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Department/Section	**WASTE MANAGEMENT**
TITLE:	**SITING JUSTIFICATION REPORT: THABANA PIPESTORE EXTENSION**

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1.0 EXECUTIVE SUMMARY

Due to the Thabana Pipestore running out of storage space, more on-site storage of spent SAFARI-1 fuel and NTP Uranium residue is required.

Various South African acts, policies, regulations, nuclear authorisations were considered. These were presented to DMRE. In addition siting considerations, considering the siting requirements specified in SHEQ-INS-0812 [1], were made and considered in this document.

This document considered storage layout options, and the geological detail of the exiting site, and concluded that the Thabana Pipestore is required to be extended, thus using the existing location, to store both SAFARI-1 spent fuel and the NTP uranium residue.

2.0 PURPOSE

The purpose of this document is to present the siting justification of the extension of the existing Pipestore Facility on Thabana.

This report is an update of NLM-REP-23/198, which was updated to address NNR comments in NIL04B0205.

3.0 SCOPE

This report is applicable to the Pipestore Facility on Thabana which is located on the Necsa site.

4.0 REFERENCES

[1] SHEQ-INS-0812	Project siting requirements and justification
[2] NIL04 (Variation 0)	Nuclear Installation Licence for the operation of the Thabana Complex
[3] NLM-PLN-00435	Management plan for the SAFARI-1 spent fuel and the NTP uranium residue
[4] CEO-DOE-LET-0745	Necsa letter: Application for approval for On-Site Storage of SAFARI-1 Spent Fuel and NTP U-Residue at the Extension of the Thabana Pipestore
[5] E2/5/9/3 (27/10/2022)	DMRE letter: Re: Application for approval for On-Site Storage of SAFARI-1 Spent Fuel and NTP U-Residue at the Extension of the Thabana Pipestore
[6] NLM-REP-17/048	Used Fuel Management Strategy for SAFARI-1. (2017)
[7] NLM-REP-18/162	The Geological Suitability of Thabana for the Extension of the Pipe Store Facility. (2018)

[8] NLM-REP-18/134 — Option Study for the Extension of the Pipe Store Facility. (2018)

[9] IAEA (2013) — Management and Storage of Research Reactor Spent Nuclear Fuel. Proceedings of a Technical Meeting held in Thurso, United Kingdom, 19–22 October 2009

[10] Roadlab Report — Engineering Geological Report for the Necsa Pipe Storage Facility. Roadlab. March 2019.

[11] Council for Geoscience Rep No 2001-0063 / Necsa report GEA 1519 — An assessment of the seismic hazard at the site of the proposed PBMR Fuel Manufacturing Plant at Pelindaba. Kijko, A; Retief, SJP; Graham, G; Andreoli, MAG; and Barker, OB, 2001

5.0 ABBEVIATIONS

BEVA:	BEVA site is part of the Pelindaba West Site (fuel fabrication area)
Fuel:	SAFARI-1 spent fuel and fuel rod elements
g:	The acceleration of gravity - 9.8 (m/s^2)
GDF:	Geological Disposal Facility
IAEA:	International Atomic Energy Agency
LTS:	Long Term Storage (Container)
MTR:	Materials Testing Reactor
Necsa:	South African Nuclear Energy Corporation
NFM:	Nuclear Facility Manager
NNE:	North-North-East
NNR:	National Nuclear Regulator
NNW:	North-North-West
NTP:	NTP Radioisotopes SOC Ltd
PGA:	Peak Ground Acceleration
RS:	Richter Scale (measurement of earthquake magnitude)
SAFARI-1:	South African Fundamental Atomic Research Installation 1—a 20 MW Material Testing Reactor (MTR) operated at Necsa as a Dedicated Isotope Production Reactor (DIPR)
SS:	Stainless Steel
TPS:	Thabana Pipestore

6.0 BACKGROUND

The Thabana Pipestore is an existing Necsa constructed storage facility which is utilised for the storage of SAFARI-1 spent fuel assemblies since 1997. It was initially constructed with 30 storage pipes (each able to contain maximum 20 fuel assemblies). In 2007 the TPS was extended with an additional 30 storage pipes.

The Thabana Pipestore facility ran out of storage capacity for the SAFARI-1 spent fuel assemblies, and NTP indicated that they require additional storage for the uranium residue from their molybdenum production processes. Therefore Necsa was requested to provide a solution in this regard.

Necsa embarked on possible on-site storage alternatives and therefore proposed an extension of Thabana Pipe Store as a solution.

Necsa considered the applicable South African acts, policies and strategies, and presented, based on these, a management plan on the further management of spent fuel and U-residue to the minister DMRE [3]. In accordance with Section 34 (1) (s) of the Nuclear Energy Act, 1999, Necsa applied for the storage of NTP uranium residue and additional SAFARI-1 spent fuel in the planned extension of the existing Thabana Pipestore on Necsa site [4].

Necsa obtained ministerial approval [5] on the above mentioned application.

The NNR approved the TPS extension Basic Design and NNR accepted Detail Design under covers NIL04B0173 and NIL04B0197 respectively. The designs were accepted by the applicable professional engineers, refer to NIL04A0158.

7.0 OTHER OPTIONS AND ALTERNATIVES CONSIDERED

According to research conducted by the International Atomic Energy Agency (IAEA) [9] and earlier IAEA publications it has become clear that storage expansion and or auxiliary interim storage construction is an important step to keep many research reactors in operation. Currently, the only final options for this type of spent fuel is either reprocessing or direct disposal in a deep Geological Disposal Facility (GDF). None of these options are yet available in South Africa. In addition, reprocessing is only viable for high enrichment fuel and uranium residue. The majority of fuel and uranium residue to be stored at TPS would be low enriched material. The IAEA also recognises that sending spent fuel abroad for reprocessing will be technically difficult (due to stringent transport regulations) and prohibitively expensive.

Many countries with research reactors have in the past sent their spent fuel back to the countries where the fuel originated from which were mostly the USA and the former Soviet Union. However, this window of opportunity has now mostly been closed and a country without nuclear power programmes has to address this themselves.

Wet storage of fuel in at-reactor pools is the most commonly used storage option for the IAEA member states. However, for long term storage of aluminium clad MTR fuels (such as SAFARI-1) for periods exceeding 30 to 40 years, dry storage is considered preferable due to the known instability of aluminium in water. The IAEA's experience with dry storage of spent fuel from research reactors include facilities such as dry-wells, vaults, hot-cells, concrete channels, vertical concrete canisters and various casks. Inert gas atmospheres (such as with the TPS) has been used in some of these designs.

The TPS has been safely and securely operated for more than 20 years and the option study [6], refer to Section 9.0, confirmed that the extension of the TPS will be the most suitable storage option for new SAFARI-1 spent fuel and uraniferous material produced by Necsa.

8.0 ASPECTS CONSIDERED IN SITING OF AN EXISTING FACILITY

As per SHEQ-INS-0812 the following was considered:

8.1 NNR Licensing

The TPS is authorised for operation and storage of spent fuel, refer to NIL-04 [2].

All the radiological aspects has been considered and included in the NNR approved Safety Assessment Report.

8.2 Neighbouring facilities

The other facilities on Thabana are detailed and authorised in NIL-04:

- Thabana radioactive waste storage facilities (trenches, bunkers and borehole facilities)
- Thabana containerised radioactive waste storage facilities (stores 1 to 5)
- CaF_2 ponds

No new or other facilities were introduced on Thabana since the initial construction of the TPS.

The extension would not have an adversary impact on any of these adjacent facilities, or visa versa.

8.3 Utilities and Services

Electricity is the only utility used at the TPS. No other utilities or services would be required when the TPS is extended.

8.4 Facility utilisation

The TPS is used for the storage of spent SAFARI-1 fuel. The facility will need to be extended to allow for the additional storage capacity. There is enough open space around the TPS to allow for the extension.

8.5 Transport considerations

Transport is routinely done to and from the TPS. The extension of the TPS will not have any change in this regard.

9.0 FACILITY LOCATION JUSTIFICATION

A techno- economic management study [6] was undertaken to establish the best option for the further storage of the SAFARI -1 spent fuel and for the uraniferous waste from NTP.

The main options that were considered included reprocessing of the spent fuel, locally or abroad, return to supplier (abroad), wet and dry storage options including importing of dry

storage canisters, storage at the Vaalputs Facility in the Northern Cape and extending the current facility. The study compared the advantages and disadvantages of each option from a practical, safety and safeguards, time constraints and risk, and economic point of view and the option to extend the current TPS clearly stood out as the best option.

The extension of the current facility on Thabana with its existing NNR licence (NIL-04, Variation 0 [2]) was therefore selected for the storage of Necsa's SAFARI-1 spent fuel and the NTP uranium based waste.

An extension option study [8] was also conducted to determine the optimum extension configuration of the current TPS in terms of practicality, economics and other criteria.

Four extension options were considered in this study:

Option 1: Install both the SAFARI-1 and NTP pipes northward from the current facility

Option 2: Install both SAFARI-1 and NTP pipes southward from the current facility

Option 3: Build a parallel conjoined facility east from the current to house both waste types

Option 4: Install the NTP waste pipes northward and the SAFARI-1 pipes southward from the current facility

The following main criteria were used (as detailed in [8]), however also taking in account the safety, security, environmental, geological and safeguards issues:

1. Minimize the need for the extension of the current electrified security fence while also respecting the space requirements on either side of the security fence.
2. Topography: minimize the volume of soil to be excavated down to floor level in order to extend the facility.
3. Avoid having to duplicate expensive equipment such as the overhead crane.
4. Maximise the distance between the extended pipe store facility and other facilities elsewhere on Thabana to avoid any cross interference during :
   a. Construction
   b. Operation and monitoring
5. Make maximum use of the current infrastructure like existing pipe store space, roads, gates, and auxiliary equipment and access doors to the facility in order to avoid unnecessary upgrades.
6. Geological formation: avoid the very hard magnetite quartzite horizon outcropping just north of the facility. It will be difficult and costly to excavate to current floor level and also difficult to drill into for the storage pipes.

By carefully applying the selection criteria to the four options (assigning weights and points), refer to [8], Option 4 was identified as the best option and selected for the extension (see Figure 1, Figure 2 and Figure 3 for illustration of extension option).

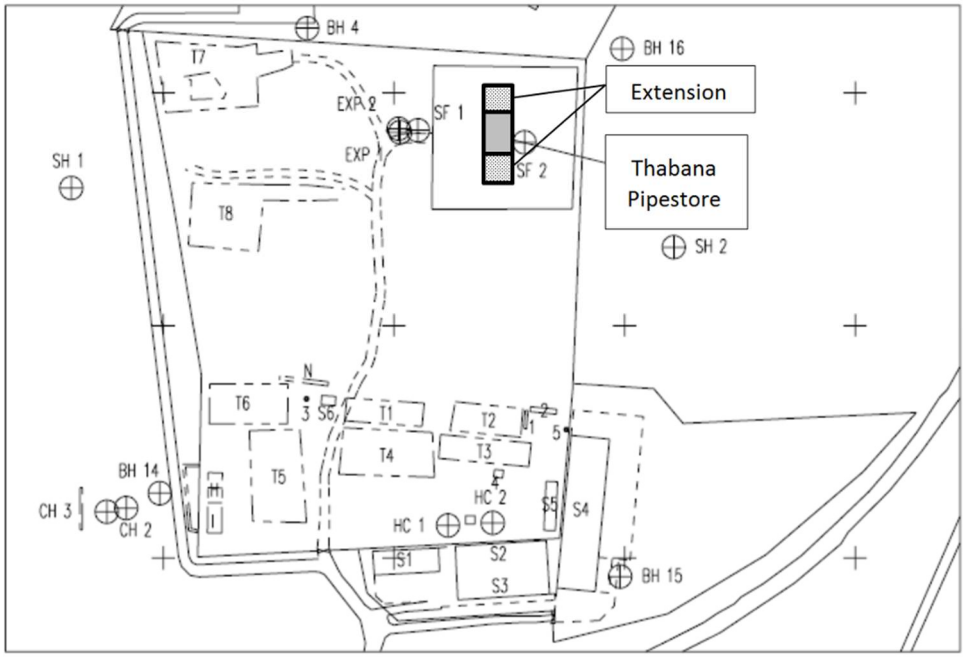

Figure 1: Location of the TPS on Thabana also showing the extension areas and other storage facilities

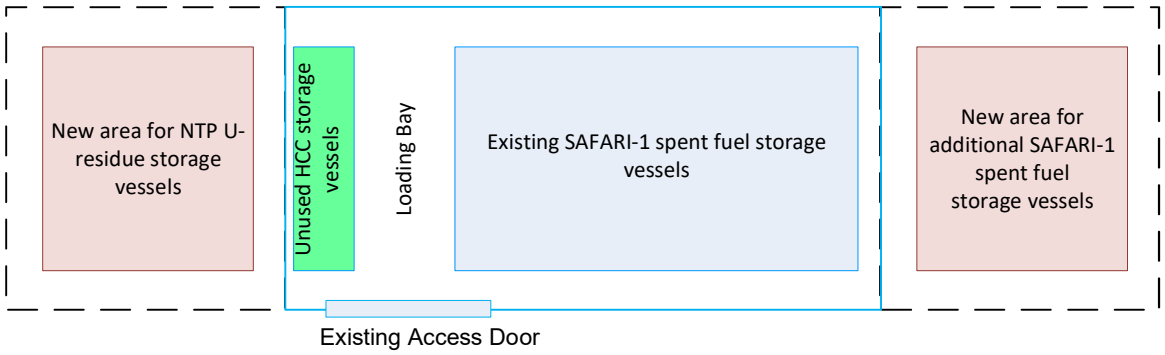

Figure 2: Layout of the TPS expansion

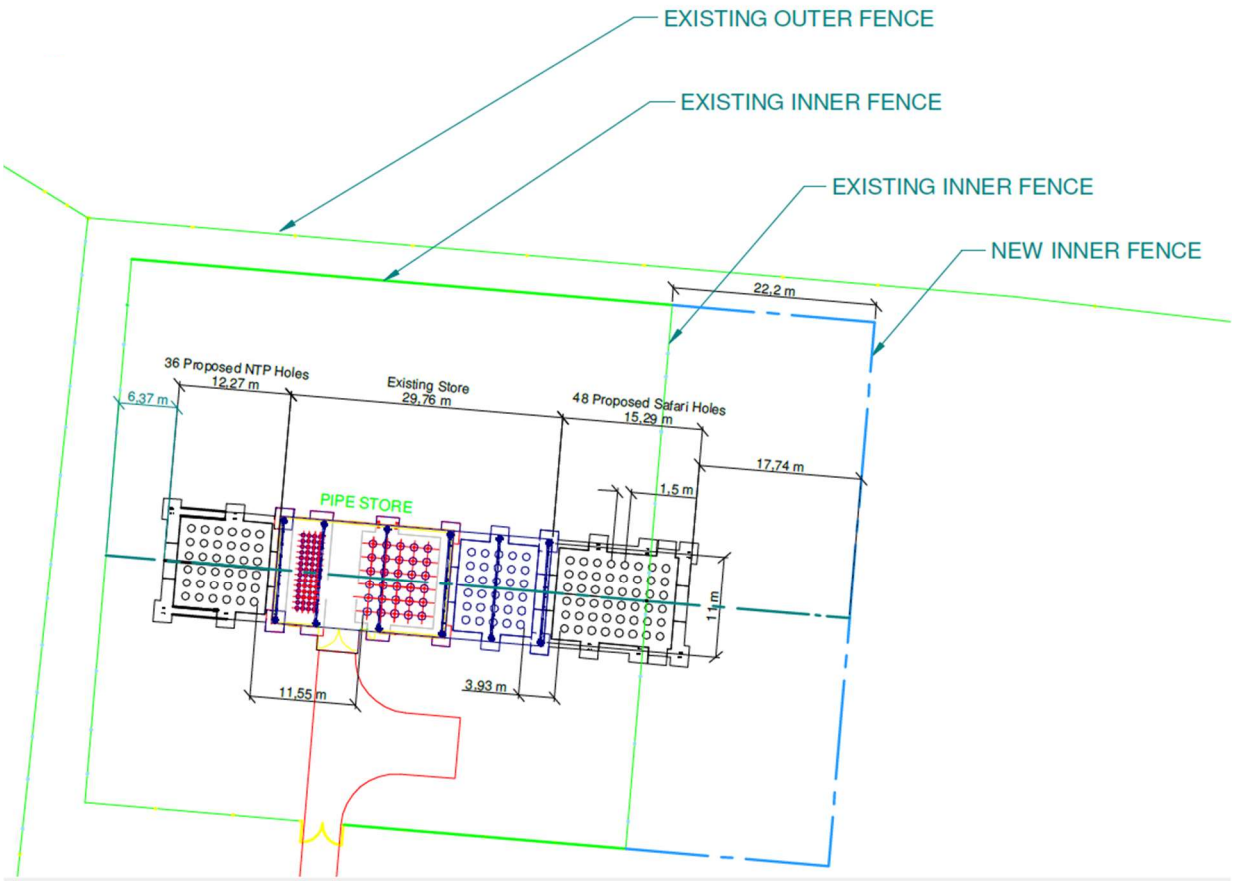

Figure 3: Area layout, showing the extended TPS facility, and the existing and new security perimeter

10.0 GEOLOGICAL SITE SUITABILITY AND SAFETY

A geological suitability report [7] provided the structural geological, hydrogeological, seismic hazard and geotechnical information relevant to Thabana and the Pipestore Facility and demonstrates the suitability of the site for the extension of the Pipestore.

The purpose of the report was firstly to provide a basic geological and hydrological model of the TPS site and environment. Secondly, the various geologically related site characteristics and features of the site were compared with national and international criteria for spent fuel storage in order to confirm the safety and suitability of the site for the extension of the facility. A brief summary of the above subjects follows below:

10.1 Geology, Geohydrology and Seismicity

The proposed extension for the TPS is located on interbedded slates and quartzites of the Rooihoogte and the Timeball Hill formation of the Pretoria Group.

The surface geology is largely dominated by a veneer of Cenozoic (geological time period) overburden consisting of likely Cenozoic gravel at the top of Thabana hill (maximum thickness ±2 m to 3 m), and by a widespread Quaternary colluvium on its flanks. Due to these deposits, the exposure of bedrock slates is sparse and largely concentrated on the steeper slopes west

of Thabana. The geological profile (from top to bottom) at the TPS can be subdivided into 5 zones, namely:

- Topsoil or Cenozoic overburden;
- Upper weathered light brown and pink slate;
- Dark brown weathered slate;
- Grey weathered slate; and
- Dark grey, unweathered slate; and purple quartzite.

The storage boreholes at the TPS intersect only the 2 top geological zones described above and the dark brown, grey and dark grey zones occur only from about 25m and deeper.

Generally, the geomorphology of Thabana is controlled by NNW trending faults responsible for the riverine incisions, whereas the quartzite, especially those rich in magnetite, have protected the more easy to weather slate from further erosion. The geology of Thabana is shown in Figure 4.

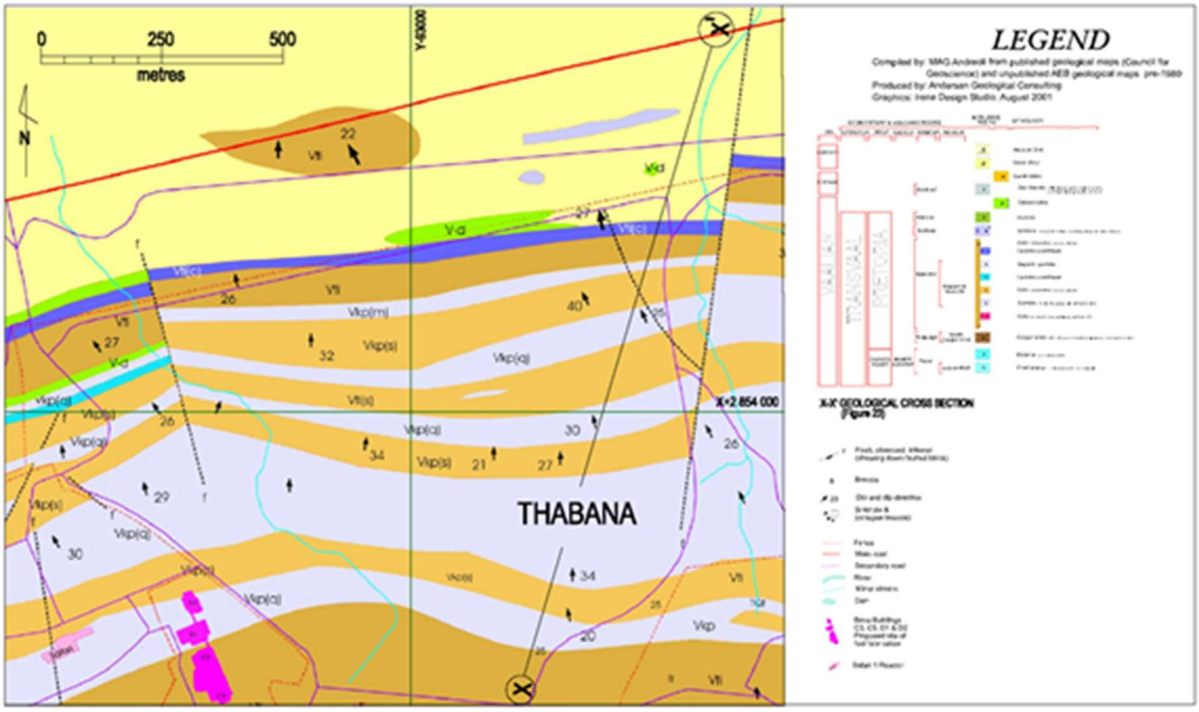

Figure 4: Geological map of Thabana and the TPS

Due to various tectonic deformational events in the geological past the rocks tend to show various fractures. Given this structural context, it is not surprising that several of these fractures yield water during drilling, while fault zones also tend to disturb the homogeneous nature of the stratigraphy. There is some degree of correlation between the fractures in the unconsolidated soils and in the neighbouring slate formations. These fracture zones serve as preferential pathways for groundwater flow which will cause slow seepage into boreholes where it is intersected by drilling.

The contact between the weathered and unweathered zones roughly follows the unsaturated-saturated interface. To the north of Thabana, intrusive dolerite or diabase outcrops as boulders

among the soil cover or as a sill in slate/quartzite. Two large-scale fault zones, with a NNW and NNE trends respectively are present east and west of Thabana. These two fault zones form the traces for the streams and are the reason for the existence of the incised valleys.

The TPS is situated on a topographical high with groundwater levels that varies in depth from 52m to 60m. The groundwater level is therefore much deeper than the bottom of the TPS and new NTP storage pipes.

Geotechnical investigations [9] have confirmed that the allowable load capacity of the site foundations can exceed 200kPa, if necessary, and that the compressibility (settling) potential is minor. This means that the engineering characteristics and capabilities of the foundations easily exceed the minimum requirements for the current and extended facility.

The Council of Geoscience has conducted a seismic hazard study [11] for a proposed pebble bed fuel plant to be sited at the BEVA area, on the western side of the Pelindaba industrial park. In view of the geological similarities between these two nearby sites, the conclusions reached by the Council for Geoscience will also apply to the TPS site. This study is based on the assumption that the seismic hazard in the BEVA site is dependent on its relative location to five mine induced seismic active areas: Welkom, Klerksdorp, Carletonville, East Rand and Rustenburg, and the Zoetfontein fault, as well as on background seismicity. The major contribution to the seismic hazard at the site comes from the magnitude of the largest earthquake in the vicinity of the site, Richter Scale (RS) = 5,05 ± 0,50, which is capable of producing a maximum possible Peak Ground Acceleration (PGA) at the site with median value of 0,178 g, with the one standard deviation confidence interval being [0,12 g; 0,36 g]. It should be noted that the value of the PGA equal to 0, 37 g corresponds to a non-exceedance probability of 84%.

This PGA value is based on the worst-case scenario, where the maximum credible earthquake increased by its standard deviation (RS = 5,55) took place at an epicentral distance of 0,25 km from the site at a depth of 10 km. A simple probabilistic assessment of the PGA indicated that such an event has a frequency of 1.8E-5 per year to occur. Deterministic assessments of the ground motion of mining induced seismic events from the mining areas surrounding Pelindaba, or any major faults indicates that these events are too far from Pelindaba in order to pose any significant threat to the TPS or any other nuclear facility on the site.

10.2 Confirmation of Site Safety Criteria

According to various IAEA guidelines [9] concerned with geological and foundation requirements for nuclear facilities the following features are being advantageous for the storage of spent fuel:

1. Stable regional geology
2. No faulting at the site
3. Negligible probability for the development of sinkholes
4. Deep groundwater level many meters below the facility
5. Insignificant seismic risk
6. Stable and simple geosphere (geology surrounding the facility) with adequate geotechnical conditions (e.g. high load capacity and minor settling potential) to support the facility engineering

7. Low erosion rates
8. Availability of detailed site characterization information for site selection purposes

The geology and structural geology of Pelindaba and Thabana described above confirm that the Pipestore is situated on interbedded shale /slate and quartzite from the Timeball Hill Formation of the Pretoria Group sediments. The Pretoria Group is well researched and the rocks of the Timeball Hill Formation are widely accepted as providing stable geology for engineering purposes. It is the same formation that the SAFARI-1 Reactor is constructed on.

Although certain areas on Pelindaba and the wider environment has a more complex geological make-up due to faulting and folding the geology of the TPS site and immediate vicinity are simple and undisturbed by faulting, as is confirmed by the drilling results and geological investigations stretching over many decades.

The TPS site is far removed from the dolomites which occur further to the south on Pelindaba and are situated on rocks which are not conducive to the forming of sinkholes. The groundwater level (or saturated zone level) on Thabana varies between 52m and 60m below the surface. The groundwater level is therefore well below the bottom of the spent fuel storage pipes which will not exceed a depth of 20m below surface.

More recent drilling results and original TPS investigations indicates no sandy layers, faulting or weak zones in the geosphere of the facility which could negatively affect the facility during a seismic event (collapse, liquefaction or sliding).

The seismic hazard investigations concluded that the design basis earthquake for facilities on the Timeball Hill Formation will have maximum possible Peak Ground Acceleration (PGA) at the site with median value 0,178 g, with the one standard deviation confidence interval being [0,12 g; 0,36 g]. It can therefore be concluded that the seismic risk hazard to the Pipestore facility and its proposed extension is insignificant.

Drilling results also confirm a uniform and undisturbed geosphere for the TPS facility.

The associated drilling penetration rates show a consistency between the boreholes and confirm the absence of cavities or soft and weak layers in the geosphere. The geosphere can therefore be considered as stable from a civil engineering point of view.

The geotechnical foundation conditions at the site have been found to be favourable and suitable for the proposed development.

The presence of the hard quartzite layers provides stability and erosion resistance for Thabana Hill and its facilities. Manual observations around Thabana and the Pipestore confirmed the absence of any developing erosional features that could affect the longevity of the facility. It therefore confirms the low erosion rate at or near the Pipestore facility.

The detailed site characterization information coupled with extensive data from previous investigations allowed for the extension option to be accurately sited on the desired position.

10.3 Summary of Site Suitability and Safety

Thabana and the TPS site have been well characterized in terms of geological features relevant to the suitability of the TPS Facility. This information has been documented in various reports

obtained over many decades and complimented with recent site specific investigations. The site characteristics have been demonstrated to comply with international guidelines and criteria which enhance the site suitability and safety for the intended extension of the facility.

A sound scientific base therefore exists to support the suitability of the site for spent fuel storage as well as for the further extension of the facility.

11.0 CONCLUSION

This report considered various siting options for the siting of the extension of the existing Thabana Pipestore.

The siting requirements in SHEQ-INS-0812 were considered. .

A techno- economic management study considered reprocessing of the spent fuel (locally or abroad), return to supplier (abroad), wet and dry storage options including importing of dry storage canisters, storage at the Vaalputs Facility in the Northern Cape and extending the current facility. The option to extend the current TPS clearly stood out as the best option.

TPS extension option study was done to establish the optimum extension configuration of the current TPS in terms of practicality, economics and other criteria. The option to install the NTP waste pipes northward and the SAFARI-1 pipes southward from the current facility was found the best option.

The geological suitability of the TPS site was considered. The structural geological, hydrogeological, seismic hazard and geotechnical information relevant to Thabana and the Pipestore Facility was considered and demonstrated the suitability of the site for the extension of the Pipestore.

The on-site storage at the TPS of the spent fuel and uranium residue was approved by the minister DMRE.

Evidence was provided that the extension of the TPS would be a suitable option and meet the applicable requirements.

Based on the above it is concluded that the extension of the TPS is the best and only option.