3 CONSIDERATION OF ALTERNATIVES

3.1 Scenario with and without the Project

3.1.1 Under the *Planning Study on Future Land Use at Anderson Road Quarry – Feasibility Study* conducted by Planning Department, extensive community engagement exercise on the suggested land use options was conducted. Rock cavern on existing rock slopes was recommended for options of land supply.

3.1.2 The proposed cavern is located at the north side of the ARQ Development, where ARQ is a highly disturbed environment with very minimum ecological value. The proposed cavern development will only affect very small amount / extent of the existing vegetation, e.g. tree and shrub planting on the exposed rock face planted under the Quarry Rehabilitation Contract.

3.1.3 With the project, the museum can be housed inside the rock cavern. This is considered a suitable location for quarry related exhibition. There would not be a need to use additional land from the ARQ development and the land could be used for other purposes. On the other hand, the project would enhance the landscape and visual quality of the existing barren rocky slope.

3.1.4 Without the project, the area will be left as a vacant rock face. The opportunity to fulfil the social needs of using the rock cavern as the alternative land supply will be lost. It will also be difficult to find space within ARQ development unless other land areas e.g. with residential/recreation uses are consumed.

3.2 Consideration of Alternative Development Options

3.2.1 The prime objectives of proposing cavern development are to fully utilize the available rock feature available and to explore the alternative way for land supply.

3.2.2 There are a number of cultural and historical heritages in Kwun Tong. Since the ARQ has been in operation for more than 50 years in the Territory, it is considered worth to make efforts for retaining some of the features of quarry operation to reflect the history. An exhibition centre or a resource centre is reckoned to be a suitable way of showing the history of past quarry operation to the public.

<u>Size of the exhibition centre</u>

3.2.3 The proposed cavern for exhibition centre with an exhibition area of 1,000 m^2, based on a usable floor area of 2.6 m^2 per visitor and a staff/visitor ratio of 1:13, is considered appropriate and sufficient for exhibition centre of similar nature.

3.2.4 Alternative footprint area of the proposed quarry exhibition cavern has been considered for accommodating larger scale of exhibition centre. In view of the characteristic of the cavern development, the proposed quarry exhibition cavern would be similar in nature to existing Science Museum of which the total exhibition area is around 7,245 m^2. In view of the geography of the ARQ Development and the nature / content of possible exhibition, the proposed quarry exhibition centre is considered sufficient with reference to some of the existing museums with similar nature and scale such as Police Museum (570m^2) and Dr Sun Yat-sen Museum (2,560 m^2), in Hong Kong. The sizes of the proposed quarry exhibition centre is approx. 1,000m^2, which is in between the Police Museum and Dr Sun Yat-sen Museum. Furthermore, the added environmental benefit of the compact design is the reduction of construction and demolition materials/wastes quantity arising from the construction stage. Thus, the recommended exhibition area of approximate 1,000 m^2 is considered appropriate.

Location of the exhibition centre

3.2.5 The location of the proposed quarry exhibition centre cavern is currently at the northern rock slope of the ARQ Site Development as shown in **Figure 3.1**, it is adjacent to the proposed public transport terminus and within the future Quarry Park area. Other possible locations as indicated in **Figure 3.1** at the existing rock slopes and within the boundary of the ARQ Site Development for situating the proposed cavern for quarry exhibition centre have been examined. These locations include

- Alternative 1 - Rock slopes at platform of +200mPD along and adjacent to the proposed carriageway of Road L1 (middle portion of existing rock slopes);
- Alternative 2 - Rock slopes at platform of +200mPD adjacent to future development sites (southeastern portion of existing rock slopes); and
- Alternative 3 - Rock slopes at platforms of other level higher than +200mPD.

3.2.6 These other possible locations were considered not as suitable as the current location. Since the existing rock slopes of Alternative 1 and Alternative 2 are mainly contiguous to the proposed public carriageway and residential developments, the size of cavern should be further enlarged to allow assembly area for visitors and vehicular loading and unloading area for the museum cavern development. Environmental dis-benefits arising from enlarging the size of cavern for Alternative 1 and Alternative 2 would be the increasing quantities of construction and demolition materials/wastes in the construction stage as well as the higher construction air quality and noise impacts. In addition, there is no public access, both pedestrian and vehicular accesses to the proposed cavern under Alternative 2. If Alternative 2 is adopted, additional vehicular and pedestrian accesses would be required. Nuisance will be created to the nearby future residential areas and school sites by the visitors of the quarry exhibition / museum cavern in case it is situated in the close proximity to the nearby development sites.

3.2.7 For Alternative 3, if the proposed quarry exhibition cavern is situated at platforms of level above +200mPD, there will be no direct connection, either pedestrian or vehicular access, from the platform of the main ARQ Site Development, which is at approximately +200mPD. Additional vehicular access and pedestrian facilities, e.g. vertical transfer system will be required for connection between the cavern and the ARQ Site Development. This will not only involve additional and substantial rock excavation and tree removal for the formation of pedestrian and vehicular accesses to the cavern (substantial construction waste and material generated as well as the associated construction air quality and noise impacts), but it will also involve extra energy consumption for the operation of the pedestrian connection (vertical transfer system) and the vehicular access road (street lighting). Furthermore, the landscape and visual impacts of Alternative 3 will be more significant and substantial comparing with the recommended location, locations of Alternative 1 and Alternative 2 since it will involve large scale site formation works for access roads and facilities.

3.2.8 The recommended location of the proposed cavern is within the boundary of and at the same level as the future Quarry Park such that some common facilities, e.g. visitor reception counter, loading and unloading facilities, car parking spaces, etc could be shared between the Quarry Park and the exhibition centre cavern. This could reduce the amount of land required and better utilization of facilities.

3.2.9 Moreover, the proposed cavern for quarry exhibition centre will be situated adjacent to the proposed public transport terminus. This can encourage and facilitate the public visiting the exhibition centre by means of public transport.

3.2.10 The proposed location of the cavern is considered to be most suitable location within the Quarry Park as the rock slope at this location will provide the largest rock cover for the cavern, as the bedrock level will be dipping toward the northern end of the rock slope. The rock quality is better and the required temporary support for the cavern is envisaged to be less substantial.

3.2.11 Since no additional rock excavation and tree removal is required for the formation of vehicular and pedestrian accesses to the proposed quarry exhibition cavern under the recommended location, the adverse environmental impacts including construction waste / material generation, noise and air quality impacts and landscape and visual impacts of the recommended location are comparatively less than the alternative locations. Summary of the environmental benefits and dis-benefits of alternative options are shown below:

Environmental Consideration	Alternative 1	Alternative 2	Alternative 3	Recommended
Rock Excavation Quantities	Extra rock excavation required for formation of loading & unloading facilities and assembly area	Extra rock excavation required for formation of loading & unloading facilities and assembly area	Substantial rock excavation required for formation of loading & unloading facilities, assembly area, vehicular access road and pedestrian connection facilities	No extra rock excavation required as visitor facilities including assembly area, loading and unloading facilities can be shared with the future Quarry Park
Impacts to Existing Trees	Removal of additional trees on rock slopes required due to the site formation works of loading & unloading and assembly area facilities	Removal of additional trees on rock slopes required due to the site formation works of loading & unloading and assembly area facilities	Removal of additional trees on rock slopes required due to the site formation works of loading & unloading, assembly area facilities, vehicular access road and pedestrian connection facilities	No additional tree removal is required
Nuisance of Operation to Nearby Development Sites	Close to the residential area and level of nuisance is slightly to moderate	No direct vehicular & pedestrian access from public road to quarry exhibition cavern. Access will be in close proximity to development sites. Nuisance to nearby development sites is substantial	Quarry exhibition cavern will be at higher level platform of existing rock slopes and will be away from development site. Nuisance is minor comparatively	Quarry exhibition cavern will be within future Quarry Park and away from the development sites. Nuisance is minimal.
Construction Noise & Air Quality Impacts	Larger extent of rock excavation due to site formation works for loading & unloading area for quarry exhibition cavern comparing with the Recommended location. Hence, the construction noise and air quality impacts are higher as well.	Larger extent of rock excavation due to site formation works for loading & unloading area for quarry exhibition cavern comparing with the Recommended location. Hence, the construction noise and air quality impacts are higher as well.	Extent of site formation works and rock excavation works will be the greatest amongst all 4 location options due to the provision of vehicular and pedestrian accesses. Hence, the construction noise and air quality impacts are the most significant.	No additional rock excavation will be required for the provision of access road and loading & unloading facilities of the quarry exhibition cavern as they are all within the future Quarry Park area. Hence, the construction noise & air quality impacts are the least amongst the 4 options.
Visual Impacts	Insignificant	Insignificant	Critical as the provision of vehicular access road and pedestrian connection facilities will involve substantial rock excavation and tree removal at existing rock slopes	Insignificant

Alternative use of cavern apart from exhibition centre

3.2.12 Apart from the use of quarry exhibition centre, the proposed cavern has been considered for other alternative functional or operational uses, e.g. public utilities facilities like the proposed fresh and salt water pumping stations of the ARQ Development.

3.2.13 Placing public utilities facilities like the proposed fresh and salt water pumping stations into the proposed cavern is technically feasible in general. However, the proposed fresh and salt water pumping station of the ARQ Site Development will be fed from the existing Anderson Road No. 3 Freshwater Service Reservoir (AR3-FWSR) and Anderson Road Saltwater Service Reservoir (ARSWSR) respectively. These two service reservoirs are currently situated level of +190mPD to +200mPD approximately which is the slightly below the level of the proposed cavern for the quarry exhibition centre. In case the proposed cavern is changed for pumping station use, the pressure head difference between the service reservoirs and the pumping stations is inadequate to drive the water pumps and hence the cavern for accommodating the pumping stations should be excavated deeper in order to achieve the functional requirement of pumping stations and hence increasing the construction difficulties and volume of rock excavation for cavern and associated pipe works. The environmental dis-benefit of this alternative would be increasing the quantity of construction and demolition materials/waste in construction stage.

3.2.14 Furthermore, the vehicular maintenance access for the pumping stations would pass through the future Quarry Park and impose significant disturbance and constraints to the operation and design of the Quarry Park. In view of the above concerns, the proposed cavern is not recommended to be used for other public facilities.

3.2.15 In consideration of the regional significance of the future Quarry Park, a cavern for museum or exhibition centre is important and appropriate use for showcasing the quarrying history of the ARQ over other possible uses of the cavern.

3.3 Alternative Construction Methods and Sequences of Works

3.3.1 There are a number of rock excavation methods to be used such as mechanical means by drill and split (or drill and break), use of chemical expansion agent, Cardox method and drill-and-blast technique.

Mechanical excavation method

3.3.2 The excavation method is by means of hydraulic excavator, hammer and hydraulic splitter. The splitter’s cylinder contains a control valve and a piston that moves a plug between two feathers. The plug and feather end is placed into a Ø100mm diameter split-hole. The plug moves down between the two feathers forcing them against the wall of the hole. When the tension increases beyond the tensile strength of the material, a split will occur. The entire operation of the cylinder is controlled by a single lever on top of the tool. The plug can be advanced and retracted with this lever. An automatic built-in valve reduces pressure after break. This method is suitable for small portion excavation, and an excavation which conducts very close to utilities that are sensitive to vibration, e.g. gas & water mains, railway track, information transmission system / communication cables, etc. Disadvantage – Slow production rate for high strength rock mass (less than 40 m^3 per 8-hrs per one-work-site, including rock removal). For worst scenario of MTR West Kowloon Terminal experience, only 30m^3 per day, with 4 drill rigs and 3 breakers.

Use of chemical expansion agent

3.3.3 This method makes use of the expansion force of the injected chemical slurry with very high expansive capability. After self-expansive chemical slurry is poured into holes drilled in rocks, the expansive stress gradually increases with time, to more than 11,000 ton/m^2 at room temperature after 24 hours. As self-expansive chemical slurry generates its expansive stress, the material to be cracked undergoes a process of (i) crack initiation, (ii) crack propagation, (ii) the increase of crack width. Therefore, this fracture mechanism is distinguished from a breakage by blasting. This method is suitable for small portion excavation, and an excavation which conducts very close to utilities that are sensitive to vibration, e.g. gas & water mains, railway track, information transmission system/communication, etc. Disadvantage of this method is slow production rate (< 40 m³ per 8-hr shift), long standing time (up to 24 hours), and not suitable for fractured & weak rock mass.

Cardox method

3.3.4 The Cardox system is based on liquid carbon dioxide being converted to high pressure carbon dioxide gas with ignition. Tubes are filled with liquid carbon dioxide. When energized by the application of a small electrical charge, the chemical heater instantly converts the liquid carbon dioxide to a gas. This conversion expands the CO_2 volume and builds up pressure inside the tube until it causes the rupture disc at the end of the tube to burst. This releases the CO_2 through a special discharge nozzle to create a powerful heaving force, at pressures up to 3,000 bar. This instantaneous build-up in pressure reaches the yielding pressure of the rupture (shear) disc which bursts releasing a heaving mass of carbon dioxide which breaks the surrounding material. The advantages are low vibration effects to surroundings, environmental friendly, highly safe of rock breaking method and have similar production to drill-and-split. However, the disadvantages of the Cardox method are relative high operation cost and not suitable for very high strength rock such as Tuff and Granite.

Conventional drill and blast method

3.3.5 This method is suitable for bulk excavation in non-sensitive area (i.e. remote area). Approx. production rate: > 100 m³ per 8-hrs per one-work-face. Disadvantage – explosive handling including supply, transportation and storage is an issue on hazards for this project. It also requires longer process time (normally longer than 9 months) applying blast permit. Geotechnical features surrounded the caverns will be key sensitive receivers to control the blasting works. Hence, 2m round per blast for excavation and 2 days per blast (which considers drill, blast, muck out and installation of temporary support) may be expected.

3.3.6 Having reviewed the general layout of the museum cavern, the anticipated excavation sequence of the entrance and exit adits of the cavern, where the section locates below the berm +210 mPD, cut-and-cover method will be adopted due to the rock cover is very shallow of 2 m. The remaining section of adits will be full face excavation. The main cavern will be excavated by using top head and bench method.

Environmental benefits and dis-benefits for construction methods

3.3.7 Common to the mechanical excavation method, use of chemical expansion agent and Cardox method, they are purposed to control the rock breaking process and the environmental impacts particularly noise and dust are minimized. As the works will be carried out inside the caverns, the environmental impacts to the surroundings are controlled and minimized. The dis-benefits would be the long construction time. For the drill and blast method, the environmental benefit is the faster construction time, while the environmental dis-benefit is the hazards to the surroundings arising from the handling, transportation and storage of explosive. Summary of the environmental benefits and dis-benefits between different construction methods is shown in the table below:

Environmental Consideration	Mechanical Excavation Method	Chemical Expansion Agent Method	Cardox Method	Drill & Blast Method
Suitability for Construction of Quarry Exhibition Cavern	Suitable	Suitable but subject to rock mass condition (not suitable for fracture and weak rock mass)	Not suitable for granite (rock of ARQ Site is mainly granite)	Suitable

Environmental Consideration	Mechanical Excavation Method	Chemical Expansion Agent Method	Cardox Method	Drill & Blast Method
Construction Duration	Long	Very long and the excavation rate is too slow	Long	Fast for large quantity of rock excavation. Similar construction rate to mechanical excavation method for small quantity due to formation of entrance & exit adits
Construction Noise & Air Quality Impacts	High for open excavation but impacts are controllable for cavern excavation since only excavation confined within cavern, noise and dust emission can be easily controlled.	Less impacts	Less impacts	High impacts due to dust and noise emission
Hazard to Public	Hazard to public is minimum	Hazard to public is minimum	Hazard to public is minimum	Hazard is high due to the delivery, storage and handling of explosives

3.4 Selection of Preferred Scenario

3.4.1 Based on the general layout of the quarry museum cavern, the calculated total excavation volume is about 14,820m³.

3.4.2 Technically, Cardox is not suitable for hard rock and chemical expansion method has low production rate. Although the chemical expansion agent method and Cardox methods seems to be more environmental friendly methods for the rock excavation of quarry exhibition cavern, they are both not recommended due to the construction suitability for the cavern construction in this Project.

3.4.3 In this connection, only mechanical excavation method and drill & blast method are suitable for this particular case and the environmental benefits and dis-benefits are compared to determine the preferred option. Detailed comparison with these two methods (only for museum cavern excavation) is summarized in the table below:

	Mechanical	Drill-and-Blast
Production rate (per 8hr shift)	30 m³ (nominal) per 1-work site-machine [60 m³ (nominal) per 2-work site-machines, and so on]	> 100 m³
Environmental Benefits	Controllable production rate and minmize the adverse impact Impacts controlled inside the caverns, thus, the dust emission and construction noise could be easily and better controlled and hence less adverse environmental impacts. Construction is within the cavern and no safety hazard and risk to the public during construction.	Shorter construction time for the bulk excavation but of similar construction rate for formation of entrance and exit adits. Duration of construction nuisance would be shorter.
Environmental Disbenefits	Slower production and longer construction time	Handling, transportation and storage of explosives having safetyhazards

	Mechanical	**Drill-and-Blast**
		and risk to surroundings and public. Additional control/restrictions during blastings. Dust and noise emission would be higher during blasting.
Permit application duration	Not applicable	At least 9 months
Excavation duration	If 2-work site-machines deployed: 14,820 / 60 = 247 days	14,820/ 100 = 149 days
Total duration	247 days	9 months + 149 days

3.4.4 The above calculation shows that mechanical excavation method (i.e. by means of drill-and-split) will be the most preferable excavation method from a construction progress view point. The method has less environmental impacts in terms of construction noise and dust emission, as the excavation works for the cavern space will be conducted within the cavern space. It does not involve delivery storage and handling of explosive and hence minimises the hazard to the public.