a sufficiently credible extent in the rock bodies. From the point of view of brittle tectonics, four first category faults and 26 second category faults were identified in the area covered by the 3D structural-geological model (Mixa et al. 2019). Fracture systems were identified according to the spatial orientation, the most common of which are relatively steep (inclination 70–90°) fractures in the directions NE–SW, NW–SE and NNW SSE. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Čertovka

The main rock body for the siting of the DGR at the Čertovka site comprises Tiský pluton with a depth range of around 3 km. It consists exclusively of coarse-grained, with occurrences of indistinctly porphyritic biotite, granite, with intrusive contacts with the surrounding Bohemian rocks and tectonic contacts with the rocks of the Žihel basin. The petrological and geochemical variability of the Tiský granite is insignificant from the point of view of the descriptiveness and predictability factor as are the internal ductile magmatic structures. The quartz veins present form N-S bodies with thicknesses of a maximum of several metres. The Tiský pluton is intruded in its central part by volcanic rocks; the intrusions are related to a significant failure zone. From the point of view of brittle tectonics, 2 first category and 32 secondary category faults were identified in the area covered by the 3D structural-geological model (Mixa et al. 2019). The fracture system is dominated by subvertical extension fractures, mostly without mineral fillings and mainly in the approximately WNW – ESE to WSW – ENE directions; a system of steep NE-SW oriented fractures is less pronounced. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Čihadlo

The main rock body for the siting of the DGR at the Čihadlo site comprises the lithologically relatively homogeneous Klenov pluton (muscovite-biotite granite with occurrences of partially assimilated xenoliths of the surrounding metamorphic rocks) with a depth range of around 2.5 km. The petrological variability is insignificant from the point of view of the descriptiveness and predictability factor. The intrusive contacts of the pluton with the surrounding Moldanubian rocks have a finger-like character and are mostly subparallel and follow the orientation of regional metamorphic foliation, the surfaces of which decline at slight to medium angles to the W to WNW. Veins of pegmatites and quartz with thicknesses of several tens of metres occur infrequently and are insignificant from the point of view of the assessment process. With respect to brittle tectonics, 2 first category and 23 second category faults were identified in the area of the 3D structural-geological model. Six fracture systems were identified, the most numerous of which are relatively steep (slopes of 70–90°) and descend to the NW, SE, NE, SW, ENE and WSW. Fractures with medium to slight slopes decline towards the SE (Kabele et al. 2018). The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Horka

The main rock body for the siting of the DGR at the Horka site comprises the Třebíč pluton which consists of melasyenites to melagranites with a porphyritic texture with variable grain sizes (medium to coarse-grained). From the point of view of the petrological properties, however, the site features a relatively homogeneous environment with the occurrence of insignificant magmatic and deformation foliation. Areas with variable representations of feldspar growths (cumulative structures), migmatite xenoliths and microgranular enclaves have been detected in the durbachites. The Třebíč pluton intrudes into the surrounding Moldanubian rocks; the contacts are intrusive. The depth range of the pluton is estimated at several km. The Třebíč pluton is intruded by small bodies of granites of up to several hundred m^2 in size. However, these lithological inhomogeneities are of only local significance and, due to their rheological similarity, do not impair the quality of the homogeneity of the rock environment. The data obtained confirms the low degree of variability of the physical properties of the rock environment. With concern to brittle tectonics, seven first category and seventeen second category faults were identified. It is not possible to unambiguously determine the dominant set of fractures; most commonly, steep fractures (inclination of 70 90°) that decline to the N, S, NW, SE, NE, SW, E and WZ occur in the area. Furthermore, fractures with medium inclinations (60-40°) occur which decline to the E, NW and SE. The commonly observed hydrothermal alterations in the minerals and the subsurface weathering of the rocks do not significantly affect the homogeneity of the rock blocks.

Hrádek

The main rock body for the siting of the DGR at the Hrádek site comprises the Moldanubian pluton, specifically the partial intrusion of the Čeřínek and Eisgarn massifs. These intrusions are represented by various types of granites with indistinct igneous foliation, which have steep intrusive contacts, thus allowing for the assumption of their relative mechanical homogeneity. The petrological variability of the granites is insignificant from the point of view of the descriptiveness and predictability factor. Based on expert estimates, it can be assumed that the thickness of the granites in the polygon of interest is around 20 km. Veins of quartz and aplites with thicknesses of several tens of metres occur mainly in the southwestern part of the Čeřínek massif; from the assessment point of view, they may be significant due to the presence of polymetallic mineralisation. With concern to brittle tectonics, one first category and 14 second category faults have been verified at the site. Fracture systems most often occur in the form of steep fractures (inclination of 80–90°) running mainly in the E-W, NE-SW, NNE-SW and NW-W directions. Fractures with medium inclinations (60–40°) running N-S generally decline towards the E and W. Sub-horizontal fractures (inclination of 0–30°), apart from the weathering of exfoliation fractures, which were excluded from the assessment, occur only rarely at the site and copy the trend of the fractures with medium inclinations. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Janoch (ETE-south)

The main rock body for the siting of the DGR at the Janoch (ETE-south) site comprises one of the rock bodies of the monotonous Moldanubian group. From the point of view of the lithological content and geological structure, the area around the Janoch (ETE-south) site is relatively simple and made up of silimanite-biotite gneisses with various degrees of migmatisation with a significant one-generation ductile metamorphic structure. The petrological and geochemical variability of the gneisses is insignificant in terms of the descriptiveness and predictability factor. Veins of microgranites and pegmatites with thicknesses of several tens of metres occur mainly in the south-eastern half of the site, as do spatially-limited variegated inserts of erlans and quartzites. Five first category and twenty-two second category faults were identified at significant distances from the considered DGR area on the edge of the 3D structural-geological model. With respect to fracture systems, fracture populations running NNE-SSW to N-S with steep inclinations towards the WNW to W; running NW-SE with steep inclination to the SW and NE; running NE-SW with a moderate tendency to the NW; and running W-E with a steep inclination to the S have been identified. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Kraví hora

The main rock body for the siting of the DGR at the Kraví Hora site comprises the Drahonín granulite body with an expected depth range of 2.8 km. The lithological composition of the surrounding rocks is relatively varied and includes the occurrence of various petrographic varieties of migmatites, amphibolites and orthogneiss with the presence of variegated rock deposits. The ductile deformation structure at the Kraví hora site is complex, comprising a heterogeneous complex of three superimposed metamorphic structures (S_1-S_3) that acquire regional significance. From the point of view of brittle tectonic structures, four first category and twenty-five second category faults have been identified. The area features three main groups of subvertical extension fractures predominantly running approximately ENE-WSW, NW (NNW) to SE (SSE) and NE-SSW with deep extents. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not appear to affect the homogeneity of the rock environment.

Magdaléna

The main rock body for the siting of the DGR at the Magdalena site comprises the Milev pluton which consists of amphibole-biotite melagranite to melasyenite of the Čertova load type with indistinct magmatic foliation, the petrological and geochemical variability of which is insignificant from the point of view of the descriptiveness and predictability factor. The Milev pluton exhibits intrusive contacts with the surrounding Moldanubian rocks. The depth range of the granitoids has been estimated at a minimum of 1 km, depending on the orientation of the ductile structures and the extent and shape of the Milev pluton. Veins of leucogranites, aplites and pegmatites of variable thickness and length occur throughout the area. From the point of view of brittle tectonics, two fault zones have been determined consisting of a series of parallel lines of first category faults and fifteen second category faults. With respect to the spatial orientation, several fracture systems have been identified, the most common of which are steep and moderately inclined fractures (inclinations of 70-90° and 60-40°) running in the NE-SW and NW-SE directions and E-W sub-horizontal fractures (inclination of 0–30°) inclined to the N. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks.

Na Skalním (EDU-west)

The main rock body for the siting of the DGR at the Skalní (EDU West) site comprises the Třebíč pluton. From the lithological point of view, the pluton is relatively homogeneous, comprising predominantly porphyritic amphibolite-biotite melagranite to melasyenite (durbachite), with the occurrence of mafic microgranular enclaves. Granites to syenites and vein granites and pegmatites also occur at the site in the durbachite rocks. The geochemical variability of the durbachites is insignificant from the point of view of the descriptiveness and predictability factor, and the petrographic differences in the durbachites refer mainly to textural characteristics in terms of the number and arrangement of feldspar growths. Based on gravimetric modelling, the depth of the southern part of the Třebíč pluton has been estimated at 1,000 m in the north up to 2,500 m. The contacts of the pluton with the surrounding Moldanubian rocks are of an intrusive nature. Granites veins are present in the E-W direction. From the point of view of brittle tectonics, four first category and fifty second category faults have been identified. The fracture system consists mainly of subvertical extension fractures with two main sets of fractures running NNW-SSE and E-W. The commonly observed alterations in the minerals and the subsurface weathering of the rocks do not affect the homogeneity of the rock blocks. Significant alterations have been detected only along the Třebíč fault in the northernmost part of the wider area.

Based on the description of spatial relationships, promising areas for both the geological research and the project design work were defined for all the areas covered by the 3D structural-geological models (Pertoldová et al. 2019, appendix 5 to this report). The knowledge gained was combined so as to create comprehensive 3D structural-geological models of the geological structures (Franěk et al. 2018), (Mixa et al. 2019) and models of fracture failure (Kabele et al. 2018). Thus, it can be stated that the knowledge of the rock environments of all the sites in terms of descriptiveness and predictability and the petrological and spatial variability of the rock environment allows for the creation of reliable comprehensive geological models of the spatial structures from the surface of the sites to the depth of the repository.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Hydraulic characteristics (ID 2.2)

5.4.3 Presence of aquifers in the isolation part of the repository (ID 2.2.1)

Description of the exclusion criterion

One of the exclusion criteria for the siting of the DGR concerns the presence of aquifers (in the isolation part of the repository). Aquifers comprise hydraulically uniform and continuous accumulations of gravitational groundwater in the rock, i.e. a continuous body of water (accumulation) in the collecting rock, which may allow for the occurrence of hydraulic impulses (mass transfer).

Assessment results

The sites were assessed in terms of the occurrence of this exclusion criterion in reports by Havlová et al. 2020a-i. No data is yet available for the assessment of the hydrogeological properties of the deeper parts of the crystalline rocks at the anticipated depth of the DGR. However, it is highly probable that at a depth of 500 m below the earth's surface, the hydraulic conductivity of the rocks will be three to five orders of magnitude lower than in the subsurface zone of weathering with the opening of fractures, and that no continuous accumulation of groundwater will occur. In the deeper parts of crystalline rocks, fractures gradually close, thus leading to a decrease in the hydraulic conductivity of the rock environment. Groundwater flows exclusively through conductive fractures and fault and failure zones. According to data available from ISVS - VODA records (www.voda.gov.cz), water is currently abstracted using exclusively near-surface groundwater resources at all the sites considered.

Neither the groundwater abstraction records or other archived exploratory hydrogeological research indicate the potential for the use of deep groundwater for water management use or the presence of aquifers at any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.4.4 Difficulty of creating hydrogeological models and predicting the development of hydrogeological conditions at the site (ID 2.2.2)

Description of the exclusion criterion

One of the characteristics of areas intended for the siting of a nuclear facility, the presence of which precludes the siting of the DGR, concerns the impossibility of creating hydrogeological models due to the difficulty of describing and predicting the hydrogeological conditions at the site.

Unacceptable uncertainties due to the difficulty of determining the influence of failure zones and other structures on the creation of hydrogeological models of the sites.

Assessment results

The sites were assessed in terms of the occurrence of this exclusion criterion in reports by Havlová et al. 2020a-i.

Detailed hydrogeological models were created for the assessment of the hydrogeological conditions at all the sites (Baier et al. 2020a,b, Černý et al. 2020a,b, Jankovec et al. 2020a,b, Polák et al. 2020, Uhlík et al. 2020a,b) which reflect current knowledge of the groundwater flow conditions at the sites with respect to deep water circulation. They were created on the basis of the use all the archive data available and recently obtained field data which, together, was considered sufficient for the creation of comprehensive hydraulic models. With respect to all the sites, further exploration work will enable the prediction of the hydrogeological conditions at the time of the commissioning, and following the closure, of the repository.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Site stability (ID 2.3)

5.4.5 Earthquakes and the presence of potentially active faults (seismic stability) (ID 2.3.1)

Description of the exclusion criterion

The site of a nuclear facility, and at a distance of up to 5 km from the boundary thereof, must not feature any faults potentially capable of shifting with manifestations on or near the surface. Maximum potential magnitude and soil vibration acceleration values, however, may be used for site comparison purposes.

Assessment results

The Březový potok, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west) sites (Havlová et al. (2020a,c-i)

No relevant data on the age and activity of tectonic failures is currently available for the assessment of potentially active faults at the above sites. If no potential for fracture movement has been proven or indicated, it is assumed that it does not exist. No fracture activity has been indicated for the assessed areas of these sites over the last 2.6 million years.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čertovka (Havlová et al. 2020 b)

A significant morpho-lineament bound to the Žihel fault (ID1) passes through the area (Franěk et al. 2018). This straight running fault slope has a developed clear upper edge, on which drainage structures have been created comprising deep ravines with short catchments areas. Such characteristics may indicate relatively young movements along the fault; however, similar geomorphological manifestations occurred as the result of the recent denudation of the inactive structure that separates the sediments of the Žihel basin from Tiský massif granitoids, which exhibit differing degrees of susceptibility to erosion. Therefore, the above morphological characteristics cannot be considered to be unambiguous indications of the presence of a fault with the potential for displacement. No further data is available on the age and activity of the tectonic features that might serve for the evaluation of potentially active faults at this site. No fracture activity has been indicated for the assessed area of this site over the last 2.6 million years.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.4.6 Subsidence or uplift of the surface of the area (vertical movements of the earth's crust) (ID 2.3.2)

Description of the exclusion criterion

The siting of the DGR is excluded at sites where movements of the earth's crust are greater than 1 mm/year.

Assessment results

Data on the sites was taken from Havlová et al. 2020a-i.

Archive data on the rate of the subsidence of the drainage system is only available at the regional scale. Values of 0.02 - 0.86 mm/year are given for the rate of subsidence during the Pleistocene based on elevation differences between aligned surfaces and preserved fluvial sediments. Correlations of the Elbe and Vltava terraces suggest average uplift rates of the central part of the Bohemian Massif in the Lower Pleistocene of 0.04 mm/year and, during the Middle and Upper Pleistocene, of up to 0.15 mm/year.

Studies based on dating methodology using the isotopes ^{10}Be and ^{26}Al are available only for the wider area of the Bohemian Massif. Erosion rates of 0.023 - 0.027 mm/year have been estimated for the southwestern edge of the Bohemian Massif and 0.025 - 0.027 mm/year for the Šluknov promontory area during the Middle and Upper Pleistocene.

While the candidate sites do not exhibit identical geological characteristics to those of the areas that were subjected to these measurement methods, they are located in similar geomorphological environments. Since similar erosion and denudation rates can be expected at the candidate sites, this data is taken into account in the site assessment process.

With respect to the **Březový potok, Čertovka, Čihadlo, Hrádek, Janoch (ETE-south) and Magdaléna** sites, no information on the rate of the deepening of the river systems is available on the immediate surroundings; the sites were assessed on the basis of data for the Bohemian Massif.

At the **Horka and Na Skalním (EDU-west)** sites, the position of preserved Lower Pleistocene terraces at the confluence of the Oslava and Jihlava rivers, the bases of which lie approximately 60 to 70 m above the current surface of the floodplain, indicate low rates of the deepening of the drainage system. This elevation difference corresponds to rates of the deepening of the river system in the order of hundreds to the low tenths of millimetres per year. The position of river terraces in the Dyje-Svratka valley corresponds to similar rates of deepening, where the base of the Lower Pleistocene terraces is 30 to 70 m above the current floodplain and the Middle Pleistocene terraces are located at a relative elevation of around 15 to 25 m above the current floodplain.

At the **Kraví hora** site, data on the rate of the deepening of the river system from the wider surroundings is available only in relation to the geomorphological position of the preserved terraces. The rates of deepening of the river system in the Svratka river basin in the area above Tišnov have been estimated in the Upper Miocene and Pliocene at 0.003 - 0.01 mm/year, during the Older Pleistocene at 0.03 - 0.04 mm/year, in the Middle Pleistocene at 0.06 - 0.09 mm/year and during the Upper Pleistocene at 0.05 - 0.1 mm/year, which is comparable to the rates of deepening and the positions of river accumulations in the Dyje-Svratka valley.

It follows from the above that the values of the vertical movements of the earth's surface, i.e. the rate of the deepening of the drainage system do not exceed 1 mm/year for any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.4.7 Post-volcanic phenomena (ID 2.3.3)

Description of the exclusion criterion

Sites with post-volcanic phenomena (gas outflows, thermal water, etc.) will be excluded.

Assessment results

Data on the various sites was taken from Havlová et al. 2020a-i.

The **Březový potok, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west)** sites are located outside the area of Cenozoic volcanism associated with the development of the Ohře rift and the dispersed alkaline magmatism of the Bohemian Massif and the Carpathian arch. There are no known manifestations of volcanic or post-volcanic activity of the Pliocene to Holocene eras within a radius of 5 km of any of these sites.

At the **Čertovka** site, the promising area for the geological research intersects lines of volcanic bodies of olivine nephelinite in the E - W direction. The easternmost and most extensive body represents a lava flow remnant, while the other bodies represent erosive remnants of small slag cones. The age of the olivine nephelinite at Tis was determined using the K-Ar method at

13.74 ± 1.25 Ma. The dimensions of the bodies and their presumed venous-elongated feeding pathways point to the very rapid cooling and crystallisation process of the magma. It is unlikely that any post-volcanic manifestations occurred in the area immediately following eruption. Occurrences of remnant of the volcanic complex of the Doupov mountains, which was volcanically active 34–20 million years ago, extend to the north-western edge of the area of the 3D structural geological model of the Čertovka site. The consequences of post-volcanic manifestations (e.g. the hydrothermal alteration of the rocks) may have occurred in the area 10 million years ago (unpublished data). However, no post-volcanic manifestations of the Quaternary are known in the area. To the west of the boundary of the 3D structural geological model, the Vladař hill, the remnant of a separate smaller volcano, is characterised by dispersed remnants from the isolated Tepelská and Slavkov volcanic bodies. The age of the activity of this volcanic field is stated to be 22 to 6.25 million years. Throughout the Tepelská and Slavkov areas, the volcanic activity took the form of separate eruptions, without the prolonged subsequent post-volcanic manifestations related to the degassing of cooling magma. There are no known manifestations of Pliocene to Holocene volcanic or post-volcanic activity within a radius of 5 km of the promising area for the project design work at the site.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Characteristics that could lead to the disturbance of the repository via future human activities (ID 2.4)

5.4.8 Presence of old mine workings (ID 2.4.1)

Description of the exclusion criterion

The presence of old mine workings precludes the siting of a nuclear facility.

Assessment results

Data on the various sites was taken from Havlová et al. 2020a-i

Březový potok, Čertovka, Horka, Janoch (ETE-south), Magdaléna, Na Skalním (EDU-west)

No old or abandoned mine workings are registered at these sites.

There is no risk of any conflict of interest with mined areas, the instability of the area in terms of old mining burdens or the threat of underground anthropogenic weakened zones.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čihadlo

No old or abandoned mine workings are registered at the Čihadlo site.

The only larger-scale mined area lies to the east, outside the defined promising area for the project design work, in an area featuring a uranium ore zone near Okrouhlá Radouň.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Hrádek

In the promising area for the geological research of the Hrádek site, 8 mine workings are registered in the database of mine workings maintained by the Czech Geological Survey, consisting of 7 old mine workings and one abandoned exploratory building stone mine working which reaches a depth of 22 m. They comprise near-surface workings outside the polygons defined for the promising areas for the project design work.

The identified phenomena are outside the promising area for the project design work.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Kraví hora

A total of 79 mine workings are registered in the database of mine workings maintained by the Czech Geological Survey for the promising area for the geological characterisation research at the Kraví hora site, of which 78 are abandoned mines following the mining of radioactive raw materials and one abandoned asbestos rock exploratory mine, which reaches a depth of 21 m.

Uranium ore was mined to a depth of 900 m below the surface in the Olší nad Oslavou – Drahonín area. The total length of the horizontal mine workings was 141.4 km. A further 52 boreholes of more than 300 m deep were also drilled in the area for exploration purposes.

The results of the assessment indicated the presence of obstacles to the siting of the DGR at the Kraví hora site. The presence of a protected deposits area for an underground gas storage facility and the definition of deposit areas for radioactive raw materials and building stone in the promising area for the geological research in the Kraví hora area represents indications of potential conflicts of interest, as does the presence of old mine workings.

However, administrative and/or technical remediation measures are available with concern to both conflicts of interest. Regarding the protected deposits area, the options comprise the adjustment, cancellation or change of the scope of the protected deposits area. In the case of mined areas and old boreholes, it must be taken into account that they do not occur in the promising area for the project design work and that this issue can be solved via the application of technical measures (technical support, filling, etc.). Hence, the Kraví hora site was not rejected from the list of candidate sites for assessment based on the defined comparative criteria.

The information obtained on the assessed properties indicates an obstacle or problem in terms of meeting the respective requirement, or potential problems with the demonstration thereof (the risk outweighs the opportunity).

5.4.9 The presence of mineral resources (ID 2.4.2)

Description of the exclusion criterion

There must be no mineral resource reserves at depths greater than 100 m.

Assessment results

Data on the various sites was taken from Havlová et al. 2020a-i.

Březový potok

The assessment of currently available data on the exploration of deposits leads to the conclusion that current and future human activity involving the economic extraction of building stone and stone for other purposes will not reach such a depth below the earth's surface at which conflicts of interest can be expected with the siting of the DGR.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čertovka

The assessment of currently available data on the exploration of deposits indicates that two deposits and three potential sources at the Čertovka site are used locally or represent unmined surface deposits, respectively, and that human activity involving the future mining of building and brick raw materials will not reach such a depth below the earth's surface that they will conflict with the siting of the DGR.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čihadlo

The assessment of available data on the exploration of deposits with respect to current and future human activity in terms of the economic mining of building stone and stone for other purposes indicates that such activities will not reach such a depth below the earth's surface at which the construction of the DGR is anticipated.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Horka

The assessment of available data on the exploration of deposits indicates the absence of deposits and predictions of the future exploitation of mineral sources at the Horka site; thus, such activities will not reach such a depth below the earth's surface at which the construction of the DGR is anticipated.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Hrádek

The assessment of available data on the exploration of deposits and current and future human activities in terms of the economic extraction of minerals, building stone and stone for other purposes indicates that such activities will not reach such a depth below the earth's surface at which the construction of the DGR is anticipated.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Janoch (ETE-south)

The deposits and defined reserves of raw materials in the area do not represent potential conflicts in terms of the disruption of the DGR via future human activities associated with raw material extraction.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Kraví hora

The northern edge of the promising area for the geological characterisation research work situated in a narrow zone between Bukov and Jabloňov overlaps with an area that has been defined as a protected area for the siting of an underground gas storage facility. The detailed definition of the priority status of the DGR and the gas storage facility, the relationship between the two defined areas and the geo-technological parameters for the two projects remain uncertain. This conflict of interest can be resolved via the application of technical-administrative measures.

The information obtained on the assessed properties indicates an obstacle or problem in terms of meeting the respective requirement, or potential problems with the demonstration thereof (the risk outweighs the opportunity).

Magdaléna

The assessment of currently available data on the exploration of deposits indicates that most of the mines and two surface deposits at the Magdaléna site are used locally, and that human activity involving the future extraction of building and brick raw materials will not reach such a depth below the earth's surface that it will conflict with the siting of the DGR.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Na Skalním (EDU-west)

There are currently no deposits, protected deposit areas or predicted sources of raw materials in the defined promising area for the geological characterisation research. The defined area features just 2 recultivated surface mines, which are currently considered unsuitable for future re-use.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.4.10 The presence of underground bodies of water or geothermal energy sources (ID 2.4.3)

Description of the exclusion criterion

The rock environment must not contain significant water sources or have the potential for the use of geothermal energy.

With respect to groundwater circulation, the existence of significant bodies of groundwater that could be permanently contaminated with radioactive substances and/or the presence of geothermal energy sources preclude the siting of a nuclear facility.

Assessment results

According to a report by Krajíček et al. (2020), it is not possible to definitively assess the presence of significant bodies of groundwater at the sites (i.e. to the extent required by the safety report); thus, this criterion was assessed in terms of the presence of water sources and the number of people they supply.

The final proof of zero impact on these sources, including potential measures that ensure their protection, will be provided as part of the relevant safety report according to Appendix 1, point 1, a), b) and e) of Act No. 263/2016 Coll., the Atomic Act.

The existence of bodies of groundwater with the above characteristics has not been proven at any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

The current state of knowledge (Havlová et al. 2020a-i) indicates the presence of no sources of geothermal energy that are potentially industrially exploitable at any of the sites. The risk of human penetration into the repository or changes in the rock mass due to the exploitation of the geothermal potential is low.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.5 Excluding operational safety criteria (ID 3)

Natural phenomena (ID 3.1)

5.5.1 The occurrence of faults (ID 3.1.1)

Description of the exclusion criterion

The occurrence of a zone with a physically or seismically active fault or other movement of the earth's crust that could result in damage to a nuclear facility, thus negatively affecting nuclear safety - up to a distance of 5 km, or the occurrence of an accompanying fault precludes the siting of a nuclear facility,

Assessment results

This criterion is based on the same research and descriptive reports as those considered by the Earthquake and presence of potentially active faults (seismic stability) criterion, with the difference that it relates to the siting of the DGR surface area. The assessment of all the sites was performed by Lahodová and Popelová (2020) and was derived from the summarisation of the findings in Havlová et al. 2020a-i, with the same results (see chapter 5.4.5).

With respect to the **Březový potok, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west)** sites, no relevant data on the age and activity of such tectonic failures is available for the assessment of potentially active faults at the sites. However, there are no indications of fracture activity at these sites over the last 2.6 million years. If no potential for movement along fractures has been proven or indicated, it is assumed that it does not exist.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čertovka

A significant morpho-lineament bound to the Žihel fault (ID1) passes through the area (Franěk et al. 2018). This straight running fault slope has a developed clear upper edge, on which drainage structures have been created comprising deep ravines with short catchments areas. Such characteristics may indicate relatively young movements along the fault; however, similar geomorphological manifestations occurred as the result of the recent denudation of the inactive structure that separates the sediments of the Žihel basin from Tiský massif granitoids, which exhibit differing degrees of susceptibility to erosion. Therefore, the above morphological characteristics cannot be considered to be unambiguous indications of the presence of a fault with the potential for displacement. No further data is available on the age and activity of the tectonic features that might serve for the evaluation of potentially active faults at this site. No fracture activity has been indicated for the assessed area of this site over the last 2.6 million years. If no potential for displacement along a fracture has been proven or indicated, it is assumed that it does not exist.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.5.2 Flooding (ID 3.1.2)

Description of the exclusion criterion

The potential for the regular flooding of the land of a nuclear facility due to extreme meteorological situations with a probability of occurrence of once every 100 years or higher precludes the siting of the DGR.

Assessment results

This criterion relates to the land of the surface area with respect to the occurrence of floods on the surface within reach of watercourse floodplains or terrain depressions following the occurrence of extreme climatic phenomena such as heavy rains or rapidly melting snow. Given that the underground part of the repository is connected to the surface area and the entrances to the underground complex are situated in the surface area, this criterion also covers the underground part of the DGR.

The siting of the surface areas was considered so as to minimise such conflicts of interest and to avoid the occurrence of exclusionary characteristics. Thus, all the surface areas are located outside floodplains. Protection against rapidly melting snow and heavy rains can be assured by the application of the relevant technical and administrative measures. Thus, it follows that none of the conditions that suggest potentially dangerous conditions in terms of this criterion apply at any of the sites.

The criterion was assessed for all the sites according to Lahodová and Popelová (2020):

Březový potok

The surface area is planned so as to be outside the reach of the specified Q100 flood area of the Březový stream.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čertovka

The surface area is planned so as to be outside the reach of the specified Q100 flood area of the Blšanka stream.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Čihadlo

The surface area is planned so as to be outside the reach of the specified Q100 flood areas of the Dírensky and Radouňsky streams.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Horka

The surface area is planned so as to be outside the reach of the specified Q100 flood areas of the Balinka and Oslava streams.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Hrádek

The whole of the surface area is planned so as to be outside flood areas

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Janoch (ETE-south)

The whole of the surface area is planned so as to be outside flood areas

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Kraví hora

The surface area is planned so as to be outside the reach of the specified Q100 flood areas of the Bobrůvka (Loučka) and Nedvědička streams.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Magdaléna

The surface area is planned so as to be outside the reach of the specified Q100 flood area of the Smutná stream.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Na Skalním (EDU-west)

The surface area is planned so as to be outside the reach of the specified Q100 flood area of the Rouchovanka stream.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

Factors influencing the management of exceptional situations (ID 3.2)

5.5.3 Proximity to an international border (ID 3.2.1)

Description of the exclusion criterion

This criterion is defined in the MP.22 methodological guidelines in connection with the effective implementation of protective measures in the event of an emergency situation and the minimisation of negative impacts on the population.

Assessment results

The criterion was assessed for all the sites according to Lahodová and Popelová (2020).

The assessment of the areas on the basis of the management of emergencies was conducted with regard to the distribution and density of settlements and the development thereof, and the potential for the implementation of emergency protective measures. The elimination of the negative factors of this criterion is possible via the application of technical and/or administrative measures.

The direct distances of the boundaries of the surface areas of the sites from state borders with Austria or Germany are shown in Tab. 4; the shorter distances to either of the state borders from the surface areas are provided. The Čihadlo site is closest to a state border, i.e. around 20 km from the boundary of the surface area. This distance has no exclusion value.

Tab. 4 Distances of the sites from international borders

Site	Distance in km from the border with	
	Austria	Germany
Březový potok		38
Čertovka		39
Čihadlo	20	
Horka	44	
Hrádek	39	
Janoch (ETE-south)	43	
Kraví hora	66	
Magdaléna	59	
Na Skalním (EDU-west)	26	

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.5.4 Ensuring access for rescue units (ID 3.2.2)

Description of the exclusion criterion

The lack of access for fire, mining rescue and ambulance services.

Assessment results

The criterion was assessed for all the sites according to Lahodová and Popelová (2020).

This criterion is defined in the MP.22 methodological guidelines in connection with the effective implementation of protective measures in the event of an emergency situation and the minimisation of negative impacts on the population. The assessment of the areas on the basis of the management of emergencies was conducted with regard to the distribution and density of settlements and the development thereof, and the potential for the implementation of emergency protective measures. The elimination of the negative factors of this criterion is possible via the application of technical and/or administrative measures.

The arrival time of rescue services was verified for all the sites at a maximum of 10 minutes. In addition, the construction of a fire, mining rescue and paramedic facility is being considered for the DGR surface areas of all the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.5.5 Ensuring information and evacuation (ID 3.2.3)

Description of the exclusion criterion

The impossibility of communicating timely information to, and the evacuation of, the population.

Assessment results

The criterion was assessed for all the sites according to Lahodová and Popelová (2020).

This criterion is defined in the MP.22 methodological guidelines in connection with the effective implementation of protective measures in the event of an emergency situation and the minimisation of negative impacts on the population. The assessment of the areas on the basis of the management of emergencies was conducted with regard to the distribution and density of settlements and the development thereof, and the potential for the implementation of emergency protective measures. The elimination of the negative factors of this criterion is possible via the application of technical and/or administrative measures.

Ensuring the provision of information for, and the evacuation of, the population are not considered relevant factors at this stage of DGR development. The fulfilment of these criteria will be ensured via the adoption of the appropriate project technical design measures.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.5.6 Ensuring measures against sabotage (ID 3.2.4)

Description of the exclusion criterion

The inability to secure the facility against sabotage precludes the siting of the DGR.

Assessment results

The criterion was assessed for all the sites according to Lahodová and Popelová (2020).

This criterion is defined in the MP.22 methodological guidelines in connection with the effective implementation of protective measures in the event of an emergency situation and the minimisation of negative impacts on the population. The assessment of the areas on the basis of the management of emergencies was conducted with regard to the distribution and density of settlements and the development thereof, and the potential for the implementation of emergency protective measures. The elimination of the negative factors of this criterion is possible via the application of technical and/or administrative measures.

Securing the DGR against sabotage is not considered a relevant factor at this stage of DGR development. The fulfilment of this criterion will be ensured via the adoption of the appropriate project technical design measures.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6 Exclusion criteria in terms of environmental impacts

The occurrence of specially protected natural areas

5.6.1 Occurrence of UNESCO biosphere reserves (ID 4.1.1)

Description of the exclusion criterion

The area designated for the surface area must not feature a UNESCO biosphere reserve (Article 1 of Ministry of Foreign Affairs communication No. 159/1991, Coll. Convention Concerning the Protection of the World Cultural Heritage).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside UNESCO biosphere reserves. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6.2 Occurrence of national parks (ID 4.1.2)

Description of the exclusion criterion

The area intended for the surface area of the DGR must not be situated in a national park. (Act No. 114/1992 Coll.).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside national parks. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6.3 Occurrence of a protected landscape area (ID 4.1.3)

Description of the exclusion criterion

The area intended for the surface area of the DGR must not be situated in a protected landscape area (Act No. 114/1992 Coll.).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside protected landscape areas. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6.4 Occurrence of national natural monuments and national nature reservations (ID 4.1.4)

Description of the exclusion criterion

The area intended for the surface area of the DGR must not be situated in areas with the occurrence of national natural monuments and national nature reservations (in all cases this refers to so-called specially protected natural area categories - Act No. 114/1992 Coll.).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside areas with national natural monuments and national nature reservations. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6.5 Occurrence of a Natura 2000 site (Area of European Importance, Bird Protection Areas) (ID 4.1.5)

Description of the exclusion criterion

The area intended for the surface area of the DGR must not be situated in Areas of European Importance and must not interfere with Bird Protection Areas (Act No. 114/1992 Coll.).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside areas of European importance and bird protection areas. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.6.6 Occurrence of nature reserves and natural monuments (ID 4.1.6)

Description of the exclusion criterion

The area intended for the surface area of the DGR must not be situated in nature reserves or at sites with natural monuments (Act No. 114/1992 Coll.).

Assessment results

The sites were assessed according to Krajíček et al. 2020.

The locations of the surface areas were determined in such a way that conflicts of interest were minimised and the conditions for the non-application of the exclusion criterion were fulfilled. Therefore, all the DGR surface areas are located outside nature reserves and areas with natural monuments. It follows from the above that the excluding conditions resulting from the given criterion do not apply to any of the sites.

The information obtained led to the conclusion that the requirement had been met (the opportunity outweighs the risk), i.e. no property was identified at any of the sites that led to their exclusion.

5.7 Conclusion of the assessment of the exclusion criteria

Based on the assessment of the available data, including data provided by Butovič et al. 2020, Havlová et al. 2020a-i, Lahodová and Popelová 2020, Krajíček et al. 2020, and in accordance with the defined methodology (Vondrovic et al. 2019), it can be stated that none of the sites are in direct violation of the exclusion criteria according to MP.22 (Vokál et al. 2017). Only at the Kraví hora site is there a conflict with the exclusion criteria related to past mining activities (IDs 2.4.2 and 2.4.1); however, this conflict can be resolved through the application of the appropriate technical and/or administrative measures. Therefore, all the sites were selected for consideration in the second stage of the assessment process.

5.8 Assessment and comparison of the sites according to the key criteria

The second stage of the assessment process involved the comparison of the sites applying the key criteria specified in the assessment methodology (Vondrovic et al. 2019).

5.8.1 Criterion C1: Size of the usable rock mass

Description of the criterion: the technical design solution of the DGR must primarily respect the structural and tectonic conditions of the host rock mass in order to fully meet the various long-term safety requirements. The potentially usable rock blocks must be at such a depth and at a sufficient distance from aquifers so as to prevent human access to the waste, to ensure that the repository is not affected by surface processes and to prevent the rapid migration of radionuclides into water-bearing fault zones. A sufficient depth for the DGR for the disposal of spent nuclear fuel is considered to be several hundred metres beneath the earth’s surface. One of the most important features of the rock environment concerns the density of smaller fracture zones and larger fractures that preclude the emplacement of waste disposal packages (WDP) in the rock mass. However, it is not possible to assess this property as part of the geological research of the surface, i.e. in the initial site selection phase. From the point of view of feasibility, it should be taken into account that the disposal spaces may intersect with a number of brittle deformations (faults and fractures), fracture zones and other lithological and structural inhomogeneities. Simple faults can be remedied during the drilling stage using grouting compounds, which must be carefully selected so that they do not adversely affect the various components of the engineered barriers. Areas that feature more serious inhomogeneities should be excluded. When determining the size of the massif, it is necessary to take into account sufficient distances from significant faults/fractures both to ensure long-term safety and the mechanical stability of the underground spaces. The Czech DGR reference concept considers engineered barriers for the disposed of spent nuclear fuel based on a “WDP-bentonite” system. The most limiting condition of the disposal system as a whole concerns the limit temperature of approximately 100°C, at which the degradation and loss of the safety functions of bentonite may occur. The residual heat output of the spent nuclear fuel and the thermal properties of the engineered barriers and the rock environment thus constitute two of the most important basic design parameters, important in terms of the assessment of the rock mass for its usability for the location of the DGR. A further important project parameter concerns the WDP disposal method. The construction of the DGR is being considered with one or two disposal horizons. Furthermore, both vertical disposal in wells drilled in disposal corridors and disposal in horizontal boreholes are currently being considered. This criterion was assessed in a report by Butovič et al. (2020).

Description and assessment of the indicators

C1a - Usability of the rock blocks

Description of the indicator: the indicator is determined as a percentage of the area required for the construction of the SNF disposal sections and RAW chambers of the total area of the potentially usable disposal area. The sizes of the disposal areas are based on a project design proposal (e.g. Bureš et al 2018 and the update thereof based on the results of the "Geofyzika" project, Mixa et al. 2019, Pertoldová et al. 2019) that takes into account distances between the WDPs determined on the basis of thermal and stability calculations (Kobylka et al. 2019), which include:

- thermal properties of the rock and an initial temperature at a depth of 500 m during disposal that do not exceed a limit temperature of 95°C throughout the lifetime of the DGR,
- mechanical and physical parameters of the rock that allow for the safe excavation of the underground spaces and minimise the occurrence of excavation damaged zones.

The area of the underground part of the DGR will be determined based on the above calculations and data from reports that evaluate the mechanical and thermal properties of representative lithologies at the various sites (Petružálek et al. 2017), and fully considering the technical requirements for the construction of the DGR (excavation technology, drainage, ventilation, etc.). For comparison purposes, a conservative option with the largest volume of excavated material (a combination of the vertical disposal method and machine excavation) was selected. The minimum axial distances between the WDPs and the various loading corridors, in combination with the technical requirements for the construction of the DGR (excavation technology, drainage, ventilation, etc.), will determine the dimensions of the underground disposal area for SNF. The chambers intended for the disposal of RAW shall be included in the total disposal area with regard to the determination of the usability of the homogeneous block only if it is not possible to locate them other than at the same level as that of the SNF disposal area (500 m beneath the earth's surface).

Quantification: the percentage of the usable area of the rock blocks (promising area for the project construction work without any areas that are unusable with respect to disposal, i.e. mainly fault structures).

Results of the assessment of indicator C1a

This indicator was assessed in detail in Butovič et al. (2020). The basic inputs for the assessment comprised the areas designated promising for the project design work (Pertoldová et al. 2019), into which the reference project design was inserted (the underground complex of the DGR, i.e. the disposal spaces necessary for the disposal of the expected volume of waste) according to the respective calculations (Kobylka 2018). The area reserve for the occurrence of category II faults and fragments deemed unusable for the project were deducted from the promising areas for the project design work, and the preliminary design solution was inserted into the most suitable part of the site for site comparison purposes (procedure according to Butovič et al. 2020). The assessment results are summarised in Tab. 5 and Fig. 14.

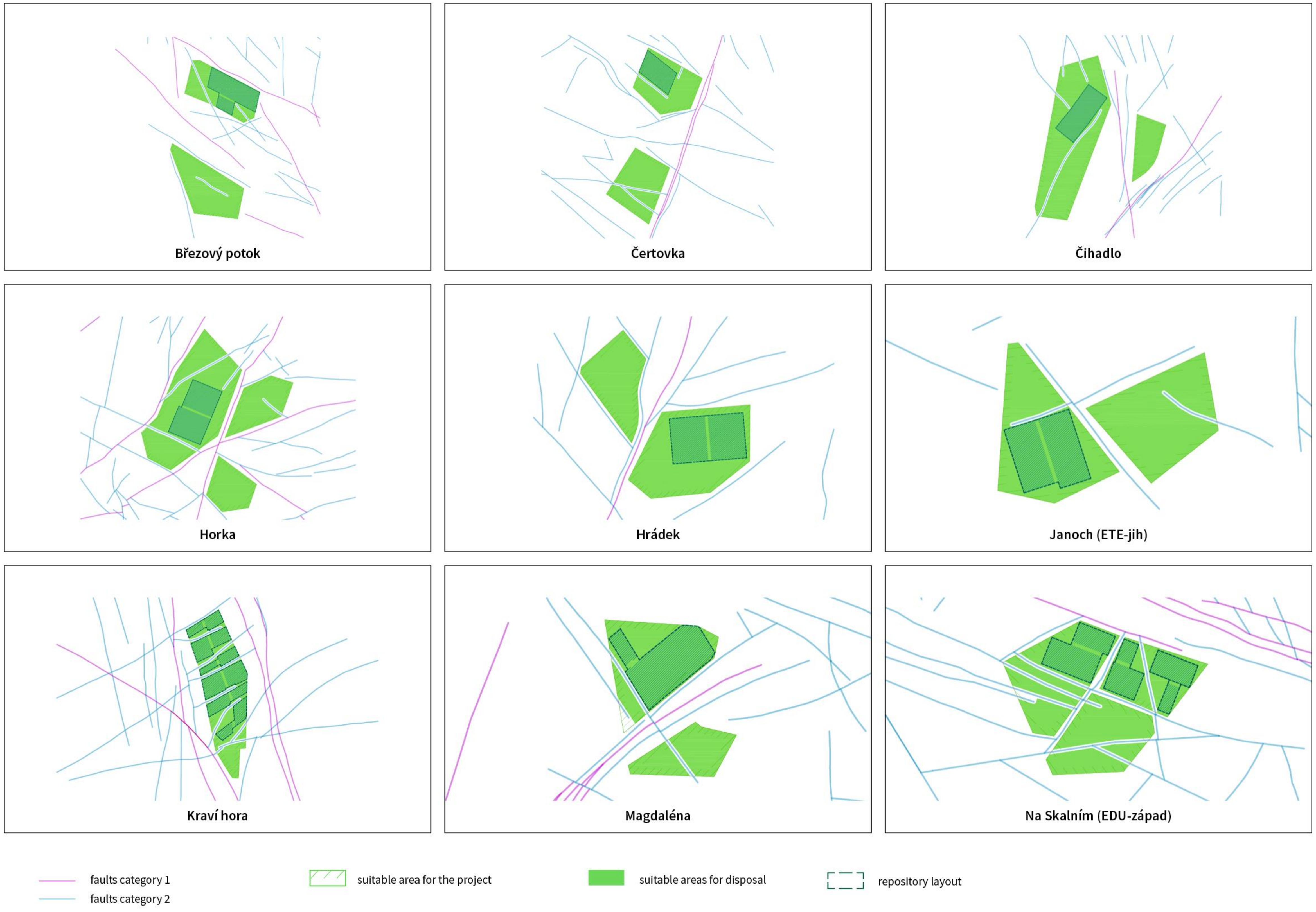


Fig. 14 Schemes of the usability of the land at the sites according to Butovič et al (2020)

Tab. 5 Overall assessment of the sites for indicator C1a according to Butovič et al. (2020)

Site	**Total Area considered promising for the project design work at repository depth** [m²]	**Unusable areas for disposal** [m²]	**Usable areas for disposal** [m²]	**Disposal area** [m²]	**Use of the rock blocks** [%]	**Indicator grade**
Březový potok	12 315 211	503 057	11 812 154	2 944 729	24.93	1.46
Čertovka	10 017 424	599 977	9 417 447	1 530 000	16.25	1.05
Čihadlo	14 050 927	718 369	13 332 558	2 030 466	15.23	1.0
Horka	14 907 830	671 538	14 236 292	2 497 119	17.54	1.11
Hrádek	9 861 730	0	9 861 730	2 671 020	27.08	1.56
Janoch (ETE-south)	10 169 161	276 484	9 892 677	2 368 963	23.95	1.41
Kraví hora	5 463 370	815 175	4 648 195	3 053 775	65.70	3.38
Magdaléna	5 406 682	364 926	5 041 756	2 134 212	42.33	2.28
Na Skalním (EDU-west)	9 124 696	1 092 825	8 031 870	2 623 746	32.67	1.82

C1b Fragmentation of the area

Description of the indicator: the indicator expresses the extent to which the defined suitable rock mass is fragmented, and represents the number of individual partial rock blocks in which the DGR can be effectively constructed and RAW disposed of with regard to the size and shape of the blocks. Due to the current uncertainty concerning the real geological and hydrogeological conditions, it is desirable that the potentially usable rock environment consists of as few rock blocks as possible (ideally just one completely compact block).

Quantification: the number of fragmented blocks in the promising area for the project design work that can be used for the disposal of SNF and RAW.

Results of the assessment of indicator C1b

The fragmentation of the area is determined mainly by the presence of continuous faults, which divide the area into smaller units. For some faults, which only partially impact the promising area for the project design work, their orientation and length are considered with respect to the layout of the disposal sections. In the event that such faults negatively affect the potential location of the disposal spaces, and their presence results in the necessity to divide or otherwise significantly modify the layout of the disposal spaces, the project area will be divided into several fragments.

Furthermore, a situation may arise in which the area is divided into practically unusable areas (in terms of size, shape and accessibility). In this case, these areas are considered unusable with regard to the potential siting of the DGR (as with faults), i.e. such fragments are not included in the consideration of the fragmentation of the area. Area fragmentation was assessed in Butovič et al. (2020).

Tab. 6 Overall assessment of the sites for indicator C1b according to Butovič et al. (2020)

Site	**Fragmentation of the area [no.]**	**Indicator grade**
Březový potok	4	2.5
Čertovka	5	3.0
Čihadlo	3	2.0
Horka	6	3.5
Hrádek	2	1.5
Janoch (ETE-south)	4	2.5
Kraví hora	8	4.5
Magdaléna	4	2.5
Na Skalním (EDU-west)	9	5.0

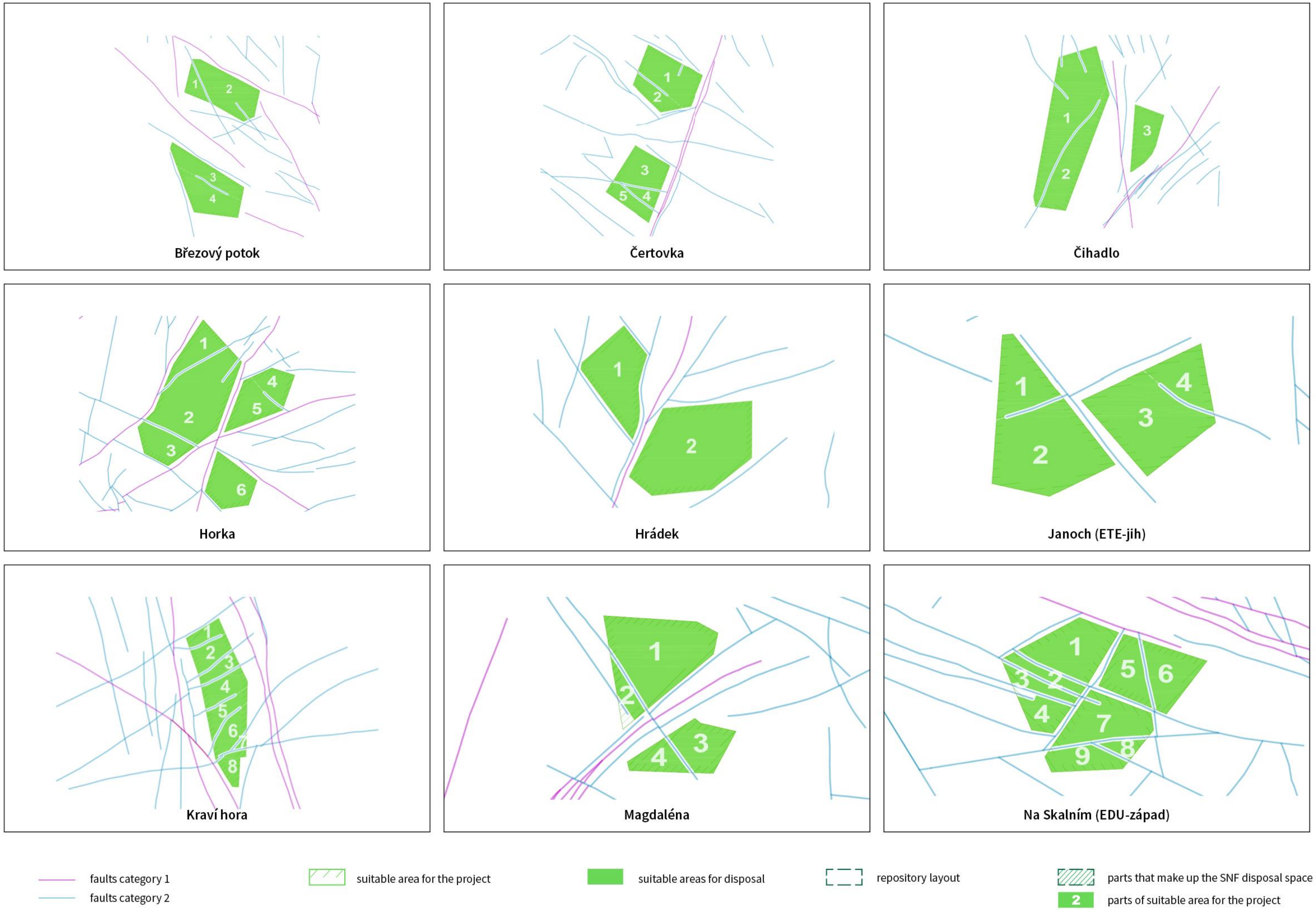


Fig. 15 Schemes of the fragmentation of the areas according to Butovič et al (2020)

C1c Fragmentation of the underground part of the DGR

Description of the indicator: the indicator takes into account the number of parts into which the disposal spaces for the SNF in the underground complex of the DGR will be divided, i.e. one compact space or several smaller, interconnected spaces. The division is related to the spatial requirements according to the final project design and the potential of the sites in terms of the expected geological and hydrogeological conditions. The division of the disposal spaces into several smaller areas raises the prospect of potential complications with drainage and ventilation, the prolongation of the time needed to transport the waste for disposal and increases in construction costs.

Quantification: the number of parts that make up the SNF disposal space, designed with regard to the density and orientation of 1st and 2nd category faults, i.e. the layout of the usable disposal spaces.

Results of the assessment of indicator C1c

The boundaries of the SNF disposal space are defined as encompassing the area that comprises the emplacement corridors between the sealing plugs. The SNF and RAW disposal areas are located in blocks of rock that allow for the disposal of SNF in disposal wells (boreholes) and RAW in disposal chambers. The SNF disposal area includes a reserve of half the projected distance between the disposal corridors. With respect to the disposal chambers, this distance is half that of the distance between the chambers. In some cases, the SNF disposal spaces are divided into several fragments due to the occurrence of an insufficiently large rock block or block with an unsuitable shape for the location of the disposal areas in one integral block. For technical and operational reasons with respect to the simultaneous excavation and disposal approach envisaged during the operation of the DGR, it will, therefore, be necessary to divide the disposal areas. In other words, the SNF disposal spaces will be divided into fragments physically separated by areas that are unusable for disposal purposes. Such areas may comprise fault structures or backbone and connecting corridors. If the disposal space is divided into two fragments separated by a backbone corridor, this space is included in the total SNF disposal area. Areas with RAW disposal chambers will be included in the total disposal area only if it is not possible to dispose of RAW at a higher level than the depth of the SNF disposal area, i.e. 500 m below the surface. In this case, the area with the RAW chambers is considered to be a separate fragment. The sites were evaluated in Butovič et al. 2020 and the results are summarised in Tab. 7

Tab. 7 Overall assessment of the sites for indicator C1c according to Butovič et al. (2020)

Site	Fragmentation of the underground part of the DGR	Indicator grade
Březový potok	2	1.36
Čertovka	1	1.0
Čihadlo	1	1.0
Horka	2	1.36
Hrádek	2	1.36

Site	**Fragmentation of the underground part of the DGR**	**Indicator grade**
Janoch (ETE-south)	2	1.36
Kraví hora	12	5.0
Magdaléna	2	1.36
Na Skalním (EDU-west)	6	2.82

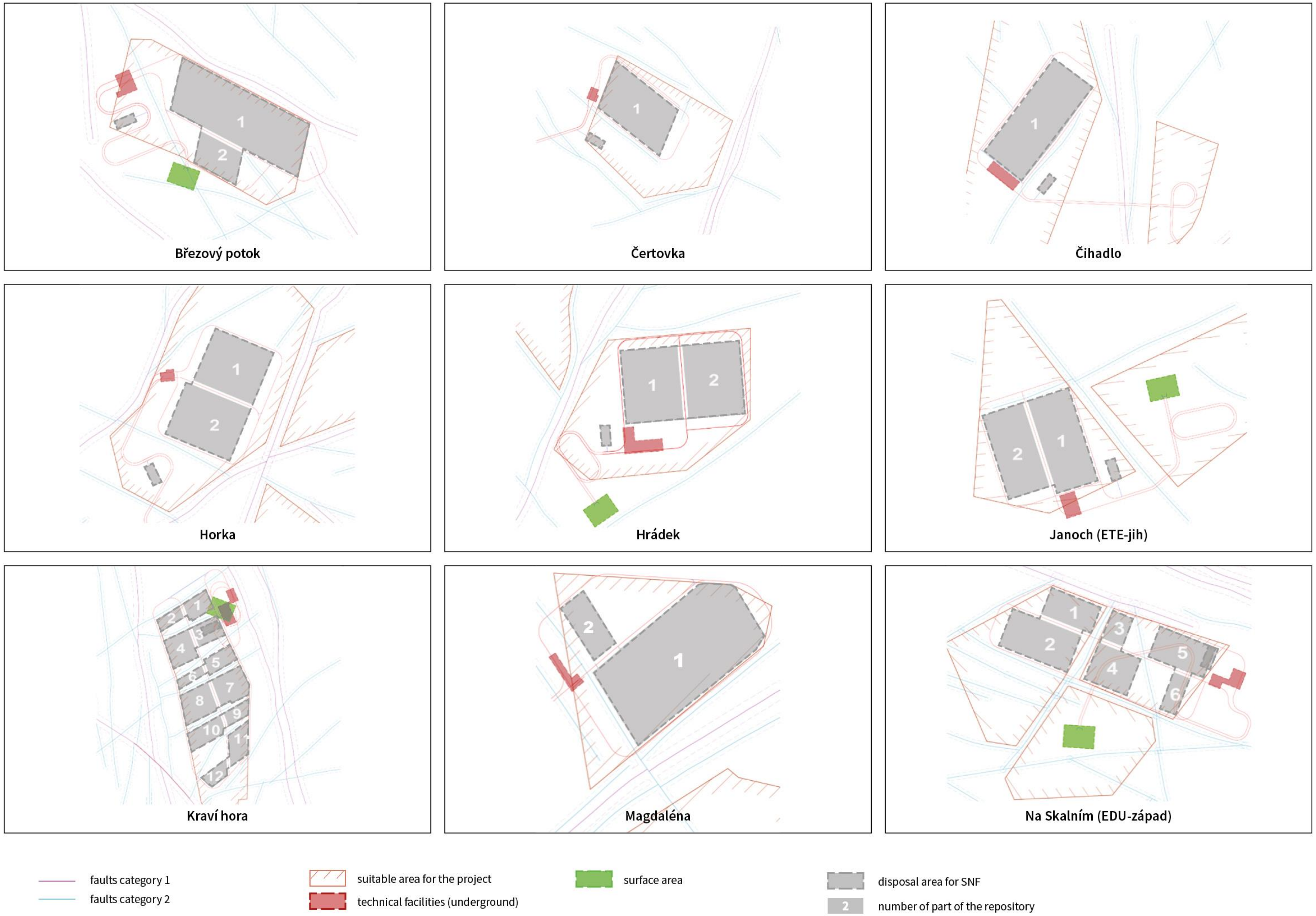


Fig. 16 Schemes of the fragmentation of the underground parts of the DGR according to Butovič et al (2020)

5.8.2 Criterion C2: Infrastructure availability

Description of the criterion: in order to ensure the construction and operation of the DGR, with respect to the preparation of the project, requirements are set concerning accessibility for construction and connection to infrastructure systems, both transport and technical. According to studies conducted to date, connection to the necessary transport and technical infrastructure systems is possible at all the candidate sites, thus the differences between the sites can be expressed only in terms of the financial costs of connecting to the existing infrastructure. Since the primary aim of this site assessment phase is to reduce the number of sites at which a safe and environmentally-friendly DGR can be constructed, economic indicators are not yet being considered. Therefore, only the following indicator was defined for this criterion, which is currently seen as more relevant than economic considerations:

Description and assessment of the indicator

C2a Potential for the permanent disposal of excavated material in the vicinity

Description of the indicator: the indicator reflects the expected excess volume of excavated material from the construction of the underground part of the DGR after deducting the expected volume of the disposal sites for this material in the vicinity (existing quarries within a range of up to 25 km). During the construction of the DGR, a large amount of excavated material will be produced. Although it will be possible for a large part of it to be used as building materials, the demand for this material at the time of the construction of the DGR cannot be predicted in this stage of the process. Therefore, in this phase of the DGR development process, excavated material is considered to be a negative DGR construction externality, and the potential for its disposal near the site of production an advantage for the selection of the candidate site.

Quantification: the excess amount of excavated material, i.e. the volume of generated excavated material after consideration of the volume of potential disposal sites for this material in the immediate surroundings of the candidate sites.

Results of the assessment of indicator C2a

The data shown in the table below is based on reports by Butovič et al. 2020 and Zahradník et al. 2020. The volume of the excavated material indicates the total volume of such material from the excavation of the underground complex of the DGR and the volume of material from the excavation of the below-ground hot chamber. The capacity options for the disposal of excavated material at the site represents the volume of such material that can, theoretically, be disposed of in quarries located near to the DGR surface area (driving distance of up to 25 km). The usable volume of such quarries is considered to be the potential volume that will result in the levelling of the quarry to the level of the surrounding terrain. Future mining at such quarries, i.e. a potential increase in the disposal capacity is not considered. The results of the assessment of the candidate DGR sites are set out in Butovič et al. 2020; a summary of the results is presented in Tab. 8.

Tab. 8 Overall assessment of the sites for indicator C2a according to Butovič et al. (2020)

Site	**Total volume of excavated material without backfill** [m³]	**Capacity options for the disposal of excavated material at the site** [m³]	**Excess excavated material** [m³]	**Indicator grade**
Březový potok	6 878 000	5 212 000	1 666 000	1.95
Čertovka	5 556 000	2 250 000	3 306 000	2.88
Čihadlo	6 813 000	1 890 000	4 923 000	3.8
Horka	7 664 000	2 040 000	5 624 000	4.19
Hrádek	6 266 000	7 700 000	0	1.0
Janoch (ETE-south)	7 491 000	1 050 000	6 441 000	4.66
Kraví hora	7 364 000	2 520 000	4 844 000	3.75
Magdaléna	6 885 000	3 000 000	3 885 000	3.21
Na Skalním (EDU-west)	8 634 000	1 590 000	7 044 000	5.0

5.8.3 Criterion C3: Describability and predictability of the homogeneous blocks

Description of the criterion: the geological conditions of the repository must allow for the creation of a reliable complex spatial geological model. The depth extent of the rock mass must be sufficient with regard to the maximum expected depth of the repository (minimum of 400 m). An unacceptable degree of uncertainty in terms of the identification and description of regional and local fault zones and other geological structures may preclude the siting of the repository. However, in this phase of the DGR site selection process (the reduction in the number of candidate sites from 9 to 4), involving the conducting of mostly surface geological research, this factor will not necessarily be considered to be excluding, but may be used for the comparison of the sites.

Description and assessment of the indicators

C3a Degree of the brittle failure of the massif - fault structures

Description of the indicator: the indicator reflects the number and extent of fault structures indicated to date and the age of movements along such faults, if known. Faults are classified according to the SKB classification (Andersson et al. 2000). From the point of view of the suitability of the sites, the degree of brittle failure should be as low as possible since fault structures represent both significant mechanical weaknesses in the rock mass and preferential groundwater pathways, especially in crystalline rock environments. Their distribution and character exert a significant impact on the assessment of site suitability. The nature of faults is given by the SKB classification system compiled by Andersson et al. (2000), according to which a 1st category fault comprises the most significant structure, which could lead to the significant mechanical weakening of the rock massif. Moreover, such faults may act as preferential groundwater pathways or as barriers. Furthermore, they may be associated with extensive alterations and fracturing in the rock environment. Category 2 faults are of a lower extent than category 1 faults. The spatial distribution of faults also exerts a significant effect on the assessment of suitability. For example, it is more advantageous if the faults in a given block (polygon) are concentrated in two tectonic zones with a relatively homogeneous rock environment between them than if the faults are distributed throughout the polygon in the form of a regular dense network.

Quantification: the evaluation of the indicator for each site compared to the other sites: 1 - lowest degree of brittle failure via fault structures, i.e. the absence of first and second order structures according to the SKB classification, 5 – a high degree of brittle failure via the fault structures of several systems; the presence of a large number of fault structures of all orders.

Results of the assessment of indicator C3a

Březový potok (Havlová et al. 2020a)

A grade of 3.5 ranks the Březový potok site in the middle of the list of assessed sites. There are four 1st category and 26 2nd category faults in the area covered by the regional 3D geological-structural model.

Of the four 1st category faults (IDs 6, 9, 12 and 17), two NNW – SSE faults (IDs 6 and 17) occur outside the perspective area for the geological characterisation research, and fault ID 9 tapers out in this area. All the 1st category faults meet the condition of occurring outside both of the promising areas for the project design work at the Březový potok site, i.e. the northern block with an area of 6.46 km^2 and the southern block with an area of 6.91 km^2. The courses of all four faults were verified via detailed geophysical research using electrical, seismic and gravimetric methods; moreover, the hydraulic functions of IDs 6, 12 and 17 were verified, and information on fragments of veined quartz had previously been documented via local geological mapping. Therefore, the various faults drawn on the geological maps were verified up to the peripheral sections thereof.

Category 2 fault systems occur in several directions, the most significant of which are oriented NW-SE to NNW-SSE and the less significant E-W to N-S. Due to the indistinct relief and low level of exposure of the site, only a small number of such faults were documented by previous geological mapping. Most of the tectonic lines were confirmed, therefore, by a mixture of geophysical methods, particularly electrical and seismic (DOP, MRS and, to a lesser extent, ERT) and gravimetric techniques. The hydraulic functions of these smaller 2nd category faults - in contrast to the 1st category faults - were documented only exceptionally in connection with the remediation of the economically intensively-used landscape.

Many of the groups of 2nd category faults are - similarly to e.g. the Čertovka site (grade 3.3) - located either only in the paragneisses of the Moldanubian, or run from these paragneisses to granodiorites, where they quickly taper out and do not affect the homogeneity of the target lithology - granodiorites (e.g. fractures: IDs 10, 38, 194, 195, 196, 198, 208 and 212). Only 10 2nd category faults of a total of 26 run into or directly occur in the rock polygon of the promising area for the geological characterisation research. Although the assessment of the fault network related primarily to the area covered by the regional 3D model, the respective expert team also took into account that the promising area for geological characterisation research is affected by the fault systems and considered the extent to which these fault systems do not impinge upon the area of interest. Hence, the expert team decided to award the Březový potok site with an average grade, similar to that of the Čertovka site, which evinces similar phenomena to those of Březový potok (i.e. 1st category faults and a proportion of 2nd category faults outside the promising area for the geological characterisation research). The Čihadlo (3.8) and Na Skalním (EDU-west) (3.9) sites received “worse” marks, especially with regard to the fact that strong 1st category fault zones run through the centres of these sites, i.e. through the promising areas for the geological characterisation research. Although the 1st category Dolnohuťský fault runs through the middle of the Hrádek (2.3) site, it does not comprise a strong tectonic zone, but rather one discrete structure, from which exceptionally homogeneous fault-free areas lie to the east and west. With respect to the Horka site (2.8), the tectonic zones can be interpreted more in terms of fractures than faults, while at the Čertovka site (3.3), all the 1st category fractures are located outside the target Tiský granite.

Čertovka (Havlová et al. 2020b)

A grade of 3.3 ranks the Čertovka site roughly in the middle of the list of assessed sites in terms of the influence of faults.

Two 1st category faults feature in the area covered by the 3D structural-geological model; however, both faults occur on the boundaries of the Tiský rock mass (the target lithology for the DGR) and do not interfere with it.

The ID2 fault (zone), running NNE-SSW (monitored via branches ID 2a and ID 8), is referred to as the Žihel fault and comprises the most significant tectonic structure at the site. This fault line has been very well documented morphologically, geologically and geophysically via a number of methods (DOP, VES, TDEM, ERT, MRS, RXS and GRAV) for all 5 profiles that cross the Žihel fault. From the east, the fault serves to limit the intrusion of the Tiský massif and defines the granite/permocarbon boundary. The fault inclines at an angle of 70–80° to the east and the weakening zone is 300-800 m thick, with the presence of mylonitisation, silicification and, rarely, hematisation, with vein quartz occurrences in places. The significant hydraulic function of the entire length of the documented fault (approx. 10 km) has been verified.

The ID 1 1st category fault running NE-SW and inclined at 70-80° in the direction of roughly 320° occurs on the NW edge of the studied area; although it represents an important geological interface between the Bohemian and the permocarbon, it does not manifest itself morphologically, geologically or geophysically in the area. This fault is sufficiently distant from the intrusion of the Tiský massif that it does not impact the promising area for the geological characterisation research, let alone the polygons that comprise the promising areas for the project design work.

A total of 32 2nd category faults have been recorded at the Čertovka site. NW-SE faults (WNW-ESE) dominate, accompanied by less abundant faults running E-W. Although there are a large number of documented fault lines, the evaluation of criterion C3a took into account that a number of 2nd category faults occur outside the intrusion of the Tiský massif (especially in the permocarbon) and do not affect the target rock, e.g. IDs 14, 18, 12, 15, 93, 47, part of 11 and 17. It was also taken into account that some faults are evident only from the morphology; their geophysical expression is weak and they may represent fracture zones without a displacement component or, especially in the NW-SE faults, they may comprise older, originally fractured movements that subsequently reactivated in the form of fracture structures. This indication is also supported by the study of fracture systems via DFN modelling, where they are observed as a dominant set of subvertical extension fractures mainly with no mineral fillings in the direction roughly WNW-ESE to WSW-ENE.

A further important structure comprises ID 11 (the Kračín-Tiský fault zone) in the E-W direction of a subvertical slope, along which occur several small effusive bodies of olivine nephelinite of the Neogene age. This tectonic line was documented as a validated line crossed by five geophysical profiles with a significant anomaly according to the DOP method, but with weak or no anomalies according to other geophysical methods (VES, TDEM, RXS), and with a probable hydraulic function. Hence, it remains uncertain whether it is a fault or only a weakened fracture zone serving as feed channels for volcanic rocks.

The rock polygons of the promising areas for the project design work, Čertovka - N with a size of 5.47 km^2 and Čertovka - S with a size of 4.83 km^2, have been geologically and geophysically well documented. The northern polygon is crossed by 8 geophysical profiles and the southern polygon by 5 profiles. Both areas are only slightly affected by faults - the northern area features one fault (ID 55), which exhibits only weak morphological geo-indications and insignificant anomalies according to the various geophysical methods applied - strong DOP, weak TDEM, MRS and RXS. The protruding ID 66 fault has been documented in the southern rock polygon, traversed by the protruding ID 16 fault.

Although a large number of category 2 faults are evident in the 3D model, the above-mentioned main arguments were taken into account in the expert assessment of the grade for the site, i.e. neither of the category 1 faults interfere with the Tiský massif, a number of 2nd category faults are situated outside the Tiský massif in the permocarbon and a number of category 2 faults exhibit weak indications and may represent reactivated fracture movements. Therefore, the Čertovka site was awarded a grade of 3.3 (i.e. “worse” than Hrádek, Horka and Janoch (ETE-south)), but “better” than Magdaléna (3.5), Čihadlo (3.8) and Březový potok (3.5) which, although they feature fewer faults, these faults affect the homogeneity of the target lithology more significantly than at the Čertovka site.

Čihadlo (Havlová et al. 2020c)

A grade of 3.8 ranks the Čihadlo site in third place from the bottom of the rankings of the assessed areas. It should be borne in mind that, according to the methodology of the site assessment process (Vondrovic et al. 2019), none of the sites at which a 1st category fault occurs can be rated 1, and that the values of the nine sites must, therefore, be in the range of 2 to 5. There are two 1st category and 23 2nd category faults in the assessed area according to a special-purpose tectonic map (1:25,000) of the Čihadlo site, of which 16 2nd category faults extend into the area of the promising area for the geological characterisation research.

Two significant tectonic zones occur in the area covered by the 3D structural-geological model comprising 1st category faults, i.e. the N-S so-called Lodher fault zone made up of the 1st category ID 1 fault and 2nd category faults IDs 81, 130 and 131, that fragment and taper out in the central part of the studied area. This structure was verified in detail by four E-W-oriented complex geophysical profiles (ERT, MRS, DOP) and are, therefore, interpreted as verified fault structures. The width of the tectonic zone in its northern part has been determined via geophysical measurements at around 300–800 m, and in the southern part at around 150–300 m. The fault is accompanied by extensive cataclasis and has a significant hydraulic function; it inclines at between 70-80° to the west.

The second 1st category fault (ID 2) comprises a tectonic zone running in the NE-SW direction together with 2nd category faults IDs 28, 32 and 33. This tectonic zone of regional importance is recorded in archived maps and was verified via technical research in connection with uranium mining; its course was updated via five geophysical profiles that crossed this fracture. The fault zone inclines at an angle of 80° to the NW, is 100 to 300 m thick and features mylonitisation and cataclasis, numerous springs and (outside the area) uranium mineralisation.

Numerous 2nd category faults running NW-SE to NNW-SSE with an inclination of around 70° to the SW occur in the NW parts of the area covered by the 3D structural-geological model (IDs 7, 8, 9, 10, 128, 129 and 58). These faults feature predominantly in Moldanubian rocks; however, they also intrude into the Klenov pluton, where they usually taper out after around 2 km. The faults exhibit dominant dextral kinematics and vary in terms of contact between the pluton and the Moldanubian by hundreds of metres. In many cases, they exert a hydraulic function and mapping has recorded quartz veins and numerous striations on granite fragments. Virtually all the faults concerned have been verified both via geophysical anomalies (especially DOP, less ERT, MRS and ÚBA) and via geological mapping and are recorded in the geological map as verified faults.

It can be stated that the Čihadlo site features intensive faulting, especially in the eastern and northern parts of the assessed area and less so in the western to south-western part of the area, where the larger promising area for the project design work is located. The total number of faults and their nature and high degree of verification led the expert team to award a grade of 3.8 since the faulting of the site is essentially similar to the fault networks at the Magdaléna and Na Skalním (EDU-west) sites and is significantly more intense than at the Čertovka (3.3), Horka (2.8) and Březový potok (3.5) sites. When deciding on the grade, the afore-mentioned high level of the verification of the tectonics and, thus, the recording of the faults as verified (in contrast to e.g. the Horka site) was also taken into account. Most of the faults have been documented via two or more geophysical profiles with evidence of significant anomalies, especially according to electrical methods; moreover, manifestations of the faults were found to be significant during field geological mapping (shifts in the lithological interfaces, crushing, quartz veins, springs, striations on fragments, etc.).

Horka (Havlová et al. 2020d)

The grade 2.8 ranks the Horka site in third place in terms of the impact of fracture structures. The area assessed in terms of structural tectonics features 7 1st category faults (IDs 2, 6, 7, 8, 9, 12 and 13). Three 1st category faults (IDs 2, 8 and 12) run through the promising area for the geological characterisation research, of which ID 8 closely follows the western boundary of the rock polygon of the promising area for the project research work, and faults ID 2, running N-S, and ID 12, running NE-SW, run through the middle of the promising area for the geological characterisation research and serve to separate the rock polygons that make up the promising areas for the project work. The category 1 faults at the site have, generally, been verified by geophysical measurements only to a minor degree and, with respect to the Horka site, it was extremely difficult to interpret the measured values in terms of deciding whether the structures comprised fault or only fracture zones (see below). The faults have been documented only sporadically on the surface via geological mapping; the terrain is not well exposed, and veins of hydrothermal quartz, alterations and springs were not usually found to accompany the faults, as is the case of the other sites.

A number of structures interpreted as faults exhibit indications of deformation at relatively high temperatures (i.e. in the initial phase of pluton placement), as indicated by ductile deformation, which is evident by the direction of feldspar outcrops (from the ID 2 1st category fault), subsequently accompanied by fracture systems, as documented by the DOP results concerning geophysical anomalies (extensive shallow zones with reduced resistance).

A number of 1st category structures (IDs 7, 8 and 9), partly recorded by surveys conducted by the Czechoslovak uranium industry, evince no field geological indications, and the structures were interpreted as faults only on the basis of various more or less significant resistance anomalies, sometimes accompanied by reduced seismic velocity zones.

Only faults ID 6 and ID 13 (1st category), located at considerable distances from the edges of the promising area for the geological characterisation research (ID 6 approx. 2.5 km SSE from the southern edge, ID 13 approx. 3 km NW from the western edge), evince significant indications of fault structures, i.e. they have been recorded via geological mapping, feature a number of springs (in the case of ID 6 with a hydrogeological borehole with a flow rate of 2 l/s) and represent significant anomalies according to the results of the DOP and MRS methods.

Furthermore, a total of 17 2nd category faults are present in the area assessed in terms of structural tectonics, of which 11 faults of various lengths extend into the promising area for the geological characterisation research; however, significant sections of the courses of only 7 of these faults (IDs 1, 24, 20, 78, 94, 167 and 33) extend into this area. The other 4 faults (IDs 47, 48, 113 and 162) only marginally encroach upon the promising area for the geological characterisation research. Six 2nd category faults (IDs 14, 29, 19, 53, 158 and 80) occur in the area assessed in terms of structural tectonics; all of them are outside the promising area for the geological characterisation research.

The determination of the grade of the impact of faults at the Horka site considered not only the number of faults and their location, but also the knowledge available on the intensity of anomalous manifestations according to geophysical research measurements and the degree of verification provided by geological mapping assessed in terms of structural tectonics.

With regard to the specific situation at the Horka site, the following text provides a detailed explanation of the interpretation of the geophysical anomalies.

Massive intact durbachites at the Horka and Na Skalním (EDU-west) sites exhibit standard electrical resistances of 800-2000 Ω, and at the Magdalena site of 600-2000 Ω. Compared to granites, durbachites generally exhibit lower resistances, which corresponds to the laboratory research results (higher conductivity was determined - inverse resistance value). With respect to certain faults (e.g. the above-mentioned ID 6 fault traversed by the HOR-01 profile at station 2 280 or 10 380), a noticeable decrease was detected in the resistance to 50 Ω, which indicated a crushed and saturated environment, i.e. a clear indication of a fault structure. However, with concern to most of the other faults mentioned above, the decreases in conductivity were not so considerable that they clearly indicated the mechanical failure of the durbachite by the respective fault. Examples are provided here of measurement stations on fault indications:

fault / profile / station:

ID 1 / HOR-03A / 6800 m,

ID 2 / HOR-09 / 4200 m,

ID 2 / HOR-11 / 3030 m,

ID 7 / HOR-01 / 800 m,

ID 8 / HOR-03A / 1450 m.

The resistances at these stations ranged between 350 and 900 Ω, thus, it was not possible to unambiguously interpret the structures as fault zones; they may indicate fractures or the deeper selective weathering of the durbachite. The resistances of clearly identified faults usually range up to 100 Ω and, with respect to significant fault zones with hydraulic functions (such as in the granites of the Čihadlo Lodhéřov fault zone or the Hrádek site Dolnohuťský fault), the resistance values drop sharply to 10-20 Ω.

The situation at the Horka site was also specific in terms of the interpretation of the velocity of seismic waves for shallow refractive seismicity. According to laboratory research, the velocity of seismic waves in intact durbachite should reach around 6000 $m.s^{-1}$, a velocity that was achieved only rarely for the Horka site, where average velocities of 2600-3200 $m.s^{-1}$ prevailed. Indeed, several geophysical profiles at the site evinced decreases in the velocity of seismic waves (over thousands of metres) to just 1200–1600 $m.s^{-1}$, which corresponds to sedimentary rather than intrusive rocks. Therefore, it was decided that it was not possible to consider solely shallow refractive seismics for the interpretation of faults at the Horka site since the results clearly reflected the widespread weathering of the durbachite at around 50-100 m beneath the surface.

As can be seen from the above, the documentation of faults at the Horka site was extremely complicated, due to the lack of the geological manifestation of faults in the geological mapping and the non-occurrence of the significant manifestation of geophysical anomalies. A number of apparently 1st and 2nd category faults were recorded conservatively as faults, even given the considerable degree of uncertainty as to whether they were in fact merely fractures or components of the deeper weathered durbachite regolith. Hence, most of the uncertain parts of such features were recorded as (unverified) faults. Moreover, a number of failure zones longer than 1 km were included as 3rd category faults since, when deciding whether to interpret geophysically weakened zones as faults or fractures, the conservative approach was applied and they were recorded as category 3 fault lines. In addition, these category 3 faults were (following the conservative approach) recommended for inclusion in the creation of the hydraulic and feasibility models.

When assessing the site, the expert team took into account all the above aspects. It was accepted by the respective experts that, in comparison with the other sites (where not so much archived data was available from surveys conducted by the Czechoslovak uranium industry), the author of the structural-tectonic evaluation of the site rightly recorded the fault network in a highly conservative way. This approach was important particularly in terms of potential future research, i.e. it is important to be aware that many of the suspected 1st and 2nd category faults may prove not to be fault zones but merely fractures or features of the deeper selective weathering of the durbachite rock environment.

Taking into account all the above uncertainties, the expert team awarded a grade for the Horka site of 2.8, which is “worse” than the slightly fault-disturbed Janoch (ETE-south) (2.0) and Hrádek (2.3) sites, but which positively reflects the various uncertainties in comparison with the more intensive and well-proven fault networks at those sites featuring granitoid formations such as Čertovka (3.3), Březový potok (3.5), Čihadlo (3.8) and Magdaléna (3.5). The Na Skalním (EDU-west) site has a significantly different structural fault plan than that of the Horka site, and is characterised by a well-proven and documented network of significant 1st and 2nd category faults; hence, this site was awarded a grade that is one degree “worse”, i.e. 3.9. Although the number of faults alone is not decisive in terms of determining the grade, the number of 2nd category faults at the Horka site (17 in total) was lower than at most of the other sites (the number of 2nd category faults at selected sites was: Březový potok 26, Čertovka 32, Čihadlo 23, Na Skalním (EDU-west) 50, Kraví hora 25 and Hrádek 14). However, it must be emphasised that the nature of the fault networks of both categories, the degree of verification, the location of the faults and the intensity of their incidence were all taken into account when determining the grade, not simply the number of faults.

The afore-mentioned conservative approach, that resulted in the consideration of the occurrence of faults on weak geophysical anomalies which might have been verified as fracture areas or deeper weathered zones at better exposed sites, led to the interpretation of the tectonic scheme of the area as having a number and direction of faults that reflected the most critical assessment variant. Nevertheless, a relatively small number of category 2 faults were identified at the Horka site compared to the other sites, and it is safe to assume that some of them will be confirmed as fractures or weathered zones rather than faults following future geological research.

Hrádek (Havlová et al. 2020e)

The Hrádek site consists of a deeply-established and clearly-delimited oval vertical intrusion of a granite massif of the Čeřínek type, intruding into granites of the Eisgarn type and a monotonous Moldanubian group. The depth of the intrusion according to gravimetric data has been estimated at a minimum of 10 km.

Although the intrusion of the Čeřinek pluton and its surroundings were documented in detail via 14 geophysical profiles using several surface geophysical methods, as well as area-measured gravimetry and one regional E-W geophysical profile using deep vibration seismic methods and TDEM, only one N-S 1st category fault (ID 99/129) (the so-called Dolnohuťský fault) was detected in the promising area for the geological characterisation research; the fault exhibits a hydraulic function. This fault was verified in detail via a number of E-W geophysical profiles. Furthermore, 14 2nd category faults have been documented, of which only 5 are located in the Čeřínek intrusion (IDs 164, 148, 144, 61 and 35), two of which form the northern stratification of the afore-mentioned Dolnohuťský fault (IDs 61 and 144).

The ID 62, 144 and 179 faults represent, at least in part, marginal subvertical failures on the eastern and western contacts of the Čeřínek intrusion with Eisgarn granite and metamorphic rocks, and, most likely, do not interfere with the said intrusion. The courses of these faults are related to the above contacts. The other 2nd category faults occur outside the Čeřínek massif and outside both of the promising areas for the project design work.

Although the assessment of the occurrence of faults concerned the area covered by the regional 3D structural-geological model, the consideration of the geological documentation and the geophysical profiles that extend into the promising area for the project design of the Hrádek site - SE with an area of 6.9 km^2 (8 profiles in total), suggests that it is highly probable that there are no undetected significant fault structures in the SE rock polygon and that the area is exceptionally homogeneous.

The western polygon of the promising area for the project design work at the Hrádek site - NW with an area of 3.4 km^2, is burdened by a higher degree of uncertainty due to the smaller number of geophysical and geological profiles (5 profiles in, or close to, the rock polygon);

however, according to the course of faults (IDs 35, 179 , 99 and 164), this area also appears to be homogeneous and unaffected by 2nd category faults.

Compared to the other sites, it is clear that the granites of the Hrádek site, especially the Čeřínek intrusions, comprise large areas that are unaffected by 1st or 2nd category faults, which is similar only to the situation at the Janoch locality (ETE-south). However, the above-mentioned 1st category fault (ID 99/129) occurs in the middle of the Hrádek site. Although a number of significant 1st category faults have been documented for the Janoch (ETE-south) site, all of them are located at a considerable distance from the promising areas for the geological characterisation research and the project design work, and do not impact the homogeneity of the promising area for the potential siting of the DGR. Thus, the Hrádek site was awarded a grade of 2.3 and the Janoch (ETE-south) site the highest grade of all the sites, i.e. 2.0. According to the site assessment methodology (Vondrovic et al. 2019), no site at which a 1st category fault occurs can be graded 1. Since the other sites feature more fracture structures of all orders than the Hrádek and Janoch (ETE-south) sites, they were awarded higher grades (i.e. worse ratings).

Janoch (ETE-south) (Havlová et al. 2020f)

A grade of 2.0 ranks Janoch (ETE-south) in first, i.e. best, position of all the assessed sites. A zone of inclined 1st category faults (IDs 8 and 11) (the Hluboká fault) and the ID 15 fault, and two 2nd category faults (ID 12) (the Zbudovský fault) and ID 16 (the Blatský fault) run in the NW-SE direction at the southern edge of the 3D model area. These faults delimit the northernmost edge of the Cretaceous basin and they are well defined geomorphologically, geologically and geophysically. These faults incline steeply to the SW with a declining component, from which the rocks of the České Budějovice basin sedimented; they are located 5 to 9 km from the nearest corner of the promising area for the geological characterisation research and do not affect the homogeneity of the area.

A second zone with 1st category faults occurs in the NW tip of the studied area, i.e. faults ID 24 and 25 that represent parts of the tens of kilometre-long line of the Vltava shear zone, according to which, during the Variscan, the south-eastern thrusting occurred of the northern Podolský complex through a monotonous series of the Moldanubian. This zone is also well defined geologically and geophysically, although ductile mylonitisation dominates over brittle deformation. Abundant quartz veins are present and the hydraulic function of the zone has been recorded. The faults in this zone are located 10 to 12 km from the nearest corner of the promising area for the geological characterisation research and also do not affect the homogeneity of the area.

Even most of the 2nd category faults are located relatively far from the promising area for the geological characterisation research. The central part of the area studied for the potential siting of the DGR has been documented in extraordinary detail via a total of 11 geophysical and geological profiles, and the whole of the area was mapped in 2016–2017 at a scale of 1:10,000.

The promising area for the geological characterisation research features only three 2nd category faults (IDs 1, 2 and 39), which indicates the lowest degree of failure of all the sites. Moreover, the ID 1 and ID 2 faults evince only weak anomalies according to the DOP, MRS and ERT methods, they have no hydraulic function and were primarily identified via geomorphological analysis rather than by geological mapping. The question remains, therefore, whether they are in fact fractures; nevertheless, the anomalies were conservatively recorded as faults. The ID 39 fault running approximately E-W penetrates into the promising area for the project design work, where, however, it gradually tapers out.

With respect to the Janoch (ETE-south) site, it can be stated that the vast majority of 1st and 2nd category faults occur at considerable distances from the central part of the studied area and the promising areas for the geological characterisation research and the project design work, and the homogeneity of this area is not violated, with the exception of the three insignificant 2nd category faults mentioned above. Hence, the expert team awarded a C3a indicator grade of 2.0, thus classifying this area as the least fault-affected of all the assessed sites.

Kraví hora (Havlová et al. 2020g)

A grade of 5 ranks the Kraví hora site in last position in the assessment of the sites, significantly behind the penultimate Na Skalním (EDU-west) site (grade 3.9). The reasons for the negative assessment are as follows:

A total of 4 significant 1st category faults were verified (IDs 5, 10, 173 and 160) at the Kraví hora site, all of which run approximately in the NNW-SSE direction and are present in the promising area for the geological characterisation research and closely border the promising area for the project design work. The faults evince signs of polyphase reactivation and are bounded by hydrothermal manifestations (mined U mineralisation, quartz veins, alteration, Cu-Fe mineralisation, chloritisation, and intensive tectonic disturbances surrounding the faults comprising shear and extension fractures); the ID 10 fault also exhibits a significant hydraulic function. The faults were documented in detail via five E-W geophysical and geological profiles; hence, their presence in this part of the site is considered sufficiently verified and, in the northern part of the promising area for the geological characterisation research their presence is considered probable.

Furthermore, a total of 25 category 2 faults have been recorded at the site, with a predominant direction that is perpendicular to the category 1 faults, i.e. ENE-WSW. Moreover, these faults are oriented perpendicular to the regional structure and shift the main lithological boundaries, often accompanied by calcification and alterations. The faults present in the promising area for the project design work have been well documented via several geophysical methods (particularly ERT, DOP and RXS): the area was studied via 5 transverse profiles (including a regional profile that used deep vibration seismic and TDEM methods) and 4 directional profiles. The faults were also confirmed via geological mapping; thus, they are considered to be verified faults.

The frequency of 1st and 2nd category faults, coupled with the fact that the studied area of the Kraví hora site is the smallest of all the sites, significantly exceeded the frequency of faults at the other candidate sites. Moreover, the fact that the faults either directly traverse (2nd category) or run close to (1st and 2nd category) the promising areas for the project design work contributed to the negative assessment. Hence, with respect to the C3a indicator, the Kraví hora site was assigned a grade of 5, significantly behind the two next-worst Na Skalním (EDU-west) (3.9) and Magdaléna (3.5) sites.

Magdaléna (Havlová et al. 2020h)

A grade of 3.5 ranks the Magdaléna site (together with the Březový potok site) in the middle of the list of assessed areas.

Two significant tectonic zones feature in the 3D model, made up of 1st category faults, i.e. the N-S so-called Sepekov fault zone comprising the ID 10, 46, 47, 48, 49 and 50 1st category faults that diminish and taper out at the SW tip of the studied area, and an intensive NNE-SSW structure known as the Božejovice fault zone that is made up of the ID 51, 52, 53, 54 and 55 1st category faults which, in combination with 2nd category faults, divides the promising area for the geological characterisation research into two halves.

Both of the afore-mentioned tectonic zones create anastomosis structures of around 500 m in thickness, which were determined to be significant via a number of geophysical methods (ERT, DOP, MRS). The fault zones are accompanied by intense alterations, mylonitisation, the formation of powerful quartz-tourmaline veins and the claying of the host rock. The declination of both structures is subvertical, and while their extent is unknown, due to the intensity of the manifestations in the erosion section, their significant depth can be assumed. The hydraulic function of the two zones could not be verified due to the extremely intense reclamation of drainage land, which has served to obscure the natural hydrogeological regime of the groundwater in the subsurface zone around the fault areas.

In addition to the two tectonic zones mentioned above, a total of 15 2nd category faults have been documented at the Magdaléna site via a number of geophysical methods, of which 8 such faults occur within the promising area for the geological characterisation research. They occur principally in a system of faults running from NW to WNW-W to ENE (e.g. IDs 1, 28, 29, 58, 61 and 66); they have been well verified via geophysical methods and are recorded mostly on geological maps as verified faults. Cataclasis and, occasionally, quartz-calcite fillings with the pyritization and chlorination of the host durbachite, often occur in these faults. All these faults have been interpreted as subvertical according to ERT and MRS anomalies.

It can be stated that the Magdaléna site is relatively intensively fault-disturbed (which was not known prior to the geophysical research) and that the character of the faults is similar to that of the Březový potok site (thus, it was awarded the same grade of 3.5) and only insignificantly less disturbed than that of the Čihadlo (3.8) and EDU-west (3.9) sites. The presence of numerous of faults, as well as the enormous number of leucogranite, aplite and quartz veins (often with edges crushed by extension and shear fractures and, most likely, also small local faults) was the main reason that only two relatively small rock polygons were defined at the Magdaléna site for the project design work (4.2 and 2.1 km^2), both on the northern border of the promising area for the geological characterisation research in the relatively more homogeneous part of the studied area which, nevertheless, features 2nd category faults.

Na Skalním (EDU-west) (Havlová et al. 2020i)

A grade of 3.9 ranks the Na Skalním (EDU-west) site (together with the Čihadlo and Magdaléna sites, 3.8 and 3.5, respectively) among the most fault-disturbed of the assessed sites. A more complicated fault structure was determined only at the Kraví hora site (5.0). It should be borne in mind that, according to the site assessment methodology (Vondrovic et al. 2019), no site that features a 1st category fault can be graded 1 and that, therefore, the grades of all nine candidate sites were determined in the interval 2 to 5.

The assessed area covered by the regional 3D model features 4 1st category faults (IDs 1,2,3 and 4) and 50 2nd category faults, which represents the highest number of faults of this category of all the assessed sites. The 1st category faults form a massive fault zone running WNW-ESE to NW-SE, that has been well documented by geological research. The zone is made up of massive faults that usually feature several branches marked with separate IDs, i.e.

the Lipnice/Výčapské fault zone (IDs 4 + 5, 8 and 52), an unnamed fault zone that follows the Lipnice fault (IDs 1, 2, 3 + 10 and 32) and a powerful fault zone known as the Klučovské fault zone in the northern part of the area which is made up of a number of 2nd category faults (IDs 14, 16, 48 and others). Subvertical slopes are considered for all these faults.

The promising area for the geological characterisation research features three 1st category faults, of which ID 4 closely follows the northern boundary of the promising areas for the project design work: EDU-west - W and EDU-west - NE. Furthermore, 12 2nd category faults are present in the promising area for the geological characterisation research running predominantly WNW-ESE (IDs 5, 10, 11, 17, 38 and 99) and less frequently NE-SW (IDs 6, 18 and 100), supplemented by faults in the NNW-SSE direction (IDs 14 and 20) and a fault in the WSW-ENE direction (ID 43).

In general, the hydraulic functions of the faults at the Na Skalním (EDU-west) site have been verified only sporadically (e.g. the ID 10 fault parallel to the Rouchovanka valley and the ID 1 fault that runs through the Rouchovanka valley, and to which a number of hydrogeological indications are linked). However, at the Na Skalním (EDU-west) site (as, for example, at the Horka and Magdaléna sites), the intense reclamation of drainage land serves to limit the detection of groundwater drainage along tectonic lines with concern to hydrogeological mapping. Hence, it is practically impossible to determine the natural circulation of the groundwater in the shallow parts of the crystalline rock environment.

Thus, it can be stated that the Na Skalním (EDU-west) site is intensively faulted (which has been well documented by both historical and recent geological and geophysical research). The relatively high number of category 2 faults, including their presence in the promising area for the geological characterisation research, as well as the occurrence of a powerful fault zone that divides the regional 3D geological model into northern and southern parts and which partly runs through the geological characterisation area, led the expert team to assign a grade of 3.9.

The nature of the fault network is similar to those at the Magdaléna and Čihadlo sites (1st category fault zones that traverse the middle of the sites, accompanied by 2nd category fault networks); thus, the three sites were assigned similar grades. Although the 1st category Dolnohuťský fault also traverses the middle of the Hrádek site (grade of 2.3), it does not comprise a strong tectonic zone, but a discrete structure, from which exceptionally homogeneous fault-free areas stretch to the east and west. The only real exception concerns the Kraví hora site, where the degree of fracture disturbance is even more complicated. Thus, the Kraví hora site was awarded a grade of 5, which is significantly “worse” than that of the Na Skalním (EDU-west) site (3.9).

Tab. 9 Overall assessment of the sites for indicator C3a according to Havlová et al. 2020a-i

Site	**Indicator grade**
Březový potok	3.5
Čertovka	3.3
Čihadlo	3.8
Horka	2.8

Site	Indicator grade
Hrádek	2.3
Janoch (ETE-south)	2.0
Kraví hora	5.0
Magdaléna	3.5
Na Skalním (EDU-west)	3.9

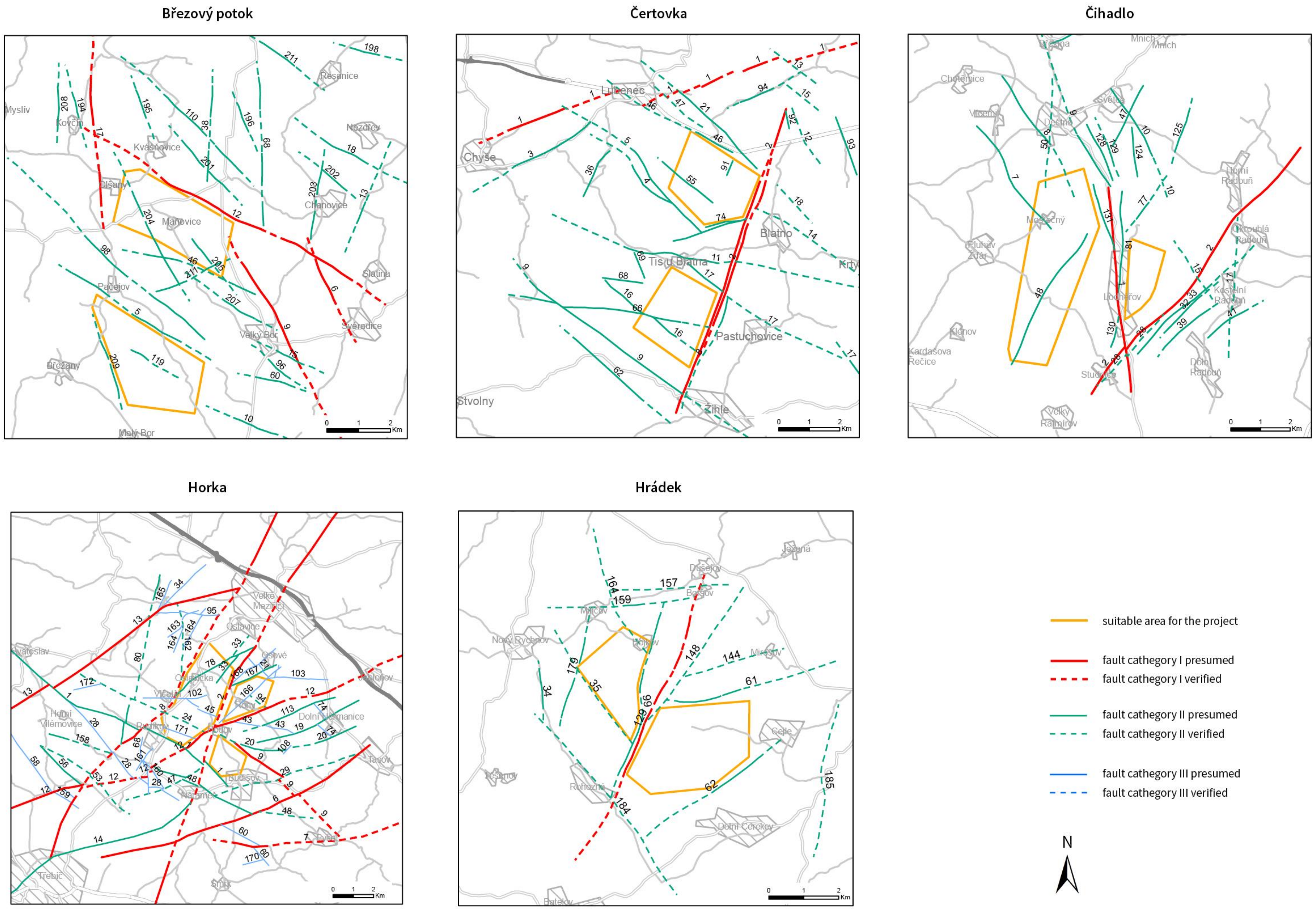


Fig. 17 Maps of fault networks for the purposes of the assessment of the candidate DGR sites

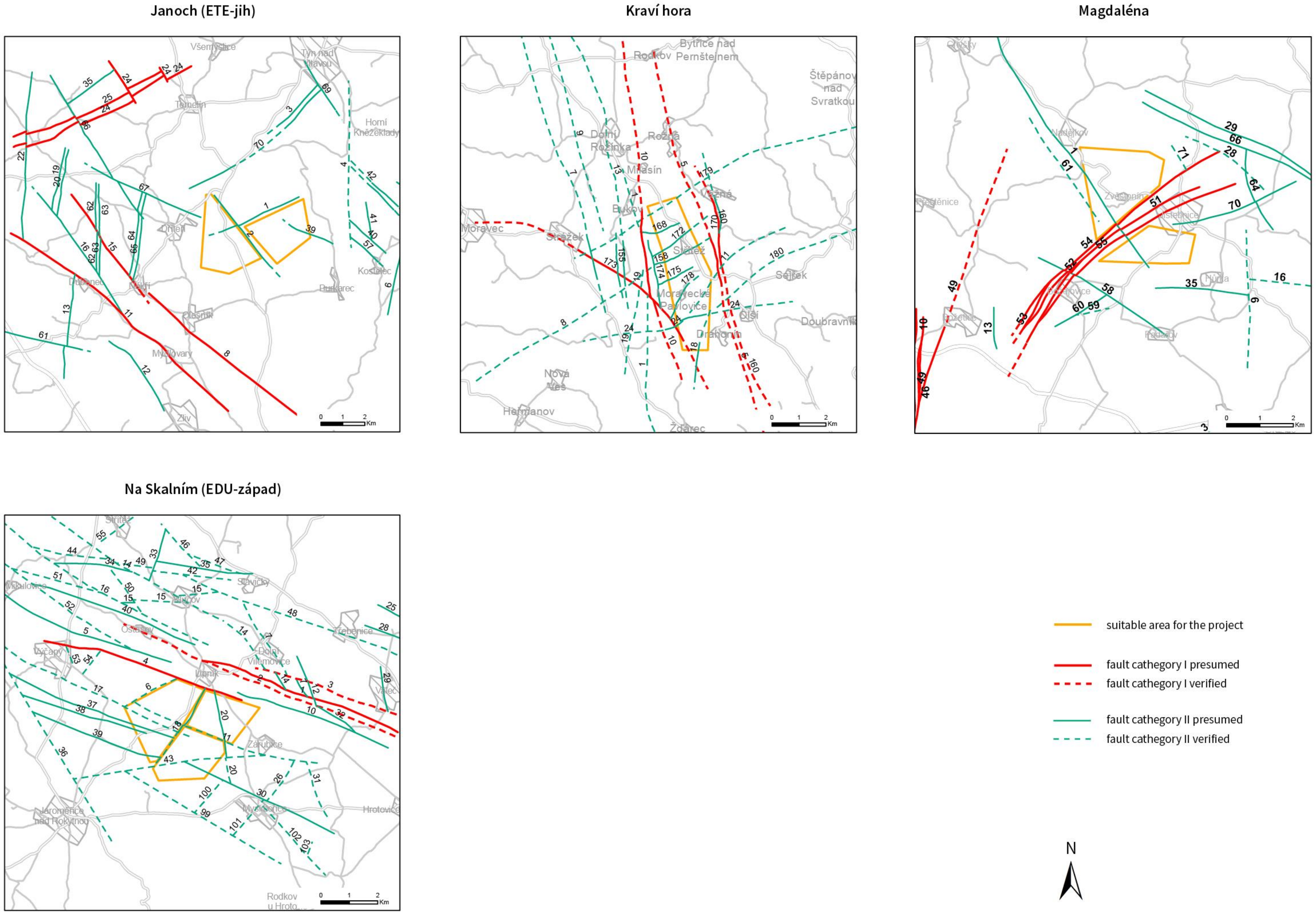


Fig. 18 Maps of fault networks for the purposes of the assessment of the candidate DGR sites

C3b Degree of brittle failure of the massif - fracture systems

Description of the indicator: the indicator reflects the number of detected fracture systems and the density of the fracture networks. Fracture systems often form dense networks of small discontinuities in the rock mass and they are usually interconnected. Parts of such networks are hydraulically conductive and may serve as potential pathways for the migration of water and gases contained in the water or, in the case of the DGR for the potential escape of radionuclides. From the point of view of the siting of the DGR, the most suitable environment is that with the lowest possible number of fracture systems and a low fracture density. Parameter P_{21} (the total length of fracture traces per unit area) for the representative lithology (lithology in which the siting of the DGR is assumed) for the siting of the DGR at the sites will be evaluated. The parameter will be determined based on data obtained from Kabele et al. (2018). Parameter P_{21} will be applied as a result of the compilation of DFN models in the DFraM program (Kabele et al. 2018), which were created primarily for hydraulic simulation purposes. The comparison of the sites will, therefore, proceed on the basis of field structural data from the outcrops documented in detail for the creation of the DFN models. In the case of normally semi-planar outcrops, parameter P_{21} best captures the degree of rock mass failure directly from the structural data obtained. Thus, a comprehensive set of data collected by means of a uniform methodology for all the sites will be used for assessment purposes. In addition, parameter P_{30} is also mentioned in Kabele et al. (2018) and related literature. This mathematically determined parameter, which describes the number of fractures per unit volume, contains elements of the applied computational procedures (large numbers of small fractures) that do not influence its use in hydraulic simulations (which is their primary purpose), but affect the overall structural evaluation. Thus, they will not be used in the comparison of the sites.

The arithmetic mean, calculated from the P_{21} parameter values for all the outcrops documented for the representative lithology of the sites, were used for the assessment. The average was chosen since at a number of sites it was often impossible, due to the poor initial situation, to assess in detail more than a small number of outcrops. In the case of a relatively low number of input values, the use of the median is not ideal, i.e. it is more suitable for larger data sets (larger numbers of outcrops). The average suitably reflects even a small number of outcrops with a significant P_{21} parameter value, which would not be reflected in the case of the use of the median. The P_{21} parameter was evaluated for 7 sites (not for the Na Skalním (EDU-west) and Janoch (ETE-south) sites). This parameter was determined by experts as being the most representative parameter since it best reflects the detection of fractures when comparing field observations and models (it evinces the lowest statistical error than other parameters, e.g. P_{30}). With concern to the Na Skalním (EDU-west) and Janoch (ETE-south) sites, the comparison was conducted of available field measurements of fractures obtained via field-based research. The data on the Na Skalním site (EDU-west) agreed very well with that on the Horka site and, since both belong to the same lithological unit, the resulting assessment of this site was similar to that of the Horka site. In the case of the Janoch site (ETE-south) it was possible to base the assessment on lithologically similar parts of the metamorphic Moldanubian complexes found at some of the other sites or on the brittle structures found at the Kraví hora site.

Quantification: the assessment of the indicator in cases where the necessary data obtained via structural-geological characterisation research for the purposes of DFN modelling was available: 1 – the lowest total length of fracture traces per unit area (m^2) for a representative lithology; 5 – the highest total length of fracture traces per unit area (m^2) for a representative lithology. The evaluation will also take into account new findings reported in Mixa et al. (2019). For those sites for which the necessary data is not available, the assessment will be performed via a comparison based on the experience of the respective expert team.

Results of the assessment of the C3b indicator

When determining the grades for indicator C3b, both the size of the P_{21} parameter was considered (the total length of fractures [m] per unit area, i.e. the extent of the plane interspersed with rock outcrops [m^2]) - see Tab. 10, and the verification of the nature of the fractures as determined by geophysical research.

Tab. 10 Evaluation of parameter P_{21}

Site	**Březový potok**	**Čertovka**	**Čihadlo**	**Horka**	**Hrádek**	**Kraví hora**	**Magdaléna**
Parameter P_{21}	1.15	0.67	1.51	0.90	1.12	0.58	0.92

<u>Březový potok</u> (Havlová et al. 2020a)

The assessment by the respective expert team resulted in the assigning of the Březový potok site with an average grade of 3.3.

The P_{21} parameter value ranked the Březový potok site in the lower half of the assessed sites; however, there were only small differences between this site and the neighbouring sites of Hrádek and Horka. Due to the small number of outcrops in the flat and intensively cultivated terrain of the area, it was difficult to determine the exact location and orientation of fracture networks in the area of the profiles mapped during the geological research. Hence, and with regard to the fact that the P_{21} parameter is based on a smaller set of measurements than at the other sites, the assessment takes into account the results of the geophysical research to a greater extent.

The fracture zones detected along the studied profiles were interpreted only on the basis of the geophysical data and their relation to the sets of fractures included in the DFN model. Zones with the relatively more frequent occurrence of fractures evinced typical decreases in velocity (MRS) and density (gravimetry). The DOP and ERT methods can also be applied for the identification of fracture zones. Wider areas with reduced resistivities are interpreted as relatively more disturbed with respect to fracture zones, while less often such anomalies are related to presumed fault structures (usually only tens of metres in extent), or contacts between granodiorite and metamorphic rocks (usually with sharp boundaries). Wide bands (often of several hundreds of metres) are interpreted as deeper fracture zones (more than 20 m deep and usually up to 40 m) of rock massif weathering, and on the basis of the characteristic shapes of resistivity curves that often indicate rock failure via numerous discrete subvertical discontinuities that are interpreted as fractures. Continuous areas of high resistivity interpreted as rock blocks of several hundreds of metres in thickness with a low degree of failure often occur between such fracture zones.

It is clear, in a similar way to the Hrádek site, that most of the tectonically disturbed zones at the Březový potok site are made up of shallow range extension fractures (lower tens of metres) with no connection to the fault tectonics. Therefore, the Březový potok site was awarded the same grade as that of the Hrádek site (3.3), very slightly “worse” than the durbachite Na Skalním (EDU-west) and Horka sites (better P_{21} parameters and weaker geophysically documented fracturing indications), and slightly “better” than the Čihadlo and Magdaléna sites (Čihadlo had a worse P_{21} parameter as confirmed by the geological and geophysical research and mostly with no connection to the fault network, whereas Magdaléna was found to evince a complicated fracture structure in connection with the reactivated edges of very numerous veined aplite zones).

Čertovka (Havlová et al. 2020b)

The P_{21} parameter value ranks the Čertovka site in second position after the Kraví hora site and in first position for the granitoid sites. It should be noted that due to the good exposure of the terrain at the Čertovka site, and the large amount of measured data, the P_{21} parameter at this site has a significantly higher informative value than at the other sites (e.g. Kraví hora or Magdaléna). At the same time, the question remains as to what extent the low value of the P_{21} parameter at the Kraví hora site is due to the rheological contrast of the paragneisses and migmatites compared to the granitoid rocks of the other sites. With regard to the assessment grade 2.4 awarded to the Čertovka site, it is necessary to bear in mind that due to the minimum differences between the P_{21} parameter values of the sites, the assessment team decided not to assign the extreme values of 1 and 5, as permitted by the assessment methodology.

The geophysical research verified fracture zones located in all cases along faults, including e.g. the western parts of IDs 9, 16, 62 66, 68 and 69 and the entire length of ID 11 (Kračín-Tiský zone). The areas between the faults are only minimally affected by fractures, as evidenced by the uneventful geophysical situation, especially according to the results of electrical and seismic methods. The presence of a large number of significant to massive rock blocks (e.g. the Baba and Dědek rocks) also indicates the minimum level of granite fracturing.

Čihadlo (Havlová et al. 2020c)

The P_{21} parameter ranks the Čihadlo site in last (i.e. “worst”) position in terms of the fracturing of the granitoid rock mass; this was further confirmed by the field mapping and geophysical image research results.

The Klenov pluton appears to be significantly fractured. The fracture system comprises 6 sets of fractures, the most numerous of which decline relatively steeply (70–90°) to the NW, SE, NE, SW, ENE and WSW. Fractures with medium to slight slopes decline to the SE and W (Kabele et al. 2018). Extensive crushing around faults was verified via geophysical methods at the Čihadlo site; however, strong fracture zones were also identified, which are clearly not related to 1st and 2nd category fault lines, and correspond more to fractures documented at outcrops according to the DFN models and mapping. Recent geophysical research identified hundreds of metres-wide areas of increased conductivity and reduced seismic velocities to depths of 20–60 metres on the anomaly profiles, which were interpreted as loose and saturated fracture systems.

Due to the intensity of fracturing documented by the DFN models, geological mapping and the interpretation of geophysical anomalies, the expert team awarded a grade of 4 to the Čihadlo site that reflects the most intense disturbance by fracture systems of all the sites assessed.

Horka (Havlová et al. 2020d)

A grade of 3.0 ranks the Horka site in the middle of the list of assessed sites, i.e. the same grade as that assigned to the similar durbachite site of Na Skalním (EDU-west) (mark 3.0). The dominant set of extension fractures in the rocks of the area of interest comprises mostly subvertical fractures without mineral fillings, which form a predominantly regular orthogonal system. Fractures of an exfoliating nature with a flat orientation are often bound only to the near-surface parts of the rock complexes. Two main trends in the orientation of the extension fractures were identified in the studied part of the Třebíč pluton, i.e. running approx. NNE-SSW and a perpendicular system running approx. WNW-ESE. Based on the obtained data, a total of 7 fracture populations were identified according to the spatial orientation (Franěk et al. 2018), of which steep fractures (inclinations of 70–90°) descend to the N, S, NW, SE, NE, SW, E and W and fractures with medium inclinations (60–40°) descend generally to the E, NW and SE. Sub-horizontal fractures (inclinations of 30–0°), with the exception of exfoliation fractures created by weathering, which were excluded from the analysis, occur only rarely at the site and descend in the same directions as the medium-inclined fractures. The various fracture sets were verified via both the DFN models and the geological mapping that formed part of the geophysical research. The geophysical research recorded extensive profile sections with weak, several hundred metre-thick anomalies of increased resistance via the DOP method, sometimes accompanied by a decrease in seismic waves, as recorded by the MRS method. The depth of these anomalies is usually in the higher tens of metres. These anomalies are likely to correspond to regional fracture systems since they are not linked to the presence of faults and the associated tectonic failure of the surrounding rock; alternatively, they may be identified by further detailed research as products of the deeper weathering of the durbachite.

Due to the average P_{21} parameter value and the similar conditions to those of the Na Skalním (EDU-west) site, at which the sets of fractures were documented in detail, especially via research by Hanžl et al. (2017, 2018), the grade for the Horka site was set at 3.0, identical to that of the Na Skalním (EDU-west) site. In terms of their fracture systems, in contrast to their fault networks, the sites are very similar; hence they were assigned the same grades.

Similar grades were awarded to the granitoid sites of Hrádek and Březový potok (3.3) with higher P_{21} parameters, i.e. 1.12 and 1.15, respectively. Čihadlo had the highest P_{21} value (1.51), a value that was also confirmed by the geological mapping and geophysical research. Therefore, the Čihadlo site was assessed as most affected by fracturing, which was reflected in the assignment of a grade of 4. Conversely, the "best" grade awarded to the Čertovka site reflected the lowest P_{21} parameter value, which was also confirmed by the results of the most recent geophysical and geological research.

Hrádek (Havlová et al. 2020e)

The P_{21} parameter value served to rank the Hrádek site at the same level as the Březový potok site and significantly ahead of the Čihadlo site; the other candidate sites evinced lower levels of fracture impacts as expressed by the P_{21} parameter. Given the minimal differences between the P_{21} parameter values, the respective assessment team decided not to apply the extreme values of 1 and 5, as permitted by the assessment methodology.

The main findings of the geophysical and geological-geomorphological surveys of the Hrádek site were as follows: fracture systems, especially in the NE-SW and NW-SE directions, were well documented by both the geomorphological analysis and the geophysical analysis (especially via the ERT and MRS methods). Fractures and the fracturing of the rock mass via exfoliation systems are insignificant at depth; the anomalies identified by the geophysical research indicated fracturing depths (i.e. open fractures) up to a maximum of tens of metres (20–60 m). This also coincides with the existence and degradation of peatlands, which are apparently not fed from deep groundwater circulation, but from meteoric water that circulates via shallow fractures (this is related to the drying out and gradual disappearance of these peatlands due to decreasing precipitation over the past 10 years). The fracture zones are not usually bound to fault lines, but occur in zones several hundred metres thick throughout the entire studied area.

The shallow and extensive occurrence of fractures is significantly less limiting in terms of the quality of the site than, for example, the fracture systems at the Magdaléna site, where the fracture systems often follow the edges of aplite and quartz veins and are, according to the geophysical research, clearly deeper in range and often exhibit a significant hydraulic function. Therefore, the expert team assigned the Hrádek site a grade of 3.3. The extent of fracturing at the Hrádek site is similar to that at the Březový potok site located in Blatenské and Červen granodiorites; hence the two sites were assigned the same grade. The Kraví hora site evinced a significantly more favourable P_{21} parameter value; however, the formation of the fracture systems was affected by the differing rheology of the rocks (paragneisses and migmatites) and, since the geophysical analysis (especially via the DOP and ERT methods) identified intense fracture zones (partly along faults and partly outside faults), the Kraví hora site was awarded a grade of 3.1, only very slightly better than the Hrádek site. Conversely, the fracture systems at the Horka site are mainly bound only to the presence of faults; the rest of the area is only insignificantly fractured (similar to the Hrádek site). Therefore, the assessment team took into account the similarly weak manifestations of the fracture systems and the slightly better P_{21} parameter value at the Horka site and, via the expert assessment, set the value of the indicator for the Horka site at slightly better than for the Hrádek site (3.0 and 3.3, respectively). The grades of the Čertovka and Čihadlo sites represent the two extremes of the grading system, as discussed in the respective chapters for these sites.

Janoch (ETE-south) (Havlová et al. 2020f)

With respect to both the Janoch (ETE-south) and the Na Skalním (EDU-west) sites, the P_{21} parameter values were not determined as part of the project (Kabele et al. 2018). However, prior to the DFN modelling project, detailed geological research was conducted at both of these sites - see Hanžl et al. (2017) and Navrátilová et al.(2017) in connection with detailed geological mapping at a scale of 1:10,000 and structural and geophysical research (supplemented by the geological and geophysical research project conducted by Mixa et al. (2019)).

The determination of the grade by the respective expert team for the assessment of the C3b indicator was performed on the basis of the above studies, the information obtained from the geophysical and geological research (Mixa et al. 2019) and analogies relating to lithologically similar parts of the metamorphic Moldanubian complexes of the other sites. Due to the absence of the determination of the P_{21} parameter, a more detailed description of the fracture systems at the site is provided below:

Shear fractures

The geological mapping (Navrátilová et al. 2018) identified four groups of shear fractures at the site: structures running NNW-SSW to N-S with steep inclinations to the WNW to W, mostly without the occurrence of striations and kinematic indicators (i), structures running NW-SE with steep inclinations to the SW and NE, with the variable occurrence of striations and with a slight inclination to the WNW, with indicators of right-hand oblique motion kinematics, possibly with younger generations of striations (ii), structures running NE-SW with medium inclinations to the NW, with the occurrence of striations with a moderate inclination to the WNW to W with indicators of declining kinematic movement (iii) and, finally, structures running W-E with steep inclinations to the S, with the variable occurrence of striations with a slight inclination to the WSW and with indistinct indicators of right-hand oblique kinematics (iv). Based on the relationship between the non-deformed pegmatite veins and the surrounding brittle reactivation, the authors concluded that these significant shear reactivations of the rock mass were older than the occurrence of the positioning of veined bodies bound to granitoid magmatism.

Extension fractures

The dominant set of extension fractures in the rocks of the area of interest comprises subvertical fractures without mineral fillings. Several main trends in the orientation of steep extension fractures have been observed: NW-SE (most abundant), NNW-SSE and NNE-SSW. The highest frequency of extension fractures in all directions has been recorded in heavily weathered paragneisses with higher degrees of crystallisation, with a fracture density of around 5-6 per metre. With respect to weakly crystallised and less weathered paragneisses, the frequency of the fractures decreases to 2-4 per metre and, in the case of erlans, to 1-2 per metre.

The geophysical analysis revealed extensive zones, the geophysical images of which reflect the impact of fracturing, i.e. mainly zones of reduced electrical resistance in combination with the deceleration of seismic waves. In order to provide an indication of the intensity of this phenomenon, the respective results of the report by Mixa et al. (2019) are presented below:

Overview of the fracture zones in the area of deep weathering

- *ETE-02AA at depths of 100–450 m and 1000–1200 m; thickness: 5–35 m (according to the MRS and DOP methods).*
- *ETE-02CA at depths of 250–600 and 1600–2350 m; thickness: 10–35 m (according to the MRS and DOP methods).*
- *ETE-02AB at a depth of 950–2050 m; thickness: 10–30 m, and in the mylonite zone at a depth of 2100–2300 m, the fracture zones may be as thick as 50 m (according to the MRS and DOP methods).*
- *ETE-02CB at depths of 450–850 m, 1150–1650 m, 2600–2850 m and 3500–3800 m; thickness 10–35 m and in the areas of fractures IDs 40, 41 and 42 it affects the fracturing of the massif to thicknesses of min. 50 m (according to the MRS and DOP methods).*
- *ETE-03A at a depth of 1000–1600 m; thickness: 10–25 m; in the vicinity of the ID 43 fault, the massif may be fractured to a depth of 50 m (according to the MRS, ERT and DOP methods).*
- *ETE-06A at a depth of 2600–2750 m; thickness: 5–7 m (according to the DOP and gravimetric methods).*

- *ETE-08 at a depth of 0–2200 m; thickness: 10–20 m (according to the MRS and DOP methods), at a depth of 5900–7700 m (in the area of the Tertiary basin), thickness: up to 20 m.*
- *ETE-09 at a depth of 600–900 m; thickness: 10–20 m (according to the MRS and DOP methods).*
- *ETE-10 at depths of 100–550 m and 1200–1450 m; thickness: 5–35 m (according to the MRS and DOP methods).*
- *ETE-11 at a depth of 500–650 m; thickness: up to 20 m (according to the MRS and DOP methods).*
- *ETE-12 at a depth of 0–150 m; thickness: 10–35 m; at a depth of 700–1800 m with a depth range of up to 20 m, and at a depth of 5100–5500 m; thickness: up to 10 m. Around the ID 53 and ID 54 faults, tectonically disturbed zones attain a thickness of up to 50 m; around the ID 1 fault of up to 30 m (all according to the MRS, ERT and DOP methods).*
- *ETE-13 at a depth of 1600–2050 m; thickness: up to 30 m, and at a depth of 3700–5100 with a depth range of 20–40 m (according to the ERT and DOP methods).*

The expert team assigned a grade of 3.2 to the Janoch (ETE-south) site with respect to the C3b indicator, which reflected the following main conclusions: fracture sets with a low frequency of fracture surfaces (2-6/metre depending on the lithology) were measured on outcrops. Therefore, it can be assumed that the P_{21} parameter value would have been as low as that determined for the Kraví hora site (P_{21} = 0.58), which also comprises metamorphic complexes. However, it is also necessary to take into account the extensive indications of fractures revealed by the geophysical images - see above. The Kraví hora site was assigned a grade of 3.1; it was considered in the comparison of these two sites that although the Janoch (ETE-south) site evinced a significantly larger distribution of fracture systems than the Kraví hora site, it was significant that the fractures at the Janoch (ETE-south) were not mineralised (they are often accompanied by alterations, crystallisation and mineralisation at the Kraví hora site); thus, the grade was set as just 0.1 points worse than for the Kraví hora site. The similarly assessed intrusive Hrádek and Březový potok sites, with grades of 3.3, evinced significantly higher P_{21} parameter values of 1.12 and 1.15, respectively; however, the manifestations shown in the geophysical images were not so extensive (fewer fractures were revealed by the geophysical research) and the range of open fractures on the granites was greater, usually 20-40 m, often up to 60 m than that on the Moldanubian metamorphites, where the range of fractures was only rarely observed to be greater than 30 m. Hence, the Janoch (ETE-south) site was assigned a grade of just 0.1 points more favourable than the above-mentioned sites located in granitoids.

Kraví hora (Havlová et al. 2020g)

Although the P_{21} parameter value ranks the Kraví hora site in 1st place (i.e. it evinces the least fractures on outcrops), the site was assigned only an average grade of 3.1 in the overall assessment, which ranks it together with the Hrádek, Horka, Magdaléna, EDU-west and ETE-south sites, which were also assigned average grades. The low value of the P_{21} parameter compared to the other sites was most probably due to the rheological contrast of the indistinguishable paragneisses and migmatites of the Kraví hora site compared to the granitoid rocks of the other sites. Moreover, it must be borne in mind that, given the minimal differences between the P_{21} parameter values, the assessment team decided against applying the extreme values of 1 and 5, as permitted by the assessment methodology.

The occurrence of fracture systems as documented by the geophysical research are significant and were determined mainly via electrical and seismic methods along faults and their immediate surroundings and outside faults. The geological mapping revealed (similarly to the faults) quartz fillings, Cu-Fe mineralisation and chloritisation in extension fractures. Compared to the granite sites, sub-horizontal fractures (inclined at 0-30°) occur only rarely, since they are usually created via exfoliation due to weathering in granite environments. The above reasons led to an expert assessment of 3.1 for the Kraví hora site, which is worse than the grade of the Čertovka site, which has only a small number of fractures (albeit with a slightly worse P_{21} index) and is similar to the assessment grades assigned to the Na Skalním (EDU-west), Janoch (ETE-south), Horka, Březový potok and Hrádek sites. While these sites had less favourable P_{21} parameters, the fractures (according to the geophysical research and geological mapping) did not evince abundant alterations, crystallisation and high intensity either along or outside the fault lines.

Magdaléna (Havlová et al. 2020h)

Although the P_{21} parameter served to rank the Magdaléna site in the middle of the table of parameter values, the findings of the geological and geophysical research were also taken into account in terms of the final grade. The information obtained from field work confirmed the average impact of fracture systems at the site. The reasons for this assessment grade were as follows.

The Magdaléna site comprises level, intensively agriculturally-used terrain with a minimum of outcrops - the number of measured outcrops was the lowest of all the assessed sites. Therefore, the P_{21} parameter was burdened with a greater degree of uncertainty in terms of its explanatory potential than it was for the other more geologically-exposed sites. However, the results of the geophysical research provided a relatively good picture of the fracturing at the site, which confirmed the moderate presence of fractures.

A significant phenomenon was discovered during the geological and geophysical research comprising the presence of extremely numerous E-W-oriented small subvertical veins of leucogranites, aplites and quartz, usually forming bodies of cm to dm thickness and, less frequently, metres to tens of metres and with lengths of up to 1 km. The number of such veins was in the thousands on the documented profiles. The veins comprise primarily intrusive contacts with durbachite; however, sometimes their edges have been brittlely reactivated by extension and shear fractures, which often play the role of hydraulic conductors and represent preferential groundwater pathways in such a weakened rock mass. This phenomenon was well documented principally via the electrical, but also via the seismic geophysical, method. While this feature does not concern all the veins, it is an important phenomenon that cannot be ignored.

The fracture systems documented by the geophysical anomalies (especially increased velocities via the electrical method and lower values according to the seismic methods) accompany only faults and the above-mentioned edges of veins. The geophysical research did not suggest the area failure of the massif. The only stronger such zone, which is probably connected to the increased degree of fracture failure that led to the deeper weathering of the durbachite up to around 40 m, occurs only in the northern part of the promising area for the geological characterisation research.

The assessment of the P_{21} parameter, the weakly-documented fracture systems on the surface discovered via geological mapping and the occurrence of brittle failure connected to faults and the edges of a number of aplite veins, led the expert team to classify the site as moderately fractured and assigned a grade of 3.0. As previously mentioned, fracture failure is related mainly to the surroundings of faults and veins, in a similar way to the Čertovka site (grade of 2.4) which, however, does not contain veined phenomena and thus led to a better P_{21} parameter value and a correspondingly better grade. The Horka, Na Skalním (EDU-west) and Hrádek sites feature fractures in the form of wide but not very powerful zones, thus indicating the shallow and extensive nature of fracture failure, which was reflected in the P_{21} parameter value. Hence, the Horka site (grade of 3.0) was assigned the same grade as the Magdaléna site and the Hrádek site, which had a worse P_{21} parameter (1.12), was awarded a grade of 3.3 as was the Březový potok site (P_{21} of 1.15).

Na Skalním (EDU-west) (Havlová et al. 2020i)

With respect to both the Na Skalním (EDU-west) and Janoch (ETE-south) sites, the P_{21} parameter values were not determined as part of the project (Kabele et al. 2018). However, prior to the DFN modelling project, detailed geological research was conducted at both of these sites - see Hanžl et al. (2017) and Navrátilová et al.(2017) in connection with detailed geological mapping at a scale of 1:10,000 and structural and geophysical research (supplemented by the geological and geophysical research project conducted by Mixa et al. (2019)).

The determination of the grade by the expert team with respect to the C3b indicator was thus based on the above-mentioned studies, the information obtained via geophysical and geological studies by Mixa et al. (2019), and via analogy to the lithologically similar Horka site, which is also located in the Třebíč pluton, around 20 km north of the Na Skalním EDU-west site. Due to the absence of the determination of the P_{21} parameter, a more detailed description of the fracture systems at the site is presented below.

The fracture systems in Moldanubian rocks appear to be highly heterogeneous. In the area west of the Třebíč pluton, the fracture network is made up of extension fractures with predominantly subvertical slopes. The fracture system comprises two equivalent and mutually orthogonal fracture sets running in the NW-SE and NE-SW directions and a less significant fracture set running WSW-ENE. The most pronounced direction is the azimuth of 120° with a median of 5 fractures per metre. Other significant directions have azimuths of 40° and 80° with a median of 4 fractures per metre.

The most significant fracture set in the Moldanubian east of the Třebíč pluton comprises fractures mainly with steep orientations and running NW-SE. Other, less numerous fracture sets comprise fractures running generally E-W to NE-SW. The density of the fractures varies considerably. Fractures with an azimuth of 160° (approx. 7 per metre) evince the highest median fracture density, while other significant azimuths are in the directions 120° and 80° and evince a median of 5 fractures per metre.

The rocks of the Třebíč pluton appear to be less fractured in comparison. The area is dominated by extension fractures with predominantly subvertical orientations, defined by a main fracture set running NNW-SSE to WNW-ESE and less significant fracture sets running NW-SE and NE-SW. The fracture density is generally uniform in most directions at around three fractures per metre. The median of the fracture densities for azimuths with directions of 10° and 120°, is lower, i.e. around two fractures per metre. Exfoliation fractures are common in the durbachite of the area and are usually sub-horizontal or inclined at an angle of up to 10°; their orientation depends on the surface morphology.

The expert team assigned a grade of 3.0 to the Na Skalním (EDU-west) site for indicator C3b, which reflected the following main findings: the P_{21} parameter for the Horka site with an identical Třebíč durbachite lithology resulted in a grade of 3.0, thus reflecting the average fracture systems of the site. Hence the Na Skalním locality (EDU-west) site was awarded the same grade. Previous geological surveys (especially Hanžl et al. 2017, 2018) recorded fracture sets similar to those at the Horka site, with the same frequency of anomalies.

The other similarly intrusive sites, i.e. Hrádek and Březový potok were awarded grades of 3.3 due to their higher P_{21} parameter values - 1.12 and 1.15, respectively. Since the Čihadlo site evinced the highest P_{21} value of 1.51, and the geophysical analysis suggested that this site is the most affected by fracturing, it was awarded a grade of 4. Conversely, the best grade as obtained by the Čertovka site reflected the lowest P_{21} parameter of all the sites, which was confirmed by the results of the geophysical and geological research.

Tab. 11 Overall assessment of the sites for the C3b indicator according to reports by Havlová et al. 2020a-i

Site	Indicator grade
Březový potok	3.3
Čertovka	2.4
Čihadlo	4.0
Horka	3.0
Hrádek	3.3
Janoch (ETE-south)	3.2
Kraví hora	3.1
Magdaléna	3.0
Na Skalním (EDU-west)	3.0

C3c Degree of ductile deformation

Description of the indicator: the indicator reflects the number of ductile structures and the complexity of the site environment in terms of ductile deformation events. It includes an expert estimate of the intensity of ductile deformation and the complexity of the resulting deformation structures, i.e. foliation and linearisation. In general, the more complex and intense the manifestations of ductile deformation, the more complicated the rock environment is in terms of geotechnical parameters; at the same time there is a higher probability of the occurrence of brittle structures. Of the various ductile elements, only foliation - magmatic and metamorphic – was included in the assessment; this is the only ductile element that can be documented in sufficient quantities for the assessment of all nine sites (information on rarely observed lineations, fold and other ductile structures and ductile shear zones does not meet the condition of being available in a sufficient amount for assessment purposes).

Quantification: 1 - the lowest degree of ductile deformation; only one generation of ductile structures is determined; 5 - the highest degree of ductile deformation; incidence of a large number of loaded ductile structures with complicated mutual relations.

Results of the assessment of indicator C3c

Březový potok (Havlová et al. 2020a)

The degree of the ductile deformation of the Blatenské and Červen granodiorites that make up the rock polygon defined for the promising area for the project design work and the surrounding area, is weak. The ductile structures, as defined by the weak preferential spatial orientation of quartz crystals, amphiboles, feldspars and mica, evince a magmatic to submagmatic character, indicating their syntectonic placement. The steep orientation of igneous foliations, generally running NE-SW predominates, accompanied by lineages that decline at mild to moderate angles to the NNE, locally reworked into a subsolid foliation that fits at moderate angles to the NW. The indistinct character of the igneous structure is further accentuated by the massive, fine to medium-grained texture of the granodiorites, and only weakly by the porphyritic character of the rocks (feldspar occurrences of max. 1-2 cm locally in the Červen granodiorites). Hence, the Březový potok site was assigned a grade of 1.2 which reflected the homogeneous granodiorite structure, as well as the weak but, nevertheless, penetrative character of the igneous foliations, which suggests more intense deformation than the merely domain-developed igneous foliations at the Čihadlo and Hrádek sites (1.0).

Čertovka (Havlová et al. 2020b)

The degree of the ductile deformation of the granites of the Tiský massif in the promising area for the project design work and the surrounding area led to the assignment of a grade of 1.5 for the site, which represents the average of the grades assigned to the granitic sites (1-2).

Areas of primary igneous foliation (the preferred spatial orientation of feldspar outcrops and aggregates of other rock-forming minerals) have been recorded in the granite. Most of the foliation areas decline at steep angles to the WSW to NNW, less so to the ESE. The manifestation of igneous foliation are weak, and initially suggested the assignment of a grade of 1 to 1.2, corresponding e.g. to the Čihadlo and Březový potok sites; however, in contrast to these sites, the granites of the Tiský massif exhibit low-temperature subsolid deformation in the form of non-penetrative cleavage with a steep orientation to the NNE-SSW located mainly along the eastern edge of the massif. Therefore, the expert assessment awarded a final grade of 1.5.

Čihadlo (Havlová et al. 2020c)

The degree of the ductile deformation of the granites of the Klenov pluton in the promising area for the project design work and its surroundings is weak. The internal structures of the granitoids of the Klenov pluton are defined by the weak preferential spatial orientation of quartz, feldspar and mica crystals. The preferred orientation of the crystals evinces a predominantly planar character that formed igneous foliations, in places with evidence of weak high-temperature subsolid deformation. Remnant steep igneous foliations oriented to the NE-SW have a domain character and were not recorded in the promising area for the project design work, as well as ductile deformations in the metamorphic rocks. Hence the expert team assessed the site as only slightly affected by one phase of ductile deformation, similar to the situation at the Hrádek and Magdaléna sites. Therefore, the Čihadlo site was awarded a grade of 1, reflecting the lowest intensity of ductile structures of all the candidate sites.

Horka (Havlová et al. 2020d)

The degree of ductile deformation of the durbachites in the promising area for the project design work and its close surroundings led to the assignment of a grade of 2 for this site, which corresponds to the grade awarded to the geologically similar EDU-west site (durbachites of the Třebíč pluton) and is slightly worse than the grades of the sites that are made up of granites (grades in the range 1.0-1.5). The reason concerns the presence of two well-developed differing generations of ductile igneous and deformation structures, defined primarily by the orientation of the minerals, especially porphyritic potassium feldspars and biotite. The igneous foliation predominantly declines at steep angles to roughly the SSE to SSW. Relatively younger deformation structures fit at small angles to the NE and serve to partially modify the orientation of the original igneous foliation.

Due to the presence of the two well-developed foliation systems, the Horka site was assigned a mark of 2 (as was the EDU-west site), which distinguished these two durbachite sites from the granite sites, which usually exhibited just one, often weak, igneous structure system.

Hrádek (Havlová et al. 2020e)

The granites of the Hrádek site, with the granitoids of the Čihadlo and Březový potok sites, evinced the lowest impacts of ductile deformation (igneous foliation) and were, therefore, assigned a grade of 1. The other extreme of the scale featured those sites made up of metamorphic rocks, the ductile deformations of which appear to be orders of magnitude more intense; therefore, values from the whole of the scale 1 - 5 were applied in contrast to, for example, the less significant differences observed in the assessment of the C3b indicator. Due to the fact that the assessment of the ductile deformations was restricted to the promising areas for the project design work and the surrounding areas, the grade does not reflect the ductile deformation of the metamorphic Moldanubian rocks, i.e. the grade reflects only the structures in the target lithology of the Čeřínek and, partly, Eisgarn granites. The ductile deformation of the site, i.e. the igneous foliation given by the alignment of biotite aggregates and feldspar outcrops, is more pronounced only in the marginal parts of the granite in the vicinity of intrusive contact with Moldanubian migmatites. The central parts of the granite body, in which the promising areas for the project design work are located, are affected by ductile deformation only to a minimum extent. Hence, the Hrádek site was awarded a grade of 1, as were the similarly minimally affected Čihadlo and Březový potok sites. Since the other sites located in granitoids, i.e. the Na Skalním (EDU-west), Březový potok, Čertovka and Horka sites evinced more intense igneous foliations, often with dual orientations, they were awarded correspondingly higher grades by the respective expert assessment team.

Janoch (ETE-south) (Havlová et al. 2020f)

The rocks of the Janoch (ETE-south) site are affected by three generations of variously intensely developed ductile deformations, i.e. the second most intensive disturbance of all the nine candidate sites (after the Kraví hora site). Hence, this site was assigned a grade of 4.

The migmatised paragneisses and migmatites of the monotonous and variegated unit of this part of the South Bohemian Moldanubian were tectonically poly-phasically impacted by the formation of three successive ductile (plastic) deformation systems.

The monotonous Moldanubian unit is affected in the area of interest mainly by S_2 penetrative foliation declining to the NW at medium angles (approx. 50°); superimposed S_3 metamorphic foliation developed only in domains and evinces slight inclinations of 0–30° to the W. Paragneiss folding is visible only at the microscale where leukosomes formed isoclinal folds of scales of mm to cm cleaved to the WSW-ENE. The paragneisses are affected by mylonitisation to the NW. No older N-S S_1 structures remain in the paragneisses of the promising area for the project design work and the vicinity thereof, but do occur in the wider surroundings.

The above-described ductile deformation of the Janoch (ETE-south) site is significantly more intense and varied than in the seven granitoid sites; therefore, the difference between the grade for the Janoch (ETE-south) site (4) and the worst-rated granitoid sites of Na Skalním (EDU-west) and Horka (both 2.0) is significant, which, according to the expert team assessment, reflects the difference between metamorphic and igneous ductile structures. On the other hand, the ductile structures of the Kraví hora site appear to have preserved all three deformation systems ($S_{1, 2, 3}$) affected by intensive fold structures (remnant folding and isoclinal shoulders, folded S_2 foliations evident especially in the composite banding of migmatites and flat open folds that deform S_3 foliation). Hence, the Kraví hora site was assigned a grade that expressed the maximum ductile disturbance, i.e. 5, and the Janoch (ETE-south) site a mark one degree lower, i.e. 4.

Kraví hora (Havlová et al. 2020g)

The rocks of the Kraví hora site have been impacted by several generations of ductile deformations, which points to the most intensive disturbance of all the nine candidate sites and resulted in this site being assigned the worst grade, i.e. 5.

The ductile deformation structures at the Kraví hora site form a heterogeneous complex of superimposed structures (metamorphic foliations, folds and lineations). Three metamorphic structures of regional significance have been identified at the Kraví hora site. The oldest structures comprise preserved remnants, especially in the granulite body and in peridotites in the form of folded shoulders and asymmetric rootless folds with dimensions of centimetres to decimetres.

The foliation surfaces of the loaded structure (S_2) are defined by compositional zoning that declines at medium to steep angles to approx. the W to SW. The superposition of the relatively younger metamorphic structure was heterogeneous; the areas of this foliation, or the S_2 folded foliation, decline at slight to medium angles to approx. the NNW to SW. The planar structures are accompanied by significant lineaments of elongation-deformed or recrystallised aggregates of quartz, feldspar and biotite or by mineral lineaments with a predominant slight inclination to the south. These metamorphic structures define the courses of the various rock lithologies (migmatites, amphibolites and granulites).

The superimposed S_3 metamorphic foliation with a slight to medium inclination (0-45°) to the ~NNW to SW is significant and represents the dominant foliation system with numerous open folds with fold planes that decline mainly at mild to medium angles to the SW, subparallel with the course of the S_3 metamorphic foliation.

The ductile deformation of the Kraví hora site described above is significantly more intense and varied than the penetrative but monotonous foliation of the paragneisses and migmatites at the Janoch (ETE-south) site. Therefore, the Kraví hora site was awarded a grade of 5 and the Janoch (ETE-south) site a grade of 4 for the C3c indicator. The ductile deformation in the intrusive rocks of the other sites, made up solely of igneous foliation of an incomparably lower intensity of plastic deformation, led to their being assigned grades in the range 1.0 to 2.0, which, according to the expert assessment team, captures the essential difference between metamorphic and igneous ductile structures.

Magdaléna (Havlová et al. 2020h)

The degree of ductile deformation of the durbachites in the defined promising area for the project design work and the surrounding area is weak. The Čertovo-type durbachites at the site have a very conspicuous porphyritic structure; however, most of them have been recorded as evincing only the weak to medium orientation of potassium feldspar growths of an igneous to sub-igneous character, while the basic dark rock matrix remains in most cases macroscopically omni-directionally grainy. Hence, the Magdaléna site was assigned a grade of 1.5, equivalent to the Čertovka site, which, as with the Magdaléna site, features weak but well-documented igneous foliations that are less intense than, for example, the two generations of clearly mappable igneous/deformation foliation at the EDU-west (grade 2) and Horka (grade 2) sites and, at the same time, somewhat more intense than the usually only domain-developed weak igneous foliation of the Hrádek and Čihadlo sites (grade 1.0).

Na Skalním (EDU-west) (Havlová et al. 2020i)

The degree of ductile deformation of the durbachites in the defined promising area for the project design work and the surrounding area led to the assignment of a grade of 2 by the expert assessment team. This grade corresponds to the assessment of the geologically similar Horka site (durbachites of the Třebíč pluton) and is slightly worse than the grades assigned to the granite sites (grades of 1.0-1.5). The reason comprised the presence of two well-developed differing generations of ductile structures, defined primarily by the orientation of minerals or the preferred orientation of elliptical or elongated mafic enclaves. Older igneous structures evince a subvertical orientation running predominantly N-S; the transposition thereof into a younger igneous structure, which fits at low angles to the NE, is easily observable.

Due to the two well-developed igneous foliation systems, the Na Skalním (EDU-west) site was assigned a grade of 2 (as was the Horka site), thus distinguishing these two durbachite sites from the granite sites, which usually featured only one system of often only weakly-developed igneous structures.

Tab. 12 Overall assessment of the sites for the C3c indicator according to reports by Havlová et al. 2020a-i

Site	Indicator grade
Březový potok	1.2
Čertovka	1.5
Čihadlo	1.0
Horka	2.0
Hrádek	1.0
Janoch (ETE-south)	4.0
Kraví hora	5.0
Magdaléna	1.5
Na Skalním (EDU-west)	2.0

5.8.4 Variability of the geological properties

5.8.5

Description of the criterion: a large degree of variability of the geological properties that does not allow for the creation of reliable 3D geological, hydrogeological and geochemical models constitutes one of the exclusion criteria. However, in this phase of the DGR site selection process (the reduction in the number of candidate sites from 9 to 4), concerning which mostly only surface geological research has been conducted, this factor is not considered to be excluding and can be used for site comparison purposes.

The requirement for the assessment of the variability of the rock environment is set out in Decree No. 378/2016 Coll. Section 18, 4b. Spatial and petrological variability were chosen on the basis of the availability of detailed data from the assessed sites (Franěk et al. 2018 and Mixa et al. 2019).They are the only two independent rock environment variability parameters which, from the geological perspective, can be applied with a sufficient degree of credibility with respect to the currently available amount and quality of data from all 9 sites. The expert assessment of spatial variability enables the indication of the amount, spatial distribution and character of the rock bodies, while the petrological variability collectively indicates the various mineralogical and geochemical properties of the various rock types (e.g. the variability of the composition of varieties of granite present at the site is combined under the item "granite"). Both of these independent parameters play an important role in terms of the assessment of the geological properties and homogeneity of the rock environment.

Description and assessment of the indicators

C4a Spatial variability of the rock environment

Description of the indicator: the indicator reflects the spatial arrangement of the rock bodies, i.e. the geometric relationships between, and the shapes of, the various bodies. This factor is described in the form of a three-dimensional rock body which is made up of a single rock type (according to Mixa et al. 2019, Franěk et al. 2018) or a dominant rock type (e.g. granite with small paragneiss xenolites is mapped as granite, but the presence of xenolites is described in the corresponding reports). The spatial variability captures the horizontal and vertical distribution, i.e. the nature and frequency of the alternation of the various rock bodies in the vicinity of the DGR site, usually at a scale of units of up to hundreds of metres. For example, a site at which two contrasting rock types alternate repeatedly to a relatively low extent will exhibit a low degree of petrographic variability, whereas a high degree of spatial variability may present complications in terms of the design of the DGR. This indicator also includes an assessment of the nature of the contacts between the various rock bodies (e.g. straight, uneven, lobed, tectonic or petrographic transition).

Quantification: 1 – the simple spatial variability of the rock environment in the horizontal and vertical directions with simple contacts between the rock bodies, 5 - very complex spatial variability of the rock environment with the alternation of various lithologies and with complicated contacts between the rock bodies.

Results of the assessment of indicator C4a

Březový potok (Havlová et al. 2020a)

The assessed area, i.e. the promising area for the project design work and its near surroundings (hereinafter referred to as the polygons), appears to be relatively very homogeneous; therefore, the site was assigned a grade for the C4a indicator of 2.1. The main argument of the expert team concerned the fact that both polygons of the promising areas for the project design work, i.e. Březový potok-N and Březový potok-S are made up of homogeneous granodiorites with only a small number of aplite veins and veined quartz, without the presence of xenoliths of the Moldanubian rocks (which occur mainly in the north and the south-east of the area covered by the regional 3D model, and partly in the south-west; in all cases outside the assessed polygons). The grade of 2.1 (only slightly worse than, for example, those of the Čertovka and Na Skalním (EDU-west) sites, both 2.0) takes into account the presence of a significant veined occurrence of aplites, lamprophyres and veined quartz running in the E-W direction between the two polygons and in the vicinity of the Pačejov - Maňovice - Velký Bor cadastral area. The Janoch (ETE-south) site, with a slightly worse grade of 2.2, was assessed similarly to the Březový potok site due to the presence of a relatively thick strip of variegated inserts (erlans, crystalline limestones and quartzites) that runs just to the south of the promising area for the project design work.

Čertovka (Havlová et al. 2020b)

The Čertovka site was assigned an expert assessment grade of 3, which ranks it as the weakest of the granite sites in terms of this indicator.

The coarse-grained biotite granite of the Tiský massif, which makes up both of the promising areas for the project design work, provides a good example of an homogeneous lithology. The rock is only slightly variable and features no xenoliths, deviations or enclaves, with only a minimum of quartz veins and practically no aplites or pegmatites. However, due to the fact that the assessment refers to the areas of the polygons that make up the promising areas for the project design work as well as the surrounding areas (hereinafter the polygons), it is necessary to take into account that Neogene effusions of olivine nephelinites occur in both polygons (approximately 700 metres from the northern edge of the polygon for the promising area for the project design work referred to as Čertovka-S and around 1200 m from the southern edge of the polygon of the promising area for the project design work of Čertovka-N). The edge of the Permocarbon sedimentary Žihel basin runs along the Žihel fault in the vicinity of both polygons, at a distance of approximately 300-400 m. Likewise, the boundary of the Permocarbon Žatec part of the Kladno-Rakovník basin runs at a distance of approximately 300 m from the northern boundary of the Čertovka-N polygon. In the south, the southern boundary of the Čertovka-S polygon lies a maximum of 900 m from the contact of the Tiský granite with phyllites and clasts of the Thermal Crystalline, where the contact metamorphosed into cherts gradually transforming into a regionally metamorphosed sequence of phyllites, clasts and metagreywakes.

Although the target lithology itself consists of homogeneous granite, the expert team took into account the presence of the diverse sequence of rocks in the vicinity, i.e. permocarbon conglomerates, sandstones and siltstones, cherts, phyllites and Bohemian and tertiary effusive nephelinites. Hence, the site was assigned a grade of 3.0.

Čihadlo (Havlová et al. 2020c)

The promising area for the project design work and the surrounding area, appears to be relatively homogeneous; thus, the site was assigned a grade of 2 for the C4a indicator. Only the Horka (1.2) and Hrádek (1.0) sites received better grades. The main argument from the expert assessment team was the fact that the Klenov pluton comprises a homogeneous rock block in terms of structure, grain size and mineralogical composition. Xenoliths of biotite migmatites occur in the assessed area (the result of the absorption of Moldanubian metasediments during the intrusion of the Klenov pluton), which serve to enhance the variability of the environment. These xenoliths, measuring up to tens of metres are made up of medium-grained migmatites with characteristic banding, with the alternation of positions rich in biotite, sillimanite and cordierite (melanosomes) and positions with the predominance of quartz and feldspars (leukosomes). Hence, the Čihadlo site was assigned a grade of 2.

Horka (Havlová et al. 2020d)

The rock of the promising area for the project design work and the surrounding area appears to be very homogeneous (unlike the rest of the site); therefore, the site was assigned a grade of 1.2 for indicator C4a, i.e. the second best grade after the Hrádek site (1.0). The assessed area is made up of one main lithology, i.e. the durbachite (or coarse-grained porphyritic melanocratic granite to syenite) of the Třebíč pluton. The rock of the area contains only small igneous enclaves with sizes of cm - dm, as well as isolated quartz veins of thickness of cm and isolated veins of leucocratic muscovite-biotite granites with tourmaline of thicknesses of up to 10 m. No other rock types were detected in the promising area for the project design work and surroundings either by the geological mapping or the geophysical research.

Veined occurrences of leucogranites to aplites in the E-W direction are present at the Horka site in larger numbers; however, they have been recorded outside (1.5-3 km to the east of) the assessed area in the cadastral areas of Kamenná nad Oslavou and Budišov. Small intrusions of medium-grained biotite granites up to several hundred metres in size have been mapped west of the assessed area around the villages of Budíkovice and Horní Vilémovice along the western boundary of the 3D model, and around 4-5 km from the edge of the promising area for the geological characterisation research. Several metres of thick quartz veins have been recorded south of the southern boundary of the assessed area in the cadastral areas of Hostákov and Kojatín and 4 km west of the assessed area in the cadastral area of Bochovice.

As can be seen from the above, the assessed promising area for the project design work and the surrounding area consists of homogeneous durbachite (coarse to medium-grained porphyritic melasyenite to melagranite) with the presence of non-abundant small mafic enclaves and isolated quartz and granite veins. Therefore, the expert team assigned the Horka site a grade of 1.2 - only 0.2 points worse than that of the ideally homogeneous granite (without the presence of veins and xenoliths) of the Hrádek site (1.0). The Na Skalním (EDU-west) site was assessed as slightly worse (2.0 – compared to the Horka site, the EDU-west site features a larger number of leucocratic granite and aplite veins and small granodiorite intrusions), the Magdalena site was assessed as considerably worse (3.7 – a significantly larger number of leucocratic granite veins compared to the Horka site), and the Čihadlo site as slightly worse (2.0 – due to the presence of biotite migmatite xenoliths).

Hrádek (Havlová et al. 2020e)

The promising area for the project design work and the surrounding area of the Hrádek site appears to be homogeneous and consists exclusively of granites, without the detected presence of veins in either the rock or quartz (only small secretory lenses of which are present), and without the presence of xenoliths or other inhomogeneities. Although some inhomogeneities do occur in the Eisgarn-type granites and partly along the contact of the Čeřínek intrusion with the Moldanubian, they do not occur in the assessed promising area for the project design work and its surroundings. With regard to the proven vertical and sharply demarcated shape of the intrusion, it is very likely that the same homogeneous rock will continue to a depth of 500 m. Thus, the Hrádek site was assessed as ideally homogeneous, with minimal spatial variability, and was assigned a grade of 1.

Janoch (ETE-south) (Havlová et al. 2020f)

The assessed promising area for the project design work and near surroundings appears to be predominantly homogeneous and is made up of monotonous paragneisses; nevertheless, the site was assigned a grade of 2.2 for indicator C4a. The reason for the site not being assigned a better grade comprised the fact that the immediate vicinity of the southern boundary of the promising area for the project design work features a strip of variegated insert rocks with the predominance of crystalline marbles and erlans, with the less frequent occurrence of quartzites and amphibolites. Veined granitoids, aplites and pegmatites are also more abundant in this zone. The strip runs E-W to ENE-WSW and the insert rocks are parallel to the foliation and fit at medium angles to the NNW. Hence, the expert team assigned a grade of 2.2 to the Janoch (ETE-south) site, which corresponds, for example, to the assessment of the Březový potok (2.1) and Čihadlo (2.0) sites with similar situations, i.e. homogeneous rocks make up the promising area for the project design work, but a certain amount of lithologically differing rocks occur nearby (veins, enclaves, xenoliths in the granitoid areas or insert meta-sedimentary or veined rocks in the paragneisses of the Moldanubian).

To a limited extent (mostly in the east of the assessed area), the crystalline rocks are covered with Neogene deposits. Isolated Tertiary denudation remnants of the České Budějovice Basin, with a very irregular extent and thickness, reach a maximum thickness of 5–20 m for the Upper Mydlovar formation and 50–70 m for the Lower Mydlovar formation. The crystalline rocks are more deeply fossil-weathered below and around these occurrences. The Quaternary is represented only to a minimal extent in the promising area for the geological characterisation research, mostly fluvial sediments around streams or clayey-sandy slopes.

Kraví hora (Havlová et al. 2020g)

The assessed promising area for the project design work and its near surroundings appears to be extremely heterogeneous at the Kraví hora site; therefore, it was assigned a grade of 5. The difference compared to the second most variable Čertovka site (grade of 3) reflects the diverse lithological structure of the Kraví hora site. The promising area for the project design work and the surrounding area contains a diverse mixture of orthogneisses, migmatites, granulites and granulitic gneisses, serpentinites, amphibolites, clasts and paragneisses accompanied to a lesser extent by pegmatite and aplite veins. The Kraví hora site is by far the most variable of the candidate sites in terms of the number of rock types and their spatial distribution.

Magdaléna (Havlová et al. 2020h)

The assessed promising area for the project design work and its surrounding area appears to be rather inhomogeneous; therefore, the site was assigned a grade of 3.7 for indicator C4a. The defined area consists of one main lithology, i.e. durbachite (or melagranite to melasyenite) of the Čertovo type. The rock features insignificant small (cm-dm) mafic microgranular enclaves; however, large quantities of the above-mentioned E-W leucocratic granite veins are present. Although there are not so many leucogranites present in the promising area for the project design work and the immediate area as in other parts of the wider studied area (hence the promising area was defined here), nevertheless, hundreds, maybe thousands of small bodies act to disturb the spatial homogeneity of the durbachite. The low degree of spatial variability of the durbachite at the Magdaléna site is common to all three of the durbachite sites, i.e. Magdaléna and the Na Skalním (EDU-west), grade of 2 and Horka, grade of 1.2 sites, and is similar – within the relatively small areas that comprise the promising areas for the project design work – to the homogeneous granites of the Březový potok and Čihadlo sites (2.1 and 2.0, respectively), which also evince the non-abundant presence of xenoliths, veins, enclaves and other foreign bodies. However, the dense network of leucogranite and aplite veins was the reason for the expert determination of a grade of 3.7, which ranks the Magdaléna site in second to last position of all the candidate sites, followed in last position by the extremely spatially diverse Kraví hora site (grade of 5).

Na Skalním (EDU-west) (Havlová et al. 2020i)

The assessed promising area for the project design work and its surrounding area appears to be relatively homogeneous in terms of the rock environment; therefore, the site was assigned a grade of 2 for the C4a indicator. The defined area consists of one main lithology, i.e. the durbachite (or coarse-grained porphyritic melanocratic granite to syenite) of the Třebíč pluton. The rock features small (cm to dm) mafic microgranular enclaves as well as E-W leucocratic granite and aplite veins and small granodiorite intrusions. The highest frequency of lithological inhomogeneities was detected in the northern and western parts of the area covered by the regional 3D model consisting mainly of fine-grained biotite granites, which form both veins and small enclave bodies, as well as fine to medium-grained granites with biotite and tourmaline appearing in the form of veins. However, these occurrences do not feature within the promising area for the project design work or in the immediate vicinity, as with the east-facing metamorphites. Thus they did not affect the determination of the grade, i.e. 2.

The low degree of spatial variability is common to both of the durbachite sites of the Třebíč pluton, i.e. Na Skalním (EDU-west) and Horka, with grades of 2 and 1.2, respectively, and is similar – within the relatively small areas that comprise the promising areas for the project design work – to the homogeneous granites of the Březový potok and Čihadlo sites (2.1 and 2.0, respectively), which also feature the relatively rare occurrence of xenoliths, veins, enclaves and other foreign bodies.

Tab. 13 Overall assessment of the sites for the C4a indicator according to reports by Havlová et al. 2020a-i

Site	**Indicator grade**
Březový potok	2.1
Čertovka	3.0
Čihadlo	2.0
Horka	1.2
Hrádek	1.0
Janoch (ETE-south)	2.2

Site	Indicator grade
Kraví hora	5.0
Magdaléna	3.7
Na Skalním (EDU-west)	2.0

C4b Petrological variability of the rocks

Description of the indicator: The indicator concerns the degree of homogeneity of the rock environment within the basic lithostratigraphic unit (items in the geological map). The petrological variability reflects the differences in the content of major rock-forming minerals, the grain size and textural features. The various properties were determined based on a detailed petrological description (macro and micro) and they have the potential to influence the thermal conductivity and/or migration of fluids.

Quantification: 1 - simple petrological variability, i.e. the contents of the main and secondary minerals, their grain size and textural features do not differ with concern to the lithology, 5 - high petrological variability, i.e. the contents of the main and secondary minerals, their grain size and textural features differ significantly with concern to the lithology.

Results of the assessment of indicator C4b

Březový potok (Havlová et al. 2020a)

The assessed promising area for the project design work and the surrounding area comprise petrologically uneventful granodiorites in the studied rock polygons, i.e. Březový potok-N and Březový potok-S; however, the grade also reflected the presence of petrologically differing veined rocks in the vicinity, especially lamprophyres, leucogranites to aplites and veined quartz. Hence, the Březový potok site was assigned a grade of 2.1.

Čertovka (Havlová et al. 2020b)

A grade of 2.2 ranks the Čertovka site in the second to last position with concern to the granitoid candidate DGR sites. Only the Na Skalním (EDU-west) site was assessed as being petrologically more variable of these sites (grade of 2.5), concerning which the expert team took into account the significant facial variability of the melanocratic granites to syenites in the promising area for the project design work and surrounding area, as well as the presence of veins of aplites, pegmatites and leucogranites, mafic enclaves and stromatitic migmatite xenoliths. While the Janoch (ETE-south) site (2.3), made up of monotonous paragneisses was also evaluated as relatively slightly more variable, the assessment took into account the presence of a strip of variegated inserts (especially crystalline limestones, erlans and quartzites) in the afore-mentioned monotonous Moldanubian paragneisses. This strip, which also contains veined rocks - aplites, pegmatites and veined quartz - runs near the southern edge of the promising area for the project design work. The sequence of rocks at the Kraví hora site was considerably more variable, which explains the significant interval between the worst and the second worst grades assigned (5 and 2.5, respectively).

Čihadlo (Havlová et al. 2020c)

The assessed promising area for the project design work and the surrounding area contains petrologically significantly different types of rocks (petrologically uneventful muscovite-biotite granites of the Klenov pluton versus biotite migmatite xenoliths with sillimanite and cordierite); however, Moldanubian xenolites occur in this area only rarely, despite being more frequent in the central part between Mostečný and Ratmírov. Thus, the Čihadlo site was assigned a grade of 2.

Horka (Havlová et al. 2020d)

The grade of 1 assigned to the durbachite of the Horka site reflects the lithologically ideally homogeneous environment made up of amphibolic-biotite durbachites (medium to coarse-grained melasyenites to melagranites with a porphyritic texture). Other rock types are rare – see the description provided for indicator C4a. The second best area in this respect comprises the Hrádek site (a slightly lower grade of 1.4), which also contains practically no differing types of rocks (xenoliths, veins, etc.); however, porphyritic and non-porphyritic textured rock types are present. The Na Skalním (EDU-west) site, also located in the durbachites of the Třebíč pluton, evinced greater textural and lithological diversity - locally smooth transitions from the dominant variety of porphyritic melasyenite to lighter melagranites, and more leucocratic and minority medium to coarse-grained biotite syenite to granite in places with amphibolite alternate with varieties of locally porphyritic and locally non-porphyritic durbachites; therefore, a grade of 2.5 was assigned to this site.

Hrádek (Havlová et al. 2020e)

The assessed area consists mainly of Čeřínek granite and a smaller part of Eisgarn granite, which is made up of several types (white rock, Rohozná, Mrákotín); the various types of granite differ in terms of their petrography, composition and texture and mainly comprise fine to medium-grained two-mica or muscovite-biotite granites with a hyper-automorphically grained structure. Characteristic accessories comprise ilmenite, apatite, zircon and monazite; andalusite is sometimes present. Čeřínek granites usually evince a hyper-automorphic grain structure and, in some places, they occur in the porphyritic variety with feldspar grains up to 3 cm in size - usually medium to coarse-grained muscovite to two-mica granites.

As with the C3c and C4a indicators, there were diametrical differences between the various sites in terms of the petrological variability (monotonous granitoids versus the varied metamorphic groups of the Kraví hora site). Therefore, the full grading scale of 1 to 5 was applied for indicator C4b.

Due to the absence of rocks other than granites (see indicator C4a), the Hrádek site was assigned the second best grade of 1.4 by the expert assessment team. Only the Horka site received a better grade, i.e. 1 due to the assessed area consisting of only one type of durbachite, without any textural or petrographic variations. However, the small difference between the grades reflected the only slight variance between the two sites. Since the other granitoid sites usually contained veins or xenoliths, they were assigned slightly worse grades with respect to both their spatial and petrological variability.

Janoch (ETE-south) (Havlová et al. 2020f)

The assessed promising area for the project design work and the immediate vicinity contain petrologically only slightly varied uneventful migmatised biotite and sillimanite biotite paragneisses; however, the wider surroundings of this area features petrologically differing insert and vein rocks, predominantly crystalline limestone and, to a lesser extent erlans, quartzites and non-abundant veined bodies of leucogranites and pegmatites. Therefore, a grade of 2.3 was assigned to the Janoch (ETE-south) site. This assessment is worse than, for example, those of the Březový potok (2.1) and Magdaléna (2.0) sites, at which rocks that are petrologically-related to the host lithology (especially aplites and pegmatites in granites) occur in the vicinity of the promising area for the project design work. However, the grade is better than, for example, that of the Na Skalním (EDU-west) site (2.5), where the promising area for the project design work features various types of melanocratic granites and syenites with abundant veined leucogranites, aplites and pegmatites and buried enclaves of stromatitic migmatite. Moreover, in the immediate vicinity of the eastern borders of the EDU-west - NE and EDU-west – S promising areas for the project design work, the Třebíč pluton comes into contact with the Moldanubian. Therefore, the grade awarded to the EDU-west site was correspondingly worse than that of the Janoch (ETE-south) site.

Kraví hora (Havlová et al. 2020g)

The main rock types of the Strážec Moldanubian unit (the western and central parts of the area of interest) include stromatitic biotite migmatites and leucocratic migmatites with amphibolite and amphibolic gneisses with evidence of weak migmatisation and with lithologically contrasting rock inserts (amphibolites and migmatised amphibolites, calcium silicate rocks). The granulite of the Drahonín massif is a relatively homogeneous rock type made up of quartz, potassium feldspar and plagioclase with the occurrence of porphyroblasts of hyper-automorphic kyanite and garnet. The Kraví hora site, which was assigned a grade of 5 for the C4b indicator, is orders of magnitude more varied than the second most varied Na Skalním (EDU-west) site which was awarded a grade of 2.5.

Magdaléna (Havlová et al. 2020h)

The grade assigned for the C4b indicator ranked the Magdaléna site in a relatively favourable position among the assessed candidate sites. The durbachite rock features only a minimally variable lithology. While the mafic enclaves differ petrologically, their rare occurrence rendered them insignificant. The only rock type that served to enhance the petrological variability comprises veins of leucocratic granites, often with accessory tourmaline and muscovite. Although the veins of leucogranites represent a significant spatial inhomogeneity, they are not mineralogically significantly different from the Čertova melagranites to melasyenites. This factor made up the main reason for the assignment of a grade of 2.0 for the extent of the petrological variability.

The promising area for the project design work and the immediate surroundings of the Horka site (grade of 1) comprise exclusively monotonous durbachite (although granite intrusions and aplite veins do occur in the wider vicinity of the promising area). On the other hand, the durbachites in the defined area of the Na Skalním (EDU west) site (grade of 2.5) contain an enhanced number of granodiorite veins and granite intrusions; moreover, the rocks of the Třebíč massif in the studied area feature the smooth local transition from the dominant variety of porphyritic melasyenite to lighter melagranites or non-porphyritic durbachites. The Březový potok, Čertovka and Čihadlo sites, with grades of 2.1, 2.2 and 2.0, respectively, comprised similarly homogeneous granite environments, disturbed only by xenoliths of differing rock types and aplite and pegmatite veins.

Na Skalním (EDU-west) (Havlová et al. 2020i)

The durbachite of the Na Skalním (EDU-west) site comprises a lithologically relatively uneventful rock environment although, for example, in comparison with the ideally homogeneous durbachite Horka site, the rocks of the Třebíč massif of the Na Skalním (EDU-west) site feature a significantly greater degree of textural and lithological diversity, with the gradual local transition from the dominant variety of porphyritic melasyenite to lighter melagranites, and leucocratic and minor medium to coarse-grained biotite syenite to granite in places with amphibolite alternating with locally porphyritic and locally non-porphyritic durbachites. Moreover, the frequency of the leucocratic granite and aplite veins, including tourmaline-biotite granites and intrusions of small granodiorite bodies, is higher than, for example, that of the completely non-varied Horka site.

Tab. 14 Overall assessment of the sites for the C4b indicator according to reports by Havlová et al. 2020a-i

Site	**Indicator grade**
Březový potok	2.1
Čertovka	2.2
Čihadlo	2.0
Horka	1.0
Hrádek	1.4
Janoch (ETE-south)	2.3
Kraví hora	5.0
Magdaléna	2.0
Na Skalním (EDU-west)	2.5

Procedure applied for determining the grades for the C3 and C4 criteria

The grades assigned for the C3 and C4 criteria were determined by a team of experts from the Czech Geological Survey, which participated in the “Geological interpretation of field geophysical data for the updating of the 3D structural-geological models of the potential DGR sites” project.

The expert team consisted of 15 members including researchers who were responsible for the assessment of the individual sites (9 members) and experts with an overall knowledge of all the sites, i.e. the leader of the Geofyzika project, the deputy project leader, the chief geophysicist, the chief hydrogeologist, the chief researcher for the DFN modelling and the chief researcher for the 3D geological modelling.

The determination of the grades for the criteria was a gradual process with the various responsible researchers presenting a paper on the structure of the respective site from the point of view of the assessed criterion taking into account all the positive and negative characteristics and uncertainties. Subsequently, grades were proposed for the sites by the project leaders and a discussion was held aimed at balancing the sites as accurately as possible. The discussion on each criterion was conducted until the expert team achieved consensus on the grades for the criterion, i.e. no voting was held on the grades, nor were the grades the result of the average of the range of opinions.

Subsequently, the background materials with the set grades were submitted to the project leader and expert panel members for further consideration and comments; one week was allowed for the raising of further such proposals and arguments, which were then considered by the expert team until consensus was reached and the final grade was assigned to the given criterion for each site.

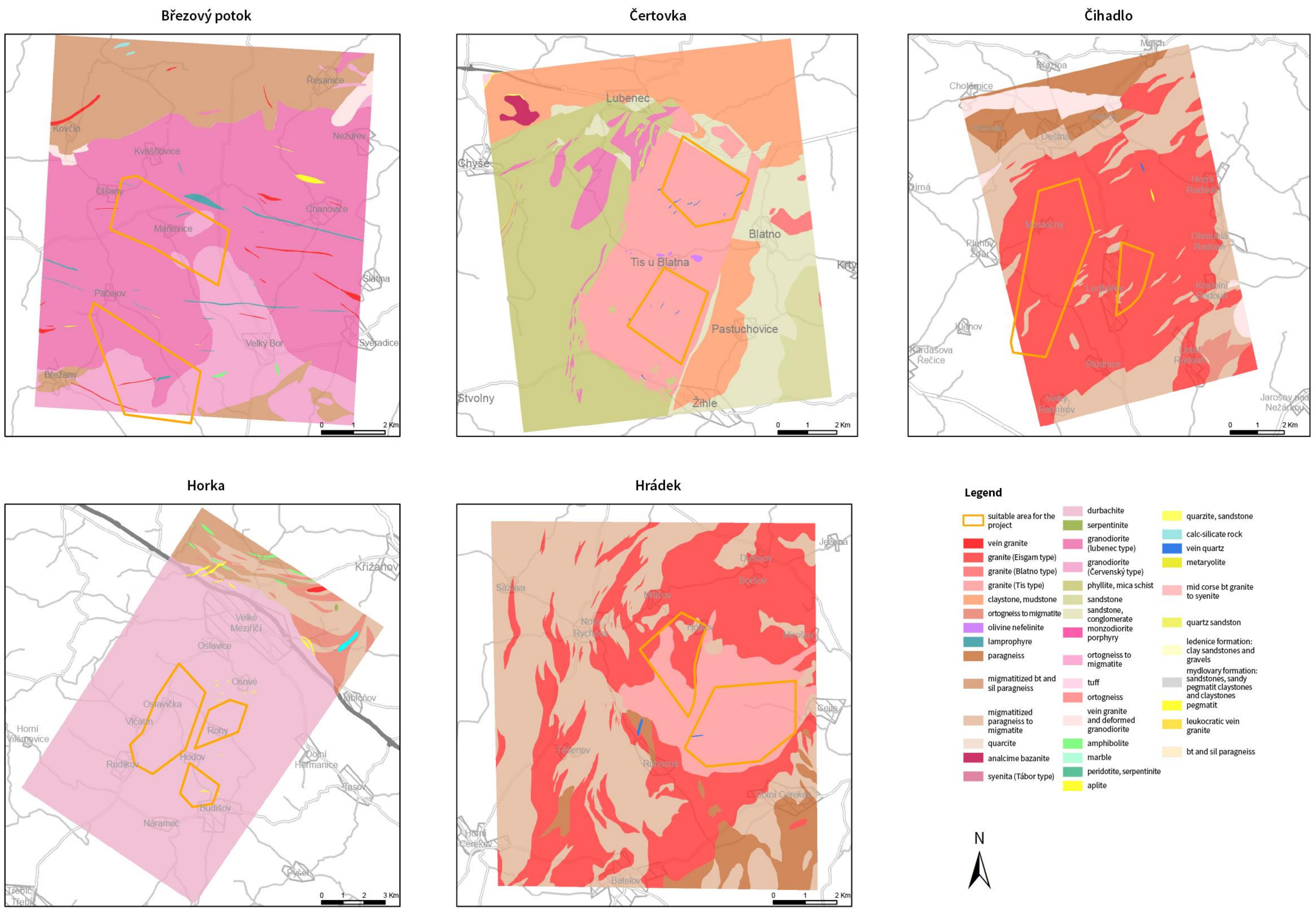


Fig. 19 Geological maps of the candidate DGR sites

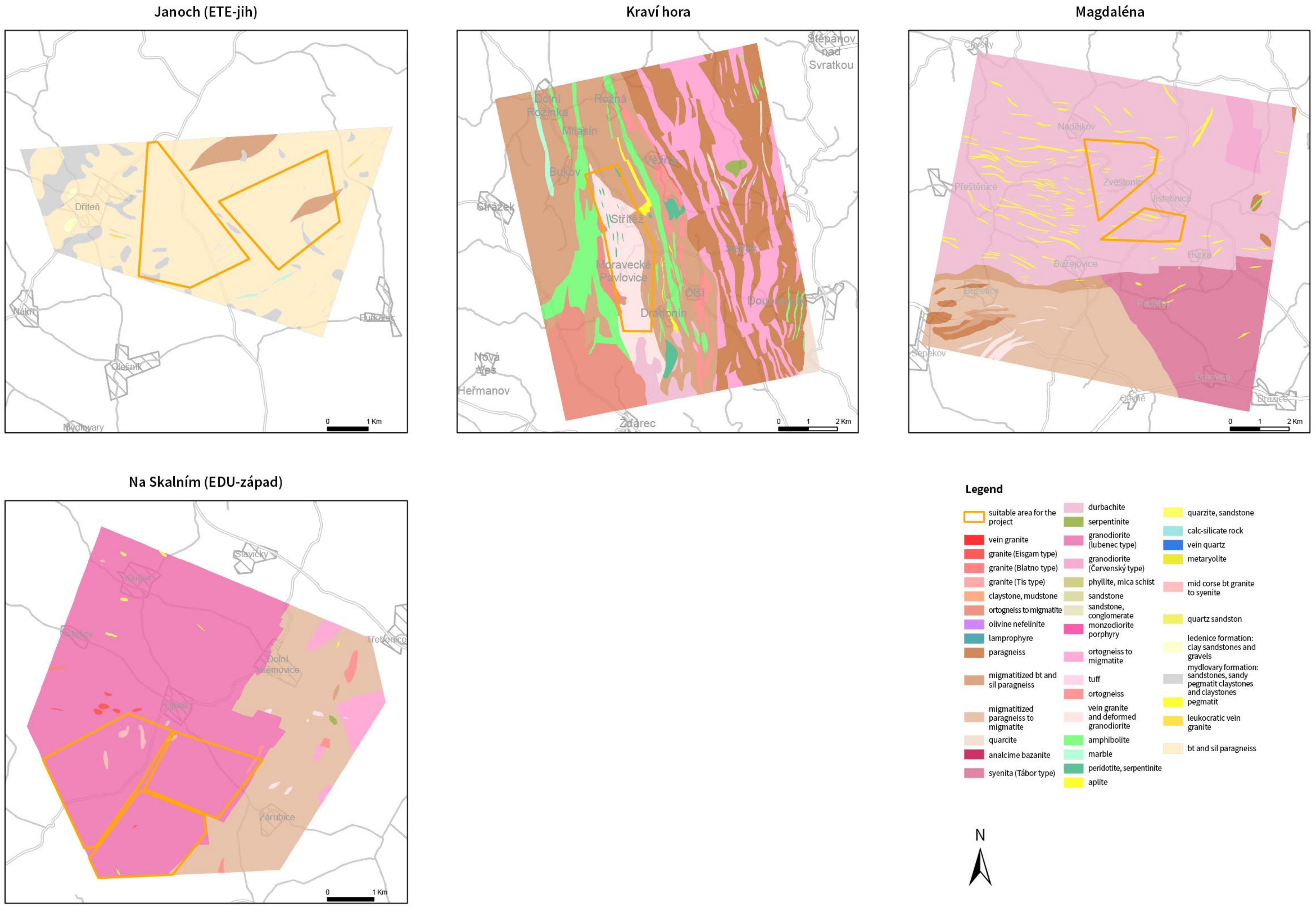


Fig. 20 Geological maps of the candidate DGR sites

5.8.6 Criterion C5: Water flow characteristics in the vicinity of the DGR and the transport characteristics (water flow rate in the repository and the permeability of the rock mass)

Description of the criterion: the evaluation of the hydrogeological and transport characteristics of the site (such as the analysis of the direction, size, flow velocity and transport between the repository and identified drainage areas) constitutes important input information for the assessment of the safety of the DGR. Radionuclides could potentially migrate from the repository only in the liquid or gaseous phases, and only if the sealing effect of the engineered barriers is disrupted. The formation of gases in the disposal area is undesirable and is prevented via the technical design of the SNF disposal system. The most important pathway for the spread of radionuclides into the surrounding environment (the biosphere) is considered to be their migration via flowing groundwater.

Crystalline host rocks, which are assumed in the Czech DGR Concept, are very impermeable (Uhlík et al. 2015), and groundwater flows at the anticipated depth of the DGR via fracture systems. The characteristics of groundwater flow in the crystalline rocks of the Bohemian Massif are described in detail in Krásný et al. (2012). Thus, the siting of the DGR must be optimised with regard to the occurrence of preferential groundwater flow pathways associated mainly with fault zones. The velocity and magnitude of groundwater flow comprise important factors that influence the potential transport of radionuclides both in the disposal area (the near-field of interactions) and in the rock mass (the remote-field of interactions). With respect to addressing the various problems associated with the siting of the DGR, the descriptive (qualitative) approach is insufficient. Groundwater flow and transport must also be quantified for the purposes of the safety assessment of the future DGR.

For the purposes of describing and quantifying the hydrogeological and transport conditions of the assessed candidate DGR sites, models of the groundwater flow and advective transport from the DGR areas were compiled for each site. The modelling work took place in three phases in cooperation with experts from PROGEO, the Technical University of Liberec, ÚJV Řež and the Czech Geological Survey. Firstly, regional models (version 1.1) were created, followed by detailed (version 1.2) and finally-updated detailed models (version 1.3). The final updating of the models reflected new data obtained from the latest structural research projects (Mixa et al. 2019). The updated siting of the DGR was also taken into account in accordance with a siting study compiled by Zahradník et al. (2019).

The research conducted via foreign modelling approaches to the siting of deep geological repositories was summarised by Uhlík et al. 2015, and a description of the methodology applied for the creation of, and overview of selected results from, regional groundwater flow models (hydrogeological models) are provided in Uhlík et al. 2016. Moreover, similar information on detailed hydrogeological models is contained in Uhlík et al. 2018, and a summary report on transport models created on the basis of detailed hydrogeological models is available in Říha et al. 2018.

The final updated hydrogeological and schematic transport models of the sites (version 1.3) are described in Baier et al. (2020 a,b) for the Hrádek and Březový potok sites, Černý et al. (2020 a,b) for the Čertovka and Magdaléna sites, Jankovec et al. (2020 a,b) for the Janoch (ETE-south) and Na Skalním (EDU-west) sites, Uhlík et al. (2018 a,b) for the Horka and Kraví hora sites and Polák et al. (2018) for the Čihadlo site. The input and output data sets provided by these models provided the basis for the assessment of the various indicators of the C5 criterion (as well as the C6 indicators described in the following chapter). With respect to the group of indicators and criteria that concern the long-term safety of the deep geological repository, the information taken into account in the C5 and C6 criteria is summarised in reports by Havlová et al. (2020a-i). The choice of indicators for criterion C5 was based on a list of the hydrogeological and transport properties of the geosphere, the consideration of which is essential in terms of the assessment of the long-term safety of the DGR (Safety Case; Turva et al. 2012).

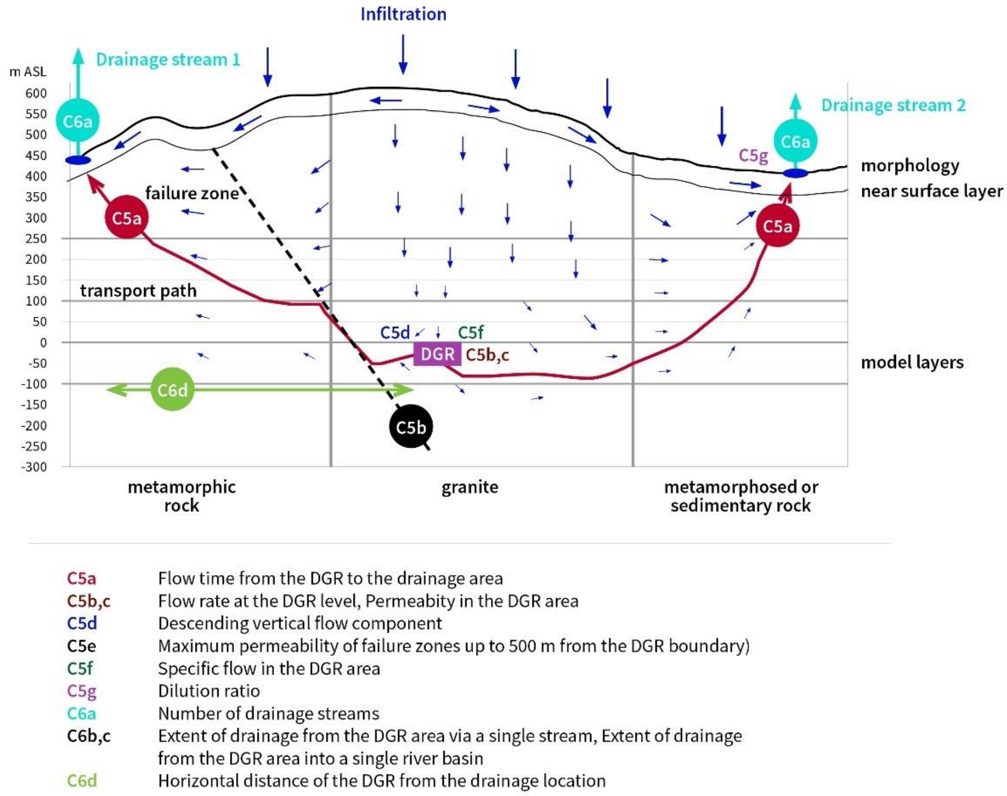


Fig. 21 Scheme of the indicators of the C5 and C6 criteria

Description and assessment of the indicators

C5a Flow time from the DGR to the drainage area

The velocity of the groundwater flow between the disposal area and the drainage area in the near-surface zone varies between the sites depending on the hydraulic resistance of the environment and the hydraulic gradient. The time of groundwater flow into the drainage areas (bases) also depends on their distance from the DGR area.

According to the results of the hydrogeological models of the assessed sites, the groundwater flow in the near-surface zone most frequently attains a velocity of hundreds of metres per year, while at greater depths in the rock mass, it attains a maximum of tens of centimetres per year. The hydraulic connection between the DGR area and the drainage bases is characterised by the flow time parameter (indicator C5a), which expresses the retention time of the groundwater in the rock environment during flow from the disposal areas to the drainage bases.

Description of the indicator: based on the hydrogeological and transport models of the candidate DGR sites and their updating, the lower (25%) quartile of the advective progression of groundwater will be determined between the DGR area and drainage bases.

Quantification: value (in years). Longer progression times form a prerequisite for the efficient functioning of the rock environment as a natural barrier. Conversely, sites with shorter progression times are less suitable from this point of view.

Results of the assessment of indicator C5a

Březový potok (Havlová et al. 2020a)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Březový potok site at 8,214 years. The flow times at the Březový potok site most frequently ranged from 6,000 to 50,000 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Čertovka (Havlová et al. 2020b)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Čertovka site at 1,726 years. The flow times at the Čertovka site most frequently ranged from 1,398 to 4554 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Čihadlo (Havlová et al. 2020c)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Čihadlo site at 3,207 years. The flow times at the Čihadlo site most frequently ranged from 2,500 to 11,000 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Horka (Havlová et al. 2020d)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Horka site at 2,889 years. The flow times at the Horka site most frequently ranged from 2,070 to 24,600 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Hrádek (Havlová et al. 2020e)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Hrádek site at 4,813 years. The flow times at the Hrádek site most frequently ranged from 3,000 to 35,000 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Janoch (ETE-south) (Havlová et al. 2020f)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Janoch (ETE-south) site at 39,164 years. The flow times at the Janoch (ETE-south) site most frequently ranged from 14,000 to 380,000 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results). The relatively long flow times at the Janoch (ETE-south) site are the result of the location of the DGR below a third-order watershed featuring significant descending flow to deep crystalline areas that are characterised by low hydraulic conductivity values.

Kraví hora (Havlová et al. 2020g)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Kraví hora site at 2,846 years. The flow times at the Kraví hora site most frequently ranged from 1,800 to 47,900 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Magdaléna (Havlová et al. 2020h)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Magdaléna site at 1,222 years. The flow times at the Magdaléna site most frequently ranged from 1,004 to 4,103 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Na Skalním (EDU-west) (Havlová et al. 2020i)

The first quartile of the groundwater flow time from the DGR to the drainage bases was calculated via the model of the Na Skalním (EDU-west) site at 3,946 years. The flow times at the Na Skalním (EDU-west) site most frequently ranged from 3,300 to 39,000 years (the interdecile range $Q_{0.1}$ - $Q_{0.9}$ results).

Tab. 15 Overall assessment of the sites for the C5a indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (years)	Indicator grade
Březový potok	8 214	4.3
Čertovka	1 726	4.9
Čihadlo	3 207	4.8
Horka	2 889	4.8
Hrádek	4 813	4.6
Janoch (ETE-south)	39 164	1.0
Kraví hora	2 846	4.8
Magdaléna	1 222	5.0
Na Skalním (EDU-west)	3 946	4.7

C5b Flow rate at the DGR level

The velocity of groundwater flow at the level of the underground part of the repository will influence the extent of the mass flow of contamination from the disposal areas of the DGR. The groundwater flow rate is influenced both by the hydraulic gradient (which depends on the morphology of the terrain in the area of the DGR) and the permeability of the rock massif. The C5b indicator concerns the assessment of the sites in terms of the factor that influences the intensity of the transport processes underway at depth in the DGR.

Description of the indicator: based on the hydrogeological models of the candidate DGR sites and their updating, the maximum velocity of groundwater flow will be determined in the rock mass in the area and at the level of the DGR.

Quantification: value of the maximum groundwater flow rate ($m.year^{-1}$). Lower velocities form a prerequisite for the efficient functioning of the rock environment as a natural barrier. Sites with more rapid flow through the DGR area are less suitable from this point of view.

Results of the assessment of indicator C5b (Havlová et al. 2020a-i)

The range of calculated flow velocities in the disposal area for assessment purposes was determined for the Březový potok site at (0.025 – 0.17) $m.year^{-1}$, for the Čertovka site at (0.34 – 0.70) $m.year^{-1}$, for the Čihadlo site at (0.18 – 0.50) $m.year^{-1}$, for the Horka site at (0.16 – 0.46) $m.year^{-1}$, for the Hrádek site at (0.2 – 0.6) $m.year^{-1}$, for the Janoch (ETE-south) site at (0.06 – 0.13) $m.year^{-1}$, for the Kraví hora site at (0.04 – 2.39) $m.year^{-1}$, for the Magdaléna site at (0.24 – 0.49) $m.year^{-1}$ and for the Na Skalním (EDU-west) site at (0.06 – 0.34) $m.year^{-1}$. The maximum value was selected as the indicator value.

Tab. 16 Overall assessment of the sites for the C5b indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value ($m.year^{-1}$)	Indicator grade
Březový potok	0.17	1.1
Čertovka	0.7	2.0
Čihadlo	0.5	1.7
Horka	0.46	1.6
Hrádek	0.56	1.8
Janoch (ETE-south)	0.13	1.0
Kraví hora	2.39	5.0
Magdaléna	0.49	1.6
Na Skalním (EDU-west)	0.34	1.4

C5c Permeability in the DGR area

The isolation part of the rock mass (below the subsurface layer of weathering and the discontinuation of fractures level) is made up of crystalline rocks at all the candidate sites. From the hydrogeological point of view, it comprises a heterogeneous anisotropic environment with fractured permeability. Due to the geostatic pressure, with increasing depth below ground level, the fractures are "squeezed", thus resulting in a decrease in the permeability of the rock mass. With respect to the hydrogeological models, the nonlinear decrease in permeability is given by the empirical equation by Gustafson and Liedholm (1989).

The hydrogeological models of the assessed sites provide a comprehensive spatial impression of the permeability distribution of the potential DGR host rock masses. The C5c indicator concerns the assessment of the sites from the point of view of the factor that acts to influence the intensity of underground water flow through the DGR area and, thus, the transport processes from the DGR area.

Description of the indicator: based on the hydrogeological models of the candidate DGR sites and their updating, the maximum permeability of the rock mass will be determined at the level and in the area of the planned DGR.

Quantification: the value of the maximum permeability ($m.s^{-1}$). Sites with higher rock mass permeability values are less suitable from this point of view. A lower degree of permeability forms a prerequisite for the efficient functioning of the rock environment as a natural barrier.

Results of the assessment of indicator C5c (Havlová et al. 2020a-i)

The range of permeability values was determined for the Březový potok site at (1.05.10^{-9} m.s^{-1} to 1.35.10^{-9}) m.s^{-1}, for the Čertovka site at (1.0.10^{-9} m.s^{-1} to 1.4.10^{-9}) m.s^{-1}, for the Čihadlo site at (1.1.10^{-9} m.s^{-1} to 2.2.10^{-9}) m.s^{-1}, for the Horka site at (2.6.10^{-9} m.s^{-1} to 3.5.10^{-9}) m.s^{-1}, for the Hrádek site at (1.2.10^{-9} m.s^{-1} to 1.9.10^{-9}) m.s^{-1}, for the Janoch (ETE-south) site at (6.6.10^{-10} m.s^{-1} to 8.3.10^{-10}) m.s^{-1}, for the Kraví hora site at (3.4.10^{-10} m.s^{-1} to 7.0.10^{-9}) m.s^{-1}, for the Magdaléna site at (2.7.10^{-9} m.s^{-1} to 3.6.10^{-9}) m.s^{-1} and for the Na Skalním (EDU-west) site at (2.6.10^{-9} m.s^{-1} to 3.2.10^{-9}) m.s^{-1}. The maximum value was selected as the indicator value.

Tab. 17 Overall assessment of the sites for the C5c indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (m.s^{-1})	Indicator grade
Březový potok	1.4E-09	2.0
Čertovka	1.4E-09	2.0
Čihadlo	2.2E-09	2.8
Horka	3.5E-09	3.7
Hrádek	1.9E-09	2.6
Janoch (ETE-south)	8.3E-10	1.0
Kraví hora	7.0E-09	5.0
Magdaléna	3.6E-09	3.8
Na Skalním (EDU-west)	3.2E-09	3.5

C5d Descending vertical flow component

With respect to all the assessed sites, standard vertical pressure field development can be assumed, involving a decreasing underground water flow component in the infiltration areas (a decrease in the hydraulic height with depth) and an ascending underground water flow component in the drainage areas (an increase in the hydraulic height with depth). In addition to the morphology of the terrain, the pressure conditions of underground water flow are also affected by the permeability of the rock mass, which is heterogeneous and anisotropic. These properties are dependent more on the course of tectonic failures, fracturing and the state of stress of the rock mass than the lithology. The flow pressure field is deformed in tectonic zones, which serve to effectively connect areas with differing hydraulic heights.

The C5d indicator provides for the assessment of the sites in terms of the degree of representation of the descending underground water flow component in the DGR area. The occurrence of the descending flow component influences the length of transport pathways and the underground water retention time, and thus the effectiveness of retardation processes with concern to the transport of radionuclides (diffusion into the rock matrix, sorption, decomposition). The vertical pressure ratios of the disposal areas determined by the model for the assessed sites are shown in Fig. 22.

Description of the indicator: based on the hydrogeological models of the candidate DGR sites and their updating, the proportion of the DGR area with a descending vertical flow component will be determined.

Quantification: the percentage (of the DGR area). A larger area with a descending flow component will serve to extend the transport pathways. Therefore, sites with lower proportions of the vertical descending groundwater flow component will be deemed less favourable.

Results of the assessment of indicator C5d

Březový potok (Havlová et al. 2020a)

Zones of descending groundwater flow are located at the level of the repository (35 m below sea level) in the area of a regional hydrological watershed stretching from the Pačejov area, north of Maňovice, towards the top of the Baba hill. According to the results of the hydrogeological model, descending flow occurs over 74% of the projected area of the DGR. Areas of ascending flow are located in the eastern part of the DGR area, which is influenced by the drainage effect of the Hájka stream, and in the southern part of the DGR area, which is influenced by the Březový stream basin.

Čertovka (Havlová et al. 2020b)

Descending groundwater flows occur in the higher parts of the site, while areas with the highest occurrence of ascending flows are concentrated in deeper valleys such as the Střela valley. Descending groundwater flow conditions prevail in the southern part of the promising area for the project design work. The drainage area is located in the north of this area in the Ležecký stream headwater area.

The results of the hydrogeological model led to the conclusion that the descending groundwater flow component prevails except for the northern edge of the area of the underground part of the DGR. Descending flow occurs over 87% of the area of the projected DGR rock polygon (located at a level of 130 m below sea level). The drainage influence of the Ležecký stream is evident at the northern edge.

Čihadlo (Havlová et al. 2020c)

The descending groundwater flow area is located in the north-eastern part of the DGR area in the Brčík hill area and the south-western slope thereof. Descending flow occurs over 58% of the projected DGR area. An area with a negative vertical pressure gradient (ascending flow component) is located in the south-western part of the DGR, where the level of the terrain above the projected DGR declines towards the Řečice and Klenovské streams and their confluence.

Horka (Havlová et al. 2020d)

The descending groundwater flow component prevails in the area of the underground part of the DGR; the maxima relate to the Hodovská elevation and other unnamed elevations between Rudíkov and Hodov. According to the results of the model, the descending flow component applies to 81% of the DGR underground area. An area of ascending flows in the DGR area was identified via modelling in the Mařek headwater area. A larger area of drainage (and upward flow) in the vicinity of the DGR is assumed in the Oslavičky valley near Vlčatín, associated with the Mlýnský stream headwater area.

Hrádek (Havlová et al. 2020e)

Descending groundwater flow prevails over 97% of the DGR area, related mainly to a regional hydrological watershed that connects the Přední skála and Čeřínek hills. Ascending flows occur in the DGR area only in the Hornohuťský stream drainage area (the southern part of the projected DGR area).

Janoch (ETE-south) (Havlová et al. 2020f)

Descending groundwater flows prevail at the repository level over practically the entire area, with a maximum gradient below the Pakostov hill. An area of ascending flows extends only marginally into the NE part of the projected DGR area. Descending groundwater flow prevails over 99% of the projected DGR area. The most significant area of ascending flows in the vicinity of the DGR is located in the east of the area, which is influenced by the drainage effect of the Rachačka stream.

Kraví hora (Havlová et al. 2020g)

Descending groundwater flow is related to the upper parts of the Střítež ridge with the Kraví hora – Dejmalka hills. Descending flow changes to ascending flow towards the Bobrůvka and Nedvědička drainage bases and in the Rožná and Olší flooded mine working areas. The projected underground part of the DGR is located almost exclusively in the area with a descending flow component, which makes up 98% of the projected DGR area according to the modelling results. The ascending groundwater flow component occurs insignificantly in the underground area of the DGR along its western edge, which is influenced by drainage from the Bukovský and Bobrůvka stream basins.

Magdaléna (Havlová et al. 2020h)

Descending groundwater flow occurs in the upper parts of the area (the Pahrbek hills near to the NE part of the Magdaléna site). Areas with the most significant occurrence of ascending flows are concentrated in the Smutná valley. The southern and north-eastern parts of the promising area for the project design work are situated in an infiltration area. The drainage area occurs mainly in the central part of the promising area - along the Smutná valley. It can be concluded from the results of the hydrogeological modelling of the site that the DGR is situated in a drainage area except for its north-eastern part. Descending groundwater flow (at the level of 1 m below sea level) makes up just 26% of the DGR area.

Na Skalním (EDU-west) (Havlová et al. 2020i)

Descending groundwater flows occur below the elevated parts of the area. The highest descending flow gradient occurs in the promising area below the Na Skalním hill. Descending flows occur over 85% of the area of the projected DGR. Ascending flow areas are concentrated below the drainage streams and extend into the northern and, marginally, western parts of the underground area of the DGR.

Tab. 18 Overall assessment of the sites for the C5d indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (%)	Indicator grade
Březový potok	74	2.4
Čertovka	86	1.7
Čihadlo	58	3.2
Horka	81	2.0
Hrádek	97	1.1
Janoch (ETE-south)	99	1.0
Kraví hora	98	1.1
Magdaléna	26	5.0
Na Skalním (EDU-west)	85	1.8

C5e Maximum permeability of failure zones up to 500 m from the DGR boundary

The hydrogeological models of the assessed sites provided a comprehensive spatial impression of the permeability distribution of the potential DGR host rock masses. The concept of the modelled description of underground water flow in the hydrogeological environments of the rock masses of the sites (with concern to safety) presupposes the existence of bands of enhanced hydraulic conductivity related to known tectonic fault zones. It can be assumed that preferential flow from the deeper horizons of the rock mass towards surface drainage bases is more likely in failure zones around significant deep-reach faults. The flow of underground water between the DGR and drainage bases may be adversely impacted (accelerated) by the presence of such failure zones.

Failure zones are classified in terms of three categories according to their significance (using the approach of Andersson et al. (2000)). The first category is the most important. It is assumed that 1st category failure zones enhance the permeability of the rock mass to the greatest extent.

The C5e indicator serves for the comparison of the sites in terms of the occurrence of permeable zones associated with tectonic failures.

Description of the indicator: based on the hydrogeological models of the candidate DGR sites and their updating, the maximum permeability of the rock environment will be determined related to the occurrence of failure zones at the level of the DGR up to a distance of 500 m from the boundary of the disposal areas.

Quantification: the value of the maximum hydraulic conductivity ($m.s^{-1}$). Higher failure zone permeability levels in the vicinity of the DGR will be deemed less favourable from the point of view of siting.

Results of the assessment of indicator C5e

<u>Březový potok</u> (Havlová et al. 2020a)

Three 1st category failure zones feature in the vicinity of the projected DGR area at the Březový potok site with hydraulic conductivities in the order of 10^{-8} m.s^{-1}:

- a fault zone that lines the northern border of the promising area for the project design work running SE-NW that follows the Kozčínský stream into which groundwater drains from the projected DGR area;
- the above-described fault zone intersects NW of the promising area with a zone leading from S to N along the W boundary of the promising area;
- a significant fault zone runs along the E boundary of the promising area in the Hájek stream (a DGR groundwater drainage stream) valley.

The western part of the promising area features a NW-SE 2nd category fault zone that leads to the intersection of other 2nd category fault zones in the Jelenovice area, which serves for the significant drainage of groundwater from the underground part of the DGR. The hydraulic conductivity of the 2nd category fault zones attains a maximum value of 1.0.10^{-8} m.s^{-1} at the level of the DGR (and at a distance up to 500 m from the DGR area boundaries). The hydraulic properties of these zones are of considerable importance for the Březový potok site and, armed with current knowledge, it is not possible to completely rule out the hydraulic connection of these fault zones with the rock mass environment of the underground part of the DGR (the course and character of such zones at DGR depth cannot be verified at present).

The maximum hydraulic conductivity of the fault zones at the DGR level up to 500 m from the boundaries of the underground part of the DGR is 1.8.10^{-8} m.s^{-1}.

<u>Čertovka</u> (Havlová et al. 2020b)

The eastern limit of the granite rock mass (and the promising area) at the Čertovka site is determined by the Žihel fault, which is accompanied by a distinctive topography with the ascending flow of groundwater. The proposed location of the DGR is approximately 1 km west of this fault and its position in the promising area is determined by 2nd category faults. The flow in the vicinity of the promising area for the project design work is further influenced by two 2nd category faults along the Struhařský stream valley.

Groundwater from the projected DGR drains into the nearby Ležecký stream drainage base via parallel 2nd category faults running NW-SE, which feature significant ascending flows. The hydraulic conductivity of the 2nd category fault zones attains a maximum value of 6.9.10^{-9} m·s^{-1} at the DGR level (and at a distance of up to 500 m from its boundaries). No 1st category fault zones occur within 500 m of the boundaries of the DGR area.

<u>Čihadlo</u> (Havlová et al. 2020c)

With respect to the siting of the DGR at the Čihadlo site, the most significant of the assumed fault networks comprises a 2nd category fault running along the south-eastern boundary of the DGR rock polygon. The line of this fault zone is visible on the surface as a depression with the Řečice stream headwater area. The significant 1st category Lodhéřov fault zone runs in the north-south direction approximately 400 m east of the defined DGR area. This fault represents a potential preferential flow pathway from the infiltration area in the upper parts of the rock mass to drainage bases south and north of the promising areas for the project design work, and also potentially connects the deeper and shallower parts of the rock mass. The hydraulic properties of this zone are, therefore, of considerable importance for the Čihadlo site and, armed with the current level of knowledge of the area, the hydraulic connection of this fault zone with the rock mass environment of the underground part of the DGR cannot be completely ruled out.

Based on the accepted concept of the decreasing hydraulic conductivity of failure zones with depth, the hydraulic conductivity of the fault zones at the level of the projected DGR is assumed to be in the order of 10^{-8} m.s^{-1} for the 1st category zones and 10^{-9} m.s^{-1} for the 2nd category zones. The maximum hydraulic conductivity in the area of the identified fault zones at a distance of up to 500 m from the boundary of the DGR according to the model of the Čihadlo site is estimated at 1.6.10^{-8} m.s^{-1}.

<u>Horka</u> (Havlová et al. 2020d)

The underground part of the projected DGR is situated between 1st and 2nd category (according to Andersson et al., 2000) fault zones. The western and eastern limits of the DGR comprise 1st category faults (IDs 8, 2 and 12). Fault ID 2 is traversed by the Mařek stream and the site model assumes drainage in the wider area of this traverse. The maximum modelled value of permeability along the fault line is estimated at 1.9.10^{-8} m.s^{-1}. The maximum modelled permeability values of the rock mass along the ID 2 fault that follows the eastern edge of the DGR at a distance of 580 m are similar.

<u>Hrádek</u> (Havlová et al. 2020e)

With respect to the Hrádek site, the western boundary of the promising area for the siting of the DGR is delimited by a 1st category fault zone running through the valley of the Dolnohuť stream. The northern and SE limits of the promising area comprise 2nd category faults. Zones of increased rock mass permeability are bound to these fault zones.

The hydraulic properties of these zones are of considerable importance for the Hrádek site and, according to the existing state of knowledge, the hydraulic connection of these fault zones with the rock mass environment in the projected DGR area cannot be completely ruled out. The fault zones up to 500 m from the boundaries of the DGR, based on the accepted concept of decreasing hydraulic conductivity with depth, evince a maximum hydraulic conductivity of 1.7.10^{-8} m.s^{-1} at the proposed DGR level.

<u>Janoch (ETE-south)</u> (Havlová et al. 2020f)

The vicinity of the projected DGR area features two intersecting 2nd category fault zones, which make up the most hydraulically conductive structures at a distance of up to 500 m from the DGR and, at the level of the DGR, their hydraulic conductivity attains a maximum value of $8.6 \cdot 10^{-9}$ $m \cdot s^{-1}$. While the hydraulic properties of these zones are of limited importance for the Janoch (ETE-south) site, armed with the current level of knowledge it is not possible to completely rule out the hydraulic connection of the fault zones with the rock mass environment of the underground part of the DGR. No 1st category fault zone occurs within 500 m of the DGR boundaries.

<u>Kraví hora</u> (Havlová et al. 2020g)

A 2nd category fault system running ENE-WSW divides the disposal area of the underground part of the projected DGR into six partial rock polygons. Moreover, these faults (IDs 179, 168, 172, 158, 175 and 178) create potential preferential groundwater flow pathways from the underground part of the DGR since they are oriented in the direction of groundwater flow from the granulite massif to the drainage area of the Bukovský stream and, especially, the Bobrůvka stream in the west and the Nedvědička stream in the east. 1st category faults (IDs 10, 5 and 160) run NNW-SSE and mainly follow the circumference of the granulite rock mass. The ID 10 fault follows the Bukovský stream valley, at which the above-mentioned 2nd category faults are "connected". The observation of the flow of mine water in the Rožná and Olší uranium mine workings excavated on 1st category faults (as well as the modelling research) verified that the permeability of the failure zones with the 1st category faults IDs 10, 5 and 160 does not significantly exceed that of the surrounding rock environment. With respect to the wider area of the abandoned flooded mine workings, however, from the hydrogeological point of view the circulation of groundwater will be permanently affected. Both of the flooded mines will naturally be drained over a period of tens and hundreds of years via the overflow of water into the main tunnels of the mines and hence to the Nedvědička stream basin. The area of the granulite rock mass is relatively small for the siting of the DGR. The SE limits of the underground areas of the projected DGR are situated at a distance of less than 500 m from the corridors of the Olší mine, and even the most permeable parts of the rock mass will be connected to the wider surroundings of this mine in the future. Due to the assumption of the influence of the tunnels of the former mine complexes, a value of $1.0.10^{-7}$ $m.s^{-1}$ was determined for the C5e indicator.

Magdaléna (Havlová et al. 2020h)

Groundwater drains from the DGR area directly via the overburden of the repository into the Smutná stream. The course of flow in the DGR area is probably tectonic. Thus, the permeability of the fault zones is of considerable importance at the site.

The SW boundary of the DGR follows two parallel 2nd category faults. The hydraulic conductivity of the 2nd category fault zones attains a maximum value of $8.2.10^{-9}$ $m.s^{-1}$ at the level of the DGR (and at a distance of up to 500 m from its boundaries). Two parallel 1st and 2nd category faults define the SE boundary of the promising area and the repository rock polygon. The 1st category fault zone occurs around 400 m southeast of the DGR boundary. The maximum hydraulic conductivity of this zone is assumed to be $1.2.10^{-8}$ $m.s^{-1}$ at the DGR disposal level.

Na Skalním (EDU-west) (Havlová et al. 2020i)

Four faults of a regional nature (all 1st category faults) occur near to the projected location of the DGR at the Na Skalním (EDU-west) site, north of the defined promising area. The faults run in the NW-SE direction and the ID 4 fault practically defines the boundary of the promising area. The hydraulic conductivity of the 1st category fault zones attains 1.4.10-8 $m.s^{-1}$ at the DGR level (and at a distance of up to 500 m from the DGR boundaries). The Rouchovanka stream is accompanied by regional faults in the area NE of the promising area, into which the DGR area drains.

Eight 2nd category faults extend into the promising area for the project design work, which define the location of the DGR complex. South of the DGR area, local faults running NW-SE extend into the promising area which, near the village of Ratibořice, intersect with a local fault running NE-SW that delimits the west of the promising area.

The hydraulic properties of the failures are of considerable importance for the Na Skalním (EDU-west) site. Armed with the current level of knowledge, the hydraulic connection of fault zones with the rock mass environment in the underground part of the DGR cannot be completely ruled out. The modelled hydraulic conductivity of fault zones at the level of the DGR up to 500 m from its boundaries at the Na Skalním (EDU-west) site was determined at a maximum of 1.4.10-8 $m.s^{-1}$.

Tab. 19 Overall assessment of the sites for the C5e indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value ($m.s^{-1}$)	Indicator grade
Březový potok	1.8E-08	2.4
Čertovka	6.9E-09	1.0
Čihadlo	1.6E-08	2.3
Horka	1.9E-08	2.5
Hrádek	1.7E-08	2.3
Janoch (ETE-south)	8.6E-09	1.3
Kraví hora	1.0E-07	5.0
Magdaléna	1.2E-08	1.8
Na Skalním (EDU-west)	1.4E-08	2.1

C5f Specific flow in the DGR area

The balance data on the DGR areas for the candidate sites was obtained from the hydrogeological models. The balance of the models in the near-surface weathering layer and open fractures was determined on the basis of the distribution of precipitation (as assessed by the Czech Hydrometeorological Institute) and the consideration of the amount of the basic runoff into the river system.

The calculation of the balance of the repository spaces depends on a combination of rock mass permeability factors and the hydraulic gradient (influenced by the morphology of the terrain). The C5f indicator concerns the assessment of the sites in terms of the amount of groundwater flow through the disposal area, which influences the intensity of transport processes.

Description of the indicator: based on the hydrogeological models of the candidate DGR sites and their updating, the magnitude of groundwater flow through the DGR area as normalised by its area (specific flow) was determined.

Quantification: the specific flow ($l.s^{-1}.km^{-2}$) of groundwater through the DGR. The amount of groundwater that flows through the DGR forms a crucial parameter for the process of the release of radionuclides into the geosphere. If a small amount of water flows through the disposal wells, only a small amount of radionuclides may be released into the geosphere and migrate further into the environment. Higher specific flow values are less suitable from this point of view.

Results of the assessment of indicator C5f

Březový potok (Havlová et al. 2020a)

The average value of infiltration into the underground water in the modelled area of the Březový potok site is 3.0 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 555 $l.s^{-1}$, 97% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of only 13.5 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $1.73.10^{-2}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $5.97.10^{-3}$ $l.s^{-1}.km^{-2}$.

Čertovka (Havlová et al. 2020b)

The average value of infiltration into the underground water in the modelled area of the Čertovka site is 2.0 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 527 $l.s^{-1}$, 67% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to the high hydraulic conductivity coefficients of the Permocarbon formation in the north-western part of the modelled area) to the extent of 173 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $3.85.10^{-2}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $2.41.10^{-2}$ $l.s^{-1}.km^{-2}$.

Čihadlo (Havlová et al. 2020c)

The average value of infiltration into the underground water in the modelled area of the Čihadlo site is 3.25 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 823 $l.s^{-1}$, 98% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of only 15.4 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $3.78.10^{-2}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $1.8.10^{-2}$ $l.s^{-1}.km^{-2}$.

Horka (Havlová et al. 2020d)

The average modelled value of underground water replenishment from precipitation infiltration was determined at 2.5 $l.s^{-1}.km^{-2}$. 659 $l.s^{-1}$ infiltrates into the underground water (over the entire area of the model, i.e. 264 km^2). A significant portion of the infiltrating groundwater participates only in the form of shallow circulation in the near-surface layer. According to the model, only 70 $l.s^{-1}$ of water flows from the first (near-surface) layer to the underlying layer, which represents the hydrogeological rock mass. Moreover, the magnitude of the flow further decreases significantly in line with the depth of the rock mass. The specific flow of underground water through the underground part of the DGR was determined at $2.3.10^{-2}$ $l.s^{-1}.km^{-2}$.

Hrádek (Havlová et al. 2020e)

The average value of infiltration into the underground water in the modelled area of the Hrádek site is 4.0 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 955 $l.s^{-1}$, 98% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of only 18 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $1.0.10^{-4}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $3.7.10^{-2}$ $l.s^{-1}.km^{-2}$.

Janoch (ETE-south) (Havlová et al. 2020f)

The average value of infiltration into the underground water in the modelled area of the Janoch (ETE-south) site is 1.5 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 372.5 $l.s^{-1}$, 94% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of only 20.8 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $2.28.10^{-2}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $9.6.10^{-3}$ $l.s^{-1}.km^{-2}$.

Kraví hora (Havlová et al. 2020g)

The modelling of infiltration was determined on the basis of the flow conditions of Nedvědička stream. The hydrogeological model determined the magnitude of infiltration to the underground water (over the entire area of the model, i.e. 263.5 km^2) of 358 $l.s^{-1}$ (i.e. 1.36 $l.s^{-1}.km^{-2}$). A significant portion of the infiltrating groundwater participates only in the form of shallow circulation in the near-surface layer. According to the model, only 49 $l.s^{-1}$ of water flows from the first (near-surface) layer to the underlying layer, which represents the hydrogeological rock mass. The specific flow through the six defined DGR disposal areas was determined at $4.2.10^{-2}$ $l.s^{-1}.km^{-2}$.

Magdaléna (Havlová et al. 2020h)

The average value of infiltration into the underground water in the modelled area of the Magdaléna site is 2.5 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 594 $l.s^{-1}$, 96.7% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of only 19.6 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $5.09.10^{-1}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $2.3.10^{-2}$ $l.s^{-1}.km^{-2}$.

Na Skalním (EDU-západ) (Havlová et al. 2020i)

The average value of infiltration into the underground water in the modelled area of the Na Skalním (EDU-west) site is 1.9 $l.s^{-1}.km^{-2}$ (Krásný et al. 1982). Of a total infiltrated amount of 593 $l.s^{-1}$, 94% of groundwater flows only within the near-surface weathering layer, fractures and the Quaternary. It infiltrates into the deeper areas of the rock mass (due to low hydraulic conductivity coefficients) to the extent of 35.0 $l.s^{-1}$. The sum of flows through the defined DGR underground area was set by the model at $4.31.10^{-2}$ $l.s^{-1}$ and the specific flow through the floor area of the DGR at $1.6.10^{-2}$ $l.s^{-1}.km^{-2}$.

Tab. 20 Overall assessment of the sites for the C5f indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value ($m^3/s/m^2$)	Indicator grade
Březový potok	6.0E-03	1.0
Čertovka	2.4E-02	3.0
Čihadlo	1.8E-02	2.3
Horka	2.3E-02	2.9
Hrádek	3.7E-02	4.4

Janoch (ETE-south)	9.6E-03	1.4
Kraví hora	4.2E-02	5.0
Magdaléna	2.3E-02	2.9
Na Skalním (EDU-west)	1.6E-02	2.1

C5g Dilution ratio

The schematic advective transport of a conservative tracer (without radioactive decay, chemical reactions, sorption and diffusion into the rock matrix) from the repository was simulated using the currents field of the hydrogeological model. The dilution ratio was determined from the proportion of the maximum concentration in the near-surface zone and in the DGR underground area.

The C5g indicator concerns the assessment of the properties of the sites in terms of the dilution of potential contamination from the DGR due to mixing with contaminated and uncontaminated underground water. This factor relates to the transport of radionuclides.

Description of the indicator: based on the hydrogeological and transport models of the candidate DGR sites and their updating, the proportion of the maximum modelled concentration of a conservative tracer in the near-surface zone and in the DGR area was determined.

Quantification: the percentage value. Higher values indicate lower suitability due to the lower degree of the dilution of contamination during advective transport from the DGR. Conversely, lower values indicate the more extensive mixing of the groundwater from the DGR area towards the drainage area.

Results of the assessment of indicator C5g (Havlová et al. 2020a-i)

The dilution ratio of the Březový potok site was set at 0.1%, for the Čertovka site 1.7%, for the Čihadlo site 0.2%, for the Horka site 0.1%, for the Hrádek site 0.3%, for the Janoch (ETE-south) site 0.1%, for the Kraví hora site 0.7%, for the Magdaléna site 0.4% and for the Na Skalním (EDU-west) site 0.3% (Tab. 21).

Tab. 21 Overall assessment of the sites for the C5g indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (%)	Indicator grade
Březový potok	0.1	1.0
Čertovka	1.7	5.0
Čihadlo	0.2	1.3
Horka	0.1	1.0
Hrádek	0.3	1.5
Janoch (ETE-south)	0.1	1.0

Kraví hora	0.7	2.5
Magdaléna	0.4	1.8
Na Skalním (EDU-west)	0.3	1.5

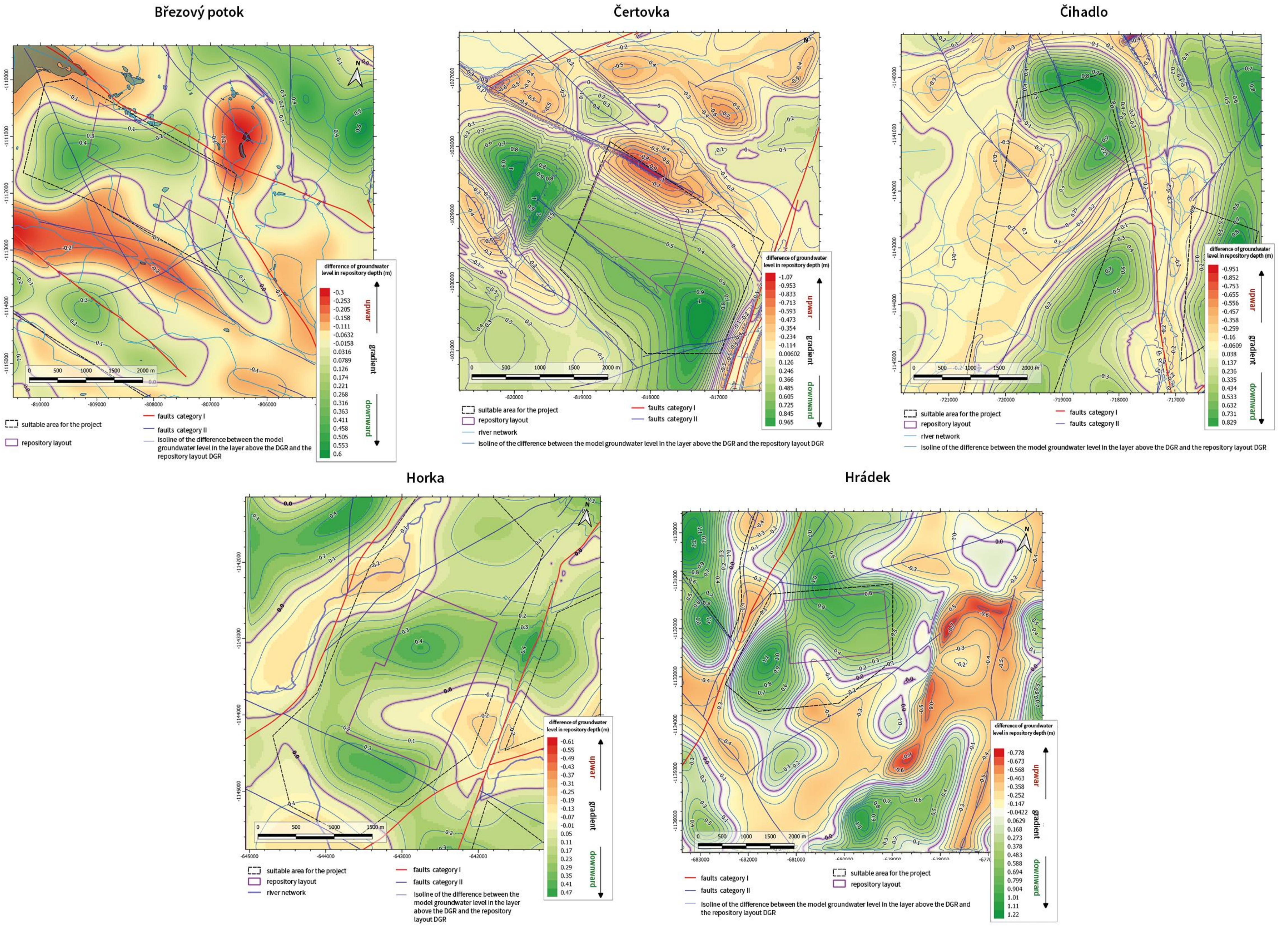


Fig. 22 Modelled vertical pressure conditions of the DGR area for the Březový potok, Čertovka, Čihadlo, Horka and Hrádek sites

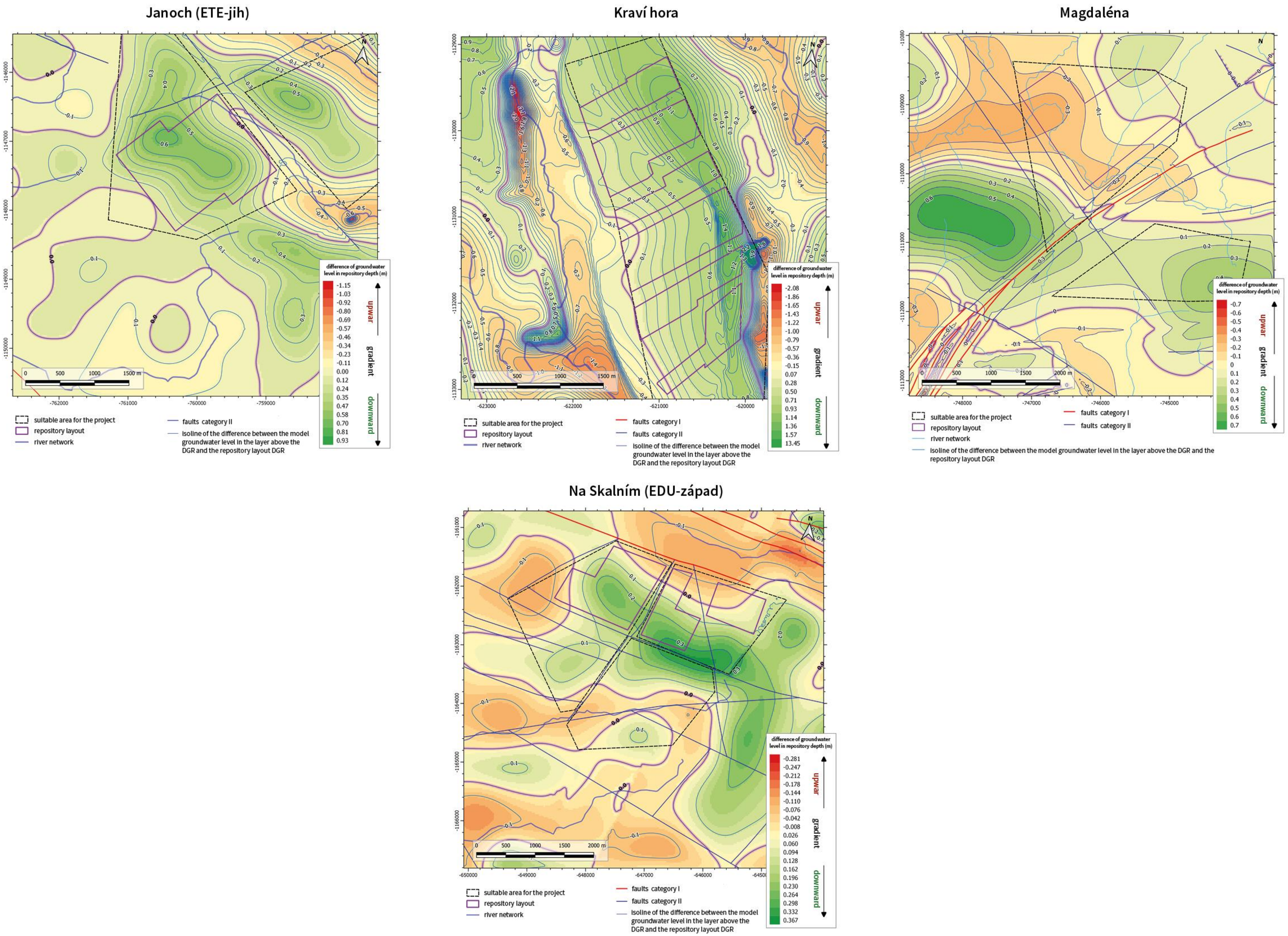


Fig. 23 Modelled vertical pressure conditions of the DGR area for the Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west) sites

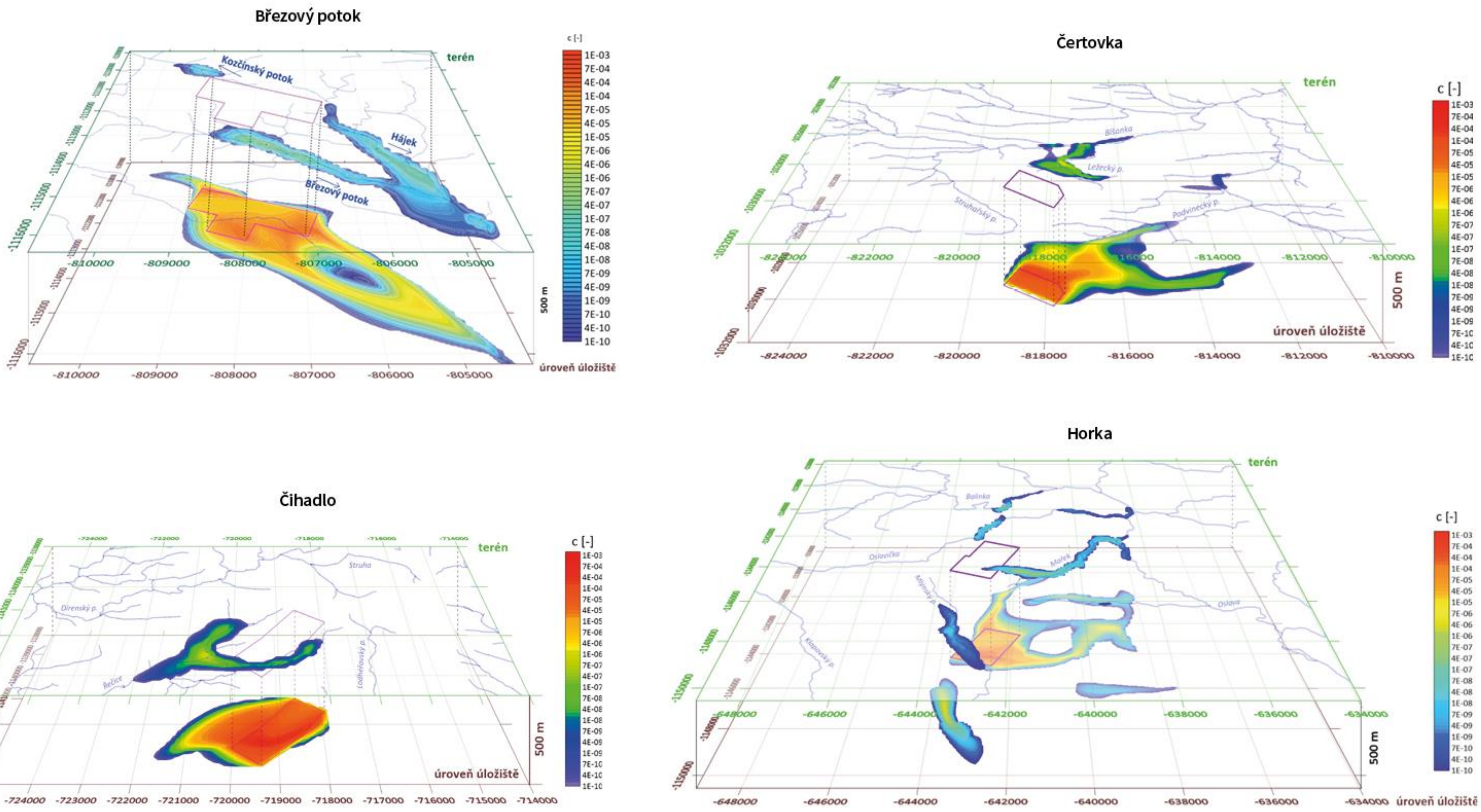


Fig. 24 Modelled stable distributions of tracer concentrations in the disposal areas and the near-surface zones for the Březový potok, Čertovka, Čihadlo, Horka and Hrádek sites

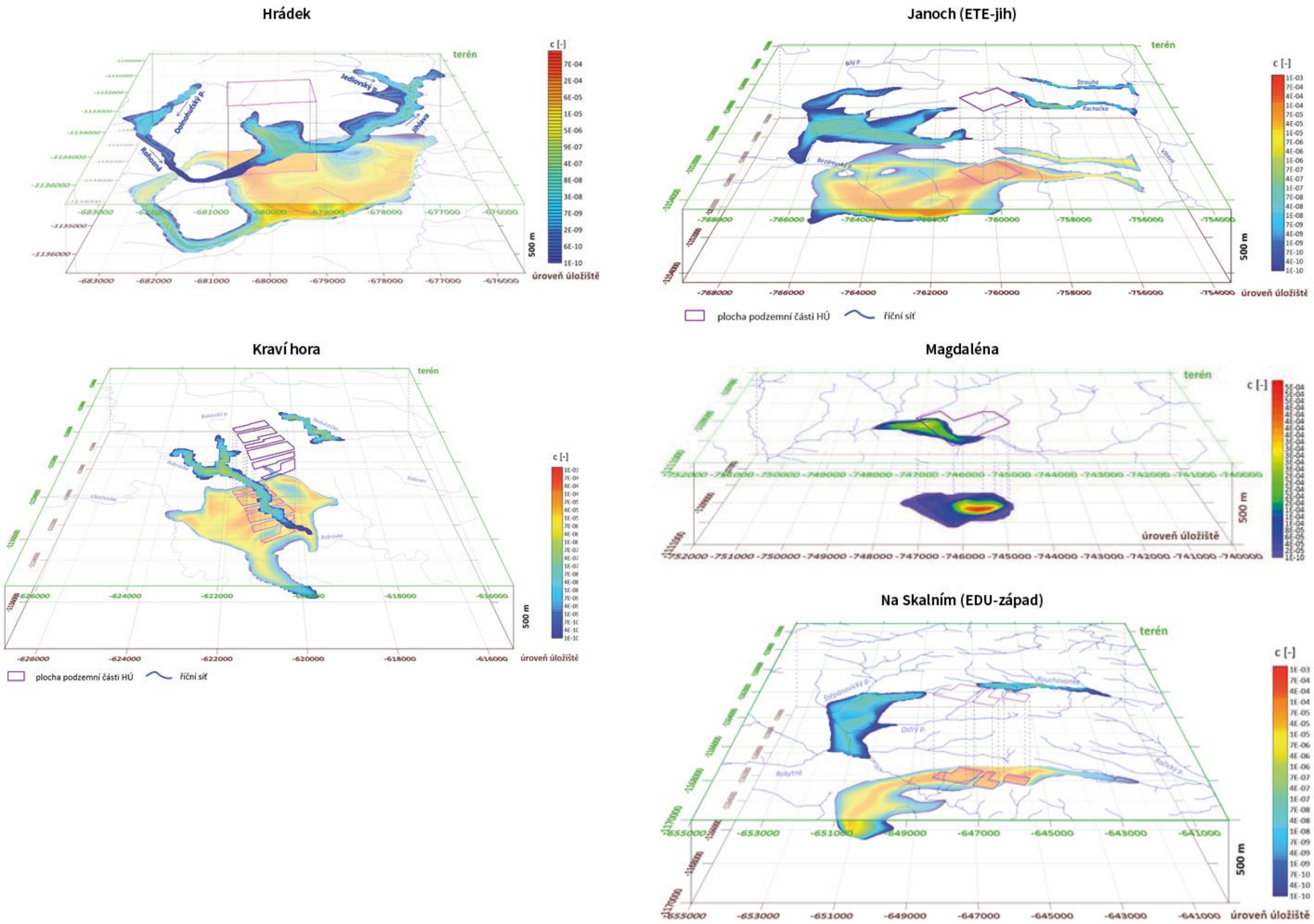


Fig. 25 Modelled stable distributions of tracer concentrations in the disposal areas and the near-surface zones for the Hrádek, Janoch (ETE-south), Kraví hora and Na Skalním (EDU-west) sites

5.8.7 Criterion C6: Identification and location of drainage bases

Description of the criterion: the identification of places at which groundwater may drain from the DGR (drainage bases) is important in terms of the safety of the site. Groundwater flow constitutes an important factor that influences the mobility of radionuclides in the rock environment. The DGR should ideally be sited so that the transport pathways of radionuclides that lead to drainage bases are as long as possible and that the transport of radionuclides is as slow as possible. The total length of the transport routes is affected by the interconnection of water-bearing structures (especially fractures).

One of the most unfavourable characteristics of sites for the location of the repository comprises the occurrence of just one dominant drainage base, to which radionuclides from the entire area of the repository will migrate following the end of the service life of the engineered barriers. The primary recipient of the groundwater, which will potentially be contaminated with radionuclides in the DGR area, will comprise the sediments of valley floodplains and, subsequently, the river network. The knowledge of the number of sections (and length) of the river network into which the groundwater will drain from the DGR complex provides valuable information on the degree of dispersion of potential radionuclide contamination.

In accordance with requirements set out in MP.22 for the characterisation of DGR drainage areas, four indicators were defined for this criterion that comprehensively provide for the description of the dispersion of transport routes from the DGR area to the drainage sites.

The drainage of groundwater from the rock mass into surface streams is mediated by the subsurface weathering layer and fractures. The drainage of deep groundwater flows depends on the heterogeneous and anisotropic resistance parameters of the rock environment. The drainage of areas with deeper flow zones can be expected particularly via tectonically-predisposed watercourses, at the intersection of streams and significant fault zones, and via deeper valleys with developed river networks.

Description and assessment of the indicators

C6a Number of drainage streams

A higher number of drainage streams indirectly indicates the greater dispersion of transport pathways from the DGR area.

Description of the indicator: the number of streams into which the entire disposal area of the DGR will drain.

Quantification: the number of streams into which contaminants from the DGR will drain via the flow of groundwater. Drainage via a single stream is deemed unfavourable.

C6b Extent of drainage from the DGR area via a single stream

A high proportion of drainage from the DGR disposal area via a single stream indirectly signals the undesirable concentration of drainage and, potentially, the occurrence of higher concentrations of radionuclides in the near-surface zone. The C6b indicator is concerned with the comparison of the sites with concern to the maximum representation of drainage from the DGR via a single stream.

Description of the indicator: a stream via which the greater part of the DGR disposal area will drain.

Quantification: percentage. The selection of the stream with the maximum share of drainage from the DGR disposal area. A high percentage of the drainage of the DGR disposal area via a single stream is deemed unfavourable. Conversely, lower values indicate the dilution of radionuclides over a larger area of the river network.

C6c Extent of drainage from the DGR area into a single river basin

The C6c indicator relates to the comparison of the sites in terms of the maximum representation of drainage from the DGR area into a single river basin. The indicator focuses on the regional distribution of drainage.

Description of the indicator: the drainage basin into which the greater part of the DGR disposal area will drain.

Quantification: percentage. The selection of drainage basins with the maximum share of drainage from the DGR disposal area and outflow to areas outside the area considered by the hydrogeological models. A high percentage of the drainage of the DGR disposal area into a single river basin is deemed unfavourable. Conversely, lower values indicate the dilution of radionuclides in other drainage basins.

C6d Horizontal distance of the DGR from the drainage location

The length of the transport pathways influences retardation processes with concern to the transport of radionuclides. With very short, or even zero, distances between the drainage location from the edge of the DGR area, the transport pathways are very short and are determined mainly by the vertical distance between the ground and DGR levels.

The C6d indicator indirectly indicates the occurrence of very short transport pathways and the potential limitation of retardation processes with concern to transport from the DGR.

Description of the indicator: the horizontal distance between the boundary of the DGR disposal area and the nearest drainage area for groundwater from the DGR complex.

Quantification: distance (m). Sites at which the drainage of groundwater from the DGR will proceed directly in the overburden of the DGR (zero distance between the drainage point and the boundary of the DGR) will be deemed less suitable from this point of view.

Results of the assessment of indicators C6a-C6d

Březový potok (Havlová et al. 2020a)

The area of the underground part of the DGR forms part of the 1-10-05 Úslava stream hydrological basin to the confluence of the Úslava with the Berounka river, and part of the 1-08-01 Vydra and Otava basin to the Volyňka stream. The drainage of the deeper zone of the rock mass is expected in the beds of tectonically-predisposed watercourses (the Hájek and Kozčínský streams), at the intersection of these streams, and along significant fault zones (the

Březový stream beyond its confluence with the Hájek stream). The assumed DGR drainage areas, at the level of 35 m below sea level, were determined by means of a flow model using the particle tracking method. The drainage of underground water flowing through the projected DGR area is via three streams (indicator C6a: The number of drainage streams).

The smallest DGR drainage area (11%) concerns the line of the Kozčín stream and, partly, the Kozčín lake, while 25% of the DGR drains into the Hájek stream. The main drainage area according to the model of the site concerns the Březový stream (63% of the water that flows through the DGR area - indicator C6b: Extent of drainage from the DGR area via a single stream). Part of the drainage function relates to beyond the confluence of the Březový and Hájek streams; the flow time and the trajectory of the underground water flow from the DGR complex to this area are the longest of all the watercourses. Drainage to the Hájek and Březový streams accordingly occurs over longer trajectories; the most intensive drainage is concentrated in areas closer to the projected DGR. Drainage to specific sections of the watercourses is largely influenced by the local character of the near-surface weathering zones and the Quaternary sediments along the streams.

A total of 88% of the area of the underground part of the DGR drains into the Březový stream basin (indicator C6c: The extent of drainage from the DGR area into a single river basin).

Drainage is calculated at an altitude of 430 m above sea level (Březový stream) to 510 m above sea level (Kozčínský stream). The shortest horizontal distance from the DGR to a drainage basin (indicator C6d: The horizontal distance of the DGR from the drainage location) according to the underground water flow model is 270 m (Kozčínský stream). The farthest drainage areas are situated 4 km from the boundary of the rock polygon that defines the proposed area of the underground part of the DGR (the Březový stream beyond its confluence with the Hájek stream).

Čertovka (Havlová et al. 2020b)

The underground area of the DGR forms part of the 1-13-03 hydrological basin of the Libocký stream and the Ohře river from the Libocký stream to the Chomutovka river. The drainage of the deeper zone of the rock mass is expected in the beds of tectonically-predisposed watercourses (e.g. the Struhařský or Blšanka streams), at the intersection of these streams and along significant fault zones (the Ležecký stream).

The drainage of underground water flowing through the projected DGR area is via two streams (indicator C6a: The number of drainage streams). The smallest DGR drainage area (4%) concerns the Blšanka stream, near its confluence with the Ležecký stream. The main drainage area according to the model relates to the Ležecký stream (96% of the water that flows through the DGR area - indicator C6b: Extent of drainage from the DGR area via a single stream). Drainage into the Ležecký stream occurs over an approximately two-kilometre section, which runs parallel to a 2nd category fault. The most intensive drainage zone concerns the confluence of the Ležecký stream and a short, unnamed tributary from areas closer to the projected DGR. Drainage to specific sections of the watercourses is largely influenced by the local character of the near-surface weathering zones and the Quaternary sediments along the streams.

A total of 100% of the area of the underground part of the DGR drains into the Blšanka stream basin (indicator C6c: The extent of drainage from the DGR area into a single river basin).

Drainage is calculated at an altitude of 330 m above sea level (the confluence of the Blšanka and Ležecký streams) to 385 m above sea level (the Ležecký stream). The shortest horizontal distance from the edge of the DGR to a drainage basin (indicator C6d) according to the flow model is 540 m (the unnamed tributary of the Ležecký stream). The farthest drainage areas begin 2.3 km from the boundary of the rock polygon that defines the proposed area of the underground part of the DGR (the confluence of the Blšanka and Ležecký streams).

Čihadlo (Havlová et al. 2020c)

The DGR area forms part of the 1-07-03-072 hydrological basin of the Řečice stream, which is part of the 1-07-03 Kamenice and Nežárka streams basin to the confluence with the Lužnice river.

The assumed drainage areas for the DGR at an altitude of 8 m above sea level were determined by the flow model using the particle tracking method. The drainage of underground water flowing through the projected DGR area is via two streams - the Řečice and Klenovské streams (indicator C6a: The number of drainage streams). The smallest DGR drainage area (approximately 3% of the DGR area) concerns the course of the Řečice stream close to its source area, and the dominant drainage area was determined by the model as the area of the confluence of the Řečice and Klenovské streams. Water from 38% of the DGR area drains into the Řečice stream above the confluence, 49% of the DGR area drains above the confluence into the Klenovské stream and around 10% of the DGR area drains into the Řečice stream below the confluence. Thus, underground water from 51% of the DGR area drains into the Řečice stream (indicator C6b: Extent of drainage from the DGR area via a single stream). The entire area of the underground part of the DGR (100%) drains into the Řečice stream basin (indicator C6c: The extent of drainage from the DGR area into a single river basin).

The drainage of the area of the underground part of the DGR is relatively concentrated. The total length of the drainage line of streams was calculated at around 3.8 km. Drainage is calculated at an altitude of 475 to 542 m above sea level at a distance of up to 1 km from the boundary of the rock polygon that defines the DGR. The most distant drainage point was calculated as being into the near-surface layer in the area of the Nové lake. The DGR also partially drains directly into the DGR overburden. Thus, the shortest horizontal drainage distance (indicator C6d) is equal to 0 m.

Horka (Havlová et al. 2020d)

The river network at the Horka site forms part of the Jihlava river basin. The potential DGR area is drained by the Oslava river (and its Oslavička, Balinka and Mařek tributaries) to the west, north and east, while the southern part of the DGR area is drained by the Mlýnský stream. Both the Mlýnský stream and the Oslava river are left tributaries of the Jihlava river.

The drainage areas of the DGR, at a proposed altitude of 34.5 m below sea level were determined by the flow model of the site using the particle tracking method. The drainage of underground water flowing through the DGR area is via up to 5 streams (indicator C6a - The number of drainage streams).

In terms of the representation of the drainage from the DGR complex, the Mařek stream dominates, i.e. according to the calculations, 81% of the underground part of the DGR drains into this watercourse (indicator C6b: Extent of drainage from the DGR area via a single stream). The remaining part of the drainage from the DGR complex is via the Balinka (9%), Oslavičky (5%), Oslava (4%) and Mlýnského (1%) streams.

A total of 99% of the underground area of the DGR drains into the Oslava catchment area (indicator C6c: The extent of drainage from the DGR area into a single river basin), while the remaining 1% drains into the Mlýnský stream.

Drainage from the DGR area is considerably dispersed due to the hydrogeological conditions and the geometry of the repository. The model predicts that the highest level of drainage intensity from the DGR will concern the initial section of the Mařek stream.

The area closest to the edge of the DGR site will drain into the Oslavičky river basin at a distance of 480 m (indicator C6d: The horizontal distance of the DGR from the drainage location). Drainage from the DGR into the Mařek river basin will occur at a distance of just 10 m more.

Hrádek (Havlová et al. 2020e)

The projected DGR area forms part of the 4-16-01 hydrological basin of the Jihlava river (Rokytná stream to its confluence) and the Svratka river (Jihlava river to its confluence). The drainage of the deeper zone of the rock mass is expected in the beds of tectonically-predisposed watercourses (Dolnohuťský stream), at the intersection of these streams, and along significant fault zones (the confluence of the Dolnohuťský and Rohozné streams). The assumed drainage areas for the DGR at a projected level of 87 m above sea level were determined by the respective flow model using the particle tracking method.

The drainage of underground water that flows through the projected DGR area is via five streams (indicator C6a: The number of drainage streams). The smallest DGR drainage area (3.1%) relates to the course of the Jedlovský stream, while less than 10% relates to the Rohozná (3%) and Dolnohuťský (6%) streams. 20% of the DGR area drains into the Huťský stream, especially in the area that features a 2nd category fault zone. The main drainage component according to the model concerns the Jihlava river, i.e. 68% of the water that flows through the DGR area (indicator C6b: Extent of drainage from the DGR area via a single stream). While the drainage lines are relatively long, the most intensive drainage areas are concentrated close to the projected DGR. Drainage to specific sections of the streams is largely influenced by the local character of the near-surface weathering layer and the Quaternary sediments along the courses of the streams. A total of 87% of the underground area of the DGR drains into the Jihlava river basin (indicator C6c: The extent of drainage from the DGR area into a single river basin).

Drainage is calculated at an altitude of around 600 m above sea level (the Dolnohuťský stream) to 500 m above sea level (the Jihlava river) at distances of 840 m (the Dolnohuťský stream, indicator C6d) to 3 km (the confluence of the Rohozná stream and Jihlava river) from the boundaries of the rock polygons that define the DGR underground complex.

Janoch (ETE-south) (Havlová et al. 2020f)

The north-western part of the DGR underground area forms part of the 1-08-03 hydrological basin of the Blanice stream and Otava river from Blanice to Lomnice, while the predominant area of the DGR is situated in the 1-06-03 basin of the Vltava from the Malše to the Lužnice.

The drainage of the deeper zone of the rock mass is expected via the various riverbeds and at the points of their intersection with significant fault zones, e.g. the Jamský stream near the village of Dívčice, and the Rachačka and Strouha streams. Other areas into which the underground areas of the DGR drain occur at locations that feature the high hydraulic conductivity of the upper zone and an underground water level that is influenced by the drainage effect of the river network.

The assumed drainage areas of the DGR, at a projected altitude of 69 m below sea level, were determined via the flow model of the site using the particle tracking method. The drainage of the underground water that flows through the DGR area is via a relatively large area and a total of 7 streams (indicator C6a: The number of drainage streams). The Bílý, Bezdrevský, Vltava and Strouha watercourses contribute to the drainage of only relatively small areas of the DGR underground complex (in single figure percentages), while most (34%) of the underground water that flows through the DGR drains to the east via the Rachačka stream (indicator C6b: Extent of drainage from the DGR area via a single stream).

The most significant drainage of the DGR area concerns the Budějovická basin hydrogeological district via the Jamský stream (19% of the DGR area) and, especially, the Olešník stream (33%) in the vicinity of the Velké Nákří lake. Together with the Bezdrevský and Bílý streams they account for the drainage of 54% of the DGR area and relate to the Bezdrevský potok catchment area (indicator C6c: The extent of drainage from the DGR area into a single river basin).

Drainage is calculated from 375 m above sea level (at the confluence of the Rachačka stream and the Vltava river) to 435 m above sea level (the western part of the area that drains into the Rachačka stream). The shortest horizontal distance of the DGR from a drainage location (indicator C6d) according to the groundwater flow model is 760 m to the Rachačka stream basin. The farthest drainage points are located 7 km from the boundary of the rock polygon that defines the DGR underground complex, in the vicinity of the village of Zbudov.

Kraví hora (Havlová et al. 2020g)

The Kraví hora site is drained by the Bobrůvka and Svratka stream networks (fourth-order river basin, tributary of the Dyje river). The assumed drainage areas of the DGR projected at an altitude of 124.5 m below sea level were determined via the flow model of the site using the particle tracking method.

The drainage of underground water that flows through the DGR is via 3 streams – the Bukovský, Bobrůvka and Nedvědička streams (indicator C6a: The number of drainage streams).

The Bobrůvka stream dominates in terms of the representation of the drainage of the DGR complex. According to the model calculations, 53% of the DGR underground area will drain into this stream (indicator C6b: Extent of drainage from the DGR area via a single stream). The remaining part of the DGR is drained by the Bukovský (12%) and Nedvědička (35%) streams. The percentages of drainage from the DGR include particles in the hydrogeological model that drain into the Olší mine (included in the drainage into the Nedvědička stream basin) and particles that drain into the flooded Habří exploration section of the Rožná mine – the model particles are included in drainage into the Bobrůvka stream basin due to flow conditions in this part of the mine workings. The hydrogeological modelling concept of the sites did not allow for the tracking of particles that flow via flooded mine tunnels.

65% of the underground area of the DGR drains into the Bobrůvka river basin (including the Bukovský stream) (indicator C6c: The extent of drainage from the DGR area into a single river basin). The remaining part of the DGR drains via the Nedvědička stream into the Svratka basin.

Drainage from the DGR area is considerably dispersed due to hydrogeological conditions and the geometry of the proposed repository. The highest intensity of the drainage of the DGR complex according to the model relates to the section of the Bobrůvka stream below the confluence with the Bukovský stream.

The shortest horizontal drainage pathway from the edge of the DGR area along the Bobrůvka stream is 632 m long (indicator C6d).

Magdaléna (Havlová et al. 2020h)

The underground part of the DGR is situated in the 1-07-04 hydrological basin of the Lužnice river from the Nežárka stream to the confluence with the Vltava river. The drainage of the deeper zone of the rock mass is expected in the beds of tectonically-predisposed watercourses (the Smutná stream), at the intersection of these streams, and along significant fault zones (also the Smutná stream) and, in general, in areas with high upper zone hydraulic conductivity and low underground water levels due to the drainage effect of the river network (deeper valleys).

The drainage of underground water that flows through the projected DGR area occurs via just one stream (indicator C6a: The number of drainage streams).

A small part of the DGR area (less than 1%) is drained via the Smutná stream directly within the overburden of the DGR underground area, whereas according to the model, the predominant part of the drainage component is situated 1 km further along the Smutná stream at its intersection with a 2nd category fault. 100% of the water that flows through the DGR is drained via the Smutná stream (indicator C6b: Extent of drainage from the DGR area via a single stream). The main area of drainage into the Smutná stream relates to a section of approximately one kilometre in length, drainage into which is largely influenced by the local character of the near-surface weathering layer and Quaternary sediments along the streams.

100% of the DGR underground complex drains into the Smutná basin (indicator C6c: The extent of drainage from the DGR area into a single river basin).

Drainage into the Smutná stream is calculated at 540 to 548 m above sea level (section in the overburden of the DGR) and 511 to 525 m above sea level (main drainage section). The shortest horizontal distance of the DGR from the drainage area (indicator C6d) is based on the overburden of the DGR, i.e. the value of the indicator is 0 m. The most distant drainage area begins 680 m from the boundary of the rock polygon that defines the underground complex of the DGR.

Na Skalním (EDU-west) (Havlová et al. 2020i)

The site forms part of the 3rd order 4-16-03 hydrological basin of the Rokytná stream. The drainage of the deeper zone of the rock mass is expected both in sections of tectonically-predisposed watercourses, including the Rouchovanka north of the DGR, and in areas with high upper zone hydraulic conductivity and low underground water levels (the Rokytná stream drainage area near Jaroměřice nad Rokytnou). The assumed drainage areas of the DGR, projected at an altitude of 81 m below sea level, were determined via the flow model of the site using the particle tracking method. The drainage of underground water that flows through the DGR area is via three streams - the Rouchovanka, Rokytná and Štěpánovický streams (indicator C6a: The number of drainage streams). Approximately 34% of the DGR area drains into the Štěpánovický stream and its left tributary, the drainage points of which are spread in a line that copies the flow from the town of Ratibořice and extends to the confluence with the Rokytná stream near Jaroměřice nad Rokytnou, at which point a small amount of the underground water drains from the DGR area (approx. 1%) directly into the Rokytná stream. Most of the projected DGR area (65%, indicator C6b: Extent of drainage from the DGR area via a single stream) drains northwards into the Rouchovanka stream and a relatively small right-hand unnamed tributary thereof. Most of the DGR area drains into the Rouchovanka stream basin (65%, indicator C6c: The extent of drainage from the DGR area into a single river basin).

Underground water from the DGR complex drains into a relatively large area between Dolní Vilémovice and Jaroměřice nad Rokytnou, a distance of 5 km from the DGR. The drainage areas are at altitudes of between 420 and 480 m above sea level. Drainage from the DGR to the Rouchovanka stream has a linear character and its intensity decreases with increasing distance from the DGR to the east. The nearest drainage points are located on the Rouchovanka stream at a horizontal distance of approx. 340 m from the DGR area (indicator C6d: The horizontal distance of the DGR from the drainage location), below the Ševčík lake. The drainage of the DGR into the Rouchovanka is influenced by the presence of regional faults, which run north of the DGR.

Tab. 22 Overall assessment of the sites for the C6a indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (number)	Indicator grade
Březový potok	3	3.7
Čertovka	2	4.3
Čihadlo	2	4.3
Horka	5	2.3
Hrádek	5	2.3
Janoch (ETE-south)	7	1.0
Kraví hora	3	3.7
Magdaléna	1	5.0
Na Skalním (EDU-west)	3	3.7

Tab. 23 Overall assessment of the sites for the C6b indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (%)	Indicator grade
Březový potok	63	2.8
Čertovka	96	4.8
Čihadlo	51	2.0

Horka	81	3.8
Hrádek	68	3.1
Janoch (ETE-south)	34	1.0
Kraví hora	53	2.2
Magdaléna	100	5.0
Na Skalním (EDU-west)	65	2.9

Tab. 24 Overall assessment of the sites for the C6c indicator according to reports by Havlová et al. 2020a-i

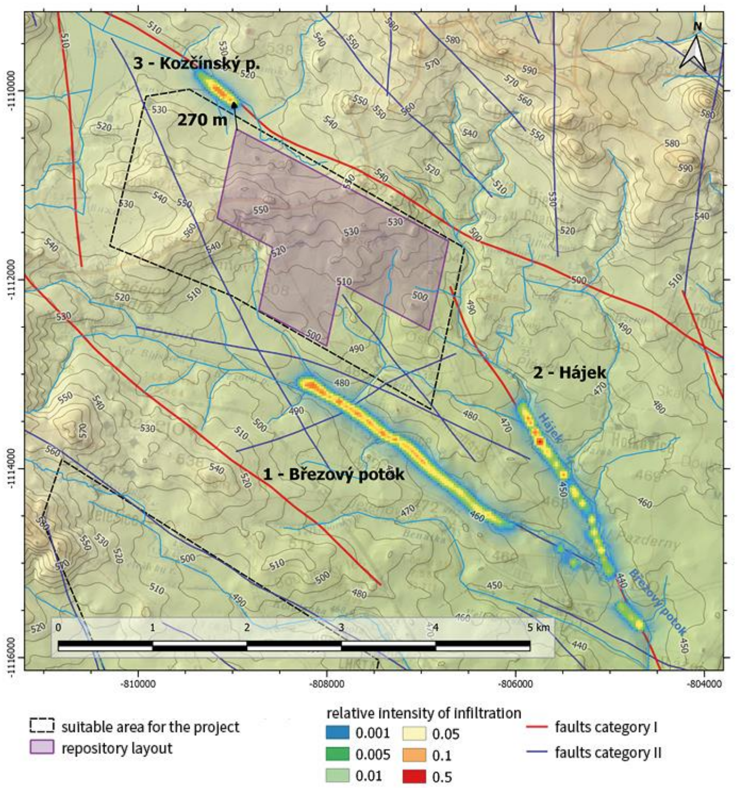
Site	Indicator value (%)	Indicator grade
Březový potok	88	4.0
Čertovka	100	5.0
Čihadlo	100	5.0
Horka	99	4.9
Hrádek	87	3.9
Janoch (ETE-south)	54	1.0
Kraví hora	65	2.0
Magdaléna	100	5.0
Na Skalním (EDU-west)	65	2.0

Tab. 25 Overall assessment of the sites for the C6d indicator according to reports by Havlová et al. 2020a-i

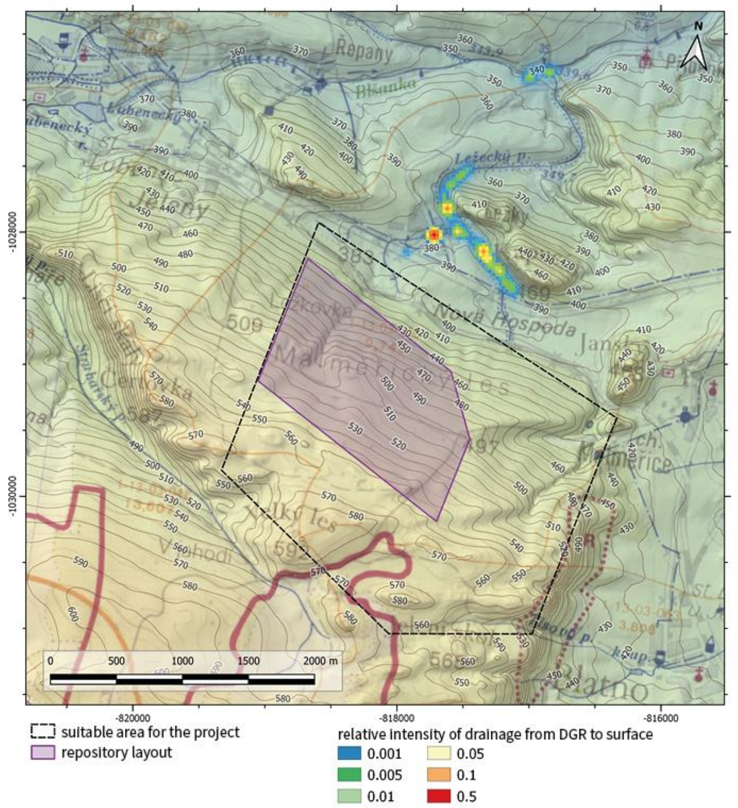
Site	Indicator value (m)	Indicator grade
Březový potok	270	3.7
Čertovka	540	2.4
Čihadlo	0	5.0
Horka	480	2.7
Hrádek	840	1.0
Janoch (ETE-south)	760	1.4
Kraví hora	632	2.0
Magdaléna	0	5.0

Site	Indicator value (m)	Indicator grade
Na Skalním (EDU-west)	340	3.4

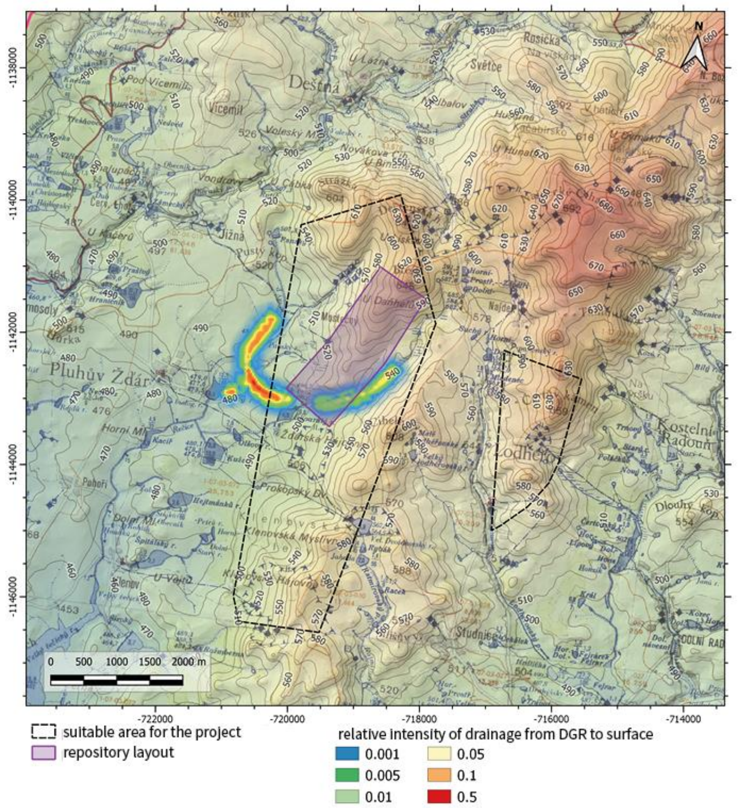
Březový potok



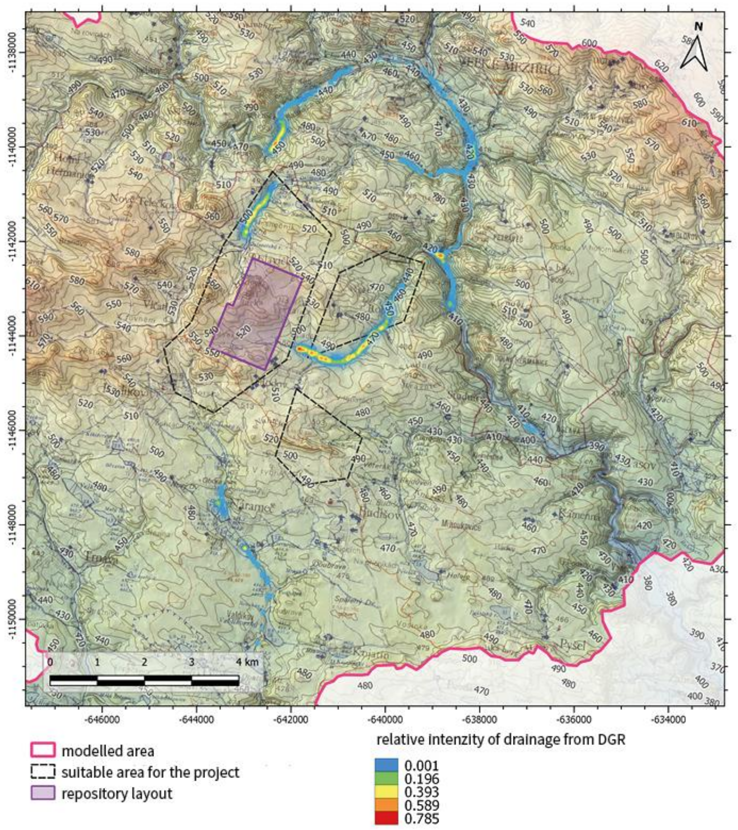
Čertovka



Čihadlo



Horka



Hrádek

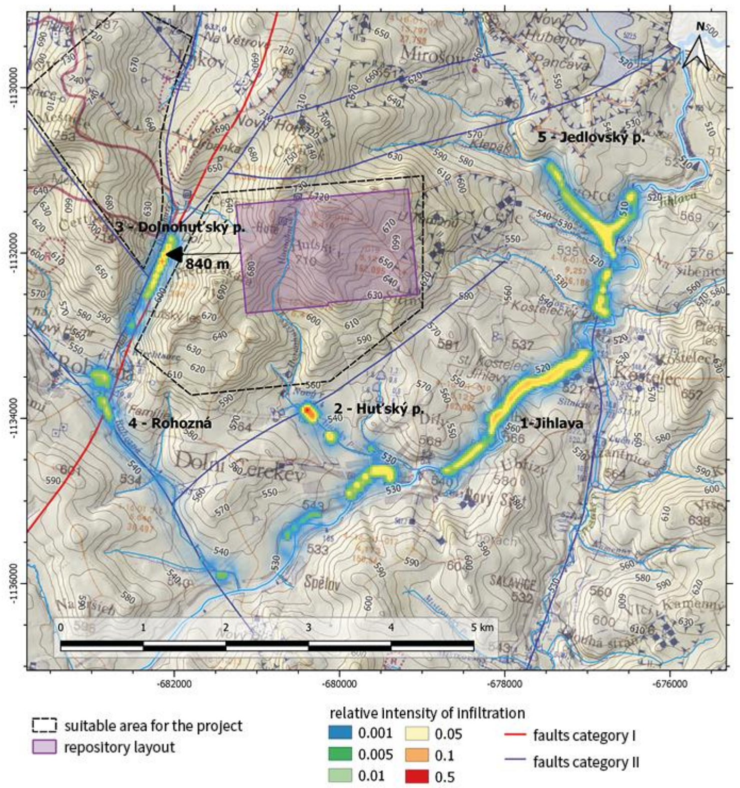


Fig. 26 Model-determined locations of groundwater drainage from the DGR area, Čertovka, Čihadlo, Horka and Hrádek sites

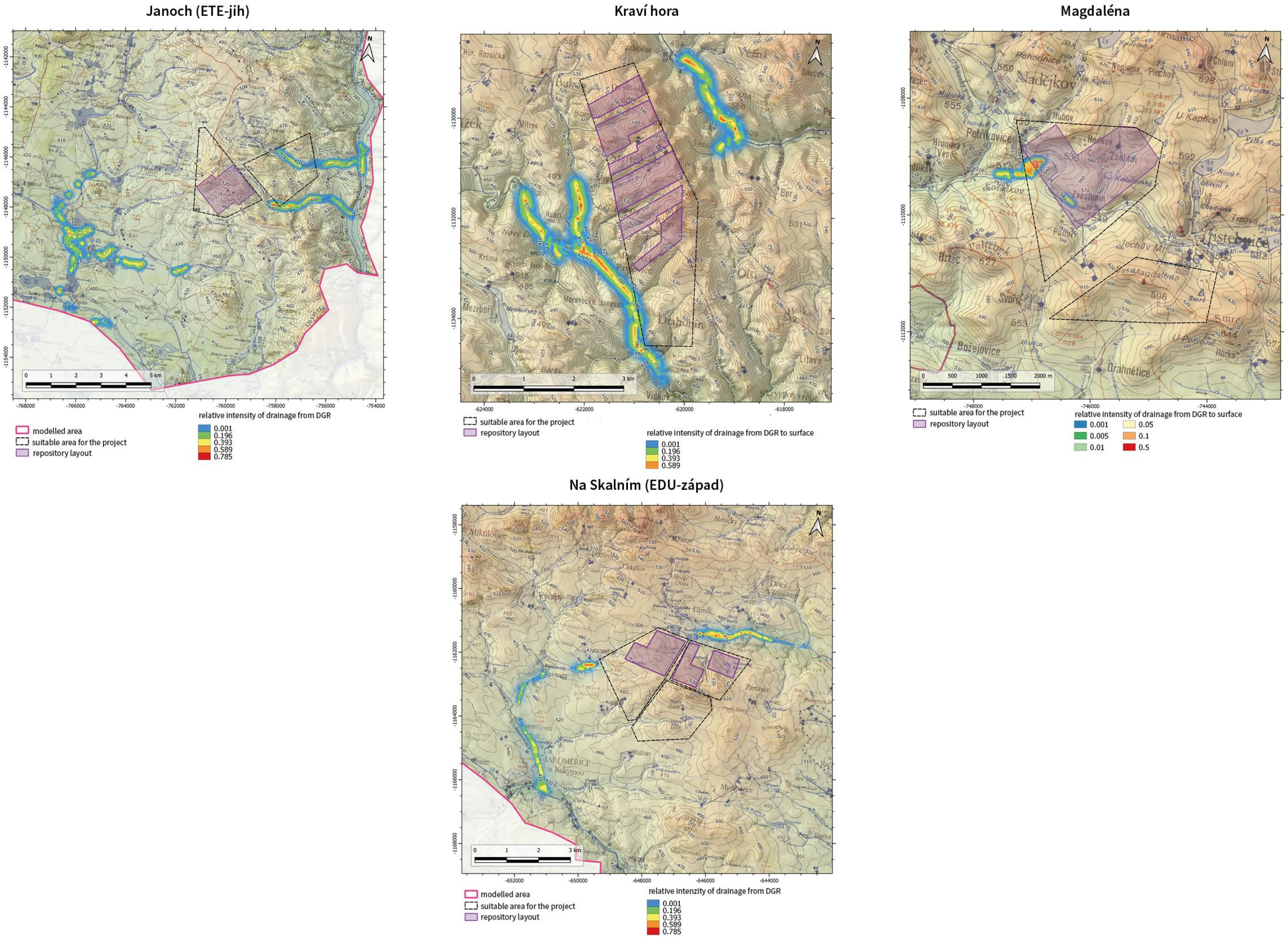


Fig. 27 Model-determined locations of groundwater drainage from the DGR area, Janoch, Kraví Hora, Magdaléna and Na Skalním (EUD-West) sites

5.8.8 Criterion C7: Seismic and geodynamic stability

Description of the criterion: the geological structure of the area for the siting of the DGR must guarantee the stability of the facility over at least hundreds of thousands of years. According to Section 18, paragraph 2, g), i) and j) of Decree No. 378/2016 Coll. the occurrence of endogenous and exogenous phenomena (g) expected climate development (i) and the vulnerability of the rock environment to long-term climate change (j) must be assessed. According to the IAEA, the DGR host environment (IAEA 2011 b) should not be susceptible to damage caused by future geodynamic processes and related subsequent phenomena and other factors (e.g. climate change, neo-tectonic movements, high seismicity) to the extent that such effects could lead to unacceptable damage to any of the safety features of the disposal system.

Description and assessment of the indicators

Assessment of the C7 indicators

C7a Value of the maximum horizontal acceleration

Description of the indicator: the value was determined by means of the PSHA method (Málek et al. 2018) for a probability of 50% and a repetition time of 10^5 years. The lower limit of the annual frequency was considered to be 10^{-6} and seismic hazard curves were determined for the 16%, 50%, 84% quantiles and the mean. The seismic threat to the sites was determined in particular via the distance from the first two significant zones and the frequency of weak near earthquakes.

Quantification: the horizontal acceleration value in $m.s^2$ for a 50% probability level and a repetition time of 10^5 years is considered.

Results of the assessment of indicator C7a

The seismic threat to the sites was determined in particular via the distance from the first two significant zones and the frequency of weak near earthquakes. The assessment value relates to the maximum horizontal acceleration determined via the probability method for a 50% probability and a repetition time of 10^5 according to Málek et al. (2018). The values determined for this indicator are summarised for the nine candidate sites in a report by Havlová et al. (2020a-i) and in Tab. 26 below.

Tab. 26 Overall assessment of the sites for the C7a indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value	Indicator grade
Březový potok	1.21 $m.s^{-2}$	2.0
Čertovka	2.04 $m.s^{-2}$	5.0
Čihadlo	1.59 $m.s^{-2}$	3.3
Horka	1.26 $m.s^{-2}$	2.1

Site	Indicator value	Indicator grade
Hrádek	0.95 m.s^{-2}	1.0
Janoch (ETE-south)	1.61 m.s^{-2}	3.4
Kraví hora	1.33 m.s^{-2}	2.4
Magdaléna	0.97 m.s^{-2}	1.1
Na Skalním (EDU-west)	1.46 m.s^{-2}	2.9

C7b Elevation gradient

Description of the indicator: the elevation gradient between the height of the aligned surface of the area and the level of the relevant local erosion base is directly proportional to the dynamics of the relief and determines the potential for the lowering of the drainage system in the future and the associated emergence of exodynamic phenomena, including long-term changes.

Quantification: the maximum value of the elevation difference (m) is considered.

Results of the assessment of indicator C7b

Březový potok (Havlová et al. 2020a)

The assessed area lies at the confluence of the Březový and Myslívský streams.

Most of the area lies upon remnants of an aligned surface. The north-western part of the area lies on an aligned surface with an altitude of around 600 m above sea level which connects to the base aligned surface level in the south of the Šumava and in the north of Brdy. The south-eastern part of the studied area (the Otava river basin) forms part of an aligned surface at an altitude of around 450–500 m above sea level. With respect to the area that drains to the north (the Myslív and Víska stream basins), the erosion base comprises the level of the floodplain of the Úslava river at an altitude of around 500 m above sea level, and the altitude difference between the highest level of the aligned surface and the erosion base for the Úslava river basin is 125 m. Concerning the southern part of the area, which lies on a lower level aligned surface, the erosion base corresponds to the surface of the Březový stream floodplain in the lower part of the catchment area at an altitude of approximately 420 m above sea level. The maximum altitude difference between the average altitude of the aligned surface and the respective erosion base was determined at 125 m on the basis of geomorphological analysis conducted as part of an erosion stability study (Hroch and Pačes, 2015) and a morpho-tectonic analysis by Kopačková et al. (2017).

Čertovka (Havlová et al. 2020b)

The local erosion bases for the area in the Střela and Rakovnický stream basins and the upper part of the Blšanka stream basin comprise the floodplain surfaces of these streams at an altitude of approx. 400 m to 370 m above sea level. Concerning the north-eastern part of the area, the aligned surface draining level lies at an altitude of 450 to 500 m above sea level. The Podvinecký and Ležecký streams comprise the erosion base of the surface of the floodplain of the Blšanka stream near the village of Kryry at an altitude of approx. 300 m above sea level

(Hroch and Pačes 2015). The greatest difference between the altitudes of the various aligned surfaces and that of the local erosion base is 230 m.

Čihadlo (Havlová et al. 2020c)

The area comprises two paleo-relief levels: the higher level, at around 600 m above sea level, relates to a relatively resistant monolithic granite massif and the lower paleo-relief level, at around 450-500 m above sea level, relates to a surface comprising metamorphic Moldanubian rocks. The altitude difference between the average altitudes of the aligned surface and the respective erosion base was determined according to the results of a geomorphological analysis conducted as part of an erosion stability study (Hroch and Pačes 2015) and a morpho-tectonic analysis by Kopačková et al. (2017). The erosion base corresponds to the surface of the Třeboň basin, i.e. at an altitude of around 450 m, which is around 150 m below the higher level of the aligned surface and 40 to 90 m below the lower level of the aligned surface.

Horka (Havlová et al. 2020d)

The Horka site is situated at the confluence of the Oslava and Mlýnský (a tributary of the Jihlava river) streams. The surface comprises remnants of aligned surfaces at an altitude of around 600 m above sea level (the northern part of the area) and at an altitude of 450 to 500 m above sea level (the southern part of the area). The two paleo-relief levels are separated by reverse and erosion slopes. The erosion base of the area consists of the Oslava river at an altitude of 390 m above sea level and corresponds to the surface of the Oslava floodplain south of Tasov, where the river valley widens. The erosion base is located at the same altitude (approx. 390 m above sea level) for the area drained by the Mlýnský stream and corresponds to the surface of the floodplain of the Jihlava river near the village of Vladislav (Hroch and Pačes, 2015). The maximum altitude difference between the aligned surface and the corresponding erosion base is 210 m.

Hrádek (Havlová et al. 2020e)

The assessed area lies in the Jihlava river basin on the watershed between tributaries of the Rohozná stream and the Jedlovský stream. The watershed area comprises aligned surfaces at an altitude of 700 to 750 m and, at the lower paleo-relief level, of around 600 m. To the east of the promising area for the geological characterisation research, in the area of the confluence with the Třešť stream, remnants of aligned surfaces have been preserved at an altitude of approximately 550 m above sea level. The various altitude levels are separated by reverse and erosion slopes. The erosion base of the assessed area corresponds to the surface of the floodplain of the Jihlava river at an altitude of approx. 510 to 530 m above sea level. With respect to the Jedlovský stream catchment area (the highest aligned surface and adjacent relief), the local erosion base lies at an altitude of approx. 600 m above sea level (corresponding to the floodplain of the Jedlovský stream near the village of Boršov). The maximum altitude difference between the average paleo-relief altitude and the erosion base is 240 m.

Janoch (ETE-south) (Havlová et al. 2020f)

The assessed area is located in the Vltava river basin; the western part of the area is drained by the Temelín and Dříteň streams that flow into the Blanice river and then into the Vltava, while the southern part is drained by left tributaries of the Bezdrev stream. The eastern part of the area is drained by the Vltava itself and its tributaries. Two main aligned surface levels have been defined in the area. The higher level lies on a watershed on mainly Moldanubian rocks at an altitude of around 500 m above sea level, whereas the lower aligned surface is related to the České Budějovice basin at altitudes of 400 to 450 m above sea level. The two levels are separated by slightly inclined reverse slopes. The surfaces of the aligned surfaces are characterised by a flat relief that is not exposed to intense reverse erosion. With concern to the higher aligned surface, which lies on Moldanubian rocks, remnants of fossil weathering are evident, while the lower level is bound to the occurrence of cretaceous and tertiary sediments that comprise the filling of the České Budějovice basin. The north-west of the area features an undulating etchplain surface in the rocks of the Podolsky complex, which has also not been affected by intense reverse erosion. The local erosion base of the western and south-western areas comprises the České Budějovice basin at an altitude of around 400 to 450 m above sea level, whereas that of the eastern part of the aligned surface comprises the Vltava river floodplain at an altitude of 350 to 360 m above sea level.

Kraví hora (Havlová et al. 2020g)

The Kraví hora site lies in the river basin of the Svratka, the right-bank tributaries of which comprise the Bobrůvka and Nedvědička. The wider studied area features two aligned surfaces of around 600 m above sea level and 500-550 m above sea level. The most coherent areas lie in the NW of the assessed area; in the immediate vicinity of the site, these aligned surfaces have been preserved only as area-limited remnants related to areas between significant erosion valleys. The erosion base corresponds to the level of the floodplain of the Svratka river, which is located at an altitude of around 300 m above sea level. The difference between the higher of the aligned surfaces and the respective erosion base is thus 300 m.

Magdaléna (Havlová et al. 2020h)

The assessed area lies in the catchment area of the Smutná, Oltyňský and Pilský streams that drain into the Lužnice river south of the watershed with the Sedlecký stream (right-bank tributary of the Vltava). The area covers remnants of two aligned surface levels. The higher level lies at an altitude of around 600 m above sea level and is located in the northern part of the area of interest, while the lower aligned surface is located at an altitude of 450-500 m above sea level and occurs in the southern part of the area. The two aligned surfaces are separated by an intensely degraded retreat slope. The maximum differences between the average altitudes of the aligned surfaces and the respective erosion bases were determined based on the geomorphological analysis presented in the erosion stability study by Hroch and Pačes (2015) and a morpho-tectonic analysis. Two local erosion bases have been defined for the given area. With respect to the higher aligned surfaces and adjacent slopes (the northern part of the area), the erosion bases comprise the floodplain surfaces of watercourses situated on the lower aligned surface at an altitude of around 480 to 500 m above sea level, while for the lower aligned surfaces and adjacent slopes (the southern part of the area), the erosion base comprises the bottom of the Lužnice river valley at an altitude of approx. 350 m above sea level. The maximum difference between the average altitudes of the aligned surfaces and the respective erosion bases is 150 m.

Na Skalním (EDU-west) (Havlová et al. 2020i)

The Na Skalním (EDU-west) site is located in the Jihlava river basin; the southern half of the site is drained by the Rouchovanka stream (a right-bank tributary of the Rokytná river), while the northern half of the site is drained by the Jihlava river and its tributaries. Three aligned surface levels have been defined in the area, the highest of which is located at an altitude of 520 to 480 m above sea level and covers the Klučovská hill and the Rouchovanka watershed, the middle surface is at an altitude of 480 to 460 m mainly in the southern part of the area, and the lowest surface comprises flat relief at 460 to 440 m above sea level above the Jihlava river valley in the northern and north-eastern parts of the area. The various aligned surfaces are separated by slightly inclined reverse and structural slopes. The aligned surfaces comprise a flat relief that has not been exposed to intense reverse erosion. In some places, low ridges occur on the aligned surfaces that comprise the basal parts of unevenly weathered areas with the exfoliation of massive rocks, mostly granitoids measuring up to a few metres (Hanžl et al. 2017). The local erosion base in the southern part of the area comprises the Rouchovanka floodplain at an altitude of approx. 410 m above sea level, and the erosion base in the northern part of the area the floodplain of the Jihlava river at an altitude of 390 to 380 m above sea level.

Tab. 27 Overall assessment of the sites for the C7b indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (m)	Indicator grade
Březový potok	125 m	1.0
Čertovka	230 m	3.4
Čihadlo	150 m	1.6
Horka	210 m	2.9
Hrádek	240 m	3.6
Janoch (ETE-south)	150 m	1.6
Kraví hora	300 m	5.0
Magdaléna	150 m	1.6
Na Skalním (EDU-west)	140 m	1.3

C7c Percentage of the relief area affected and reshaped by young cycles of reverse erosion and slope deformations

Description of the indicator: significant manifestations of reverse erosion indicate unbalanced river flow catchment conditions caused by movements of the erosion base, i.e. vertical movements of the earth’s crust, and result in the lowering of the drainage system to a greater than anticipated extent. This indicator exerts an impact on the future derivation of site development scenarios.

Quantification: in percent.

Results of the assessment of indicator C7c

Březový potok (Havlová et al. 2020a)

Reverse erosion practically does not occur in the area; flows mostly relate to shallow open valleys (Hroch and Pačes 2015, Kopačková et al. 2017). The area affected by young cycles of reverse erosion does not exceed 5%.

Čertovka (Havlová et al. 2020b)

The site features a significant area of relief that has been deformed by reverse erosion, related particularly to the Střela stream valley, which is 200 m deep and has slopes steeper than 25°, as well as the narrow and steep valleys of tributaries of the Střela stream which do not feature the presence of preserved valley accumulations. Reverse erosion, which progresses from the Blšanka and Jesenický stream basins to the paleo-relief at an altitude of 450 to 500 m above sea level, comprises a relatively dense network of eroded ravines in Late Paleozoic sediments. The northern part of the area features clear indications of river capture involving the upper course of the Rakovnický stream and the Blšanka basin. The percentage of the area affected by deformation caused by young cycles of reverse erosion is estimated at 60%.

Čihadlo (Havlová et al. 2020c)

The geomorphological characteristics indicate that most of the area is not affected by younger cycles of reverse erosion, the result of which is the creation of steep erosion slopes with deep erosion valleys. The erosion valleys in the area typically comprise slightly sunken U-shaped structures. Indications of previous deep erosion are evident only in the valley of the Dírenský stream, which has created an erosion valley of around 20–25 m deep cut into the lower of the aligned surfaces. The Dírenský stream system currently evinces a meandering character with the predominance of lateral erosion, and adjacent slopes feature erosion ravines in the order of a few metres. However, they do not evince indications of active deep erosion or significant reverse erosion faces, and their bottoms are filled with alluvial sediments. The percentage of the area affected by deformation due to reverse erosion is estimated at around 11% of the total area.

Horka (Havlová et al. 2020d)

The wider area of the site features significant areas of relief that have been deformed by reverse erosion, related particularly to the Mlýnský stream and the Oslava river and its tributaries. Indications of reverse erosion are more pronounced in the Oslava river basin, which features narrow erosion valleys of up to 100 m deep. Numerous erosion ravines and grooves are evident in the erosion slopes along smaller streams. Conspicuous reverse erosion faces have been created in the upper parts of the erosion valleys (Hroch and Pačes 2015, Kopačková et al. 2017). The percentage of the area affected by deformation due to reverse erosion is estimated at around 20% of the total area.

Hrádek (Havlová et al. 2020e)

The main streams in most of the area flow along open, quiet courses with developed floodplains, and the stream beds evince a predominantly meandering character with a mainly lateral erosion component. The valleys of smaller side tributaries also show no signs of intense deep erosion and are mostly filled with valley accumulations. The low intensity of erosion processes is confirmed by the presence of numerous preserved slope accumulations. Indications of deep reverse erosion in the relief are evident only in the lower parts of the stream basin below the village of Dolní Cerekev, where there is a noticeable narrowing and deepening of the Jihlava river valley, which is particularly evident in the lower parts of the river basin. The percentage of the area affected by deformation due to reverse erosion is estimated at around 15% of the total area.

Janoch (ETE-south) (Havlová et al. 2020f)

Indications of deep reverse erosion are evident in the eastern part of the site related to the Vltava river valley and its tributaries, which evince erosion slopes. These slopes are characterised by higher angles in the lower parts, distinct upper edges that form clear morphological interfaces with the aligned surfaces, the presence of erosion valleys with V-shaped profiles and the limited occurrence of valley accumulations. The erosion valleys exhibit erosion faces with pronounced arched closures and often with pronounced edges. However, the areas drained by tributaries of the Blanice and Bezdrevský streams (the western and south-western parts of the area) do not exhibit significantly intense reverse erosion; the slopes are usually of lower angles and the valleys mostly comprise shallow open depressions. The area affected by young cycles of reverse erosion amounts to around 30% of the total area.

Kraví hora (Havlová et al. 2020g)

The area is severely affected by reverse erosion that penetrates into the area from the main streams and erosion valleys along watercourses that are up to 200 m deep and lined with steep erosion slopes with numerous erosion ravines and significant reverse erosion faces. The wider area exhibits indications of changes in the river network (e.g. Žížala and Vilímek 2011). However, no consensus has been reached on the age and causes of river capture. The percentage of the area of the relief deformed by young cycles of reverse erosion amounts to 85%.

Magdaléna (Havlová et al. 2020h)

Only a small part of the area is affected by young cycles of reverse erosion. The erosion relief relates to the slopes of the Smutná river valley. Significant indications of deep erosion are evident south of the area of interest in the lower parts of the river basin that drain the area into the Lužnice river, and are characterised by the more pronounced deepening of river valleys, the presence of narrow V-shaped erosion valleys and erosion ravines related to the tributaries of larger streams and significant reverse erosion faces in the upper parts of erosion valleys and ravines. The area of relief that has been deformed by reverse erosion does not exceed 20% of the total area.

Na Skalním (EDU-west) (Havlová et al. 2020i)

Significant indications of deep reverse erosion are evident especially in the northern half of the area related to the slopes of the Jihlava river valley, featuring deep erosion valleys with V-shaped profiles. The slopes are characterised by higher angles in the lower parts and distinct upper edges that form clear morphological interfaces with the aligned surfaces. The bedrock of the slopes is often exposed, thus revealing natural outcrops. Reverse erosion faces often feature in the erosion valleys in the form of arched closures with pronounced edges. Indications of the effects of reverse erosion have also been observed in the Rouchovanka stream valley, comprising the occurrence of erosion valleys or ravines accompanied by steep erosion slopes and exposed bedrock; however, compared to the northern part of the area, indications of reverse erosion are less pronounced here due to the lower topographic gradient (Hanžl et al. 2017). The relief deformed by reverse erosion makes up around 40% of the total area.

Tab. 28 Overall assessment of the sites for the C7c indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value (%)	Indicator grade
Březový potok	5%	1.0
Čertovka	60%	3.8
Čihadlo	11%	1.3
Horka	20%	1.8
Hrádek	15%	1.5
Janoch (ETE-south)	30%	2.3
Kraví hora	85%	5.0
Magdaléna	20%	1.8
Na Skalním (EDU-west)	40%	2.8

C7d Occurrence of volcanic rocks of the Paleogene to Holocene eras and acids

Description of the indicator: the presence of tertiary and quaternary volcanic rocks and related post-volcanic phenomena are associated with areas that witnessed recent geodynamic activity, including tectonic movements; this factor provides an indication of the long-term stability of the area. The presence of acids in the vicinity of the site may exert a negative effect on the engineered barriers of the repository.

Quantification: the occurrence of volcanic rocks of the Paleogene to Holocene eras and the occurrence of acids are considered

Results of the assessment of indicator C7d

The Březový potok, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Kraví hora, Magdaléna and Na Skalním (EDU-west) sites (Havlová et al. 2020a,c-i)

Based on available data, no indications of volcanic or post-volcanic activity of the Paleogene to Holocene eras have been identified within a radius of 5 km of the sites (e.g. Chlupáč and Štorch 1992, Cháb et al. 2007, Franěk et al. 2018, Mixa et al. 2019). Moreover, no occurrences of acids have been determined within a radius of 25 km of any of the sites (Kolářová 1978, Kolářová and Myslil 1979).

Čertovka (according to Havlová et al. 2020b)

Both the vicinity and the wider area of the candidate site feature occurrences of Tertiary age volcanic rocks. The site area features remnants of lava flow bodies and erosive remnants of small slag cones. To the north-west of the site, remnants have been discovered of the Doupov Mountains volcanic complex and to the west of the Čertovka site lies the Vladař hill, a remnant of a separate smaller volcano, and scattered remnants of isolated volcanic bodies of the Tepelská uplands and the Slavkovský forest. The ages of these volcanic rocks range from 34 to 8 Ma.

Numerous occurrences of acids have been recorded within a radius of 25 km of the promising area for the project design work, the most numerous of which relate to tectonic zones near to indications of Neogene volcanism in the Doupov Mountains, Slavkovský forest and Tepelská plateau areas south-west, west and north-west of the site. Acids originating from the underlying crystalline rocks are also evident in the assessed area along faults in permocarbon sediments, specifically in the cadastral areas of the villages of Vroutek, Očichov and Liběšice.

Tab. 29 Overall assessment of the sites for the C7d indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value	Indicator grade
Březový potok	phenomenon does not occur	1
Čertovka	phenomenon occurs	5
Čihadlo	phenomenon does not occur	1
Horka	phenomenon does not occur	1
Hrádek	phenomenon does not occur	1
Janoch (ETE-south)	phenomenon does not occur	1
Kraví hora	phenomenon does not occur	1
Magdaléna	phenomenon does not occur	1
Na Skalním (EDU-west)	phenomenon does not occur	1

5.8.9 Criterion C8: Characteristics that could lead to the disturbance of the DGR via future human activities

Description of the criterion: the disturbance of the repository by future human activities will, according to international recommendations (the HIDRA project, EURATOM PAMINA, etc.), most likely be due to the following reasons:

1. the disturbance of the repository in order to recover the disposed of SNF as a secondary raw material or for other purposes;
2. disruption of the repository in order to use the available resources in the area following the loss of information on the existence of the repository.

With respect to the reason mentioned in point 1), it is not possible to prevent or reduce the probability of the disturbance of the repository in the future. However, those who penetrate into the repository will know what it contains, will need these materials (for whatever purpose) and will have the necessary technical means and economic resources to so. Such events concern intentional disturbance, which is not assessed in terms of impacts on humans as recommended by the International Commission on Radiation Protection (ICRP). However, it is important to prevent the unintentional disturbance of the repository by humans following the loss of information on the existence of the repository.

Description and assessment of the indicators

C8a Raw material deposit conditions at the site (mining areas, register of protected deposit areas, prediction of the presence of minerals)

Description of the indicator: reserved raw material deposit areas, mineral reserves and the forecasts thereof comprise strategic factors in terms of the development of the country and, as such, the presence of significant mineral reserves may constitute an excluding criterion when assessing and comparing the suitability of the candidate sites.

Quantification: no/insignificant/significant/yes.

Results of the assessment of indicator C8a:

Březový potok (Havlová et al. 2020a)

Reserves and forecast mineral resources are present in the assessed area in the form of three deposits and three non-utilised forecast sources, comprising tungsten and building/ornamental stone. The assessed area features 15 mining sites, four of which relate to the above deposits. The remaining sites comprise long-abandoned granite quarries.

Čertovka (Havlová et al. 2020b)

The assessment of data on the exploration of deposits concluded that two deposits and three forecast sources at the Čertovka site comprise locally exploited or as yet unmined surface deposits, and that human activity concerning the potential future mining of construction and brick raw materials will not reach or affect the depth at which the construction of the DGR is anticipated. Thus, with respect to the two monitored parameters, i.e. deposits and undermining conditions, the indications are clearly insignificant.

Čihadlo (Havlová et al. 2020c)

According to Tichý (1970), the Čihadlo site features six quarries, one of which comprises the Deštná stone quarry. The remaining five sites comprise local, long-abandoned quarries in the granitoids of the Klenov pluton with lengths of 20-100 m and wall heights of 7-12 m. The deposit conditions do not differ significantly from those of the Deštná deposit.

Horka (Havlová et al. 2020d)

According to SurIS data, no mineral deposits or forecast deposits have been recorded at the Horka site. However, the site features scattered insignificant indications of the occasional local surface mining of building materials (clay, sand). Four locations at which local mining took place in the past have been identified at the site.

Hrádek (Havlová et al. 2020e)

The mineral reserves at the Hrádek site comprise three building/ornamental stone deposits, one of which extends to the NE boundary of the site. The area defined by the rock polygon features fifteen abandoned mines, i.e. granite quarries and sand pits in the sandy eluvium (Růžičková 1970). A survey concerning the presence of radioactive raw materials at the site and its surroundings was conducted by Litochleb and Krištiak in 1985. In 1974, a radiometric anomaly in limonite zones and the surrounding fractured granites was verified in the Šance rock formation (NW of the village of Rohozná). The presence of quartz veins with sulphide mineralisation or gold in the vicinity of the village of Rohozná indicates the scattered occurrence of polymetallic mineralisation, which occurs between the Pelhřimov and Jihlava ore districts. According to an overview of minerals in the region (Pokorný et al. 1969), with respect to the Hrádek site, areas to the N, NE and NW of Rohozná in the Huť forest, the SW slopes of the Čertova hill and the area between Rohozná and the Šance rock formation were mined from the Middle Ages to the second half of the 20th century. Remnants of prospecting and mining have been preserved in the form of several hundred metre-long rows of depressions and a number of mined tunnels on quartz vein outcrops, in which pyrite, pyrrhotite and galena have been detected. Some of the quartz veins have elevated gold contents. Exploratory work on these sites conducted in the second half of the 20th century provided negative results. It is assumed that the depth range of the mining of these veins will not be important either in terms of the siting of the DGR or the intrusion characteristics.

Janoch (ETE-south) (Havlová et al. 2020f)

Just one source of mineral deposits has been identified at the Janoch (ETE-south) site in the SE part of the area (building stone). According to Tichý (1970), the assessed area features 11 former mining sites, one of which relates to the Chlumec 5136600 uranium deposit. The remaining sites comprise local, long-abandoned quarries for the extraction of building stone and crushed aggregate based on paragneisses, erlans, orthogneisses and granitoids, or sand from rocks with a predominance of quartzites (poor quality sand). All the mining sites examined in the area are currently considered unsuitable for use; however, this could change in the future.

Kraví hora (Havlová et al. 2020g)

A total of 6 deposit areas and one exploration area have been recorded at the Kraví hora site. Two deposit areas are classified as protected with respect to the potential for underground gas storage, as are two building stone deposits and two abandoned building stone and radioactive raw material deposits in the Rožná area. Other locations that feature indications of the previous mining of mineral resources have also been identified at the Kraví hora locality. According to Jaroušek (1973), the area features two abandoned quarries measuring approximately 70×30×15 m and 10×6×2 m related to the abandoned Střítež 5049200 uranium deposit near Bukov.

Magdaléna (Havlová et al. 2020h)

Around half of the southern edge of the assessed area comprises the Drahnětice II 7057200 protected brick raw material deposit. The area of the rock polygon also features five abandoned mines, one of which relates to the above-mentioned deposit.

Na Skalním (EDU-west) (Havlová et al. 2020i)

The assessed area features no deposits, protected deposit areas or forecast sources of raw materials. According to Jaroušek (1972), there are just 2 local, long-abandoned quarries in the defined area from which building stone and crushed aggregate (syenite and orthogneisses) were extracted.

Tab. 30 Overall assessment of the sites for the C8a indicator according to reports by Havlová et al. 2020a-i

Site	Indicator value	Indicator grade

Březový potok	insignificant	2.0
Čertovka	insignificant	2.0
Čihadlo	insignificant	2.0
Horka	no	1.0
Hrádek	insignificant	2.0
Janoch (ETE-south)	insignificant	2.0
Kraví hora	significant	3.0
Magdaléna	insignificant	2.0
Na Skalním (EDU-west)	insignificant	2.0

5.8.10 Criterion C9: Phenomena influenced by the spread of radioactive materials

Description of the criterion: with respect to the future DGR, this factor primarily concerns the assessment of the impact of a possible emergency situation involving the hot chamber in which the SNF will be removed from the storage and transport containers and inserted into waste disposal packages. In the event of the spread of radionuclides through the atmosphere and the interaction of negative processes such as the malfunction of the filters of the hot chamber when opening a storage/transport package with damaged fuel cells, radioactive substances may be released into the environment via the ventilation system. The spread of radioactive materials might also occur in the event of an emergency situation during the transport of the SNF from the storage facility to the DGR. Longer distances and more frequent shipments will increase the likelihood of such an emergency.

Description and assessment of the indicators

C9a The distribution and density of the population and its development in terms of the spread of radioactive material

Description of the indicator: the assessment of population density must be performed in accordance with Section 17, Decree No. 378/2016 Coll., on the siting of nuclear facilities. While this factor is not excluding, it can be used to compare the sites via the calculation of the collective dose. The collective dose, which is used to compare radionuclide releases from nuclear facilities is directly proportional to the population density around the nuclear facility; it is determined as the sum of all the effective doses of persons living in the vicinity of such a facility. The effective dose is multiplied by the number of people in given age groups (child of 3 months, 1, 5, 10, 15 years and adults) since the effect of radiation differs between age categories. Thus, the larger the population, the greater the collective dose.

Quantification: size of the population.

Results of the assessment of indicator C9a

This indicator is assessed in a report by Lahodová and Popelová (2020); the resulting values are provided in Tab. 31. The indicator considers the hot chamber that will be used for the transfer of SNF from transport to disposal containers and which will have a chimney with a height of a maximum of 15 m above ground level with a vertical air velocity of 2.2 $m.s^{-1}$. In the event of an emergency situation (the failure of the air filter chain in the hot chamber), the radiation level to which the population will be exposed will be very low and will be most pronounced in the immediate vicinity of the point of discharge into the atmosphere. Therefore, the assessment concerned the number of inhabitants within a radius of 10 km from the site.

Tab. 31 Overall assessment of the sites for the C9a indicator according to reports by Lahodová and Popelová (2020)

Site	No. of inhabitants at a distance of 10 km	Indicator grade
Březový potok	12 820	1.57
Čertovka	7 966	1.00
Čihadlo	30 290	3.64
Horka	41 765	5.00
Hrádek	18 338	2.23
Janoch (ETE-south)	19 039	2.31
Kraví hora	20 366	2.47
Magdaléna	18 552	2.25
Na Skalním (EDU-west)	15 026	1.84

C9b Distance from nuclear power plants

Description of the indicator: the probability of the occurrence of an emergency event during the transport of containers with SNF is proportional to the distance of the sites from nuclear power plants with SNF storage facilities, and the frequency of the shipment of SNF. In order to calculate the total distance travelled to the site, the current distance via the railway infrastructure is multiplied by the number of trains that will be dispatched from the storage facility. One of the assumptions for the calculation is the transport of three storage/transport containers per shipment.

Quantification: number of shipments of storage/transport containers.

Results of the assessment of indicator C9b

This indicator is assessed in a report by Lahodová and Popelová (2020); the resulting values are provided in Tab. 32. The indicator considers the railway transport of SNF from NPPs to the candidate DGR sites according to a report by Zahradník et al. (2020). The shortest transport route was chosen via existing railway lines which meet freight transport requirements, i.e. primarily an axle load of at least 20 tonnes. The lengths of the transport routes were determined from the exit of the NPP site to the entrance to the DGR site.

Tab. 32 Overall assessment of the sites for the C9b indicator according to reports by Lahodová and Popelová (2020)

Site	Transport distance from the NPP site (km)			Indicator grade
	Dukovany NPP	Temelín NPP	Total distance	
Březový potok	339.5	73.5	72 299.5	2.55
Čertovka	455.1	188.1	109 726.5	5.00
Čihadlo	215.7	103.7	54 086.5	1.35
Horka	86.1	231.1	48 717.5	1.00
Hrádek	153.3	150.3	49 393.5	1.04
Janoch (ETE-south)	304.8	11.8	57 161.0	1.55
Kraví hora	162.8	267.8	67 925.0	2.26
Magdaléna	250.7	150.3	67 120.3	2.21
Na Skalním (EDU-west)	127.3	232.3	56 387.5	1.50

5.8.11 Criterion C10: Impact on surface waters and water resources

Description of the criterion: the assessment of the potential impact of the DGR (over the whole of its life cycle - construction, operation, closure) on surface waters and groundwater, including water sources used for the supply of the population.

Description and assessment of the indicators

C10a Impact on the runoff conditions and surface water quality in the immediate vicinity of the DGR surface area

Description of the indicator: the indicator reflects the presence of watercourses and water areas in the area affected by the construction of the surface part of the DGR (surface area, mining facilities outside the surface area, related transport infrastructure - special-purpose road connection, railway siding). The impact on the local runoff conditions may be significant especially in the case of the surface area, and depends mainly on the extent of the remediation of the local landscape (spatial extent and elevation of the natural terrain) in relation to the size of the receiving catchment area and its hydrological characteristics. The direct impact concerns only the receiving catchment area and, potentially, related tributaries (small watercourses affected by the location of the surface area of the DGR). Subsequent flows in higher-order river basins may also be indirectly affected. Any change in the runoff conditions may also exert a significant impact on the biota dependent on the pre-existing hydrological conditions, including the drying and wetting of the land. In comparison with the influence of the DGR surface area, the impacts of the construction of the transport infrastructure will be less significant due to the availability of standard technical solutions (culverts, the bridging of streams). The quality of the surface water may be affected by oil spills or the leaching of excavated earth deposits.

However, standard technical and organisational measures can be adopted in order to minimise the risk.

Quantification: the impact is directly dependent on the extent of the remediation of the local landscape (spatial extent and elevation of the natural terrain) and the occurrence of watercourses and water areas in the surface area of the DGR and its immediate surroundings, and is inversely proportional to the size of the affected river basin, i.e. the relative content of water of the receiving catchment area (compared to the other sites). Grading of the impact: 1 – 5, where 1 is most favourable.

Results of the assessment of indicator C10a (Krajíček et al. 2020)

The surface area of the Čihadlo site is located at the confluence of the Lodhéřovský and Radouňský streams, both of which will serve as recipients. A system of ponds along the Radouňský stream acts to stabilise the runoff conditions. The impact on sub-basins of the right-hand tributaries of this stream (SE of Lodhéřov) is not significant in terms of the % share of the surface area of the total catchment area of the affected watercourse. The only exception concerns the watercourse that feeds the Honzík pond, into the source area of which the secured part of the surface area with the HC extends. The HC will be excavated from the surface to a level of approximately 30 m below the level of the surface area (524.0 m above sea level).

The recipient at the Horka site will comprise the Mlýnský stream, which also features a relatively significant pond system. Of its left-hand tributaries, only a short watercourse leading to the Mlýnský stream below the dam wall of the Perný pond (N of Náramče) will be significantly affected by the change in runoff conditions. Of the total catchment area of this tributary, around 23% is affected by the surface area. The surface area extends into the catchment areas of other tributaries to a much smaller extent.

The surface area of the Hrádek site is located at the confluence of the Rohozná stream and small right-hand tributaries of the Jihlava river. In the case of the Rohozná stream, just before its confluence with the Jihlava, satisfactory hydrological conditions can be assumed in terms of the recipient function. Of the small watercourses, an occasionally active watercourse, a right-hand tributary of the Huťský stream on the northern slope of the Botlusa elevation (591 m above sea level) in the immediate northern vicinity of the surface area will be partially affected. Since the surface area is proposed at a higher level than the course of this stream, it will be possible to reduce this effect via the adoption of technical measures (the drainage of rainwater outside the catchment area, the capture of water inflow from the slopes of the surface area). The other sub-basins impacted by the surface area will be significantly less affected.

The surface area of the Kraví hora site is located near the watershed between the Nedvědička and Bobrůvka (Bukovský) streams. Due to the shorter distance and more favourable hydrological characteristics, the recipient from the surface area will comprise the Nedvědička stream. The sub-basins formed by side valleys that divide the valley slopes of the Nedvědička and Bobrůvka streams will not be affected by the location of the surface area to any significant extent.

The surface area at the Březový potok site (including the secured area with the HC) extends into the upper section of a regulated left-hand tributary of the Březový stream. The recipient (the Březový stream) with its system of several ponds will be affected only to a minimum extent.

The surface area at the Čertovka site is located in the lower part of the valley of the final left-hand tributary of the Struhařský stream before its confluence with the Blšanka stream. The stream bed of the tributary crosses the northern part of the surface area, concerning which it will be necessary to divert all the surface runoff from the affected catchment area away from the surface area and to address its discharge into the Struhařský stream. From the point of view of the Struhařský stream basin, i.e. the recipient, the surface area is located on its lower course; hence, the potential effect on its hydrological characteristics is considered insignificant.

The assessment of the Janoch (ETE-south) site was based on the fact that the planned location of the surface area will lead to the deforestation of an area of approximately 26.5 ha. In addition, the affected area will occupy the most significant elevation of the terrain (68 m). The recipient (the Strouha stream) features several ponds which will, to some extent, regulate the water level of the stream. Hence, the Janoch site was assigned the same grade as the previous two sites, i.e. a highly probable but insignificant impact.

The Magdalena and Na Skalním (EDU-west) sites were assigned a grade of 4 for this indicator, i.e. the impact factor is both very probable and moderately significant. The surface areas of both sites will be relatively elevated in the catchment area, thus the water capacity of the recipients will be relatively low. The surface area of the Magdaléna site, especially the secured part with the HC, will feature a piped drainage ditch for water from the whole of the northern part of the source area of the Božejovický stream. The surface area of the Na Skalním site will be located around 250 m west of the Ostrý pond, only below the outlet from which does the Ostrý stream assume the character of a permanent watercourse (but with a minimal water content).

With regard to this indicator, the Čihadlo, Horka, Hrádek and Kraví hora sites received the lowest grades, the main reason for which comprises the fact that the presumed recipients of surface area runoff will not be directly affected (the surface areas do not interfere with the watercourses), and the water contents of the recipients is very likely to be higher than the recipients at the other sites (e.g. with respect to the hydrological order or the affected section and its outlet). The anticipated impacts on the hydrological characteristics of the recipient watercourses were assessed for these sites as low, with a medium probability of occurrence.

The Březový potok, Čertovka and Janoch (ETE-south) sites were assigned worse grades, i.e. the potential impacts were considered highly probable, but relatively insignificant with respect to the recipient.

Tab. 33 Overall assessment of the sites for the C10a indicator according to reports by Krajíček et al. (2020)

Site	Recipient (characteristic) / 3rd order river basin	Other watercourses, areas and floodplains in contact with or near the surface area (up to 200 m from the hot chamber (HC)) + altitude above sea level	Indicator grade
Březový potok	Březový stream (low water flow) / Otava river	2x left tributaries of the Březový stream reclamation ditch, contact with the edge of the surface area (approx. 500 m above sea level) <100 m from the HC unnamed stream around 270 m NE of the HC (around 500 m above sea level) Březový stream-floodplain (approx. 483 m above sea level incl. the flood zone)	3
Čertovka	Struhařský stream (low water flow) / Blšanka stream	a left-hand tributary (reclamation ditch) of the Struhařský stream crosses the N part of the surface area in the E-W direction (approx. 700 m above sea level)	3
Čihadlo	Lodhéřovský stream (low water flow) or Radouňský stream / Nežárka stream	a right-hand tributary of the Radouňský stream (via the Honzík pond), around 120 m SE of the HC, approx. 519 m above sea level.	2
Horka	Mlýnský stream (small watercourse with a pond system) / Jihlava river	no occurrence	2
Hrádek	Rohozná stream / Jihlava river	a small watercourse (source for the Menší pond) approx. 240 m from the HC (570 - 582 m above sea level) on the	2

Site	Recipient (characteristic) / 3rd order river basin	Other watercourses, areas and floodplains in contact with or near the surface area (up to 200 m from the hot chamber (HC)) + altitude above sea level	Indicator grade
		northern edge of the surface area right-hand tributary of the Hornohuťský stream	
Janoch (ETE-south)	Strouha stream / Vltava river	no occurrence	3
Kraví hora	Nedvědička stream / Nedvědička stream	source area of a right-hand tributary of the Nedvědička stream, approx. 150 - 220 m S of the surface area; watershed of the Nedvědička stream (surface area) Bobrůvka + left tributaries (promising area for the project design work)	2
Magdaléna	Božejovický stream (low water flow) / Smutná stream	a piped watercourse on the southern edge of the surface area (outlet to the Božejovický stream) a small (mostly overgrown) pond in the HC area, the Božejovický stream approx. 130 m S of the surface area (approx. 170 m from the HC)	4
Na Skalním (EDU-west)	Ostrý stream / Rokytná stream	the Ostrý pond (490 m above sea level) - approx. 250 m E of the surface area (risk of occasional flooding)	4

C10b Impact on water sources near the DGR

Description of the indicator: the indicator reflects the presence of registered sources of drinking water and water protection zones I and II within the areas considered promising for the conducting of future geological characterisation research work, the yield or quality of which could (theoretically) be affected during the life cycle of the DGR. The subject of the evaluation process comprises water sources that supply the public water system and their significance in terms of the number of inhabitants supplied. The areas covered by the assessment comprise the number of registered water sources, their yield and the total area of water protection zones I and II in the assessed area and their spatial relationships (distance, location) to the DGR surface area, mining facilities outside the surface area and access roads. With respect to smaller settlements, the existence of domestic wells is generally assumed, regardless of the extent to which they are used.

Quantification: the distance of the water source from the DGR surface area, i.e. promising area for the project design work, the extent of the overlapping of water protection zones I and II with the surface area or the promising area for the project design work, and the number and yield of registered water resources. Graded evaluation of the potential impact: 1 - 5.

Results of the assessment of indicator C10b (Krajíček et al. 2020)

For most of the sites, specifically the Kraví hora, Horka, Janoch (ETE-south), Magdaléna and Na Skalním (EDU-west) sites, the influence was assessed as insignificant. The promising areas for the geological research feature only a minimal number of water sources, or even none (the Horka and Janoch (ETE-south) sites) and, with the exception of the Magdaléna site (1 source), the sources are situated outside the promising areas for the project design work.

The impact on the Březový potok and Čertovka sites was assessed as medium. The Březový potok site features a slightly higher number of local water sources (7), of which 2 are situated in the areas designated as the promising areas for the project design work. The Čertovka site features the protection zones of 2 private water sources that supply the Nový Dvůr-Sklárna recreational facility, i.e. a Ministry of the Interior facility to the south of the two defined promising areas for the project design work.

The highest grades (very significant influence) were assigned to the Čihadlo and Hrádek sites, the areas of which feature 9 and 10 municipal water resources, respectively. According to the data available, the number of inhabitants supplied from these sources is approximately 2,200 (Čihadlo site) and approximately 3,930 (Hrádek site).

Tab. 34 Overall assessment of the sites for the C10b indicator according to reports by Krajíček et al. (2020)

Site	**Registered water resources near the DGR (total number of local water sources/total number of supplied inhabitants/number of private water sources)**	**Registered water resources near the DGR (number of significant water sources/total number of supplied inhabitants)**	**Indicator grade**
Březový potok	7 / 1 889 / 1	0 / 0	2

Čertovka	0 / 0 / 3	0 / 0	2
Čihadlo	9 / 2 200 / 0	0 / 0	3
Horka	0 / 0 / 0	0 / 0	1
Hrádek	10 / 3 930 / 0	0 / 0	3
Janoch (ETE-south)	0 / 0 / 0	0 / 0	1
Kraví hora	1 / 215 / 0	0 / 0	1
Magdaléna	2 / 52 / 2	0 / 0	1
Na Skalním (EDU-west)	0 / 0 / 2	0 / 0	1

C10c Impact on significant water sources

Description of the indicator: the indicator reflects the existence of significant water sources in the wider area of the DGR site. Since significant water sources are not defined in legislation, for the purposes of the site assessment process such sources are considered those that supply at least 3,000 inhabitants. This limit is derived from the provisions of Section 3 par. 1 of Act No. 128/2000 Coll., on municipalities, as amended, according to which a municipality with this (or a higher) population is considered to be a town. The significance of this impact is directly dependent on the number of inhabitants supplied from water sources as defined in this way.

The risk of such an impact concerns the existence of potential areas of groundwater drainage from the level of the disposal area of the DGR. Such areas have been determined via calculations based on the updated versions of mathematical models of groundwater flow at the sites (Havlová et al. 2020 a-i). The drainage areas of deep crystalline zones are usually bound to the drainage base of the respective area (watercourse channels) and to the intersection of such channels and significant fault zones. The final demonstration of the absence of such impacts on these sources, or the availability of measures to ensure their protection, will be addressed in the relevant safety reports according to parts a), b) and e) of point 1 of Appendix 1 to the Atomic Act.

Quantification: the number of significant sources and the evaluation of potential impacts on such sources. Graded evaluation of the potential impact: 1 - 5.

Results of the assessment of indicator C10c (Krajíček et al. 2020)

Significant water sources as defined for the purposes of this assessment, i.e. those to which a minimum of 3,000 inhabitants are connected, were identified only at the Březový potok site (Horažďovice water source, total of 5,091 inhabitants) and the Hrádek site (the Pelhřimov, Třešť and Hubenov water sources, total of 190,000 inhabitants).

The Horažďovice water source is located west of the town of Horažďovice in an area delimited by the Mlýnský stream and the Otava river. The drainage of the groundwater that flows through the DGR area at the Březový potok site is via three streams. The major part of the DGR (approx. 88%) drains into the Březový stream and its left-hand Hájek tributary located in the Otava river basin. Drainage predominates in the area above the confluence of these streams.

The remaining part drains into the Kovčín stream in the Úslava basin. No significant water sources feature in the wider area in the direction of the Kovčín stream. The Březový stream flows into the Otava river approximately 11 km downstream from the Horažďovice water source. The direction of the outflow of the surface and shallow groundwater is towards the Březový stream catchment area to the south-east, i.e. outside the Horažďovice water source area.

The groundwater at the Hrádek site drains through the projected DGR area to varying extents into a total of 5 watercourses, i.e. the Jedlovský (3%), Rohozná (3%) Dolnohuťský (6%) and Huťský (20%) streams and the Jihlava river (68%). Drainage into the Jedlovský stream occurs only in its lower part between the village of Klepák and its confluence with the Jihlava river, i.e. lower downstream from the Jedlovský feeder that supplies the Hubenov reservoir from the Jedlovský stream. The risk of negatively impacting the Hubenov reservoir is, therefore, considered minimal. The other significant water sources at the site are also located outside the flow directions of surface and shallow groundwater and, again, the impact risk is minimal.

Due to the minimal risk of negatively impacting significant water resources at either of the above sites, only the number of significant sources and the number of supplied inhabitants were taken into account in the assessment of the indicator. The Březový potok site was thus rated "2" and the Hrádek site "3", due to the high number of supplied inhabitants.

Since no significant water sources were determined in the wider areas of interest of the Čertovka, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Kraví hora and Na Skalním (EDU-west) sites, they were assigned the lowest grade, i.e. 1.

Tab. 35 Overall assessment of the sites for the C10c indicator according to reports by Krajíček et al. (2020)

Site	Significant public water resources in the wider area of the site/total number of supplied inhabitants	Indicator grade
Březový potok	1 / 5 091	2
Čertovka	0	1
Čihadlo	0	1
Horka	0	1
Hrádek	3 / > 190 000	3
Janoch (ETE-south)	0	1
Kraví hora	0	1
Magdaléna	0	1
Na Skalním (EDU-west)	0	1

5.8.12 Criterion C11: Impacts on nature and landscape protection

Description of the criterion: the criterion includes an assessment of the impact of the construction and operation of the DGR, including the related transport infrastructure, on nature and the landscape, concerning which certain restrictions (protective conditions) apply to the siting, construction and use of such a facility as defined in the Nature and Landscape Protection Act and the implementing regulations thereof.

Description and assessment of the indicators

C11a Impacts on biodiversity (flora, fauna, ecosystems, small specially protected areas MZCHÚ, internationally protected habitats, territorial ecological stability systems ÚSES, other natural habitats, significant landscape components VKP)

Description of the indicator: the indicator reflects the occurrence of protected species of flora and fauna and their habitats, including internationally protected habitats, small specially protected areas, other naturally valuable habitats and significant landscape components and their spatial links (distance + terrain relief) in relation to the DGR surface area and the related transport infrastructure. The most significant impacts are associated with direct intervention in such protected areas via the siting of the DGR surface area, access roads and railway sidings (= construction directly in such habitats). The impacts on such characteristics and phenomena in the vicinity of construction sites (approximately up to a distance of the first hundreds of metres) are significant, especially with concern to the construction of deep geological repositories (noise disturbance, negative impacts on migrating species, the expansion of non-native species due to changes in habitat conditions, water and soil pollution via oil spills).

Quantification: the impacts will be directly proportional to the share of the area of such natural phenomena affected by the construction of the DGR surface area of the total area. In the case of territorial ecological stability system bio-corridors, the impact will depend on the extent of and method used for traversing the DGR surface area and will be inversely proportional to the distance of the DGR surface area from the natural phenomena. In addition to the distance from the DGR construction site, the extent of the impact could be reduced by the existence of spatial barriers (relief, forests). In the case of the transport infrastructure, the degree of impact depends on the length of roads/railway sidings and the extent to which they traverse such areas of important natural phenomena. Graded evaluation: 1 – 5.

Results of the assessment of indicator C11a (Krajíček et al. 2020)

This composite indicator relates to areas protected under the Nature and Landscape Protection Act. The assessment covered the occurrence of the various areas in the DGR surface areas and the degree of their overlap, as well as more distant areas and spatial relationships, including the existence of barriers that provide for a screening effect. The period with the highest risk of the occurrence of negative impacts (habitat capture, mortality, disturbance) is assumed to be the construction phase of the DGR, including transport to and from the site. Hence, the main impacts relate to the surface area and the access roads. Due to the differing degrees of the consideration of this issue in the respective environmental impact studies (Krajíček 2018, Marek 2018a-g, Navrátilová et al. 2018), the occurrence of protected species of flora and fauna was applied as an input assumption when assessing the impacts on biodiversity with respect to territorial ecological stability systems, significant landscape components and other natural habitats registered in the databases of the Nature Conservation Agency of the Czech Republic and larger forest complexes.

Surface area

No small specially-protected areas, which are considered to be an exclusion criterion in terms of DGR siting (Vokál et al. 2017) and where the highest probability of the occurrence of protected species (especially in nature reserves) can be assumed, feature in the surface areas of any of the sites. With respect to the promising area for the geological research, small specially-protected areas occur only at the Čertovka site (the Blatenský nature reserve) and the Hrádek site (the Hojkovské mooorlands, Nad Svitákem, Pod Měšnicí, Přední rocks, Čertův and Na Skalce nature reserves and natural features). Only the Hojkovské moorlands and the Přední rocks areas impinge upon the rock polygons of the promising areas for the project design work. The risk of negatively impacting these areas via the siting of e.g. ventilation shafts can be minimised in the technical phase of the design of the underground complex of the DGR.

In terms of impacts on territorial ecological stability systems, some parts will be liquidated (Čertovka, Janoch (ETE-south)) or their functioning disrupted (Kraví Hora, Na Skalním (EDU west)) due to the siting of the surface areas. In all these cases, the affected areas form parts of local level territorial ecological stability systems. With respect to the Březový potok, Čihadlo and Magdaléna sites, no such systems have been defined in the surface areas or their immediate surroundings.

In terms of the occurrence of other natural habitats and significant landscape components, the least affected sites comprise Březový potok and Magdaléna, where intensively used agricultural land predominates with the limited occurrence of naturally valuable areas (hedges, meadows, etc). Slightly more significant impacts can be expected with concern to the Čertovka (a stand of trees in the surface area, the Struhařský stream), Horka (numerous small areas of non-forest vegetation in the surface area), Janoch (ETE-south) (forest over the whole of the surface area) and Na Skalním (EDU-west) (protected species/habitats in the peripheral parts of an adjacent forest) sites. Based on the conclusions of a report by Mixa et al. (2019) that documented the significantly limited permeability of the rock mass at the Hrádek site, negative impacts on a wetland habitat on and to the north of the Čeřínek massif (including the above-mentioned small specially-protected area) are considered unlikely.

Transport infrastructure

The research on the expected directions of road and railway network connections to the surface areas of the sites revealed the crossing of transport routes and local territorial ecological stability system bio corridors at the Čertovka, Janoch (ETE-south) and Na Skalním (EDU-west) sites.

In terms of the occurrence of other naturally valuable habitats and significant landscape components, the relatively most significant conflicts of interest were recorded at the Březový potok and Čihadlo sites concerning transport routes. The Březový potok site features an area of protected plant and animal species west of Maňovice, in a wooded area with remnants of previous stone quarrying, which conflicts with a potential road connection to the II/186 road. The potential conflict at the Čihadlo site concerns an access route that crosses the Lodhéřovské stream valley, which features naturally valuable habitats with the possible occurrence of protected species.

Overall assessment

With respect to this indicator, the sites differ mainly in terms of the probability of the occurrence of a related impact, as determined either from the direct contact of the observed phenomena with the surface area via access routes (high impact) or from near contact with such routes (medium impact). The impacts were assessed as of low significance in all cases. The Březový potok, Čihadlo, Horka and Magdaléna sites were assigned a grade of 2, which reflects their slightly more favourable assessments compared to the Čertovka, Kraví Hora, Hrádek, Janoch (ETE-south) and Na Skalním (EDU-west) sites (grade of 3).

Tab. 36 Overall assessment of the sites for the C11a indicator according to reports by Krajíček et al. (2020)

Site	Small specially-protected areas	Territorial ecological stability systems	Occurrence of protected plant species and animals, natural habitats	Indicator grade
Březový potok	no occurrence	no occurrence	limited occurrence of natural habitats with the possible occurrence of protected species in the surface area, especially non-forest vegetation in the N part (secured part of the surface area) + a meadow on the left bank of the Březový stream (SW edge of the surface area) + approx. 250 m N of the surface area	2
Čertovka	no occurrence	local bio corridor (left-hand tributary of the Struhařský stream) - intersects the northern part of the surface area	natural habitats with the possible occurrence of protected species, especially in the recipient (Struhařský) stream natural habitats connected to a left-hand tributary of the Struhařský stream (N part of the surface area) and an erosion trench (S edge of the surface area) natural habitats approx. 100 m from the SW edge of the surface area + in the valley of the Struhařský stream (approx. 400 m E of the surface area) and in the area of the Struhař pond (approx. 650 m SE of the surface area)	3
Čihadlo	no occurrence	no occurrence	natural habitats with the possible occurrence of protected species linked to the Lodhéřovské stream and valley	2
Horka	no occurrence	no occurrence	natural habitats with the possible occurrence of protected species in the vicinity (SE) of the surface area (remnants of forest stands and non-forest vegetation)	2
Hrádek	no occurrence	local bio centre around 250 m W of the surface area	natural habitats with the possible occurrence of protected species around 150 m NW of the surface area + adjacent forest stands	3

Site	Small specially-protected areas	Territorial ecological stability systems	Occurrence of protected plant species and animals, natural habitats	Indicator grade
Janoch (ETE-south)	no occurrence	local bio corridor S of the Mlýnský pond – crosses the W part of the surface area	possible occurrence of protected species especially in preserved forest remnants (surface area) and in natural habitats along potential transport routes natural habitat along the Strouha stream	3
Kraví hora	no occurrence	local bio centre in contact with the S edge of the surface area	natural habitats with the possible occurrence of protected species close to the surface area (meadows, shrubs + adjacent forest stands) meadows on the opposite side of the II/385 road near a DGR transport route connection	3
Magdaléna	no occurrence	no occurrence	possible occurrence of protected species in isolated natural habitats in the SE part of the surface area (water meadow) and in connection with Božejovický stream	2
Na Skalním (EDU-west)	no occurrence	2x local bio centres around 100 – 150 m W and N of the surface area Ostrý pond local bio centre - around 300 m ESE of the surface area	probable occurrence of protected species of fauna and flora in natural habitats in the surroundings of the surface area (forest stands N of the surface area, the Ostrý pond, a line of vegetation to the W and S of the surface area, Ostrý stream); distances of between 50 - 200 m	3

C11b Impacts on migration corridors and areas important for migration

Description of the indicator: the indicator reflects the existence of animal migration corridors and areas important for migration and their spatial links to the DGR surface area and transport infrastructure - distance, terrain relief, siting of the DGR surface area in areas important for migration, length and method of the traversing of such areas and corridors by the transport infrastructure. Migration barriers comprise transport routes (especially roads) with a high intensity of traffic that traverse migration corridors and areas important for migration. One of the indirect impacts consists of noise interference from construction work on, and the subsequent operation of, the surface area. Reducing the migratory permeability of the area (especially for large mammals) exerts a negative impact on animal populations that exist in confined spaces.

Quantification: the impact will be inversely proportional to the distance from the surface area to migration corridors, taking into account mutual spatial connections. In the case of areas important for migration, only the positioning of the surface complex in such areas, or the overlapping of the surface complex and such areas, are assessed. With concern to access roads, only the length and the way in which they cross migration corridors and areas important for migration are assessed. Graded evaluation: 1 – 5.

Results of the assessment of indicator C11b (Krajíček et al. 2020)

The impacts of the siting of the surface area (including access routes) on the migration permeability of the landscape were assessed in terms of the definition of migration corridors and important areas according to the Nature Conservation Agency of the Czech Republic database. Due to the fact that significant impacts on the functioning of migration corridors and areas relate to noise sources and other factors that cannot be accurately estimated based on current knowledge, the indicator addressed the wider area of the DGR, i.e. the promising area for the geological characterisation research.

The lowest grades were assigned to the Horka and Na Skalním (EDU-west) sites, where the surface areas and access routes are not in conflict with any migration corridors or areas. Concerning the Magdaléna site, the boundary of a migration area is located around 300 m south of the surface area, outside the promising area for the geological research; a grade of 2 reflects the medium level of risk and low significance of the potential impact. The Březový potok, Čertovka, Čihadlo, Kraví hora and Hrádek sites all feature surface areas and/or access roads that are in conflict with migratory areas; the risk of impacts and their significance was, thus, assessed as medium. The increased significance of this impact (with the same level of risk) was determined for the Janoch (ETE-south) site, at which the surface area is defined approximately 350 m east of a migration corridor; moreover, its surroundings (with the exception of the area west of the surface area) form part of a migration area.

Tab. 37 Overall assessment of the sites for the C11b indicator according to reports by Krajíček et al. (2020)

Site	Impacts on migration corridors and areas important for migration Occurrence of migration corridors and areas important for migration	Indicator grade
Březový potok	the Maňovice – Jetenovice area (incl. the surface area) is not part of a migration area; the central and northern parts of the promising area for the geological research form part of a migration area	3

Site	**Impacts on migration corridors and areas important for migration** **Occurrence of migration corridors and areas important for migration**	Indicator grade
Čertovka	almost the entire promising area for the geological research, including the southern part of the surface area is part of a migration area; a long-distance migration corridor in the E-W direction south of the village of Tis u Blatna	3
Čihadlo	the surface area is situated on the edge of a migration area; the entire promising area for the geological research, with the exception of Lodhéřov and other settlements, forms part of a migration area; a migration corridor passes through the promising area for the geological research in the SW-NE direction, along the W slopes of the Na Klenové (588 m above sea level) and Cihelný (607 m) elevations and along the Brčík (645 m) - Najdecké Čihadlo (692 m) axis, with no contact with the surface	3
Horka	no occurrence in the surface area or the immediate vicinity; a migration corridor passes along the edge of the promising area for the geological research in the WNW-ESE direction (north of Oslavičky and Rohy) the N part of the promising area for the geological research forms part of a migration area (the boundary is approx. N of Rudíkov – N of Hodov – S of Rohy)	1
Hrádek	the whole of the promising area for the geological research incl. the surface area forms part of a migration area	3
Janoch (ETE-south)	the eastern part of the surface area and the promising area for the geological research form part of a migration area; a migration corridor approx. 350 m E of the surface area	4
Kraví hora	the whole of the promising area for the geological research incl. the surface area forms part of a migration area; a migration corridor in the Kraví hora site area (see territorial ecological stability systems)	3

Site	Impacts on migration corridors and areas important for migration Occurrence of migration corridors and areas important for migration	Indicator grade
Magdaléna	boundary of a migration area approx. 300 m S of the surface area (railway line no. 201 Tábor - Milevsko) migration corridor in the E-W direction approx. 1 km S of the surface area in the upper parts of the Panský hills (528 m above sea level)	2
Na Skalním (EDU-west)	no occurrence	1

C11c Impacts on Natura 2000 bird areas and sites of European importance

Description of the indicator: The aim of Natura 2000 protected areas is to protect rare and endangered species of birds and other animals, plants and rare natural habitats in the EU. The system defines two types of areas - bird areas and sites of European importance. The distance is assessed of the DGR surface area from such areas or the downstream distances along watercourses depending on the reason for protection. The territorial integrity of neither Natura 2000 bird areas nor sites of European importance is affected by any of the candidate DGR sites.

Quantification: the impact will be inversely proportional to the direct distance of such areas from the DGR surface area, and inversely proportional to the downstream distance (in the case of aquatic objects). Graded evaluation: 1 – 5.

Results of the assessment of indicator C11c (Krajíček et al. 2020)

None of the surface areas, including access roads, are in conflict with Natura 2000 bird areas and sites of European importance. Thus, the exclusion condition for the surface area (Vokál et al. 2017) is fulfilled. With regard to the distance to the nearest Natura 2000 bird areas and sites of European importance, potential impacts are considered insignificant with little or no probability of occurrence for all the sites.

The comparison of the candidate sites in terms of possible impacts on Natura 2000 components was based on the direct distance from the surface area, which is important especially in cases where the area affected by the siting of the surface area (including surrounding areas) serves as a feeding habitat. In addition, the occurrence of Natura 2000 components connected to aquatic environments was monitored on recipient watercourses and potentially affected 3rd order catchment basins.

The lowest grades with respect to the indicator were assigned to the Březový potok and Horka sites based on the conclusions of a report by Mixa et al. (2019), as well as the Hrádek site, where the impact of the surface area on Natura 2000 components was considered very unlikely. The risk at the other sites was assessed as medium. With respect to the Čertovka site (the Doupovské hory bird area approx. 2.7 km NW of the surface area), the Janoch (ETE-south) site (approx. 3.3 km SE of a bird area and the Hlubocké meadows site of European importance) and the Kraví hora site (the Bobrůvka and Trenckova valley sites of European importance in contact with the promising area for the project design work), the short distances of such phenomena from the sites were considered. With regard to the Čertovka, Čihadlo, Magdaléna and Na Skalním (EDU-west) sites, the reason for this assessment concerned the occurrence of sites of European importance relating to aquatic environments downstream from the river basins into which the surface areas drain.

Tab. 38 Overall assessment of the sites for the C11c indicator according to reports by Krajíček et al. (2020)

Site	**Impacts on Natura 2000 bird areas and sites of European importance** **(incl. downstream of the watercourses of the river basins concerned)**	**Indicator grade**
Březový potok	site of European importance E of Morávka – around 5.5 km from the surface area	1
Čertovka	site of European importance – Jezerský uplands - around 1.8 km W of the surface area Doupov hills bird area - around 2.7 km NW of the surface area Blšanka confluence with the Ohře in the Ohře site of European importance	2
Čihadlo	Surface area in the drainage basin of the Lužnice and Nežárka site of European importance (lower course of the Nežárka, approx. from Stráž n. Nežárka)	1
Horka	Kobylinec site of European importance – 4.25 km SW of the surface area	1
Hrádek	Na Oklice site of European importance – N of the edge of the geological block, 5.6 km from the surface area	1
Janoch (ETE-south)	Hlubocké bird area and site of European importance 3.3 km SE of the surface area	2
Kraví hora	Bobrůvka site of European importance – 3.2 km S of the surface area + on the contact of the SW boundary of the promising areas for the geological research and the project design work Trenckova valley site of European importance 4.3 km south of the surface area + S of the edge of the promising area for the project design work	2
Magdaléna	Skalka u Sepekova quarry site of European importance - on the Smutná stream (newt protection area) around 2 km SW of the surface area	2
Na Skalním	Surface area in the Rokytná drainage basin site of European importance (around 10.5 km downstream of the surface area)	2

Site	Impacts on Natura 2000 bird areas and sites of European importance (incl. downstream of the watercourses of the river basins concerned)	Indicator grade
(EDU-west)		

C11d Impacts on the landscape

Description of the indicator: the indicator includes impacts on specific characteristics of the landscape (scale, dominant aspects, visual linkages) and related natural, cultural-historical and aesthetic factors. The scope of the DGR research field work and visual exposure compared to the current use of the landscape, the existence of natural parks and the use of designated forest areas are assessed. The potential creation of a landfill site for excavated material is not included in this evaluation indicator.

Quantification: the impact will occur according to the extent, character and visual exposure of the areas affected by the siting of the DGR surface area. Graded evaluation: 1 – 5.

Results of the assessment of indicator C11d (Krajíček et al. 2020)

Impacts on the landscape caused by the siting of the surface area are considered highly probable at all the sites due to the assumed spatial parameters of the facility. The significance of the impact on the various areas was assessed based on the siting of the surface area, its visual exposure, the spatial parameters of the various surface facilities and conflicts with the basic characteristics of the landscape (relief, the openness of the landscape, the size and structure of the various landscape components and land use).

Very significant impacts on the landscape were determined for the Hrádek and Janoch (ETE-south) sites. The surface area of the Hrádek site is located on the edge of the Čeřínek nature park, at the foot of a landscape-attractive massif of the same name (761 m above sea level) with partial visual exposure, especially from the south and east. The surface area of the Janoch (ETE-south) site is situated on the upper part of a forested ridge. The visual impact of the surface area is emphasised by the significant elevation of the terrain (68 m) in which it will be located and a mine tower of around 40 - 50 m high. While from the south and north, the surface area is largely invisible, the visual exposure from the west and the east is significant. The only way to reduce the visual impact will involve the planting of new forest areas around the perimeter of the surface area which will act as a visual barrier.

With respect to this indicator, the surface area at the Na Skalním site, located in the Ostrý stream valley, is the best located of all the sites; at the same time both of the spatially most significant facilities of the DGR (the mine facility and the hot chamber) are situated in the rock mass in accordance with the preferred variant set out in the updated reference project (Navrátilová et al. 2018). The surface area is located so that the landscape-valuable area around the Ostrý pond is hidden from the DGR by a line of trees along the road connecting Ostrý dvůr and Horní Dvůr. The impact on the landscape is therefore considered to be of low significance.

With respect to the Březový potok, Čihadlo, Horka, Kraví hora and Magdaléna sites, these impacts are considered to be moderately significant, despite the fact that in most cases the affected areas are agricultural in character or forested landscapes with a low proportion of landscape-enhancing elements. The main reason for the medium assessment concerns the degree of visual openness of these areas and, thus, the more pronounced visual effect of the surface area as an anthropogenic addition to the landscape. The medium impact on the landscape at the Čertovka site is due to the fact that the surface area will be located in the immediate vicinity of the Čertovka (587 m above sea level) and Velký les (592 m above sea level) forested massifs, the natural and landscape values of which are comparable to the Horní Střela nature park to the south.

The impacts of access routes on the landscape will be several orders of magnitude lower than those of the surface area. With concern to power lines, it will be possible to assess their impact on the landscape following the decision on the voltage level of the DGR electricity supply (22 kV or 110 kV), which will influence the routing of the lines.

Tab. 39 Overall assessment of the sites for the C11d indicator according to reports by Krajíček et al. (2020)

Site	Landscape impacts/ significant landscape characteristics + visual exposure of the surface area	Indicator grade
Březový potok	• slightly undulating agricultural-to-forested landscape supplemented by pond systems on watercourses + water areas formed by abandoned quarries • the surface area is situated in the open shallow valley of the Březový stream and its left-hand tributaries (partly regulated); predominance of arable land with small fragments of forest and non-forest vegetation (incl. in the surface area) • visual exposure of the surface area, especially from the ESE	4
Čertovka	• mostly forested landscape with numerous rock formations, incl. in the steep-sided valley of the Struhařský stream • similar landscape characteristics as the Horní Střela nature park over the whole of the promising area for the geological research • significant recreational area (Lubenec, Tis u Blata, Žihle – Sklárna) • mixed forestry landscape along the edges of the area (incl. the surface area) incl. non-forest greenery and significant landscape elements – hedgerows etc. • visual exposure of the surface area, especially from the N and E	4
Čihadlo	• undulating forested landscape with numerous small rural settlements • surface area located on a SE slope (agricultural land) above the Radouňský stream valley (visual exposure from the E and SE)	4

Site	Landscape impacts/ significant landscape characteristics + visual exposure of the surface area	Indicator grade
Horka	• slightly undulating forested-agricultural landscape with forest stands especially on plateau elevations and in the valleys of watercourses that feature pond systems • surface area located on agricultural land in the area of a broad rounded hill, with numerous small occurrences of landscape-attractive forest and non-forest vegetation • the SW edge extends into the Třebíčsko nature park; visual exposure from the S to the E	4
Hrádek	• interface of agricultural and forest landscapes, at the foot of the mostly forested Čeřínek massif (761 m above sea level) • regionally important recreational area (Dolní + Horní Hutě) • surface area located on the southern edge of the Čeřínek nature park, above the left-bank slope of the Rohozná stream (visual exposure from the S and E)	5
Janoch (ETE-south)	• in the surface area - a rugged forest landscape with deeply cut valleys of tributaries of the Vltava • in the wider area - slightly undulating forested-to-agricultural landscape with numerous rural settlements and the Temelín nuclear power plant and related infrastructure • significant visual exposure, especially from the N, W and E	5
Kraví hora	• sparsely-populated agricultural-forested landscape on a plateau of the Stříťažské ridge which separates the steep-sided valleys of the Nedvědička and Bobrůvka streams • limited visual exposure only from the NE	4
Magdaléna	• slightly undulating agricultural-to-forested landscape, with rural settlements • surface area and vicinity – occasional occurrence of non-forest vegetation related mainly to watercourses and water areas • south of the surface area - small forest stands; northern edge – the Na Panském hill forest area • visual exposure from the W, E and N	4
Na Skalním (EDU-west)	• slightly undulating agricultural-to-forested landscape with the frequent occurrence of pond systems along watercourses, non-forest vegetation especially along watercourses and near water areas • surface area located in the open valley of the Ostrý stream, at the foot of the Na Skalním massif; with the exception of the WSW direction (Jaroměřice n. Rokytnou), the surface area is visually hidden by the surrounding terrain	3

Site	Landscape impacts/ significant landscape characteristics + visual exposure of the surface area	Indicator grade
	• line of greenery along a former field track crosses the surface area along an E-W axis • east of the surface area – Ostrý Dvůr - Ostrý pond - Horní dvůr landscape-attractive area (track bordered by trees along the dam wall of a pond)	

5.8.13 Criterion C12: Impacts on agricultural land and land intended for forestry

Description of the criterion: the assessed criterion includes estimated requirements for the use of agricultural land and land intended for forestry due to the construction of the DGR.

Description and assessment of the indicators

C12a Impact on agricultural land

Description of the indicator: the indicator expresses the extent of the use of agricultural land (especially of land included under protection classes 1 and 2) due to the construction of the DGR surface area and the related transport infrastructure.

Quantification: the impact occurs whenever permission is granted to use agricultural land for the siting of the DGR surface area or the related transport infrastructure, and will be directly proportional to the amount of agricultural land required, with respect particularly to the use of high quality agricultural land (protection classes I and II). In the case of linear transport infrastructure, the extent of the use of such land is derived from the lengths of those sections that traverse agricultural land. Graded evaluation: 1 – 5.

Results of the assessment of indicator C12a (Krajíček et al. 2020)

As in the case of impacts on the landscape, impacts on agricultural land are inevitable since the siting of the surface area and access routes in all cases will result in the occupation of agricultural or forest land. Given that, according to the available data, the surface areas of all the sites are located almost exclusively on agricultural or forest land, it is logical that the lower occupation of agricultural land will be compensated for by the higher occupation of forested land and vice versa.

The occupation of class I and II agricultural land relates to a significant extent only to the Březový potok, Horka and Na Skalním sites. Despite the slight differences in the total extent of occupation (Březový potok 17.3 ha, Horka 15.8 ha, Na Skalním (EDU-west) 12.3 ha), the impact was assessed as moderately significant for all three sites. Conversely, the Janoch (ETE-south) was assigned the lowest possible grade in this respect (1) since the surface area occupies exclusively forested land.

The total occupation of agricultural land of the other five sites ranges from 10.8 ha (Kraví hora) to 17.5 ha (Magdaléna) with the presence of various agricultural land protection classes; however, the presence of the most valuable classes I and II is either zero or very low (Čihadlo = a maximum of 5% of the area). The impacts on these sites is, therefore, considered of low significance.

Tab. 40 Overall assessment of the sites for the C12a indicator according to reports by Krajíček et al. (2020)

Site	Impacts on agricultural land Total occupation of agricultural land / of which protection classes (PC) I + II	Indicator grade
Březový potok	• circa 17.3 ha • predominantly PC II and IV, marginally PC III	4
Čertovka	• circa 17.5 ha • predominantly PC III and IV, marginally PC V	3
Čihadlo	• 12.5 ha • predominantly PC IV and V	3
Horka	• 15.8 ha • predominantly PC II	4
Hrádek	• circa 15.7 ha • primarily PC V, smaller part PC III and IV	3
Janoch (ETE-south)	• 0 (surface area located exclusively on forested land)	1
Kraví hora	• circa 10.8 ha • predominantly PC IV and V	3
Magdaléna	• circa 17.5 ha • predominantly PC III - V	3
Na Skalním (EDU-west)	• circa 12.3 ha • of which circa 58% PC I	4

C12b Impact on land intended for forestry

Description of the indicator: the indicator expresses the extent of the use of land intended for forestry and the respective protection zones (taking into account the higher importance of protected forests and special purpose forests) due to the construction of the DGR surface area and the related transport infrastructure. In the case of linear transport infrastructure, the extent of the use of such land is derived from the lengths of those sections that traverse land intended for forestry.

Quantification: the impact will be directly proportional to the extent of the use of land intended for forestry. The occurrence and extent of protected forests and special purpose forests will also be taken into account. Graded evaluation: 1 – 5.

Results of the assessment of indicator C12b (Krajíček et al. 2020)

All the cases in which the location of the surface area results in a demonstrable or probable intervention into land intended for forestry relate to commercial forests. No special purpose or protected forests feature in or near the surface areas of any of the candidate sites.

The highest grade (5) was assigned to the Janoch (ETE-south) site, the surface area of which is greater than any of the sites (approx. 26.5 ha) and is located exclusively on forested land. The impact was, therefore, assessed as very significant. With concern to the Čihadlo, Kraví hora, Hrádek and Na Skalním (EDU-west) sites, the surface areas are defined relatively close to isolated forest stands; thus, it is not possible to determine at this stage whether it will be necessary to remove the forestation. If so, in all cases, the removed forestation will not exceed a few tenths of a hectare. The impact was, therefore, assessed as moderately probable but insignificant.

The surface areas of the remaining sites (Březový potok, Čertovka, Horka and Magdaléna) occupy exclusively agricultural land. Thus, they were assigned the lowest possible grade (1) with respect to this indicator.

Tab. 41 Overall assessment of the sites for the C12b indicator according to reports by Krajíček et al. (2020)

Site	Impacts on forested land, Total occupation of forested land	Indicator grade
Březový potok	• 0 (surface area occupies exclusively agricultural land)	1
Čertovka	• 0 (surface area occupies exclusively agricultural land)	1
Čihadlo	• circa 0.07 incl. a protected zone • no occurrence of protected forests or special purpose forests	2
Horka	• 0 (surface area occupies exclusively agricultural land)	1
Hrádek	• circa 0.2 ha • no occurrence of protected forests or special purpose forests	2
Janoch (ETE-south)	• circa 26.5 ha • no occurrence of protected forests or special purpose forests	5

Kraví hora	• circa 0.13 ha, intervention into a protected zone • no occurrence of protected forests or special purpose forests	2
Magdaléna	• 0 (surface area occupies exclusively agricultural land)	1
Na Skalním (EDU-west)	• N edge of the surface area + slope with protected forest (50 m) • no occurrence of protected forests or special purpose forests	2

5.8.14 Criterion C13: Impacts on the population, property and protected monuments

Description of the criterion: the criterion includes an assessment of the disturbance of the quality of life and the recreational environment, as well as changes in the use of buildings and impacts on protected monuments.

Description and assessment of the indicators

C13a Disruption of well-being factors

Description of the indicator: the disruption of "well-being factors" will occur mainly via increases in noise and emissions in the local residential and recreational environments (not necessarily beyond the relevant public health limits). The indicator reflects the character of residential building development (continuous/individual) and recreational buildings and facilities and their distance from the surface area, and the related transport infrastructure, taking into account the existence of shielding barriers (landscape relief, forested areas).

Quantification: the impact is inversely proportional to the distance of residential buildings and recreational facilities from the surface area, and from the related transport infrastructure taking into account the existence of shielding barriers (relief, forest areas in the intermediate area). Graded evaluation: 1 – 5.

Results of the assessment of indicator C13a (Krajíček et al. 2020)

The disruption of well-being factors in the form of the deterioration of the quality of residential, recreational and even protected areas as a result of the construction of the DGR surface area and the related increase in traffic (especially along DGR access routes) is considered highly probable at all the sites (noise, vibration, emissions, dust). The main reason for this assumption comprises, almost exclusively, the rural character of the settlements surrounding the surface areas of all the sites. The degree of impact depends mainly on the distance of settlements from the surface area, access roads and railway sidings, the character of the settlements (solitary, scattered, built-up) and the existence of barriers that exert a shielding effect (relief, forest).

This impact is considered significant with respect to the Březový potok, Čertovka, Čihadlo, Hrádek, Magdaléna and Na Skalním (EDU-west) sites. In the case of the Březový potok and Magdalena sites, the reason concerns the direct spatial connection of the edges of Maňovice (distance 800 m) and Božejovice (approx. 500 m) with the surface area without the existence of visual or (especially) noise shielding barriers. The approach to the Magdaléna site passes the built-up Božejovice - U nádraží area along the II/122 road.

The impacts at the Čertovka and Hrádek sites concern the recreational potential of the areas that have been defined for the geological characterisation research. With respect to the Čertovka site this concerns mainly the Lubenec recreation centre (approx. 450 m E of the surface area) and the Nový Dvůr - Sklárna outdoor educational facility which occupies a naturally attractive area located between Lubenec and Nový Dvor, the southern part of which lies in the Horní Střela nature park. The recreational potential of the Hrádek site concerns the Čeřínek recreational area that includes a skiing area and provides for a wide range of other recreational activities (hiking, cycling etc.), the catchment area of which includes the regional capital Jihlava (approx. 50,000 inhabitants) and Pelhřimov (approx. 16 thousand inhabitants).

Significant well-being disturbance factors at the Na Skalním (EDU-west) site relate to the potential route of the railway connection near to the Jaroměřice n. Rokytnou settlement (Popovice suburb) and that of the road connection approx. 250-300 m south of the village of Boňov, which has village preservation zone status.

The impact at the Čihadlo site concerns the railway siding which, according to Bureš et al. (2018b), will have a length of approx. 10.3 km from its connection with railway line no. 225 at Velký Ratmírov.

Regarding the remaining sites (Kraví hora, Horka and Janoch (ETE-south)), the disturbance of well-being factors is considered less significant due to the overall characters of the affected areas, the distance of the surface area and access roads from residential buildings, and the extent of shielding factors.

Tab. 42 Overall assessment of the sites for the C13a indicator according to reports by Krajíček et al. (2020)

Site	**Nearest residential or recreational development + distance from the surface area / railway siding / access road**	**Indicator grade**
Březový potok	• from the surface area: - Maňovice (circa 512 m above sea level) - circa 800 m NNE - Jetenovice (circa 478 m above sea level) - circa 1.1 km SE - Pačejov station SE edge (circa 520 m above sea level - circa 1.1 km W - Pačejov (circa 536 m above sea level) - circa 1.3 km NE • from the railway siding: - circa 850 m (W edge of Jetenovice) • from the access road: circa 500 m (W edge of Maňovice)	4
Čertovka	• from the surface area: - Lubenec (circa 380 m above sea level) - circa 600 m NE - Žďárek (circa 550 m above sea level) – circa 900 m (shaded by terrain and forest stands) - Vítkovice (500 - 550 m above sea level) - circa 1.1 km S (protected forest stands) • from the railway siding: - circa 500 m (W edge of Lubenec) • from the access road: circa 700 m (W edge of Lubenec)	4
Čihadlo	• from the surface area: - Lodhéřov (circa 526 m above sea level) - circa 800 m W (partly shielded terrain) - Dolní Radouň (circa 500 m above sea level) - circa 1.1 km E (partly shaded by forest stands) • from the railway siding: - Velký Ratmírov, Studnice, Lodhéřov - distances in the order of hundreds of metres • from the access road: SE edge of Lodhéřov - 650 m (N)	4
Horka	• from the surface area: - Budišov (circa 490 m above sea level) - circa 860 m	3

Site	Nearest residential or recreational development + distance from the surface area / railway siding / access road	Indicator grade
	- Náramеč (circa 470 m above sea level) - circa 800 m • from the railway siding: - circa 600 m (W edge of Budišov) • from the access road: SW edge of Budišov, circa 400 m NE	
Hrádek	• from the surface area: - Rohozná - Familie (circa 565 m above sea level) - circa 750 m W visually and spatially separated by the Kolna hill (575 m above sea level) - W edge of Dolní Cerekev (cca 552 m above sea level) - circa 700 m E • from the railway siding: - circa 600 m (W edge of Dolní Cerekev) • from the access road: circa 600 m (W edge of Dolní Cerekev)	4
Janoch (ETE-south)	• from the surface area (all the settlements shielded by the relief): - Nová Ves (circa 510 m above sea level) - circa 1.7 km SW - Jeznice (circa 390 m above sea level) - circa 2.2 km E - Kočín (circa 460 m above sea level) - circa 2.4 km NW - Litoradice (circa 435 m above sea level) - circa 2.6 km N • from the railway siding: - circa 600 m (E edge of Kočín) • from the access road: circa 1.4 km (N edge of Nová Ves)	3
Kraví hora	• from the surface area (both the settlements are shielded by the relief to a great extent): - Střítež (circa 575 m above sea level) - circa 800 m - Bukov (circa 530 m above sea level) - circa 1.3 km W • from the railway siding: - no railway siding forms part of the DGR • from the access road:	3

Site	Nearest residential or recreational development + distance from the surface area / railway siding / access road	Indicator grade
	circa 800 m (N edge of Střítež)	
Magdaléna	• from the surface area (both settlements partly shielded by the terrain): - Božejovice (circa 526 m above sea level) - circa 500 m N (partly shielded by the terrain) - Božejovice – U Nádraží (circa 493 m above sea level) – circa 500 m SE - Jezvice (circa 526 m above sea level) - circa 700 m NW (partly shielded by the terrain) • from the railway siding: - circa 450 m (S edge of Jezvice) • from the access road: - circa 250 m (Božejovice - U Nádraží) then after passing buildings, road II/122	4
Na Skalním (EDU-west)	• from the surface area: - Boňov (circa 470 - 480 m above sea level) - circa 1.1 km W (partly shielded by forest stands) - Přiložany (circa 460 m above sea level) - circa 1.4 km SW (shielded by a terrain elevation) • from the railway siding: - option TE – z1: circa 100 m (Popovice) + circa 300 m (Boňov – S edge) - option TE – z2: 100 m (Jaroměřice n. Rokytnou) + circa 300 m (Boňov - S Edge) • from the access road: - option TE – s1 (from road II/360) – circa 250 m (S edge of Boňov) option DU – s1 (from road II/150) - circa 250 m S of Boňov + 500 m W of Přiložany	4

C13b Impacts on residential, recreational and listed buildings

Description of the indicator: the indicator reflects the occurrence and number of residential, recreational and listed buildings in the immediate vicinity of the surface area and the related transport infrastructure, concerning which purchase or change of use cannot be ruled out due to the impossibility of ensuring the quality of the local environment or compliance with the relevant public health limits.

Quantification: the impacts will be directly proportional to the occurrence of residential, recreational and other buildings in the defined surface area and in its immediate vicinity and in the vicinity of access roads/railways. Graded evaluation: 1 – 5.

Results of the assessment of indicator C13b (Krajíček et al. 2020)

The indicator considers the impact of changes in the current use of residential, recreational and other buildings at the sites due mainly to the impossibility of meeting set limits concerning noise and/or air pollution, especially during the DGR construction period. The assessment considers the distance of such buildings from the surface areas of the sites and access routes and the number of such buildings.

As mentioned above (indicator C13a), the Lubenec recreational centre is located around 450 m east of the surface area of the Čertovka site. Although forest stands create a visual barrier to the surface area, noise and vibration levels that will significantly reduce the quality of this recreational area to a level that precludes its current use cannot be ruled out. This impact was, thus, assessed as medium-risk and very significant.

High impact risks were identified for the Janoch (ETE-south) and Na Skalním (EDU-west) sites, at distances of 400 m and 300 m from the surface areas of which are located a family recreation facility (Coufalka) and residential area (Ostrý Dvůr), respectively. Moreover, around 200 m east of the Skalní (EDU-west) surface area lies a former farm building that is currently used as a storage facility for agricultural machinery. Due to the sparse nature of the development of the affected areas, however, this impact was assessed as being of low significance. The other sites do not feature any residential or recreational buildings/facilities in the immediate vicinities of their surface areas.

The risk of impacts on valuable cultural monuments is high at the Hrádek site, specifically concerning small religious monuments that line the Rohozenská road (the Passion of Christ) that passes through the surface area. Due to their limited number and the potential for their relocation, e.g. along a re-sited Rohozenská road, this impact is considered insignificant.

The risk of the disturbance of mound burial grounds in the vicinity of the surface area and access routes at the Janoch (ETE-south) site is considered negligible. Similarly, such impacts were assessed as minimal with concern to the remaining sites (Březový potok, Čihadlo, Kraví hora, Horka, Magdaléna and Na Skalním (EDU-west)), where no threats to the considered phenomena (including the protection of monuments) were identified. The assessment process fully took into account obligations set out in Section 22, 2 of Act No. 20/1987 Coll., on the care of state monuments, which requires the conducting of archaeological studies if construction is planned in areas with known archaeological artefacts.

Tab. 43 Assessment values for the C13b indicator according to Krajíček et al. (2020)

Site	Nearest residential and recreational buildings/facilities	Listed building/monuments	Indicator grade
Březový potok	• from the surface area: - Pačejov Nádraží (recreational cottages) - circa 850 m W	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road:	1

Site	Nearest residential and recreational buildings/facilities	Listed building/monuments	Indicator grade
	- family recreational facility by a small lake - Velký Blýskota (Ovčín) circa 750 m SW • from the railway siding: - no occurrence • from the access road: - Maňovice (family recreational facility by a flooded quarry) - circa 100 m NE	- no occurrence	
Čertovka	• from the surface area: - recreational centre, Lubenec – circa 450 m E (partly shielded by the terrain and forest stands) - Struhaře castle – circa 650 m S (shielded terrain) • from the railway siding: - no occurrence • from the access road: - no occurrence	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	4
Čihadlo	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	1
Horka	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	1
Hrádek	• from the surface area: - recreational facility (near the Klechtavec pond) – circa 750 m (shielded terrain)	• from the surface area: - small religious monuments along the	1

Site	Nearest residential and recreational buildings/facilities	Listed building/monuments	Indicator grade
	• from the railway siding: - no occurrence • from the access road: - no occurrence	Rohozenská road • from the railway siding: - no occurrence • from the access road: - no occurrence	
Janoch (ETE-south)	• from the surface area: - Coufalka (residential building, no. 29 Knín) - circa 350 m SW - Krejcárka (residential building, no. 8 Nová Ves) - circa 800 m SW (shielded terrain) • from the railway siding: - Coufalka (residential building, no. 29 Knín) circa 250 m SW of the road and railway tunnel • from the access road: - Coufalka (residential building, no. 29 Knín) circa 250 m SW of the road and railway tunnel	• from the surface area: - mound burial grounds S, E (will not be affected) • from the railway siding: - mound burial grounds along the route (will not be affected) • from the access road: - mound burial grounds along the route (will not be affected)	3
Kraví hora	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	1
Magdaléna	• from the surface area: - residential building no. 5 (Jezvice area) – circa 700 m SW • from the railway siding: - residential building no. 5 (Jezvice area) – 100 m • from the access road: - no occurrence	• from the surface area: - no occurrence • from the railway siding: - no occurrence • from the access road: - no occurrence	1

Site	Nearest residential and recreational buildings/facilities	Listed building/monuments	Indicator grade
Na Skalním (EDU-west)	• from the surface area: - Ostrý dvůr (Myslibořice) – circa 200 m E • from the railway siding: - option TE-z1, z2 - circa 100 m from a garden allotment area in the Štěpanovicky stream valley • from the access road: - option TE–s1 (from road II/360) - circa 100 m from a garden allotment area in the Štěpanovicky stream valley	• from the surface area: - Boňov village preservation zone - circa 1.1 km • from the railway siding: - Boňov village preservation zone - circa 300 m (option TE–z1,z2) • from the access road: - Boňov village preservation zone - circa 250 m (option TE–s1); condition - S and W of the Jaroměřice n. Rokytnou bypass (town preservation zone and national cultural monument)	3

6 Determination of the weightings of the criteria and indicators, comparative calculations

The assessment of the sites represented the culmination of the current stage of the Czech DGR development process. The assessment served for the quantification of current knowledge on the various sites according to the detailed research conducted that involved a broad range of scientific and technical disciplines. In order to provide for an objective comparison of the suitability of the nine candidate sites for the subsequent research stage, it was necessary to interpret the acquired knowledge in the form of the comparison of the sites involving the application of the graded scale approach.

The multicriteria analysis approach was used for the assessment as described in detail in Vondrovic et al. (2019), via which the values of the indicators were converted to a grade of from 1 to 5 applying the weighted sum method. The weightings of each of the indicators as defined for all the criteria were determined by the respective expert assessment team, and the weighting of the various criteria was based on the average of the values provided by the various assessment experts according to the Saaty matrix of pairwise comparisons. See chapters 6.2 and other for more details.

With regard to the demonstration of the sufficient degree of robustness of the assessment method, a detailed analysis was performed applying comparative calculations with respect to 8 modifications.

The main aim of the assessment process was to determine the four relatively more suitable sites from the nine assessed candidate sites. The outputs of this assessment approach comprised the results obtained via the calculation procedure set out in the Assessment Methodology study (Vondrovic et al. 2019), as addressed in chapter 7.

The order of subchapters 6.1 **Chyba! Nenalezen zdroj odkazů.** to 6.6**Chyba! Nenalezen zdroj odkazů.** corresponds to the progress of the site evaluation process in the order:

- determination of the weightings of the indicators with concern to the criterion
- determination of the weightings of the criteria
- determination of the indicator values
- standardisation of the indicator values
- comparative calculations

It is necessary to emphasise here that in order to maintain the objectivity of the assessment process, the values of the criteria weightings were not known to the assessment experts or to the experts who worked on the indicator grades until the final meeting of the Expert Advisory Panel, at which the assessment results were confirmed.

6.1 Determination of the weightings of the indicators

The defined indicators of the key criteria (see Chapter 4) were assigned weightings by the respective assessment teams, which were then used for the determination of the values of the criteria. The weightings of the indicators were defined according to the expert knowledge of the respective professional specialists who participated in determining both the values and the characteristics of each of the indicators and, subsequently, the various indicator grades.

The rationale for the determination of the weightings of the indicators by the assessment teams lie in the fact that they were acquainted in detail with the subject matter of the indicators and were fully aware of the uncertainties involved in determining the values of the indicators and were able to consider this factor when determining their relative significance.

An overview of the various weightings and the determination procedure according to the set methodology (Vondrovic et al. 2019) is provided in Tab. 44.

Tab. 44 Determination of the weightings of the indicators

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
C1	**Size of the usable rock mass**	C1a	Usability of the rock blocks	74%	The size of the homogeneous blocks and the disposal spaces that are included in this indicator fundamentally affect the siting of the DGR with respect to the disposal level. The degree of utilisation of the defined suitable homogeneous blocks is thus perceived as the most important indicator with the highest weighting in terms of the comparison of the sites with respect to the C1 criterion. The weighting of the indicator was determined via the Saaty method by the CTU expert team.
		C1b	Fragmentation of the area	9%	This indicator describes the fragmentation of the respective area into several blocks. The fragmentation of the area may partially affect the layout of the underground complex of the DGR. The indicator reflects cases in which the area of interest is divided into several fragments, each of which is smaller than the required disposal area. In such cases, however, since the fragmentation of the area is considered directly in the fragmentation of the underground part of the DGR indicator, it is not necessary to consider this factor in this

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					context. Thus, the indicator provides a general idea of the overall fragmentation of the area, which will not influence the project design. Hence, the fragmentation of the area indicator is accorded the lowest weighting. The weighting of the indicator was determined via the Saaty method by the CTU expert team.
		C1c	Fragmentation of the underground part of the DGR	17%	The fragmentation of the underground part of the DGR is determined by the technological requirements for the excavation, construction and operation of the DGR. These factors significantly reduce the efficiency of the use of the homogeneous blocks for disposal. The weighting of the indicator was determined via the Saaty method by the CTU expert team.
C2	**Infrastructure availability**	C2a	Potential for the permanent disposal of excavated material in the vicinity	100%	There is only one indicator under this criterion, therefore it will be applied in full.
C3	**Describability and predictability of the homogeneous blocks**	C3a	Degree of the brittle failure of the massif - fault structures	70%	In the crystalline environments of all 9 sites, of all the geological indicators, faults exert by far the greatest influence on the safety of the repository - especially on the hydraulic and geomechanical parameters of the rock environment. At this stage of the site evaluation process, since higher-order fault structures define the total potential rock volume for

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					disposal planning and repository design purposes (Andersson et al. 2000), this indicator was accorded the highest weighting.
		C3b	Degree of brittle failure of the massif - fracture systems	20%	The weighting was chosen due to the level of representativeness of the evaluated data, which was based on the research (Kabele et al. 2018) of a limited number of surface outcrops at the sites. In addition, the hydraulic models of the sites (Havlová et al. 2020 a-i) applied the equivalent porous media (EPM) method with deterministically determined higher-order structures.
		C3c	Degree of ductile deformation	10%	The internal anisotropy of the rocks as indicated by ductile deformation exerts only a small impact on the safety characteristics of the rock environment; moreover, no complicated ductile structures can be expected in the target lithologies for the siting of the repository (Franěk et al. 2018, Mixa et al. 2019).
C4	**Variability of the geological properties**	C4a	Spatial variability of the rock environment	75%	The indicator expresses the vertical and horizontal distribution of the properties of the rock mass, on the basis of which it is possible to consider the inhomogeneity of the rock environment in which changes in the migration of fluids may occur. Alternations and the irregular shapes of rock bodies complicate the geotechnical parameters and the calculations associated with the long-term

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					safety of the repository and, moreover, increase the uncertainty of the 3D geological models (Franěk et al. 2018). The spatial arrangement of the rock bodies expresses the vertical and horizontal distribution of lithological boundaries, on the basis of which it is possible to consider the inhomogeneity of the rock environment and the properties thereof. Frequent alternations of the lithologies and the irregular shapes of rock bodies lower the degree of suitability for DGR siting both from the geotechnical point of view for repository construction and in terms of the calculations necessary to ensure the long-term safety of the repository. Furthermore, they increase the uncertainty of the 3D geological models and, not least, contribute to the localisation of fragile structures at the various interfaces. Inhomogeneities in the form of calcium-silicate rocks may indicate the presence of caverns in the rock massif. Since the spatial arrangement of the rock bodies exerts a significant impact on safety, a significant weighting was assigned to this indicator.
		C4b	Petrological variability of the rocks	25%	The petrological variability exerts an impact on the mechanical properties of the rocks under specific conditions (rheological, thermal conductivity and the production of radiogenic heat, fluid migration etc.); however, the impact on safety is relatively

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					low. According to the hydraulic models created to date and discussions with hydrogeologists, the influence of brittle tectonics is disproportionately more significant in the rock environment from the point of view of safety than the petrological variability or, for example, ductile rock structures.
C5	**Water flow characteristics in the vicinity of the DGR and the transport characteristics**	C5a	Flow time from the DGR to the drainage area	20%	All the selected indicators for the C5 criterion are closely related to the safety of the sites. The weightings for the various indicators were set relatively evenly based on an expert panel discussion. The indicators characterise both the groundwater flow ratios (C5b, c, d, e, f) and the transport ratios of the sites (C5a, C5g). The indicators that characterise groundwater flow were accorded a total weighting of 60% and the transport indicators 40%. The lowest weightings (10%) were accorded to those indicators that were based “only” on an expert estimation and the accepted input assumptions of the models (C5b, C5c, C5e). The C5d and C5f indicators were assigned higher weightings (15%) since their assessment included data on the geometry of the sites (terrain height and river network distribution). Weightings of 20% each were assigned to the C5a and C5g transport indicators.
		C5b	Flow rate at the DGR level ($m.year^{-1}$)	10%	
		C5c	Permeability in the DGR area ($m.s^{-1}$)	10%	
		C5d	Descending vertical flow component (% of the DGR area)	15%	
		C5e	Maximum permeability of failure zones up to 500 m from the DGR boundary ($m.s^{-1}$)	10%	
		C5f	Specific flow in the DGR area ($l.s^{-1}.km^{-2}$)	15%	
		C5g	Dilution ratio (%)	20%	

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
C6	**Identification of drainage bases**	C6a	Number of drainage streams	30%	The indicators of the C6 criterion characterise the dispersion of the transport routes from the area of the DGR. The weightings were determined for the various indicators based on an expert panel discussion. The indication of the dispersion of advective transport pathways expressed by the number of drainage flows (C6a, 30%) and the proportion of drainage from the DGR into the river network were accorded the highest weightings (indicators C6b and C6c - both 20%). Due to the greater uncertainty of the calculation, the indicator of the distance of the DGR from the drainage basins was assigned a lower weighting (30%).
		C6b	Extent of drainage from the DGR area via a single stream	20%	
		C6c	Extent of drainage from the DGR area into a single river basin	20%	
		C6d	Horizontal distance of the DGR from the drainage location (m)	30%	
C7	**Seismic and geodynamic stability**	C7a	Value of the maximum horizontal acceleration ($m.s^{-2}$)	25%	The value of the maximum horizontal acceleration for seismic phenomena is directly proportional to the manifestation of earthquakes and related accompanying phenomena, which are able, without warning and in a very short time, to significantly negatively affect the safety of the DGR. This indicator expresses the potential seismic hazard, the assessment of which is set out in Decree No. 378/2016 Coll.
		C7b	Elevation gradient	25%	The elevation gradient between the level of the surface area and that of the local erosion base is directly proportional to the dynamics of the local relief and determines the potential for the

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					lowering of the drainage system in the future and the associated occurrence of exodynamic phenomena, including long-term changes in the relief.
		C7c	Percentage of the relief area affected and reshaped by young cycles of reverse erosion and slope deformations	25%	The significant manifestation of reverse erosion is associated with the unbalanced gradient conditions of river flows, which are caused by movements of the erosion base, i.e. vertical movements of the earth's crust. This results in the increased intensity of erosion processes which, over the long term, may result in significant changes to the local relief, including the lowering of the surface in the DGR overburden and changes in the hydrological and hydrogeological regime.
		C7d	Occurrence of volcanic rocks of the Paleogene to Holocene eras and acids	25%	The presence of Tertiary and Quaternary volcanic rocks and related post-volcanic phenomena are linked to areas with recent geodynamic activity, including tectonic movements, thus providing an indicator of the long-term stability of the area, especially in terms of endogenous processes. The presence of acids in the vicinity of the site may exert a negative impact on the DGR engineered barriers. The requirement for the assessment of the volcanic rocks of the Paleogene to Holocene eras and post-volcanic phenomena is set out in Decree No. 378/2016 Coll.

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
C8	**Characteristics that could lead to the disturbance of the DGR via future human activities**	C8a	Raw material deposit conditions at the site (mining areas, register of protected deposit areas, prediction of the presence of minerals)	100%	
C9	**Phenomena influenced by the spread of radioactive materials**	C9a	The distribution and density of the population and its development in terms of the spread of radioactive material	90%	The population density is known with a high degree of accuracy. From the point of view of certainty, this factor comprises a reliably determinable parameter; therefore, it was assigned a weighting of 90%.
		C9b	Distance from nuclear power plants	10%	Since the relevant data on the sites for determining the total distance of the surface area from NPP sites is not equally relevant, a weighting of just 10% was assigned to this indicator.
C10	**Impact on surface waters and water resources**	C10a	Impact on the runoff conditions and surface water quality	30%	A slight preference for indicators that consider the protection of water resources is expressed in criterion C10 (C10b and C10c) due to the direct link with potential impacts on the health of the population. The allocation of a higher weighting was limited by the fact that the potential impacts on runoff conditions and the quality of the surface water (C10a) may also affect biota and habitats whose conditions are dependent on the existing hydrological conditions of the area A change in the runoff conditions may also significantly

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					impact habitats that are dependent on existing hydrological conditions, including the drying out and hydration of the land. The direct impact concerns only the catchment area of the recipient watercourse and, potentially, the tributaries thereof (small watercourses affected by the location of the surface area). Subsequently, flows in higher-order river basins may be indirectly affected.
		C10b	Impact on water sources near the DGR	35%	The potential impact on water resources comprises a crucial factor not only in terms of water as a component of the environment but, especially, concerning the supply of drinking water to the population and the elimination of potential health risks. The source of the impact will comprise exclusively local water sources, i.e. local (municipal) water mains systems and domestic wells in the surrounding settlements (in relation to both the surface area and the area deemed promising for the project design work).
		C10c	Impact on significant water sources in the wider area	35%	Significant water resources are considered to be those resources that supply 3000 or more inhabitants. The indicator concerns the potential impact on the supply of drinking water to the population.

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
C11	**Impacts on nature and landscape protection**	C11a	Impacts on biodiversity	25%	The indicators that comprise the C11 criterion reflect all the main topics and phenomena addressed by Act No. 114/1992 Coll., on nature and landscape protection. With regard to the current level of knowledge of the natural conditions of the various sites and on the basis of the precautionary principle, a conservative approach was adopted when determining the weightings of the individual indicators, with a relatively limited degree of mutual differentiation. The reason for this approach was to avoid delays with respect to certain aspects of the evaluation procedure. The phenomena observed in C11a represent the most important components with respect to the ecological stability of the affected areas.
		C11b	Impacts on migration corridors and areas important for migration	20%	Any reduction in the migratory permeability of the area (especially for large mammals) exerts a negative impact on the affected animal populations.
		C11c	Impacts on Natura 2000 bird areas and sites of European importance	30%	Natura 2000 protected areas have been established throughout the EU for the protection of rare and endangered species of birds and other animals, plants and natural habitats. The assessment considers both the distance from the surface area and the distance downstream if the subject of

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
					protection is linked to an aquatic environment.
		C11d	Impacts on the landscape	25%	The minimisation of the impacts of the construction of the DGR (especially the surface area) on the landscape comprises fundamental aspects of both the Nature and Landscape Protection Act (Section 12) and the Building Act (Section 18, para. 5).
C12	**Impacts on agricultural land and land intended for forestry**	C12a	Impact on agricultural land	30%	The mutual relationship between the weightings of these two indicators is based on the general assumption of the higher ecological stability of forested areas than that of agricultural land. This assumption is not exclusive however, e.g. some permanent grasslands (extensively mown meadows) may have a high degree of ecological stability. Nevertheless, at the given scale and with regard to the level of knowledge of the assessed sites, this simplification is deemed acceptable.
		C12b	Impact on land intended for forestry	70%	

ID	Criterion designation	ID	Indicator designation	Weighting	Rationale
C13	**Impacts on the population, property and protected monuments**	C13a	Disruption of well-being factors	50%	The allocation of equal importance to the two indicators of criterion C13 is based on the content thereof. In the case of indicator C13a, this concerns a so-called "soft impact" (subjective), which will exert a long-term impact (at least during the construction of the DGR). On the other hand, indicator C13b represents a one-off but significant impact on the property rights of the owners of the affected buildings and facilities. The minimisation of this impact may significantly contribute to the acceptance of the DGR by the populations of the surrounding settlements.
		C13b	Impacts on residential, recreational and listed buildings	50%	This a one-off but significant impact, which may affect the property rights of the owners of the buildings and facilities affected.

The determination of the weightings of the criteria indicators was based on the reasoning of the respective expert teams. As can be seen from Tab. 44, the procedure for determining the weightings varied from team to team. While the team that considered feasibility (criteria C1 and C2) applied the Saaty matrix of pairwise comparisons approach, the other teams (safety and the environment) proceeded via expert consensus agreement on the indicator weightings.

While both approaches are based on expert estimates, only the Saaty matrices allowed for the subsequent mathematical processing. Although the latter approach still relies on the expert determination of mutual significance, compared to expert estimates it better takes account the input of the individual assessment experts since the expert estimates of the weightings of the indicators had to be determined via consensus. Moreover, while it was assumed that the ratios of the indicators for each criterion would not differ significantly from the expert determination after applying the Saaty method, the former approach allowed for the expression of the weightings in terms of whole numbers.

6.2 Determination of the weightings of the criteria

The Saaty quantitative comparison method (Saaty 1980, 2008) using a pairwise assessment matrix (Vondrovic et al 2019) was applied to the thirteen assessed key criteria.

This method involves the assessment of pairs of all the criteria both mutually and quantitatively according to the numerical scale shown in Tab. 45. In order to allow for the more accurate expression of the differences between the criteria, it was also possible to assign intermediate values, i.e. 2, 4, 6 and 8 if deemed appropriate.

Tab. 45 Numerical preferences of the pairwise assessment of the criteria

Numerical value	Explanation
1	The criteria are equally important
3	The first criterion is slightly more important than the second
5	The first criterion is strongly more important than the second
7	The first criterion is very strongly more important than the second
9	The first criterion is absolutely more important than the second

The assessment of the significance of the criteria took place at a meeting of the assessment experts on 22 October 2019, and the procedure to be applied for determining the weightings of the criteria was finalised via a brainstorming session involving all the assessment teams. Presentations were made of each of the criteria, which included the description of the criterion and the phenomena and quantities it covered, the content of the indicators and the methods applied for the determination of the values of the indicators of each criterion. The presentation also included an explanation of the meaning of the indicators with respect to the given criterion (the determination of the weightings of the indicators), including the uncertainties in the information available on the indicators.

All those involved in the process were acquainted at the meeting with the methodology of the assessment process and the time schedule. Each of the criteria were presented by the teams responsible for the respective criterion, including explanations of the content of the criterion, the quantities and phenomena described, physical dimensions etc. The presentation also included explanations of the significance of the various indicators within the given criteria, i.e. the determination of the weightings of the indicators and the method applied to the determination of the weightings, including the various uncertainties involved. Evaluations were also presented on the extent to which the significance of the indicators might change following the inclusion of information obtained from borehole drilling in the next stage of the investigation research at the sites. The presentation meeting further included a discussion and question/answer session and an explanation of the subsequent mathematical processing of the data (grades). Each of the presentations on the various criteria, including the discussion session, lasted between 15 and 25 minutes.

Following the criteria presentations, the assessment experts were introduced to the procedure concerning the determination of the weightings of the criteria via a presentation on the Saaty method, including the principles and procedures to be applied in the subsequent assessment calculations and a question/answer session. The experts were shown how to complete the Saaty matrix of pairwise comparisons via a test example.

Subsequently, each of the assessment experts performed the pairwise comparison of the thirteen key criteria according to the Saaty method, each expert completing the appropriate matrix individually. No time limit was applied, thus ensuring that the experts were not under any time pressure with respect to the careful and detailed consideration of the importance of the issues involved. The resulting completed pairwise comparison matrices were then verified by mathematical calculations in the R language (http://www.r-project.org/) and the FuzzyAHP software package (https://cran.r-project.org/package=FuzzyAHP). The source code of the calculation is available at https://github.com/JanCaha/FuzzyAHP/blob/master/R/function-consistencyRatio.R; the library also lists the index values of a randomly generated RI matrix for matrix calculations up to an order of 15x15. With respect to the site assessment process, an RI index of 1.56 was used to calculate the consistency ratio (CR) of the assessed matrices, which corresponds to a matrix of the order 13x13. The calculation served to verify whether the matrices were consistent in accordance with the requirements of the method, subsequently revealing that 6 of the matrices did not fulfil the consistency condition, i.e. the matrix consistency ratio exceeded 0.1 (these consistency ratios ranged from 0.12 to 0.15). The six experts were, therefore, asked to revise their pairwise comparisons. Since one of the assessment experts was unable to adjust his paired assessment due to his heavy workload, this matrix was excluded from further consideration. The results of the remaining 26 experts were subsequently submitted to the next stage of the assessment calculation process.

Once it had been determined that all the pairwise comparison matrices met the consistency condition, the average criteria weightings were calculated from the weightings of the 26 assessment experts. A summary of the assessment matrices of the various experts is provided in Appendix 1A.

Tab. 46 Criteria weighting values according to the various assessment experts (ID), and their average values

ID	**CR**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**
1	0.009	13.5	1.7	22.3	8.7	13.6	8.1	1.7	2.8	4.7	13.6	4.8	2.8	1,7
2	0.003	6.9	6.9	23.3	13.9	13.9	13.9	6.9	1.8	3.5	3.5	1.8	1.8	1,8
3	0.059	11.8	3.1	23.8	8.0	18.5	13.6	3.8	1.1	6.1	4.5	2.3	1.8	1,4
4	0.093	4.7	2.9	18.1	22.8	14.7	6.8	2.2	1.3	1.8	9.6	8.0	3.6	3,4
5	0.058	12.8	3.2	9.8	8.6	23.5	17.2	7.3	4.8	4.0	2.8	2.5	1.9	1,7
6	0.035	8.3	2.5	21.2	11.3	21.2	11.3	8.3	3.7	2.5	5.3	1.3	1.3	1,7
7	0.003	13.9	6.9	23.3	13.9	13.9	6.9	6.9	3.5	1.8	3.5	1.8	1.8	1,8
8	0.076	23.7	1.2	18.6	13.8	11.5	6.9	8.7	1.1	1.9	4.8	3.7	2.8	1,4
9	0.042	14.3	3.4	24.3	7.6	13.8	7.6	4.4	1.1	2.3	14.0	3.4	1.6	2,3
10	0.070	15.4	1.9	14.7	9.9	14.1	8.6	13.4	2.2	5.1	5.3	5	1.2	3,1
11	0.034	14.1	4	23.7	23.7	7.5	7.5	1.7	1.7	3.4	7.5	1.7	1.7	1,7
12	0.072	20.7	1.3	17.9	14.1	11.9	7.0	5.5	1.1	10.5	2.0	2.8	0.9	4,3

ID	CR	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
13	0.065	13.4	2.1	21.7	6.8	18.9	12.4	7.1	1.0	3.4	6.8	2.7	1.3	2,3
14	0.075	5.9	3.5	24.1	20.5	15.8	11.3	7.9	2.1	1.5	2.8	1.9	1.9	1,1
15	0.059	10.8	9.5	24.0	13.6	11.4	11.8	4.5	3.0	1.7	4.7	1.8	1.8	1,5
16	0.050	21.7	2.5	22.2	12.9	9.8	7.4	6.4	1.2	3.0	5.6	1.7	1.4	4,0
17	0.035	13.3	1.6	19.0	19.0	11.5	4.5	3.5	1.3	2.4	7.2	9.4	1.5	5,7
18	0.045	18.5	4.1	1.8	4.0	1.4	1.0	6.0	2.5	9.2	13.7	9.2	9.2	19,3
19	0.045	5.1	1.1	10.3	5.1	17.9	17.9	4.3	9.3	21.0	2.3	2.3	2.3	1,3
20	0.050	9.0	7.0	22.4	11.2	18.0	3.2	13.8	1.1	1.2	5.3	2.3	1.8	3,8
21	0.050	8.1	2.7	6.8	15.3	15.3	7.6	15.3	4.1	1.6	13.9	5.3	1.7	2,4
22	0.031	17.3	2.2	19.3	8.5	11.5	14.5	7.8	4.7	4.4	3.2	2.2	1.8	2,6
23	0.057	22.2	2.8	17.0	10.1	15.3	6.8	3.9	2.2	6.8	8.8	1.8	1.3	1,0
24	0.042	5.2	1.9	25.7	10.7	16.7	16.3	6.6	3.0	2.2	3.8	2.6	2.5	2,7
25	0.085	18.9	0.8	13.3	16.3	12.4	11.4	5.1	3.6	3.4	9.2	1.9	1.9	1,9
26	0.097	15.0	4.8	27.2	8.0	19.7	8.1	2.3	0.9	4.7	4.7	1.1	1.1	2,4
Average		**13.2**	**3.3**	**19.1**	**12.2**	**14.4**	**9.6**	**6.4**	**2.5**	**4.4**	**6.5**	**3.3**	**2.1**	**3.0**

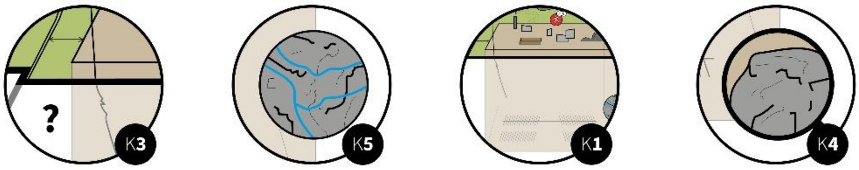
CR = the matrix consistency ratio, which must be < 0.1.

The average values of the criteria weightings were then entered into the assessment calculations.

6.3 Assessment of the significance of the criteria in terms of the site assessment process and uncertainties concerning the values of the weightings

The determined weightings of the criteria based on the SAATY pairwise comparison method served to divide the key criteria into three groups, i.e. relatively more important criteria with weightings of 10-20%, moderately important criteria with weightings of 5-10% and relatively less important criteria with weightings of below 5%.

Relatively more important criteria (weightings in the range 10-20%)



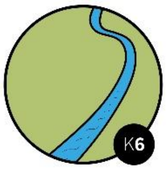
The most important criterion in this group, and thus for the whole assessment process, comprised criterion C3 (the describability and predictability of the homogeneous rock blocks), which was assigned a weighting of 19.1%. The data on which this criterion was assessed was based primarily on the analysis of known large-scale geological interfaces (first and second category fault structures, fracture systems and ductile structures). These interfaces have been described to a reliable degree in SÚRAO-commissioned projects (Geobariéra, Research support for the DGR safety assessment and the Description of the geological structures of the DGR candidate sites using geophysical methods). These interfaces will be described in further detail following the subsequent stage of geological research. The criterion serves for the assessment of indicators (fault and fracture failures of the rock mass, ductile deformation) that are important in terms both of the safety of the DGR and its technical feasibility. The criterion further reflects the potential of the candidate areas in terms of the creation of accurate and objective 3D geological models that will serve as the basic input for the estimation of the properties of the sites at repository depth, i.e. with respect to the volume of the rock mass that is suitable for disposal and the difficulties involved in describing the wider areas of the candidate sites with concern to fulfilling legislative requirements, in particular Decree No. 378/2016 Coll., on the siting of nuclear facilities. Both comprise important factors in terms of the future demonstration of the safety of the DGR and the project design. The characteristics of specific fault structures not assessed by this criterion comprised input information for the modelled simulation of groundwater flow and the overall design of the DGR.

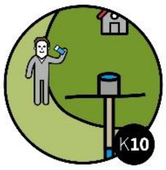
The second most important criterion in this group comprises criterion C5, the Water flow characteristics in the vicinity of the DGR and transport characteristics, which was assigned a weighting of 14.4%. The assessment was based on hydraulic models of the sites (Baier et al. 2020a,b, Černý et al. 2020a,b, Jankovec et al. 2020a,b, Uhlík et al. 2018a,b, Polák et al. 2018) and involved the synthesis of all the available hydrogeological data on the candidate DGR sites. Due to the consistency of the approach to the hydraulic modelling, the values of the various indicators were determined in a uniform way for all the sites. The criterion also served for the assessment of one of the most important long-term safety parameters, i.e. the rate of underground water flow through, and the overall permeability of, the rock mass.

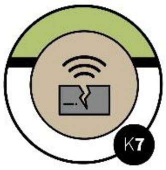
The third relatively important criterion comprised criterion C1, the Size of the usable rock mass, which was assigned a weighting of 13.2%. The assessment of this criterion was based on the preliminary design projects for each site (Zahradník et al. 2020) and served for the synthesis of the available knowledge of the sites with concern to the mechanical and thermal properties of the rock environment. The calculations of the extent of the usable rock mass were based on heat dissipation models and stability calculations (Kobylka 2018), combined with a knowledge of the dimensions of the promising areas for the project design work (Pertoldová et al. 2019) and the preliminary DGR project designs. The criterion serves for the assessment of one of the most critical indicators, i.e. the size of the repository and the reserve area and the potential of the site to provide a sufficiently large volume of rock with a reserve for the disposal of the anticipated waste inventory.

The final criterion in this group comprises criterion C4, i.e. the Variability of the geological properties, which was assigned a weighting of 12.2%. This criterion, in a similar way to criterion C3, concerns the description of the geological structure as ascertained from SÚRAO-commissioned geological projects, which allowed for the assessment of the candidate DGR sites in a consistent way and at the same quality level. The criterion indicators are important in terms of the potential to create the basic descriptive site models necessary for the reliable safety assessment of the repository.

Moderately important criteria (weightings in the range 5-10%)





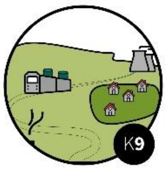


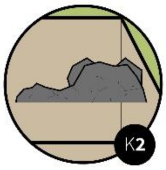
The first criterion in this group comprises criterion C6, the Identification and location of drainage bases, which was assigned a weighting of 9.6%. In a similar way to criterion C5, it is based on the hydraulic models of the sites (Baier et al. 2020a,b, Černý et al. 2020a,b, Jankovec et al. 2020a,b, Uhlík et al. 2018a,b, Polák et al. 2018) and serves for the synthesis of all the available hydrogeological data on the candidate DGR sites. Due to the consistency of the approach to the hydraulic modelling, the values of the various indicators were determined in a uniform way for all the sites. Moreover, this criterion covers one of the most important safety analysis parameters, namely the drainage bases, i.e. the locations to which radionuclides will potentially migrate from the repository. The relatively lower significance of this criterion compared to the C5 criterion is logical since the safety assessment of the sites assigns greater importance to the rate of the flow of underground water.

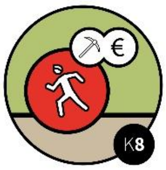
The second criterion in this group comprises criterion C10, Impact on surface waters and water resources, which was assigned a weighting of 6.5%. The criterion concerned the assessment of registered sources of drinking water and related protection zones and involves elements of long-term safety, technical feasibility and environmental impact assessment. The assessment was based on data available in national databases. The moderate significance of the criterion reflects the ability to objectively evaluate the data. Detailed comprehensive safety analyses will have to be conducted at the sites going forward so as to fully assess the impacts covered by this criterion.

The final criterion in this group comprises criterion C7, Seismic and geodynamic stability, which was assigned a weighting of 6.4%. This criterion is based on an estimate of the future development of the sites in terms of erosion characteristics, seismic hazard, relief dynamics and the occurrence of acids. The relative medium importance of this criterion was in accordance with the assessed data, which indicated that the seismic threat is low at all the sites, with some of the sites displaying higher incidences of relief affected and deformed by young cycles of reverse erosion and elevation gradients. The indicator on the occurrence of volcanic rocks and acids identified only one relatively affected site.

Relatively less important criteria (weightings in the range 0-5%)







The first criterion in this group comprises criterion C9, Phenomena that affect the spread of radioactive materials, which was assigned a weighting of 4.4%. The criterion served for the assessment of aspects that will have to be considered in the future operation of the DGR (operational safety) and was based on objectively determined parameters (population density and the number of waste shipments to the DGR) and phenomena that are very unlikely to occur (the leakage of radionuclides from the hot chamber).

The second relatively less important criterion comprises criterion C2, Infrastructure availability, which was assigned a weighting of 3.3%. The criterion served for the evaluation of the availability of quarries in the vicinities of the potential DGR sites for the disposal of excess excavated material. Its relatively low weighting correlates with the assessed data, i.e. the presence of local landfill quarries. Furthermore, the amount of excavated material will depend on the project design at the specific site and the selected nuclear waste disposal method which, at the time of this assessment process, had not been finally decided.

The third criterion in this group comprises criterion C11, Impacts on nature and landscape protection, which was assigned a weighting of 3.3%. The argumentation with concern to this aspect was the same as for the other environmental criteria, all of which are considered relatively less significant at this stage, i.e. criteria C13 Impacts on the population, property and the protection of monuments with a weight of 3%, and C12 Impacts on agricultural land and land intended for forestry with a weight of 2.1%. The evaluation of these factors is based on the final location of the surface area of the DGR, which is tied to the location of the homogeneous rock blocks and the waste disposal spaces, a parameter that is currently subject to a high degree of uncertainty. Furthermore, with concern to the siting of the surface areas, only former exploration areas for special intervention into the earth's crust were investigated at this stage of the assessment process. However, the surface area may potentially be located up to 5 km from the underground complex (expected length of the access tunnel). Thus, many of the aspects of the surface area (operation, building, extent and construction approach) can be modified prior to the confirmation of the final project design, i.e. the design projects will be updated with respect to conditions at the finally selected four sites as more information becomes available. Hence, these criteria were assigned relatively low weightings.

The final criterion in this group comprises criterion C8, Characteristics that could lead to the disturbance of the DGR via future human activities, which was assigned a weighting of 2.5%. The criterion served for the evaluation of the occurrence of raw material deposits at the sites. The data available led to the identification of just one affected site, i.e. Kraví hora. Hence, the assigned weighting corresponds to the assessed data.

The key criteria are based on the SÚRAO MP.22 internal guideline document (Vokál et al. 2017) and the site assessment methodology (Vondrovic et al. 2019), which divide the key criteria into safety, project design and environmental categories. The total weighting of the safety criteria (i.e. C3-C9) was 68.7%, the project design criteria (C1 and C2) 16.5% and the environmental criteria (C10-C13) 14.9%. This classification clearly favoured the long-term safety criteria with respect primarily to geological and hydrogeological considerations. The project criteria prioritised the size of the rock mass, and the environmental criteria the protection of water resources.

6.4 Processed data

The assessment calculations and the subsequent sensitivity analysis were based on the data presented in Butovič et al. 2020, Havlová et al. 2020a-i, Lahodová and Popelová 2020 and Krajíček et al. 2020 consisting of the values that were assigned to the various indicators for each of the sites.

Tab. 47 shows the so-called primary values of the various indicators and the units (%, number, etc.) via which they were determined. Those indicators that were assessed via qualitative descriptions (e.g. the geological characteristics) were expressed via a qualitative grading scale. With respect to the values of the quantifiable indicators, the grades were assigned in a way that expressed their importance on a scale of 1 to 5, thus allowing for the expression of all the indicators on the same scale and converting their values to uniform relationship values, i.e. all the indicators were expressed on the same qualitative scale – the higher the value, the worse the indication. The calculation of the indicator values is described in detail in chapter 5.8. The determined grades were represented in the subsequent calculations by the value **X**.

Since with respect to most of the indicators it was not possible to determine the absolute limits of their value ranges, or the values were only theoretical-hypothetical, the final values were determined via the expert assessment approach.

The primary aim of the site assessment process was to determine the differences between the sites. The reason for the levelling of the indicator values to **X** grades concerned the differences in the values of the indicators; the real mutual significance of the indicators within the criteria was thus expressed via their weightings. Therefore, with respect to the indicators expressed via real numerical values (especially those in the C5 criterion, which were determined via calculations according to the hydrogeological models), the respective assessment experts followed an approach that defined the worst value as the maximum and the best value as the minimum; thus, the real values were converted to **X** grades. For those indicators that could only be expressed via a qualitative description, it was necessary to select a value (interval) scale according to which these phenomena were converted via the expert assessment approach.

The following abbreviations are used in the tables below to indicate the nine candidate sites:

BP – Březový potok, CE – Čertovka, CI – Čihadlo, HO – Horka, HR – Hrádek, JA – Janoch, KH – Kraví hora, MA – Magdaléna, NS – Na Skalním.

Tab. 47 Indicator values and the primary X grades of the indicators

Indicator		BP	CE	CI	HO	HR	JA	KH	MA	NS
ID	Unit									
1a	%	24.93	16.25	15.23	17.54	27.08	23.95	65.7	42.33	32.67
	grade	1.46	1.05	1.0	1.11	1.56	1.41	3.38	2.28	1.82
1b	no.	4	5	3	6	2	4	8	4	9
	grade	2.5	3.0	2.0	3.5	1.5	2.5	4.5	2.5	5.0
1c	no.	2	1	1	2	2	2	12	2	6
	grade	1.36	1.0	1.0	1.36	1.36	1.36	5.0	1.36	2.82
2a	1000 m^3	1 666	3 306	4 923	5 624	0	6 441	4 844	3 885	7 044
	grade	1.95	2.88	3.8	4.19	1.0	4.66	3.75	3.21	5.0
3a	grade	3.5	3.3	3.8	2.8	2.3	2.0	5.0	3.5	3.9
3b	grade	3.3	2.4	4.0	3.0	3.3	3.2	3.1	3.0	3.0
3c	grade	1.2	1.5	1.0	2.0	1.0	4.0	5.0	1.5	2.0
4a	grade	2.1	3.0	2.0	1.2	1.0	2.2	5.0	3.7	2.0
4b	grade	2.1	2.2	2.0	1.0	1.4	2.3	5.0	2.0	2.5
5a	year	8 214	1 726	3 207	2 889	4 813	39 164	2 846	1 222	3 946
	grade	4.3	4.9	4.8	4.8	4.6	1.0	4.8	5.0	4.7
5b	$m.year^{-1}$	0.17	0.7	0.5	0.46	0.56	0.13	2.39	0.49	0.34
	grade	1.1	2.0	1.7	1.6	1.8	1.0	5.0	1.6	1.4
5c	$m.s^{-1}$	$1.4.10^{-9}$	$1.4.10^{-9}$	$2.2.10^{-9}$	$3.5.10^{-9}$	$1.9.10^{-9}$	$8.3.10^{-10}$	7.10^{-9}	$3.6.10^{-9}$	$3.2.10^{-9}$
	grade	2.0	2.0	2.8	3.7	2.6	1.0	5.0	3.8	3.5
5d	%	74	86	58	81	97	99	98	26	85
	grade	2.4	1.7	3.2	2.0	1.1	1.0	1.1	5.0	1.8
5e	$m.s^{-1}$	$1.8.10^{-8}$	$6.9.10^{-9}$	$1.6.10^{-8}$	$1.9.10^{-8}$	$1.7.10^{-8}$	$8.6.10^{-9}$	1.10^{-7}	$1.2.10^{-8}$	$1.4.10^{-8}$
	grade	2.4	1.0	2.3	2.5	2.3	1.3	5.0	1.8	2.1
5f	$l.s^{-1}.km^{-2}$	6.10^{-3}	$2.4.10^{-2}$	$1.8.10^{-2}$	$2.3.10^{-2}$	$3.7.10^{-2}$	$9.6.10^{-3}$	$4.2.10^{-2}$	$2.3.10^{-2}$	$1.6.10^{-2}$
	grade	1.0	3.0	2.3	2.9	4.4	1.4	5.0	2.9	2.1
5g	%	0.1	1..7	0.2	0.1	0.3	0.1	0.7	0.4	0.3
	grade	1.0	5.0	1.3	1.0	1.5	1.0	2.5	1.8	1.5
6a	no.	3	2	2	5	5	7	3	1	3
	grade	3.7	4.3	4.3	2.3	2.3	1.0	3.7	5.0	3.7
	%	63	96	51	81	68	34	53	100	65

Indicator ID	Unit	BP	CE	CI	HO	HR	JA	KH	MA	NS
6b	grade	2.8	4.8	2.0	3.8	3.1	1.0	2.2	5.0	2.9
6c	%	88	100	100	99	87	54	65	100	65
	grade	4.0	5.0	5.0	4.9	3.9	1.0	2.0	5.0	2.0
6d	m	270	540	0	480	840	760	632	0	340
	grade	3.7	2.4	5.0	2.7	1.0	1.4	2.0	5.0	3.4
7a	$m.s^{-2}$	1.21	2.04	1.59	1.26	0.95	1.61	1.33	0.97	1.46
	grade	2.0	5.0	3.3	2.1	1.0	3.4	2.4	1.1	2.9
7b	m	125	230	150	210	240	150	300	150	140
	grade	1.0	3.4	1.6	2.9	3.6	1.6	5.0	1.6	1.3
7c	%	5	60	11	20	15	30	85	20	40
	grade	1.0	3.8	1.3	1.8	1.5	2.3	5.0	1.8	2.8
7d	grade	1.0	5.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8a	grade	2.0	2.0	2.0	1.0	2.0	2.0	3.0	2.0	2.0
9a	inhabitant	12 820	7 966	30 290	41 765	18 338	19 031	20 366	18 552	15 026
	grade	1.57	1.0	3.64	5.0	2.23	2.31	2.47	2.25	1.84
9b	km	72 299.5	109 726.5	54 086.5	48 717.5	49 393.5	57 161	67 925	67 120.3	56 387.5
	grade	2.55	5.0	1.35	1.0	1.04	1.55	2.26	2.21	1.5
10a	grade	3	3	2	2	2	3	2	4	4
10b	grade	2	2	3	1	3	1	1	1	1
10c	grade	2	1	1	1	3	1	1	1	1
11a	grade	2	3	2	2	3	3	3	2	3
11b	grade	3	3	3	1	3	4	3	2	1
11c	grade	1	2	1	1	1	2	2	2	2
11d	grade	4	4	4	4	5	5	4	4	3
12a	grade	4	3	3	4	3	1	3	3	4
12b	grade	1	1	2	1	2	5	2	1	2
13a	grade	4	4	4	3	4	3	3	4	4
13b	grade	1	4	1	1	1	3	1	1	3

The values shown in the table are taken from Butovič et al. (2020) for 1a-2a, Havlová et al. (2020a-i) for 3a-8, Lahodová and Popelová (2020) for 9a-9b and Krajíček et al. (2020) for 10a-13b.

6.5 Standardisation of the indicator values

The site assessment process, as described in Vondrovic et al. (2019), required the identification of the differences between the sites. Thus, in order for the calculations to be relevant, it was necessary to standardise the values of the indicators for calculation purposes on a common basis. The standardisation calculation was applied based on the weighted sum method via the equation:

$$Y_i^L = 1 + 4 \times \frac{X_i^L - X_{i,min}}{X_{i,max} - X_{i,min}} \quad (1)$$

where: Y_i^L expresses the resulting standardised value of the grade for the *i-th* indicator, the *L-th* site for the calculation of the overall assessment

X_i^L is the grade value of the *i-th* indicator of the *L-th* site according to Tab. 47

$X_{i,min}$ is the lowest grade value of the *i-th* indicator

$X_{i,max}$ is the highest grade value of the *i-th* indicator

$i \in \langle 1; N \rangle$ (is the number of indicators according to the relevant criterion)

$L \in \langle 1; 9 \rangle$ (is the number of sites)

Following on from the above calculation (1), the standardised values were distributed within the interval $\langle 1; 5 \rangle$, where the standardised value 1 was assigned to the sites with the lowest indicator grades and the standardised value 5 to the sites with the highest indicator grades, with the other sites proportionally distributed within the interval $\langle 1; 5 \rangle$.

The calculations are shown Appendix 1B and the standardised values of the indicators for further calculation purposes are summarised in Tab. 48 below.

Tab. 48 Standardised values of the Y grades of the indicators determined via the weighted sum method

Indicator	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1a	1.8	1.1	1.0	1.2	1.9	1.7	5.0	3.2	2.4
C1b	2.1	2.7	1.6	3.3	1.0	2.1	4.4	2.1	5.0
C1c	1.4	1.0	1.0	1.4	1.4	1.4	5.0	1.4	2.8
C2a	2.0	2.9	3.8	4.2	1.0	4.7	3.8	3.2	5.0
C3a	3.0	2.7	3.4	2.1	1.4	1.0	5.0	3.0	3.5
C3b	3.3	1.0	5.0	2.5	3.3	3.0	2.8	2.5	2.5
C3c	1.2	1.5	1.0	2.0	1.0	4.0	5.0	1.5	2.0
C4a	2.1	3.0	2.0	1.2	1.0	2.2	5.0	3.7	2.0
C4b	2.1	2.2	2.0	1.0	1.4	2.3	5.0	2.0	2.5
C5a	4.3	4.9	4.8	4.8	4.6	1.0	4.8	5.0	4.7
C5b	1.1	2.0	1.7	1.6	1.8	1.0	5.0	1.6	1.4
C5c	2.0	2.0	2.8	3.7	2.6	1.0	5.0	3.8	3.5

Indicator	BP	CE	CI	HO	HR	JA	KH	MA	NS
C5d	2.4	1.7	3.2	2.0	1.1	1.0	1.1	5.0	1.8
C5e	2.4	1.0	2.3	2.5	2.3	1.3	5.0	1.8	2.1
C5f	1.0	3.0	2.3	2.9	4.4	1.4	5.0	2.9	2.1
C5g	1.0	5.0	1.3	1.0	1.5	1.0	2.5	1.8	1.5
C6a	3.7	4.3	4.3	2.3	2.3	1.0	3.7	5.0	3.7
C6b	2.8	4.8	2.0	3.8	3.1	1.0	2.2	5.0	2.9
C6c	4.0	5.0	5.0	4.9	3.9	1.0	2.0	5.0	2.0
C6d	3.7	2.4	5.0	2.7	1.0	1.4	2.0	5.0	3.4
C7a	2	5	3.3	2.1	1.0	3.4	2.4	1.1	3.9
C7b	1.0	3.4	1.6	2.9	3.6	1.6	5.0	1.6	1.3
C7c	1.0	3.8	1.3	1.8	1.5	2.3	5.0	1.8	2.8
C7d	1.0	5.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
C8a	3.0	3.0	3.0	1.0	3.0	3.0	5.0	3.0	3.0
C9a	1.6	1.0	3.6	5.0	2.2	2.3	2.5	2.3	1.8
C9b	3.2	5.0	2.3	2.0	1.0	2.4	3.0	2.9	2.4
C10a	3.0	3.0	1.0	1.0	1.0	3.0	1.0	5.0	5.0
C10b	3.0	3.0	5.0	1.0	5.0	1.0	1.0	1.0	1.0
C10c	3.0	1.0	1.0	1.0	5.0	1.0	1.0	1.0	1.0
C11a	1.0	5.0	1.0	1.0	5.0	5.0	5.0	1.0	5.0
C11b	3.7	3.7	3.7	1.0	3.7	5.0	3.7	2.3	1.0
C11c	1.0	5.0	1.0	1.0	1.0	5.0	5.0	5.0	5.0
C11d	3.0	3.0	3.0	3.0	5.0	5.0	3.0	3.0	1.0
C12a	5.0	3.7	3.7	5.0	3.7	1.0	3.7	3.7	5.0
C12b	1.0	1.0	2.0	1.0	2.0	5.0	2.0	1.0	2.0
C13a	5.0	5.0	5.0	1.0	5.0	1.0	1.0	5.0	5.0
C13b	1.0	5.0	1.0	1.0	3.7	1.0	1.0	1.0	3.7

6.6 Comparative calculation procedures

In order to verify the accuracy of the assessment results, comparative calculations were subsequently applied using alternative calculation procedures and the processing of the primary data (the indicator values).

Comparative procedure no. 1 - The calculation of the ranking of the sites was applied according to the set criteria weightings using the Saaty matrix of pairwise comparisons of each of the members of the assessment teams, and the final ranking was determined by averaging the resulting grades for the sites. The weightings of the indicators and the standardised values of the indicator grades were determined in the same way as in the basic procedure; details are provided in Chapter 8.1

Comparative procedure no. 2 - The calculation was based on the principle of the basic assessment calculation, i.e. the weightings of the criteria were determined by averaging the values of the weightings of the criteria of the various assessment experts obtained from the Saaty matrix of pairwise comparisons. The indicator weighting values were the same as those used in the basic procedure (see Chapter 8.2**Chyba! Nenalezen zdroj odkazů.**). The indicator grades were standardised in the 1-5 value range via the interval method; details are provided in Chapter 8.3

Comparative procedure no. 3 - The calculation was based on the evaluation of the sites by each member of the assessment teams separately according to the criteria weightings determined using the Saaty matrix of pairwise comparisons and the overall result obtained by averaging the grades of the sites, similar to comparative procedure no. 1. It differed from procedure no. 1 with concern to the approach to the standardisation of the indicator grade values (the use of the interval method); details are provided in Chapter 8.3.

Comparative procedure no. 4 - The calculation was based on a balanced approach to the criteria, i.e. on their equal weightings (significance). The calculation included two modifications (a, b) based on different approaches to standardising the values of the indicator grades, i.e. the weighted sum and the interval methods. Each criterion was assigned a weighting of 100% and the resulting values for each site were summed over all the criteria; details are provided in Chapter 8.4. The weightings of the indicators were set by the assessment teams.

Comparative Procedure no. 5 – This procedure comprised an absolute comparison approach that did not take into account the weightings of the criteria and the indicators and was based on the simple totalling of the grade values. This served to eliminate the mathematical computations to a minimum. Comparative procedure no. 5 involved 3 modifications (a-c) according to the method applied for determining the standardised values of the grades, a) - by means of the weighted sum method, b) – via the interval method and c) – via the absolute values of the grades without their standardisation; details are provided in Chapter 8.5.

Since the assessment calculation was based on determining the significance of the assessed phenomena and quantities (for both the indicators and the criteria), the levels of significance, i.e. weightings were determined as the first step; details are provided in Chapters 6.1 and 6.2.

The assessment process involved determining the differences between the candidate sites via the relative mutual comparison approach. Thus, it was necessary to express all the quantities and properties (for the indicators and the criteria) of the compared sites in a uniform mode and range. Therefore, the standardisation of the data comprised an essential step in the assessment process; for further details see Chapter 6.5**Chyba! Nenalezen zdroj odkazů.**. Moreover, it was also necessary to clearly define the assessment procedure and the various stages thereof. The results obtained according to the basic calculation were subjected to analysis via a comparison with the results of the comparative calculations as described in procedures 1 to 5 (above); for further details see Chapter 8.

7 Basic assessment calculation

The basic procedure, as described in (Vondrovic et al. 2019), comprised a multicriteria analysis using the Saaty method for the determination of the weightings of the criteria. The inputs for the calculation comprised:

- the standardised indicator grade values;
- the indicator weightings;
- the criteria weightings.

The determination of the standardised indicator values is described in detail in Chapter 6.5; the indicator values are also documented in Appendix 1B.

The weightings of the indicators are described in detail in Vondrovic et al. (2019), Butovič et al. (2020), Havlová et al. (2020a-i), Lahodová and Popelová (2020) and Krajíček et al. (2020); a summary is provided in Chapter 6.1

The weightings of the criteria were determined using the Saaty matrix of pairwise comparisons according to the procedure set out in Vondrovic et. al. (2019) and as described in Chapter 6.2; the criteria values are also documented in Appendix 1A.

The calculation was applied according to the procedure described in Vondrovic et al. (2019) for each site as summarised below:

The standardised value of the grades of the indicators were multiplied by the respective indicator weightings. All the indicators within each of the criteria were then totalled and the total was multiplied by the weighting of the respective criterion. The resulting criteria-weighted values were then totalled for each site. The result comprised the overall grades for each of the sites - the resulting utility values. The total grades thus obtained were then arranged in an ascending order of values and the four lowest values were selected.

The mathematical expression of the calculation is set out below.

The criterion grade was calculated as the sum of the product of the standardised indicator value and its weighting within the relevant criterion.

$$K_j^L = \sum_{i=1}^{n_j} Y_{i,j}^L \times v_{i,j}, \tag{2}$$

where: K_j^L is the value (grade) of the *j-th* criterion of the *L-th* site (j=1, 2, ..., 13, L = 1, 2, ..., 9),

$Y_{i,j}^L$ is the standardised grade of the *i-th* indicator of the *j-th* criterion of the *L-th* site (i=1, 2, ..., n_j),

$v_{i,j}$ is the weighting of the *i-th* indicator of the *j-th* criterion,

n_j is the number of indicators of the *j-th* criterion.

The final utility value of each site was determined according to the formula:

$$Z_L = \sum_{j=1}^{13} K_j^L \times W_j, \tag{3}$$

where: Z_L is the final weighted grade for a given site,

K_j^L is the value (grade) of the *j-th* criterion of the *L-th* site *(j=1, 2, ..., 13, L = 1, 2, ..., 9),*

W_j is the weighting of the relevant *j-th* criterion.

The calculation is documented in Appendix 1C, and the results of the assessment are summarised numerically in Tab. 49 and graphically in Fig. 28.

Tab. 49 Weighted values of the grades for the sites according to the basic assessment calculation

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1	0.229	0.161	0.139	0.185	0.232	0.221	0.653	0.364	0.355
C2	0.064	0.095	0.125	0.138	0.033	0.154	0.124	0.106	0.165
C3	0.548	0.432	0.665	0.410	0.330	0.325	0.869	0.525	0.606
C4	0.256	0.342	0.244	0.140	0.134	0.271	0.610	0.400	0.259
C5	0.305	0.459	0.392	0.385	0.391	0.157	0.558	0.470	0.364
C6	0.344	0.381	0.402	0.311	0.229	0.108	0.245	0.480	0.299
C7	0.08	0.275	0.115	0.125	0.114	0.133	0.214	0.088	0.128
C8	0.075	0.075	0.075	0.025	0.075	0.075	0.125	0.075	0.075
C9	0.073	0.062	0.150	0.202	0.093	0.098	0.108	0.099	0.079
C10	0.195	0.150	0.156	0.065	0.247	0.104	0.065	0.143	0.143
C11	0.067	0.140	0.067	0.050	0.117	0.165	0.140	0.098	0.106
C12	0.046	0.038	0.053	0.046	0.053	0.080	0.053	0.038	0.061
C13	0.090	0.150	0.090	0.030	0.090	0.070	0.030	0.090	0.130
Total	**2.374**	**2.758**	**2.673**	**2.113**	**2.138**	**1.96**	**3.793**	**2.975**	**2.769**

The colour highlighted values in the table represent the calculated threshold values for the given criteria. The lowest values, highlighted in green, represent the qualitatively most suitable sites with respect to the given criterion, while the orange highlighted (highest) values represent the qualitatively least suitable sites concerning the given criterion.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 1.833 and the differences between the sites range from 0.6% to 44.6%. The difference between the more suitable four and less suitable five sites is 16.4% of the total difference between the first and ninth sites, i.e. a difference in the grades of 0.3; see the overview presented in Chapter 9.1.

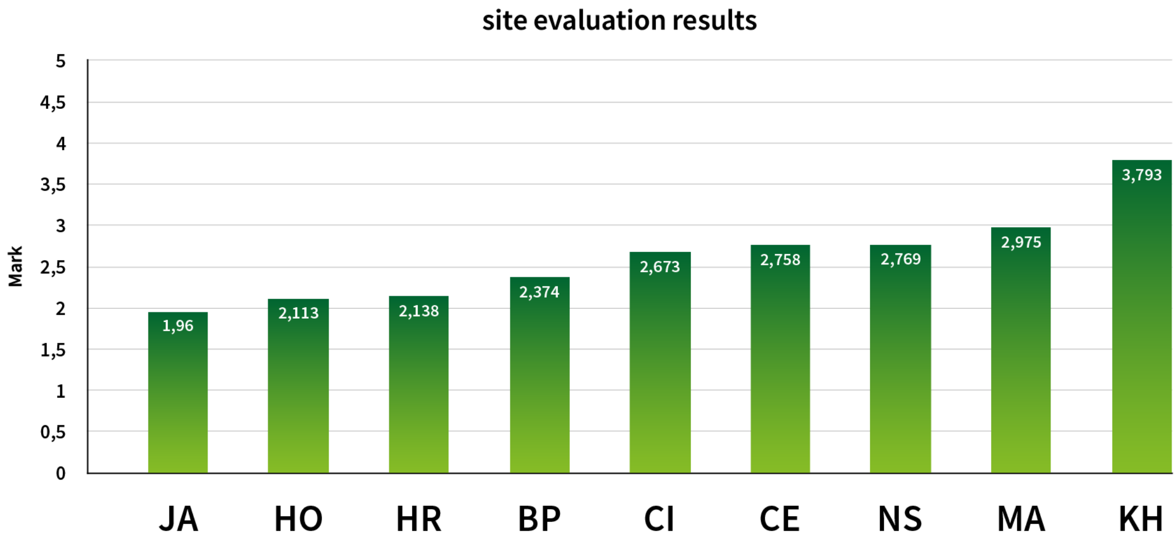


Fig. 28 Graph of the results of the site assessment calculation according to the basic calculation variant

As can be seen from Fig. 28, the 2nd and 3rd placed sites are relatively close, and from the point of view of the uncertainties that are included in the assessment process, these two sites can be considered as being identical.

Similarly, with respect to the group of five less suitable sites, the 6th and 7th placed sites can be considered identical in terms of the assessment results.

The basic calculation approach resulted in the selection of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

The following five sites were considered less suitable (backup) sites (in alphabetical order): Čertovka, Čihadlo, Kraví hora, Magdaléna and Na Skalním.

8 Comparative calculations

The aim of the comparative calculations was to verify the results of the assessment in Chapter 6 via a comparison with other computational approaches. It was considered that the recommendation of the four most suitable sites should not be dependent on just one assessment calculation approach. The comparative calculations differed from the basic calculation with respect to the approaches employed to the calculation of the weightings and the standardisation of the input values.

An overview of the differences between the various calculation procedures is presented in Fig. 29.

Calculation No	Variant	Weights of criteria	Weights of indicators	Values of indicators (normalization)
reference		aritmetical mean from all SAATY evaluation matrix	YES	Interval normalisation
1		statistical calculation of each evaluation	YES	Interval normalisation
2		aritmetical mean from all SAATY evaluation matrix	YES	Standard deviation
3		statistical calculation of each evaluation	YES	Standard deviation
4	a	NO	YES	Interval normalisation
	b	NO	YES	Standard deviation
5	a	NO	NO	Interval normalisation
	b	NO	NO	Standard deviation
	c	NO	NO	Estimated values

Fig. 29 Principles of the various assessment calculations

Following the text above and Fig. 29, the indicator grade values were standardised by means of the interval method for the purposes of the testing of the comparison of the sites via a reduction in the extent of their mutual differences.

Standardisation via the interval method is based on statistical quantities, where the range of values is divided into five intervals defined from the average value. Each interval is represented by a standardised grade value of 1 to 5, as shown graphically in Fig. 30.

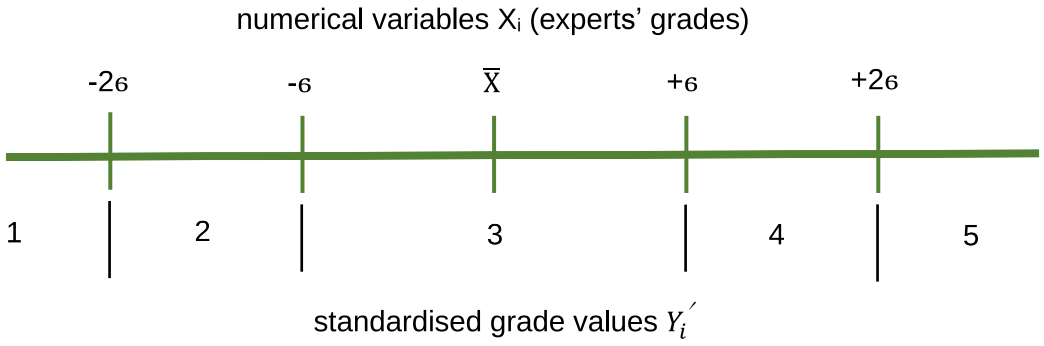


Fig. 30 Scheme of the interval distribution of the standardisation of values by means of the interval method

Due to the identification of the grades using letters, the standardised values of the weighted sum method were assigned the letter **Y** in accordance with the set methodology (Vondrovic et al. 2019) and for the assessment calculation. In order to preserve the logic of the calculation, the standardised values were assigned the symbol **Y'** with respect to the interval method. The notation **Y** (**Y'**) thus signifies throughout the text that the grades were standardised and that the index distinguishes the standardisation method.

The standardisation procedure for each single indicator was such that we determined the average value $\bar{X}$ and the standard deviation **6** from the vector of the grades for all the sites for the given indicator $X_i \in \{X_1, X_2, \dots, X_9\}$, which comprised a separate set of data. The X_i values were then converted to Y_i'values (the standardised grades of the indicators) according to the following relationships, which express the affiliation of the X_i value to the given standardisation interval and the Y_i'value:

for

$$X_i < (\bar{X} - 2\sigma) \Rightarrow = 1,$$

$$(\bar{X} - 2\sigma) \leq X_i < (\bar{X} - 1\sigma) \Rightarrow \; Y_i' = 2,$$

$$(\bar{X} - 1\sigma) \leq X_i < (\bar{X} + 1\sigma) \Rightarrow \; Y_i' = 3,$$

$$(\bar{X} + 1\sigma) \leq X_i < (\bar{X} + 2\sigma) \Rightarrow \; Y_i' = 4,$$

$$X_i \geq (\bar{X} + 2\sigma) \Rightarrow \; Y_i' = 5. \tag{4}$$

A summary of the calculations is presented in Appendix 2C.

The resulting standardised indicator grades determined via the interval method are shown in Tab. 50.

Tab. 50 Standardised Y' grade values of the indicators as determined via the interval method

Indicator	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1a	3	3	3	3	3	3	5	3	3
C1b	3	3	3	3	2	3	4	3	4
C1c	3	3	3	3	3	3	5	3	3

Indicator	BP	CE	CI	HO	HR	JA	KH	MA	NS
C2a	2	3	3	3	2	4	3	3	4
C3a	3	3	3	3	2	2	4	3	3
C3b	3	2	5	3	3	3	3	3	3
C3c	3	3	3	3	3	4	5	3	3
C4a	3	3	3	2	2	3	5	4	3
C4b	3	3	3	2	3	3	5	3	3
C5a	3	3	3	3	3	1	3	3	3
C5b	3	3	3	3	3	3	5	3	3
C5c	3	3	3	3	3	2	4	3	3
C5d	3	3	3	3	3	3	3	5	3
C5e	3	2	3	3	3	3	5	3	3
C5f	2	3	3	3	4	2	4	3	3
C5g	3	5	3	3	3	3	3	3	3
C6a	3	3	3	3	3	2	3	4	3
C6b	3	4	3	3	3	2	3	4	3
C6c	3	3	3	3	3	2	2	3	2
C6d	3	3	4	3	2	2	3	4	3
C7a	3	5	3	3	2	3	3	2	3
C7b	2	3	3	3	3	3	5	3	3
C7c	2	4	3	3	3	3	5	3	3
C7d	3	5	3	3	3	3	3	3	3
C8a	3	3	3	1	3	3	5	3	3
C9a	3	2	4	5	3	3	3	3	3
C9b	3	5	3	3	3	3	3	3	3
C10a	3	3	3	3	3	3	3	4	4
C10b	3	3	4	3	4	3	3	3	3
C10c	4	3	3	3	5	3	3	3	3
C11a	2	3	2	2	3	3	3	2	3
C11b	3	3	3	2	3	4	3	3	2
C11c	2	3	2	2	2	3	3	3	3
C11d	3	3	3	3	4	4	3	3	2
C12a	4	3	3	4	3	1	3	3	4
C12b	3	3	3	3	3	5	3	3	3
C13a	3	3	3	2	3	2	2	3	3

Indicator	BP	CE	CI	HO	HR	JA	KH	MA	NS
C13b	3	4	3	3	3	4	3	3	4

It is clear from Tab. 50 that the value interval standardisation method leads to the significant levelling out of the values for the sites and the subsequent need for the consideration of the expert assessment of the various differences.

8.1 Comparative procedure no. 1

This comparative calculation procedure comprised the determination of the more suitable sites using the criteria weightings determined according to the Saaty matrix of pairwise comparisons, as in the basic calculation (see Chapter 6), but with the assessment of the sites according to the weightings of the assessment experts and the subsequent averaging of the grades determined for the sites.

The same values as determined via the standardisation calculation of the indicator grades and the same indicator weightings were applied as in the basic calculation, see Chapters 6.5 and 6.1. The weightings of the criteria were determined by each of the assessment experts using the Saaty pairwise comparison matrix.

The reason for the application of this procedure was to maintain the individuality of the opinions of the assessment experts for as long as possible in the calculations. This was achieved by requiring each expert to calculate their own assessment. The result of the procedure comprised the averaging of the resulting values.

The mathematical notation of the calculation procedure is identical to that applied in Chapter 6. The difference between the basic calculation and comparative procedure no. 1 comprised the fact that the mathematical calculation was repeated for each of the assessment experts, i.e. a total of 26 assessments were performed.

The calculation is documented in Appendix 2B; the results for each of the experts are included in Appendices 1A (Matrix of pairwise comparisons), 2B1 (Calculation of the assessment) and 2B2 (Summary calculation).

The resulting calculation procedure comprised the determination of the average grade for each site from the results provided by each of the assessment experts.

The basic premise of comparative calculation no. 1 was that all of the experts provided accurate assessments, bearing in mind that the expert group provided a wide range of often very different views on the various issues. Therefore, outliers were not included in the assessment and the complete set of results was applied in order to maintain the variability of the expert opinions on the sites.

Ultimately, this meant that all the grades obtained for the sites from all the experts were averaged. The results are shown in Tab. 51.

Tab. 51 Weighted values of the grades of the sites according to comparative assessment calculation procedure no. 1

BP	CE	CI	HO	HR	JA	KH	MA	NS
2.374	**2.757**	**2.673**	**2.111**	**2.137**	**1.961**	**3.795**	**2.976**	**2.770**

The colour highlighted values in the table indicate the calculated threshold assessment values. The lowest values, highlighted in green, represent the qualitatively most suitable site, while the orange highlighted (highest) values represent the qualitatively least suitable site.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 1.834 and the differences between the sites range from 0.7% to 44.6%. The difference between the more suitable four and less suitable five sites is 16.3% of the total difference between the first and ninth sites, i.e. a difference in the grades of 0.3; see the overview presented in Tab. 52.

Tab. 52 Results of the site assessment calculations - comparative procedure no. 1

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Comparative procedure no. 1									
Site	**JA**	**HO**	**HR**	**BP**	CI	CE	NS	MA	KH
Grade	1.961	2.111	2.137	2.374	2.673	2.757	2.77	2.976	3.795
Grade difference		0.151	0.026	0.237	0.299	0.085	0.012	0.206	0.819
Difference %		8.2	1.4	12.9	**16.3**	4.6	0.7	11.2	44.6

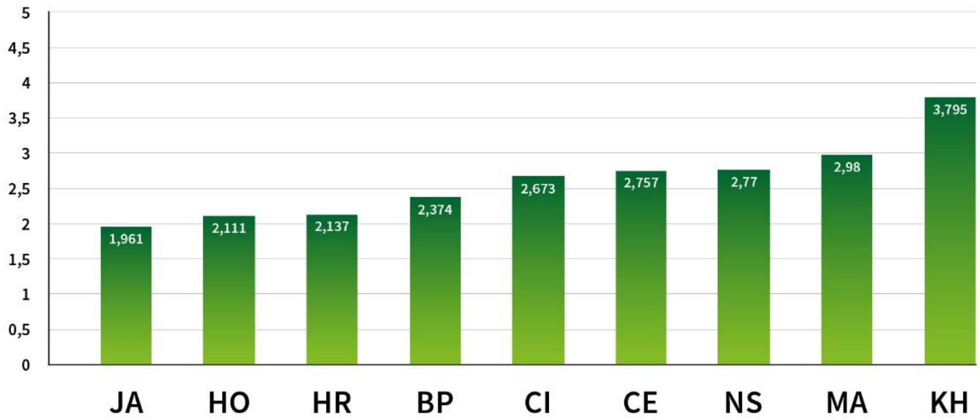


Fig. 31 Graph illustrating the results of comparative calculation no. 1

The results revealed the similarity of the 2nd and 3rd placed sites and the 6th and 7th placed sites. The comparative calculation produced practically the same results as did the basic procedure.

Comparison procedure no. 1 was based on a different approach to the use of the criteria weightings to that of the basic calculation. The basic procedure involved the averaging of the weightings of the criteria, which led to the convergence of the results of the assessment experts even though they may have had completely different views on the significance of the criteria.

Comparative calculation no. 1, on the other hand, took this fact into account via the calculation method.

The calculation according to comparative procedure no. 1 resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

8.2 Comparative procedure no. 2

The second comparative calculation procedure was based on the same principle as that of the basic calculation. However, the difference comprised the method used for determining the standardised indicator grades, see Fig. 29.

The standardisation of the grade assessment of the indicators, i.e. conversion to a scale of 1 to 5, where 1 is the best value of the given indicator and 5 is the worst value was performed via the interval method, see the introduction to Chapter 8 and Appendix 2A. The selected calculation procedure was used for the checking of the assessment result in the case that differences between the sites are minimised by standardising the values of the indicators to the interval.

The subsequent calculation procedure is identical to the basic calculation.

The weightings of the indicators are described in detail in Vondrovic et al. (2019), Butovič et al. (2020), Havlová et al. (2020a-i), Lahodová and Popelová (2020) and Krajíček et al. (2020) and summarized in Chapter 6.1**Chyba! Nenalezen zdroj odkazů.**.

The weightings of the criteria were determined using the Saaty matrix of pairwise comparisons according to the procedure set out in Vondrovic et. al. (2019) and described in 6.2 (accompanied by their values). Further, see Appendix 1A.

The calculation was performed according to the procedure described in Vondrovic et al. (2019) for each site as follows:

The standardised grade of a given indicator Y_i' was multiplied by the value of the respective indicator weighting. All the weighted indicator values within each of the criteria were then totalled and multiplied by the weighting of the respective criterion. The resulting weighted values of the criteria were then totalled for each site. The result comprised an overall grade for each site - the resulting utility value. The determined grades were arranged in ascending order and the four lowest values were selected.

The mathematical expression of the calculation procedure is identical to that described in Chapter 7.

The calculation is documented in Appendix 2C and the results are summarised in Tab. 53 and, graphically, in Fig. 32.

Tab. 53 Weighted values of the grades of the sites according to comparative assessment calculation procedure no. 2

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1	0.396	0.396	0.396	0.396	0.384	0.396	0.648	0.396	0.408

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C2	0.066	0.099	0.099	0.099	0.066	0.132	0.099	0.099	0.132
C3	0.573	0.535	0.649	0.573	0.439	0.458	0.745	0.573	0.573
C4	0.366	0.366	0.366	0.244	0.275	0.366	0.610	0.458	0.366
C5	0.410	0.475	0.432	0.432	0.454	0.338	0.526	0.475	0.432
C6	0.288	0.307	0.317	0.288	0.259	0.192	0.269	0.365	0.269
C7	0.16	0.272	0.192	0.192	0.176	0.192	0.256	0.176	0.192
C8	0.075	0.075	0.075	0.025	0.075	0.075	0.125	0.075	0.075
C9	0.132	0.101	0.172	0.211	0.132	0.132	0.132	0.132	0.132
C10	0.218	0.195	0.218	0.195	0.263	0.195	0.195	0.215	0.215
C11	0.081	0.099	0.081	0.074	0.097	0.114	0.099	0.091	0.084
C12	0.069	0.063	0.063	0.069	0.063	0.08	0.063	0.063	0.069
C13	0.09	0.105	0.09	0.075	0.09	0.09	0.075	0.09	0.105
Total	**2.924**	**3.088**	**3.149**	**2.874**	**2.773**	**2.76**	**3.841**	**3.207**	**3.052**

The colour highlighted values in the table represent the calculated threshold values for the given criteria. The lowest values, highlighted in green, represent the qualitatively most suitable sites with respect to the given criterion, while the orange highlighted (highest) values represent the qualitatively least suitable sites concerning the given criterion.

Tab. 53 also reveals the levelling of the values of the sites due to the standardisation of the grades, which is reflected in the larger number of occurrences of the same grades for the sites for a given criterion, even with concern to extreme values, i.e. the minimum and maximum.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 1.08 and the differences between the sites range from 1.2% to 58.7%. The difference between the more suitable four and less suitable five sites is 11.8% of the total difference between the first and ninth sites, i.e. a difference in the grades of 0.127; see the overview presented in Tab. 54.

Tab. 54 Results of the site assessment calculations - comparative procedure no. 2

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Comparative procedure no. 2									
Site	**JA**	**HR**	**HO**	**BP**	NS	CE	CI	MA	KH
Grade	2.76	2.773	2.874	2.924	3.052	3.088	3.149	3.207	3.841
Grade difference		0.013	0.1	0.051	0.127	0.037	0.061	0.057	0.635

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Difference %		1.2	9.3	4.7	**11.8**	3.4	5.6	5.3	58.7

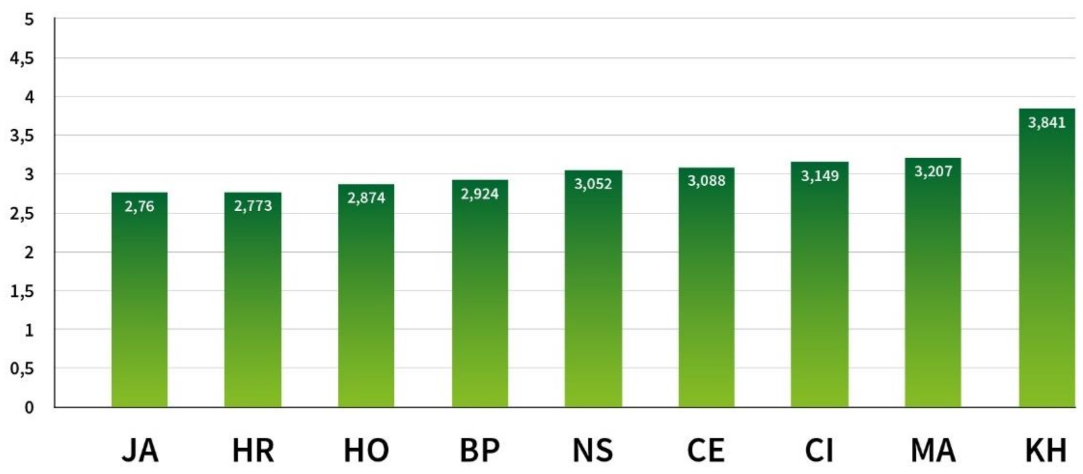


Fig. 32 Graph illustrating the results of comparative calculation no. 2

Comparative procedure no. 2 is computationally (in terms of the applied operations) the same as the basic calculation. The difference lie in the method used for the standardisation of the indicator grades as described in Chapter 8; this standardisation method led to the convergence of the sites and acted to diminish the smaller differences between them. This was reflected in a change in the rankings of those sites which, according to the basic calculation, were very close, and the diminution of the overall difference between the lowest and highest grades (the difference between 1st and 8th sites was just 0.45). Moreover, the difference between 4th and 5th sites was diminished, which forms the boundary between the more suitable four sites and the less suitable five sites.

In comparison with the basic calculation, the order of the sites that were very close (2nd and 3rd) was reversed. The change in the calculation also affected the 5th and 7th positions.

However, the overall result was identical to that determined by the basic calculation in terms of the four more suitable sites, the grade difference between which and the five less suitable sites was 11.8%, i.e. 4.6% lower than the value determined by the basic calculation; nevertheless, it represents a material difference.

The calculation according to comparative procedure no. 2 resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

8.3 Comparative procedure no. 3

Comparative calculation procedure no. 3 was based on the determination of the more suitable sites using the criteria weightings determined via the Saaty matrix of pairwise comparisons, as with the basic calculation, but with the evaluation of the sites according to the weightings assigned by the assessment experts and the subsequent averaging of the site grades according to the assessment experts, see comparative procedure no. 1.

Comparative procedure no. 3 combines comparative procedures 1 and 2.

The same indicator weightings were used for the calculation as in the basic calculation, see Chapter 6.1. The weightings of the criteria were determined by each of the assessment experts via the Saaty matrix of pairwise comparisons, see Appendix 1A.

The standardisation of the assessment of the grades of the indicators was performed by means of the interval method, see Appendix 2A.

The basic premise of comparative calculation no. 3, as in the case of comparative calculation no. 1, was the fact that none of the experts provided inaccurate ratings and that the selections of the experts involved a wide range of often very different views on each of the issues. Hence, outliers were not considered in the assessment and the complete data set of results was used in order to maintain the variability of the expert opinions on the assessed sites.

Ultimately, this meant that all the grades obtained for the sites from all the experts were averaged, see Appendix 2D. The result is shown in Tab. 55.

Tab. 55 Weighted values of the grades of the sites according to comparative assessment calculation procedure no. 3

BP	CE	CI	HO	HR	JA	KH	MA	NS
2.925	**3.088**	**3.149**	**2.872**	**2.773**	**2.761**	**3.843**	**3.207**	**3.052**

The colour highlighted values in the table represent the calculated assessment threshold values. The lowest value, highlighted in green, represents the qualitatively most suitable site, while the orange highlighted (highest) value represents the qualitatively least suitable site.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 1.082 and the differences between the sites range from 1.1% to 58.8%. The difference between the more suitable four and less suitable five sites is 11.7% of the total difference between the first and ninth sites, i.e. a difference in the grades of 0.127; see the overview presented in Tab. 56.

Tab. 56 Results of the site assessment calculations - comparative procedure no. 3

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Comparative procedure 3									
Site	**JA**	**HR**	**HO**	**BP**	NS	CE	CI	MA	KH
Grade	2.761	2.773	2.872	2.925	3.052	3.088	3.149	3.207	3.843
Grade difference		0.012	0.099	0.052	0.127	0.036	0.061	0.058	0.636

Ranking	1	2	3	4	5	6	7	8	9
Difference %		1.1	9.2	4.8	**11.7**	3.4	5.6	5.4	58.8

Comparative procedure no. 3 is computationally (according to the applied operations) identical to comparative procedure no. 1. The difference in the approach comprises the application of standardised indicator grades via the interval method, see Chapter 8.3. This standardisation approach led to a reduction in the differences between the sites, which was reflected in a change in the rankings of those sites which, according to the basic calculation, were very close, and the diminution of the overall difference between the lowest and highest grades; moreover, the difference between 4th and 5th sites was diminished, which forms the boundary between the more suitable four sites and the less suitable five sites.

Compared to comparative procedure no. 2, which is based on the same standardised indicator grades, the difference is insignificant and the ranking of the sites is identical. The difference between the four more suitable and the five less suitable differed by no more than 1%.

Compared to the basic calculation, as in the case of comparative procedure no. 2, the ranking of the 2nd and 3rd sites changed relative to each other, as did the 5th and 7th sites. However, the overall result was identical to that determined by the basic calculation in terms of the four more suitable sites, the grade difference between which and the five less suitable sites was 11.7%, i.e. 4.6% lower than the value determined by the basic calculation.

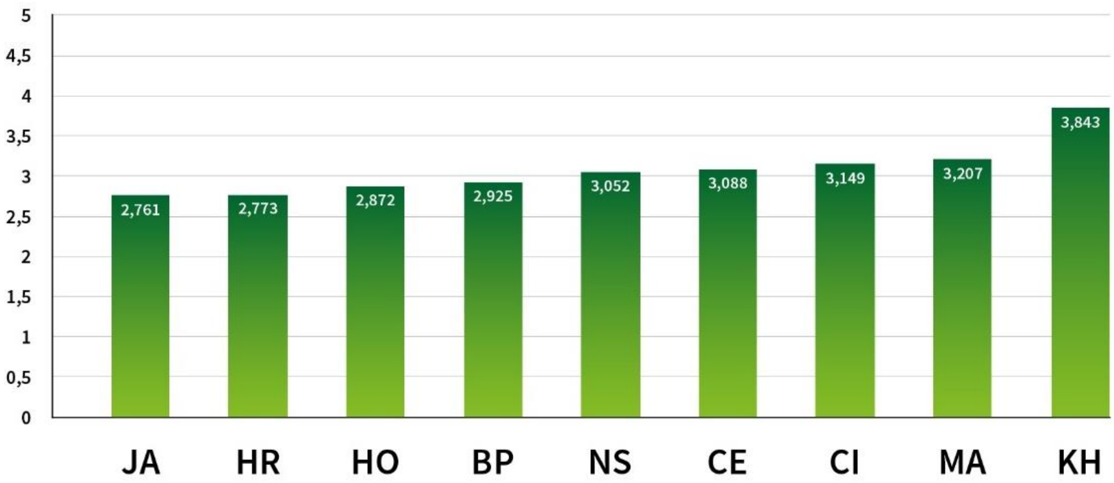


Fig. 33 Graph illustrating the results of comparative calculation no. 3

The calculation according to comparative procedure no. 3 resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

8.4 Comparative procedure no. 4

Comparative procedure no. 4 comprised a balanced approach to the criteria. The calculation was based on the standardised indicator grades according to Chapter 6.5.

The weightings of the indicators are described in detail in Vondrovic et al. (2019), Butovič et al. (2020), Havlová et al. (2020a-i), Lahodová and Popelová (2020) and Krajíček et al.(2020) and summarised in Chapter 6.1.

The standardised grade value for a given indicator was multiplied by the value of the respective indicator weighting. All the indicators that referred to each criterion were subsequently totalled and the resulting value comprised the value of the respective criterion.

Each criterion was assigned a weighting of 100% and then the calculated values of the various criteria were totalled for each site.

The result comprised the overall grade of each site - the resulting utility value. The grades attained were arranged in ascending order and the four lowest values were selected from the result. With respect to the method used for the standardisation of the indicator grades, this calculation procedure is hereinafter referred to as procedure no. 4a. The calculation of the standardised indicator values is documented in Appendix 1B; the standardised indicator values are presented in Chapter 6.5.

The mathematical expression of the calculation is set out below.

The criterion grade is calculated as the sum of the products of the standardised indicator value and its weighting within the relevant criterion.

$$K_j^L = \sum_{i=1}^{n_j} Y_{i,j}^L \times v_{i,j} \quad (5)$$

where: K_j^L is the value (grade) of the *j-th* criterion of the *L-th* site (j=1, 2, ..., 13, L = 1, 2, ..., 9),

$Y_{i,j}^L$ is the standardised grade of the *i-th* indicator of the *j-th* criterion of the *L-th* site (i=1, 2, ..., n_j),

$v_{i,j}$ is the weighting of the *i-th* indicator of the *j-th* criterion,

n_j is the number of indicators of the *j-th* criterion.

The final utility value of each site was determined according to the formula:

$$Z_L = \sum_{j=1}^{13} K_j^L \times 100\% \quad (6)$$

where: Z_L is the final weighted grade for the given site,

K_j^L is the value (grade) of the *j-th* criterion of the *L-th* site (j=1, 2, ..., 13, L = 1, 2, ..., 9).

The calculation is documented in Appendix 2E1 and summarised in Tab. 57; it is graphically illustrated in Fig. 34.

Tab. 57 Values of the grades of the sites according to comparative assessment calculation procedure no. 4a

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1	1.736	1.216	1.051	1.404	1.758	1.674	4.949	2.756	2.689
C2	1.950	2.880	3.8	4.190	1	4.660	3.75	3.21	5
C3	2.87	2.263	3.48	2.147	1.73	1.7	4.55	2.75	3.173

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C4	2.1	2.8	2	1.15	1.1	2.225	5	3.275	2.125
C5	2.12	3.185	2.725	2.675	2.715	1.09	3.875	3.265	2.525
C6	3.58	3.97	4.19	3.24	2.39	1.12	2.55	5	3.11
C7	1.25	4.3	1.8	1.95	1.775	2.075	3.35	1.375	2
C8	3	3	3	1	3	3	5	3	3
C9	1.668	1.4	3.411	4.6	2.111	2.234	2.449	2.246	1.806
C10	3	2.3	2.4	1	3.8	1.6	1	2.2	2.2
C11	2.033	4.233	2.033	1.5	3.533	5	4.233	2.967	3.2
C12	2.2	1.8	2.5	2.2	2.5	3.8	2.5	1.8	2.9
C13	3	5	3	1	3	2.333	1	3	4.333
Total	**30.51**	**38.35**	**35.39**	**28.06**	**30.41**	**32.51**	**44.21**	**36.84**	**38.06**

The colour highlighted values in the table represent the calculated threshold values for the given criteria. The lowest values, highlighted in green, represent the qualitatively most suitable sites with respect to the given criterion, while the orange highlighted (highest) values represent the qualitatively least suitable sites concerning the given criterion.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 16.151 and the differences between the sites range from 0.6% to 36.3%. The difference between the more suitable four and less suitable five sites is 17.8% of the total difference between the first and ninth sites, i.e. a difference in the grades of 2.88; see the overview presented in Tab. 58.

Tab. 58 Results of the site assessment calculations - comparative procedure no. 4

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Comparative procedure no. 4a									
Site	**HO**	**HR**	**BP**	**JA**	CI	MA	NS	CE	KH
Grade	28.06	30.41	30.51	32.51	35.39	36.84	38.06	38.35	44.21
Grade difference		2.357	0.095	2.004	2.879	1.453	1.218	0.286	5.858
Difference %		14.6	0.6	12.4	**17.8**	9	7.5	1.8	36.3

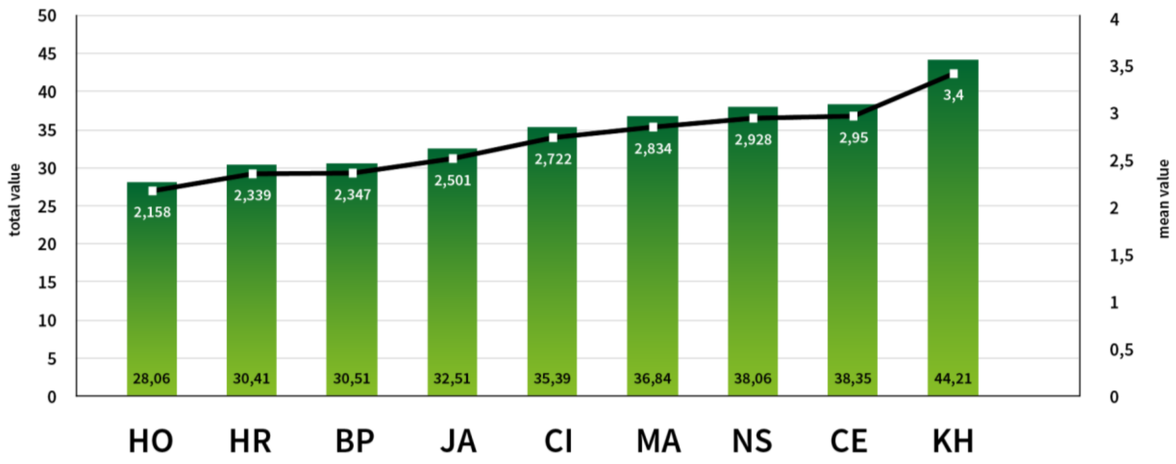
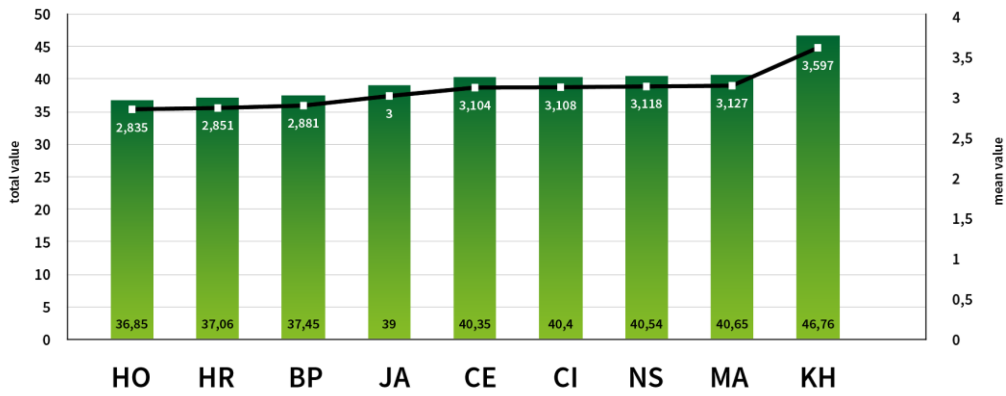


Fig. 34 Graph illustrating the results of comparative calculation no. 4a

The calculation according to comparative procedure no. 4a resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.



Due to the use of two methods for the standardisation of the indicator grade values, a control calculation (4b) was performed in the same way as calculation 4a, the difference being the standardisation of the indicator values using the interval method; see the introduction to Chapter 8.

The calculation is documented in Appendix 2E2, the results of the comparative calculation are summarised in Tab. 59 and illustrated graphically in Fig. 35.

Tab. 59 Values of the grades of the sites according to comparative assessment calculation procedure no.4b

Criterion	BP	CE	CI	HO	HR	JA	KH	MA	NS
C1	3	3	3	3	2.91	3	4.91	3	3.09
C2	2	3	3	3	2	4	3	3	4
C3	3	2.8	3.4	3	2.3	2.4	3.9	3	3
C4	3	3	3	2	2.25	3	5	3.75	3
C5	2.85	3.3	3	3	3.15	2.35	3.65	3.3	3
C6	3	3.2	3.3	3	2.7	2	2.8	3.8	2.8
C7	2.5	4.25	3	3	2.75	3	4	2.75	3
C8	3	3	3	1	3	3	5	3	3
C9	3	2.3	3.9	4.8	3	3	3	3	3
C10	3.35	3	3.35	3	4.05	3	3	3.3	3.3
C11	2.45	3	2.45	2.25	2.95	3.45	3	2.75	2.55
C12	3.3	3	3	3.3	3	3.8	3	3	3.3
C13	3	3.5	3	2.5	3	3	2.5	3	3.5
Total	**37.45**	**40.35**	**40.4**	**36.85**	**37.06**	**39**	**46.76**	**40.65**	**40.54**

The colour highlighted values in the table represent the calculated threshold values for the given criteria. The lowest values, highlighted in green, represent the qualitatively most suitable sites with respect to the given criterion, while the orange highlighted (highest) values represent the qualitatively least suitable sites concerning the given criterion.

The relative differences are evident from the calculated total grades. The total difference between the grades of the most and least suitable sites is 9.91 and the differences between the sites range from 0.5% to 61.7%. The difference between the more suitable four and less suitable five sites is 13.6% of the total difference between the first and ninth sites, i.e. a difference in the grades of 1.35; see the overview presented in Tab. 60.

Tab. 60 Results of the site assessment calculations - comparative procedure no. 4

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
comparative procedure no. 4b									
Site	**HO**	**HR**	**BP**	**JA**	CE	CI	NS	MA	KH
Grade	36.85	37.06	37.45	39	40.35	40.4	40.54	40.65	46.76
Grade difference		0.21	0.39	1.55	1.35	0.05	0.14	0.11	6.11
Difference %		2.1	3.9	15.6	**13.6**	0.5	1.4	1.1	61.7

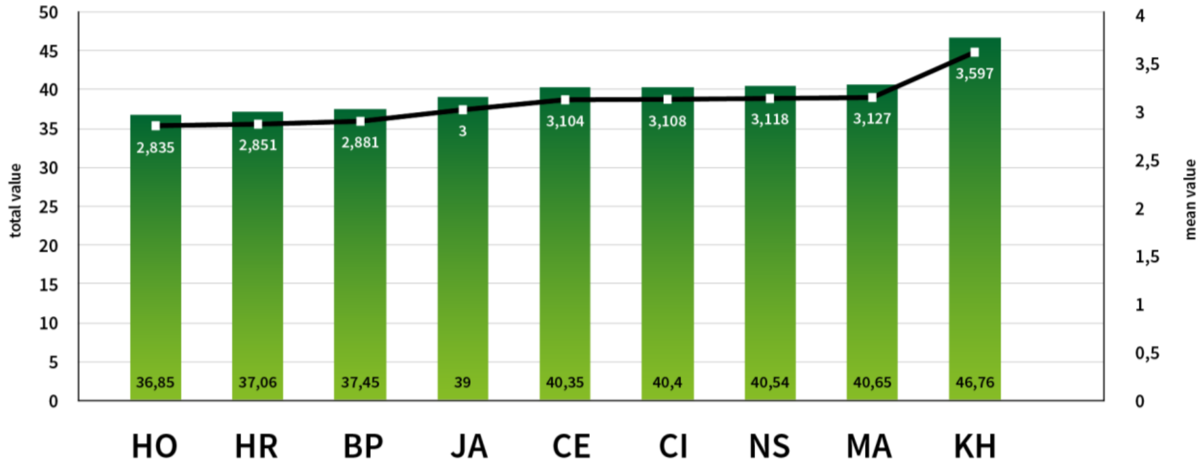


Fig. 35 Graph illustrating the results of comparative calculation no. 4b

The calculation according to comparative procedure no. 4b resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

Comparative procedure No. 4 is based on the equality of the various criteria, see Chapter 8.4, which is, naturally, reflected in the resulting site grades, which comprise the summation of the weighted indicator grades.

Due to the lack of consideration of the relative significance of the criteria, this procedure led to changes in the ranking of the sites due, in turn, to the amplification of the significance of those criteria, the values of which were suppressed by their lower weightings in the basic calculation. The result of the calculation procedure comprised the determination of a totalled grade for each site. The grades determined in this way cannot be compared to those determined via the basic calculation or the other comparative calculations. Any comparison is possible only on a relative basis, i.e. the ranking result and the differences between the order of the sites. For mutual comparison purposes, the average grades were calculated from the totalled grades, which was possible thanks to the assumption inherent in comparative calculation 4, i.e. the equality of the criteria.

Due to the equality of the criteria, the absolute values of the grades were higher than in the basic calculation.

The levelling of the criteria was reflected in a change in the ranking of the sites. The choice of the approaches to the standardisation of the values of the indicator grades, in terms of which the two modifications of the comparative procedure differed, also resulted in a reduction in the differences between the sites. However, the overall result, i.e. the determination of the four more suitable sites versus the five less suitable sites, was the same as in the basic calculation, only in a different order. In other words, the four more suitable sites were the same as those indicated by the basic calculation. The differences between the 4th (more suitable) and the 5th (less suitable) sites were 13.6% (4b) and 17.8% (4a).

8.5 Comparative procedure no. 5

Comparative procedure no. 5 can also be considered a variant of the absolute calculation, according to which the weightings of the criteria were not taken into account in the calculation of the utility value, a similar approach to that of procedures 4a and 4b. In addition, the weightings of the various indicators were also disregarded, which meant that all the indicators were assigned the same importance.

In order to be able to perform the comparative calculation according to procedure no. 5, it was necessary to convert all the indicator values on the same basis, i.e. the grades. Three sets of grade values were available for calculation purposes, i.e. grades as represented by the standardised values according to the weighted sum method $\mathbf{Y_i}$, standardised values according to the interval method $\boldsymbol{Y'_i}$and the primary values of the grades $\mathbf{X_i}$. A total of three variants were thus derived for comparative procedure no. 5.

The mathematical expression of procedure no. 5 is then simplified to the following form:

The site grade – the utility value was calculated as the sum of the standardised grades according to Chapter 6.4 for all the indicators for the relevant site.

$$Z_L = \sum_{j=1}^{13} \sum_{i=1}^{n_j} Y_{i,j}^L \quad (7)$$

where: Z_L is the final grade of the given site,

$Y_{i,j}^L$ is the standardised grade of the *i-th* indicator of the *j-th* criterion of the *L-th* site (i=1, 2, ..., n_j),

n_j is the number of indicators of the *j-th* criterion.

Note: when calculating variants b and c, the formula was the same, only the values $\boldsymbol{Y_{i,j}^L}$ were replaced by the values $\boldsymbol{Y'^L_{i,j}}$ or $\boldsymbol{X_{i,j}^L}$ according to the method applied for the standardisation of the indicator values.

The calculation is documented in Appendices 2F1-2F3 and the final results are summarised in Tab. 61 for all three modifications of comparative procedure no. 5. The results are shown graphically in Fig: 36.

Tab. 61 Summary table of the total of the indicator grades according to comparative procedure no. 5

Site	BP	CE	CI	HO	HR	JA	KH	MA	NS
Variant 5a									
Total	**89.1**	**118.7**	**98**	**82.8**	**92.7**	**85.3**	**129.7**	**106.4**	**105.8**
Variant 5b									
Total	**110**	**122**	**117**	**109**	**112**	**109**	**136**	**119**	**116**
Variant 5c									
Total	**86.0**	**111.6**	**95.5**	**88.2**	**85.4**	**80.9**	**124.2**	**101.9**	**98.5**

The colour highlighted values in the table represent the calculated assessment threshold values. The lowest value, highlighted in green, represents the qualitatively most suitable site, while the orange highlighted (highest) value represents the qualitatively least suitable site.

The relative differences are evident from the calculated total grades. The total differences between the grades of the most and least suitable sites are 46.9 for variant 5a, 27 for variant 5b and 43.3 for 5c, and the differences between the sites range from 1.2% to 26.3% (variant 5a), 0.0% to 51.9% (variant 5b) and 1.4% to 29% for variant 5c. The differences between the more suitable four and less suitable five sites are 11.4%, 14.8% and 16.9%, respectively of the total difference between the first and ninth sites, i.e. differences in the grades of 5.34 (variant 5a), 4 (variant 5b) and 7.33 (variant 5c), respectively.

The results are summarised in Tab. 62.

Tab. 62 Results of the site assessment calculations - comparative procedure no. 5

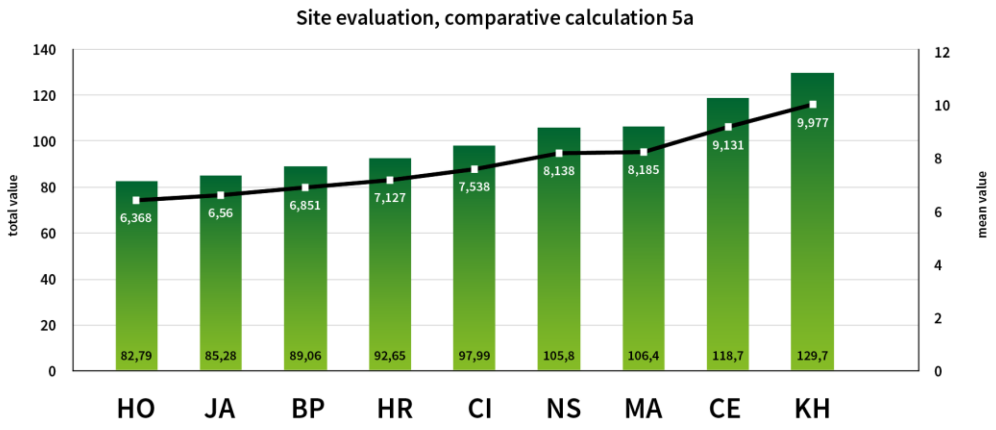
Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
comparative procedure no. 5a									
Site	**HO**	**JA**	**BP**	**HR**	CI	NS	MA	CE	KH
Grade	82.8	85.3	89.1	92.7	98	105.8	106.4	118.7	129.7
Grade difference		2.49	3.78	3.59	5.34	7.84	0.59	12.3	11
Difference %		5.3	8.1	7.7	**11.4**	16.7	1.2	26.3	23.3
comparative procedure no. 5b									
Site	**HO**	**JA**	**BP**	**HR**	NS	CI	MA	CE	KH
Grade	109	109	110	112	116	117	119	122	136
Grade difference		0	1	2	4	1	2	3	14
Difference %		0	3.7	7.4	**14.8**	3.7	7.4	11.1	51.9
comparative procedure no. 5c									
Site	**JA**	**HR**	**BP**	**HO**	CI	NS	MA	CE	KH
Grade	80.9	85.4	86	88.2	95.5	98.5	101.9	111.6	124.2
Grade difference		4.5	0.6	2.17	7.33	2.99	3.43	9.72	12.53
Difference %		10.4	1.4	5	**16.9**	6.9	7.9	22.5	29

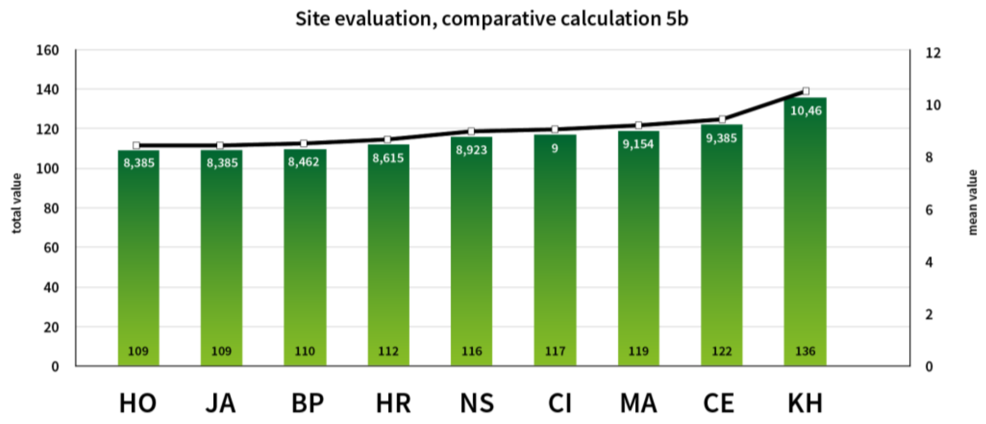
It is clear from Tab. 61 that the interval standardisation of values method applying the mean and standard deviation leads to the significant levelling of the resulting values for the sites and the requirement for the consideration of the differences as determined via the qualitative expert assessment process.

The calculation according to comparative procedure no. 5a resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

The calculation according to comparative procedure no. 5b resulted in the identification of the following four most suitable sites for the conducting of future geological investigation research (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.

The calculation according to comparative procedure no. 5c resulted in the identification of the following four most suitable sites (in alphabetical order): Březový potok, Horka, Hrádek and Janoch.





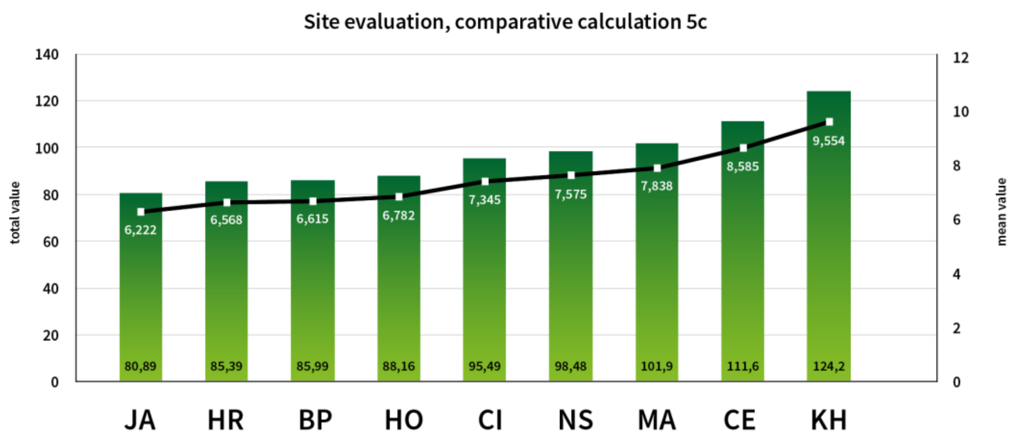


Fig: 36 Graph illustrating the results of comparative calculation no. 5

Comparative procedure no. 5 basically comprised the assessment of the ranking of the sites on the basis of the simple totalling of the indicator grades, both the primary values and those standardised by the two methods applied in the procedures described above. It comprised an absolute approach without considering the relative importance of the various indicators. Procedures 5a and 5b involved the use of the standardised grades; for more details see Chapter 8.5. However, the three versions of the comparative procedure provided the same results as the basic calculation in terms of the selection of the four more suitable sites. In addition, the difference between the four more suitable and the five less suitable sites was between 11.4% and 16.9%, which is in line with the other 4 procedures.

However, this comparative procedure fails to take into consideration the varying significance of the indicators.

9 Evaluation of the calculations and the uncertainties of the assessment process

9.1 Evaluation of the calculations

The basic site assessment calculation, see Chapter 7**Chyba! Nenalezen zdroj odkazů.**, identified the most suitable sites for the next stage of investigation work as follows (in alphabetical order):

- Březový potok;
- Horka;
- Hrádek;
- Janoch.

Tab. 63 Results of the site assessment calculation - basic procedure

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Site	**JA**	**HO**	**HR**	**BP**	CI	CE	NS	MA	KH
Grade	1.96	2.113	2.138	2.374	2.673	2.758	2.769	2.975	3.793
Grade difference		0.153	0.025	0.236	0.3	0.085	0.011	0.206	0.818
Difference %		8.3	1.3	12.9	**16.4**	4.6	0.6	11.2	44.6

It is clear from the overview presented in Tab. 63 that the selected calculation procedure for the determination of the four most suitable sites from the nine assessed sites determined a significant difference between the two groups of sites, i.e. one-sixth of the difference between the most suitable and least suitable sites.

In order to verify the robustness of the basic calculation (hereinafter referred to as the reference) and the results thereof, five different comparative calculations were performed, two of them involving partial calculation modifications. Thus, a total of 8 results variants were calculated for the comparison and verification of the results of the reference assessment calculation. The principles and detailed results of the various comparative calculations are addressed in Chapters 8.1 to 8.5. Tab. 64 shows the results attained via the various calculation approaches.

Tab. 64 Ranking of the sites according to the various calculations

Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Basic calculation	**JA**	**HO**	**HR**	**BP**	CI	CE	NS	MA	KH
comparative 1	**JA**	**HO**	**HR**	**BP**	CI	CE	NS	MA	KH
comparative 2	**JA**	**HR**	**HO**	**BP**	NS	CE	CI	MA	KH

Ranking	1	2	3	4	5	6	7	8	9
comparative 3	**JA**	**HR**	**HO**	**BP**	NS	CE	CI	MA	KH
comparative 4a	**HO**	**HR**	**BP**	**JA**	CI	MA	NS	CE	KH
comparative 4b	**HO**	**HR**	**BP**	**JA**	CE	CI	NS	MA	KH
comparative 5a	**HO**	**JA**	**BP**	**HR**	CI	NS	MA	CE	KH
comparative 5b	**HO**	**JA**	**BP**	**HR**	NS	CI	MA	CE	KH
comparative 5c	**JA**	**HR**	**BP**	**HO**	CI	NS	MA	CE	KH

The basic conclusion drawn from the results of the comparative calculations is the fact that the same four more suitable sites were indicated by all the procedures, albeit sometimes in different orders. The difference between the fourth and fifth placed sites, which forms the boundary for the selection of the sites is, in all cases, significant.

Tab. 65 shows the frequencies of the ranking of the sites according to the various calculations. The four more suitable and the five less suitable sites are discretely divided. The more suitable four sites are the same (albeit with changes in their order) with respect to all the calculations, as are the five less suitable sites. The ranking of the sites in the table header is according to the basic calculation, and the frequencies are given according to the various comparative calculations.

Tab. 65 Frequency of the occurrence of the ranking of the sites according to the comparative procedure calculations

Ranking	JA	HO	HR	BP	CI	CE	NS	MA	KH
1.	4	4							
2.	2	1	5						
3.		2	1	5					
4.	2	1	2	3					
5.					4	1	3		
6.					2	3	2	1	
7.					2		3	3	
8.						4		4	
9.									8

As can be seen from Tab. 64, the calculations that considered the weightings of the criteria, i.e. the basic calculation and comparative calculations 1 to 3, provided the same results with respect to the 1st and 4th places, while the order varied with concern to the 2nd and 3rd places. This was due to the application of the standardisation of the indicator values via the interval method, which served to diminish the differences between the sites. This phenomenon occurred due to the small difference between the 2nd and 3rd placed sites according to the basic calculation, i.e. just 1.3% of the grade which, in turn, was the result of the discrete values of the indicator grades which, following standardisation via the weighted sum method, were divided proportionally within the standardisation interval ⟨1; 5⟩ according to the ratio of mutual differences. Conversely, following standardisation via the interval method, the standardised values assigned represented the interval defined on the basis of the standard deviation; thus, acting to equalise some of the closer values following standardisation. This phenomenon is particularly noticeable in procedures 4b and 5b, where the values were not recalculated using the grades. However, since the priority of the assessment process was to determine the four more suitable sites, this phenomenon, i.e. the variation in the order of the sites, is practically irrelevant.

A graph illustrating the differences in the ranking of the sites is shown in Fig. 37.

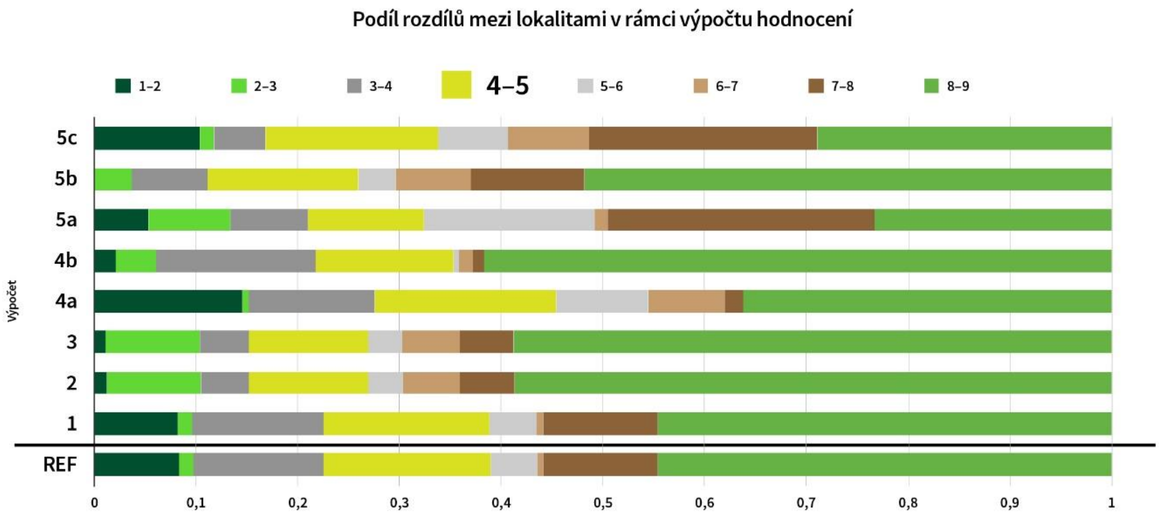


Fig. 37 Graph of the differences between the sites according to the various calculations

The above results (Tab. 64, Tab. 65) clearly indicate that the selected basic calculation procedure, which took into account the mutual significance of the criteria, was sufficiently robust for the selection of the four more suitable sites. The various comparative calculations that involved changes to the input values led to the same result.

The second stage of the assessment of the sites according to the methodology set out in Vondrovic et al. (2019), i.e. utility value calculations based on the determined levels of the significance of the various indicators and criteria and the resulting values for each site, and the subsequent comparative calculations (Tab. 49 and Tab. 51 to Tab. 65), determined four sites for further research, with only minor fluctuations in the order of these four sites. There was a significant difference between these four sites and the other five sites (which also included minor fluctuations in the order of the sites).

The assessment process was indifferent even to relatively fundamental changes in the input parameters and successfully distinguished four sites both with (basic calculation) and without (comparative procedures 4 and 5) the inclusion of the weighting of the values. The difference between the four more suitable and the five less suitable sites ranged between 11% and 17.8%

according to the calculation approach applied, which convincingly distinguished the two groups of sites.

9.2 Uncertainties of the assessment

9.2.1 C1 Size of the usable rock mass

The main assessment uncertainties concern a number of main areas (selection from Butovič et al. 2020). The first area concerns the uncertainty surrounding the way in which the SNF will be disposed of. The assessment of the project design is based on an update to the spatial location of the disposal sections in the rock polygons as defined in Pertoldová et al. (2019). The vertical disposal variant was chosen for the purpose of the comparison of the sites. Any future change in the disposal method will affect the assessment of the various related project indicators (Utilisation of the rock blocks, Fragmentation of the usable area and the Potential for the permanent disposal of the excavated material in the surrounding area). The SNF disposal method itself involves a number of technological uncertainties, which may affect the construction requirements with concern to the size and shape of the access and loading corridors and chambers. However, it can be assumed that this effect will be similar at all the sites, therefore it will not lead to any changes in terms of the relationships between the sites. A further uncertainty concerns the geological description of the sites, especially the orientation of the identified fault structures and their dimensions at repository depth. In terms of the stability and thermal calculations, the greatest uncertainties concern the parameters of the rock environment. Samples for the laboratory assessment of the rock environment parameters were taken from surface outcrops and the parameters of the rock environment were determined from a very limited number of samples. The final assessment uncertainty concerns the thermal-technical assumptions. The most important parameter in this respect comprises the thermal conductivity coefficient, which affects both the spacing between the disposal packages and the overall development of the temperature field over the observed time period. Even a small change in the order of tenths of W/mK will exert an impact on the spaces between the WDPs and this impact will be felt over the whole of the temperature field. Due to the high level of sensitivity and the fact that this thermophysical property is related to the anisotropy of the rock environment, it will be necessary to further investigate the influence of this factor going forward both theoretically and experimentally. The initial temperature comprises (after the coefficient of thermal conductivity) the most important thermal property. However, its significance and influence on the spacing and disposability of the WDPs (without extending their interim storage time) is strongly related to the thermal conductivity coefficient and, thus, is difficult to predict at the present time. With respect to those sites with below-average thermal conductivity coefficients (less than approx. 2.4 W/mK), where an initial temperature of 25°C is considered, it will be necessary to extend the SNF storage period to 65 years. The reduction of the initial temperature by 1-3°C, however, would allow for disposal without having to consider such a process, i.e. a standard storage period. Moreover, with respect to those sites with average and slightly above-average thermal conductivity coefficients, a small reduction in the initial temperature of the rock block will allow for a significant reduction in the spacing between the WDPs. The importance of the initial temperature decreases with increasing thermal conductivity, and at those sites with the highest thermal conductivities (around 3 W/mK and more) a reduction in the initial temperature will exert almost no practical effect on the spacing of the WDPs, since the temperature will decrease to below the value chosen as the technological minimum required for e.g. drilling and loading. Clearly, an increase in the initial temperature above the considered 25°C will exert the opposite effect. The significance of the initial temperature on the maximum temperatures in the rock block and the temperature field over the longer time horizon following disposal is significantly less than that of the thermal conductivity coefficient. The advantage of measuring and determining this quantity at the sites lies in the fact that it will always be approximately constant at a specific site, i.e. without the occurrence of any significant spatial inhomogeneities and, at the same time, it is an easily measurable quantity. Since during the project design phase (specifically the processing of the thermal engineering calculations) the temperatures at the disposal level at the various sites was unknown and a conservative value of 25°C was assigned to all the sites, this factor was not included in the assessment.

It is also necessary to note here that the influence of the above-mentioned parameters was assessed under the assumed input conditions of the project as a whole, which were often simplified and merely estimated since, at the current stage of the DGR development project in the Czech Republic they are not yet accurately known. The parameters concern the thermophysical properties of the bentonite (sealing material) and the interface between the rock blocks and the bentonite (and the related changes over time), as well as the ability of the internal parts of the WDPs to dissipate heat from the fuel assemblies to the surface of the container. These parameters act to significantly impact the maximum allowable temperature of the rock block.

9.2.2 C2 Infrastructure availability

In the current phase of project development, it is as yet unknown to what extent the excavated material will be used in the DGR project, especially with concern to its closure, i.e. whether it will be necessary to establish temporary (but long-term) landfill sites near to the DGR surface area. Alternatively, the excavated material will be used for construction purposes elsewhere or will be permanently disposed of. The current assessment of the suitability of the sites thus includes the consideration of the total volume of excavated material as well as the potential for its storage near the planned surface areas.

9.2.3 C3 Describability and predictability of the homogeneous blocks and C4 Variability of the geological properties

The assessment of the candidate DGR is a complex task that requires a huge amount of input data that is, necessarily, burdened with varying degrees of uncertainty (Havlová et al. 2020a-i). With respect to the spatial issues covered by these criteria, one of the uncertainties concerns the significant lack of information presently available (Wellmann and Regenauer-Lieb 2012). When evaluating the sites, it is important to identify and quantify the various sources of uncertainty. Given the current state of knowledge of the rock environments at the sites, however, the degree of uncertainty related to the various geological indicators cannot be accurately quantified. To date, none of the geological environments at the sites have been quantitatively defined. Therefore, the uncertainties in this area were determined via expert estimations. The semi-quantitative determination of the various uncertainties will be possible only after the conducting of more extensive geological exploration research, including the drilling of deep boreholes. The uncertainty associated with the assessment process concerns mainly the lack of knowledge of the spatial geometry of the faults and the thicknesses and character of their fillings, as well as their hydraulic and geomechanical parameters. For most of the faults so far registered at the candidate DGR sites, their inclinations and courses at DGR depth have not yet been precisely described. These parameters cannot be determined without further technical research and subsequent field testing. It is also difficult to determine the exact rate of rock mass fracturing at the planned DGR depth. However, the structural data obtained from the surface and their mathematical extrapolation provide a realistic picture of the form and density of fracture systems in the near-surface zones of the investigated rock masses. Nevertheless, the occurrence of fractures of similar orientations at greater depths can only be assumed at this time. The field work performed to date allows for the determination of the dominant fracture systems in the investigated areas; however, the accurate prediction of their changes with depth is not possible without the drilling of boreholes supplemented by logging methods and, ideally, mining exploration. Uncertainties are also associated with the course of water-bearing fault zones at DGR depth.

9.2.4 C5 Water flow characteristics in the vicinity of the DGR and the transport characteristics, and C6 Identification of drainage bases

All the hydrogeological data used as input information for the creation of hydraulic models of the sites concerns the surface and near-surface zones. None of the hydrogeological surveys and research performed to date has reached DGR depth, where differing rock hydraulic properties can be expected. The data on deep hydrogeological structures that would allow for a comprehensive hydrogeological assessment is not yet available, especially concerning the occurrence, orientation and hydraulic properties of water-conducting faults and failure zones at DGR depth. The evaluation of the hydrogeological conditions at DGR depth thus can only be based on the interpretation of surface data, analogical comparisons and expert estimations.

9.2.5 C7 Seismic and geodynamic stability

No relevant data on the age and activity of tectonic structures is available that would allow for the evaluation of potentially active faults. The next phases of the assessment process should, therefore, include the conducting of studies that include tectonic mapping and detailed geomorphological and morpho-tectonic analysis, including monitoring using optical methods, remote sensing and, ideally, the establishment of local seismic monitoring networks. The criteria and indicators concerning geodynamic stability were based primarily on the visual geomorphological interpretation of the candidate sites. Data sources on the velocity of denudation processes, vertical movements of the surface and the rate of the lowering of the drainage system are highly heterogeneous and, to some extent, unreliable due mainly to short measurement intervals and the reason for the acquisition of data. Some data sources are even in mutual conflict depending on the methodology used. Archival data on the rate of the lowering of drainage systems was taken from studies at the regional scale, and is not available on specific drainage basins. More recent studies, based on dating methods employing the isotopes ^{10}Be and ^{26}Al, have addressed only the wider area of the Bohemian Massif. Thus, there is a lack of more detailed analysis on the development of drainage systems in the affected river basins, including modern surface dating analysis.

9.2.6 C8 Characteristics that could lead to the disturbance of the DGR via future human activities

In terms of the evaluation of indicators that concern the monitoring of the probability of future human penetration into the DGR, no significant uncertainties were determined at any of the sites that might affect the decision-making process in the future. A small degree of uncertainty concerned possible changes in the delimitation of protected deposit areas and changes to the permitted depth range of certain stone deposit quarries (this mainly applies to the Deštná and Tis deposits). Uncertainty in terms of the potential use of geothermal energy are related to the current lack of a suitable legislative definition of geothermal energy sources in the Czech Republic since current technologies allow for the extraction of energy from low-temperature geothermal sources, without reference to natural geothermal anomalies.

In the case of the Kraví hora site (Havlová et al. 2020g), the uncertainties in the assessment relate to the presence of a relatively high number of significant deposits.

9.2.7 C9 Phenomena influenced by the spread of radioactive materials

The amount of released radioactive substances that could affect the radiation exposure of the population in the vicinity of the outlet of the DGR hot chamber is expressed via the so-called collective effective dose, the calculation of which requires a knowledge of the direction and strength of the wind thus determining the most likely point of impact of the radioactive substance. At this stage of the assessment process, no accurate meteorological data specifically on the sites is available; therefore, data from the nearest Czech Meteorological Institute station was used to calculate the collective effective dose. This data could differ from the actual values at the sites, specifically the DGR surface areas; hence the calculation of the collective effective dose is burdened by a certain degree of uncertainty. However, the collective effective dose depends on the number of inhabitants, which is known from the 2011 census conducted by the Czech Statistical Office. However, indicator C9a (the distribution and density of the population) is burdened by uncertainties related to natural migration and population growth and by census errors.

In order to assess the distance of the sites from nuclear power plants, the shortest transport route was selected using existing railway lines that meet the requirements of freight transport, especially a minimum weight of 20 t per axle. These distances were determined very precisely and correspond to the current railway network. However, it was calculated that the distance of the Na Skalním (EDU-west) site from the Dukovany nuclear power plant determined in this way is 127.3 km, while the direct distance is less than 20 km. In order to determine the probability of an emergency situation during the transport of SNF, it will be necessary to commission studies that assess the potential for the building of new railway connections and the impact of the frequency of the use of the respective lines and transport hubs. These factors exert an impact on the uncertainty surrounding the determination of the probability of the occurrence of an emergency situation during the transport of SNF from the storage sites to the DGR.

9.2.8 C10 Impact on surface waters and water resources

The assessment of this criterion will require additional data on the hydrological characteristics of the recipient watercourses. Moreover, it will be necessary to more accurately quantify the degree of disturbance of the runoff conditions in the surface areas via hydro-technical calculations, especially in cases where the surface area is traversed by watercourses.

From the point of view of underground water, it will be necessary to determine the risk to, and degree of impact on water resources that might be impacted by the underground part of the DGR as part of the geological characterisation research work and the compilation of a more detailed project design. One of the tasks of the safety reports on the various candidate sites is to prove that the construction and operation of the DGR will not adversely affect water resources in the wider areas of interest.

9.2.9 C11 Impacts on nature and the landscape

The basic condition for the more detailed assessment of the impacts on biodiversity and animal migration permeability at the candidate sites comprises the conducting of biological surveys that cover the entire vegetation period (approximately April-October) repeatedly over 2-3 years so as to sufficiently objectively document the biota status of the surface area and along the routes of proposed access routes, and including the evaluation of natural population fluctuations. Populations of all species undergo changes that are not directly related to the external environment, i.e. natural fluctuations. Their extent and the duration of the various phases thereof is, in some cases, not sufficiently known. The conclusions of the assessment concerning possible impacts on Natura 2000 and bird areas will need to be confirmed via the conducting of a standard impact assessment study according to Section 45i) of the Nature and Landscape Protection Act, especially in cases where the respective nature protection authority does not rule out significant negative impacts. In order to assess the effects on the landscape, it will be necessary to determine the specific features (target qualities) of the landscape in the affected areas and the degree of the disturbance thereof via the siting of the surface area. Based on the same data, it will also be possible to assess the degree of the visual exposure of the surface areas of the sites.

9.2.10 C12 Impacts on land

This criterion is impacted by only a small degree of uncertainty. The need to use agricultural and/or forested land for the surface areas of the DGR will be accurately determined in the subsequent more detailed stage of the project design work.

9.2.11 C13 Impacts on the population and property

As part of the next more detailed stage of the project design work concerning the surface parts of the DGR (surface area, access roads, electricity supply, excavated material management method, including potential external landfill sites), it will be necessary to compile standard dispersion and acoustic studies at least with concern to the DGR development and construction stages that will allow for the determination of the highest levels of exposure in the areas concerned. In addition to the assessment of the various individual components of the construction process, the compilation of a comprehensive assessment study of the cumulative and synergistic effects of the development and construction of the DGR as a whole in terms of time and space will be essential. Both studies will then form the basis for the assessment of the (non-radiation) health risks for the population in the affected areas.

The above uncertainties, especially those concerning key criteria C11-C13, are also burdened by uncertainties resulting from the current level of detail of the overall design project of the DGR and the absence of a range of input information that would allow for the more accurate quantification of the various influences considered by the respective set of indicators and, subsequently, the conducting of the standard EIA process according to the applicable legislation. According to Appendix 4 of the EIA Act, the assessment of climatic effects forms part of the EIA process. According to the currently valid methodological interpretation set out by the Ministry of the Environment (20 October 2017), the following aspects must be considered:

a) (a) the mitigation of the climate change impacts of the project;
b) (b) the impact of the project on climate change and the vulnerability of the project to the effects of climate change.

Moreover, with respect to the characteristics of the area that must be assessed in connection with the siting of nuclear facilities, climatic and meteorological phenomena must be considered as set out in Section 10 of Decree No. 378/2016 Coll., on the siting of nuclear facilities. Four parameters have been identified in this respect (certain variables may be included in several parameters):

a) parameters concerning the impact of the project on the Earth’s climatic system;
b) parameters concerning the impact of the project on local climatic conditions;
c) parameters concerning the influence of climatic conditions on the project;
d) input data for the determination of wind factors.

In order to obtain this data for the candidate sites, it will be necessary to monitor the selected phenomena to the extent proposed in Svoboda et al. (2019):

a) direct greenhouse gas emissions - annual total;
b) indirect greenhouse gas emissions - annual total;
c) air temperature - daily averages;
d) precipitation - daily totals;
e) relative humidity - daily averages;
f) wind direction and speed - 10-minute averages and the maximum value of the wind speed within given intervals.

A further uncertainty of the assessment process concerns the siting of the surface area and related transport routes, which will form the main sources of impacts on the environment. The maximum horizontal distance between the surface and underground parts of the DGR has been set at 5 km (according to technical and economic conditions). This distance was derived from the maximum permissible slope of the tunnel (10%) that connects the surface area and the disposal section of the DGR. This principle is respected by the technical designs of all the sites. The assessment is also based on the results of geophysical and geological research conducted at the sites (Mixa et al. 2019), based on which promising areas for the project design work were defined according to the presence of rock blocks with potentially favourable properties for the siting of the disposal sections. If the more detailed technical project designs for the selected sites prove the need for changes to the delimitation (spatial arrangement) of the surface area, or identify problems resulting from its location, a more suitable location for the surface area which exerts the least possible impact on the environment will be determined. Similarly, if follow-up surveys and assessments indicate the significant negative effects of the surface area on the environment, without the potential for their prevention, it will be excluded or the effects will be mitigated via the application of technical and/or organisational measures.

Despite the incidence of the above uncertainties, it can be stated that, at the expert estimate level, it was possible to adequately assess the candidate sites according to the set criteria and indicators.

10 Conclusion

10.1 Assessment results

Based on the conclusion of the first step of the assessment process, eight candidate DGR sites (Březový potok, Čertovka, Čihadlo, Horka, Hrádek, Janoch (ETE-south), Magdaléna and Na Skalním (EDU-west) were found not to be in direct conflict with any of the exclusion criteria based on the available data. While the site assessed to be in ninth place, Kraví hora, was found to be in conflict with the exclusion criteria related to the nearby Rožná and Olší former uranium mines, it was determined that this conflict could be resolved via the adoption of administrative-technical measures. Therefore, all the sites met the conditions for the siting of the DGR based on the available data and according to the set assessment methodology (Vondrovic et al. 2019).

The second step of the assessment process - the comparison of the sites according to the calculation described in Chapter 7**Chyba! Nenalezen zdroj odkazů.** - resulted in the identification of the four most suitable sites, i.e. (in alphabetical order) Březový potok, Horka, Hrádek and Janoch (ETE-south). There was a significant difference in the resulting values with respect to the next four (less suitable) sites, i.e. Čertovka, Čihadlo, Magdaléna, Na Skalním (EDU-west) and a further significant difference between these sites and the least suitable site, i.e. Kraví hora. This result was confirmed by the comparative calculations set out in Chapters 8.1 to 8.5.

The assessment calculation thus successfully distinguished the relatively more suitable four sites from the five less suitable sites.

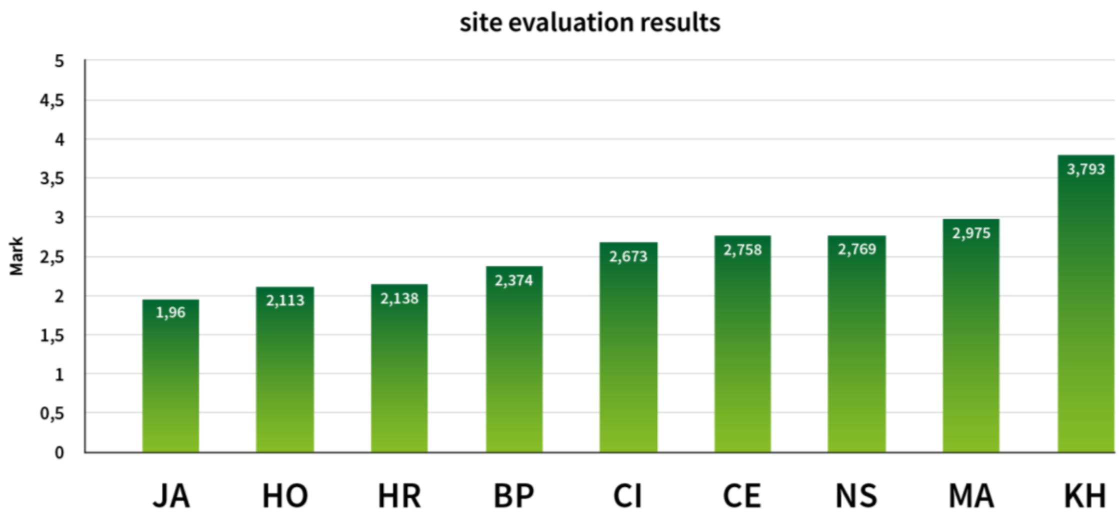


Fig. 38 Result of the site assessment process

Therefore, in line with the results of the assessment process based on the multi-criteria analysis approach, the following sites were recommended to the Government of the Czech Republic for follow-up research work (in alphabetical order):

- **Březový potok**
- **Horka**

- **Hrádek**
- **Janoch (ETE-south).**

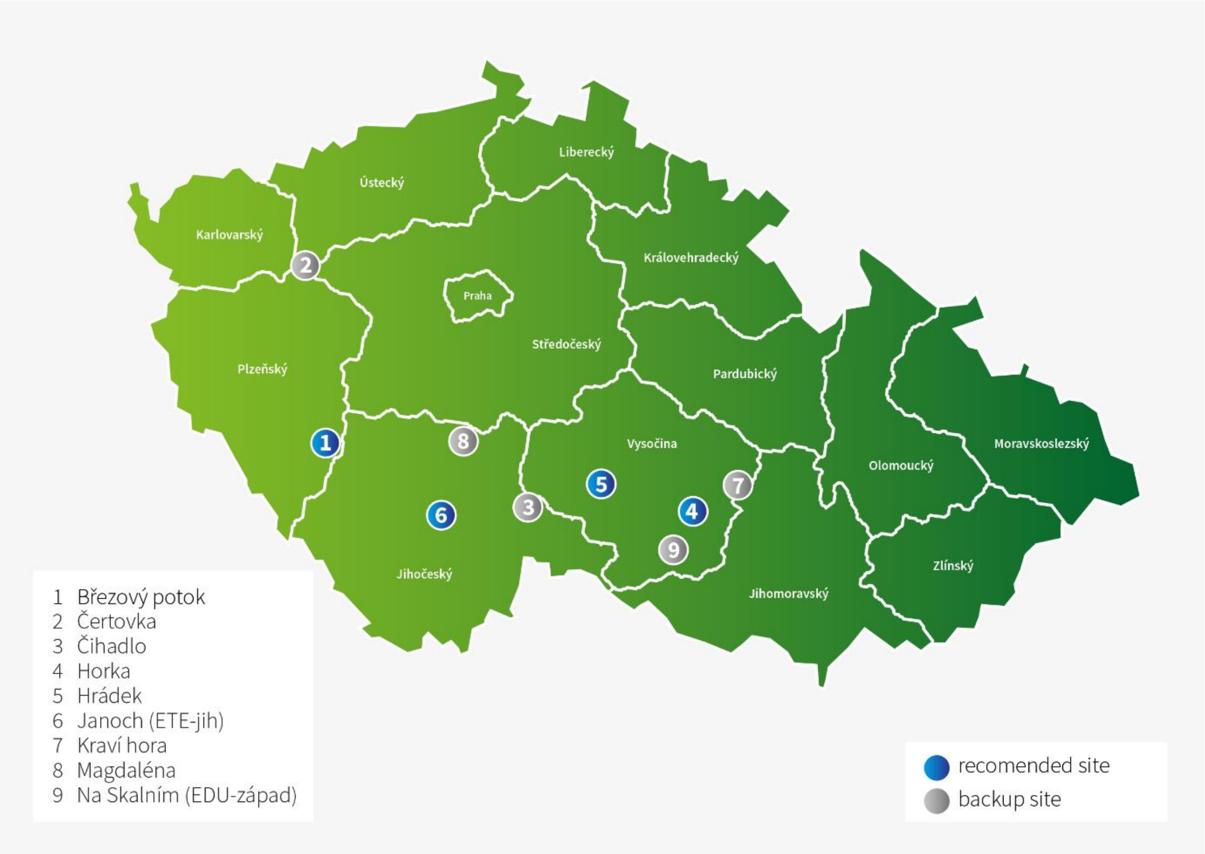


Fig. 39 DGR sites destined for the next stage of research (recommended sites) and sites not recommended for the next research stage (backup sites)

The other sites that were not recommended for the next stage of research are considered backup sites (in alphabetical order):

- Čertovka
- Čihadlo
- Kraví Hora
- Magdaléna
- Na Skalním (EDU-west).

Based on the current level of knowledge, these sites also fulfilled the safety and technical requirements for DGR siting according to the methodology (Vondrovic et al. 2019). If the subsequent geological characterisation stage identifies rock environment conditions at the four more suitable sites that result in their immediate exclusion from the assessment process, these five sites could be included once more in the assessment process under certain assumptions with respect to the exclusionary characteristics listed in Decree No. 378/2016 Coll. on the siting of nuclear facilities and the availability of the knowledge on the assessed criteria that is required in order to meet the regulatory conditions for the issuing of the relevant safety certification. Due to the fact that such situations could occur only during the conducting of subsequent more detailed research at the sites, it would be necessary to re-assess the exclusion criteria with respect to the re-inclusion of a particular site based on newly-acquired information on the site. Furthermore, it would be necessary to assess the prospects of the remaining sites so as to ensure that the re-included backup site exhibits similar properties to those of the previously defined more suitable sites so that the characteristics of the newly-added site are not significantly worse than the those of the others. Only then can it be recommended to return the site to the assessment process. In addition, it is important to bear in mind that the ultimate aim of the assessment procedure according to the current version of the DGR Concept is to select one main and one backup site, i.e. at further reducing the number of sites.

Due to the principle of the gradual reduction of the number of sites and the repeated inspection of the sites in terms of the exclusion criteria, the probability of returning one of the backup sites to the assessment process is very unlikely for technical reasons.

Without further detailed geological characterisation research work (obtaining data from the expected depth of the repository) it is unlikely that any significant qualitative changes will be identified at any of the sites, especially from the point of view of proving the safety and feasibility of DGR construction at specific sites.

10.2 Recommendations for follow-up work at the recommended sites in the next research stage based on the assessment process

Work on the recommended sites will focus both on the reduction of uncertainties in the descriptions of the sites as described in Chapter 9.3 and, specifically, on the characteristics according to which the sites are unique according to the assessment grades assigned.

Recommendations for the sites subjected to further study based on the assessment of the uncertainties

The planning of the research at all four recommended sites is based primarily on the uncertainties of the current assessment stage as outlined in Chapter 3 of this report. With respect to technical feasibility, it will be necessary to determine the technical parameters of the rock blocks, obtain data for the assessment of the compatibility of the engineered barriers and the rock environment at DGR depth, and address both thermal dimensioning issues and the overall project design. Furthermore, such research will have to be carried out at the sites, which will allow for the accurate definition of the rock blocks for the isolation part of the DGR and the determination of the DGR surface area including its overall layout and the various technical issues involved along with the economic assessment of the local infrastructure. The geological research will take the form of both research *per se* and the conducting of geological surveys, depending on the defined aims. The research will focus mainly on verifying the nature and thickness of the rock interfaces that could serve as preferential groundwater flow pathways and the verification of existing knowledge on the character thereof. Moreover, geophysical research at the sites will be of key importance; the drilling of experimental boreholes will allow for the accurate determination of the characteristics of the rock environment and the position of the rock mass in terms of fulfilling the various requirements of the isolation part of the DGR.

With respect to underground water circulation, the research will focus on the verification of data on deep hydrogeological structures, especially on the occurrence, orientation and hydraulic properties of conductive faults and fracture zones at DGR depth. Concerning the stability characteristics, it will be necessary to obtain long-term data from monitoring research and, with respect to operational safety, both monitoring research and studies will be conducted aimed at verifying the transport routes for the waste and the respective handling procedures. Aimed at addressing the environmental criteria, data will be obtained from the long-term monitoring of the various components of the environment, and research will be conducted for the preparation of a comprehensive assessment of the cumulative and synergistic impacts of the development and construction of the DGR as a whole in terms of time and space considerations. These studies will then form the basis for the assessment of the (non-radiation) health risks for the population in the affected areas.

The multi-criteria assessment process, based on currently available data, identified the four relatively more suitable DGR candidate sites. In order to fully demonstrate the safety, technical feasibility and environmental impacts of the DGR project and to select the final site for the DGR it will be necessary to ensure that the outputs of the research involved fully meet the requirements of Decree No. 378/2016 Coll. on the siting of nuclear facilities and Act No. 100/2001 Coll. on environmental impact assessments. The research involved in the selection of the final and backup sites will aim to confirm the location of both the underground part of the DGR (i.e. promising area for the project design work) and the surface area/access infrastructure and to fully resolve any outstanding conflicts of interest. The data obtained from each of the four sites, together with the final disposal and safety concept, will then allow for the objective selection of the final and backup sites, the submission of applications for the establishment of protected areas for special intervention into the earth’s crust and the planning of an underground confirmation laboratory. Furthermore, it will be necessary to initiate the long-term monitoring of the defined areas, which will serve to determine the impact of DGR operation on the environment and the population. However, the above objectives can only be achieved via the provision of information to the municipalities concerned on all the stages of the process and the consideration of their requirements and comments concerning the technical design of the DGR project, e.g. through the establishment of working groups at the sites.

The recommendation of sites based on the assessment procedure and the comparison of the sites

Březový potok

The assessment of the Březový potok site was the most balanced of all the sites with respect to the considered criteria. Further work should focus on determining the exact location of the promising area for the project design work and the siting of the underground disposal area in the most suitable part of the homogeneous rock block(s), especially with regard to the transport characteristics of the rock environment. Furthermore, the parameters of the surface area should be determined to a more precise extent.

Hrádek

The Hrádek site was assessed relatively positively especially with respect to the geological (C3) and infrastructure availability (C2) criteria, it was comparable with the other sites concerning the hydrogeological criteria (C5 and C6) and was relatively worse than the other recommended sites in terms of criteria C10 and C1. The subsequent research of this site should focus primarily on the verification and possible expansion of the promising area for the project design work and, especially, the more precise assessment of the influence of the DGR on local water resources. Furthermore, as with all the sites, it will be necessary to assess the siting of the surface area and its layout.

Horka

The Horka site was assigned the best grades of all the recommended sites with respect to criterion (C1), and the best grades of all nine compared sites concerning the environmental (C10, 11, 13) and site stability (C8) criteria. However, these criteria were assigned relatively lower weightings in the assessment process. Further work should focus mainly on verifying the nature of the identified geological interfaces and the exclusion of relatively unsuitable geological structures. Although the surface area is sited favourably with regard to the environmental criteria, its location should be subjected to further optimisation. The worst rating for the site concerned criterion C9; the negative assessment for this criterion reflected primarily the local population density, a factor that cannot be mitigated by technical or other measures.

Janoch (ETE-south)

The Janoch (ETE-south) site was assessed favourably in terms of the hydraulic (C5 and C6) and geological (C3) criteria. The particularly favourable assessment for this site concerned primarily the location of the underground part of the repository, i.e. along a hydrological watershed with a relatively extensive reserve. Follow-up work should, therefore, focus primarily on verifying the defined rock blocks and the geological structures in the immediate vicinity of the site. However, it was rated less favourably for the criteria concerning the location of the surface area (especially criteria C11 and C12). Hence, it will be necessary to re-evaluate and optimise the existing surface area in terms of its location and layout during the subsequent research of the site.

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Appendix 1 Site assessment calculations (available only in CZ version of the report)

Appendix 1A – Determination of the criteria weightings using pairwise comparison matrices (Saaty)

Appendix 1B – Standardisation of the indicator grades via the weighted sum method

Appendix 1C – Site assessment calculation

Appendix 2 Comparative calculations (available only in CZ version of the report

Appendix 2A – Standardisation of the value of the indicator Y'_i via the interval method.

Appendix 2B1 – Calculation of the assessment according to comparative procedure no. 1.

Appendix 2B2 – Summary calculation for comparative procedure no. 1.

Appendix 2C – Calculation of the assessment according to comparative procedure no. 2.

Appendix 2D1 – Calculation of the assessment according to comparative procedure no. 3.

Appendix 2D2 – Summary calculation for comparative procedure no. 3.

Appendix 2E1 – Calculation of the assessment according to comparative procedure no. 4a.

Appendix 2E2 – Calculation of the assessment according to comparative procedure no. 4b.

Appendix 2F1 – Calculation of the assessment according to comparative procedure no. 5a.

Appendix 2F2 – Calculation of the assessment according to comparative procedure no. 5b.

Appendix 2F3 – Calculation of the assessment according to comparative procedure no. 5c.

Appendix 3 Assessment experts

Appendix 3A – Alphabetical list of the SAATY matrix of pairwise comparison assessment experts (in alphabetical order).

Ing. Jaromír Augusta, Ph.D.

He graduated in Construction and Traffic Engineering at the Faculty of Civil Engineering of the Czech Technical University.

He works as the Head of the Design and Engineering Activities department of SÚRAO. He is a member of the Czech Tunnelling Association ITA-AITES and the Blasting Technology and Pyrotechnics Society. He has certification in the fields of geotechnics, the testing and diagnostics of buildings and mining and is a court-appointed forensic expert in construction issues: expansion disconnection, blasting and its impacts on the environment, and geotechnics.

Professional experience: 25 years in the field of geotechnics, 4 years in the field of the development of the DGR.

RNDr. Mgr. Zita Bukovská, Ph.D.

She graduated in geology at the Faculty of Science, Charles University.

She works at the Czech Geological Survey as a research and development expert in geological and related fields. She is a member of the Czech National Committee and the Czech Geological Society and has expertise in geochemistry, the research of geological structures and environmental geology.

Professional experience: 6 years, of which 4 years in the field of the development of the DGR.

Ing. Alexandr Butovič, Ph.D.

He graduated in Construction and Traffic Engineering at the Faculty of Civil Engineering of the Czech Technical University.

He works at SATRA, s.r.o. as the production director. He has certification in the fields of geotechnics and mining design and is an expert consultant for the Czech Mining Authority. He teaches at the Department of Geotechnics, Faculty of Civil Engineering, Czech Technical University, is a member of the Czech Chamber of Authorised Engineers and Technicians in the field of geotechnics and was awarded the “Quida Záruba academic award” for young engineering geologists and geo-technicians in 2004.

Professional experience: 20 years in the field of the design of underground structures and 5 years in the field of the development of the DGR.

Ing. Matěj Černý, Ph.D.

He graduated in Environmental Modelling at the Czech University of Life Sciences.

He works as an independent researcher at PROGEO s.r.o. and is a member of the Czech Geothermal Association.

Professional experience: 9 years in the field of hydrogeological modelling and hydrological assessment, 5 years in the field of the development of the DGR.

Ing. Markéta Dohnálková

She graduated in Geotechnics and Underground Structures at the Faculty of Civil Engineering, Technical University of Ostrava.

She works as a specialist in the research and development of the DGR (SÚRAO). She is a member of the Young Generation section of the Czech Nuclear Society and the Czech Tunnelling Association.

Professional experience: 12 years in the field of nuclear waste repositories, 10 years in the field of the development of the DGR.

RNDr. Václava Havlová, Ph.D.

She graduated in Geochemistry and Applied Geology at the Faculty of Science, Charles University.

She works as the Head of the Fuel Cycle Chemistry Department of the Fuel Cycle Chemistry and Waste Management Division at ÚJV Řež, a.s. She is a member of the Natural Analogues Group, the Crystalline Club and the Czech Nuclear Society. She holds high-level certification in the field of radiation protection.

Professional experience: 26 years in the field of radioactive waste, 12 years in the field of the development of the DGR.

doc. Ing. Jan Jelínek, Ph.D.

He graduated in Applied Geology and Geological Engineering at the Faculty of Mining and Geology, VŠB-Technical University in Ostrava.

He works for the Czech Geological Survey as a research and development expert in geological and related fields. He is a member of the review committee of the Czech Association of Raw Materials Deposit Geologists.

Professional experience: 21 years in 3D modelling, morpho-structural and morphotectonic analysis and structural-tectonic and regional geological research, 4 years in the field of the development of the DGR.

Ing. Dušan Kobylka, Ph.D.

He graduated from the Faculty of Mechanical Engineering at the Brno University of Technology in Thermal and Nuclear Power Machinery and Equipment, and the Faculty of Nuclear and Physical Engineering at the Czech Technical University in Nuclear Engineering.

He works as an assistant professor at the Faculty of Nuclear and Physical Engineering at the Czech Technical University, where he teaches and supervises student dissertations.

Professional experience: 21 years in the energy and safety of nuclear power plants, 4 years in the field of the development of the DGR.

Ing. Kateřina Konopáčová

She graduated in the Processes and Management of Chemical and Food Production at the Faculty of Chemical Engineering of the University of Chemistry and Technology, Prague.

She works as a technical development specialist in the Design and Engineering Activities department of SÚRAO.

Professional experience: 19 years in the field of environmental and quality management, 3 years in the field of the development of the DGR.

RNDr. Libor Krajíček

He graduated in Basic and Deposits Geology at the Faculty of Science, Charles University.

He works as an executive and as the chief designer at Atelier T-plan, s.r.o. He is a member of the Association for Urbanism and Area Planning and holds certification for the processing of documentation and EIAs according to Section 19 of Act. No. 100/2001 Coll., on environmental impact assessment.

Professional experience: 33 years in area planning and environmental impact assessment, 17 years in the field of the development of the DGR.

Ing. Zdena Lahodová

She graduated from the Faculty of Nuclear Sciences and Physical Engineering at the Czech Technical University in technical, physical and analytical chemistry; she specialises in statistical data processing.

She works as a technical specialist in long-term safety at SÚRAO. She holds certification in statistical data analysis in the energy sector.

Professional experience: 16 years at the LVR-15 nuclear reactor research centre, Řež, 3 years in the field of the development of the DGR.

Ing. Jiří Martinčík, Ph.D.

He graduated in Nuclear Engineering at the Faculty of Nuclear and Physical Engineering at the Czech Technical University.

He works as a research and development expert in physics at the Faculty of Nuclear Sciences and Physical Engineering at the Czech Technical University in Prague.

Professional experience: 14 years in the field of nuclear radiation research, 2 years in the field of the development of the DGR.

RNDr. Martin Milický

He graduated in Hydrogeology and Engineering Geology at the Faculty of Science, Charles University.

He works as the Managing Director and executive of PROGEO, s.r.o. He is a member of the Czech Association of Hydrogeologists and the Czech Geothermal Association. He holds certification of professional competence in the design, performance and evaluation of geological work in the fields of hydrogeology and remediation geology.

Professional experience: 32 years in the fields of hydrogeology, hydrogeological modelling and exploration, 26 years in the field of the development of the DGR.

RNDr. Petr Mixa

He graduated in Raw Materials Deposits Geology at the Faculty of Science, Charles University.

He works at the Czech Geological Survey as the deputy Managing Director and geological specialist. He is a member of the Czech Geological Society, IAGOD and secretary of the Czech Tectonic Group. He holds certification of professional competence in the fields of geological structures and geochemistry.

Professional experience: 34 years in raw materials deposits geology, geological mapping and structural geology, 3 years in the field of the development of the DGR.

RNDr. Jaroslava Pertoldová CSc.

She graduated in Raw Materials Deposits Geology at the Faculty of Science, Charles University.

She works as the head of department and research and development expert in geological and related fields at the Czech Geological Survey. She holds certification in the design, performance and evaluation of geological research with concern to deposits geology, geological structure research and environmental geology.

Professional experience: 33 years in the exploration of mineral resources and geological research, 15 years in the field of the development of the DGR.

Ing. Eva Popelová, Ph.D.

She graduated in Nuclear Chemistry and Analytical Chemistry at the Faculty of Nuclear and Physical Engineering at the Czech Technical University.

She works at SÚRAO as the head of the RAW Safety Assessment department.

Professional experience: 17 years in the design of nuclear facilities - RAW management, and 2 years in the field of the development of the DGR.

Mgr. Lenka Rukavičková, Ph.D.

She graduated in Engineering Geology and Hydrogeology at the Faculty of Science, Charles University and in Natural Science Engineering at the Technical University of Liberec.

She works as a research and development expert in geological and related fields at the Czech Geological Survey. She holds certification in the design, performance and evaluation of geological research with concern to the research of geological structures and hydrogeology.

Professional experience: 30 years in the field of groundwater hydrochemistry and the hydrogeology of solid rocks, 25 years in the field of the development of the DGR.

Ing. Zdeněk Skořepa

He graduated in Chemical and Technical Environmental Protection at the University of Pardubice - Faculty of Chemical Technology.

He works at Atelier Bohemiaplan as the head of the environment group at Valbek, s.r.o. He holds certification concerning environmental impact assessment.

Professional experience: 24 years in the field of environmental protection, 1 year in the field of the development of the DGR.

Ing. Jiří Svoboda, Ph.D.

He graduated in Construction and Traffic Engineering specialising in Geotechnics and Physical and Materials Engineering at the Faculty of Civil Engineering of the Czech Technical University.

He works at the Centre of Experimental Geotechnics of the Faculty of Civil Engineering, Czech Technical University. He is a member of ITA-AITES and is an IAEA consultant.

Professional experience: 15 years in the field of geotechnics and engineered barriers, 15 years in the field of the development of the DGR.

Mgr. Ondřej Švagera

He graduated in Structural Geology at the Faculty of Science, Charles University.

He works as a research and development expert in geological and related fields at the Czech Geological Survey.

Professional experience: 7 years in the fields of structural geology, 3D geological modelling and geological mapping, 4 years in the field of the development of the DGR.

Ing. Radek Trtílek

He graduated in Nuclear Engineering from the Faculty of Nuclear and Physical Engineering of the Czech Technical University in Prague and in the Chemistry of Nuclear Power Plants at the Comenius University in Bratislava.

He works as a division head at ÚJV Řež a.s. He is an IAEA expert mission member and member of an OECD/NEA working group, the Czech Nuclear Society and the Czech Nuclear Association.

Professional experience: 31 years in the field of nuclear energy and radioactive waste management, 6 years in the field of the development of the DGR.

Ing. Jan Uhlík, Ph.D.

He graduated in Geo-hydraulics at the Faculty of Civil Engineering at the Czech Technical University.

He works as the deputy Managing Director and executive of PROGEO, s.r.o. He is a member of the Czech Association of Hydrogeologists.

Professional experience: 24 years in the field of hydrogeology and hydrogeological modelling, 13 years in the field of the development of the DGR.

Mgr. Jozef Urík

He graduated in Applied Geophysics at the Faculty of Science, Charles University.

He works as the head of the Geological Barriers department and chief specialist for technical development at SÚRAO. He holds certification in geophysics (Ministry of the Environment of the Czech Republic) and in working with closed sources of ionising radiation both in the Czech Republic (SÚJB) and Slovakia (Public Health Office of the Slovak Republic).

Professional experience: 14 years in the field of geophysics, 4 years in the field of the development of the DGR.

Ing. Antonín Vokál, CSc

He graduated in Chemistry at the University of Chemistry and Technology, Prague and studied for one year at a British university.

He works as a research and development coordinator at SÚRAO and managed the “Research support for the safety assessment of the deep repository” project. He holds high-level certification in various aspects of radiation protection.

Professional experience: 43 years in the field of nuclear research, 10 years in the field of the development of the DGR.

RNDr. Lukáš Vondrovic, Ph.D.

He graduated in Structural Geology at the Faculty of Science, Charles University.

He works as the Head of the Radioactive Waste Repository Development department at SÚRAO. He is a member of the OECD/NEA and is chair of the IGSC Crystalline Club.

Professional experience: 12 years in the field of geology, 5 years in the field of the development of the DGR.

Mgr. Ondřej Zahradník

He graduated in Engineering Geology at the Faculty of Science, Charles University.

He works as a project manager at Mott MacDonald CZ, s.r.o.

Professional experience: 13 years in the field of geotechnics, GT monitoring and the supervision of infrastructure projects, 3 years in the field of the development of the DGR.

Appendix 3B – Assessment expert statements on the creation of the Saaty matrices of pairwise comparisons - listed according to the order of the assessment experts in the calculations.

Assessment expert 1:

I proceeded from the consideration of the overall initial matrix arrangement; in my opinion the significance of the criteria was in the order commencing C3 (without a definable rock block, it is not possible to consider the construction of a DGR at the site - the quality of the defined rock block(s) is taken into account in the grade assessment of the sites). This was followed by the slightly less important criteria C1, C5 and C10, concerning the sufficient extent of the rock block, favourable hydrogeological properties and the protection of water resources at the site, all of which are important for the siting of the underground part of the DGR. I considered C6 and C4 still less important criteria due to the lower level of significance of the variability of the geological properties compared to the size of the rock block since, whereas the isolation capacity of the massif will be ensured by the thickness of the rock overburden, the influence of the drainage bases is, in my opinion, dependent on the settings of the HG model. Lower in the order of importance are criteria C9 and C11. C9 reflects the operational safety of, particularly, the surface part of the DGR and is an area that is heavily regulated through legislation, and the fulfilment of these requirements requires the adoption of the appropriate technical and administrative measures; however, it is a source of potential risk to the population. C11 concerns impacts on nature and the landscape, which depend on the siting of the surface area in particular and, again, are addressed by legislation. Given the current uncertainties concerning the siting and layout of the surface areas of the sites, these criteria were not assigned significant priority; nevertheless, the minimisation of these impacts must not be neglected. The penultimate criteria in my opinion are C8 and C12, which reflect possible intrusion into the DGR and the effects on land. Intrusion (accidental intrusion into the DGR due to the loss of information on the DGR is a decisive factor), is a factor that is burdened with a high level of uncertainty related to future requirements for mineral resources, the exploitation of which would disrupt the functioning of the DGR. Impacts on land are unavoidable, however the extent of this impact will be directly dependent on the location and layout of the surface area, concerning which there remains a relatively high degree of uncertainty. Finally, criteria C2, C7 and C13; criterion C2 takes into account the handling of excavated material at the sites, which is burdened by a high degree of uncertainty concerning its possible reuse. C7 reflects the stability of the sites and, with regard to the current level of uncertainty, many of the risks can be mitigated by adopting the appropriate technical measures. C13 concerns influences on the "well-being" of the population which, again can be addressed via the adoption of technical and administrative measures and must be considered in conjunction with the interest of society as a whole with respect to ensuring safety.

Assessment expert 2:

The matrix assessment was performed via an initial comparison of the criteria according to their importance (in my opinion) in terms of the significance and influence of the outputs of each criterion. Therefore, greater emphasis was placed on the criteria related to the underground complex, the construction of which can be influenced to some extent by technical remediation measures, while less importance was accorded to the surface area-related criteria. My assessment was conducted on the basis of several years of experience of working on DGR safety issues.

Assessment expert 3:

Before the meeting of the various experts, I studied all the available relevant SÚRAO reports, on which I based my final assessment. During the meeting, I followed the presentations and detailed discussions of my colleagues on those criteria with which I have limited professional experience and posed a number of questions aimed at forming a more accurate idea of their relative importance.

I then divided the 13 criteria into 3 groups (of varying numbers) according to their importance from my point of view in terms of reducing the number of candidate DGR sites. My classification of the criteria was based on the degree of knowledge currently available on the various issues, the sensitivity of changes to and refinement of the available information based on future research and surveys, and the potential for the influence of the adoption of administrative and/or organisational measures.

Subsequently, I compared the criteria in the most important group, then the criteria in the second group both mutually and in relation to the criteria in the most important group so as to maintain the consistency of my assessment. Finally, I took the same approach with concern to the group of criteria that I considered the least important.

Assessment expert 4:

Following the presentations on the various assessment criteria, I classified them according to professional-personal criteria. In first place, I allocated those criteria that are difficult to address via the adoption of technical measures, i.e. the geological and hydrogeological properties of the sites. Conversely, I considered the least important criteria to be those on which there is relatively little data, or to those that were similar for all the sites. I placed a relatively high value on the ecological and relatively low value on the socio-economic aspects.

Assessment expert 5:

Based on the presentations on the assessment criteria and my expert opinion, I considered the most important aspects of the assessment process to concern the homogeneous rock blocks, which serve to define the size of the future DGR; these characteristics cannot be influenced by the technical design of the repository and are, therefore, insurmountable. Furthermore, all the criteria concerning the safety of the DGR are relatively important. These criteria were followed by those that can be influenced by the technical design of the repository and that do not impact the safety of the DGR.

Assessment expert 6:

Following the explanation of the various criteria (presentations from the assessment experts), I allocated the highest weightings to those criteria that are in my opinion:

- the most important in terms of the given phase of the DGR development programme, i.e. mainly the geological and hydrogeological criteria
- best able to distinguish the sites based on the available data
- are not linked to the surface area (it can be relocated)
- cannot be significantly influenced by the adoption of technical or administrative measures.

From my point of view, the most important criteria comprise C3, the Describability and predictability of the rock blocks, which is of high importance in terms of the location of the underground part of the DGR outside failure zones (it is related to the importance of criteria C1, the Size of the usable rock blocks) and C5 and, hence, C6 which are significant with respect to the potential influence of the migration of radionuclides towards the environment and, thus, significantly affect the long-term safety of the DGR.

Other criteria that are connected mainly with the location of the surface area and conflicts of interest are, in my opinion, less significant at this stage.

Assessment expert 7:

I placed the greatest emphasis on the criteria that I considered to be the most important from the point of view of long-term safety and stability, i.e. criteria that are linked to the description of the character of the rock environment, which cannot be influenced by the adoption of legislative or technical measures and which also distinguish well between the various sites. These criteria will enable the accurate definition of the most suitable parts of the homogeneous rock blocks. I considered of less importance those criteria that are related to the technical design of the construction of the DGR complex. I also considered those criteria linked to current legislation on the long-term safety of the repository to be of lower importance.

Assessment expert 8:

Based on the information obtained from the presentations of my colleagues and from my own work on various related projects, I assigned the highest importance to those criteria that in my opinion most affect long-term safety and the construction and design of the DGR. I took into account the current state of knowledge of the data on the sites to a lesser extent since the data will be supplemented going forward, and I slightly preferred those criteria that could be clearly quantified. Therefore, I consider the most important criteria to be those related to the rock blocks and their properties. I considered the criteria relating to the environment to be of lesser importance and I attached the least importance to those criteria that can be addressed by the adoption of the relevant technical or other measures.

Assessment expert 9:

The basic condition for the siting of the DGR (with a sufficient spatial reserve) comprises a homogeneous rock block with properties that allow *inter alia* for a certain level of predictability in terms of long-term safety.

Thus, I considered (at this stage of the assessment process) the criteria that took into account the above factors to be of highest importance. Further important criteria also include those that consider the flow of water in the vicinity of the DGR, including transport characteristics (long-term safety) and impacts on surface water, groundwater and water resources (climatic changes).

I evaluated those criteria that included factors that can be addressed by technical and administrative measures as being of lower importance - the locations of the surface areas at the sites are reference locations only and can be changed in the future.

The importance of those criteria that are currently assessed as being of less importance (e.g. environmental factors) will increase in the next phases of the assessment process.

Assessment expert 10:

The determination of the weightings of the criteria was based on the following considerations:

The siting and the technical design of the DGR at the recommended sites must (with a sufficient reserve) meet all the requirements concerning long-term and operational safety and must be technically feasible and exert the lowest possible impacts on the population and the various components of the environment. With respect to the environmental criteria (C10 - C13), I prioritised those aspects associated with the potential occurrence of non-radiation health risks for the population of the affected area (distance of the nearest residential and recreational buildings from the surface area, water resources) and impacts on the protection of nature and the landscape.

Assessment expert 11:

Before filling in the Saaty matrix, we listened to presentations on all the key criteria. We learned how the criteria were selected, which indicators serve for each criterion and what data and information was available. Based on this information, I created my own ranking of the criteria according to how they related to the long-term safety of the DGR and whether the monitored properties can/cannot be mitigated via the adoption of technical or other measures. Since the criteria related to the surface area and, thus, their values will change should there be a change in the location of the surface area, I rated this factor as less significant. I then compiled my own criteria ranking following the comparison of each of the pairs of criteria, as required by the Saaty matrix.

Assessment expert 12:

During the presentations, I attained a rough idea of the importance of the individual criteria and their uncertainties, which resulted mainly from a lack of data. I further considered the assessment model according to whether it is possible to influence the criteria via the adoption of technical measures. I then concluded that the most important criteria concerned those relating especially to the size of the rock blocks, potential spatial reserves and other associated factors. Furthermore, I attached high importance to the criteria that exert a direct impact on the long-term safety of the DGR, especially the presence of significant geological faults and the related risk of flooding at DGR depth. In my opinion, the criteria concerning the surface area and operational safety are less important since they can be remediated via the adoption of technical measures. I then ranked the assessed criteria in the Saaty matrix based on this classification.

Assessment expert 13:

Following the detailed presentations on all the criteria and indicators, I clarified the order of the criteria according to their significance (from my point of view). I considered the most important criteria to be those concerning long-term safety which, moreover, cannot be influenced via the adoption of technical measures and cannot be compensated for in any way. Therefore, I ranked the geological criteria (especially C3) most highly followed by the hydrogeological criteria (especially C5) associated with underground water flow and drainage, and the transport of contaminants (after C3 only because there is currently not enough data available for an accurate assessment). An exception to the prioritisation of the long-term safety criteria concerned C7, which I included relatively low down in the list since, in my opinion, this factor is similar for all the sites (with one exception) and relatively less “dangerous”. Conversely, I included C1 in the more important criteria since the size of the rock mass as a barrier around the DGR positively influence long-term safety. In my opinion, the criteria with medium and short-term impacts on safety were of moderate importance since they can be completely or at least partially remedied via the adoption of technical measures, i.e. C10, C11, C9 and C8. In my view, both the economic criterion (C2) and the short-term criteria C12 and C13 (originally intended for the assessment of completely different types of constructions to the DGR) were the least significant.

Assessment expert 14:

I have become thoroughly acquainted with the content of the various criteria over the last two years via a number of group and bilateral discussions, which included the exchange of input information for the processing of the descriptions of the criteria. Therefore, I consider the competence of the assessment experts to evaluate all of the criteria to be at a sufficient level. My assessment prioritised the “uncontrollable” criteria, i.e. those that cannot be influenced via the adoption of administrative or technical intervention measures. These criteria (geology, hydrogeology) currently have the greatest impact on the differentiation and long-term safety of the sites and the definition of the homogeneous blocks. I assigned lower importance to the technical aspects of the construction of the future DGR (size, reserve) and the lowest weightings I assigned to those criteria that can be technically or administratively influenced (location of the surface area, conflict with the environment and cultural aspects).

Assessment expert 15:

The range of criteria from C1 to C13 were presented by the responsible researchers at a seminar on 22 October 2019. The presentation of each of the criteria was followed by an expert discussion on the relevant topics. In his presentation, Ing. Vokál explained the assessment procedures, again followed by a detailed discussion. Subsequently, I created my own groups of criteria, the content of which were, in my opinion, of similar importance and then followed the same procedure within each group. I assigned the highest importance to the criteria that involved the definition of the homogeneous blocks, that differentiate the sites and that take into account those aspects that affect the dimensions of the future DGR with the appropriate reserve. Other important criteria included those that concern the hydrogeological conditions, the safety of which were demonstrated to a high degree by the hydraulic models. I considered of less importance those criteria that can be influenced by the adoption of remediation measures (project design), especially those related to the location of the surface area.

Assessment expert 16:

Following the presentations on the various criteria, I classified them according to their significance and according to whether they allowed me, based on the available data and information, to distinguish between the assessed sites. I prioritised the evaluation of long-term safety, which is associated with the “quality and quantity” of the selected rock environment, i.e. I regarded the most important criteria as those that define the suitable rock blocks and their size, including the required reserve. Since, from the point of view of safety, the potential migration of radionuclides is also important, I also prioritised the criteria concerning this issue, i.e. on the criteria that relate to the hydrogeological characteristics. I rated the criteria that concern the location of the surface area and its impact on the surrounding environment as less important, since the final project design must meet all the requirements set aimed at reducing impacts on the population and the environment to the greatest extent possible.

Assessment expert 17:

The priority of my evaluation concerned those criteria that directly defined the potential for the siting of the DGR in a suitable rock environment, i.e. especially the criteria that serve for the assessment of the size of the usable rock mass and the degree of the potential occurrence of fracture failures. I also prioritised the hydrogeological characteristics of the rock environment determined on the basis of the hydraulic models of the sites. The geological and hydrogeological criteria, i.e. the quality of the rock blocks and the nature of underground water flow, are crucial for the safety of the DGR. In my opinion, the criteria concerning environmental issues and groundwater resources are moderately important and the biggest threats to the surface components at the site are largely related to the above-mentioned important criteria.

I considered of least importance those criteria of a technical nature, such as the availability of infrastructure or the potential for the disruption of the repository by human activities. These criteria can be influenced by the final project design and by ensuring the security of the facility.

Assessment expert 18:

I assigned the highest priority to criteria C1 - the size of the usable rock mass, which is a prerequisite for the siting of the DGR, and C13 - impacts on the population, which assesses the overall impact on the population living near the site, including subjective, physically unmeasurable effects. As an expert who was involved in the process from the environmental interests perspective, I assigned higher priority to the criteria that considered these factors. The near-surface part of the repository must meet the safety criteria concerning the minimisation of the potential for the spread of radiation, regardless of the location of the site. The excavation of the excess rock material, its transport and storage/disposal, increased demands on the transport system, noise, emissions and a change in the relief of the landscape will all exert significant impacts on the surrounding area. In addition, there will be a feeling of the "presence of an invisible danger" for the surrounding population. The transport of radioactive waste itself presents a potential risk. I assume that the other experts, especially geologists and hydrogeologists, prioritised the criteria aimed at assessing the predictability of rock blocks and geological properties. However, I believe that the assessment process should result in a balanced view that reflects the importance of all interests and assessment areas.

Assessment expert 19:

When compiling the ranking of the various criteria, I started from the point of view of long-term safety. Furthermore, I proceeded from the opinion that the current description of the sites is based on limited data (and is therefore burdened with considerable uncertainty) and that the assessment process should lead to the selection of sites with the highest probability of fulfilling long-term safety requirements while ensuring the sufficient capacity of the DGR.

Criteria were prioritised that assign priority to factors that are directly or indirectly linked to long-term safety and the reduction of impacts on the population (in the event of the malfunctioning of the repository or associated facilities), i.e. particularly those criteria that reflect the ability to describe groundwater flow, describe and predict the extent of the rock blocks and consider both the prevention of human intrusion into the repository and the population density. Conversely, I assigned the lowest priority to those influences that are temporary (only during construction and operation) and which can be addressed via the adoption of technical measures.

Assessment expert 20:

Based on the presentations on the various criteria, I approached their assessment according to the current level of knowledge on the issues with respect to both the DGR and the sites, as well as the amount of data obtained to date. In my opinion, in the current site selection stage, those criteria that are directly related to the rock mass that will serve as the main repository barrier and its hydraulic parameters are particularly important. I also considered the technological measures available with concern to the WDPs and the engineered barriers of the DGR. The criteria related to the local situation (traffic load, jobs, local environmental issues, with the exception of the protection of drinking water sources) are, in my view, less important at the current site selection stage.

Assessment expert 21:

My consideration of the pairwise comparison was based on the following facts:

- I have been dealing with radioactive waste management and radiation protection issues all my professional life.
- My education concerning nuclear and physics-related subjects and 30 years of experience in the field allow me to form an understanding of interdisciplinary issues even where I am not a specialist.
- I have been working on the development of the DGR and long-term safety issues at ÚJV Řež, a.s. since 2010, during which time I have attended the working meetings of various research teams, project inspection days and several professional conferences. However, I have not been involved in any specific research or project issue, which allowed me to form an overview and to appreciate the various links between the subjects considered.

The principles of my comparison approach were as follows:

- At the formal level - I incorporated into the comparison the opinions that I have consistently presented at both the working and official levels for many years. I did not know, with 2 exceptions, any of the other assessment experts and I was not aware of their assessments or evaluation approaches. I did not have the opportunity to compare my ratings with those of the other experts.
- I considered aspects surrounding long-term safety to be of key importance in the assessment:
  - These aspects as a whole are reflected in the calculation of the dose for a representative person throughout the life cycle and for different scenarios. It is possible to implement technical and project measures that ensure that the dose remains below the set limit for our lifetimes and with consideration to the limits of our technical abilities (around 50 and 300 years). The main issue (which is outside our usual experience) is to prove that the dose value will remain (with the lowest possible degree of uncertainty derived from currently available information) below the set limit for a period of a minimum of 100 thousand years.
  - Many of the criteria that are of high importance for present generations and our current sense of well-being and safety will be irrelevant within a few decades time. For example, according to demographic development forecasts, the Czech population will comprise from 8.1 to 10.8 million inhabitants in 2050 (which will lead to a change in population density) and, according to another forecast, we can expect a climate in the Czech Republic that is similar to today's Mediterranean climate in 50 years' time which means, for example, that the number of vegetation days will double (which will influence e.g. the composition of the requirements for agricultural land and forests). Hence, the values of the criteria assigned to these factors will be irrelevant in 10 or 100 thousand years.
- In my view, the following will exert a very significant or decisive influence on the long-term normal development of the DGR at a given site:
  - The composition and variability of the geological formation.
  - Water flow and the resulting transport characteristics through the relevant geological formations.
  - The overall geodynamic stability of the site over the next 1 million years.
- Further important site selection aspects not directly related to long-term safety include the usability of the rock block with a sufficient reserve even for other potential requirements and, with concern to the environment, the protection of water resources (minimisation of the impacts of the construction and operation of the DGR).

I consider other aspects to be less important than those mentioned above due to a reduction in their significance over time, the availability of technical remediation measures and the potential for substitutability.

Assessment expert 22:

My approach to completing the Saaty matrix aimed at determining the weightings of the 13 key site suitability comparison criteria was based on the presentations of the criteria plus my long-term participation in the DGR siting project.

The criteria C1 - C13 cover the areas of safety (long-term and operational), the environment and technical issues (the project design).

The completion of the coefficients of the Saaty matrix was preceded by the general determination of the order of importance of the criteria (initially in groups). I based this process on the assumptions that the site must first and foremost provide a suitable location for the construction of the underground part of the DGR and suitable conditions for long-term safety. Both of these factors are burdened by uncertainty due to the current limited level of knowledge. The descriptive models of the sites – especially the geological and hydrogeological models – are crucial to the assessment of these factors in the given phase of the DGR site selection process.

The result of this approach was a preference for criteria C1 and C3 - C6. The other criteria were based on the recognition of the need for the DGR and its uniqueness. Partial non-compliance with these criteria can be solved by the adoption of technical and/or administrative measures.

Assessment expert 23:

My approach to the issue was to assign the highest weightings to the criteria that are associated with the characteristics of the rock environment in which the DGR will be constructed. Currently, the DGR development programme is still in the phase of determining the optimal place for the construction of the facility and, moreover, only in the stage of reducing the number of sites. I considered these factors when assigning weightings to the various criteria both for their mutual comparison and for completing the Saaty matrix. The most fundamental questions at this stage are: whether there is a large enough space to dispose of the required amount of waste and whether the quality of the selected rock environment is high enough for waste disposal purposes. Therefore, both the definition of the rock environment in terms of its homogeneity (more precisely the occurrence of failure zones and degree of variability) and the definition of the underground water circulation regime are important. I prioritised these criteria since, at this stage of the process, I consider it essential to choose sites that fulfil these basic - natural - conditions as much as possible, especially in terms of long-term safety over several thousand to hundreds of thousands of years (in geological terms, a very short period of time). The criterion concerning seismic and geodynamic stability is an exception compared to the other so-called geological criteria; I assigned a lower weighting to this criterion due to the lower ability to compare the sites and the relative lack of data on the sites in this phase of the process. However, this does not diminish the importance of this criterion in the future; on the contrary, from the point of view of the long-term safety assessment, this criterion is very important and is also subject to legislation.

I consider the other criteria to be less important at this stage since, in terms of the time of the existence of the DGR (including its development and construction), they represent highly variable factors. In addition, several of these criteria can be addressed societally and via the adoption of legislative and technical measures. However, it is clear from the societal acceptance of the DGR point of view, that the importance of these criteria will increase significantly in the next phases of the site selection process.

Assessment expert 24:

I assigned priority to the criteria that exert the greatest impact on the long-term safety of the DGR, i.e. especially the descriptiveness and predictability of the site. I considered the hydrogeological parameters to be less important since they are based only on estimates; however, they will be decisive in terms of assessing the safety of the repository in the future. The impact on the environment is also very important, but significantly less so than the long-term safety of the repository. The C1 criterion, i.e. the usability of the rock mass, comprises one of the most important criteria; however, given the current level of knowledge, I assigned it a lower weighting than the descriptiveness and predictability of the rock mass and hydrogeological criteria. The other criteria, again given the current level of knowledge are, in my opinion, significantly less important.

Assessment expert 25:

Following the presentations, I attempted to assign the highest importance to the criteria that, in my opinion, best distinguished the sites, as well as those characteristics that cannot be remedied by the adoption of technical measures either now or in the future and those factors concerning which enough data already exists. In my opinion, the most important criteria concerned the definition of the homogeneous rock blocks, further taking into account aspects that affect the size of the future repository and the relevant reserves. A further important factor concerned the demonstration of the safety of the DGR according to the outputs of the hydraulic models. I considered the other criteria, especially those related to the location of the surface area (that can be influenced by the project design), to be less important.

Assessment expert 26:

When evaluating the key criteria, I prioritised those criteria that concern the natural conditions at DGR depth, which are decisive in terms of the feasibility of the DGR and its long-term safety. The evaluation of these criteria (albeit on the basis of available and, therefore, necessarily limited information at this stage) is a major limiting factor for each site which, in principle, cannot be compensated for by the adoption of technical measures during the development and construction of the DGR, and (as with criterion C3) which involve uncertainties in terms of the predictability of the rock environment, which may subsequently exert a significant negative impact on the feasibility of the DGR.

I considered the criteria for the assessment of the surface/near-surface conditions to be less significant due to their limited impact on the long-term safety of the DGR and also because they are relatively easily predictable; moreover, any negative impacts can be effectively compensated for by the adoption of the appropriate technical measures in the DGR project preparation phase.

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