Sampling Optimization for the Characterization of a Drum Disposal Legacy

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INTRODUCTION

The Bauzot site, located in Burgundy, France, was initially an underground mining site for uranium extraction in the 1950s. Then for a dozen of years, very low level radiological waste and mining residues were stored on the former pithead. Later in the 1980s, mining works came back with an open pit at the edge of the storage. This site is now AREVA Mines's property and is a Classified Installation for Environmental Protection.

According to recent environmental regulation, the physicochemical and radiological knowledge of the 50 years old storage site has to be significantly improved to complete the existing monitoring. In addition to new piezometers and the update of the hydrogeological model beneath the site for potential transfer to the surrounding environment, it is then necessary to carry out a sampling campaign to characterize the storage itself.

Despite a sizeable budget, the possible number of drillholes (water-free, confined) is limited and their locations have to be thoroughly selected. That is why a better prior understanding of the storage setting up is necessary.

This paper presents first the different sources of information and their exploitation to build a 3D reconstitution of the storage. Based on this improved historical knowledge, an expertise sampling strategy is initially proposed and adapted taking on site drilling results into account.

HISTORICAL RECONSTITUTION

Analysis of Archive Documents

In addition to a very large number of papers related to the mining works in the 1950s, a significant amount of archives is available for the storage period of the site. Working with regular records, inspection reports and so on, an initial inventory presents the three origins and corresponding tonnages of the drums stored on the site (Table 1.).

Thus, the first two origins represent the major part of the storage. They are composed of uranium-thorium-radium waste with different fingerprints.

The last origin shows a singular isotopy with Caesium-137. In addition, this third waste family only represents 1% or 2% of the total number of stored drums.

Table 1. Waste inventory of Bauzot site.

Origin	Drum quantity	Waste nature
Nuclear fuel factories	48,000	Graphite, quartz, sludge
Concentration plant	32,600	Uranium ore residues
Dismantling of a research plant	A few hundreds	Rubbles and soils

Before 1964, precise pieces of information on drum quantities and arrival dates are not available. After 1964 (and untill the end of the storage periode in mid-1969), quarterly reports describe accurately drum arrivals and storage locations, which is a very valuable information.

Most interesting, the storage is found to be divided into two parts: the North-East area was declared filled in mid-1961. After a one year or so transition period with no drum arrival (political contretemps), the second storage area was implemented in the West part of the site, slowly growing from North to South direction (Figure 1).

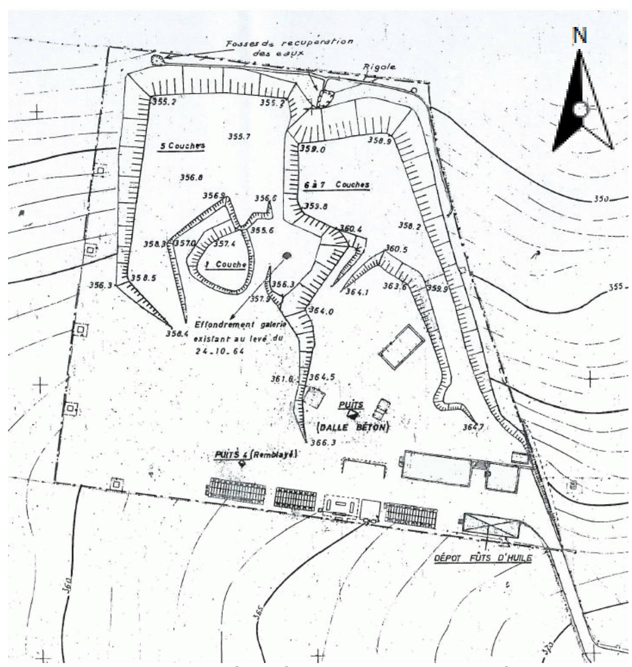

Figure 1: Topographical survey in September 1965.

This chronological understanding of the storage setting up higlights a very short time period for Caesium-137 waste arrival on site just before the transition period. Corresponding drums are supposed to be groupped together.

In addition to paper document analysis, on site photos confirm that drums are stored in neat sub-horizontal layers.

Drums layers are intercalated by materials directly taken on site from the former mining dump (with very low uranium grade).

Figure 2 illustrates a load arrival and three horizontal drum layers of the early storage. In the background, the mining dump is progressively used to constitute the blocking layers for a better stabilisation of the storage. Figure 3 shows a partial drum layer; the photo was taken from the top of mining dump.

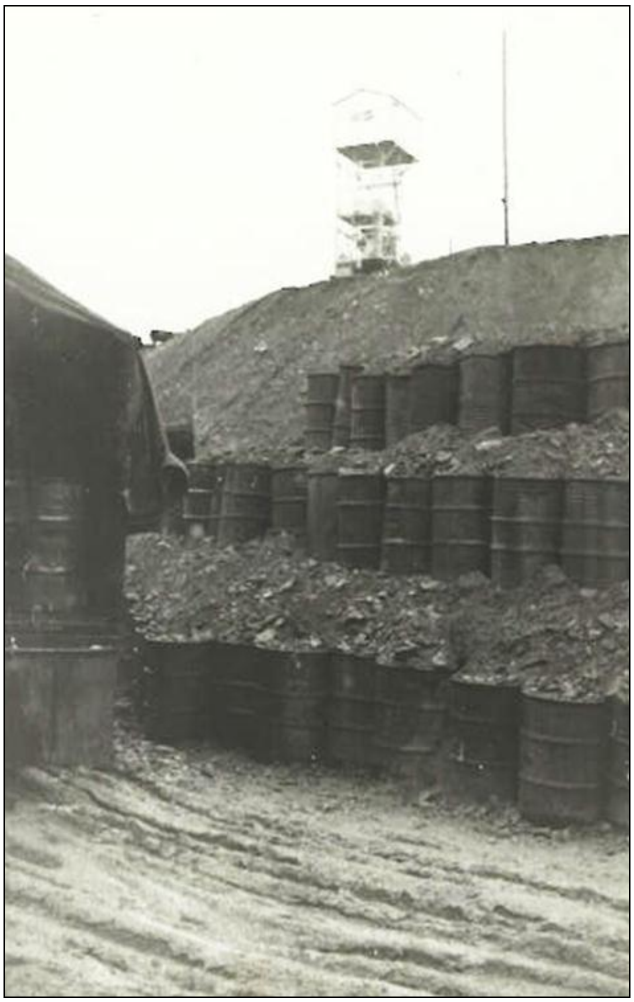

Figure 2: Load arrival and horizontal drum layers of the storage.

Figure 3: Constitution of a drum layer.

Other photos show how the drums were unloaded and put in place by a tractor with forks or the fact that empty squashed drums were also stored on the site.

Topographical Survey and Aerial Photos

Due to the past mining activity of the site, topographical survey was a common practice. A large number of maps were performed during the storage setting up. They represent a very valuable source of information as regards borders, layer per layer, storage filling, elevation figures, handwritten annotations…

During the storage lifetime until nowadays, a dozen of surveys are available with elevation data. Between 1964 and 1969, we have access to one map per year but unfortunately only one map dates from the first part of the storage (for example Figure 1 illustrates the site state at the end of 1965). The quality is variable between clear hand-drawn maps and useless blueprints. The finished first storage area can be identified in the North-East part while the second area is already 5 layers high in its North part slowly enlarging in the South direction.

Similarly, aerial photos from campaigns of the National Geographic Institute were taken regularly above the site. Color contrasts put the emphasis on taken pathes, recently modified areas, etc. Figure 4, which is approximatelly syncroneous with Figure 1, advantageously complete the 1965 topographical survey.

Figure 4: Aerial photo in August 1966.

3D Modelling of the Storage Setting Up

As a result, the site can be modelled on the basis of topographical surveys analysis. Each survey is digitalised thanks to contour lines and handwritten elevation data. Then a quick surface interpolation is performed tacking abrupt topographic changes into account with calculations faults. Finally, materials related to a given period (arrived for drums, and removed for the mining dump) are determined by subtraction between corresponding elevation surfaces.

This 3D reconstitution (Figure 6) allows a better understanding of the storage setting up. Most relevant slices of this model are presented in Figure 5.

Waste drums are stored in subhorizontal layers the same way a geological deposit does. On the contrary, the size of the mining dump reduces along years like an erosion process to follow the geological comparison. Uncoloured areas inside the storage are associated with lateral uncertainties. They are mainly connected with the interface between the rest of the mining dump and the drums layers.

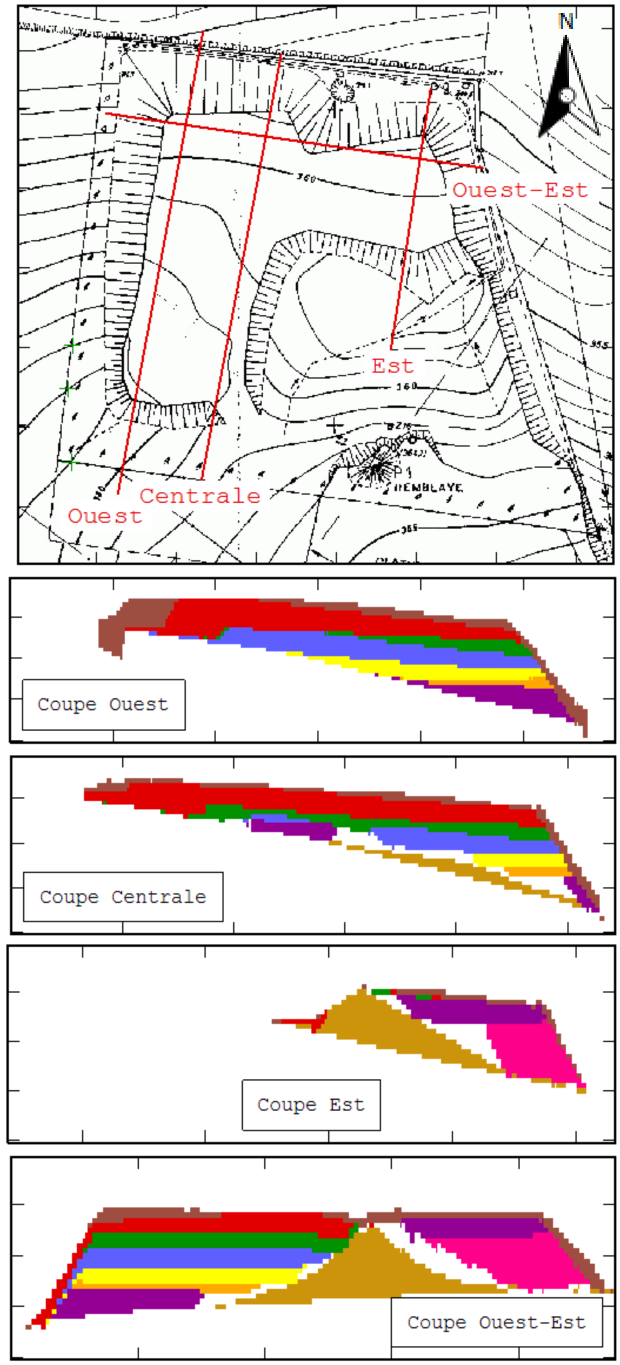

Figure 5: Four slices of the 3D topographical reconstitution (each colour is related to a limited time period).

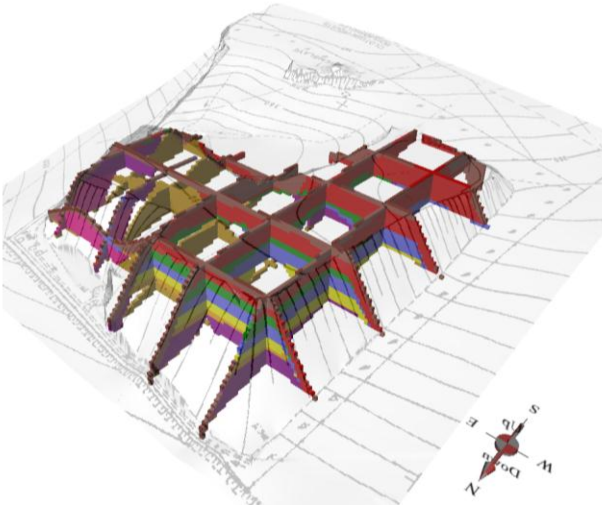

Figure 6: 3D reconstitution of the storage setting up (similar colours to Figure 5). Only a few slices inside the storage are presented.

This way, a very good coherence and complementarity can be noticed between all sources of information (paper archives, surveys and aerial views). Moreover the global storage coverage and dimensions are better estimated, in particular using the difference between current and initial altitudes (a few meters up to a dozen). The two storage areas are confirmed and visible both on surveys and aerial photos. The rest of the mining dump represents 15-20 % of the total storage volume and separates the two storage areas.

Additional Maps of Initial Surveys

More recent results are added to this 3D modelling of the storage. They consist in geophysical survey performed a few months before the drilling campaign. Measurement positions follow a regular grid with a 5 m x 5 m mesh inside the site and 10 m x 5 m mesh in surrounding meadow.

The magnetic map (Figure 7) confirms the two storage areas and the global boundaries of the site (detected metal supposed to be closely linked with drum presence). In addition, one magnetic anomaly (M2) is identified in the small basin in the middle of the site. The last drums that arrived in 1969 were stored in this particular area but they might have been removed after.

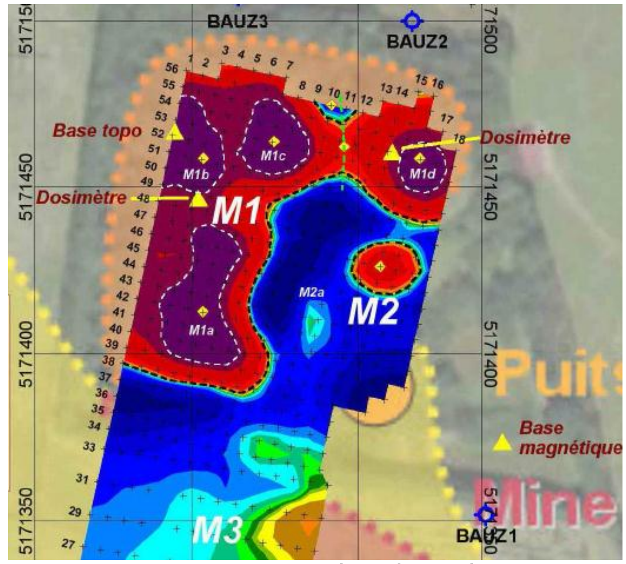

Figure 7: Magnetic survey identifying the two storage areas and one anomaly.

Using gamma spectrometry measurements, the uranium surface radiation map (Figure 8) illustrates the storage reshaping in 1985 with the open pit mining wastes. The South part of the storage is mainly concerned. U2 anomaly is consistent with M2 anomaly of the magnetic survey.

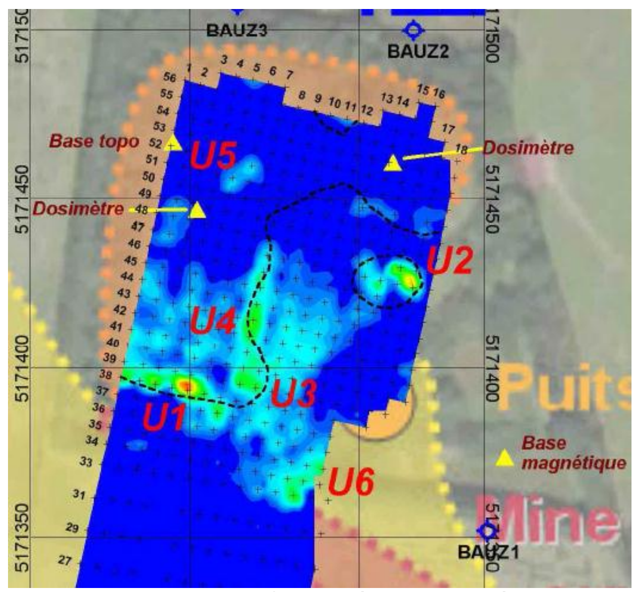

Figure 8: Uranium surface radiation map by gamma spectrometry.

Synthesis of Historical Reconstitution

Aerial or on-site photos, survey maps, written archives, hydrogeological and geophysical studies lead to a comprehensive 3D modelling of sub-horizontal layers of approximately 80,000 drums with at least 3 different radiological fingerprints.

Three different locations are identified for Cs-137 waste storage, one of them with a higher probability. Drums layers are intercalated by mining wastes and finally capped by a waterproofing layer.

Destructive samples have then to be collected in order to validate this historical reconstitution and assess activity levels.

EXPERTISE AND ADAPTIVE SAMPLING DESIGN

Sampling Strategy

The determination of the sampling design is a crucial issue to fulfil the characterisation goals. As already mention, due to limited time and despite a sizeable budget, only 22 drillings are possible as the drilling technique is quite expensive (water-free sonic drilling, entirely confined to avoid contamination spreading…).

In order to maximize value of data to be collected, the initial sampling design is then divided into two sets. The first set aims at characterizing the storage from a global point of view and validating the historical setting up. Then after analysis of on-site drilling results, the second drilling set is located to improve the storage modelling in particular areas. This sequential sampling approach provides better results but requires interactivity and efficiency between all actors (drilling team, measuring workstation and data analysis).

First Set of Drilling Positions

The first ten locations (Figure 9) are decided on judgmental expertise, taking the 3D modelling of the historical reconstitution into account. A homogeneous coverage of the entire storage area is also respected.

Nevertheless each drilling is linked to a precise objective:

- Sampling of the mining dump for #1 and #2 (and drilling operations running in).
- Characterisation of the first storage area for #3.
- Characterisation of the second storage area for #4, #5, #6, #7 and lateral continuity with #8.
- #9 is the middle of the major area of interest.
- #10 is located in a strongly modified area during the storage setting up.

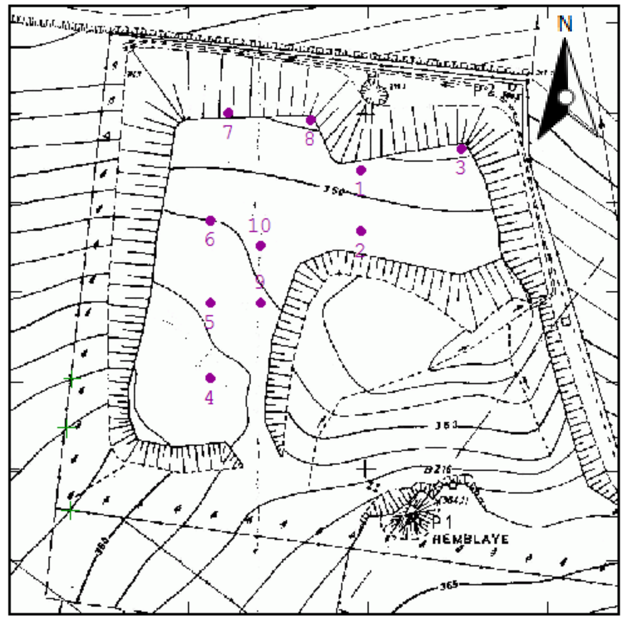

Figure 9: Base map of the first ten drilling positions (first stage of the characterisation).

In addition, for each of these positions, the estimated height of the storage and the expected number of drum layers are announced to facilitate drilling works.

On-Site Results to Adapt the Strategy

To make a sequential sampling strategy possible, on-site results (gamma scanning of all samples, gamma ray logging inside the drilling holes) are collected in real-time. They confirmed prior knowledge as for number of drum layers, altimetry, and encountered matrix. Moreover, Cs-137 waste is confirmed in the most expected area, giving even more confidence in the historical reconstitution.

Figure 10 illustrates these quick on-site results on drilling site #6. Matrix identification and drilling log match almost perfectly. The drilling recovery varies between 50 and 100 % due to voids in the barren rock (small and big blocks) and above all in drums.

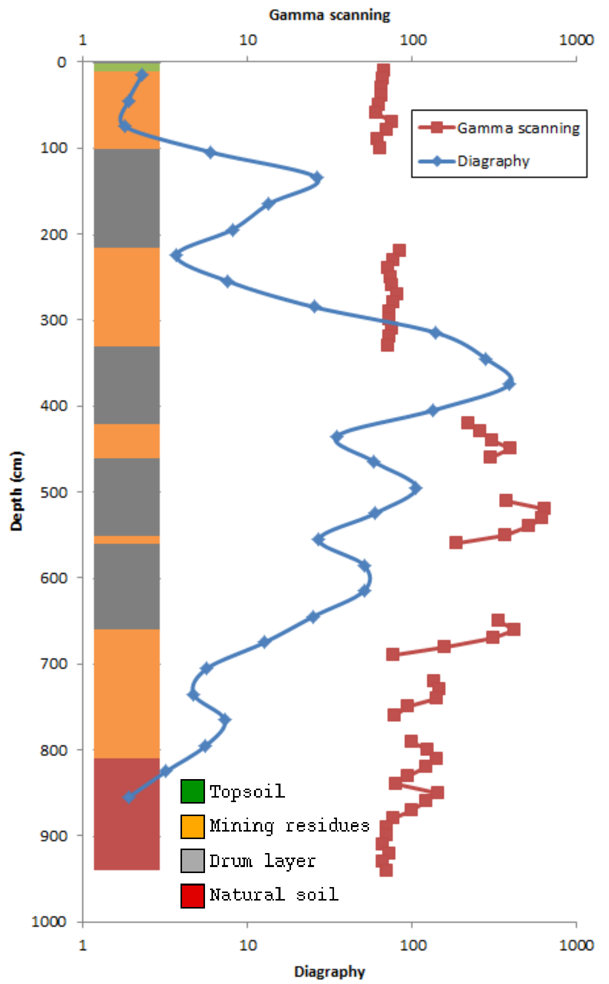

Figure 10: Drilling log, diagraphy in the drilling hole and gamma scanning on the core.

Second Set of Drilling Positions

The remaining 12 drillings (Figure 11) are then positioned to improve available information in areas with large uncertainties: spatial variability of drum layers, high dose rate or activity levels, different fingerprint, etc.

In particular:

- The area around drillhole #9 is oversampled to delineate the extent of Cs-137 waste (#13, #14, #15 and #16).
- Locations #11 and #12 aim at improving knowledge for the first storage area.
- Drillholes #17 and #18 are located in the second storage area to consolidate results and interpretation.
- Locations #19, #20 and #21 intent to confirm or not the presence of the last drums arrived in 1969 in the small basin in the middle of the site.

The last drilling is located outside the site to get a rough characterization of background levels.

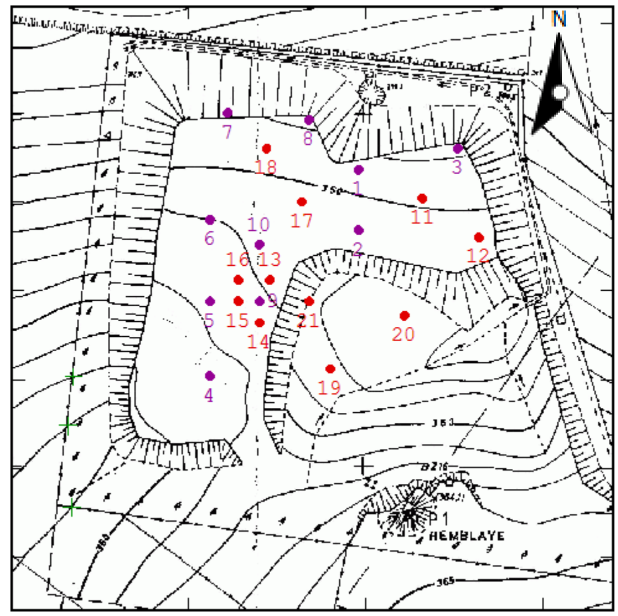

Figure 11: Base map of all drilling positions (second stage in red).

RESULTS/LESSONS LEARNED

Improving the physical and radiological knowledge of Bauzot site was a quite big challenge. A unique and complex site characterisation has been successfully implemented to confirm the presence of three drum origins and to validate areas of interest.

The final characterisation is on the process as laboratory results are just arriving at the end of 2012 (gamma spectrometry on all samples and advanced analyses on targeted samples). The global synthesis will be available soon.

The adaptive sampling strategy is very efficient in combination with on line data interpretation to refine interactively the sampling plan. Based on a high level historical reconstitution, it proves to be the best approach to optimize the collected data due to the limited number of drillings. That way, the waste family representing only 1% of all stored drums has been properly delineated with only a very limited drum sampling yield at the storage scale (only 80 drums over 80,000 are passed through).

After 6 months of preparation, 3 months of drilling operations and 6 months of laboratory analyses and data interpretation, the Bauzot site is on the point of been correctly characterized thanks to an outstanding cooperation between all stakeholders.

Furthermore, no radiological incident has occurred toward drilling workers (despite the extreme climatic conditions) nor toward the environment.

The sampling preparation, notably the historical reconstitution, has been very valuable to optimize the investigation effort. In the light of this updated site characterization, AREVA Mines is now in position to decide on the storage future, in agreement with regulation authorities.