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TOPOGRAPHICAL SURVEY AND SOIL CHARACTERIZATION OF A CANDIDATE SITE FOR RADIOACTIVE WASTE REPOSITORY

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ABSTRACT

Brazil has already initiated the establishment of a national near-surface repository for the low- and intermediate short-lived radioactive wastes generated within its territory. With two nuclear power plants in operation and a third one under construction, five active nuclear research institutes and another one planned for the intermediate future, operational constraints and social pressure built up for a disposal solution for such a waste category. The Brazilian Nuclear Commission CNEN was tasked at designing, building and commissioning this repository, which implies, among other activities, finding a suitable place for the facility. After an initial technical desk job, a federal land, not far from the NPPs, was appointed and *in situ* studies for the site characterization were started. This paper describes the topographical survey and soil drilling campaign carried out for the initial evaluation of the feasibility of the site *vis-a-vis* the applicable national regulations for site selection and disposal facilities licensing.

1 INTRODUCTION

The Brazilian Nuclear Commission CNEN was tasked at establishing a near-surface repository for low and intermediate level wastes generated by the Brazilian two nuclear power plants – NPP – units, the nuclear fuel production facility and by the nuclear research facilities operating in the country, as well as by future nuclear installations. One of the most challenging activities of this enterprise is the selection of a proper site that would meet the diverse technical and socio-economic criteria to host such a facility. After extensive desk studies, one area at a federal land was appointed as the most appropriate option, due of its Government owned status, sufficient area, appropriate topographic features, proximity to the NPP site, connection to the paved road grid, and lack of any technical or legal impediments. In order to gather preliminary technical information on the candidate site's terrain and landscape, hydrogeological and geophysical features and basic data of its constituent layers – depth, nature and strength –, topographical survey and soil characterization studies were conducted at the site and its immediate vicinity.

The objectives of the former were the determination and recording of the site's perimeter, surface and declivity and the characterization of its natural features and man-made buildings and elements. The terrain presents moderate declivity, interrupted at its central portion by a flat area, potentially allowing the building of two plateaus where the planned disposal structures and auxiliary buildings could be located.

The soil consists of successive layers of sandy and silt-sandy clay, gneissic saprolite and gneiss. Ground water was detected only in the lowest portion of the terrain. No relevant

disadvantages were found that could preclude the use of the site for the establishment of the near-surface repository for low and intermediate level radioactive wastes.

The four boreholes where ground water was detected were prepared to be used as monitoring wells and are planned to be used during the preoperational phase to gather information on the ground water distribution. Biological and physicochemical analyses were conducted for the characterization of the ground water.

According to the results of the studies carried out so far it can be said that the candidate site is appropriate for the establishment of a near-surface repository for radioactive wastes *vis-a-vis* the applicable national regulations for site selection and disposal facilities licensing [1], [2].

2 THE REPOSITORY CONCEPT

The repository consists of waste disposal areas, operational support buildings and facilities for research and development [3]. The main buildings of the enterprise include reception facilities for people, materials and waste access control, edifices for waste packages storage analysis and sampling, administration and maintenance, technical support, Environmental Monitoring and Radiological Program (EMRP) and RD&I activities on radioactive waste back-end.

The basic information about the required areas for each one of the buildings is detailed in Table 1 and its arrangement on the site presented in Figure 1.

Table 1: Repository buildings [3]

Building	Objective	Area (m^2)
Visitor Centre	Public information	1,500
Gatehouse	Access control	200
Administration	General administration and logistic support	1,000
Technical Support	Auxiliary services support	2,000
Suppliers Shed	Supplies and products storage	600
EMRP and RD&I Laboratory	Implementation of the EMRP and RD&I activities	1,200
Waste Processing	Waste packages reception, temporary storage and conditioning in overpack	378
Waste Characterization	Waste package contents verification, radiochemical and physical testing	190
Concrete Plant	Mortar manufacture, raw materials (cement, sand and additives) and empty containers storage	525
Disposal Module	Disposal of low and intermediate level wastes	11,165
Disposal Trench	Disposal of very low level wastes	1,875
Ecological Preservation Unit	Nursery seedlings, native species preservation and public visitation	N/A
Meteorological Tower	Record of Atmospheric data	N/A
Fences	Delineation of the perimeter and internal areas	N/A

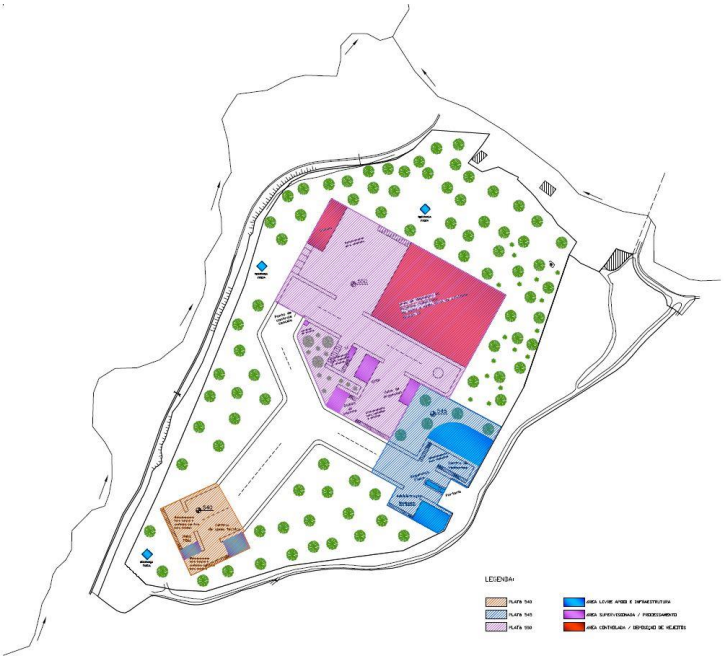

Figure 1: Arrangement of the buildings on the candidate site

3 MAIN SITE CHARACTERISTICS

An adequate site for the establishment of a near-surface repository shall have characteristics that allow the minimization of the risk of human exposure to radiation and environment contamination. The selected site shall meet, among others, suitable physiographic, meteorological, geotechnical, hydrogeological and tectonic requirements. The selection and licensing of a near-surface repository is regulated by Brazilian nuclear authority [1], [2].

In order to verify compliance with the regulations' requirements, the main site characteristics to be scrutinized at the present site selection stage are the following.

- Absence of natural resources, especially mineral ores;
- Absence of significant farming and grazing activities;
- Distant from airports and airplane routes;
- Proximity to the paved road grid;
- Distant from permanent settlements;
- Low population density and not included in new development plans;
- Distant from flooding areas;
- Moderate declivity;
- Not subjected to extreme climate phenomena, as tropical storms or extra-tropical cyclones;
- Maximum water table level below waste level;
- Simple geological formation;
- Good soil stability.

4 SITE GEODETIC AND TOPOGRAPHIC ASPECTS

The geodetic-topography survey was carried out in December 2014. In line with the established good practices, the Brazilian Technical Standards Association ABNT guidelines [4] and the Federal Government practices [5] were followed and the Brazilian geodetic information system technology [6], including the nearby geodetic IBGE stations, was used to link to the site geodetic survey. Conventional technology using a polar-linear network of points was employed. The elevation of the points of interest was defined by trigonometric leveling.

The first activity consisted of the establishment of two geodetic reference points, consisting of pyramidal concrete pillars (Figure 2). The recorded coordinates were processed using the GNSS Solution software. The next step in the determination of the boundary polygonal was the installation of a network of supporting points. All points are stabilized on wooden pillars with forced centering devices for observation and were used for regular precision multi-purpose measurements.

Figure 2. Geodetic reference point

All relevant features of the region, e.g. roads, trails, fences, constructions and natural elements were surveyed according to the same network of reference points and recorded.

As a result of the geodetic and topographic surveys, the following data were determined:

- Lowest elevation: 500 m a.m.s.l.[1]; highest level: 565 m a.m.s.l.;
- Total terrain surface: 272,402 m^2;
- Terrain perimeter: 2,189.27 m

The site topographic map is shown in Figure 3.

[1] a.m.s.l. – above mean sea level

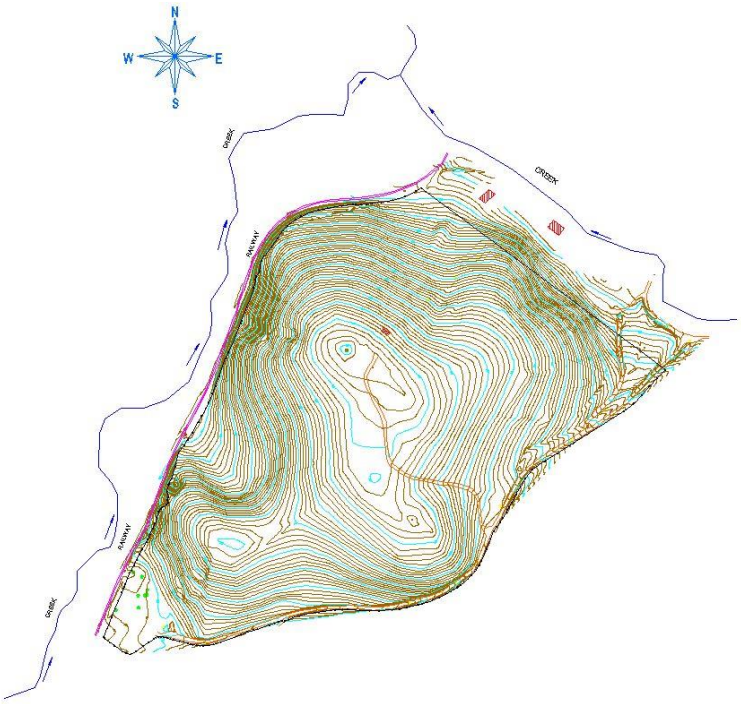

Figure 3. Candidate site topographic map

5 SOIL CHARACTERIZATION STUDIES

5.1 General data of soil drilling

The soil investigation consisted of the drilling of twelve boreholes across the site, denominated SM-01 to SM-12. A combination of rotary drilling with SPT – Standard Penetration Test – measurements was used throughout the investigation. The samples were preserved for further laboratory tests. Four boreholes – the ones where groundwater were detected – were subsequently prepared to be used as groundwater observation wells. The location of the boreholes is shown in Figure 4.

The soil was drilled until sound rock was reached, when a hole was drilled three meters deep into the rock.

The different sections of each borehole were conditioned in wooden boxes for visual inspection and further laboratory analyses.

5.2 Main results obtained

The lithography of the soil consists basically of distinct well defined layers above the bedrock. The uppermost layer is sandy clay, non-plastic, of brown yellowish color, medium stiffness. This is followed by a sandy silt clay, non-plastic, red to brown soil of hard consistency, then sandy clayish soil from rock weathering, hard consistency, variable color, until a gneissic saprolite layer is reached. The latter contains decayed, powdered and friable minerals of variable color and presents inferior physical-mechanical properties comparing to the preceding layer. The bedrock is made of a sound, intact and preserved gneiss of grey color with dark veins, presenting no evidence of physic-chemical alteration.

Figure 5 shows the above mentioned lithography spectrum, which was found as complete as described previously in elevations above 540 m and depths between 26 and 45 meters. In none of these boreholes underground water was detected, which happened only in the drilling points located in the lowest elevations.

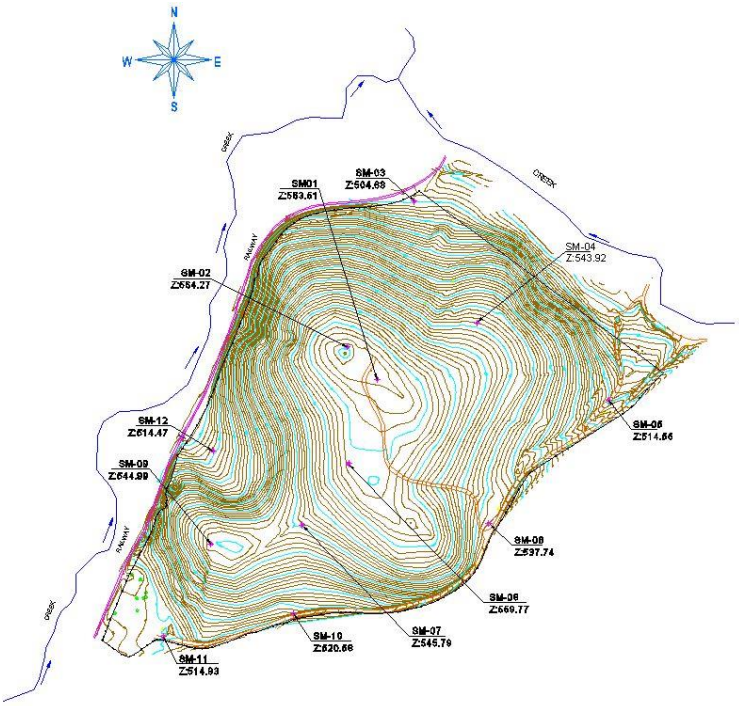

Figure 4. Location of the boreholes for soil investigation

Figure 5. Typical soil composition, from top sandy clay to gneissic rock

6 GROUNDWATER FLOW AND QUALITY

6.1 Monitoring wells description

The four boreholes where water was detected were later adapted to be used as monitoring wells to assess hydrological conditions and ensure environmental control (boreholes SM-03, SM-10, SM-11 and SM-12 in Figure 4). The parameters and data to be recorded are changes in the piezometric level, groundwater flow and direction and quality of both ground water and the surface water collected in the surrounding area. The information collected will be used in the environmental impact studies and for the characterization of the local hydrology.

The monitoring well arrangement is shown in Figure 6. The bottom of the well consists of a sediment box filled with bentonite in pebbles. A slotted ϕ2" PVC pipe, surrounded by a pre-filter layer of gross sand, constitutes the filtering section of the well. The top elements are a two-meter long capped ϕ2" PVC geomechanical pipe and a sanitary seal to prevent the filter contamination. The sealing material is a bentonite-cement-water filling mud. Figure 7 shows aspects of a monitoring well construction.

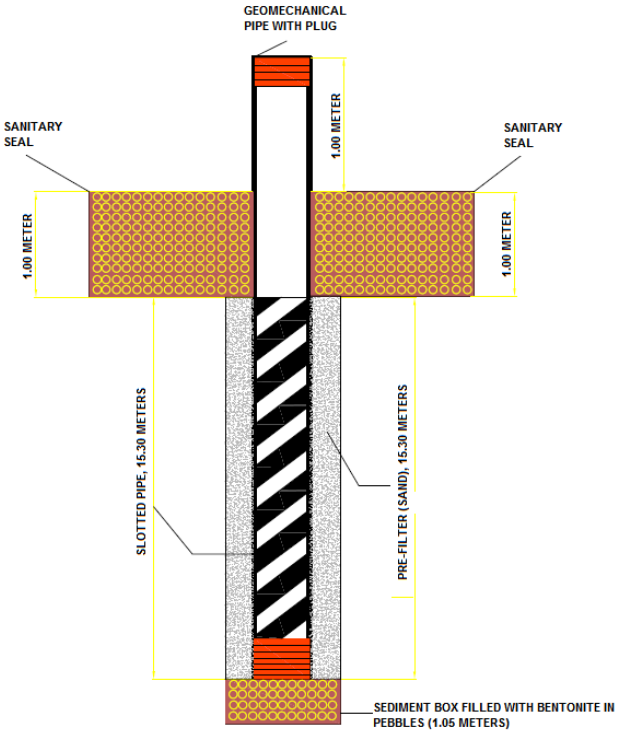

Figure 6. Monitoring well arrangement

6.2 Water quality results

The water collected in the monitoring wells was submitted to analyses to determine its physical-chemical and organic parameters. The chemical characteristics of groundwater, as it keeps a close relationship with the types of rocks in its pathway, can provide information about the terrain through which it percolates. Likewise, information about the products of human activities acquired along its path can be inferred from these analyses.

Figure 7. Construction of a monitoring well

The results of the analyses conducted showed high values for total aluminum, total iron, total manganese, turbidity, color apparent, heterotrophic bacteria, total coliform and Escherichia coli. Geochemical anomalies can be associated with the presence of aluminum, iron and manganese elements. Iron is persistently present in almost all groundwater systems and, due to geochemical affinities, is almost always accompanied by manganese. The presence of high iron concentration values, when in contact with oxygen from the air, can also cause an increase in color apparent and turbidity. The high concentration values for color apparent, total iron, manganese and total turbidity can thus be explained by probable geochemical anomalies in the region. The results for heterotrophic bacteria, total coliform and *E. coli* relate more specifically to fecal contamination originating from warm-blooded animals. These contamination levels are likely due to agriculture and cattle grazing activities in the region under study. The results for ammonia, being below maximum allowable values, indicate contamination by activities not recently carried out.

6.3 Preliminary conceptual model of underground water flow

From the analysis of the topography data and drilling profiles it can be inferred that the higher elevation portion of the terrain is the aquifer recharge area. The water flow is probably predominantly vertical through the silty and sandy clay and gneissic saprolite layers, with a horizontal component appearing when lower permeability layers are reached. The flow has the potential to occur in all directions around the recharge areas, and flows westward tend to be directed to the nearby creek (Figure 3). All water-yielding boreholes are located in the western region of the site, close to this stream.

Due to the small number of hydraulic recharge measurements and the lack of topography information at the vicinity of the creek, a potentiometric map of the area cannot be drawn. It is noteworthy that the drilling was carried out during the rainy season, but in a year of unusually low rainfall. Thus, while the potentiometric surface is in its highest level during this time of year, more intense rainy periods can generate higher potentiometric levels.

Supposing that there is continuity in the surface aquifer, the piezometric levels measured in these four monitoring wells indicate an underground stream in northwest direction, with the largest hydraulic load of 515.78 m on the SM-10, located south of the area, and the smallest of 495.60 m on the SM-03, north of the area.

The hydraulic gradients between the monitoring wells were estimated between 0.8 and 3.4%, the largest gradient identified between SM-12 and -03, still supposing that there is hydraulic connection between them.

7 CONCLUSIONS

The characteristics of the candidate site and the results of the studies carried out so far lead to the conclusion that the chosen area presents no impediments to the establishment of a near-surface repository for low and intermediate level radioactive wastes. As of space availability, the surface measured by the topography survey – 28 hectares – is larger than the minimum necessary for the enterprise – 20 ha. The distances from the paved road grid and to basic infrastructure – water, electricity, data & voice services – are within manageable economic and logistic limits. Also the relatively proximity to the nuclear power plants, the main Brazilian radioactive waste generator, adds up to the previous positive site features.

In line with the recommendations of national nuclear guidelines [1], [2], the site is within a federal area, lent to CNEN for a long-term period, encompassing the operational and institutional control periods. Other favorable facts are the absence of mineral deposits of interest, maximum altitude below limit – respectively 565 and 1,800 meters a.m.s.l –, and moderate declivity.

The hilly profile of the terrain allows the distribution of the two planned leveling plateaus and repository buildings in such a way that there will be no interference in the surface water flows, either from rainwater runoff and the nearby creek. Therefore no increase in erosion of flooding risks will be induced by the establishment of the repository.

The site vegetation, consisting almost entirely of pasture fields, features widely spaced, scattered bushes and therefore practically no vegetation suppression will be necessary for the repository implementation. Likewise no interference in the nearby neighboring protection areas will be required; on the contrary, it is highly desirable that they are kept as a greenbelt, a visual and physical protection barrier against human intrusion into the repository area.

Regarding anthropogenic factors, there is no facilities, settlements or economical activities of importance within 5 km from the site that could adversely impact the environmental monitoring and radiation protection studies.

It is also possible to conclude that, based on the preliminary building distribution layout and topography study results, the whole soil volume to be excavated for the plateaus' and buildings' construction can be disposed of inside the site's boundary, thus minimizing the environmental impact of earth movement and particulate dispersion in the air.

As for the soil geological structure and properties, the well-defined and relatively simple soil structure (consecutive layers of sandy and silt-sandy clay, gneissic saprolite and gneiss) constitute a positive perspective for the future safety analysis of the facility.

It can be then concluded that, based on the field studies and observations so far completed, the candidate site presents no impediment for the establishment of the planned sub-surface radioactive waste repository. Further studies however on the hydrogeological, geochemical, climatology and hydrology features of the site, as well as on the geomorphological processes important for the soil conformation, must be carried out for a final site characterization and its approval.

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