TECHNICAL NOTE

JBA Project Code	2020s0715
Contract	La Gigoulande Quarry
Client	Granite Products (C.I) Ltd
Day, Date and Time	18th September 2020
Author	Rebecca Varga-Schembri and Oliver Francis
Reviewer / Sign-off	James Howard and Alastair Dale
Subject	La Gigoulande - Initial assessment of Jersey Water proposal

Executive summary

This document has been prepared as a technical statement to provide Granite Products, the owners of La Gigoulande Quarry, with information to support discussions and representations regarding the practicality of Jersey Water's proposal to use La Gigoulande as a water storage reservoir. The approach is to consider the technical implications of Jersey Water's proposals to understand whether the principle of such development can reasonably be supported. Initially the focus of the assessment is to understand the available storage volumes and the technical challenges and practicalities associated with a number of different approaches to store water within the existing void in the western portion of La Gigoulande.

In summary the assessment evidences that the proposed storage volumes suggested by the available Jersey Water press releases are not achievable. The initial assessment is limited in scope and has not addressed relevant water resource, environmental or viability issues that when investigated might also raise issues that demonstrate that the principle of such development cannot be supported.

	Approach		
	1	**2a**	**2b**
Description of approach	**No lining of quarry - void fills naturally with groundwater**	**Lined by targeted grouting of rock mass**	**Lined with structural concrete liner**
Storage Volume (m³)	100,000 to 225,000 varying seasonally with groundwater levels	Up to 240,000	200,000 - 220,000 depending on liner geometry
Main technical challenges / requirements	Lack of storage volume when groundwater levels low Stabilisation of rock face	Stabilisation of rock face Some exfiltration (seepage) of water possible after grouting if groundwater levels are low	Anchoring liner in place to resist uplift pressures. Dewatering system required for operation Buildability of the liner
Practicality	Without a liner the quarry void cannot be used as a pumped storage reservoir due to the permeability of the rock mass. Stored water volume will be lowest at times of peak demand	Rock mass grouting will be expensive and the success in reducing seepage will not be known until afterwards. Relatively low maintenance and can be used for pumped storage if seepage is low.	Most stable storage volume and could be used as a pumped storage reservoir but the lining system and dewatering requirements are technically complex and likely to be prohibitively expensive.

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1 Purpose

This document has been prepared as a technical statement to provide Granite Products, the owners of La Gigoulande Quarry, with information that they can use to support responses on the practicality of Jersey Water's proposal to use La Gigoulande as a water storage reservoir. This document has been prepared solely for the use of Granite Products and focusses on a limited number of issues that affect the practicality of the proposal. It is possible that other issues not addressed in this note could also determine that the principle of Jersey Water's proposal cannot be supported.

This document focuses on key engineering challenges, that would need to be overcome to convert the quarry into a water storage reservoir, only. It does not seek to provide an opinion as to whether Jersey Water's proposal has merit on other grounds.

2 Site overview

La Gigoulande Quarry is situated to the south east of Route de la Vallée, St Mary, Jersey. Figure 2-1 shows the site boundary and the site topography taken from a drone survey in February 2019. The site is an active granite quarry comprising:

- a deeper excavation in the western portion of the site which is currently dewatered as it extends considerably below natural groundwater levels;
- shallower excavations limited to 55mAD in the eastern portion of the site; and
- various buildings and processing facilities.

The site is bounded by public highways to the south, west and northwest; agricultural land to the east; and a residential property to the north.

Following completion of quarrying activities on site Granite Products are consented to infill the deeper excavation and raise ground levels with inert waste. There are future plans to extend the quarry southwards but this has yet to be consented.

The focus of this report is on the western portion of the quarry where it has currently been excavated in excess of 30m below the natural ground levels. Based on topographic survey undertaken in February 2019 the volume excavated below natural ground level is approximately 240,000m^3.

The lowest levels along the rim of the deep excavations are approximately 55mAD in the north-western corner and the natural ground in this portion of the site rises to in excess of 80mAD in the south.

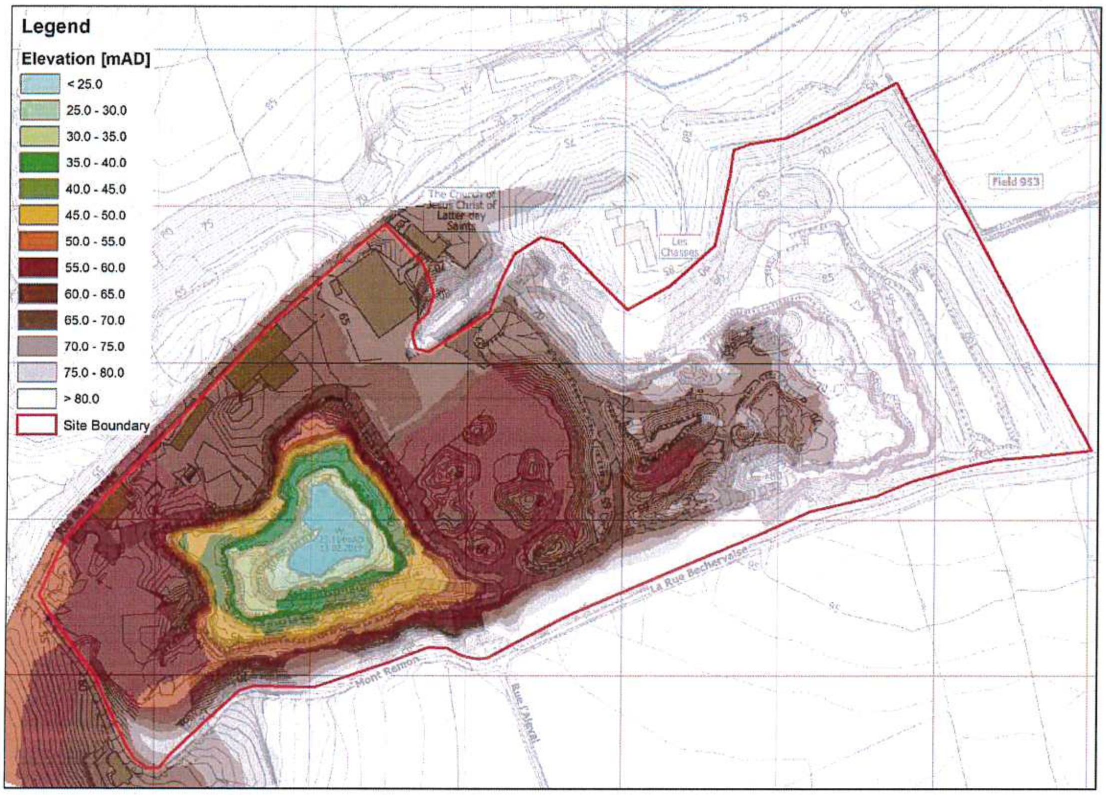

Figure 2-1: Elevation profiles of the quarry from 2019 survey

3 Assessment

This assessment has reviewed the available geotechnical and hydrological reports provided by Granite Products and has considered the engineering feasibility of the works required to convert the quarry to a water storage reservoir. Consideration has been given as to how the site could be repurposed for water storage based on two concept approaches. The approaches considered are:

- Approach 1: Allowing the quarry to fill with water naturally without engineering works to isolate it from groundwater
- Approach 2: Forming an engineered reservoir isolated from natural ground water. Two alternatives for this approach have been considered

We have not made an assumption as to whether the site would most appropriately be used to store raw or treated water as this should not affect the overall practicality of the approaches considered, however, it is recognised that the Jersey water proposals may require assessment of additional operational considerations, as these will also potentially determine whether it is possible for the principle of the development to be supported.

3.1 Approach 1

This approach considers allowing the quarry to fill with water naturally and hence have hydraulic connectivity with the ground water. It is to be noted that the current dewatering activities will not allow for this to occur, and this option is only feasible once quarrying has ceased and ground water is allowed to rebound. If the proposed southerly extension to La Gigoulande were to be consented and allowed for excavation below the groundwater level then dewatering activities associated with future quarrying could impact this approach.

This approach has potential to allow for extraction of stored water at a high rate subject to sufficient recharge. A significant limitation in this approach however relates to the connection between the ground water and the water within the quarry. This connectivity limits the storage volume since excess head above the natural ground water will likely induce seepage losses from the quarry. **Error! Reference source not found.** and **Error! Reference source not found.** illustrate how the quarry would fill naturally and the situations where water would be lost to seepage.

Natural groundwater levels at the site are recorded to fluctuate between 1m and 12m below ground level. From this it is reasonable to infer that water levels within the quarry will likely react in a similar manner although there may be a lag in the response.

Based on the excavation profile at the date of survey (Feb 2019), the volume of available storage would vary between approximately 100,000m^3 and 225,000m^3 depending on groundwater levels. This approach cannot therefore realistically be expected to provide a reliable or predictable stored volume. Whilst this approach might support use of the quarry as a large water extraction facility, this option offers little benefit over borehole abstractions.

Further consideration as to whether the full volume of the reservoir would be usable has also been made. It is expected that the base of the quarry will currently contain debris associated with quarry activities ranging in size from clay to boulders. This material could impact water quality and unless it is removed it would be advisable to abstract water from a level above which disturbance of this material could occur. This could render the lower 2-3m of the reservoir unsuitable for use further reducing the potential capacity. It is not considered that water inflow from the surrounding catchment would result in significant further inputs of sediment. However, initial impoundment will result in mobilisation of sediment from the existing benches and slopes resulting in suspended sediment within the water column that will settle over time. Frequent fluctuation in impounded water level might result in repeated mobilisation and deposition of sediment but the impact of this should decrease over time as sediment accumulates on the base of the reservoir

Five (5no.) discontinuity sets were identified in the Geotechnical Assessment (Quarry Design, March 2017). Kinematic analysis indicates that three potential failure modes exist in the quarry. Changes in water level may be beneficial to slope stability but, under some circumstances, changes in water pressure on discontinuity surfaces can instigate slope failures. There is potential for rock slope failure during impoundment, or subsequently as ground and impounded water levels fluctuate during operation of the reservoir. The level of risk will depend on the rate of change and the magnitude of the difference between groundwater and the impounded water. The proposed drawdown rates during operation of the reservoir are unknown but the risk is likely to increase where drawdown is rapid. The consequences of rock slope failure may include:

- Failures extending to ground level that result in damage to surrounding infrastructure
- Displacement of stored water resulting in overtopping/ flooding if the reservoir is at or near to capacity
- Short term contamination of stored water with suspended sediment

Works to stabilize these failures (e.g. rock bolting or scaling) are likely to be required prior to impoundment of the quarry.

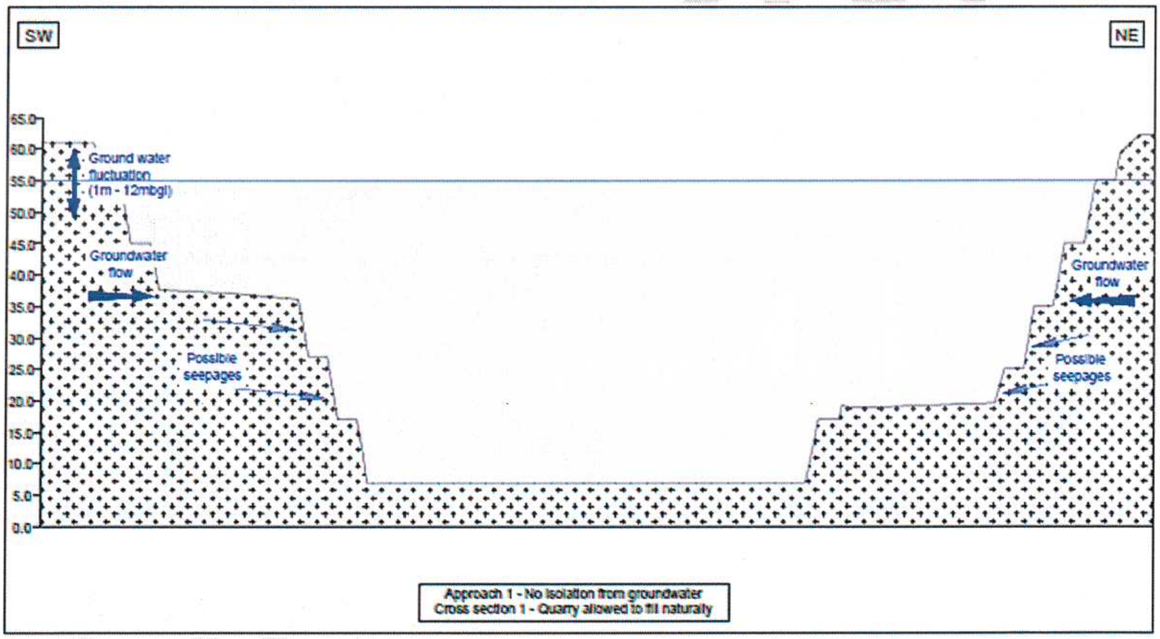

Figure 3-1: Cross section illustrating groundwater fluctuations

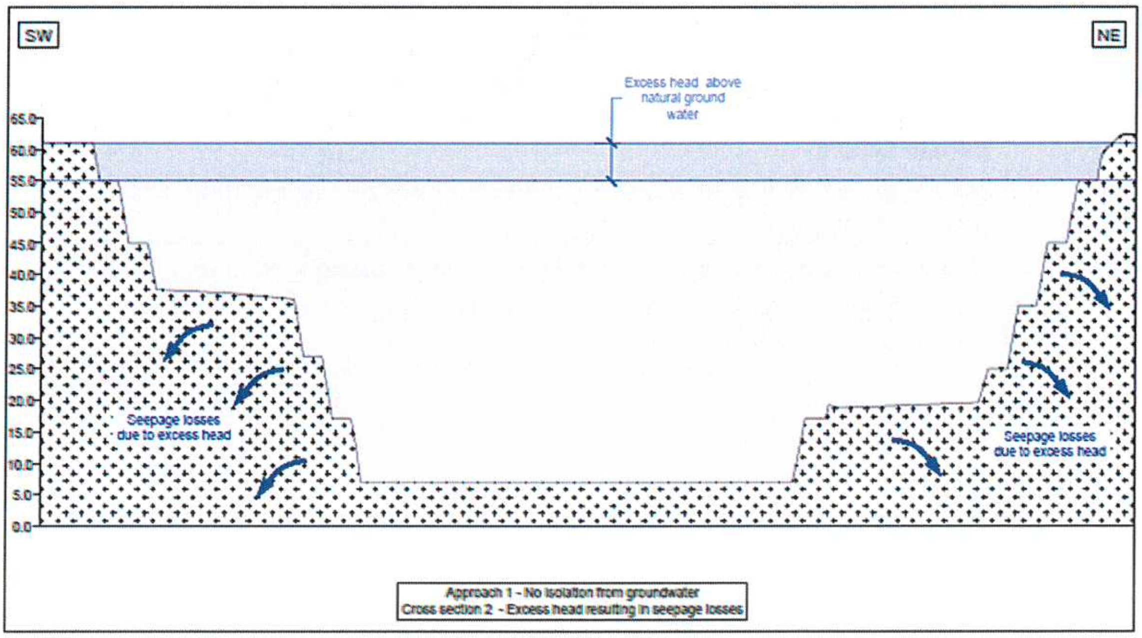

Figure 3-2: Cross sections illustrating seepage losses for Approach 1

3.2 Approach 2

Isolating the reservoir from the natural groundwater will reduce the seepage from the reservoir when the head of stored water is above the local groundwater level enabling the reservoir to maximise its storage volume irrespective of groundwater levels. Where the reservoir is fully isolated from the groundwater it will be unable to fill naturally and will likely need to operate as a pumped storage reservoir given that the volumes of water required to fill the reservoir are unlikely to be resourced through the natural catchment.

There are two potential solutions for isolating the reservoir from groundwater:

- Forming a reservoir by grouting of the rock mass around the quarry to decrease permeability
- Forming a reservoir by installation of an impermeable structural liner

Presently, ongoing dewatering associated with current operations at the existing quarry has depressed groundwater levels in the vicinity of the deep excavation. Following the cessation of dewatering operations the groundwater will rebound, potentially to within approximately 1m below ground level. This will likely generate significant uplift pressures on the base and sides of the reservoir due to the greater than 50m head difference when the reservoir is empty. Managing groundwater pressure on the outside of the reservoir will present a significant engineering challenge.

3.2.1 Approach 2a - targeted grouting of rock mass

This solution entails sealing fractures by grouting the rock mass around the quarry. This would reduce flux of water into or out of the reservoir. This method has been utilized in underground mines and tunnels and beneath dams to minimize ground water infiltration. It is important to note that this solution can only be expected to reduce, not prevent, seepage to and from the reservoir (**Error! Reference source not found.** and **Error! Reference source not found.**).

Grouting the rock mass around the quarry would involve treatment of a large volume of rock but, given the competent rock mass, it is anticipated that only fractures would require treatment. Validation and subsequent testing would be essential. The most straightforward testing method would involve temporarily ceasing dewatering activity at the active quarry and observing seepage into the reservoir prior to impoundment. This approach would identify defective areas which could then be treated further. It is understood that ceasing dewatering activity for the duration of the test might be impractical due to the need to support ongoing quarrying works elsewhere on site. However, disregarding such testing would leave a significant risk of high seepage loss which will be challenging to identify and treat once the reservoir is filled with water.

This solution offers advantages in managing uplift pressures because it utilizes the self-weight of the rock to resist uplift (**Error! Reference source not found.**). It does not require maintenance once works are completed and verified by testing. Additionally, this solution would not in itself reduce available storage volume within the quarry. The maximum capacity would remain in the order of 240,000m^3 based on excavation profiles at the time of survey (Feb 2019).

As noted with Approach 1 the potential for debris at the base of the excavation could render the lower 2-3m of the reservoir unusable and similarly suspended sediments within the water column may be a particular concern during initial impoundment or if frequent fluctuations in impounded level are experienced.

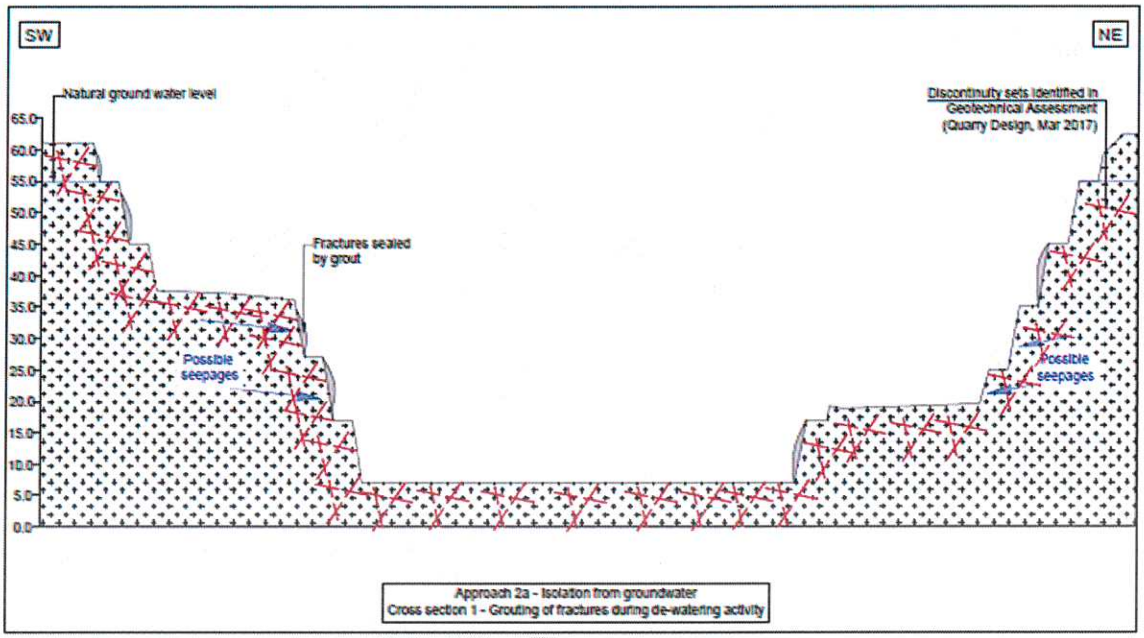

Figure 3-3: Cross section illustrating fractures sealed by grout for Approach 2a

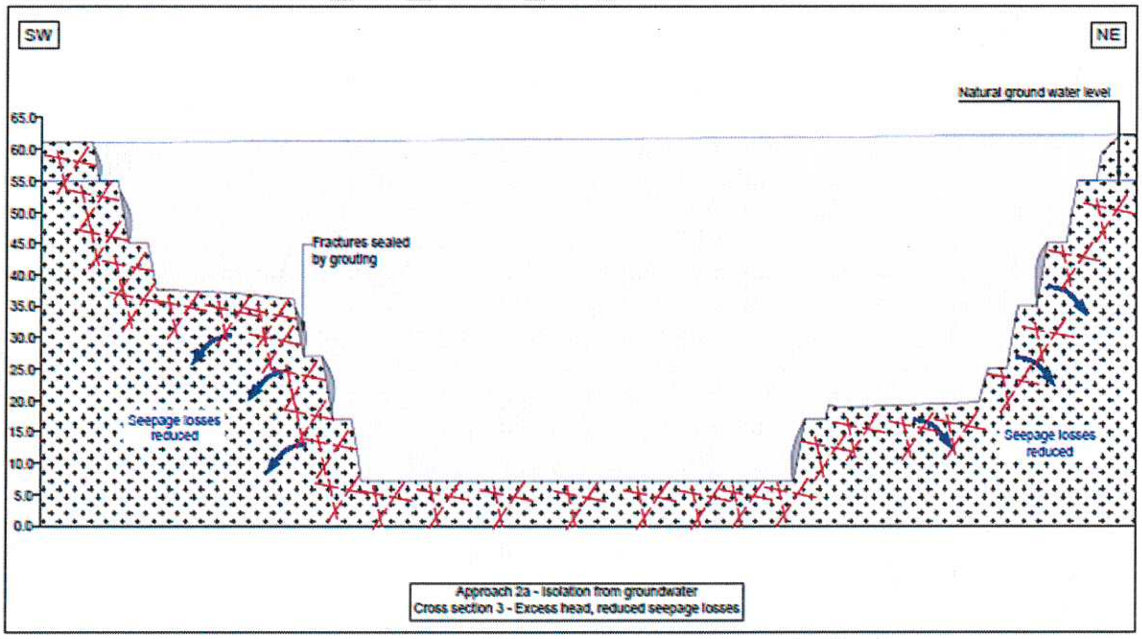

Figure 3-4: Cross section illustrating seepage losses for Approach 2a

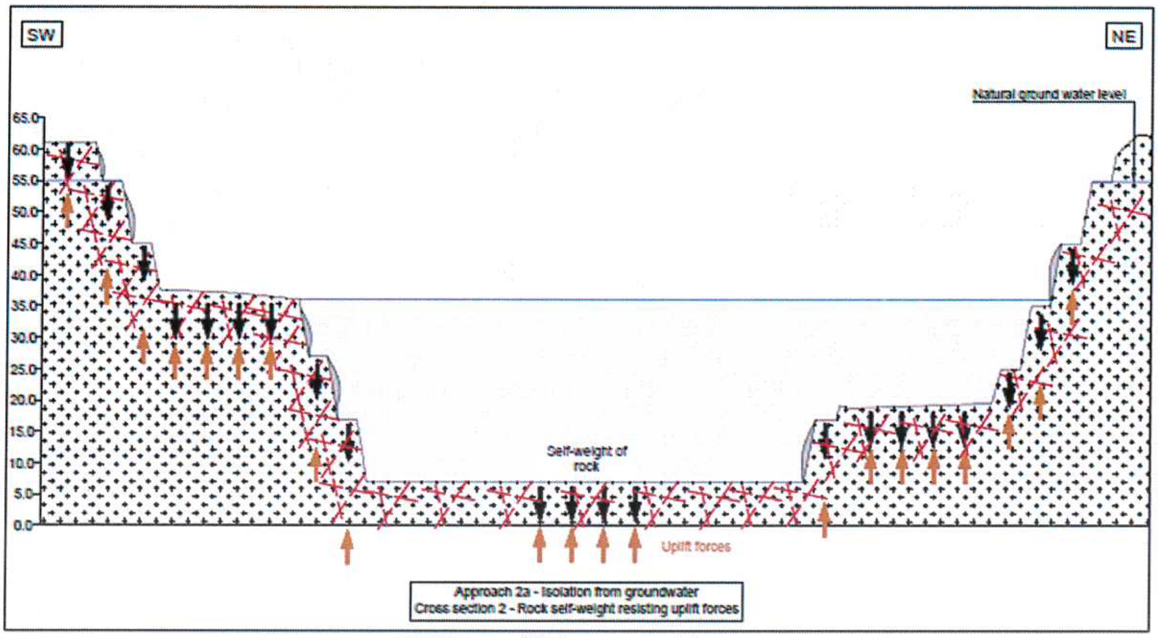

Figure 3-5: Cross section illustrating rock self-weight resisting uplift for Approach 2a

As with Approach 1 there remains the potential for rock slope failure occurring during impoundment of water within the reservoir. In addition to the consequences described in 0 above, there is the risk that rock slope failures damage the grouting works. This risk could be resolved in isolation by undertaking grouting works sufficiently distant from the quarry boundary. Works to stabilise these failures (e.g. rock bolting or scaling) are likely to be required prior to allowing water to fill the quarry.

3.2.2 Approach 2b - installation of an impermeable structural liner

This solution offers a verifiable method of isolation of the reservoir from the water table. However, due to the size of the quarry and the shallow ground water complete isolation from the water table will likely require the liner to withstand significant uplift pressures, potentially in excess of 500kPa. Consequently, it is expected that the liner installation will need to be a sizeable structure, which will appreciably reduce available water storage capacity (**Error! Reference source not found.** and **Error! Reference source not found.**). Preliminary estimates are that the average thickness of the concrete liner would be in the order of 1m. The thickness of the liner and the potential need for adjustments to the profile and geometry of the void would be expected to result in a 10-15% reduction in stored volume compared with Approach 2a

Unlike Approach 1 and Approach 2a the presence of debris at the base of the excavation are unlikely to result in a further reduction of usable storage volume as it assumed that it would either be removed or incorporated as part of the liner.

For the purpose of this assessment, a reinforced concrete liner fastened down with rock bolts is assumed. Rock bolts will achieve good capacity in the granite, but the installation of the liner will present a significant and complex engineering challenge due to the size and depth of the quarry, its irregular shape, the high structural loads to be accommodated, the size of the concrete liner required and the complexity of the temporary works (dewatering, formwork, temporary supports) required to ensure safe construction. Maintenance of the liner and rock bolts will be essential through the design life of the structure, posing additional challenges once the reservoir is impounded. Future inspection and repairs could require the reservoir to be emptied in order to complete the works.

The installation of the liner and the rock bolts would need to incorporate measures to stabilise the quarry faces to prevent rock slope failures.

A perpetual commitment to dewatering outside and in the vicinity of the reservoir may be required to manage the external uplift pressures. Dewatering can be expected to be required whenever the water level within the reservoir is low. The requirement for a dewatering system would increase the cost and complexity of reservoir operations and if dewatering failed while the reservoir was empty could result in failure of the structure.

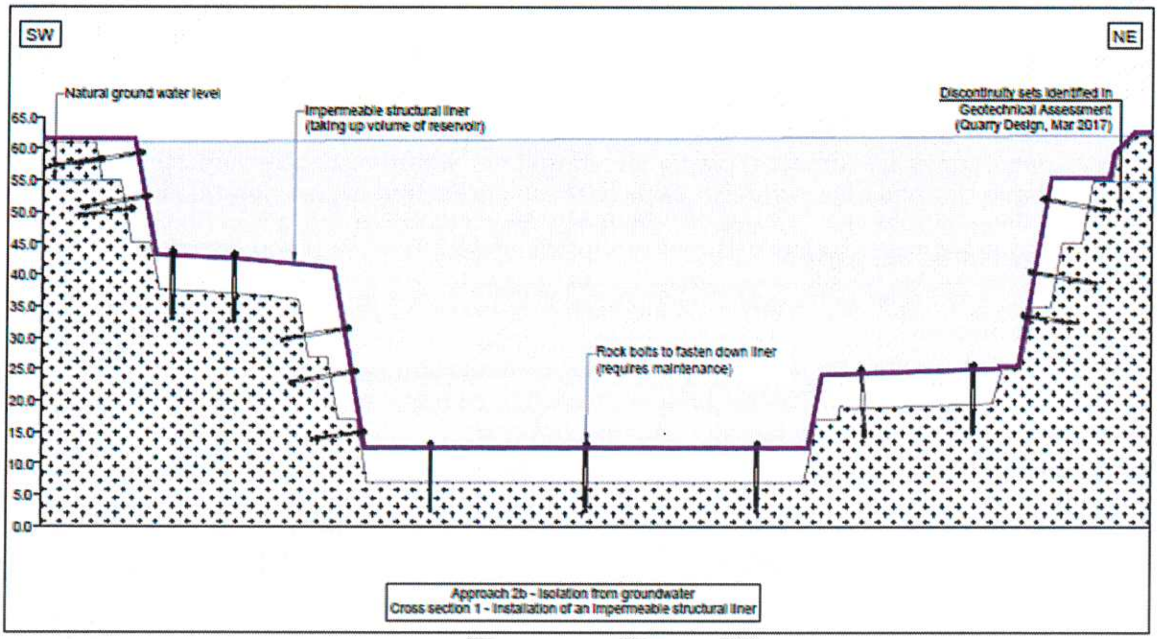

Figure 3-6: Cross section illustrating installation of an impermeable structural liner and the volume taken up by the installation for Approach 2b

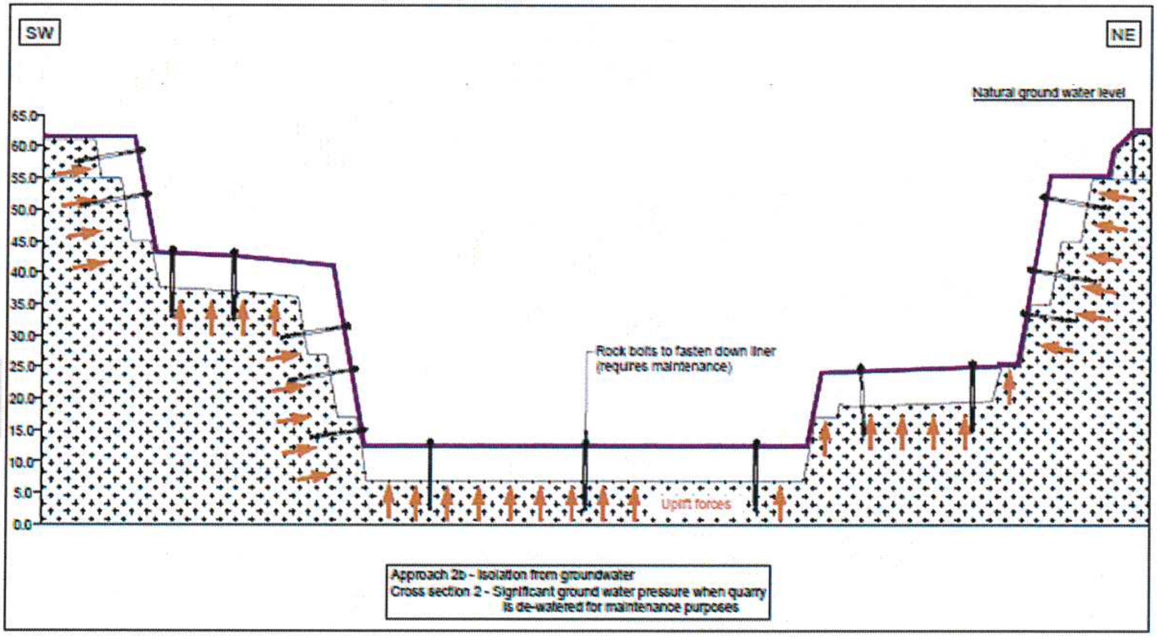

Figure 3-7: Cross section illustrating the requirement of the liner to resist uplift forces for Approach 2b

4 Discussion

The assessment has considered aspects of the engineering practicality of a water storage facility at La Gigoulande. The assessment has identified substantive engineering constraints and challenges. Wider challenges including reservoir safety, environmental impacts, planning constraints, water resources limitations and finances have not been considered. Each of these respective issues potentially in themselves evidence that the principle of implementing a water storage reservoir at La Gigoulande cannot be supported.

The key constraints and challenges identified in the initial assessment are summarised as follows:

- Substantial variation in groundwater levels and permeability of the surrounding rock that significantly affects the ability to maintain a reliable storage capacity of water without isolation from groundwater.
- There is a material risk of rock slope failure when impounding water, or in response to future fluctuations in impounded and ground water levels during operation of the reservoir. This could result in failures at ground level resulting in damage to surrounding infrastructure, displacement of stored water resulting in overtopping/ flooding if the reservoir is at or near to capacity and short-term contamination of stored water with suspended sediment.
- If a scheme involved isolating stored water from groundwater the potential for differential heads in excess of 50m and this presents significant technical challenges in preventing/reducing seepage and resisting uplift forces.

Whilst not unresolvable or outside the bounds of acceptability the constraints identified will need to be fully addressed and managed to evidence claims that the principle of a water storage scheme can be supported. The financial, economic viability of such requirements has not been considered but may prove challenging.