The French Geological Repository Project: A Converging Approach - 11013

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ABSTRACT

One of the main projects in ANDRA is to design, build and operate a geological disposal facility for high-level and intermediate-level long-lived radioactive waste. History has shown that a geological repository project is a subtle combination of earth sciences and political decision making. The geological disposal history in France began in the 1980's, but the first politically and socially structured approach was launched by the Law of 30 December 1991. According to its main principles, a call for candidate sites was issued in 1993. It was led by a Member of Parliament and based on a new open way of governance, with clear rules for the local economic development as well as for the control and the assessment of the research programmes. Over 30 candidates volunteered at that time. From the geological criteria as well as from the political and socio-economic situation, 4 districts were selected by the Government to have investigations performed. Field investigations were performed and all relevant studies were done for the implementation of an underground laboratory. Given the results of those investigations and the very preliminary safety evaluations, a license for constructing and operating an underground laboratory was granted in 1999 for the Meuse/Haute-Marne site, in an argillite formation. A huge quantity of results was then collected, analyzed and reported in the so-called DOSSIER 2005. The result was that geological disposal is feasible in the Callovo-Oxfordian argillite formation, that safety could be achieved and demonstrated. From further investigations performed after the 2006 Planning Act, a restricted area of 30 km^2 was defined. The Government allowed ANDRA in March 2009 to finalize its detailed investigations programme for the exact location of the repository and its related surface facilities. The license application for the geological repository will be submitted by end of 2014, for a planned commissioning in 2025.

INTRODUCTION

As the CSA (Centre de Stockage de l'Aube) surface repository was being designed at the end of the 80s for disposing of low and intermediate short-lived radioactive waste generated in France, a question was raised concerning the disposal of high-level and intermediate level long-lived waste resulting from the nuclear-power industry. Those residues are processed at the AREVA Treatment Plant, located in La Hague. They consist mostly in glass matrices containing non-recoverable high-level and long-lived radionuclides. Due to safety reasons, their specific radioactive and thermal characteristics do not allow for their disposal of in surface facilities over the long term.

Studies were necessary in order to locate suitable formations for deep geological disposal. With that objective in mind various survey campaigns started in 1989 in four different geological media: clay, salt, granite and schist, with the prospect to further investigations in underground laboratories. Activities were rapidly met with opposition, sometimes violent, and came to an abrupt end. The Prime Minister announced a moratorium that led to the adoption of the *Law of 30 December 1991* which structured research activities regarding the management of high-level and intermediate-level long-lived waste. This Law also granted Andra the status of an independent establishment from radioactive-waste producers. Over the following 15 years, Andra pursued not only its research programmes, but also its industrial mission relating to the design, construction and operation of radioactive-waste disposal facilities. During the summer of 2003, a disposal facility for very-low-level waste (CSTFA) was commissioned at Morvilliers, close to the CSA.

Based on the results achieved during the 15 year research, a new Act was passed in 2006, with clear deadlines toward commissioning a geological repository.

Each of those laws improved the governance and the decision making process in France for disposing of high-level and intermediate-level long-lived radioactive waste.

A LEAP FORWARD WITH THE LAW OF 1991

The crisis that the first attempts to implement research sites for the disposal of high-level and intermediate-level long-lived waste generated in 1989 marked a major turning point in France. Until then, only technicians and scientists working in the nuclear sector had been dealing with radioactive-waste management, when it suddenly became a societal issue. With the mission entrusted upon the Parliamentary Office for Scientific and Technological Options (*Office parlementaire pour l'évaluation des choix scientifiques et technologiques* – OPECST), followed by the adoption of the Law of 30 December 1991, radioactive-waste management gained a national scope under the supervision of Parliament. A formal structure was given to research and investigations on radioactive waste with a strict framework and clear deadlines. Roles, missions and responsibilities of every stakeholder were clarified.

Within that context, Andra became a public Agency, as a structure allowing the State to manage radioactive waste, as well as to design and to carry out research programmes. All industrial and research activities are financed through agreements with waste producers in accordance with the "polluter-pays" principle.

Governance and Decision-Making Process

Governance in matters relating to radioactive-waste management also evolved and new intervention modes were developed. First and foremost, by becoming independent from the waste generators, the leadership for research regarding the disposal of radioactive waste promoted the mobilisation of the overall scientific community around the different issues raised by the management of such waste. Programmes and results are placed under the control of a national review board that reports directly to the government and Parliament. The new mechanism involves a high level of transparency as a driving force for the intensification of research programmes and especially for the quality of methodological developments and scientific knowledge. Throughout the events that followed, it was clear that mobilising various skills proved to be one of the richness and success factors of the research programme.

The Law of 30 December 1991 was also innovative with respect to the decision-making process. It set up an open and progressive process with a 15-year research phase at the end of which a new deadline was prescribed to hold a national discussion with a view to determining future steps. In the light of the results achieved with the different alternative solutions under consideration (partitioning and transmutation, long-term storage), the decision was taken that the implementation of a repository for high-level and intermediate-level long-lived waste was feasible.

The Search for Sites

Following the adoption of the Law of 30 December 1991 and the publication of the implementing Order, the government entrusted upon Mr. Christian Bataille, Member of the French Parliament, a consultation mission aimed at searching for suitable sites for the construction of underground laboratories where investigations could be carried out on the deep geological disposal of high-level and intermediate-level long-lived waste. In 1993, four candidate sites were selected among approximately 30 volunteer communities:

- One site located in a granite formation, under a sedimentary cover, in the Vienne District;
- One site in deep marls located in the Gard District, near the Rhône River; and
- Two sites located in Callovo-Oxfordian argillites, in the Meuse and Haute-Marne Districts respectively; due to their proximity, both sites were quickly combined to form the Meuse/Haute-Marne Site.

Detailed investigations were conducted from the surface. Borehole-drilling operations and geophysical-measurement campaigns were launched as early as 1994 and lasted for 2 years. The qualities of each site could be verified during this phase. A 400-m-thick formation in the subsoil of the Gard District, near the Rhône River, was also discovered during those investigations.

Local Information and Oversight Committees (*commission locale d'information et de suivi* – CLIS) together with incentive funds were implemented on every site during that period. Following the studies it conducted, Andra submitted three applications to authorise the implementation of one underground laboratory in each of the Vienne, Gard and Meuse/Haute-Marne Districts. Those applications took stock of all existing information concerning the three sites, described the work programmes involved with the implementation of underground laboratories, as well as the research and experimentation programmes intended to complement the body of required data in order to meet the 2006 deadline, as prescribed by the Law of 1991.

In 1997, the applications were the subject of public inquiries. All candidate communities confirmed their willingness to host an underground laboratory and therefore agreed to its construction

The Decision Concerning the Underground Laboratory

Once the applications were reviewed by relevant services, the government decided to continue work activities on the Meuse/Haute-Marne Site by implementing an underground laboratory at Bure. On the other hand, both the Gard and Vienne Sites were abandoned. In the latter case, the National Assessment Board (*Commission nationale d'évaluation* – CNE) had reservations because the sedimentary series covering the granite block contained water resources that are used for agricultural purposes. As regards the clay formation, the Callovo-Oxfordian formation on the Meuse/Haute-Marne Site is better known and its geometry is more suitable than the Gard Site. In parallel, the government instituted a research mission to seek a new granite site. However, the mission did not achieve adequate local support and was confronted with a large number of demonstrations, so much so that it was abandoned in 1999. In the meantime, preparatory activities were undertaken for the construction of the Meuse/Haute-Marne Underground Research Laboratory. The construction and the first experiments at Bure took place between 2001 and 2006; they are described in the *Dossier 2005 Argile* [1], which was submitted to the government in mid-2005 (Fig. 1).

During the same period, the *Dossier 2005 Granite* was also prepared on the basis of the overall information gathered on that type of geological formation by integrating the experience acquired through foreign underground laboratories and programmes in Canada, Switzerland, Sweden and Finland.

Fig. 1. Aerial photo view of the Meuse/Haute-Marne Underground Laboratory (2010).

The *Dossiers* presented to the government contained a compilation of the overall information acquired on the geological formations, waste packages and potential means for the implementation of a deep geological repository. Analyses demonstrated the feasibility of a repository within the Callovo-Oxfordian formation; its reversibility may be guaranteed beyond a century. Safety functions consisting in retarding radionuclide migration are satisfactory. Safety calculations showed that the radioactivity level likely to be released into the human environment would be several orders of magnitude lower than the regulatory limit, with a peak at a few hundreds of thousands of years after closure.

DECISION-MAKING STEPS

During the preparation of *Dossier 2005*, Andra called upon various professionals among the French scientific community and representatives of foreign counterpart agencies in order to carry out a critical review of the main documents. In 2005, the *Dossier 2005 Argile* was the subject of a triple assessment at the request of public authorities:

1. A scientific and technical assessment conducted by the CNE, as prescribed by law;
2. A safety assessment performed by the Nuclear Safety Authority (*Autorité de sûreté nucléaire* – ASN), as part of its prerogatives;
3. A peer review carried out at the request of Andra's supervisory ministries by a group of international experts under the aegis of the OECD Nuclear Energy Agency (OECD/NEA) in order to verify the soundness of approaches and results used by Andra in relationship to international standards.

The CNE continued to monitor the advance of the research programme on a continuous basis and submitted its final assessment report to the government on 30 January 2006. It addressed the three research areas prescribed by law. More specifically, it recommended that disposal be selected as the reference solution. It also considered that the work conducted on that theme met "the best international standards". The CNE also felt that investigations had shown that the Callovo-Oxfordian formation constitutes a "*remarkable achievement, both in quality and quantity*"; the work also demonstrated that, from such a standpoint, the rock of the Meuse/Haute-Marne Site was very homogeneous and free of water-conducting faults.

At the request of the ASN, the Institute for Radiation Protection and Nuclear Safety (*Institut de radioprotection et de sûreté nucléaire* – IRSN) also reviewed the *Dossier 2005 Argile*, and published an assessment report that was in turn submitted to the Standing Waste Group whose final opinion was transmitted to Andra as follows: "*The Standing Group emphasises that the* Dossier 2005 Argile *contains a thorough and high-quality presentation, constituting a significant advance. [It] issues a favourable opinion concerning Andra's assessment and considers that a radioactive-waste repository within a clay formation for which ongoing investigations are taking place in the Bure Underground Laboratory, is feasible. […] the Standing Group also considers that there is no safety-related obstacle to the search for a repository site within the perimeter of Andra's delineated transposition zone"*. In the opinion presented to the government on 1 February 2006, the ASN mentioned that "a deep geological waste repository is a final management solution that appears to be unavoidable".

The peer review of the *Dossier 2005 Argile* carried out by the International Review Team (IRT) set in place by the OECD/NEA concluded especially that the programme met fully the best international practices and was leading in several fields. Andra's reversibility approach was considered as innovating without compromising the safety of the repository [2].

At the government's request, a national debate was also held on the long-term management of radioactive waste under the auspices of the National Commission on Public Debate with six months of preparation and 13 meetings between September 2005 and January 2006. Scientific and technical issues, as well as management and governance strategies, were discussed at length. In its report, the National Commission underlined the general view that all radioactive waste be taken into account by the new act, the need to improve governance with regard to radioactive-waste management, the benefits of a stepwise decision-making process and the need for a concrete territorial project for the districts in which a potential waste repository may be implemented.

Lastly, the OPECST (Parliamentary Office for Scientific and Technological Options (*Office parlementaire pour l'évaluation des choix scientifiques et technologiques*) report, published in March 2005, analysed investigation results from the standpoint of management strategies and confirmed the complementarity of the three research areas examined pursuant to the *Law of 30 December 1991:* partitioning and transmutation, deep geological disposal and long-term storage.

THE NEW PLANNING ACT

The *Planning Act of 28 June 2006* [3] extends the scope of the *Law of 1991* by prescribing specific deadlines for the different management solutions to come into force. With regard to the implementation of a reversible waste repository within a deep geological formation, the prescribed schedule requires all relevant elements for the review of the licence application to implement such facility to be ready by 2015 at the latest. The commissioning date of the repository is set in 2025, a date that is compatible with the production estimates for high-level and intermediate-level long-lived waste generated by the French nuclear power cycle.

The Act also reinforces socio-economic incentives in the territories concerned by a potential waste repository. Hence, it strengthens the existing public interest groups promoting local development in the Meuse and Haute-Marne Districts. It also aims at encouraging nuclear industrialists to participate in local industrial projects and confirms the statute of the CLIS.

The *Planning Act of 28 June 2006* details the framework and the objectives relating to radioactive-waste management for the years ahead. The major next step for high-level and intermediate-level long-lived waste will consist in preparing in time for 2015 the licence application for the implementation of a deep

geological repository. The licence application involves the identification of a specific site as well as the definition of a satisfactory repository concept and architecture with respect to safety and reversibility requirements.

In Search of a Final Location for a Geological Repository

The identification of a suitable site requires not only that geological characteristics be consistent with the requirements imposed by the repository, but also that local populations accept its implementation. In the framework of the *Dossier 2005 Argile* was delineated a 250 km² transposition zone (TZ) corresponding to the area within which geological properties are similar to those found at the Meuse/Haute-Marne Site, as confirmed mainly from the Bure Underground Laboratory (Fig. 2).

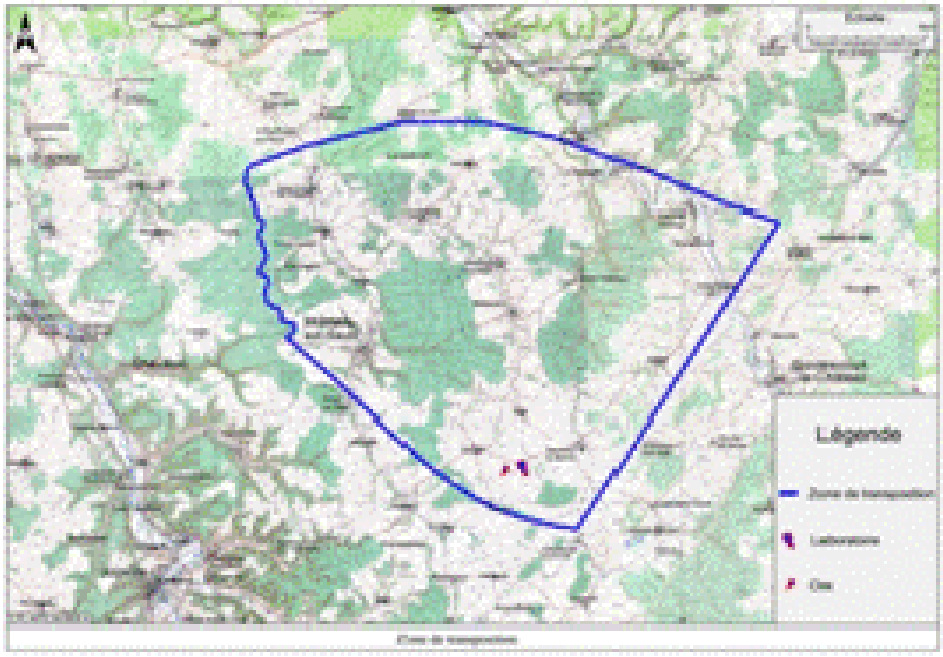

Fig. 2. The 250 km^2 transposition zone.

The following exclusionary criteria were used in 2005 to delineate the TZ:

- Geometrical criteria:
  - *a maximum implementation depth for underground structures set at 630 m (thus limiting the TZ to the west);*
  - *a minimum thickness of the upper layer set at 130 m (thus limiting the TZ to the southwest);*
- Structural criterion:
  - *a distance of at least 1 km from major a fault (zone of diffuse fracturing and Marne faults to the south and Gondrecourt Rift to the east); and*
- Lithological criteria:
  - *a thickness of the upper level ("R0") of the clay layer (richer in smectites) exceeding 65 m, and*
  - *a silt proportion not exceeding 20-30%.*

The geological-survey campaign (boreholes, seismics, mapping) carried out in 2007-2008 in the TZ and its surroundings helped in providing a homogenised knowledge of the geology within in it and in confirming its perimeter.

During years 2006 to 2009, additional investigations were performed in this TZ, with new boreholes cored in the Callovo-Oxfordian, new boreholes drilled for improved description of the local hydrogeological system, and a detailed 2D seismic survey. During the same period, the underground experiments were going on in the Bure laboratory, with more and more technological tests.

FOCUSSING ON A RESTRICTED ZONE

In order to pursue studies and investigations and to prepare the proposal for an implementation site, it was essential to reduce the investigation perimeter to a smaller interest zone on the order of 30 km² (i.e., about twice the size of the underground disposal facility). That helped Andra in conducting new and more detailed surveys at a reasonable scale by applying heavy technical means, such as 3-D seismics.

Since the CNE emphasised that the geological quality must be a determining criterion, Andra first undertook the most comprehensive review as possible of the geological criteria to be taken into account. Contrary to the approach that led to the definition of the TZ by means of exclusionare criteria, the criteria for defining the interest zone aimed at delineating a potentially more promising area within the TZ from a technical or scientific standpoint in order to implement the underground structures.

The results from the different geological-survey campaigns showed a remarkable lateral continuity and homogeneity of the clay layer and of the containment properties of the rock throughout the TZ. Consequently, the properties of the rock (permeability, mechanical properties, etc.) did not constitute at this stage of the project, adequate criteria for the actual location of the interest zone. Nevertheless, by relying on the ALARA principle with regard to long-term safety, it was possible to recognise that:

- The thickness of the layer, with limited amplitude in variations, remains an objective and relevant parameter; and
- Certain zones likely to host the highest vertical hydraulic gradients appeared less favourable for the implementation of underground structures under heavily degraded hypothetical conditions.

With respect to the optimisation of operating and operational-safety conditions, it should be noted that the amplitude of excavation-induced damages appears to be much more significant beyond 540-590 m in depth and that the zones where the dip of the layer would not complicate excessively the design of the repository may be preferable.

As a complement to those elements, the delineation of the interest zone relied on the exchange and dialogue approach. In fact, this approach oriented Andra’s proposal by allowing the expression of preferences, either positive (by privileging a certain type of zones for specific reasons) or negative (not laying down underground structures in certain locations for specific reasons).

Based on the results from the 2006-2009 campaign, the interest zone shown on Fig. 3 was proposed to the government before the end of 2009.

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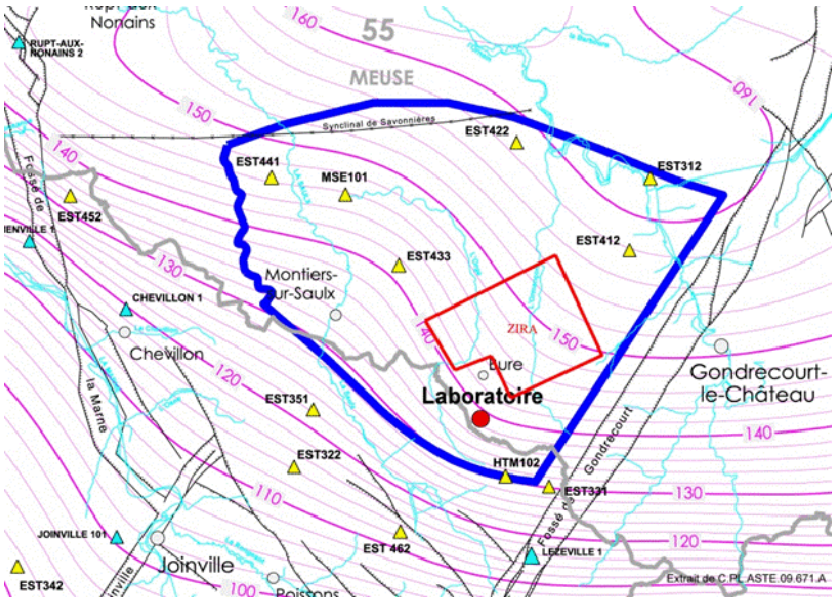

Fig. 3. Underground location of the interest zone for the geological repository.

In March 2010, based on advices from the National Assessment Board and from the Nuclear Safety Authority, and on the opinion from National and local elected representatives, the government allowed Andra to follow its detailed investigation programme in this restricted interest zone. Thus, a more detailed campaign was launched during spring of 2010 in this restricted interest zone.

Surface installations will also have to be located in close association with the construction of underground structures. Studies have shown that some concept choices offered versatility for implementation purposes. In fact, the use of more or less steep inclines or a combination of shafts and inclines would probably decouple part of the surface installations (i.e., especially in the case of nuclear facilities) by several kilometres (e.g., about 5 km for a 10% dipping incline) from the underground structures (Fig. 4). The other part of the installations will remain vertical relative to the underground structures for technical reasons (air-return shaft) or industrial reasons (e.g., industrial excavation-related activities).

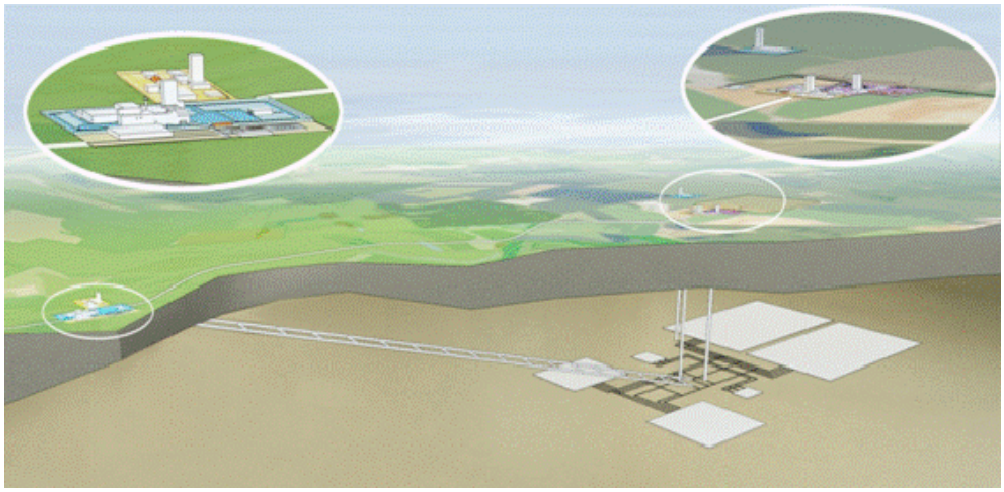

Fig. 4. General architecture of the geological repository with its surface installations.

The next step in the site implementation is to define the 15 km^2 location for underground facilities from the last detailed investigation campaign and to locate the surface facilities. This includes a close work with the local stakeholders.

In order to define those scenarios for the implementation of surface installations, it is essential to consider the various constraints to which the industrial project is submitted. Those requirements, which are more or less constraining, include notably the integration of the following components:

- The relief: zones with a low dip are preferable for implementing surface installations;
- Easily-flooded zones, damp valley bottoms and protection perimeters of drinking-water catchments, as well as criteria with a potential impact on the size of the surface nuclear installations (air-crash risk and flood hazards, etc.);
- Urban areas, isolated dwellings and historical monuments; and
- Outstanding natural sites, such as Natura 2000, natural zones of ecological, faunistic and floristic interest, etc.

In parallel, it is necessary to examine connection possibilities with transport infrastructures (road, railroad, navigable waterways) and to take into consideration the local socio-cultural and tourist heritage. Lastly, the implementation scenarios for surface installations under study and the proposed interest zone must be consistent.

NEXT STEPS TOWARD CONSTRUCTION OF THE GEOLOGICAL REPOSITORY

Holding a public debate prior to the submission of the licence application to authorise the implementation of a deep geological repository provides an additional opportunity for all stakeholders to express their views in the light of the entire body of knowledge made available by Andra. The purpose is to ensure collectively that current and future generations, even over the very long term (hundreds of thousands of years), will benefit from suitable conditions in order to manage the repository both safely and efficiently. The current investigation programme includes a public debate to be held between the end of 2012 and the beginning of 2013.

By adopting a stepwise approach, Parliament wished to be consulted once again before the government makes any licensing decision. Two control points have been established. The first prescribes that the reversibility conditions of the repository be determined before any authorisation to implement a repository is granted. According to the schedule set by the *Planning Act of 28 June 2006*, a corresponding law should be adopted after the submission of the licence application, in other words, in 2016. Later, once operations will have come to an end after several decades, only a new law may formalise the final closure of the facility. By observing and monitoring the behaviour of the disposal structures and of emplaced waste packages throughout those decades will provide technical information upon which that decision will be based.

Finally, pending on the licensing of the repository, construction works will begin at the earliest in 2017, for commissioning of the initial stage of the repository by 2025.

CONCLUSIONS

Lesson learnt from those last 20 years shows that only a stepwise approach could lead to progress in implementing a geological repository. The progressivity of the decision is based on a combination of technical findings and of national and local concerns, acting each new step and defining the next ones.

For the French case, it is remarkable to see how from a first set of over 30 candidate sites, a first selection of 4, and then 3 sites for kept for preliminary site investigations, for the aim of constructing an underground research facility.

Based on the results achieved in 1996, the Government decided to proceed with the construction of an underground laboratory at the boundary of the Meuse / Haute-Marne districts. Then detailed investigations led to the definition of a 250 km^2 zone giving favourable characteristics. In 2006, further investigations were committed on this zone. A more restricted zone of 30 km^2 was then proposed in 2009 to the government, and selected for the final detailed investigations. The underground 15 km^2 disposal facility will now be located in this restricted zone, while the surface installations are being located along through a dialogue with the local stakeholders.

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