

WATRP Mission to the Czech Republic

International peer review
of the Czech programme of the geological repository development

Background materials

a1) The Geological Repository Development Program for Spent Fuel and High-Level Waste in the Czech Republic

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1 INTRODUCTION

The Czech Republic operates two nuclear power plants, Dukovany and Temelin, with a total capacity of 3 760 MW. Nuclear power plant operation as well as nuclear research, the use of radionuclides in various spheres of human activity and uranium mining and milling, create radioactive waste of different types, forms and activity levels.

The Czech Government controls waste management through the Ministry of Trade and Industry and the independent state authority, The Radioactive Waste Repository Authority (RAWRA). RAWRA's mission is to ensure the safe disposal of existing and future radioactive waste in the Czech Republic and to guarantee the fulfillment of strict requirements concerning the protection of human life and the environment from the potential adverse impacts of such waste.

The Czech Republic's main radioactive waste producer is CEZ, a. s. (The Czech Power Company, plc.) which operates both the Dukovany and Temelin nuclear power plants. DIAMO, a state-owned company in charge of uranium production facilities, is the second largest producer. The third main producer is the Nuclear Research Institute Plc., whose activities include nuclear research and development as well as providing a wide range of expertise and services in the fields of basic and applied research.

The independent supervision of the nuclear sector is the responsibility of the State Office for Nuclear Safety (SÚJB). This organization is responsible for governmental regulation, administration and supervision pertaining to the uses of nuclear energy and ionizing radiation. The authority and responsibilities of the SÚJB are set out in Act No. 18/1997 Coll., on the Peaceful Utilization of Nuclear Energy and Ionizing Radiation (the Atomic Act). The Ministry of the Environment is indirectly involved in this process as a result of its decision-making role in related Environmental Impact Assessment procedures.

A total of four radioactive waste repositories have been commissioned in the Czech Republic. The Hostim repository was the first to be put into operation where, from 1953 to 1965, approximately 400 m³ of institutional waste were placed in two of the galleries of an abandoned limestone mine several dozen meters below ground.

In 1964 the Richard repository became operational. Also situated in an abandoned limestone mine about 40 - 60 m below ground, this facility was designed for the disposal of that institutional waste not contaminated by natural radionuclides.

The third repository, Bratrství, is used solely for waste contaminated by natural radionuclides (²²⁶Ra, ²¹⁰Po, ²¹⁰Pb, and uranium and thorium isotopes). This facility was built in an abandoned uranium mine located in a metamorphosed rock complex of the Jáchymov formation and is situated near the town of the same name.

A near-surface repository for low and intermediate level waste has been in operation since 1995 at the site of the Dukovany NPP. This facility boasts a fully engineered structure containing vaults with reinforced concrete walls insulated by a layer of asphalt-propylene micro-concrete. Water movement is controlled by specially designed drainage systems. The void spaces within the vaults are filled with concrete after the double rows are filled with waste canisters whereupon a final multi-layered cap or lid is installed.

In May 2002 the Czech Government approved the "Concept of radioactive waste and spent fuel management in the Czech Republic", regarding high-level waste and spent

nuclear fuel. This crucial document set out the State's long-term strategy in this area and at the same time created a basic framework for the role of the Radioactive Waste Repository Authority as the body responsible for the safe disposal of radioactive waste throughout the Czech Republic. This document obliges RAWRA to undertake the following:

- To provide the storage of high-level waste and spent fuel until a deep geological repository becomes operational;
- To choose two sites suitable for the construction of such a repository and to enter them into relevant land-use plans before 2015;
- To demonstrate the feasibility of constructing a repository at one of these sites before 2025;
- To begin the construction of an underground laboratory at this site sometime after 2030; and
- To support research and development into alternative spent fuel management processes.

It is assumed, based upon information provided by the principal spent fuel producer, that the transportation of spent fuel to the repository will commence in 2065. In the meantime spent fuel will be stored in specially-designed transport-storage containers in self-reliant storage facilities provided either at the nuclear power plants themselves or at a central storage facility.

2 BRIEF HISTORY OF THE GR DEVELOPMENT PROGRAM

Initial studies concerning a geological repository development program in the Czech Republic commenced in the early 1990s. At the outset however, the program was of a somewhat theoretical nature. Studies carried out by various institutions at that time included the development of a system of site selection geological criteria and an assessment of several areas thus selected, a geological investigation project aimed at the safe disposal of high-level waste as well as the selection of prospective regions in the Bohemian Massif. A large number of other studies and reports of a geological character quickly followed. These studies were carried out under the auspices of the State plan for research and development and were funded partly from the State budget through the Czechoslovak Atomic Energy Commission and the Ministry of Industry and Trade and partly by potential users of the results of such projects including The Czech and Slovak Power companies and Kralovopolska Machinery, Brno. Following the split of Czechoslovakia, these studies continued as part of two independent national programs and were funded from separate resources.

In 1992 the basic approach to radioactive waste disposal changed from the purely theoretical. In compliance with the national energy policy at the time, the former Czech Ministry of the Economy and Industrial Development supported by the Ministry of the Environment, launched a coordinated program aimed at building a geological repository in the Czech Republic. A working group was set up composed of government representatives, the main waste producers and design and research organizations, later to be replaced by a

special committee, the so-called Council of Six, the main coordinator being the Nuclear Research Institute.

The main aims of this committee included bridging the time period prior to the establishment of the proposed national radioactive waste disposal agency, to put a geological repository development program in motion, to engage experts to work on the project, and to commence all those activities necessary to put a repository into operation sometime after 2020.

In 1993, the geological repository development program was subjected to an international technical review organized by the International Atomic Energy Agency. The final conclusions of this review, otherwise known as WATRP (Radioactive Waste Assessment and Technical Review Program), emphasized the following:

- The need to establish legal and juridical links between the parties involved in the various individual projects;
- The need to formulate a detailed national radioactive waste management program;
- The need to separate waste producers and repository operators from the authorities;
- Requirement to specify unambiguous responsibility and funding for waste disposal and their definition on a legal basis;
- The need to design specific quality assurance programs for waste management systems, research and development, construction, repository operation and final closure;
- Appropriateness of delaying underground geological investigation until final repository site is approved;
- The need to specify priorities and project time schedule;
- The significance of performing a consistent revision of radioactive waste quantities and types;
- The need to consider technical as well as non-technical factors in assessing existing alternatives;
- Exact definition of the components forming the multi-barrier system;
- The need to utilize all the available knowledge of system evolution and confirmation of such premises experimentally;
- the need to direct safety assessment towards the repository's operation and closure phases;
- The immediate need to perform time and economic estimates of program demands for planning reasons.

It was agreed that the Czech Republic had a sufficient number of specialized and technical personnel capable of solving these problems. However, the expert group emphasized the necessity of establishing and maintaining international cooperation throughout all the various areas of activity and during all the phases of development and realization. The aim

of such international contacts should be to access sources of technical and methodological information which need not be restricted solely to multi-barrier systems with structures similar to those of the engineered barriers and host rock planned in the Czech Republic.

In the following years, more than ten organizations participated in the “Deep geological repository development program for high-level waste and spent nuclear fuel under those conditions pertaining to the Czech Republic”.

The year 1997 saw Parliamentary approval of the Atomic Act, resulting, among other things, in the establishment of a new state organization, the Radioactive Waste Repository Authority (RAWRA). This organization became responsible for commissioning studies, the preparation of tenders for individual development projects, and from 1998 onwards, the funding of the repository program from the Nuclear Account, to which all waste generators are legally bound to contribute and which is designed to fund the final disposal of accepted waste. At the same time both the so-called “geological repository reference design in a granitic rock with no connection to a real site” project, and a general geological investigation project were completed. Moreover, a proposal was put forward determining both the aim and extent of research and development supporting the geological repository program.

Thus the conceptual phase of the geological repository program came to an end. The necessary foundations (programs and general projects) had been laid for commencing the technical stage of the project leading to the selection of a suitable geological disposal system. Firstly however, two things were necessary: to produce a basic strategic document for the long-term planning of the development of the repository and to start the site selection process aimed at identifying specific locations at which technical investigations could begin.

3 OVERVIEW OF STUDIES CARRIED OUT TO DATE AS PART OF THE GR DEVELOPMENT PROGRAM

3.1 Selection of a Favourable Repository Site

At the beginning of the 1990s, a study entitled “The geological research of safe radioactive waste disposal” was prepared by the Czech Geological Institute, the aim of which was to identify those regions in the Czech Republic suitable for deep geological disposal. The study identified 27 prospective regions in various rock types based on regional geological information.

A follow-up to this study entitled “A critical evaluation of pre-existing geological information”, was ordered by the Economy Ministry. The aim was to collate all the available geoscientific information on the granitic regions of the Bohemian Massif and to assess their suitability for the selection of sites for the permanent disposal of high-level radioactive waste and spent nuclear fuel.

Information was gathered on a total of 13 different regions from the perspective of a number of geoscientific disciplines. In total, 1 426 pieces of background information were studied and assessed (including descriptions of 1 999 individual boreholes). Furthermore, 825 documents were studied and evaluated concerning the neo-tectonics, geodynamics and seismicity of the Bohemian Massif and its trans-boundary. This study identified 8 sites located in five separate regions.

During the preparation stage of the geological repository development program it had been stated that, in certain seismically stable regions of the Bohemian Massif, large granitic bodies occur which most probably could host a geological repository. However, it had also been stated that the choice of a favorable site would require many years of detailed investigation and study.

At the very outset of the geological disposal program, studies commenced on geological investigation methodology aimed at choosing a favorable host rock structure. These studies were based upon two pre-existing studies, namely “General project on various geological studies associated with the development of a geological repository in the Czech Republic”, which set out certain requirements on the application of geological methodology in different phases of repository development, and “The catalogue of geoscientific investigation”, which summarized and categorized individual methods. The authors concluded that not all the necessary methods are sufficiently applied in the Czech Republic. Nevertheless, a universal project dealing with the homogeneity of the Bohemian Massif was prepared (without linking it to a specific site), which consisted of a geological investigation aimed at finding candidate sites in the Bohemian Massif and containing a definition of the critical route and nodes (across all the geoscientific disciplines).

In addition, a study was carried out on the stability verification of a broader region in the Bohemian Massif. It showed (regarding the necessity for statistically processed observation) that stability verification is a long-term activity in which a number of experts from various geoscience disciplines should be involved. Three basic subject areas were covered:

- Seismic movements;
- Geodynamic movements of the upper part of Earth’s crust;
- Neo-tectonic activity.

In parallel with the aforementioned, other studies have been carried out on the definition of the criteria for the selection of favorable sites. As part of which, individual criteria set out in the Atomic Act and by State Office for Nuclear Safety regulations were closely analyzed. The SÚJB, in regulation 215/1997, lists the criteria for the siting of nuclear installations and significant sources of ionizing radiation with regard to nuclear safety and radiation protection. Finally, a summary was prepared identifying exclusion and conditional criteria and outlining the application of individual criteria to the surface and underground structures of a geological repository.

In 1999 data from existing mines in magmatoids was studied with the aim of characterizing in detail the geological media in the magmatic rocks of the Bohemian Massif. A database of these workings (the majority of which had been drilled as part of an investigation into and the mining of polymetallic ore by Ore Mines, Příbram, and uranium by DIAMO and their predecessors) was prepared. All of these mines are currently inaccessible yet this database provides a source of information which could be used in the future for determining the general characteristics of the deeper parts of granitic massifs. It is assumed that the results of these studies will form an inseparable part of the geological media characterization of granitic host rocks in the future.

As part of the Czech geological repository development program, the Melechov test site was chosen for the site characterization stage having a geological position very close to that of the main study site (common Varisean granitic body in the Bohemian Massif). Although

this location was selected as the test site it is unacceptable as a study site because part of it is situated in a protected drinking water source area thus ruling it out as a potential site for a disposal facility. Nevertheless, the main objective of operating a test site is to have the opportunity to adjust to new methods or methods not commonly used in the Czech Republic, essential in terms of making a quality selection of a repository site from the geological point of view. Consequently, it is necessary to establish polygons for verifying the methods and procedures used in geological studies and investigations and to learn how to interpret these methods correctly. Investigations at the test site are coordinated by specialists of the Czech Geological Survey (formerly the Czech Geological Institute). Geological, hydrogeological, geochemical, hydrological, petrographic, and geophysical data gathered at the site were used to describe the geological structure of the Massif. The focus of the initial stage at the test site was to conduct geophysical studies and geological, structural and hydrogeological mapping, as well as to investigate the region's geochemistry. Special attention was paid to evaluating possible conflicts of interest which were subsequently mapped. Three areas were selected according to the above criteria. The second stage of the program concentrated on building a detailed characterization of the three selected areas prior to the commencement of tests. Studies were carried out which led to the final selection of polygons and which enabled the testing of selected geological research and investigation methods to begin.

The verification of processes and events under underground laboratory conditions is an important part of most foreign geological repository projects. Underground laboratories should provide for the performing of geological, geotechnical and geochemical studies whilst the shafts and tunnels in such laboratories should enable geologists to confirm the arrangement of local geological layers which had previously been predicted from the surface using geophysical methods.

In the Czech Republic, a mine shaft (No. 16 at Haje near Pribram) was appropriated for conducting tests. Studies conducted by specialists from DIAMO examined the effects of eventual shaft decommissioning and of certain requirements set out by RAWRA to preserve access to the shaft after closure for a period of four years and the impact of potential re-opening. An estimate was made of the effects of the shaft flooding with mine water and the impact of this water upon underground laboratory construction. At the end of the study, the relevant administrative and legislative steps were taken to ensure the conservation of the shaft in a dry and safe condition.

A project determining the tests to be conducted in an underground laboratory was proposed in 1998. Following a summarization of current knowledge, experiments were put forward including both the methods to be used for the characterization of the geological media and the technology to be employed in repository construction, including the design of the engineered barriers (model testing). Moreover, the project was required to contribute towards increasing public confidence in and awareness of the deep geological repository project.

However, due to the high financial demands of an underground laboratory, a decision was made to construct such a laboratory only at the final site and that it would serve the purpose primarily of confirming the appropriateness of the rock medium eventually chosen (a so-called confirmation laboratory). Until that time it was recommended that all the necessary information should be gathered and methodology confirmed through the involvement of Czech institutions in research programs organized by foreign underground laboratories as well as through the use of the Melechov test site.

3.2 Repository Design Studies

All of the geological repositories already designed in various countries around the world are similar in appearance. They consist of a surface area, access shafts and tunnels, and disposal areas where spent fuel and high-level waste are placed in hermetically closed containers. The surface buildings consist both of facilities for the construction of the underground part of the repository and for the control of operations until the repository is filled and closed down. The whole area will resemble that of a mine but without the usual piles of extracted material. An important part of the complex will consist of facilities at which spent fuel will be accepted and conditioned. Spent fuel conditioning however may well be carried out at a separate site (e.g. at existing nuclear power plants). Shafts and tunnels (or a spiral access route) will provide access for personnel, equipment, materials, and spent fuel and high-level waste containers into the underground area. The containers will be placed in the large underground network of tunnels either vertically in disposal modules dug into the tunnel floor or horizontally in the tunnel corridors.

Design studies of both the surface and underground facilities were conducted as part of the geological repository development program. The most likely process for the handling of spent fuel and other wastes was selected from a number of alternatives. A technical analysis and subsequently a feasibility assessment of the chosen handling process were then carried out taking into account safety, technology, economy, and time. In parallel, a study was made of a VVER-1000 type spent fuel container and an evaluation carried out of changes in geothermal gradient at the geological repository level.

All these studies served as the background for a reference design for surface and underground repository systems in a host medium of granitic rock at a hypothetical site in the form of a conceptual design at the level of a design study. In this case the repository is situated in a non-specified site and, therefore, is not concerned with infrastructure, transportation and access roads. This level of study should serve to narrow down the technical and economic modeling of future investment, one of the feasibility criteria of this structure.

The design study encompasses both the surface and underground structures and facilities, describes the likely composition of engineered barriers, and proposes several alternatives for certain elements of the repository. It is supplemented by an evaluation of the legal requirements stemming from and the legal standards pertaining to the Atomic, Construction and Mining Acts. Close attention is paid to the basic documents required for the licensing procedure at the planning stage namely the conceptual safety assessment, the repository decommissioning report, and the Environmental Impact Analysis (EIA). The quality assurance program is also documented. This document is designed to be used not only during the documentation process but also throughout the entire repository project.

The design study includes both the surface structures and the underground facilities constructed in a stable geological formation at a depth of several hundreds meters with the aim of securing the long-term isolation of radionuclides contained in the waste from the biosphere. The design deals with the alternative of spent fuel disposal without disassembly in unshielded disposal containers. In this case the containers would be surrounded by a layer of bentonite and placed in a vertical position in corridors dug into the granitic massif at a depth of approx. 500 meters. In addition, these containers would be surrounded by backfill and buffer material, which would prevent the leakage of water, retain the radioactive materials, and allow the release of the heat caused by radioactive decay.

The design study creates a research program related to the planning and time schedule of repository construction and operation which takes into consideration various alternatives concerning nuclear plant operation in the Czech Republic. The estimated cost of the repository's entire life cycle i.e. development, construction, operation, closure and post-closure is 46.9 billion CZK (at 1999 price levels).

The objective of the design study was to describe as fully as possible the broad solution of a geological repository and collect the background material with which all future studies of a technological and constructional nature will be compared. The first step was to identify those problems impacting on the site selection decision-making process. Subsequently, the technological and constructional elements necessary for optimization were identified (surface area, method of spent fuel conditioning, transportation routes underground etc.). The aforementioned recommendations should be regarded as terms of reference for future, more detailed design studies.

The potential impact of repository construction and operation on the population living in the locality has been quantitatively evaluated. Not surprisingly, major ecological problems might be caused in the repository construction phase. The purchase of land for construction and access roads and, in particular, the transportation of large amounts of excavated and backfill material may become a source of friction. These constitute, however, purely non-radiation impacts, whilst public radiation exposure from the site itself and along the transportation routes will be insignificant.

Item	mil. CzK
Research and development	5 240
Legislation, public relations	200
Supporting design studies	620
Total building costs	17 517
Repository operation	23 065
Repository closure	300
T o t a l c o s t s	46 942

Table: Expected costs of the geological repository program (in millions of CZK – 1999 price levels, 1€ = approx. 30 CZK)

3.3 Studies of Engineered Barriers

Studies conducted on events and processes occurring in near interactions i.e. those related to a repository's engineered barriers, can be subdivided into two groups. The first involves studies of spent fuel, its composition and thermal output, the second is devoted to the engineered barriers i.e. to containers, backfilling and sealing and buffer materials.

The collection of input data on emplaced materials, particularly spent fuel, is necessary for the design of underground disposal areas (distance between disposal modules), and also for the study of their behavior in a given medium. Studies began with model calculations of both VVER-440 and VVER-1000 spent fuel characteristics and with procedures for evaluating the mobility of radionuclides contained in fuel which further resulted in general models for the evaluation of geological disposal system behavior. Careful attention was paid to the modeling of the distribution coefficients K_d of individual radionuclides, the creation of chemical and thermodynamic models, and the modeling of sorption reactions.

One of most important studies in this context was an analysis of the impact of spent fuel radiochemical composition and its thermal output on the degree of burnup. Study parameters were determined depending on cooling time (0, 300, and 1 000 years) for both the VVER-440 and VVER-1000 spent fuel types. Potential changes in these parameters as a result of utilizing a different fuel such as uranium-plutonium fuel MOX or transmuted fuel were verified experimentally.

In 1999 sensitivity analysis was conducted for the spent fuel of both the Dukovany and Temelin nuclear power plants on how the radiochemical composition and thermal output depend upon the degree of burnup and cooling time. A computer code VJP- TEPL0 was developed and verified enabling these parameters to be determined. The results of this study should serve as background material for the design of disposal containers and the geometry of repository disposal modules.

In the year 2000 a study was prepared concerning optimum container lifetime which aimed at determining so-called "break points" in the development of spent fuel activity over time for both VVER-440 and VVER-1000 types and an analysis was made of the radiochemical composition at these points. Calculations were performed for a time period of between 100 and 1 500 years by means of the ORIGEN-2 computer program.

The spent fuel container should be constructed using the minimum number of construction parts to prevent material contamination and to allow easier manipulation during transportation and disposal. For this reason, a study has been carried out devoted to the selection of materials in view of their corrosion and corrosion-mechanical properties and which describes a range of testing methods under model conditions corresponding to possible conditions at a future repository site.

The overall program for the development of engineered barriers was prepared in 1998. It included testing quantities and engineered barrier parameters determined by means of functional analysis and included an analysis of legislative requirements. A procedure similar to that of the interaction matrices method was used to determine the choice of parameters.

In the mid 1990s, with backfill, sealing and buffer materials in mind, an overview of 31 clay deposits in the Czech Republic, registered and unregistered, was put together in which bentonite reserves were valued and calculated. These deposits are situated in the Ceske Stredohori, Doupovske hory, and in some tertiary basins. In parallel, studies were made of the handling and transportation, including the storage and pretreatment of these materials, as well as studies concerning their physical and physico-chemical properties. A follow-up to these studies involved the analysis of radionuclide transport and retardation processes in various barrier materials, in particular in bentonitic clays. A model study followed of hydro-geochemical changes in a host rock in the granitic medium caused by typical engineered barrier materials. Careful attention was paid to certain important parts of these geochemical models including activity coefficients, equilibrium constants and proper sorption processes.

Studies into backfill and buffer materials have been made as part of an IAEA scientific research program aimed at evaluating discontinuities in a bentonite mass under thermal loads and variable humidity. This subject came under further scrutiny as part of the FEBEX international experiment demonstrating the function of the engineered part of the geological repository barrier system. The project is taking place under the supervision of the Spanish radioactive waste agency ENRESA, in the Grimsel underground laboratory, Switzerland, with the support of the EC through the 5th Framework Program. It is

expected that the results could provide important information for the design of disposal areas in the Czech geological repository.

Laboratory studies of the geotechnical characteristics of engineered barriers have focused to date on the behavior of bentonites under high temperatures and variable humidity and on demonstrating the behavior of bentonite barriers in the vicinity of simulated high-level waste. Tests are currently underway in the Czech republic in cooperation with Swedish partners using a small physical model as well as an assembly under a pilot-plant arrangement (MOCKUP-CZ); this assembly is unique even on a worldwide scale concentrating as it does on the vertical arrangement of disposal modules (nests). In both cases bentonites of Czech origin have been tested, treated or untreated, pressed into bricks or tablets, or in the form of poly-dispersed materials. The objective of this research is to identify the limits at which changes could occur which might adversely affect the natural evolution of the disposal system.

In 1998-1999 a comparison was made of montmorillonitic GE clay (Green Earth) from the Zelena deposit and bentonite from the Rokle deposit. All the selected clay samples underwent the following analyses: basic silicate analysis, determination of the content of macro- and micro-elements, determination of cationic ion exchange capacity, determination of specific surface area and mineralogical composition. Furthermore, sorption experiments were performed with the following radionuclides: ^{134}Cs , ^{85}Sr , ^{141}Ce , ^{181}Hf , ^{95}Zr , ^{131}I , and with fission products obtained by the irradiation of uranium salt (tracers); selected clay samples also underwent desorption tests with ^{134}Cs , ^{85}Sr , and ^{141}Ce . The resulting data was assessed, distribution coefficients and their time dependence were compared with the published results of particularly foreign authors. It is expected that the findings can be utilized in designing engineered barriers for the Czech geological repository.

With samples of the GE clay, natural and pretreated bentonite, sand, ground granite, and mixtures of these materials swelling pressures, permeability (tri-axial), basic engineering-geological characteristics, and granulometry (including the densimeter method) were determined. Silicate analysis, determination of mineralogical composition (X-ray, diffraction method, including glycol preparations) were performed. The exchange capacity of the GE clay and the bentonites was determined. Later, an international project began with the participation of Swedish and Finnish partners, aimed at an assessment of the use of Czech montmorillonitic clays in deep, as well as shallow land repositories. Five deposit sites containing suitable materials were identified and samples taken which were subjected to geotechnical, geochemical, mineralogical, and sorption characteristic testing.

To systematically evaluate corrosion, sorption and diffusion, testing procedures were developed and verified and the necessary equipment constructed. Tests on the majority of the parameters can be performed under controlled conditions in both aerobic and anaerobic media. The results will be used for the modeling of engineered barrier system behavior. Foreign as well as Czech computer software was procured and verified enabling the determination of credible prognoses of processes occurring in the interaction area.

Sorption studies of radionuclides and selected engineered barrier materials and a modeled description of the behavior observed became the subject of an international study coordinated by NEA/OECD (the so-called Sorption Project).

3.4 Safety Aspects of Geological Disposal

For safety assessments it is necessary to implement and verify the proper modeling tools. With this objective in mind a sample safety assessment was prepared and structured according to territorial licensing requirements. Similarly, a sample EIA study was prepared. In compliance with the then valid Act 244/1992., which defined the requirements for such documentation, close attention was paid to repository design and to the events and processes which might occur in the near field area i.e. in the immediate vicinity of the emplaced waste materials as well as longer distances away, in case of potential contaminant transport through the host rock and, subsequently, into the biosphere. The aim of both studies was to complete the outline of a potential safety report with the resulting data and to specify further studies to be carried out in the future in order to complete the data.

A subsequent study was dedicated to the reciprocal interactions of individual components of the disposal system due to events likely to occur under geological repository conditions. The studies were aimed at the identification of features, events, and processes related to various periods of time following repository closure. Based on the conclusions of these studies, a revision of background information was performed in 1996, where particular attention was paid to including a verification program in the geological repository development project. Having a system for identifying features, events, and processes is the starting point for scenario construction; in this way the basic alternatives for the design of both the surface and underground parts of the repository were assessed.

Studies performed during the next stage were directed at simulations of normal repository evolution in respect of the source term, near field area and the biosphere. The source term was calculated with the use of AMMBLOCK3x and GoldSim, whereas hydrogeological transport was assessed with the use of GoldSim and software developed by DIAMO. The biosphere was evaluated by means of the tabular tool K2M and BIOS. Based on these studies, a recommendation followed that a more economical, faster and simpler product (e.g. GoldSim) should be used in orientation and screening calculations whereas for more spatially complicated data from farther afield areas, it would seem more advantageous to use a model constructed specifically for the solution of a given problem (for example DIAMO).

In environmental impact assessments the system of parameters important as regards safety can be divided into the following areas: the host rock, backfill, and the container. This approach enables the separation of safety analysis into subsystems in a way that allows the research and development program to be directed towards gathering input data for safety analysis whilst taking into account the system's sensitivity towards individual parameters. The results of the analysis will represent the basis for the specification of limiting conditions and criteria applied individual subsystems, particularly to the engineered barriers and the host medium. In the case of sensitivity analysis, interaction matrices methods were used to assess the importance of parameters in the individual subsystems since it allows the simplification of the sensitivity analysis in relation to individual elements of the matrix. For an assessment of the significance of individual indicators, analytical calculations were carried out including both normal repository evolution and the unusual initial conditions characteristic of the near field area. The calculations form part of the SPIN international project.

In the long term, climatic changes play a significant role in the safety of disposal systems and this subject is being studied for a period of the last million years or so as part of the BIOCLIM international project. Palaeoclimatic and palaeohydrogeological data on the

Czech Republic has been analyzed and quaternary ecosystems reconstructed. The objective of the project is to arrive at a classification of safety indicators and indicators of disposal system behavior over a large period of time. Palaeohydrogeological data has been collected as part of another international project, PADAMOT. In order to collect the data, a 100 meter deep borehole has been drilled at the Melechov test site. In addition to an evaluation of drill cores and the chemistry of the medium under investigation, this borehole has also provided “granitic” water which will assist in the study of engineered barrier behavior.

All three studies were carried out as part of international projects supported by the EC through the 5th Framework Program.

In the selection of a suitable geological repository site, it is important to specify to what extent it is necessary to put in place measures for the protection of the population in case of events not defined in, or beyond, the repository’s basic design. A preliminary calculation has been made for a general, non-specified site. The results show that even an accident under the most unfavorable conditions would not cause a radiation impact which would require the establishment of an emergency zone; this applies to both the surface and underground repository facilities. However, it has been decided that prior to geological repository construction the calculation will be made again employing verified and real input data.

For the verification of the calculation tools the data and knowledge obtained from studies of so-called natural analogues are used. This involves the recognition and description of events and processes having similar features to those likely to occur in the geological repository. At the same time it is possible to gather data with which the results of laboratory experiments can be completed. These studies are valuable for the development of conceptual models, gathering data on certain initial and limiting conditions of a given geological medium and, last but not least, for the validation of models of the long-term evolution of engineered barriers and their interaction with the host medium.

In the Czech Republic two studies are underway which deserve particular mention. One involves an assessment of the long-term evolution and migration of uranium and thorium in clay sediments and the second is a study dedicated to finding glass analogues which might be used for the study of the vitrification of high-level waste. An indirect result of these studies is the verification of the degradation of artificial uranium glass and slag, as well as an assessment of the migration of released radionuclides in the natural environment.

In the past, geological investigations have shown that in parts of both the Sokolov and Cheb basins, in tertiary bentonitic clays, uranium ore mineralization occurs. Consequently, the Ruprechtov site was selected at which uranium accumulation occurs at acceptable depths (up to 40 meters); this does not require the opening of workings and, moreover, a detailed geological investigation of uranium and kaolin had already been conducted here. During the pilot phase of the project in 1996-1998, basic data describing the properties of the system’s sediments, groundwater, pore water and uranium accumulation was obtained. Subsequently, boreholes were drilled and, based on a description of the core and the results of logging, the boreholes were equipped with samplers and piezometers. Selected samples have undergone detailed chemical, mineralogical and X-ray analysis and tests have been carried out on water samples. These studies are currently ongoing and an evaluation of the results is being carried out in cooperation with the Nuclear Research Institute and GRS mbh Braunschweig (Germany). From the results obtained so far it is evident that the groundwater of the tertiary horizon is not in contact with the deeper aquifer in the underlying granitic rock, most likely due to a relatively impermeable kaolin layer between

the tertiary clays and the granite. As a result, the content of uranium in the groundwater under reduction conditions is very low thus confirming its very low mobility in the given media.

The study of glasses colored with uranium found in the dumps of former glassworks could answer the question of how rapidly such glasses degrade under relatively unfavorable conditions (when exposed to the direct effects of natural events). At the same time, the migration of uranium and its daughter products in the earth covering the dump was also monitored.

It is assumed that the findings of both projects can be utilized for the verification of geological repository models.

As part of the "Thermodynamic database" project, coordinated by the NEA/OECD, the collection, evaluation and modification of the thermodynamic characteristics of selected elements was undertaken. This data, in modeling radionuclide transport in the natural media, allowed a description to be made of both the physical and chemical interactions between radionuclides and artificial or natural materials. The implementation of such advanced computation tools represents another approach to describing the processes which might occur under geological repository conditions.

3.5 Development of the Information System and Coordination of Studies

The geological repository development program could last for several decades. Because of the need to involve different research and development institutions as well as construction organizations all with different priorities and approaches, the program is unique and exceptional. Therefore, it requires an elaborate management system as well as the collection, sorting and archiving of all the technical information that will be produced throughout the project, even up to the closure of the repository and beyond. The preserving of information on the repository for future generations is a huge task in itself.

Following the commencement of the coordinated program, close attention has been paid to the selection of an appropriate information system. This task began with a comparison of existing domestic and foreign systems. Subsequently, an indicative database was formed to serve as a basic list of potential sources for the whole disposal system. In the course of preparing the full-text database, two technologies were tested, one of which was selected as the prototype for the information system. Special attention has been paid to the processing of computerized data and documents. In addition the problem of security of authorized access to databases was solved. In the next stage specific hard and software was selected for individual components of the information system.

An important step in the planning of a geological repository development program is the implementation of management methodology in which the following principles are applied:

- Consistently structured process of system management;
- Four-level implementation: long-term plans, medium term, three-year and yearly planning;
- Systems analysis of project management.

According to these principles, long term plans were put together as well as plans of work concerning different areas of repository development (geological activities, research and development studies, design activities, safety analyses, etc.). These became the basis for the design of a geological repository program flow chart, containing an overview of all the main activities, their interconnections, and also an estimate of their time and economic demands. Technical issues were also assessed taking into account existing national legislative requirements and international responsibilities. It may be safely concluded that the various legal requirements represent an unambiguous starting point for defining research, investigation, and construction priorities.

Regarding quality assurance, quality systems built in compliance with ISO 9000 norms and TQM (Total Quality Management) were studied. Furthermore, manuals, management control processes for documentation, research studies, peer reviews and contracts were prepared.

In the period 1998-2001, a great deal of effort was put in to coming up with a national concept for radioactive waste and spent nuclear fuel management. This concept is a basic document formulating national strategy for the period up to approximately 2025, containing an outlook for the future up to the end of the 21st century. It puts forward proposals which will ensure radioactive waste management in compliance with the requirements for the protection of human health and the environment, without transferring, in an unacceptable way, the present consequences of the utilization of nuclear energy and ionizing radiation to future generations.

The concept is a follow-up to materials from the first half of the 1990s, approved by the Government, and was designed in compliance with Government energy policy approved by the government resolution No. 50 of 12 January 2000. Such a concept is required in connection with preparations for the Czech Republic's accession to the European Union and in connection with the IAEA's Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management, signed by the Czech Republic in 1997.

3.6 Public service aspects of geological disposal

Concerning public service aspects of geological disposal, in 1995 an analysis was made of nuclear issues in media. More than 1600 contributions with nuclear themes in both the national and regional press were selected for study. The data obtained was subjected to quantitative processing e.g. by means of an analysis of the frequency of nuclear issues in selected newspapers, frequency of partial issues (such as storage facilities, impact of nuclear energy on foreign countries, nuclear research and development etc.), as well as frequency of domestic as opposed to foreign information. It was found that negative attitudes were expressed most often by populations in ecologically badly hit regions i.e. North Bohemia and North Moravia.

This was followed by the monitoring of nuclear issues in the media regarding community attitudes which proved valuable in the design of a public involvement program. The strategy of communication with the public regarding the Geological Repository Development Program and the objectives of the communication program were critically reviewed by a group of specialists (psychologists, sociologists, public relations experts, as well as experts having personal experience with similar external projects). The group recommended that the feasibility of the safe disposal of spent fuel in the Czech Republic be first demonstrated and only then to decide on the next course of action.

In addition to public inquiries, information materials were prepared on radioactive wastes, their disposal, environmental impact and so on. Since the beginning of 1998 the internet has been used to provide information which enables information to be kept constantly updated. Radioactive waste disposal was also the subject of a set of informative articles published by the Ministry of the Interior for the information of local community officials. Subsequently, a targeted communication program was developed which is aimed at creating confidence in both disposal technology and in those organizations responsible for implementing this technology. These activities were complemented by the publication of a terminological dictionary on radioactive waste management and geological disposal.

In 2001 an Information Center at RAWRA's Prague headquarters was opened to the public which includes photographs, drawings, models, movies, and a multi-medial presentation on the theme of disposal. A similar center was opened in 2002 at the Richard near-surface repository near Litomerice (North Bohemia).

The need was ascertained to inform representatives and inhabitants of those communities in whose vicinity investigative studies would be carried out. Meetings were organized in the regions involved at which RAWRA explained the issues connected with waste disposal and the proposed geological repository and where members of the public were invited to raise their own concerns. In 2001, the Radioactive Waste Repository Authority set up the so-called Committee of Mayors so as to facilitate communication with local community leaders.

3.7 Development of Transmutation Technologies

The artificially produced nuclear transformation of radionuclides in spent nuclear fuel, so-called transmutation, can favorably affect the long-term radioactive hazard of disposed materials. It is unlikely that in such a manner radioactive materials can be eliminated, nevertheless this subject is being studied on a worldwide basis.

In the Czech Republic studies have been conducted on individual parts of the complex system for the nuclear transmutation of fission products and actinides contained in spent fuel. The results were evaluated according to three basic areas:

- a) Neutron sources for ADTT systems;
- b) Composition of originated
- c) Chemistry of the ADTT process.

In one of studies of the chemistry of the transmutation process, the results of the most important chemical separation procedures of spent fuel reprocessing, considered for use in the fuel cycle of the transmutor, are summarized. Experience from the development of pyrochemical technologies in the Czech Republic was evaluated and its usefulness in the transmutation project was assessed. A concept for the transmutation fuel cycle was proposed, based upon the use of an accelerator driven homogeneous reactor with liquid fuel based on fluoride salts. Part of this study involved a research and development project on pyrochemistry and a discussion its involvement in international transmutation projects.

A further study in this area dealt with the suitability of construction materials for the pyrochemical reprocessing of fuel from pressurized water reactors of the VVER type within the fuel cycle of the transmutation reactor (ADS). The study includes:

- a project for a technological scheme for spent fuel conditioning into a form suitable for transmutation;
- technological research into fuel reprocessing by means of the fluoride method including adaptation and operation of unique equipment for uranium fluorination;
- laboratory research into electro-separation methods;
- development of both materials and equipment for ADS technologies;
- an ADS system study.

The waste thermal output, which could arise after spent fuel transmutation, was calculated. Subsequently information on the spectra of radionuclides resulting from the transmutation process was evaluated. If necessary, the results of this study can be used as a basis for designing disposal containers for transmuted wastes as well as geological repository disposal modules.

A further project was dedicated to gathering experimental data which might be used for validating computer codes used in the modeling of transmutation processes in sub-criticality reactors. The project consists of three parts: preparatory experiments in Czech nuclear reactors with simulated fission material, an irradiation experiment conducted at the Kurchatov Institute, Moscow, using real fission materials (including transuranium elements), and a proper validation of computer codes.

Czech institutions became involved in international projects on transmutation technologies mainly due to invitations to participate in several projects in both the 5th and 6th EC Framework Programs. Besides pyrochemical technologies (PYROREP project) hydrometallurgical extraction processes for certain radionuclides from the spent fuel (CALLIXPART) have also been studied. Both of these themes are included in a new project, EUROPART, presently at the approval stage. Czech institutions participated in the development of a system study on previous work relating to the use of MSR (Molten Salt Reactor) technology, MOST. This study has become a valuable reference for the planning of future studies in this field.

4 SHORT-TERM FUTURE PLANS FOR GR DEVELOPMENT

Narrowing down the number of sites under consideration (geological studies, 2003-2006)

The objective of this stage is to narrow down the number of potential sites for the location of a geological repository. Studies will be carried out in conjunction with a project entitled "Homogeneity study of selected rock massifs – study project at a hypothetical site" (Skopovy, et al., 1999). These studies are part of the prior-to-realization site selection phase and encompass the updating of the archived literature search for geological information at selected sites, the establishment of geographic information systems for individual sites, the taking of aerial geophysical measurements, evaluation of satellite, radar, aircraft and field reconnaissance photographs and the identification of land owners. Geobariera is a subcontractor to this project.

At the end of 2005 a final report will be presented by RAWRA. The report will include an evaluation of existing geological information and remote sensing, the results of airborne

geophysics, an evaluation of conflicts of interests and a pre-feasibility study. Based on the data obtained and expert recommendations, sites with an area of 10 km² each will be selected for further characterization. Further geological research work at the sites will require the permission of the Ministry of the Environment.

The next stage is expected to commence in April 2006. The aim of the project will be a detailed evaluation of the massif including geological and hydrogeological mapping, detailed geological work, verification of anomalies, location and sinking of 1000 m deep boreholes, one borehole per site. Since there is strong public opposition in all the sites chosen to date against the future construction of a DGR as well as against the exploration of sites, RAWRA, in agreement with the MII, is currently considering the postponement of all its activities at these sites for at least five years.

Further projects on engineered barriers and on safety assessment will be carried out.

5 EXPENDITURE TO DATE

Geological repository program expenditure, in the period from 1993, is shown in the next Table. Finance provided by “founders” to individual organizations within their budgets, e.g. the Ministry of the Environment to the Geological Survey, Ministry of Education to universities etc. is not included.

Year	Governmental institutions	RAWRA	Total
1993	6,4		6,4
1994	23,6		23,6
1995	15,0		15,0
1996	17,0		17,0
1997	18,0	1,9	19,9
1998	1,4	15,1	16,5
1999	11,0	31,3	42,3
2000	22,0	26,7	48,7
2001	15,0	39,8	54,8
2002	16,2	36,0	52,2
2003	15,0	49,8	64,8

Table: Overview expenditure on the Geological Repository Development Program and associated R&D during the period 1993-2003 (in millions of CZK)

6 LIST OF ABBREVIATIONS

ACTINET	The project submitted in the 6th EC Framework Programme
ADS	Accelerator driven system
ADTT systems/processes	Accelerator-driven transmutation technology
AkEnd	A German Committee of experts established to develop a procedure and criteria for the selection of repository sites for radioactive waste
ALARA	As low as reasonably achievable
AMSTER project	Project of Molten Salt Reactor developed by Electricité deFrance.
BARRA	International project on bentonites evolution under geological

	repository conditions (Spain)
BIOCLIM	Scientific basis and practical methodology for assessing possible impacts due to long-term climate and environmental change on the safety of radioactive waste repositories in geological geological formations
Blanka	Project of experimental verification of transmutor blanket's behavior
CALIXPART project	Project of development and testing of selective extractants
CLAB	Swedish spent fuel storage facility
DIP	Document Image Processing
EIA	Environmental impact assessment
EUROPART	Project of the 6th EC Framework Programme (pyrochemical separation system)
FEBEX I. FEBEX II	Projects of the EC framework programs
FEPs	Features, events, and processes
FERDA	Fluoride experimental research and development assembly
GE clay	Green earth clay
GEOFOND, Prague	Archive of geological documentation, currently the part of Czech Geological Survey
GEOMON	International project on geological monitoring
GEOTAB	Swedish database
GEOTRAP project	OECD/NEA Project on Radionuclide Migration in Geologic, Heterogeneous Media
GIS	Geographic information system
GPS	Global Positioning System
InfoSTREAMS	Information, Storage, Retrieval, Access and Management System
INTERGRAPH and ARC/INFO	Database and geographic information systems
MOCK-UP CZ Experiment	Experiment aimed at confirmation of future evolvement of sealing materials (bentonites) under realistic conditions
MSR	Molten Salt Reactors
PADAMOT, PDM-1	Palaeohydrogeological Data Analysis and Model Testing, Padamot-1 is a borehole drilled within the international project
PHARE	Pre-accession instruments financed by the European Communities to assist the applicant countries of central Europe in their preparations for joining the European Union.
PSA	Probabilistic safety analysis
PYROREP	Project of the 6th EC Framework Programme, pyrometallurgical reprocessing and storage of spent fuel
RAWRA, Prague	The state organisation – Radioactive Waste Repository Authority, Prague
RISCOM II	Risk Communication is part of the 5th Framework Program of the European Commission and the EURATOM
TDB Project	Thermodynamic Database Project
TQM	Total Quality Management
VVER-440, VVER-1000	Pressurized water reactor types

In the summaries the following computer codes and models are mentioned:

AMABER, AMMBLOCK, BIOS, GEANT, GOLDSIM, INC, K2M, LAHET, MCNP, MIVCYL, MODFLOW, MSTs, ORIGEN-2, PAGODA, RZ1, RZ2, SWIFT, TAPS, TEPLO

As part of the Geological repository Development Program, the Czech parties cooperated with the following foreign organs and organizations:

ANDRA, CERN, COVRA, ENRESA, GRS Braunschweig, IAEA, NAGRA, NIREX, OECD/NEA, POSIVA, SCK/CEN, SKB

List of Czech organizations participating in the Geological Repository Development Program:

Aquatest	Aquatest, Prague, plc.
CEG ČVUT	Czech Technical University, Prague – Faculty of Civil Engineering
ČGÚ	Czech Geological Institute, Prague, currently Czech Geological Survey
ČVUT FE	Czech Technical University, Prague, Faculty of Electrical Engineering
ČVUT FSv	Czech Technical University, Prague, Faculty of Civil Construction
DIAMO s.p.,	DIAMO, Straz p. Ralskem
EGPI	EGP Invest, Uhersky Brod, Ltd.
Energoprůzkum	Energoprůzkum Prague, Ltd.
Energovýzkum	Energovýzkum, Brno, Ltd.
FJFI	Czech Technical University, Prague, Faculty of Nuclear and Physical Engineering
Geobariéra	Association of geological companies Geobariera
Geofyzika	Construction Geology – Geophysics
Geomin	GEOMIN, cooperative
Geotechnika	Construction Geology – Geotechnics
MU Brno	Masaryk University, Brno – Faculty of Science
PRO ENGINEERING	PRO ENGINEERING, Ltd., Prague
PřF UK	Charles University, Prague, Faculty of Natural Sciences
RWM-CS	Radioactive Waste Management - Consulting Services, Prague
SW-konzult	SW-Consult, Prague
ŠKODA JS	Skoda – Nuclear Engineering, Plzen, plc.
ÚG AV ČR	Czech Academy of Science, Prague, Geological Institute
ÚJF AVČR	Czech Academy of Science, Prague, Institute of Nuclear Physics
ÚJV Řež, a.s.	Nuclear Research Institute, Řež, plc.
VŠChT Praha	Institute of Chemical Technology, Prague