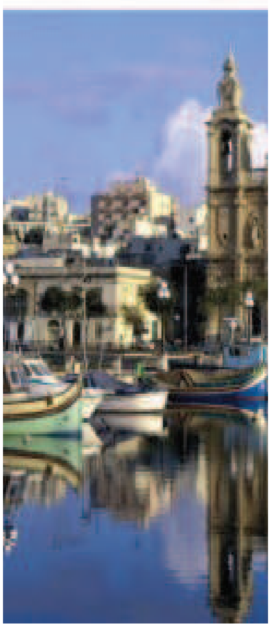
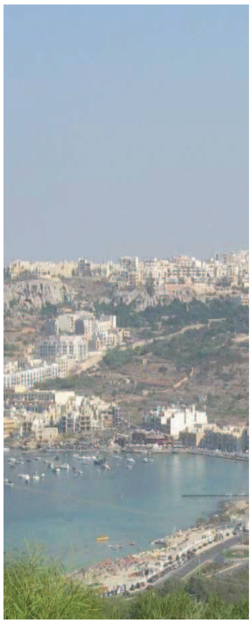
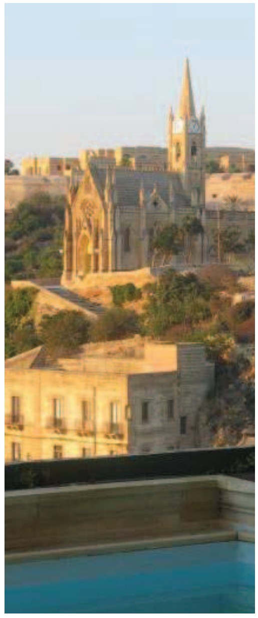

Preliminary Analysis

Assessment of Road Tunnel Options between Malta and Gozo

March 2012
Client Ref: 2011 023 MT ROD ROD

Mott MacDonald

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Assessment of Road Tunnel Options between Malta and Gozo

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Appendices 122

Executive Summary

Mott MacDonald was appointed in July 2011 through the Lot 4: Transport and Urban Infrastructure Framework Agreement for Technical Assistance to JASPERS (Joint Assistance to Support Projects in European Regions) to carry out a preliminary analysis of road tunnel link options between Malta and Gozo. The output of this study could be used as input into a future feasibility study considering all options for a transport link between Malta and Gozo.

The purpose of this study is to provide an initial annotated list of technical, engineering, environmental and economic issues related to potential tunnel fixed-link options to connect Malta and Gozo. The primary output of this project includes a conceptual / high level analysis of a number of road tunnel options. This assessment work has been based on existing data, studies, information and site visits and discussions with local stakeholders.

The key points from the economic assessment are as follows:

- The proposed tunnel is likely to reduce average journey times between the islands of Gozo and Malta by at least 40 minutes;
- Base case forecasts assuming a similar level of toll to the ferry are 2,700 vehicles / day / direction in 2021 rising to 6,400 vehicles / day / direction in 2051. Without a toll on the tunnel the traffic levels would be 34-43% higher than the levels with a similar toll to the tunnel;
- High growth forecasts have been calculated and are 3,400 vehicles / day / direction in 2021 increasing to 9,200 vehicles / day / direction if the toll is set at a similar level to the ferry. Without a toll traffic would exceed 10,000 vehicles / day / direction in 2041;
- The effect on the current ferry service is likely to be high if a tunnel is built; and
- Tolls from a tunnel could cover the operating cost with a significant surplus, but would not cover all costs, and a road tunnel could be considered with EU / national grants and / or private sector funding.

A review of fixed sub-sea tunnel links relevant to the Malta - Gozo crossing was undertaken and included studies of immersed tube tunnels, bored tunnels as well as low traffic volume case studies from undersea tunnels in Norway.

Four tunnel alignment options for a Malta Gozo tunnel are considered taking into account engineering and environmental constraints. Both single bore and twin bore tunnel options are considered.

With regard to the overall length, depth and configuration and size of tunnels an undersea tunnelled link between Malta and Gozo would be feasible and does not exceed the capability of current technology.

The geology of the project area is potentially complex, with evidence of extensive faulting, and is not well documented. A detailed geological and geotechnical investigation is required to determine the optimum tunnel alignment, tunnel form, cost and construction methodology.

A preliminary high level environmental assessment of the options and potential tunnel portal locations has been undertaken. Further more detail environmental assessment will be required at the feasibility stage.

For bored tunnel options, the vertical alignment would be well below the seabed and the main environmental impact would be at tunnel portal locations potentially in or close to areas of high landscape and agricultural value, and a Natura 2000 site. The bored tunnel alignments would go beneath but not impact on the island of Comino.

An immersed tube tunnel option would require construction of a trench within the seabed which is within a potential marine Natura 2000 site. The environmental impact on the seabed, coastline and associated fauna and flora would be significant, and may not be acceptable. The immersed tube option would also require a 2.5km link road in an area of high landscape and ecological value on Gozo.

The construction stage for a tunnel would be approximately 5-7 years.

The location, geology and characteristics of the project (contractual, economic and market conditions, regulatory requirements, working practices and local environmental conditions) can have a significant effect on the cost of the tunnel and the estimated cost is difficult to evaluate at this early stage. Costs (at 2010 prices) have been estimated based on case histories and could be expected to be approximately in the range of €156m to €492m for a single bore 3-lane tunnel on the shortest practical alignment route.

A more detailed investigation of the rock strata, degree of faulting and geotechnical properties would be required to determine the optimum alignment, construction methodology, lining type and hence more accurate programme and cost estimate.

1. Introduction

1.1 Preface

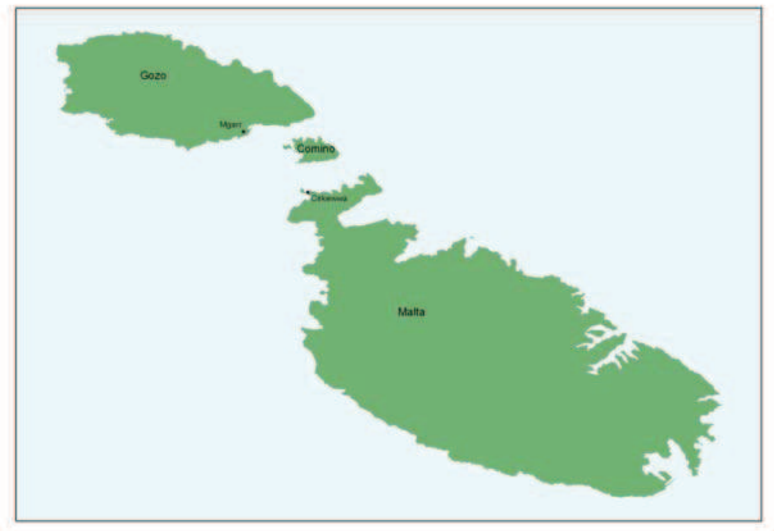
Mott MacDonald was appointed in July 2011 through the Lot 4: Transport and Urban Information Framework Agreement for Technical Assistance to JASPERS (Joint Assistance to Support Projects in European Regions) to carry out a preliminary analysis of road tunnel link options between Malta and Gozo.

1.2 Location

The three populated islands of the Maltese archipelago are Malta, Gozo and Comino. Malta and Gozo are interdependent for commerce and the provision of services and are linked by the Trans-European Transport Network (TEN-T) with a ferry crossing from Cirkewwa on Malta to Mgarr on Gozo. This is used predominantly by passenger vehicles and pedestrians but also carries some freight. There is a dedicated freight route from the Sa Maison landing in the Marsamxett harbour (near Valletta) on Malta to Mgarr. Work is being carried out to upgrade the ferry terminal at Cirkewwa but the prospect of a potential complete reconstruction of the harbour at Mgarr to accommodate more vessels and refurbishment or replacement of an ageing ferry fleet has triggered a need to consider future options for a sustainable public service between the islands.

The sea connection between Malta and Gozo is part of the TEN-T network. Provided that technical, economic and environmental conditions are satisfied, a fixed link project may be eligible for EU Structural funding. A fixed link crossing is included in the post 2011 Malta TEN-T comprehensive network as a planned road. Comino lies between Malta and Gozo just to the north-east of the main ferry crossing (Cirkewwa to Mgarr).

Figure 1.1: Malta, Comino & Gozo Location Plan



Source: Malta Environmental and Planning Authority (MEPA)

The purpose of this study is to provide an initial annotated list of technical, environmental and economic issues related to potential tunnel fixed-link options to connect Malta and Gozo. The primary output of this project includes a conceptual / high level analysis of a number of road tunnel options. This assessment work has been based on existing data, studies, information and site visits by relevant experts during July and August 2011 where extensive discussions with local stakeholders and JASPERS staff took place.

The preliminary analysis considers the key issues for the provision of the road tunnel link option between Malta and Gozo. This could be used as an input into a future feasibility study considering all transport options including bridge, viaduct and causeway alongside non-fixed link services such as air and ferry options.

1.3 Structure of Report

The report is set out as follows:

- Chapter 2: Background Review and Stakeholder Meetings - including an overview of background to the study and key issues identified during engagement with key stakeholders;
- Chapter 3: Economic Assessment - including traffic modelling and demand forecasts, assessment of wider economic impacts and tolling demand and revenue forecasts;
- Chapter 4: Tunnel Options and Assessment – including topography, geology, cost and requirements for future project stages;
- Chapter 5: Environmental Assessment; and
- Chapter 6: Key Issues and Conclusions.

1.4 Economic Assessment

An economic assessment of the following:

- Existing traffic demand (passenger and freight);
- Traffic projections – fixed link and inter-island ferries;
- Wider traffic affect on transport network and trip generation;
- Wider socio-economic impact on Malta, Gozo and Comino including effect on social services, business, labour market and tourism;
- The likely economic impact on current inter-island ferry operations; and
- An indicative “order of magnitude” tolling and revenue forecast for a tunnel toll system.

1.5 Tunnel Options and Assessment

A technical / engineering assessment of the options considering the following:

- Assessment of physical environment and study area including topography and geology;
- Review of design criteria and regulatory issues, including road engineering design standards;
- Assessment of sub-sea tunnels including possible route alignments between Malta and Gozo, tunnel design aspects (including bored , road header excavation, drill and blast and immersed tube tunnel options) and construction approaches;
- Assessment of capital cost estimates and programming; and
- Assessment of design, engineering and survey requirements for future project stages.

1.6 Environmental Assessment

A high level qualitative environmental review has been undertaken to assess three conceptual options for a road tunnel crossing between Malta and Gozo, which are discussed in Chapter 4.

The report discusses the potential effects of the construction and operation of each of the options. Consideration has also been given to the impacts associated with any significant amendments to the existing highway network as well as the supporting infrastructure such as service buildings, power and water supply. A focused desk based study has been undertaken using readily available data and information obtained from a site visit. As well as the assessment of options a brief outline of the main mitigation measures are discussed with key constraints highlighted and recommendations for further considerations in the future environmental assessment.

The following environmental aspects are considered of most importance and are discussed in the environmental review:

- Noise;
- Air quality;
- Landscape;
- Archaeology and cultural heritage;
- Biodiversity;
- Water resources;
- Journey ambiance;
- Soils and land use;
- Marine users / navigation;
- Tourism and recreation; and
- Waste.

Previous reports prepared by The Government of Japan in the early 1970's, looking into a road link between Malta and Gozo, have not fully considered the environmental implications of the tunnel options under consideration; rather the focus was mainly on the feasibility of the engineering and other technical aspects including the economic context.

1.7 Acronyms and Abbreviations

Table 1.1: Acronyms and Abbreviations used in this document

AADT	Annual Average Daily Traffic	M&E	Mechanical and Electrical
AEI	Area of Ecological Importance	MEPA	Malta Environment and Planning Authority
BOT	Build Operate Transfer	MMO	Marine Mammal Observer
CEMP	Construction Environmental Management Plan	MSL	Mean Sea Level
CF	Cohesion Fund	NSO	National Statistics Office
D&B	Drill and Blast	PIARC	World Road Association
DBO	Design Build Operate	PPP	Public Private Partnership

DPA	Development Planning (Amendment) Act 1997	SAC	Special Area of Conservation
EIA	Environmental Impact Assessment	SCI	Site of Community Importance
EPA	Environmental Protection Act (CAP.435)	SEA	Strategic Environmental Assessment
ERDF	European Regional Development Fund	SMART	Storm Water Management and Road Tunnel
ESP	Environmental Planning Statement	SPA	Special Protection Area
EU	European Union	SSI	Site of Scientific Interest
GDP	Gross Domestic Product	TBM	Tunnel Boring Machine
HEATCO	Harmonised European Approaches to Transport Costing	TEN-T	Trans-European Transport Network
IBA	Important Bird Area	UCL	Upper Coralline Limestone
ID	Internal Diameter	UK	United Kingdom
ITT	Immersed Tube Tunnel	UNESCO	United Nations Economic and Social Council
JASPERS	Joint Assistance to Support Projects in European Regions	WHO	World Health Organisation

2. Background Review and Stakeholder Meetings

2.1 Previous Tunnel Reports

A preliminary survey report on the proposed link between Malta and Gozo Islands was carried out in March 1972 by the Overseas Technical Cooperation Agency of the Government of Japan [1].

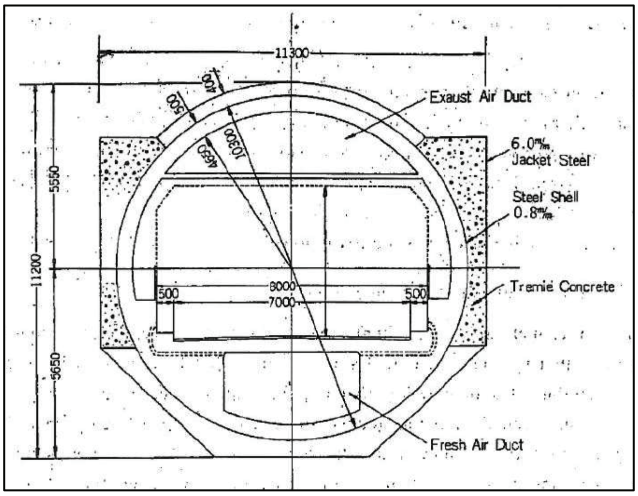
The object of survey was to examine the technical feasibility of a road link between the islands looking at various construction methods including immersed tube tunnel, bridge and causeway. The proposed road route was from Malta to Gozo via the small island of Comino as shown below:

Figure 2.1: Crossing Alignment from 1972 Study

Source: Overseas Technical Cooperation Agency of the Government of Japan Report

The total route length was approximately 9km and based on a design traffic volume of 4,000 vehicles per day. The proposed total carriageway width of road was 8m (2 x 3.5m lanes plus 2 x 0.5m shoulders). The cross section of the sunken tube considered is shown below:

Figure 2.2: Sunken Tube Cross Section from 1972 Study



Source: Overseas Technical Cooperation Agency of the Government of Japan Report

The study only considered an immersed tube tunnel (ITT) option and a deep bored tunnel below the seabed was not considered. No reason for this was given. The proposal also indicated a road link across the island of Comino.

A single bore tunnel was proposed for bi-directional traffic with the provision of transverse ventilation. The construction cost for the 1.4km long South Comino channel ITT was estimated at €12.4m in 1972 prices. The North Comino channel was not considered suitable for an ITT on construction cost grounds due to the high cliffs on the Gozo side of the channel.

A follow up report titled: “Feasibility Report on Link Road between Malta and Gozo Islands” was also prepared by the Overseas Technical Cooperation Agency Government of Japan in March 1974 [2]. This report concluded that the bridge option excelled the others in every respect and did not consider any tunnel options further.

2.2 Stakeholder Engagement

In support of the project meetings were held with key contacts in Malta and representatives from JASPERS, to enable our project team to gain a full understanding of background technical work that has been undertaken looking at transport links between Malta and Gozo and to appreciate local issues and contextual information.

To date we have met with representatives of the following:-

- JASPERS;
- Government of Malta;
- Transport Malta;
- Malta Environment and Planning Authority; and
- Gozo Stakeholders and Business Chamber.

A list of the background material received by the project team to support our preliminary assessment is set out in Appendix A (reference material for tunnelling assessment) and Appendix B (reference material for environmental assessment).

3. Economic Assessment

3.1 Introduction

The Gozo Channel Company operates two ferry services between Malta and Gozo as shown in Figure 3.1. A passenger and vehicle service operates daily between Mgarr and Cirkewwa with a crossing time of 25 minutes. The frequency of the service is approximately every 45 minutes between 06:00 and 19:00 in the winter, with frequencies extending to almost 2 hours overnight. In the summer additional services are provided extending the 45 minute frequency service to 21:45. A commercial vehicle service operates between Mgarr and Sa Maison near Valletta three days a week with a crossing time of 90 minutes.

Figure 3.1: Ferry Routes between Malta and Gozo

Source: Gozo Channel Company Ltd

Table 3.1 shows the capacities of the ferries operated by the Gozo Channel Company.

Table 3.1: Ferry Capacities

Ferry	Vehicles	Passengers
Gaudos	72	900
Malita	138	900
Ta'Pinu	72	900

Source: Gozo Channel Company Ltd

A fixed link between Malta and Gozo is part of the TEN-T comprehensive network as planned. The existing and draft proposed TEN-T network is shown in Figure 3.2. Provided that technical, economic and environmental conditions are satisfied, a fixed link project may be eligible for EU Structural Funding.

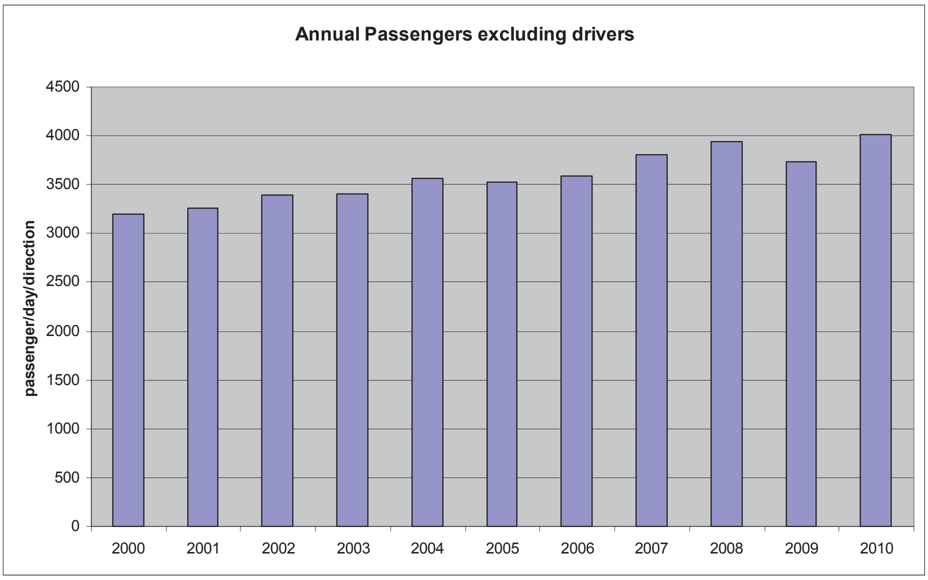
Figure 3.2: Draft TEN-T Network

Source: Transport Malta

3.2 Historic Ferry Demand

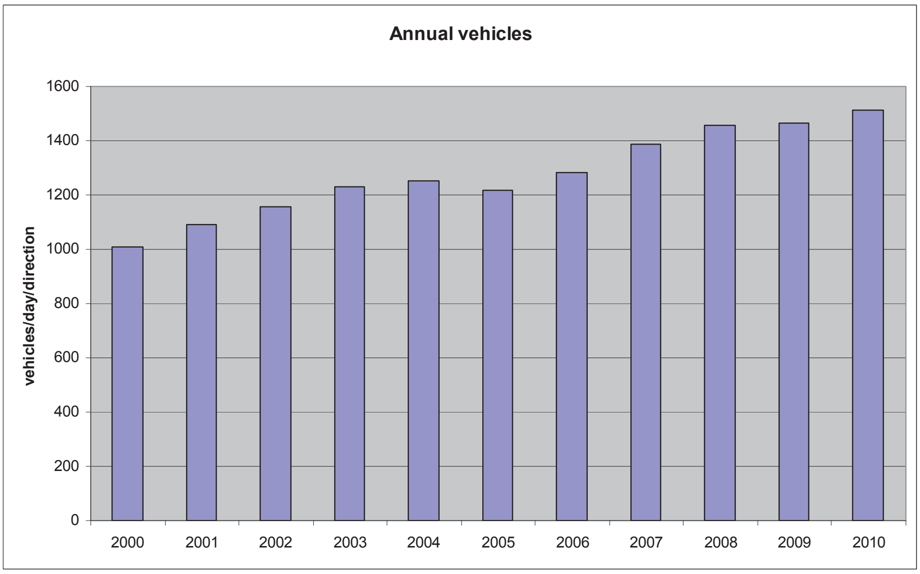
The National Statistics Office (NSO) of Malta has historic data on the number of passengers (including vehicle drivers) and vehicles that travel between Malta and Gozo. Figures 3.3 and 3.4 show the average numbers of passengers (excluding drivers) and vehicles per day per direction between 2000 and 2010. Average annual growth over this period has been 4.1% per annum for vehicles and drivers, and 2.3% for other ferry passengers.

Figure 3.3: Annual Passengers (excluding drivers) 2000-2010



Source: Malta NSO

Figure 3.4: Annual Vehicles 2000-2010



Source: Malta NSO

The Gozo Channel Company Ltd has provided ticketing data. The fares for different categories of users are shown in Table 3.2 for passengers and cars. Tickets are purchased when travelling from Gozo to Malta, but are the equivalent of a return ticket. Vehicle fares include the driver, any vehicle passengers are required to purchase a passenger ticket. There are a variety of discounts depending on time of travel, age of passenger and residency, Gozo residents fares are subsidised due to a Public Service Obligation (PSO) by the Government of Malta. A Gozo resident pays 25% of the standard passenger fare and 52% of the standard car & driver fare.

Table 3.2: 2011 Passenger and Private Vehicle Ferry Fares (Euros)

	Ticket Type	Fare
Passenger	Standard passengers	4.65
	Standard passengers night fare	4.05
	Child Fare	1.15
	Gozo resident	1.15
	Senior Fare - Gozitan	0.00
	Senior Fare	0.00
	Standard passengers - NSTS Discount	4.40
	Standard passengers - Discount on advert	4.15
	Passenger - Winter scheme	1.40
Car & Driver	Car & Driver Standard Fare	15.70
	Car & Driver Night Fare	12.80
	Car & Driver Standard Fare - NSTS Discount	14.90
	Car & Driver Standard Fare - Discount on advert	14.10
	Standard motorcycle and rider fare	8.15
	Motorcycle and rider night fare	6.95
	Gozo resident car fare	8.15
	Senior driver car fare - Gozitan	6.95
	Gozo resident motorcycle and rider fare	4.65
	Gozo resident motorcycle and rider fare - Senior Fare	3.45
	Senior driver car fare - Standard Fare	11.05
	Bicycle	1.15
	Towed trailer	13.95
	Gozo Winter Scheme - Car & Driver	8.40

Source: Gozo Channel Company Ltd

Commercial vehicle fares are categorised by length of vehicle. Return fares for the two routes operating between Malta and Gozo are shown in Table 3.3. Discounts of 3-13% of the fare are available for Gozo residents.

Table 3.3: 2011 Commercial Vehicle Ferry Fares (Euros)

Vehicle length	Cirkewwa	Sa' Maison	Gozo Resident Cirkewwa	Gozo Resident Sa' Maison
Under 5m	20.95	22.10	17.45	18.60
5m to 6.5m	27.90	29.65	24.40	26.15
6.5m to 8m	39.55	41.85	36.05	38.35
8m to 10m	58.20	62.25	54.70	58.75
10m to 12m	67.50	72.15	64.00	68.65
12m to 14m	79.15	85.55	75.65	82.05
Over 14m	93.15	100.10	89.65	96.60

Source: Gozo Channel Company Ltd

Table 3.4 shows the average daily number of tickets purchased in 2010 by customer type. These data match the number of passengers but are 6% lower than the NSO data on numbers of vehicles.

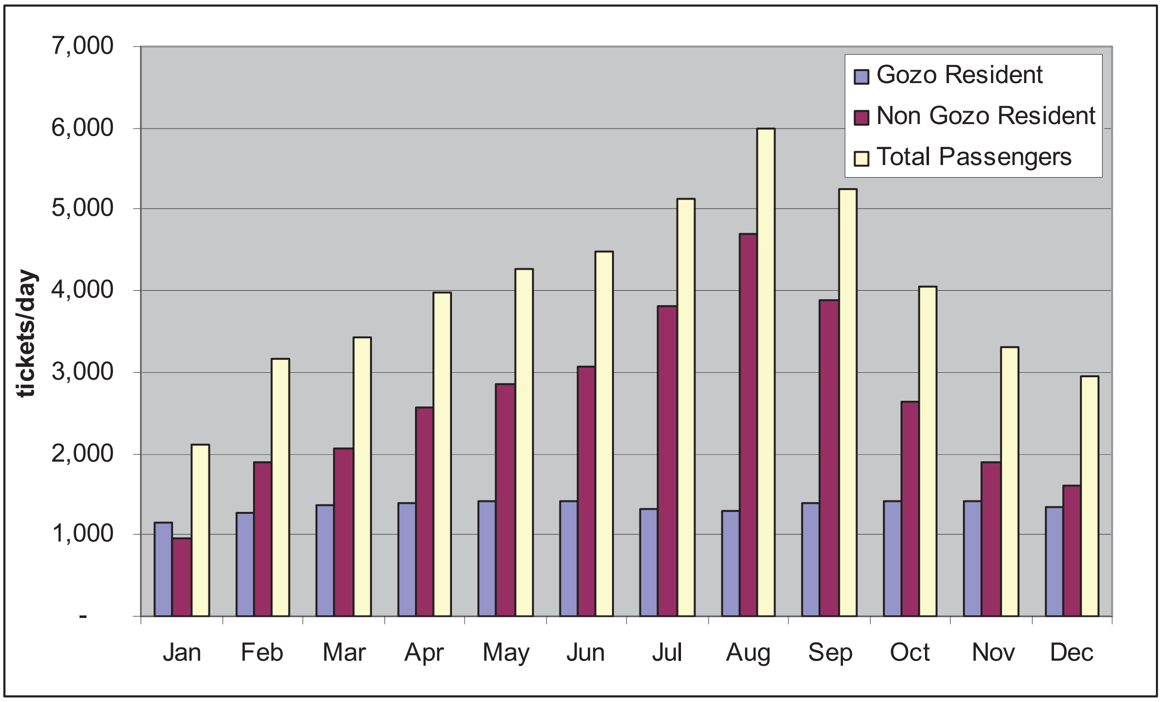
Table 3.4: 2010 Average Daily Ticket Purchases by Customer Type

Customer type	Tickets	%
Passengers	4,014	74%
Cars	1,324	25%
Trailers	4	0%
Motorbikes	22	0%
Bicycle	3	0%
Commercial	68	1%
Sa Maison Commercial	6	0%

Source: Gozo Channel Company Ltd

Figure 3.5 below shows the monthly profile of passenger tickets purchased in 2010 for Gozo and non-Gozo residents. This shows that there is little seasonal variation in passenger numbers for Gozo residents, monthly ticket numbers range between approximately 1,200/day and 1,400/day. Non-Gozo resident passenger ticket numbers varied from approximately 900/day in January to 4,700/day in August. A total of 34% of passenger tickets over the whole year were purchased by Gozo residents.

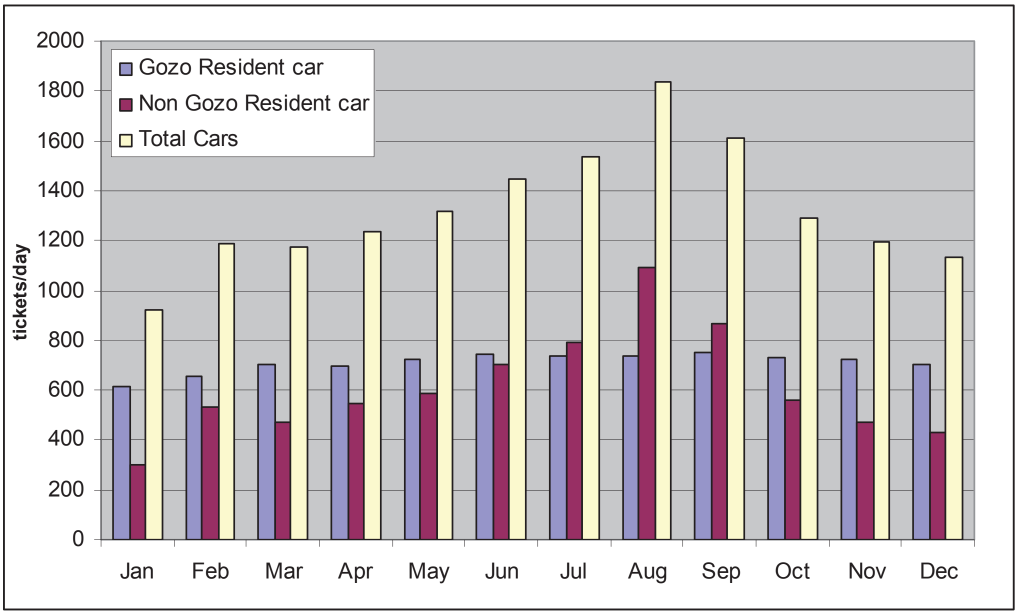
Figure 3.5: 2010 Passenger Tickets by Residence



Source: Gozo Channel Company Ltd

Figure 3.6 shows the monthly profile of car plus driver tickets purchased during 2010. This also shows that there is little seasonal variation in the number of tickets purchased by Gozo residents (approximately 600-700/day) but non-Gozo resident car tickets varied from 300 tickets/day purchased in January to 1,100 tickets/day in August. 54% of car tickets over the whole year were purchased by Gozo residents.

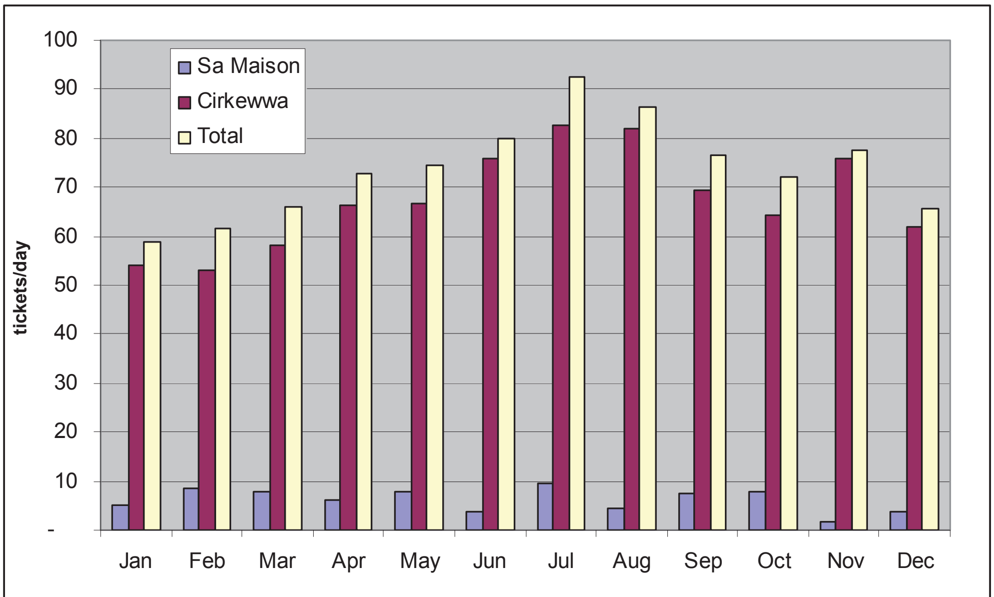
Figure 3.6: 2010 Car and Driver Tickets by Residence



Source: Gozo Channel Company Ltd

Figure 3.7 shows the monthly profile of commercial vehicle tickets purchased on both routes. 92% of tickets were for the Mgarr-Cirkewwa route. Ticket sales varied from approximately 60 - 90 vehicles/day.

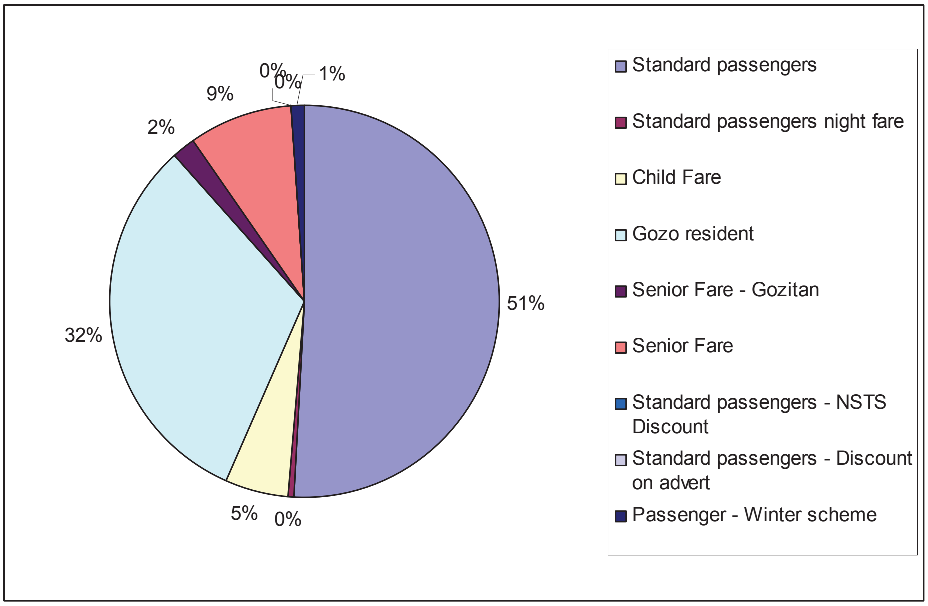
Figure 3.7: 2010 Commercial Vehicle Tickets by Route



Source: Gozo Channel Company Ltd

Passenger tickets accounted for 74% of total tickets purchased in 2010. Figure 3.8 shows the proportions of each type of passenger ticket purchased. 51% of passenger tickets were for the standard fare, 32% of tickets were for the Gozo resident fare, 11% of tickets were for senior passengers who travel for free (Gozo and Malta residents) and 5% of tickets were purchased for children (25% of standard fare), other discounted tickets accounted for 1% of purchases.

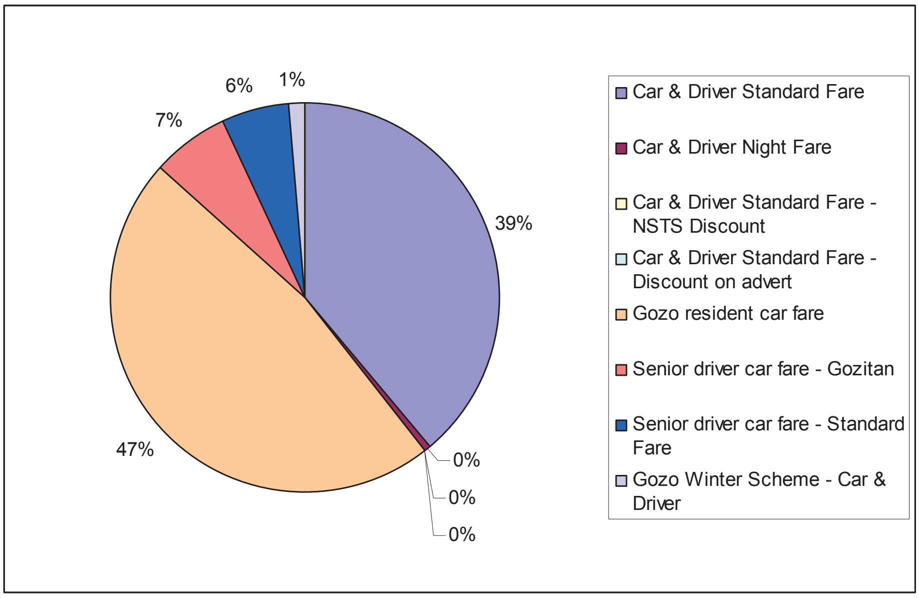
Figure 3.8: Type of Passenger Ticket Purchased 2010



Source: Gozo Channel Company Ltd

Car tickets accounted for 25% of ticket purchases in 2010. Figure 3.9 shows the proportion of each type of car ticket purchased. 39% of tickets were purchased at the standard fare, 47% were for the Gozo resident fare, 13% were senior fares (Gozo and Malta Residents) and less than 2% accounted for other discounted fares.

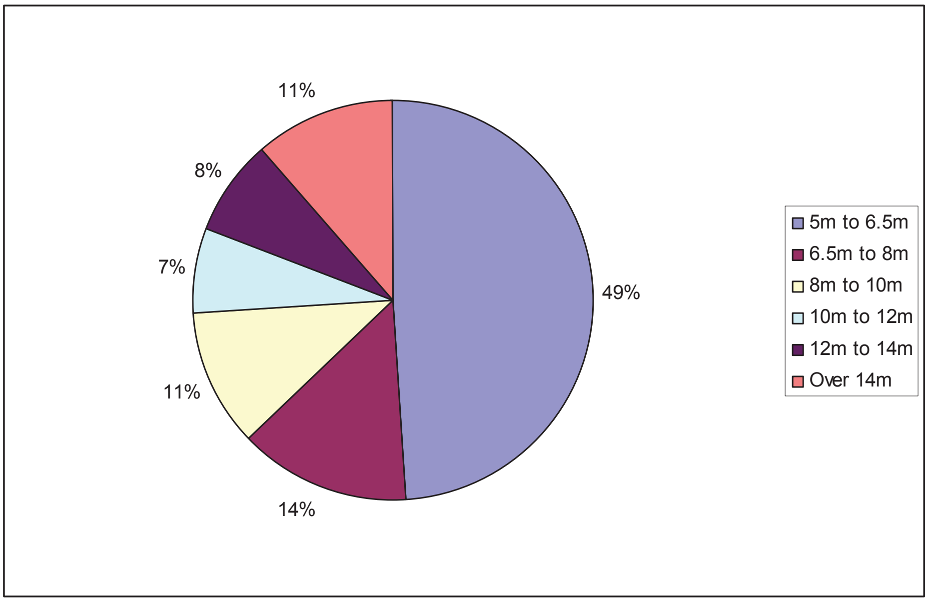
Figure 3.9: Type of Car Ticket Purchased 2010



Source: Gozo Channel Company Ltd

Commercial vehicles account for 5% of total vehicle tickets purchased in 2010. Figure 3.10 shows the proportion of tickets in each length category purchased over the two routes available for commercial vehicles. The majority of commercial traffic is made up vehicles less than 8m long, the 11% of vehicles over 14m is the equivalent of 8 vehicles/day.

Figure 3.10: Type of Commercial Ticket Purchased 2010

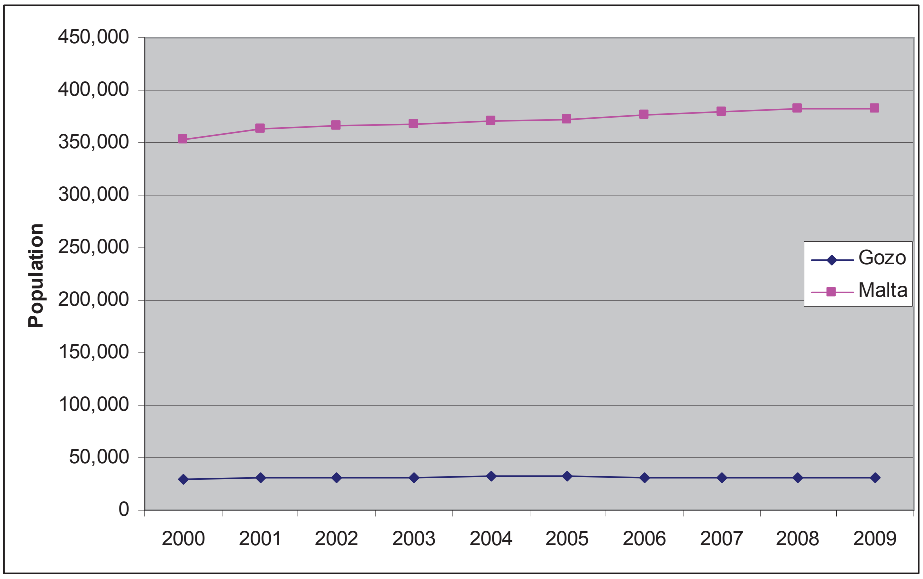


Source: Gozo Channel Company Ltd

3.3 Historic Socio Economic Data

The Malta National Statistics Office has population data by region for 2000-2009. In 2009 the population of the Maltese Islands was 413,000. This was split 92% on Malta (382,000) and 8% on Gozo/Comino (31,000) although actual residents living on Gozo may be less than the reported figure due to some people living on Malta whilst officially being classed as a resident of Gozo. Figure 3.11 shows the growth in population since 2000. Average annual growth from 2000-2009 has been 0.9% on Malta and 0.6% on Gozo.

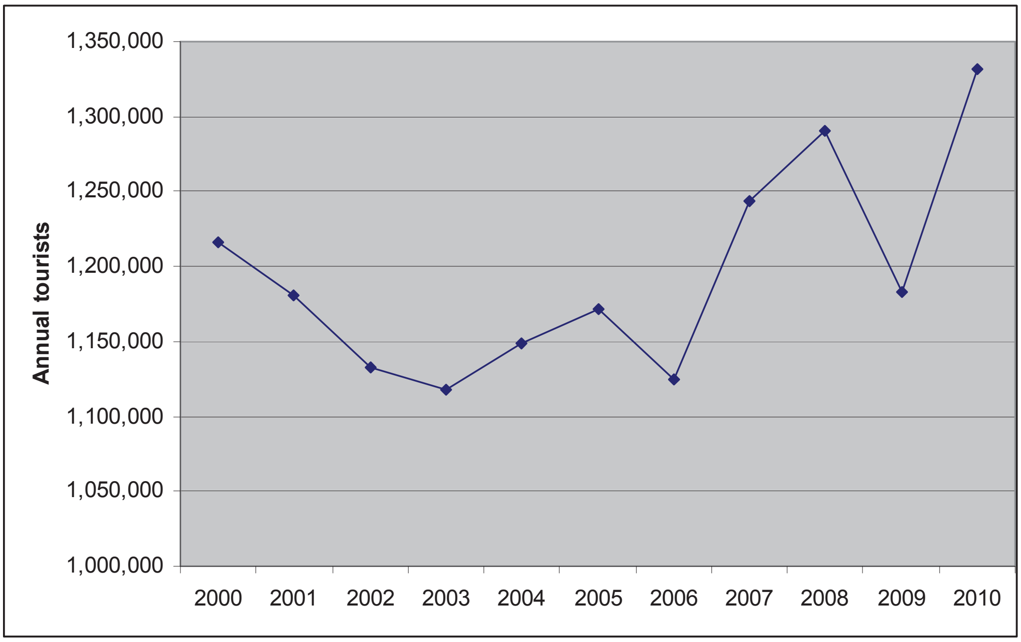
Figure 3.11: Population Growth 2000-2009



Source: Malta NSO

The number of tourists visiting the Maltese Islands was over 1.3 million in 2010. Figure 3.12 shows the change in tourist numbers since 2000, average annual growth has been 0.9% per annum, however there was a 13% increase in numbers between 2009 and 2010 and latest figures for 2011 indicate a 10% increase for the period January-July 2010 and 2011. Surveys of tourists carried out between 2001 and 2004 showed that over 50% of tourists visited Gozo during their holiday.

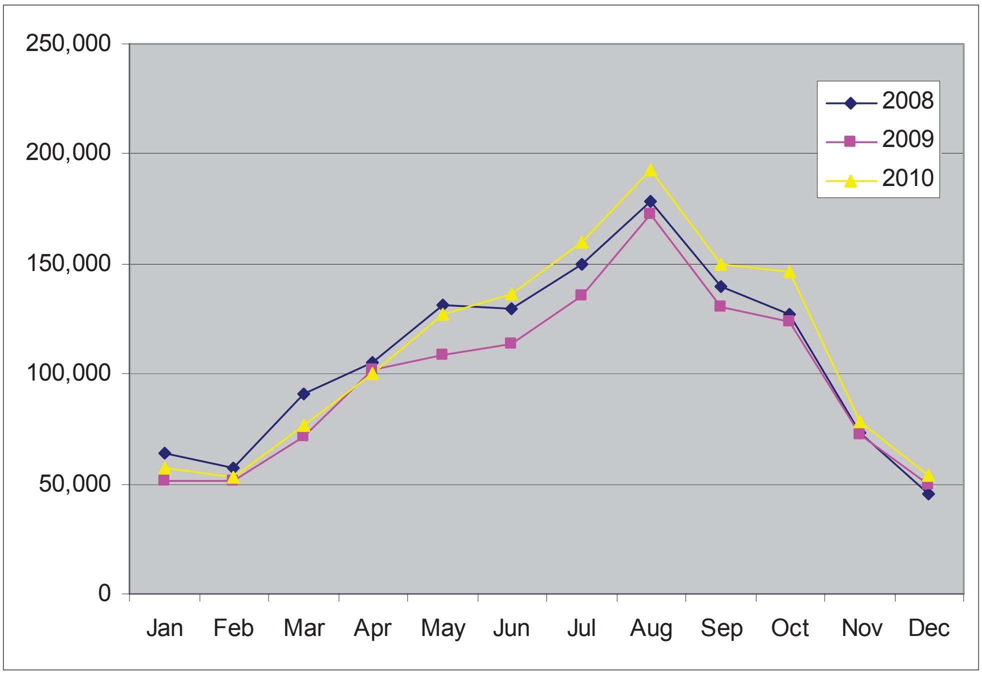
Figure 3.12: Growth in Tourist Departures 2000-2010



Source: Malta NSO

The monthly profile of tourists is shown in Figure 3.13 for 2008-2010.

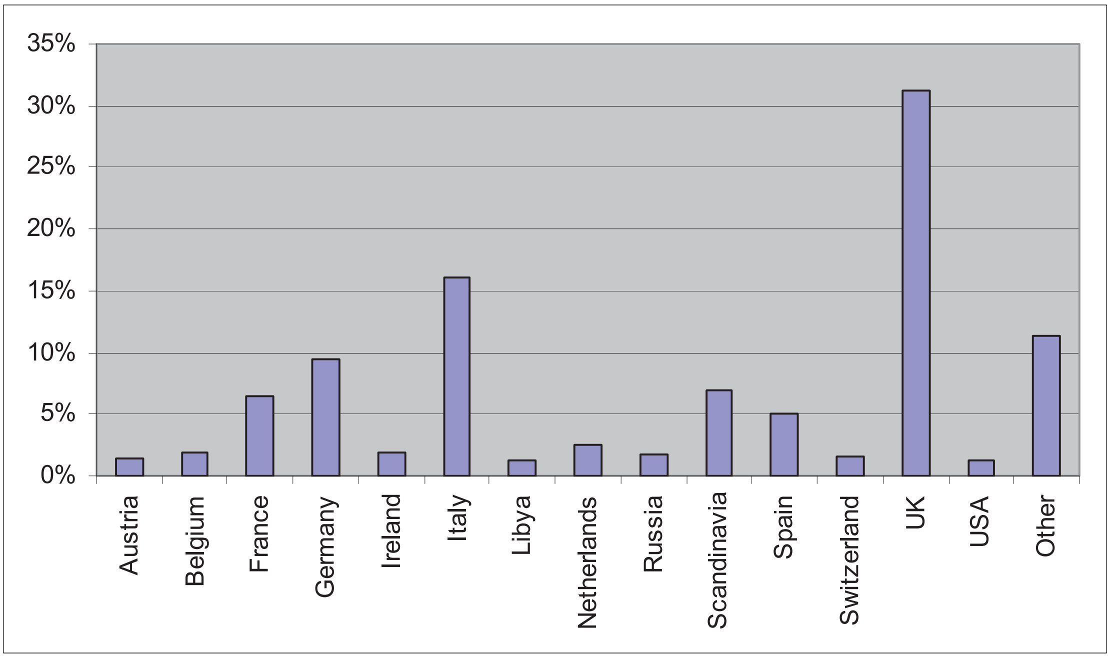
Figure 3.13: Monthly Profile of Tourist Departures



Source: Malta NSO

Figure 3.14 shows the proportion of tourists by country in 2010. Approximately a third of the annual tourists are from the UK, with Italy and Germany also providing significant numbers of tourists.

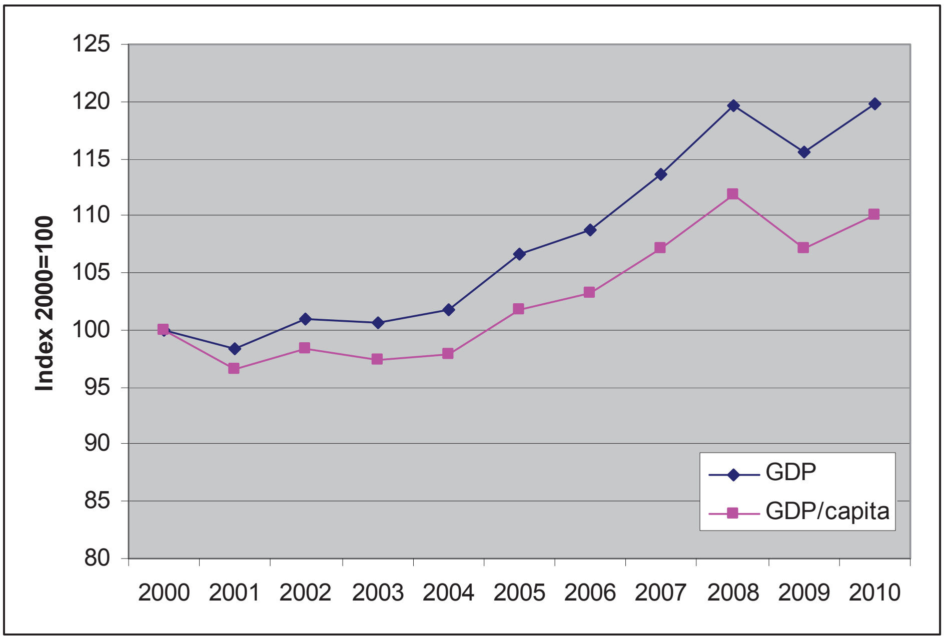
Figure 3.14: Percentage of Total Tourists by Country



Source: Malta NSO

Figure 3.15 shows GDP and GDP/capita growth for the Maltese Islands since 2000. Over the whole period average GDP growth was 1.8% per annum and GDP/capita growth was 1.0% per annum.

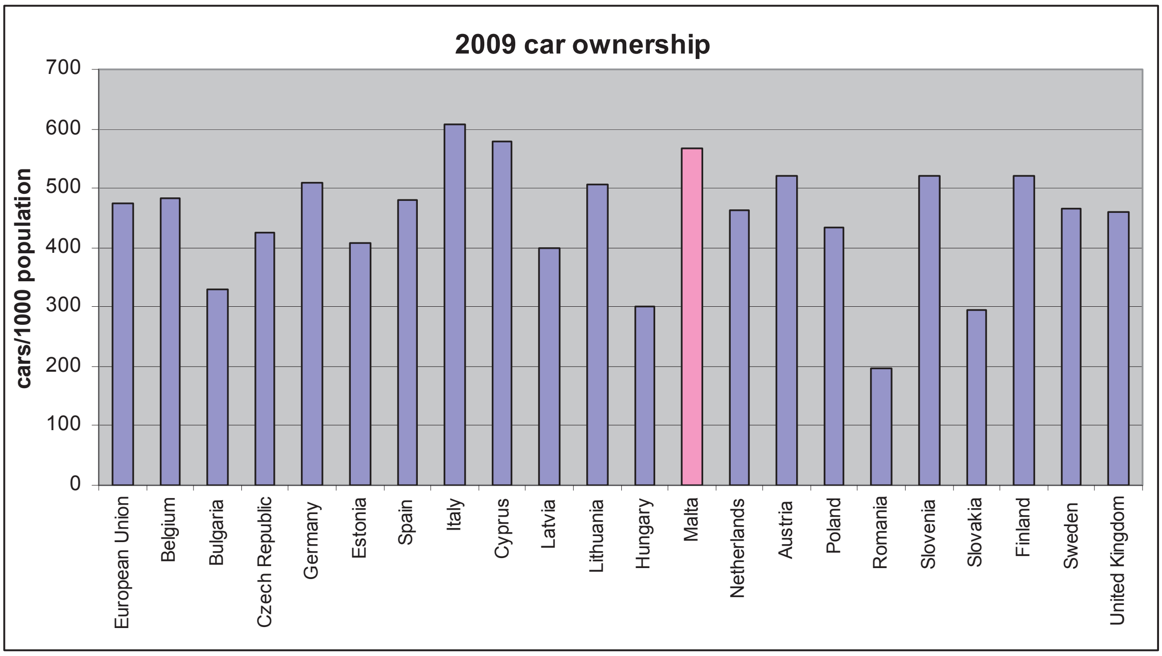
Figure 3.15: Economic Growth 2000-2010



Source: IMF World Economic Outlook Database, April 2011

Car ownership levels in the Maltese Islands are amongst the highest levels in the European Union, as shown in Figure 3.16 of figures available for 2009. Only Italy and Cyprus had higher levels than Malta.

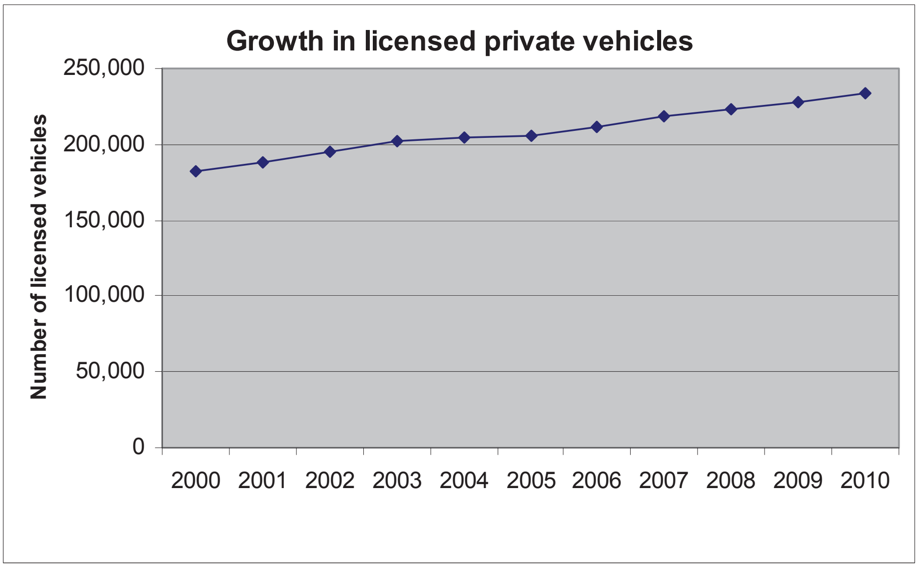
Figure 3.16: 2009 Car Ownership in Europe



Source: Eurostat

The number of licensed private vehicles in the Maltese Islands since 2000 is shown in Figure 3.17. The average growth rate since 2000 is 2.5% per annum, in 2010 there were over 233,000 licensed private vehicles.

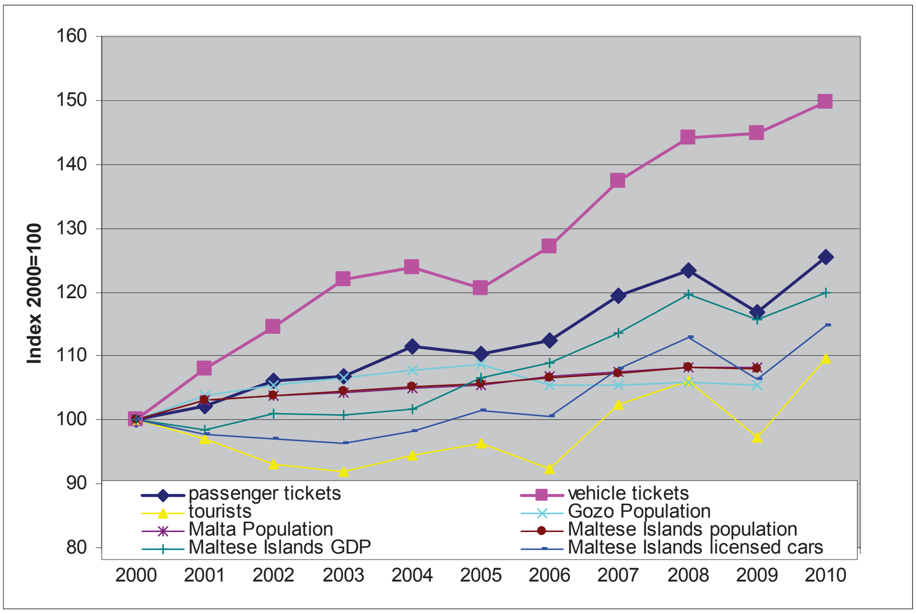
Figure 3.17: Growth in Licensed Private Vehicles 2000-2010



Source: Malta NSO

The growth in ferry vehicle and passenger tickets has been compared to the socio economic factors in order to establish relationships that explain the ferry ticket growth rates. Figure 3.18 shows that the growth in vehicle tickets is significantly higher than both economic growth and growth in socio economic factors. The growth in passenger tickets is also higher than these factors.

Figure 3.18: Comparison of growth rates



Source: Malta NSO, IMF

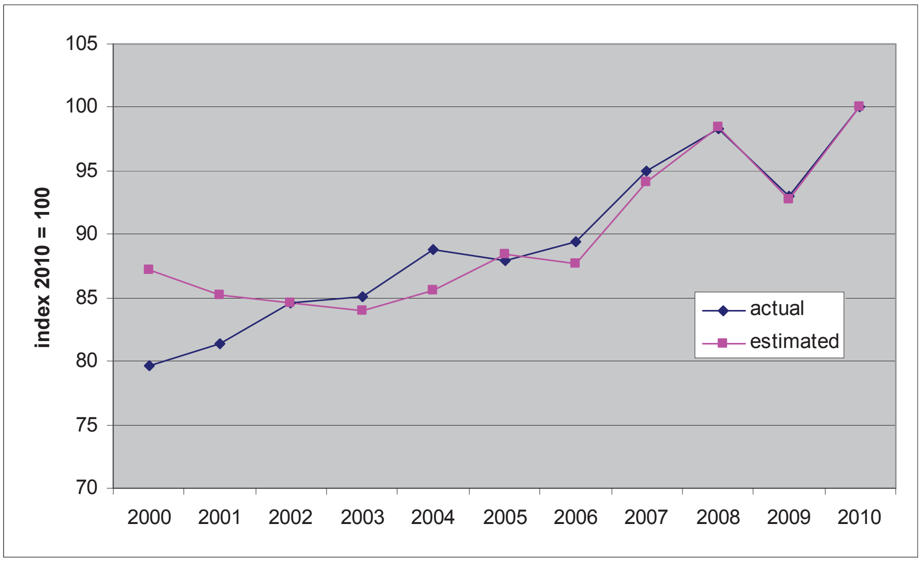
The 2010 ticket data were used to split the number of tickets into Gozo residents and non-Gozo residents, then data from the 2010 Household Travel Survey was used to determine how many of the non-Gozo resident tickets were Malta residents, the remainder of the tickets were assumed to be foreign tourists. This gave the following vehicle and passenger splits in 2010.

Table 3.5: 2010 vehicle/passenger proportions

	Vehicles	Passengers
Gozo Resident	51%	34%
Malta Resident	27%	18%
Foreign	17%	48%
Commercial	5%	0%

The number of foreign tourist passenger tickets was assumed to be directly related to tourist numbers. Therefore the numbers of tourist passenger tickets in previous years were estimated based on the growth in tourists between 2000 and 2010. The number of Malta and Gozo resident passenger tickets in previous years was estimated based on Maltese Islands GDP as Figure 3.18 shows that Maltese GDP growth was the closest factor to passenger ticket growth. Figure 3.19 shows the actual and estimated growth in passenger tickets based on tourist and GDP growth weighted by the proportions of foreign and national residents purchases. It can be seen that from 2002 - 2010 actual passenger ticket growth has been very similar to GDP and tourist growth. A regression of this data gives an R^2 value of 0.81 using data from 2000 – 2010 however between 2002 – 2010 the R^2 value increases to 0.96. R^2 is a measure of how well the regression line approximates the real data points. R^2 values range from 0.0 to 1.0 with 1.0 indicating a perfect fit.

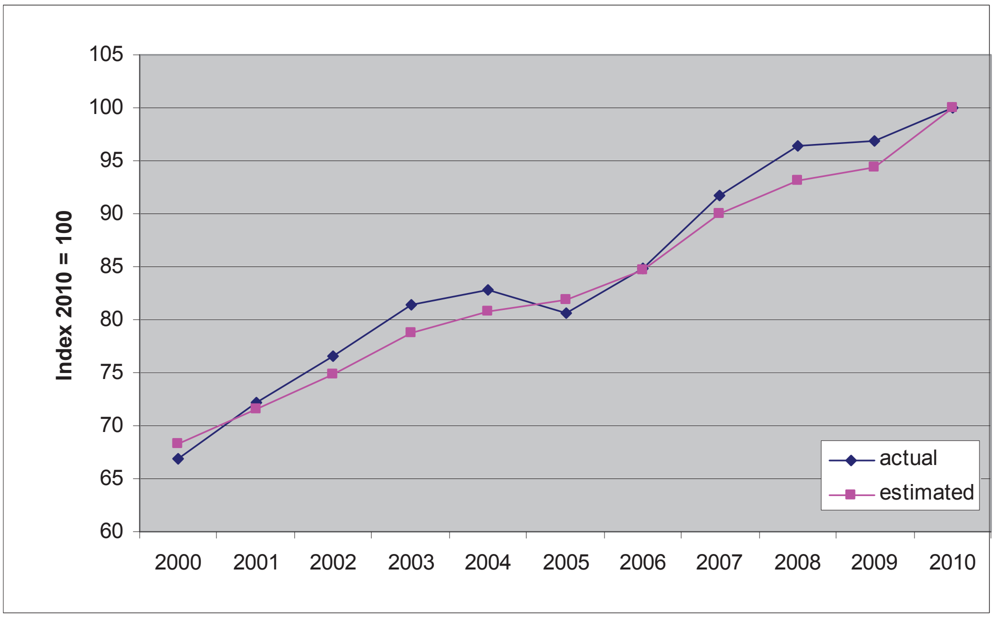
Figure 3.19: Comparison of Actual and Estimated Passenger Ticket Growth



Source: Malta NSO

Similarly for vehicle tickets the numbers of foreign tourist tickets were assumed to be directly related to tourist numbers, therefore tourist growth rates were used to estimate the number of foreign vehicle tickets in previous years. The remaining national vehicle tickets (Malta resident, Gozo resident and commercial) were estimated based on two times the growth in the number of private vehicles between 2000 and 2010 as the high growth in vehicle tickets shown in Figure 3.18 suggests that car usage has also been increasing. Figure 3.20 shows the actual growth in tickets and the estimated growth in vehicle tickets based on tourist and car ownership growth weighted by the proportion of national and foreign tickets. A regression of this data gives an R^2 value of 0.98 using data from 2000 – 2010.

Figure 3.20: Comparison of Actual and Estimated Vehicle Ticket Growth



Source: Malta NSO

3.4 Forecast Data

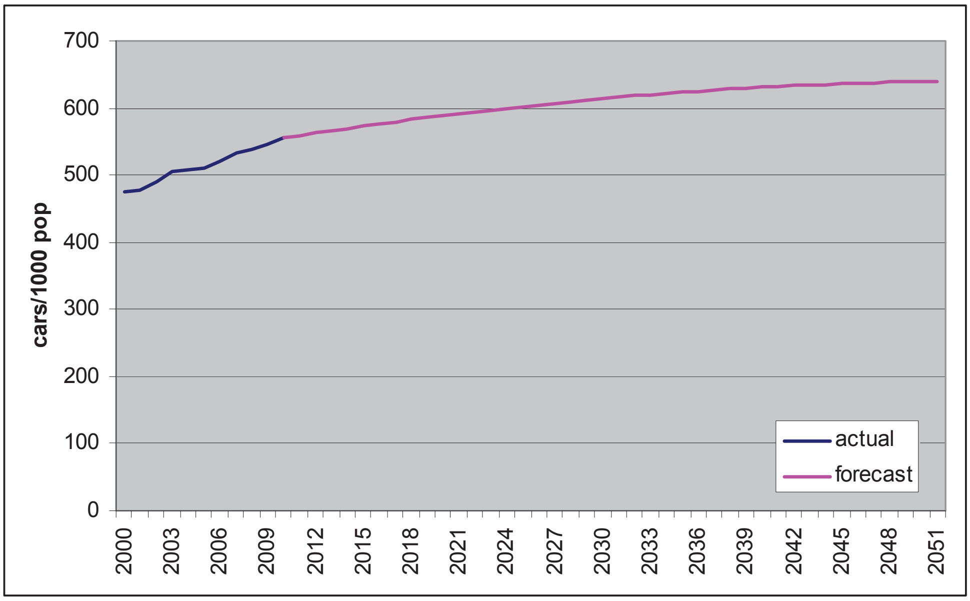
A comparison of forecasts of GDP growth for the Maltese Islands is shown in Table 3.6. The IMF forecasts GDP growth up to 2016 and have been used to forecast demand for crossing the Gozo Channel. Long term GDP growth after 2016 has been assumed to be 2.0% per annum.

Table 3.6: GDP Growth Forecasts

	IMF April 2011	EU spring forecast	Oxford Economics
2011	2.5%	2.0%	2.7%
2012	2.2%	2.2%	2.8%
2013	2.2%		3.0%
2014	2.3%		3.0%
2015	2.3%		3.0%
2016	2.4%		

We have calibrated a car ownership model with actual GDP/capita and car ownership data between 2001 and 2010. Historic and forecast car ownership is shown in Figure 3.21.

Figure 3.21: Actual and Forecast Car Ownership



Values of time have been taken from the EU funded research project HEATCO, which aimed to develop harmonised European approaches for transport costing and project assessment. Deliverable 5 (submitted Feb 2006) gives 2002 values of time for work and non work trips for 26 European countries and recommends that these values of time increase with GDP/capita at an elasticity of 0.7 These values of time are recommended for assessing TEN-T projects. Table 3.7 shows the values of time assumed in the forecast years, they have been converted into 2011 prices based on IMF GDP/capita and inflation growth. Commercial vehicles are assumed to have the same values of time as cars on business. Foreign tourist value of time has been weighted according to the 2010 proportions of UK, German and Italian and other tourists. All "other" tourists were allocated the EU average value of time. Long distance trips are defined as inter-urban and have therefore been used for travel between Malta and Gozo.

Table 3.7: Forecast Values of Time €/hr (2011 prices)

€/hr	2021	2031	2041	2051
Malta Business	28.41	31.83	35.67	39.96
Malta Other Long Distance	10.70	11.99	13.43	15.05
Foreign Tourist (Other Long Distance)	12.93	14.32	15.86	17.58

The World Travel and Tourism Council published a forecast of the number of foreign tourists visiting Malta in 2011 and 2021 in their report "Travel and Tourism Economic Impact 2011:Malta". The average annual growth between 2011 and 2021 was 3.2% per annum. It has been assumed that this growth rate continues beyond 2021.

The current ferry fares for vehicles include the driver and any passengers in the vehicle are required to pay the passenger fare in addition. The average vehicle occupancy of Maltese Islands residents is 1.4 based on the 2010 National Household Travel Surveys. A site visit was carried out between 17th and 19th August 2011 to observe ferry usage. During that period ferry usage for around 20 crossings was observed covering 0600-0930 and 1630-2300. Detailed surveys were not possible however estimates of numbers of passengers and vehicles and vehicle occupancies were made. An average vehicle occupancy of three has been assumed for foreign tourists based on observations during a site visit. Ferry fares are paid when leaving Gozo, they have been assumed to represent the fare for a return trip. The average price paid per vehicle for a 1-way trip on the ferry in 2010 is shown in Table 3.8 based on vehicle occupancy and the ferry fares in Tables 3.1 and 3.2.

Table 3.8: Average Ferry Fare per vehicle (1-way) 2010

Vehicle	Fare (Euro)
Gozo Resident Car	4.22
Malta Resident Car	8.29
Foreign Resident Car	11.25
Commercial	22.82

Source: Gozo Channel Company Ltd

The tunnel tolling has been based on factors of these average fares. It has been assumed that Gozo residents will continue to receive the same levels of discounts that they currently receive. Foreign resident cars are assumed to pay the same toll as Malta resident cars (i.e. less than the current ferry fare due to the lower vehicle occupancy assumed for Malta residents). Tolls are assumed to increase with inflation over time.

3.5 Forecast Model

The forecast demand for crossing the Gozo Channel is based on the 2010 split between foreign and national ticket purchases, as shown previously in Table 3.4. Foreign ticket purchases increase with tourist growth for both passengers and vehicles, national vehicle tickets increase at double the growth in number of cars and national passengers increase with GDP growth. Tourism and GDP growth have been treated as independent variables. Table 3.9 shows the number of passengers and vehicles for the forecast years, passengers are then allocated to vehicles according to vehicle occupancy rates of 1.4 for national vehicles and 3.0 for foreign tourist vehicles to give the remaining “foot passengers”. These are the Do-Minimum scenario forecasts of the ferry crossings.

Table 3.9: Do-Minimum 1-way Annual Average Daily Traffic (AADT) (base case)

	Passengers excluding drivers			Vehicles and drivers			Foot Passengers		
Year	Maltese	Foreign	Total	Maltese	Foreign	Total	Maltese	Foreign	Total
2010	2,100	1,900	4,000	1,300	200	1,500	1,600	1,400	3,000
2021	2,600	3,000	5,600	1,900	400	2,300	1,900	2,200	4,100
2031	3,200	4,000	7,300	2,600	500	3,100	2,200	3,000	5,200
2041	3,900	5,500	9,500	3,400	700	4,100	2,600	4,100	6,700
2051	4,800	7,600	12,400	4,400	1,000	5,300	3,000	5,700	8,700

A comparison of actual and forecast growth rates is shown in Table 3.10. The growth rates for passengers is higher than recently observed due to the forecast growth rates in tourists being higher than the average over 2000 and 2010, however 2010 and 2011 have shown much higher growth rates in tourists than forecast. Growth rates for vehicles gradually reduce over time.

Table 3.10: Do-Minimum growth rates (% per annum)

Period	Passengers (exc drivers)	vehicles
2000-2010	2.3%	4.1%
2010-2021	3.1%	4.0%
2021-2031	2.7%	3.0%
2031-2041	2.7%	2.8%
2041-2051	2.7%	2.6%

The national vehicles were split into Gozo Residents (Business and Non-business), Maltese Residents (Business and Non-business) and Commercial vehicles based on Ferry ticketing data and the National Household Travel Survey.

Table 3.11: National vehicle trip purpose splits

	Total	Business	Non-business
Commercial	6%	6%	0%
Gozo Residents	62%	23%	38%
Malta Residents	32%	4%	28%

The average speed in the tunnel has been assumed to be 80kph and the length 10km giving a journey time of about 8 minutes compared to 25 minutes by ferry. This is the maximum allowed speed as it is the speed limit, some vehicles may travel at slower speeds, others might exceed this speed if speed limits are not strictly enforced. It has been assumed that the frequency of the ferry service will reduce to every 1.5 hours with the tunnel operating, so a waiting time of 45 minutes has been assumed for vehicles wishing to use the ferry. An average driving time of one hour has been assumed to represent the time taken to drive from origin to destination excluding the ferry crossing, this is representative of most trips between Gozo and the Harbour area or airport on Malta. With a tunnel this time has been reduced to 50 minutes as the tunnel portals are located inland of the ferry terminals. This assumes that there is a 5 minute journey time saving at each end of the journey due to the tunnel portals being closer to most origins/destinations than the ferry terminals based on observations carried out during the site visit in August 2011. Table 3.12 shows that the overall journey time saving with a tunnel (in this scenario, assuming a 1.5 hour ferry interval, rather than the currently operating 45 minute ferry interval) would be 1.2 hours.

Table 3.12: Journey Time Comparison (Hours)

	Waiting Time (Hrs)	Channel Crossing (Hrs)	Remaining Driving Time (Hrs)	Total Journey Time (Hrs)
Ferry	0.8	0.4	1.0	2.2
Tunnel	0.0	0.1	0.8	1.0

The mode choice of using the tunnel or ferry has been calculated using a utility based choice model of the form:

$$P_{TUNNEL} = \frac{\exp(U_{TUNNEL})}{\exp(U_{TUNNEL}) + \exp(U_{FERRY})}$$

Where:

P_{TUNNEL} = probability of using tunnel

U_{TUNNEL} = utility for journey using tunnel

U_{FERRY} = utility for journey using ferry

$$U = \lambda\left(time + \frac{toll}{VOT}\right)$$

Time = total journey time in hours

Toll = ferry fare or tunnel toll in euros

VOT = value of time in euros/hr

Values for λ for business (-4.0) and non-business (-4.5) have been taken from UK WEBTAG guidance.

The utility calculations do not take into account other factors such as comfort levels and reliability which also affect people mode choice behaviour. Stated preference surveys would need to be carried out in order to determine these affects and may increase the probability of people choosing to use the tunnel.

Additional tunnel traffic generated due to the reduction in journey time has been calculated based on standard UK elasticities of traffic to journey time savings shown in Table 3.13.

Table 3.13: Journey Time Elasticities

Trip Purpose	Elasticity
Business	-0.35
Tourism	-0.20
Other	-0.26

Source: DMRB vol 12

In order to take account of the effect of different levels of toll for the tunnel the toll has been converted into an equivalent time based on the values of time. In addition at zero toll it is assumed that 50% of foot passengers transfer to cars. This additional mode shift at zero toll is based on evidence from the Skye Bridge in the UK. [1]

[1] The Skye Bridge in the UK replaced a ferry service linking mainland Scotland with the Isle of Skye in 1995. In 2004 tolls were removed from the bridge. A February 2007 report by DHC "Evaluation of the Economic and Social Impacts of the Skye Bridge" reported that the removal of tolls significantly reduced the number of "foot passengers" and increased the number of vehicles using the bridge.

The forecasts of tunnel traffic are shown in Table 3.14 for a variety of toll levels. EU Directive 2004/54/EC Clause 2.1.2 states that a twin tube tunnel would be required if forecast traffic exceeds 10,000 vehicles/day/lane 15 years after opening. Traffic does not exceed 10,000 vehicles/day/direction in any of the forecast years or scenarios. These forecasts assume that the remaining foot passengers forecast in Table 3.9 still use the ferry if there is a toll on the tunnel, at zero toll it has been assumed that 50% of the foot passengers would use a car for their journey.

If the tunnel toll is set at the same level as the ferry fare the tunnel traffic is 25% higher than the Do-minimum levels. With zero toll there is 34-43% more traffic compared to the tunnel with the ferry toll. [2]

Table 3.14: 1-Way Tunnel AADT (base case)

Year	zero toll	ferry toll	1.5 x ferry toll	2 x ferry toll	3 x ferry toll
2021	4,000	2,700	2,500	2,400	1,600
2031	5,300	3,700	3,500	3,300	2,400
2041	6,900	4,900	4,700	4,500	3,500
2051	9,000	6,400	6,200	5,900	4,900

Table 3.15 shows the number of vehicles and foot passengers that would remain on the ferry. If the tunnel toll is three times the current ferry toll then vehicle demand for the ferry would be approximately 50% of current ferry traffic levels.

Table 3.15: 1-Way Ferry AADT (base case)

Year	Vehicles/day					Foot passengers/day	
	Zero toll	ferry toll	1.5x ferry toll	2.0x ferry toll	3.0x ferry toll	Zero toll	toll
2021	<100	<100	<100	100	800	2,000	4,100
2031	<100	<100	<100	100	800	2,600	5,200
2041	<100	<100	<100	100	800	3,400	6,700
2051	<100	<100	<100	100	800	4,400	8,700

Annual revenues are shown in Table 3.16. Tolls are assumed to increase with inflation. Revenues range from €13.5m-€19.5m in 2021 depending on the toll rate charged.

Table 3.16: Annual Tunnel Revenue €000s (2011 prices inc. VAT) (base case)

Year	zero toll	ferry toll	1.5 x ferry toll	2 x ferry toll	3 x ferry toll
2021	0	13,500	19,100	23,200	19,500
2031	0	18,500	26,300	32,500	30,800
2041	0	24,600	35,300	44,300	47,100
2051	0	32,500	46,600	58,900	68,500

A high growth scenario has also been tested which increases GDP and tourist growth by an additional 2% per annum and doubles the amount of generated traffic due to the tunnel. All other assumptions are the same as the base case forecasts. Traffic forecasts for the higher growth scenarios are shown in Table 3.17 and 3.18.

[2] As a comparison the opening of the Skye Bridge in the UK increased traffic by about 20% compared to ferry levels of traffic, when tolls were subsequently removed from the Skye Bridge traffic increased by about an additional 50%.

Table 3.17: Do-Minimum 1-way AADT (high case)

	Passengers excluding drivers			Vehicles and drivers			Foot Passengers		
Year	Maltese	Foreign	Total	Maltese	Foreign	Total	Maltese	Foreign	Total
2010	2,100	1,900	4,000	1,300	200	1,500	1,600	1,400	3,000
2021	3,200	3,600	6,800	2,000	500	2,400	2,400	2,700	5,100
2031	4,700	5,900	10,700	2,700	800	3,500	3,700	4,400	8,100
2041	7,000	9,900	16,900	3,500	1,300	4,800	5,600	7,400	13,000
2051	10,400	16,400	26,800	4,500	2,100	6,600	8,600	12,200	20,800

Table 3.18: 1-way Tunnel AADT (high case)

Year	zero toll	ferry toll	1.5 x ferry toll	2 x ferry toll	3 x ferry toll
2021	5,300	3,400	3,100	2,900	2,000
2031	7,600	4,800	4,500	4,200	3,300
2041	10,600	6,600	6,300	6,000	5,100
2051	15,300	9,200	8,800	8,400	7,500

In 2040 with zero toll the traffic exceeds 10,000 vehicles/day/lane, however this is likely to be over 15 years from opening so a twin tube tunnel is unlikely to be required for this scenario.

Table 3.19: Annual Tunnel Revenue €000s (2011 prices inc. VAT) (high case)

Year	zero toll	ferry toll	1.5 x ferry toll	2 x ferry toll	3 x ferry toll
2021	0	17,000	23,400	28,000	24,900
2031	0	24,600	34,300	42,000	45,100
2041	0	34,100	48,300	60,500	74,000
2051	0	48,000	68,100	86,000	112,000

3.6 Wider Socio-Economic Impacts

Time savings and improved journey time reliability will benefit the economies of both Gozo and Malta. In 2021 the base case forecast with the tunnel toll at the same level as the ferry toll gives time savings for business trips equivalent of €10m, this is equivalent to 0.2% of 2010 Maltese Islands GDP.

In 2009 data from NSO showed that Gozo contributed about 6% to the total Maltese Islands Gross Value Added. Additional visitors to Gozo due to the tunnel would benefit the Gozo economy as they will spend money on the island, however the value of this is very dependant on whether the visitors are day trippers or stay overnight and it should be noted that there would probably be very little difference to the total contribution tourism makes to the GDP of the Maltese Islands. The provision of the tunnel could increase tourist traffic by 14% if the tunnel toll is set at the same level as the ferry.

Ernst and Young's 2009 Malta Attractiveness Survey asked 101 foreign owned companies that are present in Malta whether their company had considered investing in Gozo. Only 8% of companies had either invested or considered investing in Gozo. The companies surveyed were categorised into 17 business sectors. When asked for the reasons for not investing in Gozo the current poor transport links between Gozo and the airport on Malta were mentioned by companies in 13 out of the 17 business sectors. A more reliable and faster connection may increase business investment on Gozo in the future, but may not affect business investment on the Maltese Islands as a whole.

Population growth on Gozo is currently less than the population growth on Malta (0.6% per annum compared to 0.9% per annum).

When the Skye Bridge in the UK opened and replaced the ferry, the population on Isle of Skye increased at a higher rate when compared to the surrounding area on mainland UK. This illustrates that a tunnel link between Malta and Gozo has the potential to reduce the isolation of Gozo and increase its attractiveness as a place to live.

3.7 Viability of the Ferry

The viability of the existing ferry will be severely affected by the tunnel unless tolls are set significantly higher than the ferry fare. If the tunnel toll is set at 3 times the current ferry fare the vehicle demand for the ferry is still less than 50% of current demand. These forecasts assume that the ferry operates at a 1.5 hour frequency and continues to transport foot passengers. There may be a continuing role for ferries for the carriage of hazardous goods. Foot passengers could be catered for by providing bus services through the tunnel, however some tourist foot passengers may prefer to travel by ferry. There may be opportunities for alternative ferry services such as a high speed passenger service and increased services between Gozo and Valletta (currently Sa Maison). This Gozo Valletta route reduces the need to drive to the north end of Malta to access Gozo from the south of Malta. The forecasts of tunnel traffic may be affected if alternative services were operated.

3.8 Value for Money

The costs of building the proposed tunnel are estimated in Chapter 4. Comparisons of opening year revenue have been made against the lower estimate of construction costs for a single bored tunnel (€156m) and the upper estimate of construction costs for the single bored tunnel (€492m). If the tunnel toll is set at 2 times the ferry fare (the optimum toll for revenue) the base case forecast 2021 revenues are the equivalent of 2-4% of the construction cost. For the high growth forecasts this increases to 7-9% of construction costs in 2021.

3.9 Finance

Sources of funds for a project such as the Malta Gozo tunnel can encompass diverse sources including national funds (general taxation or specific taxation), international funds (such as EU and other International Financial Institutions) and user charges.

Whichever source of funds is used, consideration must also be given to the financing arrangements under which the funds can contribute to the project expenditure.

The timing of the availability of funds will have a strong influence over the suitability of the method of financing chosen.

User charges (primarily tolls) are only available after the construction project is complete, although consideration can be given to using charges from the existing ferry service, possibly in the form of a surcharge. Funds therefore only become available over a protracted period, and some form of finance is required in the interim.

Specific taxation could take the form of special taxes applied to targeted groups, usually those who are likely to gain from the project, such as property taxes applied in areas that would benefit from increased property values or development potential following implementation of the project.

If private finance is used, it should be recognised that the project is unlikely to generate sufficient revenues to fully cover the costs of construction, operation, maintenance and finance. Some provision will therefore be required to fund the shortfall.

If European Union assistance is sought for funding, adjustments will be made to available funding due to revenue-generation. Reference should be made to European Commission Draft Revised Guidance Note on Article 55 for ERDF and CF of Council Regulation (EC) No 1083/2006: Revenue-Generating Projects (reference COCOF 07/0074/08).

Further guidance can be found in the following two JASPERS Working Papers: Combining EU Grant Funding with Public Private Partnership (PPP) for Infrastructure: Conceptual Models and Case Examples; and Combining EU Grant Funding with PPP for Infrastructure: Guidelines for the use of Design Build and Operate (DBO) to procure Infrastructure projects using EU Structural Funds.

It should be noted that PPP-type models may not always be suitable or economically appropriate. Where private finance is used, there is commonly a higher cost of finance compared to using sovereign debt. Under some circumstances this can provide value for money, but this should be the subject of further investigation. The advantages and disadvantages of such an approach must be considered with care, to ensure that suitable mechanisms are selected.

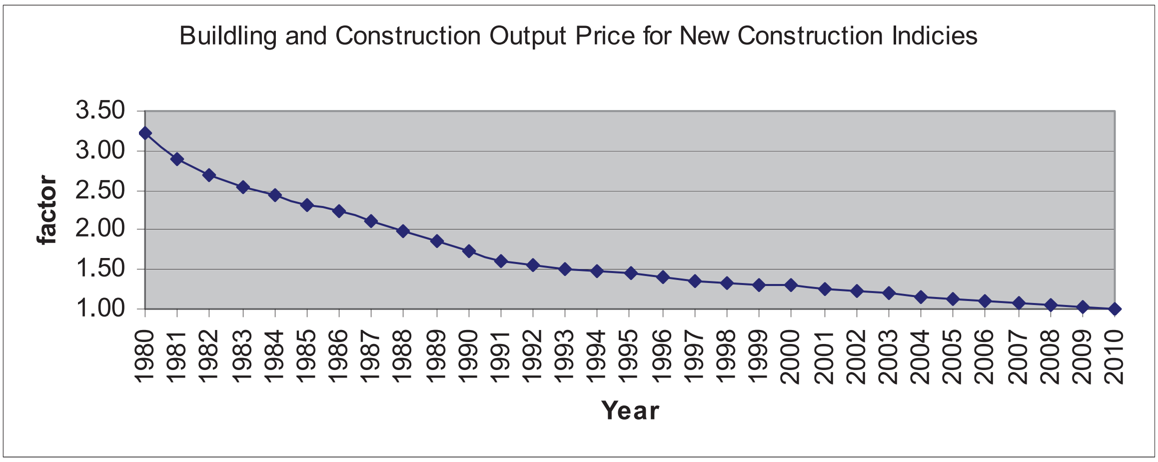
It is also important to consider the “affordability” of the project within the context of the national economy. Whilst a project may be justifiable in cost benefit terms, it can in some cases be found that the overall impact of expenditure on the national budget is unsustainable.

4. Tunnel Options and Assessment

4.1 Review of Relevant Fixed Sub-sea Tunnel Links Worldwide

Eight fixed sub-sea tunnel links worldwide relevant for comparison with a Malta Gozo Road Tunnel Crossing were reviewed in order to assess the feasibility of such an under sea crossing as well as to determine the range of construction costs that could be expected. The review included studies of both immersed tube tunnels (ITTs) and bored tunnels – and included both high and low traffic volume case studies from undersea tunnels around the world. The construction costs of the fixed sub-sea links are approximate only and were taken from a number of sources which have not all been verified. Estimated costs have been adjusted to 2010 prices including using historical data from the UK Office for National Statistics, Building and Construction, Chapter 4, Price Indices, Table 4.9 - Output Prices for New Construction. The indices are shown in graphical form in Figure 4.1 below:

Figure 4.1: Construction Price Indices



Source: UK Office for National Statistics (from 1997)

The following 2011 exchange rates have been assumed to convert all currencies into Euros for comparative purposes:

€1 = £0.83; €1 = $1.31 and €1 = 7.75 Nor. Kroner.

The costs are assumed to include the total capital construction costs including the civil and mechanical and electrical elements of the work. These costs are for comparative purposes only.

4.1.1 Immersed Tube Tunnels

Three immersed tunnel case studies were chosen that have particular relevance to the Malta-Gozo crossing. As the crossing would be one of the longest in the world, three long road tunnels, constructed or planned for offshore type environments have been selected.

4.1.1.1 Øresund Crossing

The Øresund Link connects Denmark and Sweden across the Øresund Channel. The crossing accommodates a four-lane highway (two lanes in each direction) and a twin track rail line. The 22km channel is crossed by a combination of a 16km long bridge and a 4km long ITT. The tunnel section is below a primary shipping channel. A secondary shipping channel is beneath the long cable-stayed span within the bridge section.

The multi-functional requirement of the tunnel suited the low profile rectangular structure provided by an ITT. The requirement for both rail and road resulted in a structure approaching 40m in width that would have been difficult to accommodate in a bored tunnel configuration. The 22m deep shallow channel also lent itself to ITT construction.

The main lesson learnt from this crossing was that a different approach to constructing tunnel elements is beneficial for longer immersed tunnel crossings, improving construction programme and leading to lower costs, yet maintaining a high standard of quality in construction. A purpose built casting facility was constructed that enabled rapid factory-like production of the tunnel elements. Twenty tunnel elements were built in a period of two years. A significantly longer construction programme would have been required if a more conventional dry dock or casting basin was used. This new approach to construction has since been adopted for all other long offshore tunnels.

The Øresund tunnel also showed the possibilities of constructing immersed tunnels within limestone. The trench was successfully dredged in the Copenhagen limestone and the tunnel elements were placed onto a thin gravel bed screeded in the bottom of the trench.

Table 4.1: Øresund Tunnel - Summary Data

Feature	Description
Location	Denmark – Sweden (Malmo to Copenhagen)
Function	Road / Railway
Type	Immersed Tube (concrete)
Built	1995-2000
Status	In use
Length tunnel section	4,050m
Length Immersed Tube	3,510m
Depth	22m
Number Units	20
Road Configuration	2-lanes in each direction
Ventilation	Longitudinal (Jet Fans)
Costs Tunnel	€830m (2010 prices)
Cost per m/bore (i.e. 4 bores) / 4050.	€51,234 per m/bore (2010 prices)

4.1.1.2 Busan-Geoje Fixed Link Project

The 8.2km long link is in South Korea between Busan and the island of Geoje. The ITT section is approximately 3.7km long and includes a four-lane (2-lanes in each direction) highway.

Figure 4.2: Busan Geoje ITT – Floating Out

Source: Mott MacDonald

The link was completed in 2010 at a cost of €534m.

The fixed link project was implemented along the lines of the privately-financed build, operate, transfer model.

The total length of tunnel is approximately 3.7km, with 270m portals connecting the tunnel to the bridge section and Geoje Island. The tunnels were designed for two-lane traffic with emergency / crawler lane hard shoulders. Running between the two carriageways is a service lane / escape route.

The ITT was placed at a maximum water depth of 50m and is the deepest road immersed tube tunnel ever constructed. Eighteen precast tunnel elements (weighing up to 50,000t) make up the tunnel. These were floated into position and sunk into a pre-dredged trench. The maximum gradient is 5%.

This project demonstrates the viability of building long immersed tunnels in deep offshore conditions. This project had additional challenges of high seismicity and poor ground conditions, which required a significant quantity of ground treatment at depth using techniques such as deep soil mixing and sand compaction piles.

The tunnel elements were constructed in a similar way to the Øresund tunnel, permitting a reasonably rapid construction programme and maintaining a high quality of concrete construction. As the location for this tunnel is in a warmer climate, the construction techniques developed for the Øresund tunnel were able to be simplified to achieve a lower relative cost. This is an important lesson to be taken from the project that is of significance to the Malta - Gozo crossing.

Table 4.2: Busan-Geoje Fixed Link - Summary Data

Feature	Description
Location	South Korea
Function	Road – 4 lanes
Type	Immersed Tube (concrete)
Built	2004-2010
Status	Construction complete
Total Crossing Length	8.2km
Length Immersed Tube	3.7km
Depth	50m
Number Units	18
Road Configuration	2-lanes in each direction
Ventilation	Longitudinal ventilation (jet fans)
Tunnel Costs	€272m (2010 prices)
Cost per m/bore (i.e. 2 bores) / 3700.	€36,756 per m/bore (2010 prices)

4.1.1.3 Fehmarnbelt Fixed Link

A fixed link is proposed across the Fehmarnbelt between Lolland (Denmark) and Fehmarn (Germany). The Fehmarnbelt Fixed Link would connect Scandinavia and the centre of continental Europe with a combined double track rail and a 4-lane (2 in each direction) motorway.

A feasibility study explored a number of possible solutions, including bridge and tunnel (immersed and bored) options. An immersed tunnel was identified as the preferred solution by the client and has been accepted by the Danish politicians in February 2011 as the basis for preparing planning applications to the authorities.

The ITT solution would set new records in terms of dimensions. With a length of 17.6km and foundation depths reaching more than 40m under the sea surface it will be the deepest and the longest combined road-rail immersed tunnel to be built. The Fehmarnbelt Fixed Link tunnel will be approximately five times longer than the world's longest existing concrete immersed tunnel.

The vertical alignment of the tunnel is defined by the existing levels on the landsides and the depth of the tunnel protection layer below the seabed within the marine section. The protection layer would ensure that the tunnel is sufficiently buried to avoid sustaining any damage from anchors or from stranded ships.

The tunnel cross section consists of two tubes for road and two for rail. Both road tubes accommodate two traffic lanes and an emergency lane. A service and refuge gallery is provided between the two road tubes with escape from the train tubes via the road tube.

The immersed tunnel would consist of 79 standard elements, each approximately 217m long and 10 special elements, each approximately 45m long, making up the 17.6km long immersed tunnel section.

Tunnel ventilation is designed as a longitudinal system. The longitudinal ventilation concept eliminates the need for ducts and an intermediate ventilation island. This reduces the navigational risk in the strait, the environmental impact and the cost of the project.

Although not yet constructed there are some useful lessons that can already be drawn from the project planning activities. The tunnel element construction is envisaged to be carried out in a purpose built factory similar to that used for the Øresund tunnel, but larger in order to achieve the necessary production rate for a six year construction programme. This will make it the fourth longest offshore tunnel to utilise this method of construction.

This project has also demonstrated the competitiveness of immersed tunnels to high level bridges, particularly for combined road and rail. The tunnel has been preferred on the basis of cost, environmental impact (both short and long term) and overall project risk.

Table 4.3: Fehmarnbelt Fixed Link - Summary Data

Feature	Description
Location	Germany / Denmark
Function	Road / Railway
Type	Immersed Tube (concrete)
Built	Expected construction programme (2014-2020)
Status	In Design
Length tunnel section	17.6km
Length Immersed Tube	17.6km
Depth	40m
Number Units	79 + 10 special units
Road Configuration	2-lanes in each direction
Ventilation	Longitudinal (Jet Fans)
Costs Tunnel	€4billion (client's estimate)
Cost per m/bore (i.e. 4 bores) / 17,600.	€56,818 per m/bore (2010 prices)

4.1.2 Bored Tunnels

Five bored tunnel case studies were chosen that have particular relevance to the Malta-Gozo crossing. The key reference document used for this analysis is the "International Symposium on Technology of Bored Tunnels under Deep Waterways, Copenhagen, Denmark, 3-5 November 1993" [13]. Mott MacDonald internal records were also used.

4.1.2.1 Great Belt Eastern (Storebælt) Crossing

The Storebælt Crossing between the islands of Funen and Zealand in Denmark opened in 1998 and is part of the highway and rail connection between Denmark and Sweden. The 20km wide Storebælt connects the Baltic to the North Sea, dividing eastern and western Denmark, and is a major shipping channel from the Baltic to the rest of the world. The project consists of a road and rail link across this channel. The road crosses the Eastern Channel on a suspension bridge while the railway passes beneath the channel in twin bore parallel tunnels. The road and rail rejoin on the island of Sprogo in mid channel and cross the shallow Western Channel on a combined low-level road / rail bridge to reach the island of Fyn.

Considered to be one of the most technically difficult constructed, the 8km long, 7.7m internal diameter (ID) tunnels were driven through glacial tills underneath fissured marls at a depth of 80m below sea level and at up to 8-bar water pressure.

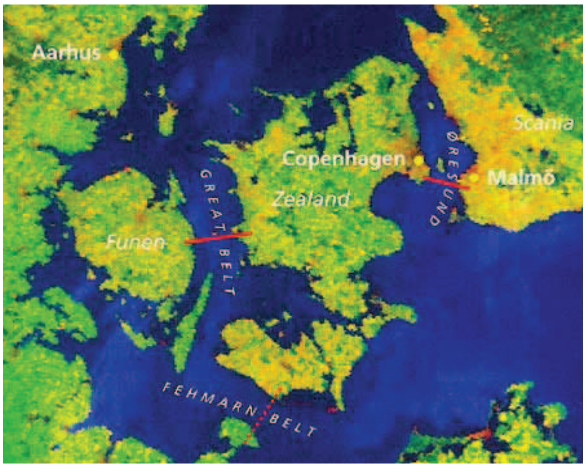
Due to the complex geology combined with high water pressures Earth Pressure Balance Tunnel Boring Machines were utilised. The tunnel was lined with 400mm thick pre-cast concrete segments designed to withstand the expected hydrostatic pressures. A variety of pre-excavation ground treatment measures were used including ground freezing, contact grouting, chemical grouting, dewatering both from the seabed and from within the tunnel.

The crossing provides a four-lane road and a twin track rail line. The depth of the channel and the tunnel cross-sections suited bored tunnels and made an immersed tube tunnel not economically competitive.

Figure 4.3: Great Belt Crossing – Photograph

Source: Mott MacDonald

Figure 4.4: Great Belt Crossing - Location



Source: Mott MacDonald

The key lesson learnt from the tunnel section was that bored tunnels could be built in very challenging ground conditions at depths up to 80m below sea level.

Table 4.4: Storebælt Crossing - Summary Data

Feature	Description
Location	Denmark
Function	Road / Railway
Type	Bridge / Bored (TBM)
Built	1991-1998
Status	In Use
Length tunnel section	8km
Depth	80m
Lining Type	Precast concrete segmental (7.7m ID)
Rail Configuration	1-line in each direction
Ventilation	Jet fans
Total Link costs	€67.5m per km (2010 prices)
Costs per m/bore (i.e. 2 bores)	€33,750 per m/bore (2010 prices)
Costs per m/bore /m internal diameter (i.e. /7.7)	€4,383 per m/bore/m ID (2010 prices)

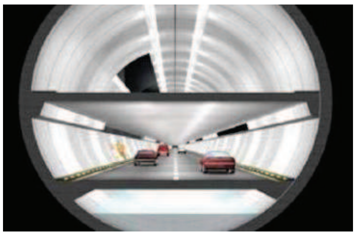
4.1.2.2 Storm-Water Management and Road Tunnel (SMART)

SMART is a unique solution to Kuala Lumpur's long-term traffic and storm-water problems. It was conceived as a flood relief tunnel to divert the 1-in-100yr flood away from the city centre. The 11.8m internal diameter tunnel is also used in periods of low rain fall as a highway tunnel to alleviate traffic congestion. The project was opened to traffic in May 2007.

Figure 4.5:

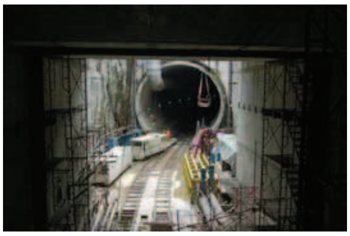
Source: Mott MacDonald

Figure 4.6:



Source: Mott MacDonald

Figure 4.7:



Source: Mott MacDonald

The overall scheme consists of 9km of bored tunnel with the central 4.5km having a twin deck road deck within. Complex water control gate structures were located at either end of the highway tunnel. Two ventilation shafts were sited in the heart of Kuala Lumpur and were constructed in limestone rock, the largest excavation being 180m in length, 20m wide and 28m deep. These shafts served as the launch sites for the TBMs.

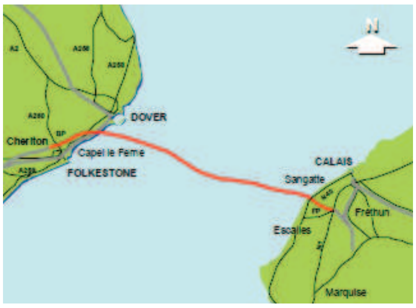
Table 4.5: SMART Tunnel - Summary Data

Feature	Description
Location	Kuala Lumpur, Malaysia
Function	Road / Storm-water
Type	Bored (TBM)
Built	2003-2007
Status	In Use
Length tunnel section	9.7km
Depth	20m
Lining Type	Precast concrete segmental (11.8m ID)
Road Configuration	Double deck 2-lanes in each
Ventilation	4 ventilation shafts
Costs	€484 million (2010 prices)
Costs per m/bore (i.e. 1 bore) / 9700	€49,897 per m/bore
Costs per m/bore /m internal diameter (i.e. /11.8)	€4,228 per m/bore/m ID (2010 prices)

4.1.2.3 Channel Tunnel (England/France)

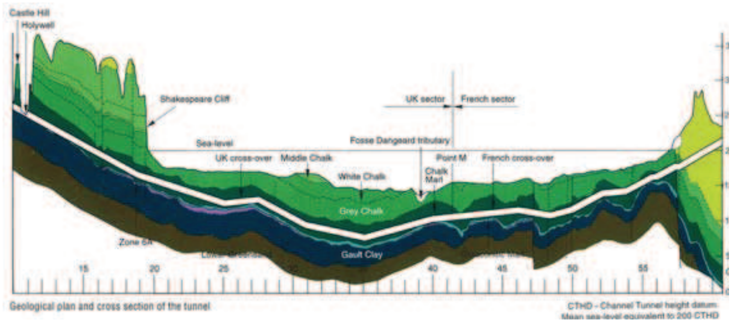
The Channel Tunnel is an integrated road / rail system to transport passengers, vehicles and goods between continental Europe and the UK.

Figure 4.8: Channel Tunnel Location



Source: Mott MacDonald

Figure 4.9: Channel Tunnel – Longitudinal Section

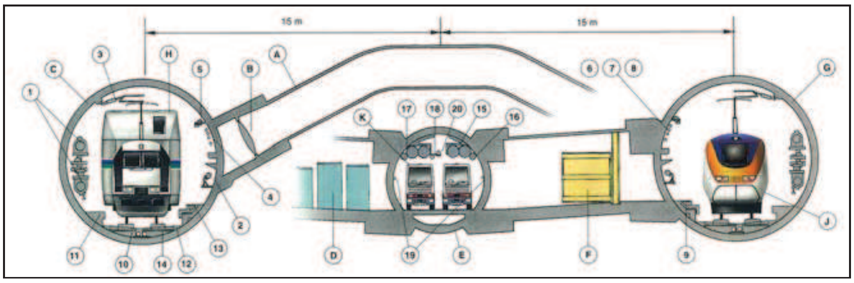


Source: Mott MacDonald

The 50km long tunnel comprises two 7.6m diameter bored running tunnels with a central 4.8m diameter service tunnel, connected at regular intervals by cross passages.

In two vast undersea caverns (one in the UK section, one in the French) scissor crossovers linking the main running tunnels allow operations to continue should a section of tunnel need to be closed. The UK cross-over cavern is 156m long by 18m wide and 10m high.

Figure 4.10: Channel Tunnel – Cross Section



Source: Mott MacDonald

The Channel Tunnel was opened in 1994. The tunnel is actually three 50km long parallel tunnels; two running tunnels carrying rail tracks and one service tunnel for maintenance vehicles and for emergency egress. The tunnels were constructed by tunnel boring machines excavating in a layer of chalk marl that extends across the Channel.

The chalk marl was an ideal tunnelling material. It was reasonably impermeable, easily excavated and fairly stable. These properties allowed very impressive advance rates to be achieved by the TBMs. On the French side, the marl was fractured and earth pressure balance TBMs with gasketted concrete segmental linings were selected due to the more difficult ground conditions.

Table 4.6: Channel Tunnel - Summary Data

Feature	Description
Location	England / France
Function	Rail / Service Road
Type	Bored (TBM)
Built	1987-1994
Status	In Use
Length tunnel section	50km
Depth	130m
Lining Type	Precast concrete segmental (7.6m ID)
Road Configuration	3-lane
Ventilation	Ventilation shafts at each coast
Costs	€8.0 billion (2010 prices)
Link costs	€135.1m per km. (2010 prices)
Costs per m/bore (i.e. 3 bores)	€45,033 per m/bore (2010 prices)
Costs per m/bore / average m internal diameter (i.e. / 6.7)	€6,721 per m/bore/m ID (2010 prices)

4.1.2.4 Bømlafjord Tunnel - Norway

The Bømlafjord sub-sea tunnel connects the island Føyno with the mainland near Valevåg. It is part of European route E39. The construction began in 1997 and it was opened in 2000. The tunnel is 7.9km long and is one of Norway's longest undersea highway tunnels, dropping to a deepest point of 260m below sea level. The tunnel is 11m wide and is a triple-lane single tube tunnel; two lanes on the uphill section and one lane on the downhill section.

The tunnel was excavated through Precambrian metamorphic rocks (gneiss, phyllite & greenstone) using drill and blast (D&B) techniques. According to the Norwegian standards rock cover was at least 34m for this sub-sea tunnel. The maximum gradient was 8%.

Table 4.7: Bømlafjord Tunnel - Summary Data

Feature	Description
Location	Norway
Function	Road
Type	Drill & Blast (D&B)
Built	1997-2000
Status	In Use
Length tunnel section	7.9km
Depth	260m
Lining Type	Rock bolts and shotcrete
Road Configuration	3-lane
Ventilation	Longitudinal ventilation
Costs	€61 million (2010 prices)
Costs per m/bore (i.e. 1 bore)	€7,721 per m/bore (2010 prices)

Feature	Description
Costs per m/bore /m internal diameter (i.e. / 11	€702 per m/bore/m ID (2010 prices)

4.1.2.5 Laerdal Tunnel - Norway

The Laerdal road tunnel was constructed from 1995 to 2000. It is 24.5km long and has a maximum gradient of 3%. The tunnel is 9m wide and is a double-lane single bore constructed using D&B techniques through a mountain range but not undersea.

Table 4.8: Laerdal Tunnel - Summary Data

Feature	Description
Location	Norway
Function	Road
Type	Drill & Blast (D&B)
Built	1995-2000
Status	In Use
Length tunnel section	24.5km
Depth	Under land through mountain range
Lining Type	Rock bolts and shotcrete
Road Configuration	2-lane
Ventilation	Longitudinal ventilation
Costs	€182 million (2010 prices)
Costs per m/bore (i.e. 1 bore)	€7,425 per m/bore (2010 prices)
Costs per m/bore /m internal diameter (i.e. / 9	€825 per m/bore/m ID (2010 prices)

4.1.3 Conclusions from Case History Review

The review of the number of different types of undersea tunnels demonstrates in general terms that with regard to the overall length, depth and configuration and size of tunnels, an undersea tunnelled link between Malta and Gozo would be feasible and does not exceed the capability of current technology. From a constructability point of view, both an immersed tube option and a bored option (by TBM, road header or D&B) would be potentially feasible (dependent on a detailed geological investigation) for the construction of the undersea fixed link between Malta and Gozo.

The review demonstrates that the location, geology and characteristics of the project can have a dramatic effect on the cost of the facility. Refer to Section 4.7 of this report for an evaluation of the range of costs from case histories, and their relevance to the Malta Gozo crossing.

For the immersed tube tunnels and bored tunnels the construction duration ranged from about 5 to 7 years including initial facilities, civil construction, mechanical & electrical works and testing and commissioning. Due to unforeseen ground conditions, fires or flooding delays to tunnel projects lasting over a year have been known.

4.2 Geological and Geotechnical Conditions

4.2.1 Geology

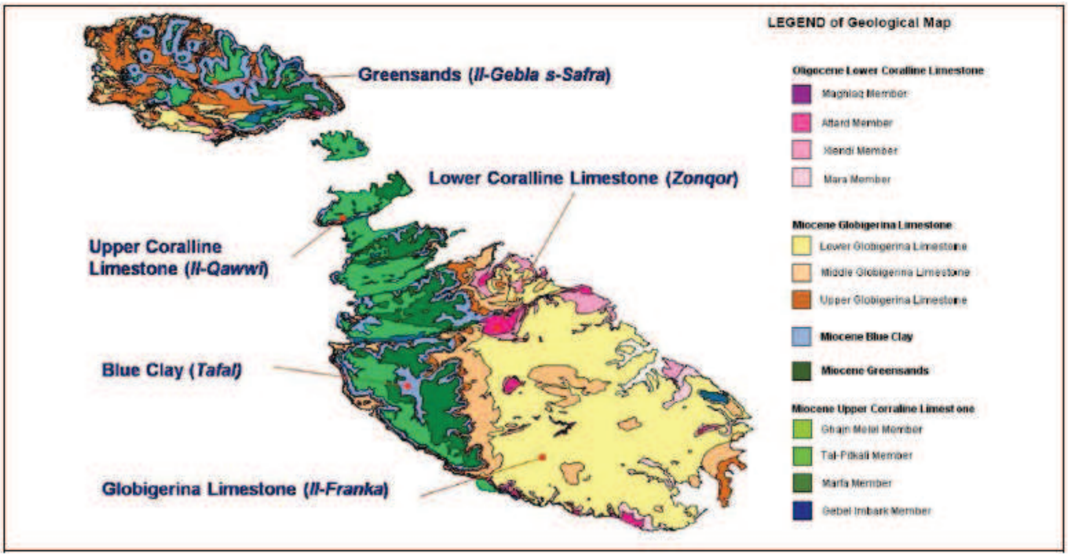
The key references used to assess the geology of the project area are:

- Geological Map of the Maltese Islands, Oil Exploration Directorate, Office of the Prime Minister, Malta, 1993 [3]; and
- Physical Geography and Ecology of the Maltese Islands: A Brief Overview, University of Malta, 1993 [4].

Geologically, the islands are composed almost entirely of marine sedimentary rocks, mainly limestone of Oligo-Miocene age. There are also some minor quaternary deposits of terrestrial origin.

The rocks forming the actual surface geology of the Maltese islands give evidence of a period of marine sediment deposition ranging from just over 30 to around 6 million years before present (from Lower Oligocene to Upper Miocene).

Figure 4.11: Malta Gozo – Summary Geological Map



Source: National Flood Relief Project

The rock sequence falls into five main distinct layers which, although slightly disturbed by almost vertical faults displacements, lie almost horizontally across the islands with a minor generalised NE dip.

The five main rock types are (in order of decreasing age):

- Lower Coralline Limestone - exposed to a thickness of 140m. This is the oldest exposed rock type in the Maltese Islands and started being laid down between 30-25 million years ago. A hard, pale grey limestone unit that forms sheer cliffs that may be from ten to over a hundred meters high. It contains some beds with fossil corals and common remains of marine calcareous algae. Age: Oligocene, Chattian;
- Globigerina Limestone - exposed to a thickness ranging from 23m to 207m and subdivided into three units (Lower, Middle and Upper Globigerina Limestone) by two pebble beds. A softer yellowish fine-grained limestone unit that forms irregular slopes in which small terrace-like steps a few meters high

pick out slightly harder bands. Globigerina is the common name for a type of microscopically small fossil shell that is abundant in this limestone. Age: Miocene, Langhian to Aquitanian. Globigerina Limestone is used for building materials;

- Blue Clay - exposed to thicknesses of up to 65m. A very soft unit that within the islands normally forms rolling low slopes that are mostly covered by carbonate raw soil or scattered rubble. Fresh exposures consist of medium grey and soft pelagic marls, typically with well developed pale bands rich in planktonic foraminifera but lower clay content. Goethite concretions are common in the upper beds. The age is Langhian to Tortonian, in the Miocene (approx. 10 - 15 my). Blue Clay is generally impermeable and holds water;
- Greensand - exposed to a maximum thickness of 12m. This formation proved distinctive enough to have deserved a separate name although it is not of sufficient thickness to affect the form of the land surface. It consists of massive, friable, intensely burrowed greyish-green, brown to dark grey marly limestone. The dark colour is influenced by the glauconite which in places appears brown due to oxidation. It is of Tortonian age in the Miocene (approx. 6 - 10 my); and
- Upper Coralline Limestone - exposed to a thickness of up to 162m. This formation is a complex association of limestone. Deposition of these marine sediments stopped some 10 million years ago when the seabed rose above sea level. This formation constitutes the coralline plateaux that top most of the hills of Gozo and Malta. It overlies the Blue Clay in an irregular pattern. These rocks are hard and provide a dominant feature over the western part of the islands. The Coralline Limestone is often used for road surfacing and hard aggregate potential. Issues around the solubility of the rocks forming karstic features such as voids, caves and open rock structures have been reported.

At Cirkewwa and on the western coast of Malta the upper Coralline Limestone outcrops in plateau. Near the Red Tower on Malta, steep coastal cliffs are present in the Coralline Limestone, but further towards Paradise Bay the relative relief reduces into more gentle coastal slopes.

On the Gozo, Mgarr side the Blue Clays are more evident and these rocks underlie the Coralline Limestone often forming spring lines at their boundary. The Blue Clays are noted as being very susceptible to erosion. Coastal Slopes of blue clay are present along the Gozo coast, some of which are susceptible to land sliding owing to the geological configuration.

Structural geology in terms of faulting and displacements are more prevalent on Gozo, with more consistent geological structure present on Malta, with sub-horizontal strata dominating.

4.2.1.1 Soils

Maltese soils are characterised by their close similarity to the parent rock material, their relatively young age, the ineffectiveness of the climate in producing soil horizon development, and the great importance of human activities in modifying them. Using the Kubiena classification system, Maltese soils are of three main types:

- Terra Soils which are relic soils formed during the Pleistocene and which are little affected by the present climate. They are mature and extensively weathered, have a low calcium carbonate content, and are also low in organic matter. Terra soils develop on karstland;
- Xerorendzinas which are immature soils with a high calcium carbonate content and low in organic matter. These develop on weathered Globigerina Limestone and on valley deposits; and

- Carbonate Raw Soils which are also immature and which have a very high calcium carbonate content and are very low in organic matter. These develop on weathered quaternary sandstones, Greensand, the lower beds of the Upper Coralline Limestone, Blue Clay and on Globigerina Limestone.

4.2.2 Geomorphology

Erosion of the different rock types gives a characteristic topography. Lower Coralline Limestone forms sheer cliffs which bound the islands to the west; inland this rock type forms barren grey limestone platform plateaux on which karstland develops.

The Globigerina Limestone, which is the most extensive exposed formation, forms a broad rolling landscape. Blue Clay slumps out from exposed faces to form 45° taluses over the underlying rock. Upper Coralline Limestone forms massive cliffs and limestone platforms with karstic topography similar to the Lower Coralline Limestone.

Both main islands are tilted seawards to the northeast. The highest point is at Ta' Zuta on Dingli Cliffs (SW Malta) which is 253m above sea level; the highest point on Gozo is at Ta' Dbiegi (191m).

The islands are riven by normal faults grouped in two main families: those trending NE-SW which predominate and those trending NW-SE. The principal faults of the NE-SW system are the Great Fault in Malta and the South Gozo Fault. The Great Fault bisects the island of Malta perpendicular to its long axis from Fomm ir-Rih on the southwest coast to Madliena on the northeast coast. The South Gozo Fault runs parallel to the Great Fault and crosses the island of Gozo from Ras il-Qala on the east coast to Mgarr ix-Xini on the southeast. Between these two master faults is a system of ridges and valleys. The principal member of the family of NW-SE trending faults is the Maghlaq Fault along the southern coast of Malta. South of the Great Fault, much of the Upper Coralline Limestone, Greensand and Blue Clay strata have been eroded away, leaving the Globigerina Limestone exposed. Here, large scale gentle folding is an important structural feature and this gives southern Malta its characteristic topography of plains and shallow depressions separated by low hills. South of the Great Fault, it is only in the Rabat-Dingli plateau that all five strata still remain. Much of the surface of this plateau is typical karstic limestone platform.

Block faulting north of the Great Fault gives rise to a sequence of horsts (ridges) and grabens (valleys) which, proceeding from the Great Fault are: the Bingemma Basin, Wardija Ridge, Pwales Valley, Bajda Ridge, Mistra Valley, Mellieha Ridge, Ghadira Valley and Marfa Ridge. The next graben in the sequence is inundated by sea water and forms the South Comino Channel separating Malta from the island of Comino. The highest part of the next horst is exposed above sea level as the island of Comino and the next graben is again under water and forms the North Comino Channel.

Topographically, Gozo consists of a series of hills each topped by an Upper Coralline Limestone plateau and separated by low-lying plains where the rock has been eroded down to the Globigerina stratum. The plateaux are karstic, the hillsides are covered with clay taluses and the plains between the hills roll gently.

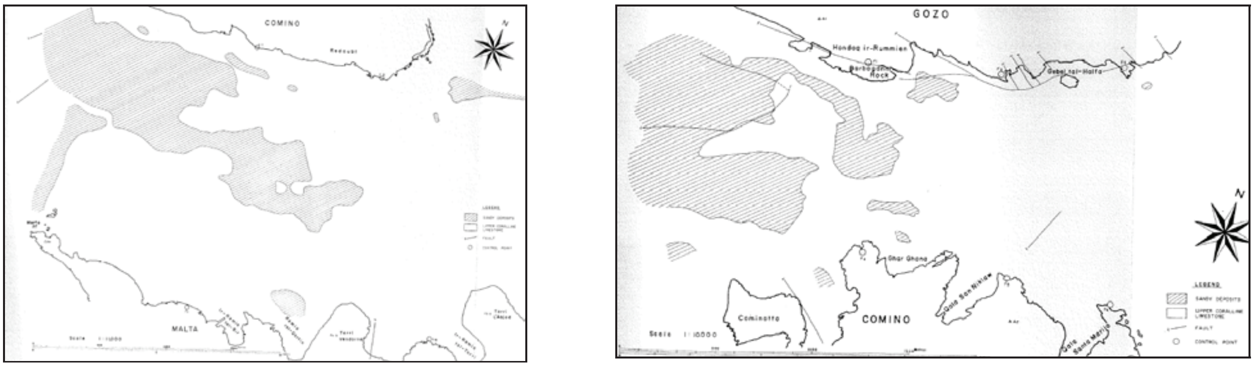
Characteristic topographic features of particular ecological importance are the rdum and widien (singular wied). Rdum are near vertical faces of rock formed either by erosion or by tectonic movements. Their bases are invariably surrounded by screes of boulders eroded from the rdum edges. Because of the shelter they provide and their relative inaccessibility, the rdum sides and boulder screes provide important refuge for many species of Maltese flora and fauna, including many endemics. Widien are drainage channels formed either by stream erosion during a previous (Pleistocene) much wetter climatic regime, or by tectonism, or by a combination of the two processes. Most widien are now dry valleys, that is, they only carry water along their watercourses during the wet season; a few widien drain perennial springs and have some water flowing through them throughout the year, attaining the character of miniature river valleys. By virtue of the shelter provided by their sides and their water supply, widien are one of the richest habitats on the islands; they are also extensively cultivated.

4.2.3 Oceanography

The depths to seabed and seabed geology are an important part in considering the engineering options especially for the immersed tube tunnel option. The seabed depths have be taken from the Admiralty charts as supplied by Transport Malta [10].

There are areas of the channel where the seabed has sandy deposits and these areas would have to be identified. As shown on the sketches below (taken from the Overseas Technical Cooperation Agency Government of Japan in March 1974 study) it is understood that sandy deposits generally lie to the western side of the channel.

Figure 4.12: Location of Sand Deposits from 1972 Study



Source: Overseas Technical Cooperation Agency of the Government of Japan

For immersed tube tunnels the height and length of waves at the tunnel site will have an impact on the design of the tunnel elements for their floating condition. It will be necessary to determine the significant wave height and maximum wave height to design the tunnel and plan the construction activities. However, the experience from projects such as the Bjorvika Tunnel in Norway and Peit Hein Tunnel in the Netherlands is that elements can be designed for severe wave loading without significant impact on the project costs or viability. Both of those projects featured long sea tows of tunnel elements in the North Sea. Similarly the Øresund Tunnel was subject to large wave loading during the towing of elements in the Baltic Sea. The tunnels were not designed for the maximum wave heights but a procedure was implemented to plan towing and immersion activities to fit within a window of suitable weather predicted from sophisticated long range weather forecasts. This is the normal approach for immersed tunnels which means that the wave heights do not limit the ability to build an immersed tunnel. In the Mediterranean Sea the wave heights and lengths are expected to be well below those for the projects mentioned and so will not be a problem for the design or construction.

Currents will primarily affect the marine activities for manoeuvring and immersing the tunnel elements. They will have an impact on the bending moments that the tunnel elements have to be designed for but this is generally not critical. The currents in the vicinity of the channel are noted as being up to 1.2 knots. This is well within the range that marine dredging plant, barges and immersion rigs can operate. The influence on currents in the Comino channels due to the localised seiches will need to be understood but it is not expected that they would give rise to currents that cannot be managed. The key is to understand the current speeds and directions that may arise so that appropriate anchoring systems can be provided to maintain stability of the construction vessels so they may achieve the necessary accuracy. For comparison the tunnel constructed as part of the Marmaray project in Istanbul was built successfully in the Bosphorus Straits which has regular current speeds of 4 knots, along with a two layer current system.

The tidal range in the Mediterranean Sea is relatively small compared to many locations around the world and is therefore very favourable for an immersed tunnel construction. The tidal range must be taken into account for the design of flood protection at the coastlines, and an understanding of available water depth for the marine plant will be needed, but this will not otherwise play a significant role in the design or construction of the tunnel.

4.2.4 Seismic Activity

The conclusions from the Earthquake Occurrence on the Maltese Islands report [5] are as follows:

- There have been a number of documented cases of damage to buildings in the Maltese Islands due to earthquakes. Large earthquakes in the Hellenic arc region and in SE Sicily and low-moderate magnitude events in the Sicily Channel have the potential to produce strong ground shaking in the islands; and
- Seismic monitoring has revealed earthquake activity occurring as close as 15km from the islands. Although the seismic activity in the Sicily channel is in general of small magnitude, the possibility of a larger event on these faults cannot be discounted.

In general, tunnels perform well in earthquakes because they are constrained by the ground around them and are not subjected to inertial effects like above-ground structures. Precast concrete lined tunnels perform particularly well in earthquakes because of their circular, largely symmetrical shape, and their flexibility relative to the ground surrounding them. Research shows that such tunnels perform well when subjected to seismic ground motions, based on case histories and a lack of reported damage to many more tunnels that have been subjected to similar shaking.

It is understood that there may be an active fault in the channel between Gozo and Comino which may cause difficulties for tunnel construction and should be investigated further.

4.2.5 Geological Implications for Tunnelling

The geology in the project area could be complex due to the number and orientation of faults. Tunnelling beneath the sea could be challenging and the following should be considered in any future feasibility studies and designs:

- The geology in this area, especially in the channel between Malta and Gozo is not clearly understood and there are gaps in the published literature;
- There is currently insufficient geotechnical information to allow a detailed feasibility study to be undertaken and more investigation such as borehole and seismic investigation data is required especially in the channels between the Islands. Sonar investigations should be carried out to confirm depth of seabed and details of sandy deposits;
- It is understood that during oil research works, seismic data was obtained (in two lines across the seabed between Malta and Gozo, one each side of Comino, but beyond the narrow channel). This information could provide good information on the rock formations below the seabed and it is possible

that it could be made available during further feasibility studies. However, this information may be more concerned with deeper geology and specific geophysical seismic surveys should be undertaken to identify rock strata and faults in the zone of the proposed tunnelling works;

- There is extensive rock faulting in north Malta and south Gozo and in the channel between and this may be more extensive than shown on the geological maps. It is possible that some fault zones remain active. Tunnelling across an active fault zone could be problematic and special construction methodologies applied to prevent inundation should the fault become active. A detailed risk analysis should be carried out to determine the level of risk and consequence of such an occurrence;
- From recent experience, problems were encountered during drilling of boreholes in the sea just outside Mgarr due to the presence of boulders in the clay layer;
- Tunnelling through karstic formations (especially below the sea) is potentially problematic to tunnelling. The Upper Coralline Limestone Formation is prone to karsts as can be seen from the caves around Comino. Karstic formations in the Globigerina and Lower Coralline Limestone formations are less likely, but further geotechnical investigation should be carried out to verify the nature of these karstic formations;
- Where possible, the tunnel alignment should be developed to go beneath the Upper Coralline Limestone and below the impermeable Blue Clay layer. The tunnel alignment should as far as possible extend within the Globigerina and Lower Coralline Limestone formations where karsts are understood to be scarce. However, for a construction methodology utilising a tunnel boring machine it may be possible to have a tunnel alignment that passes through the clay layer;
- Due to the faulted rock conditions and depending on the construction methods employed extensive ground treatment works such as grouting may be required to stabilise the rock and control groundwater inflows;
- For the portal locations currently identified, the tunnel would have to be excavated through soils, the Upper Coralline Limestone and Blue Clay formations in order to get to the limestone formations below the clay that are potentially more attractive to tunnelling. Through these areas ground treatment will likely be required to stabilise the ground for tunnelling and slope stabilisation would likely be required at the portals; and
- An assessment needs to be made of the permeability of the ground below the channel to determine the amount of water that could enter the excavation and the degree of ground treatment required to control water inflow to acceptable limits or determine whether a fully watertight tunnel would be required.

A more detailed investigation of the rock strata and geotechnical properties is required to determine the optimum vertical alignment and construction methodology and tunnel form.

4.2.6 Aquifers

The Maltese islands obtain their potable water supply from groundwater and seawater desalination in equal proportions. Groundwater is mainly extracted by means of draining galleries in the saturated zones of the aquifers found in the limestones. Groundwater is currently endangered by seawater intrusion due to over-pumping from irrigation wells and by various forms of domestic and agricultural pollution.

The Mellieha / Qammiegh aquifer stands at sea-level and is supported in the Upper Coralline Limestone (UCL) formation and bounded by the coast and the underlying Blue Clay formation.

Figure 4.13: Upper Coralline Limestone Aquifer

Source: Malta Resource Authority

The Marfa Coastal aquifer dips towards the north and its lower limits are defined by the occurrence of the Blue Clay formation. At the northern edge of Marfa, the Blue Clay formation is expected to occur at depths of 15-20m below sea level; and thus this depth can be assumed to define the limits of this aquifer. (Note this value is inferred - and it is recommended that geological coring is undertaken to determine the exact value).

The Gozo Mean Sea Level (MSL) Aquifer is located at sea-level and can reach a maximum depth of around 100m below sea-level at the central regions of the island. This depth thins as one goes towards the coast.

Figure 4.14: Mean Sea Level Aquifer

Source: Malta Resource Authority

The first two aquifer systems are utilised by the agricultural sector whilst the Gozo Mean Sea Level aquifer is (apart from other uses) the main aquifer for potable supply to Gozo. It is understood that the practice in Malta is to have a number of low yield wells abstracting water from an aquifer system, which abstraction points will be distributed over the whole area of the aquifer system; and not a single centralised high production well.

The tunnelling methodologies would need to take account of the aquifers in the project area.

The UCL aquifer is located above the clay layer and may be affected by tunnelling works notably at the portal areas. In these areas the tunnel lining would need to be essentially water-tight so as not to have any long term influence on the aquifers. In the short term during tunnel construction ground treatment (such as grouting) may be required to stabilise the ground prior to excavation. Environmentally friendly grouting products are available that would not compromise the aquifers. Generally the non immersed tube options for the tunnel will be constructed beneath the channel and below the clay layer and would not affect the UCL aquifer.

The extent of the MSL aquifer on the Gozo side needs to be better defined. At the coast the aquifer would be located at sea level but the extent is not fully known.

To protect the aquifers a fully water-tight tunnel may be required to prevent any inflow from the ground into the tunnel.

4.3 Regulatory Issues and Design Criteria

4.3.1 Regulatory Issues

The key document relating to legal and regulatory issues is the EU Directive 2004/54/EC (29th April 2004) [7] on minimum safety standards for road tunnels on the Trans-European Road Network. This Directive intends to harmonise the technical requirements and organisation of safety across Europe.

The Directive states that where certain structural requirements can only be satisfied through technical solutions which either cannot be achieved or can be achieved only at disproportionate cost, the implementation of risk reduction measures can be adopted as an alternative to application of those requirements. The EU Directive specifies minimum safety requirements for a comprehensive range of aspects of road tunnel design and operation including structures and equipment.

The UK's Design Manual for Roads and Bridges – Volume 2 - Section 2 – Part 9 - BD 78/99 – Design of Road Tunnels which was published in August 1999 [8] is useful to help determine safety requirements. Malta does not at present have it's own national standards for long tunnels. When developed, it is thought they are likely to be influenced by British and German Standards.

The table below contains the key clauses from the directive together with a commentary on how the requirement would be addressed for the Malta to Gozo under-sea tunnel.

Table 4.9: Compliance with EU Directive 2004/54/EC

Reference	Requirement	Commentary on Compliance
2	**Infrastructure measures**	
2.1	**Number of tubes and lanes**	
2.1.1	The main criteria for deciding whether to build a single or a twin tube tunnel shall be projected traffic volume and safety, taking into account aspects such as the percentage of heavy goods vehicles, gradient and length.	Figures show that in 2010 the average daily traffic was 1,500 vehicles per day/direction. (3,000 AADT 2-way). By 2041 it is expected that the 1-way AADT would be less than the 10,000 vehicles per day / lane threshold except for the high growth scenario at zero toll where the forecast is 10,600. Both single bore and twin bore options are
2.1.2	In any case, where, for tunnels at the design stage, a 15-year forecast shows that the traffic volume will exceed 10,000 vehicles per day per lane, a twin	

Reference	Requirement	Commentary on Compliance
	tube tunnel with unidirectional traffic shall be in place at the time when this value will be exceeded.	considered.
2.1.3	With the exception of the emergency lane, the same number of lanes shall be maintained inside and outside the tunnel. Any change in the number of lanes shall occur at a sufficient distance in front of the tunnel portal; this distance shall be at least the distance covered in 10 seconds by a vehicle travelling at the speed limit. When geographic circumstances prevent this, additional and/or reinforced measures shall be taken to enhance safety.	Same lane configuration would be adopted inside and outside the tunnel.
2.2	**Tunnel geometry**	
2.2.2	Longitudinal gradients above 5% shall not be permitted in new tunnels, unless no other solution is geographically possible.	The 5% gradient would be adopted where possible. Where geographically not possible, gradients up to 6% would be considered (as allowed in BD 78/99 Cl. 4.22).
2.2.3	In tunnels with gradients higher than 3%, additional and/or reinforced measures shall be taken to enhance safety on the basis of a risk analysis.	Risk analysis would need to be carried out.
2.2.4	Where the width of the slow lane is less than 3.5m and heavy goods vehicles are allowed, additional and/or reinforced measures shall be taken to enhance safety on the basis of a risk analysis.	Minimum lane width to be 3.5m.
2.3	**Escape routes and emergency exits**	
2.3.1	In new tunnels without an emergency lane, emergency walkways, elevated or not, shall be provided for use by tunnel users in the event of a breakdown or an accident. This provision does not apply if the construction characteristics of the tunnel do not allow it or allow it only at disproportional cost and the tunnel is unidirectional and is equipped with a permanent surveillance and lane closure system.	In accordance with BD 78/99 Table 4.5, a 1,000mm wide verge could be expected to be provided.
2.3.3	Emergency exits allow tunnel users to leave the tunnel without their vehicles and reach a safe place in the event of an accident or a fire and also provide access on foot to the tunnel for emergency services. Examples of such emergency exits are: - direct exits from the tunnel to the outside. - cross-connections between tunnel tubes, - exits to an emergency gallery, - shelters with an escape route separate from the tunnel tube.	For the twin tube tunnel options cross passages could be expected to be provided e.g. at 100m centres to comply as BD 78/99 Cl. 3.16 – 3.18. And up to 500m as Cl. 2.3.8.
2.3.4	Shelters without an exit leading to escape routes to the open shall not be built.	In a single bore tunnel the escape route would be an escape gallery beneath the road deck. Entrances to escape gallery would be provided at 100m – 500m centres.
2.3.8	Where emergency exits are provided, the distance between two emergency exits shall not exceed 500m.	See reference 2.3.3 and 2.3.4.
2.3.9	Appropriate means, such as doors, shall be used to prevent smoke and heat from reaching the escape routes behind the emergency exit, so that the tunnel users can safely reach the outside and the emergency services can have access to the tunnel.	Doors would be provided to prevent smoke and heat from reaching the escape routes.
2.4	**Access for emergency services**	

Reference	Requirement	Commentary on Compliance
2.4.1	In twin tube tunnels where the tubes are at the same level or nearly, cross-connections suitable for the use of emergency services shall be provided at least every 1,500m.	Cross passages spaced would be used for emergency services. Cross connections for vehicular access at 1,500m centres would be provided.
2.4.2	Wherever geographically possible, crossing of the central reserve (median strip) shall be made possible outside each portal of a twin or multi-tube tunnel. This measure will allow emergency services to gain immediate access to either tube.	Crossovers would be provided at tunnel approaches.
2.5	**Lay-bys**	
2.5.1	For new bi-directional tunnels longer than 1,500m where traffic volume is higher than 2,000 vehicles per lane, lay-bys shall be provided at distances which do not exceed 1,000 metres, if emergency lanes are not provided.	For a bi-directional tunnel option an emergency lane 3.5m wide would be provided for a TBM bored option. Lay-bys (with emergency stations) at 1,000m centres would be provided for a drill and blast tunnel option.
2.5.3	If the construction characteristics of the tunnel do not allow it or allow it only at disproportionate cost, lay-bys do not have to be provided if the total tunnel width which is accessible to vehicles, excluding elevated parts and normal traffic lanes, is at least equal to the width of one normal traffic lane.	
2.5.4	Lay-bys shall include an emergency station.	
2.6	**Drainage**	
2.6.1	Where the transport of dangerous goods is permitted, the drainage of flammable and toxic liquids shall be provided for through well-designed slot gutters or other measures within the tunnel cross sections. Additionally, the drainage system shall be designed and maintained to prevent fire and flammable and toxic liquids from spreading inside tubes and between tubes.	Transport of dangerous goods is assumed not to be permitted as the risk of fire is greater. A safety risk assessment would need to be carried out..
2.7	**Fire resistance of structures**	
	The main structure of all tunnels where a local collapse of the structure could have catastrophic consequences, e.g. immersed tunnels or tunnels which can cause the collapse of important neighbouring structures, shall ensure a sufficient level of fire resistance.	Fire resistance to be provided to concrete tunnel structures, using polypropylene fibres.
2.8	**Lighting**	
2.8.1	Normal lighting shall be provided so as to ensure appropriate visibility day and night for drivers in the entrance zone as well as in the interior of the tunnel.	Space provision for lighting would be provided.
2.8.2	Safety lighting shall be provided to allow a minimum visibility for tunnel users to evacuate the tunnel in their vehicles in the event of a breakdown of the power supply.	
2.8.3	Evacuation lighting, such as evacuation marker lights, at a height of no more than 1.5m, shall be provided to guide tunnel users to evacuate the tunnel on foot, in the event of emergency.	
2.9	**Ventilation**	
2.9.2	A mechanical ventilation system shall be installed in all tunnels longer than 1,000 metres with a traffic volume higher than 2,000 vehicles per lanes.	A mechanical ventilation system would be provided.
2.9.3	In tunnels with bi-directional and/or congested unidirectional traffic, longitudinal ventilation shall be	Longitudinal ventilation would be provided for twin tube options. Air would be ventilated out through the

Reference	Requirement	Commentary on Compliance
	allowed only if a risk analysis according to Article 13 shows it is acceptable and/or specific measures are taken, such as appropriate traffic management, shorter emergency exit distances, smoke exhausts at intervals.	tunnel portals. Transverse ventilation would be provided for bi-directional single bore options. Air and smoke extraction dampers would be installed. Air would be ventilated via ventilation shafts adjacent to the tunnel portals.
2.9.4	Transverse or semi-transverse ventilation systems shall be used in tunnels where a mechanical ventilation system is necessary and longitudinal ventilation is not allowed under point 2.9.3. These systems must be capable of evacuating smoke in the event of a fire.	
2.9.5	For tunnels with bi-directional traffic, with a traffic volume higher than 2,000 vehicles per lane, longer than 3,000m and with a control centre and transverse and/or semi-transverse ventilation, the following minimum measures shall be taken as regards ventilation: - air and smoke extraction dampers shall be installed which can be operated separately or in groups, - the longitudinal air velocity shall be monitored constantly and the steering process of the ventilation system (dampers, fans, etc.) adjusted accordingly.	
2.10	**Emergency stations**	
2.10.1	Emergency stations are intended to provide various items of safety equipment, in particular emergency telephones and extinguishers, but are not intended to protect road users from the effects of fire.	Emergency stations (telephones, extinguishers, etc.) would be provided at 150m centres.
2.10.2	Emergency stations can consist of a box on the sidewall or preferably a recess in the sidewall. They shall be equipped with at least an emergency telephone and two fire extinguishers.	
2.10.3	Emergency stations shall be provided near the portals and inside at intervals which for new tunnels shall not exceed 150m and which in existing tunnels shall not exceed 250m.	
2.11	**Water supply**	
	A water supply shall be provided for all tunnels. Hydrants shall be provided near the portals and inside at intervals which shall not exceed 250m. If a water supply is not available, it is mandatory to verify that sufficient water is provided otherwise.	A water supply would be provided at each portal and hydrants provided at 250m centres.
2.13	**Control centre**	
2.13.1	A control centre shall be provided for all tunnels longer than 3,000m with a traffic volume higher than 2,000 vehicles per lane.	A tunnel service building would be provided at each portal. A primary tunnel service single storey building measuring about 30m x 20m and a secondary tunnel service single storey building measuring about 20m x 10m at the other portal.
2.14	**Monitoring systems**	
2.14.1	Video monitoring systems and a system able to automatically detect traffic incidents (such as stopping vehicles) and/or fires shall be installed in all tunnels with a control centre.	Tunnels would be provided with incident and fire detection systems.
2.14.2	Automatic fire-detection systems shall be installed in all tunnels which do not have a control centre where the operation of mechanical ventilation for smoke	

Reference	Requirement	Commentary on Compliance
	control is different from the automatic operation of ventilation for the control of pollutants.	
2.15	**Tunnel-closing equipment**	
2.15.2	Inside all tunnel longer than 3,000m, with a control centre and a traffic volume higher than 2,000 vehicles per lane, equipment to stop vehicles in the event of an emergency is recommended at intervals not exceeding 1,000m. This equipment shall consist of traffic signals and possibly additional means, such as loudspeakers, variable message signs and barriers.	Variable message signs (VMS) and Lane Control signs would be installed at intervals not exceeding 1,000 metres.
2.16	**Communication systems**	
2.16.1	Radio re-broadcasting equipment for emergency service use shall be installed in all tunnels longer than 1,000m with a traffic volume higher than 2,000 vehicles per lane.	Radio re-broadcasting would be provided.
2.16.2	Where there is a control centre, it must be possible to interrupt radio re-broadcasting of channels intended for tunnel users, if available, in order to give emergency messages.	
2.17	**Power supply and electrical circuits**	
2.17.1	All tunnels shall have an emergency power supply capable of ensuring the operation of safety equipment indispensable for evacuation until all users have evacuated the tunnel.	Power would be supplied from both portals and an emergency power supply (such as a generator) would be provided, all in the tunnel service buildings.

4.3.2 Design Criteria

The key documents assumed as guidance for design are:

- The UK's Design Manual for Roads and Bridges – Volume 2 - Section 2 – Part 9 - BD 78/99 – Design of Road Tunnels which was published in August 1999; and
- Cross Section Geometry in Unidirectional Road Tunnels – The World Road Association (PIARC) (2001) [9].

4.3.2.1 Number of Bores or Tubes

A fundamental consideration would be the number of bores or tubes to be provided for the Malta - Gozo crossing; a single bore option or a twin bore option.

Due to the relatively low forecasted traffic flows, the EU Directive would permit a single bore tunnel with bi-directional traffic. A single bore solution would also be in keeping with the current road infrastructure either side of the proposed tunnel. However, the risk of collision in a single bore tunnel is increased with bi-directional traffic and ventilation, safety and evacuation possibilities are all compromised unless additional mitigation measures are incorporated. Additionally providing a satisfactory escape route from the highway to the escape gallery beneath the road deck may be problematic due to the long length of the tunnel and the ability to get safely from the road level down to the escape passage. It is noted that in the Norwegian Public Roads Administration, Road Tunnels Manual, April 2004, Section 4 for a total AADT in both directions greater than 9,000 a twin bore tunnel would be required.

For a single bore tunnel, either an emergency lane or lay-bys at 1,000m (max) centres are required. Therefore for a TBM bored tunnel a 3-lane carriageway would be required. For a road header or drill and blast tunnel, caverns could be constructed to create lay-bys at 1,000m centres. A single 3-lane tube for an immersed tube tunnel would not be considered as the span would be too great for a rectangular structure to be cost effective.

A twin bore tunnel solution with interconnecting cross-passages would provide a better solution in terms of safety, operation and maintenance and would normally be specified for a crossing of this length in Europe, although this would generally be required by traffic flows in any case. The following configurations should be considered further depending on the construction methodology adopted:

- Single Bore Tunnel (3-lane) – TBM, Road Header or D&B construction;
- Twin Bore (2-lane) with cross passages - TBM, Road Header or D&B construction;
- Single Bore Tunnel (2-lane) with lay-bys and escape adit - Road Header or D&B construction; and
- Immersed Tube Tunnel - Single structure containing 2 tubes with a central escape gallery with inter connecting doors.

An option with a single 2-lane tunnel with unidirectional traffic was considered with traffic flow operating in a shift tidal flow system. This would consider traffic from Gozo to Malta in early morning, Malta to Gozo mid morning, Gozo to Malta mid afternoon and Malta to Gozo in the evening. This has been discounted due to operational conflicts with the cross channel ferries.

4.3.2.2 Operational Classification

On the advice of Transport Malta, we have assumed an 80kph design speed through the tunnel with a reduction to 60kph at the tunnel portals. It is noted that Malta highway standards are generally similar to those of the UK, but that the national speed limit is less at 80kph.

In dual carriageway roads leading into the tunnel, central reserve crossings would be provided on tunnel approaches to enable contra flow working in twin tunnels. For a single bore tunnel, vehicles would need to be grouped into convoys in certain circumstances to allow for lane closures for maintenance of the tunnel infrastructure.

4.3.2.3 Fire Life Safety

Serious tunnel incidents have occurred within the past 20 years, including the Mont Blanc, Tauern and St. Gotthard tunnel fires where many lives were lost. Also it was reported that 5 local people died in a head on collision in June 2009 in the Eiksund undersea road tunnel in western Norway which is 7.7km long with low traffic volumes.

Fire in a confined space such as a tunnel is a significantly greater hazard than on the open road. Following significant loss of life in tunnel fires a European Directive was introduced defining minimum requirements for significant road tunnels in Europe. The Directive is strictly applicable for tunnels longer than 500m located on the Trans European Road Network (TEN-T) route.

The Directive states that “safety measures should enable people involved in incidents to rescue themselves, allow road users to act immediately so as to prevent more serious consequences, ensure that emergency services can act effectively and protect the environment as well as limit material damage.”

Tunnels are required to be provided with facilities, which in case of an emergency incident mitigate the hazards (e.g. from fire or spillage) by the following means:

- Prevent and detect incidents, e.g. lighting, traffic control, CCTV, fire and incident detection;
- Support self rescue, e.g. warning and communications systems, ventilation systems to ensure tenable conditions, clear escape routes, etc;
- Provide infrastructure which is resilient, e.g. passive or active fire resistance of structures and equipment; and
- Provide suitable facilities and access for the emergency services, e.g. fire mains and hydrant systems.

Regarding escape routes, in twin bore tunnel options these would be the interconnecting cross passages and doors. For a single bore tunnel an escape gallery (perhaps with safe refuges) would have to be provided taking into account fire life safety and ventilation requirements and in agreement with the local emergency services. This could be in the form of an escape gallery below the road deck or an adit adjacent to the main tunnel.

To comply with the above requirements, the tunnel would include:

- Emergency exits between road tunnels at between 100m and 500m centres. Note: BD78/99 stipulates 100m centres, the French regulations specify 400m for rural tunnels, and the EC Directive specifies minimum spacing of 500m;
- Illuminated directional signs indicating the distance to the nearest emergency exits on the side walls at distances of no more than 25m;
- A public address system to allow the Control Centre to broadcast to the tunnel occupants;
- Emergency stations at 150m centres containing a telephone connected to the control centre and 2 fire extinguishers;
- Fire hydrants for use by the emergency services, at 250m minimum intervals; and
- An uninterruptible power source to maintain minimum lighting levels in the tunnel following loss of the main tunnel lighting.

The tunnel lining could be of reinforced concrete construction or precast concrete segmental construction and in both instances polypropylene fibres would be included in the concrete mix at a dosage of not less than 1kg/m3 to impart fire resistance.

4.3.2.4 Geometric Design

The tunnel spatial requirements would be based upon local standards. For the purpose of this report, it is assumed that the design guidelines are those advised by the UK Highways Agency Standard for the Design of Road Tunnels BD 78/99, together with PIARC - Cross Section Geometry in Unidirectional Road Tunnels, 2001.

The size of the tunnel is determined by the clearance space required for the types of vehicles and the number of traffic lanes. Currently no European overall standard exists on cross-section geometry in road tunnels.

Based on local practice and the recommendations given in PIARC 2001, a lane width of 3.5m has been adopted together with a maintained height of 4.5m with an additional 0.2m safety zone giving an overall traffic gauge height of 4.7m. Based on (British Standards) BD 78/99 the minimum verge or walkway width has been taken as 1.0m.

For the traffic envelope and carriageway width specified above a tunnel with an internal diameter of about 10m would be required for a twin bore tunnel option and 13.5m for a single bore 3-lane option.

4.3.2.5 Alignment

The vertical alignment will be governed by the geotechnical conditions and seabed level as well as the maximum gradient permitted by regulations (generally 5% unless geographically not possible). It is noted that the EU Directive on Safety standards states that longitudinal gradients above 5% shall not be permitted in new tunnels, unless no other solution is geographically possible, and in tunnels with gradients higher than 3%, additional and/or reinforced measures shall be taken to enhance safety on the basis of a risk analysis. Using the guidance in British Standard BD 78/99 Cl. 4.22 gradients up to 6% could be considered.

Horizontal curvature is determined by highway design criteria and sight lines within the tunnel as well as the minimum radius that a TBM could negotiate, considered to be approximately 500m.

4.3.2.6 Ventilation

Tunnel ventilation would provide two key functions;

- To supply sufficient fresh air to all parts of the tunnel, maintain vehicle exhaust pollutants within prescribed levels and provide a hazard free environment for tunnel users; and
- Forced tunnel ventilation to control smoke and heat in the event of a fire.

A mechanical ventilation system would be installed as the tunnel is longer than 1,000 metres with a traffic volume higher than 2,000 vehicles per lane.

For twin bore / tube unidirectional tunnel options longitudinal ventilation would be provided. This would likely be in the form of jet fans located in the tunnel crown. Air would be ventilated out through the tunnel portals. In a fire situation smoke would be blown in the direction of the moving traffic.

For single bore bi-directional tunnel options transverse ventilation will be provided. This is a more complex ventilation system and air would be ventilated via ventilation ducts located above the crown or below the road deck. Air and smoke extraction dampers would be installed so that localised extraction and supply of air could be achieved. This is required because in a fire situation traffic would be moving in both directions and smoke would have to be removed via the ventilation duct rather than the tunnel itself. Air would be ventilated via ventilation shafts located somewhere adjacent to the tunnel portals.

A preliminary ventilation design would be based on; Peak traffic flow, European standard for vehicle emissions, percentage of vehicles taken to be trucks, fire size (30, 50 or 100 MW) and traffic speed limits. The pollution levels are assumed to be based on the requirements of PIARC 2004, PIARC document “Pollution by Nitrogen Dioxide in Road Tunnels” (1999) and the UK Highways Agency standard for tunnels, BD78/99.

4.3.2.7 Electrical Supply and Lighting

Power supply is normally received at high voltage, typically 11kV and is distributed to one or more substations along the line of the tunnel where it is transformed down to 400 Volts for final distribution to plant and equipment. Primary supplies would be derived from two independent sections of the 11kV network.

An uninterruptible power supply (UPS) would be provided in the event of a main electrical supply failure to maintain power to safety-critical systems and safe controlled closure of the tunnel.

Normally, safety and evacuation lighting would be provided.

4.3.2.8 Drainage

Drainage would be provided to allow water that enters the tunnel either via the portals or from the ground into the tunnel to be collected at low point sump(s) and pumped out of the tunnel portals into a main impounding sump and drainage system. A watertight tunnel would minimise the amount of water entering the tunnel and reduce ongoing pumping costs.

4.3.2.9 Tunnel Service Buildings

A primary tunnel service building housing the control centre, transformers, switch rooms, UPS room, and communications room would most likely need to be provided adjacent to one of the portals. This is likely to be a single storey building with a plan area of about 30m by 20m. This would most likely need to be manned 24 hours per day.

At the opposite portal there may need to be a secondary services building, again a single storey building measuring about 20m by 10m.

Consideration should be given to locating some of the facilities of the tunnel service buildings to remote locations if considered more suitable for operational reasons.

4.4 Construction Methodologies

A number of key construction methodologies have been considered for the Malta to Gozo sub-sea tunnel. These are; a bored tunnel using tunnel boring machines (TBMs), a bored tunnel using a road header or drill and blast techniques and an immersed tube tunnel (ITT) and are described briefly below.

4.4.1 Tunnel Boring Machines (TBMs)

TBMs are specialised machines that provide a safe method of forming tunnels through soft ground and rock, whilst supporting the ground being excavated. Simple TBMs comprise a basic circular shield, which is thrust forward into the ground, providing support to the roof of the tunnel, but exposing the full cut face of the ground to be excavated. More sophisticated TBMs can be designed to provide full support of the ground ahead of the tunnelling face and to prevent water from entering through the front of the machine, thus maintaining a dry and safe environment for the workforce.

Figure 4.15: Typical TBM

Source: Mott MacDonald

A TBM-excavated tunnel is circular in shape. The machines work by erecting a lining of precast concrete segments within the front shield of the TBM. The machine then jacks itself forward from the erected ring of segments, the jacks are withdrawn, and a new ring of segments erected the cycle is then repeated. There are a number of TBM types, which provide different methods of ground support. The selection of the TBM for the Malta Gozo tunnel would depend on the depth and alignment, and hence the likely ground conditions and water pressures.

A rule-of-thumb for selecting the vertical alignment for a TBM tunnel is that the crown of the tunnel should be at least one tunnel diameter below the ground, or surface of the seabed. It should also be noted that soft ground tunnelling under water using TBMs has only previously been carried out to pressures of up to about 80m of water.

A TBM bored tunnel would likely be constructed using a bolted segmental concrete lining incorporating a gasket to provide a high degree of water tightness. From our experience on previous road tunnel projects we consider it preferable that a fully watertight tunnel is provided, meaning there is no dripping of water onto the carriageway or in tunnel equipment. Although gaskets will provide a high degree of water-tightness it is inevitable that there will be isolated wet patches and drips inside of the segmental lining. A secondary lining around the intrados of the segmental lining could be provided.

Ideally the TBM alignment would follow a single rock stratum that is most suitable to tunnelling. It is harder to design a machine to excavate through different strata. Due to the number and extent of faults this may not be possible. The TBM would generally follow the limestone strata below the Blue Clay or alternatively would pass through the Blue Clay layer. At the portal approaches the alignment would have to pass through the Upper Coralline Limestone, and the Blue Clay layers if the main tunnel was in the lower limestone strata.

Excavation rates for TBM construction can very significantly depending on the geotechnical conditions. Excluding major breakdowns the average construction time for driving the running tunnels ranged from 20 to 25m per day in the UK side of the Channel Tunnel to about 5 to 10m per day for the more challenging ground conditions for the Great Belt Tunnel. A reasonable expectation for the Malta Gozo tunnel would be an average excavation rate of about 20m per day working 24 hours per day 7 days per week although it is possible that excavation rates could be much faster than this if the encountered ground conditions were very good.

4.4.2 Road Header Construction

Tunnels in medium to soft rock such as sandstone or some limestone can be constructed using road headers. The rock has to be sufficiently stable and free from running water to allow the excavation to stand up until a sprayed concrete lining can be installed against the exposed rock surface.

Figure 4.16: Road Header Excavation

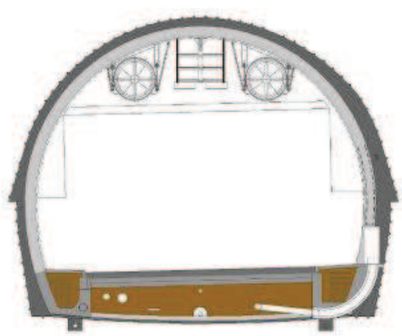
Source: Mott MacDonald

Figure 4.17: Road Header

Source: Mott MacDonald

The rock is excavated several metres at a time using picks on a rotating wheel or with an excavator if the rock is soft enough, the spoil is removed and then the excavation is supported with a sprayed concrete lining. These steps are repeated one advance at a time. The excavation would typically be divided into a number of smaller adits as a full face excavation would generally not be sufficiently stable. A typical final tunnel cross-section is shown below.

Figure 4.18: Typical Tunnel Profile for Road Header Construction



Source: Mott MacDonald

As the excavation needs to be stable this method cannot be used through very soft, fissured or water bearing rock unless the ground is grouted in advance of excavation. Grouting the ground ahead of an excavation can be a very time consuming and expensive operation. The lining could be waterproofed by installing a membrane between the concrete layers. This method of excavation would be slower than a TBM operation and be in the order of 3-6m per day.

4.4.3 Drill & Blast (D&B)

Drill and blast techniques are generally used for constructing tunnels in hard rock conditions and may be appropriate for use in some hard limestone rock formations. They are constructed using the following procedures; a number of holes are drilled into the rock, which are then filled with explosives. Detonating the explosive causes the rock to collapse. The rock is then removed and the exposed tunnel surface is reinforced. These steps are repeated one advance at a time.

Figure 4.19: Typical Drill & Blast Excavation

Source: Mott MacDonald

The positions and depths of the holes (and the amount of explosive each hole receives) are determined by a carefully constructed pattern, which, together with the correct timing of the individual explosions provides a tunnel of the correct dimensions.

As the tunnel is incrementally excavated the roof and sides of the tunnel would be supported to stop the rock falling into the excavation. The philosophy and methods for rock support vary widely but typical rock support systems can include: rock bolts or rock dowels, shotcrete, ribs and lagging and in-situ concrete. Typically a rock support system would include a number of these support methods, each intended to undertake a specific role in the rock support. Usually the rock support requirements are determined based on the actual rock conditions encountered.

As with the road header excavation, the advantage of D&B is that there is greater flexibility in the shape of excavation and unlike a TBM driven tunnel the cross-section of the tunnel can be varied in order to create a flattened invert and lay-bys or turning points for example. This method is not appropriate in soft ground such as clay. This method cannot be used through severely fissured or water bearing rock unless the ground is grouted in advance of excavation. Grouting the ground ahead of an excavation can be a very time consuming and expensive operation.

Different sections of the tunnel could be designed as drained or un-drained depending on rock and water conditions. For a drained tunnel, water would be controlled to acceptable limits by grouting, remaining water would be allowed to enter the tunnel, drained to low point sumps and be pumped to the portals. For an un-drained tunnel the lining would be made water-tight and a secondary in-situ concrete lining would be provided. A watertight tunnel may be required in the under land sections to prevent water draw down and any adverse impact on the aquifers.

Generally drill and blast tunnels are constructed in hard rock conditions where the rock is generally self supporting and requires minimal additional support. This may be possible in certain rock strata for the Malta Gozo tunnel. A significant depth of rock cover (in the order of 50m) would be required below the seabed.

However, below the channel, the Upper Coralline Limestone is underlain by the clay layer and a drill and blast construction profile would have to be through the limestone below this clay layer to provide adequate cover to the bottom of the clay layer. Cave-ins caused by faulted rock have been reported in D&B tunnels even where rock cover has exceeded 35-40m. In addition, for the portal locations identified the alignment at the portal approaches would have to pass through significant lengths of the Upper Coralline Limestone and the Blue Clay layers and heavily faulted zones. This would most likely preclude drill and blast techniques. A drill and blast option would require steeper gradients on the portal approaches in order to achieve the deeper vertical alignment and this has to be considered in terms of the EU regulations governing the maximum tunnel road gradients. This would particularly apply for Options 2 and 4 where the vertical alignment shown is not as far below sea level as Option 1 on the Gozo side of the channel.

For a drill and blast tunnel an average advance rate of 3 - 6m per day could be assumed.

4.4.4 Immersed Tube Tunnel (ITT)

An immersed tunnel is formed by a number of tunnel elements that are constructed elsewhere and floated to the tunnel site to be sunk into place and then linked together. They are commonly used for road and rail crossings of rivers, estuaries and sea channels and harbours. Immersed tubes are used in conjunction with cut and cover tunnels which are necessary to continue the tunnel from near the water's edge to the portal at the land surface.

Figure 4.20: Interior of Immersed Tube Tunnel

Source: Mott MacDonald

The tunnel element forming the immersed tube may be constructed in one of two methods. In the United States, the preferred method has been to construct steel or cast iron tubes which are then lined with concrete. This allows use of conventional shipbuilding techniques, with the segments being launched after assembly in dry docks. In Europe, reinforced concrete box tube construction has been the standard; the sections are cast in a basin which is then flooded to allow their removal. Our assumption is that concrete construction will be used.

The structure of an immersed tunnel is a relatively conventional reinforced concrete structure sized to accommodate the two road bores and the emergency escape / service bore and to ensure a factor of safety against uplift is provided. The structure may be waterproofed either with an external membrane applied, or through the use of watertight concrete. If the tunnel is to have watertight concrete a more sophisticated approach to concrete curing is necessary as well as intermediate joints along a tunnel element length. The choice between the two types of construction does not have an impact on feasibility and can be chosen at a later stage of the project development.

The reinforced concrete elements are prefabricated in a manageable length for towing and manoeuvring, then have their ends sealed with temporary bulkheads so they can be floated out into the channel. At the same time a trench on the bottom of the channel is dredged and a foundation layer of gravel placed and graded in the base of the trench to support the elements. Once the tunnel elements have been towed to the site, they are immersed by placing additional ballast weight inside the element to allow it to sink in a controlled manner; this being a critical stage to ensure each element is aligned correctly. After immersion the joint between the new element and the tunnel is dewatered and then made water tight, this process continuing sequentially along the tunnel. The trench is then backfilled and any necessary protection, such as rock armour, added over the top. After these stages the tunnel is complete, and the internal fit out can be carried out.

A disadvantage of an immersed tube can be the environmental impact of the dredging process on the seabed and the coastline. The key advantage is that the depths of the immersed tubes are much lower reducing the entrance and exit gradients and generally shortening the tunnel compared to a bored tunnel or high level bridge.

The original study for the Malta-Gozo crossing carried out in 1974 suggested an immersed tunnel sitting on the seabed that is protected by an earthworks embankment. This appears to have been suggested to avoid extensive removal of bedrock. We have assumed this would not be environmentally acceptable as it is usual practice now to place the whole of the tunnel alignment beneath the seabed level so that the bed can be reinstated to its original condition.

The water depth increases quickly with distance from the shorelines and it would therefore be an advantage to keep the alignment as close to the island as possible. This is particularly the case if the surface geology at bed level is coralline limestone. It is anticipated that it will be possible to dredge this material with a cutter suction dredger but this will need to be verified. This type of dredging vessel can only dredge up to around 40m depth below the water level which means the water depth along the chosen alignment should be no more than 25-30m. If softer materials overly the coralline limestone then this may not be a problem and alternative dredging plant that can operate to greater depths could be used.

A casting yard would need to be provided to fabricate the concrete elements. It is understood that a dry dock “Dock No.6” in Valletta may be available but this is to be confirmed. This is a relatively small facility that would not be ideal for a tunnel of this length. A tunnel length of around 6km will require construction of about 35 to 40 tunnel elements, depending on their precise length, and the dry dock would allow four elements to be constructed in one cycle. This would require 10 uses of the dock with a period of 6 months per cycle, leading to a construction period of around 5 years just for the tunnel elements. The construction of the tunnel cut and cover connections and finishing and fitting out work would extend this for at least a further 18 months which may make the construction duration unattractive. Therefore an alternative facility would probably be needed that can produce tunnel elements at a faster rate.

It should also be noted that existing docks are unlikely to give up seasonal and long term business for the one-off construction of a tunnel, and a dis-used dock that can be refurbished is usually a better prospect. Alternatively a parcel of land on the shoreline that has good road access and access to good water depth that can be developed would need to be found.

4.4.5 Construction risks

Generally construction risks should be managed in accordance with the Code of Practice for Risk Management of Tunnel Works as prepared by the International Tunnelling Insurance Group, January 2006 [14]. The main construction risks are associated with unforeseen ground conditions and fire or flooding of the tunnel.

4.4.5.1 Immersed Tube Tunnel

Construction risk associated with an immersed tunnel is largely associated with the marine operations as the construction of the tunnel elements within a dry dock or casting basin is largely a conventional in-situ reinforced concrete construction process.

Accidents have been few on previous immersed tunnel projects but examples exist where elements have been damaged during their transportation or immersion, or difficulty has been encountered when immersing tunnel elements. There are no aspects identified for the Malta-Gozo crossing that are beyond the technologies currently used around the world or beyond the capabilities of professional contractors accustomed to building immersed tunnels.

Some of the construction risk issues that need to be addressed are described in Table 4.10 below.

Table 4.10: Immersed Tube Tunnel Construction Risks

Construction risk	Methods to mitigate risk
Adverse wind, wave or current conditions during towing or immersing of tunnel elements	Advanced weather forecasting and go/no-go decision process for commencing tow and immersion activities allows safe weather window approach to be taken. Tow distances of many hundreds of kilometres can be undertaken safely.
Strong currents may exist in the Malta Gozo channel	Provided current variation has been measured and can be predicted, marine plant anchoring can be designed to manage strong currents.
Safety of vessels using navigation channels	Temporary closures, diversion of channels need to be approved by the appropriate navigation authority and notice to mariners issued.
Risk to divers working on construction	Use of divers is becoming less necessary. Projects such as the Busan tunnel in Korea have shown that diver time can be minimised and many operations be carried out remotely.
Feasibility of dredging	Surface geology on the proposed alignment to the north-west of Comino is unknown but expected to be coralline limestone. The presence of limestone will prevent dredging by conventional means to a depth 40m below sea level. Below this may require chiselling or blasting which will be highly undesirable environmentally.
Handling and immersing elements (with approximate 40,000DWT)	Handling of elements needs to be done by contractors with specific experience in this field.

4.4.6 Removal of Spoil

The tunnelling operations would create a large quantity of spoil that would have to be removed and disposed of. The volume of spoil would be greater than the volume of ground removed as the material would bulk up following excavation. According to the UK Institution of Civil Engineers construction guide, for limestone, the in-situ bulk density would range from 2.4 to 2.7Mg/m^3 and the bulking factor would range from 40-70%.

For a typical excavation rate of 20m per day with a cross-section area of 163 m^2 would result in approximately 5,500m^3 of material to be disposed of per day. The muck could be removed from the tunnel by truck or by conveyor belt.

Removal of material by both road and ship should be considered. A suitable location to dump and / or re-use the material needs to be determined.

4.4.7 Temporary Works and Facilities

Temporary facilities are required to support the project throughout the construction period. The main site would be located near to one of the portals with a secondary smaller site at the opposite portal. These sites would require temporary services and utilities such a water, power and drainage. The site would require sufficient space to accommodate the required plant and equipment and provision for offices and welfare facilities. A casting basin would also be required, but this could be located in a remote facility adjacent to the sea either in Malta or further afield. The units would be floated to the location from site.

4.5 Portal Locations

4.5.1 Bored Tunnel Potential Portal Locations

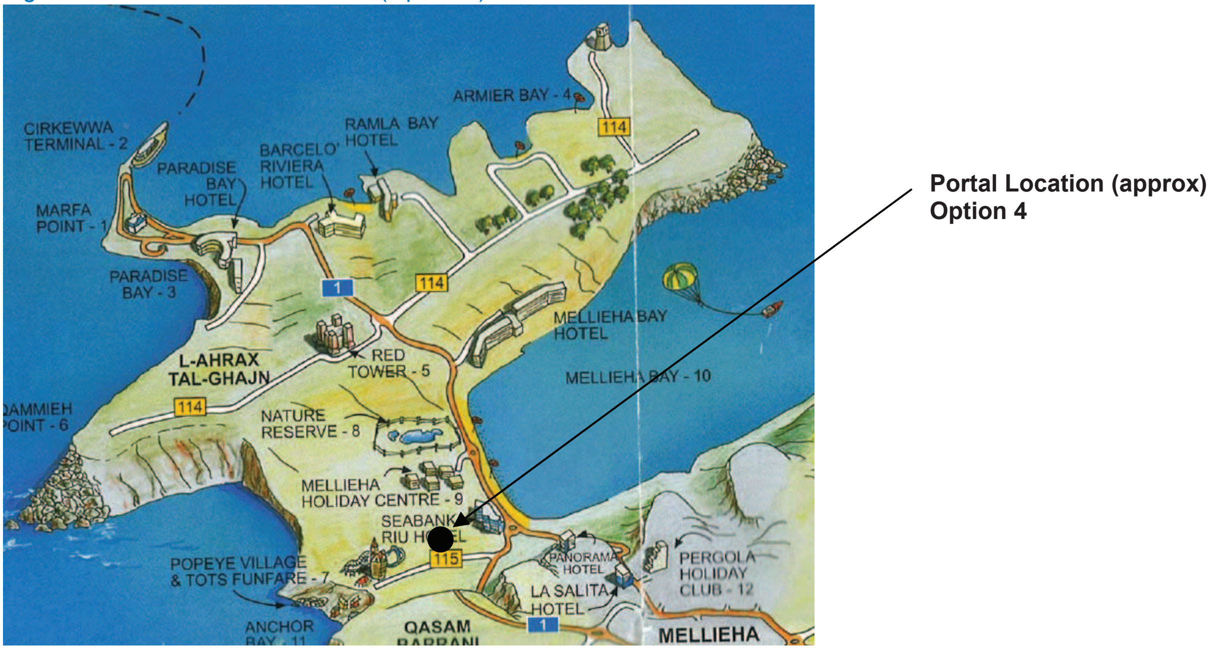
On the Malta side of the crossing the potential location of the tunnel portal for Options 1 and 2 could be adjacent to Route 1 just south of the Marfa Ridge and just west of the Mellieha Bay Hotel .

Figure 4.21: Malta Portal Location (Options 1 & 2)

Source: Landmark Cartography

For Option 4 the potential location for the tunnel portal is south of the Natura 2000 site and bird sanctuary in the Mellieha Bay Valley near Biskra. It would require a short link to existing Route 1 over agricultural land, joining with existing Route 1 on the north facing slope of Mellieha Ridge, west of Mellieha.

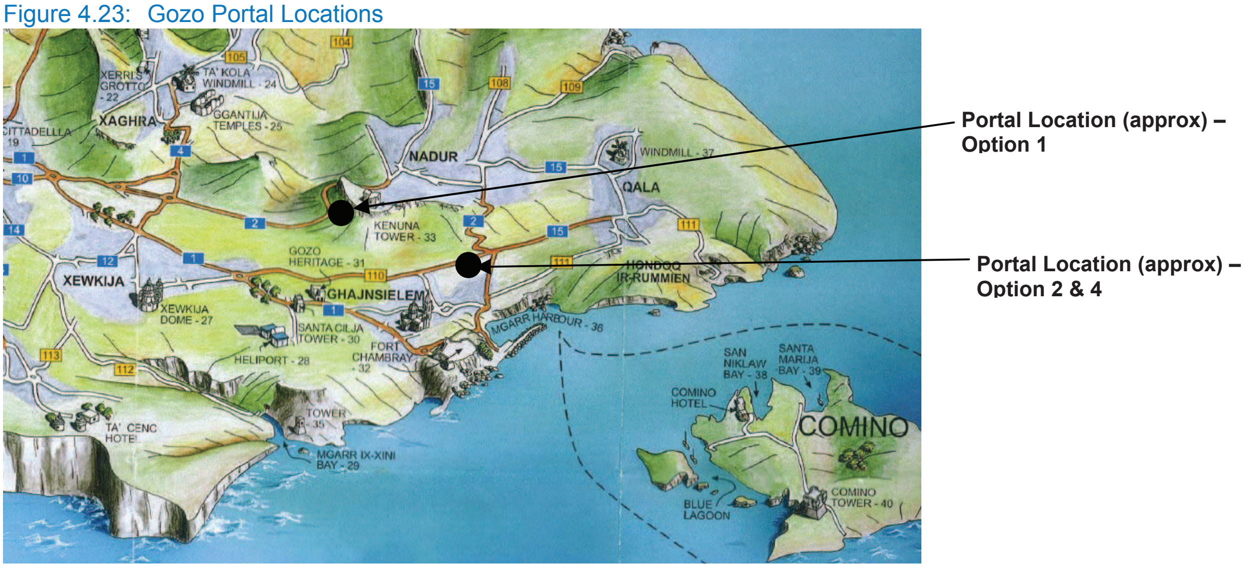
Figure 4.22: Malta Portal Location (Option 4)



Source: Landmark Cartography

On the Gozo side two potential locations for tunnel portals are considered. One is to join with Route 2 east of the racecourse and west of Nadur, and the tunnel would enter the ridge just below the Keuna Tower (Option 1). The other potential location is close to the junction of Route 110 and Route 2 north of Mgarr (Options 2 and 4). From this portal location, the route to Rabat (Victoria), the capital city of Gozo, would be along the existing Route 110 to join with the existing Route 1 just east of Xewkija. Both these portal locations would result in through traffic avoiding the main built up areas of Mgarr and Ghajnsielem.

Figure 4.23: Gozo Portal Locations



Source: Landmark Cartography

Figure 4.24: Gozo Portal Location (Option 1) looking east from Route 2

Source: Mott MacDonald

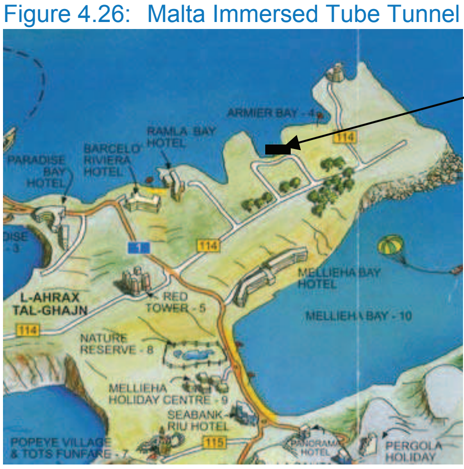
Figure 4.25: Gozo Portal Location (Options 2 and 4) looking east from Route 110

Source: Mott MacDonald

4.5.2 Immersed Tube Tunnel Portal Locations

On the Malta side of the crossing the portal to the immersed tube (which would need to convert to cut and cover near the coast) would be adjacent to the coast at Armier Bay.

Figure 4.26: Malta Immersed Tube Tunnel Portal Location (Option 3)



Source: Landmark Cartography

Source: Mott MacDonald

On the Gozo side the portal to the immersed tube tunnel would be adjacent to the coast. A section of cut and cover tunnel would be required near the coast. From the portal location, a significant length of new road which would require major structures such as viaducts, cutting on the side of the hill, retaining walls and / or hairpin bends would be required to join to suitable existing roads.

Figure 4.27: Gozo Immersed Tube Tunnel Portal Location (Option 3)

Source: Landmark Cartography

Source: Mott MacDonald

4.5.3 Portal Locations – Further Considerations

The following Issues related to positioning of portals should be considered in future studies:

- Site constraints for the location of toll plazas/electronic toll systems should be considered. Open electronic toll solutions could be adopted; and
- Protection measures against flooding, storm or other natural occurrences should be considered.

4.6 Tunnel Alignment Options

Four main alignments have been considered for a crossing from Malta to Gozo:

- Option 1 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of the Marfa Ridge on Malta and Route 2 west of Nadur on Gozo;
- Option 2 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of the Marfa Ridge on Malta and Route 110 north of Mgarr on Gozo;
- Option 3 – An immersed tube tunnel option from the Armier Bay area on Malta to Hondoq-Ir-Rummien on Gozo and
- Option 4 - A bored tunnel beneath Comino, the portals being on Route 1 west of Mellieha on Malta and Route 110 north of Mgarr on Gozo.

For all tunnel alignments the surface of the Island of Comino would remain untouched. There would be no advantage in climbing to the surface in Comino if tunnels are required both north and south of the island and there is no need for emergency access on Comino - substantial major cuttings would be necessary if the tunnel was not continuous, and the effect on the environment would be significantly adverse. In principle it would be possible to include an intermediate ventilation shaft on Comino but in practice it may be difficult to obtain permission due to the environmental sensitivity of the area, and technically intermediate ventilation shafts are not thought to be essential in any case.

Tunnel options from Malta to Gozo to the west of Comino have been considered but discounted before detailed analysis due to the depth of the channel in this area, particularly close to the coast of Gozo. For this reason, an immersed tube solution would not be feasible. For a bored tunnel the vertical alignment beneath the channel would be so deep that due to gradient constraints the tunnel would need to be significantly longer than the other tunnel options on the Gozo side of the channel.

A further option for an alternative portal position for a bored tunnel on Gozo, in this case east of Mgarr Harbour, was also considered but discounted before detailed analysis. This option was considered because there was the potential for a shorter tunnel with improved geological conditions. A desk study, however, identified that there are major geological faults in this area and the blue clay layer could not be avoided. The key reason why this option was discounted is because it would have required a 1.5km surface link road on Gozo east of Mgarr in an area of high landscape value and high ecological protection on the coastal slope. The impact of this would be similar to the effects of the surface link road also required for Option 3.

The tunnel and route alignments considered for analysis (Options1-4), together with geological sections for the bored tunnel options (Options 1, 2 and 4) are included in Appendix C.

The proposed route alignments are indicative only and would need to be refined following detailed site investigation and survey work, and would depend on the selected tunnelling methodology. For example, a TBM option with a precast concrete lining could have a flatter alignment and be constructed within the blue clay strata. For a road header or drill and blast construction methodology the alignment would have to be deeper and constructed well below the blue clay strata and within the limestone formations where possible.

The bored tunnel options would create a significant amount of rock material to be disposed of. The bulking factor assumed in calculating the rock volume that has to be disposed of has been taken as 70%.

4.6.1 Tunnel Alignment Option 1

Tunnel Alignment Option 1 extends from a portal at Route 1 on the southern slope of Marfa Ridge on Malta and extends to a portal at Route 2 east of Nadur below the Kenuna Tower on Gozo and goes beneath the Island of Comino. The longitudinal profile is shown on drawing 282725 - SK002 in Appendix C. The total length of the tunnel would be approximately 10km from portal to portal.

The tunnel configuration for this alignment could be one of the following:

- A TBM constructed precast concrete lined, single bore, 3-lane bi-directional tunnel as indicated on drawing 282725 - SK0015 in Appendix D. The excavated cross-sectional area is approximately 163m^2. The volume of excavated rock (including bulking factor) would be approximately 2.8 million m^3;
- A TBM constructed precast concrete lined, twin bore 2-lane unidirectional tunnel, with cross-passages as indicated on drawing 282725 - SK012 in Appendix D. The excavated cross-sectional area is approximately 95m^2 per bore. The volume of excavated rock (including bulking factor) would be approximately 3.2 million m^3; and
- A road header (or drill and blast) option comprising a single bore 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel. This tunnel configuration is indicated on drawing 282725 - SK016 in Appendix D. The excavated cross-sectional area would be approximately 95m^2 for the road tunnel and 15m^2 for the adit. The volume of excavated rock (including bulking factor) would be approximately 1.9 million m^3.

4.6.2 Tunnel Alignment Option 2

Tunnel Alignment Option 2 extends from the portal at Route 1 on the southern slope of Marfa Ridge on Malta to a portal near the junction of Route 2 and Route 110 north of Mgarr on Gozo and again goes beneath the Island of Comino. The longitudinal profile is shown on drawing 282725 - SK003 in Appendix C. The total length of the tunnel would be approximately 8.2km from portal to portal. It is similar to Option 1 except that it is shorter and the portal on the Gozo side is in a different location. The tunnel configurations would be the same as for Option 1 but with reduced length and hence reduced volumes of excavated material as follows:

- A TBM constructed precast concrete lined, single bore, 3-lane bi-directional tunnel. The volume of excavated rock (including bulking factor) would be approximately 2.3 million m^3;
- A TBM constructed precast concrete lined, twin bore 2-lane unidirectional tunnel, with cross-passages. The volume of excavated rock (including bulking factor) would be approximately 2.6 million m^3; and
- A road header (or drill and blast) option comprising a single bore 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel. The volume of excavated rock (including bulking factor) would be approximately 1.6 million m^3.

4.6.3 Tunnel Alignment Option 3

Tunnel Alignment Option 3 is an immersed tube tunnel option and extends from the Armier Bay area to Hondoq-Ir-Rummien. The longitudinal profile is shown on drawing 282725 – SK005 in Appendix C. The length of the immersed tube tunnel itself would be about 6km. In pure technical terms the construction of an immersed tube tunnel in the channel would be feasible. The tunnel configuration is shown on drawing 282725 – SK014 in Appendix D.

Extensive cut and cover works, deep sidelong cuttings, retaining walls and / or hairpin bends would be required to navigate the steep slopes particularly on the Gozo side of the crossing to connect the immersed tube tunnel up to the existing road network. These works would significantly affect the coastal landscape and would need to be considered further especially from an environmental viewpoint.

In addition the immersed tube construction would impact on the protected seabed within the channel. Again these issues would have to be considered from an environmental viewpoint to determine whether or not the ITT option is feasible for the Malta - Gozo crossing.

4.6.4 Tunnel Alignment Option 4

Tunnel Alignment Option 4 extends from Biskra in the Mellieha Bay Valley and a short link road connects it with Route 1 on the northern slope of Mellieha Ridge on Malta. It extends to a portal near the junction of Route 2 and Route 110 north of Mgarr on Gozo and again goes beneath the Island of Comino. The longitudinal profile is shown on drawing 282725 – SK009 in Appendix C. The total length of the tunnel would be approximately 9.2km from portal to portal. It is similar to Option 2 except that it is longer and the portal on the Malta side is in a different location on the south side of the Mellieha Bay Valley. The tunnel configurations would be the same as for Option 2 but with increased length and hence increased volumes of excavated material as follows:

- A TBM constructed precast concrete lined, single bore, 3-lane bi-directional tunnel. The volume of excavated rock (including bulking factor) would be approximately 2.6 million m^3;

- A TBM constructed precast concrete lined, twin bore 2-lane unidirectional tunnel, with cross-passages. The volume of excavated rock (including bulking factor) would be approximately 2.9 million m^3; and
- A road header (or drill and blast) option comprising a single bore 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel. The volume of excavated rock (including bulking factor) would be approximately 1.8 million m^3.

4.7 Costs

4.7.1 Case History Review of Construction Costs

A review of tunnel construction costs for different types of tunnel around the world (including those in the case history review) has been undertaken. The different tunnels have been chosen because they could be relevant in one way or another to the anticipated cost of a Malta Gozo road tunnel. It should be noted that none of these tunnels displays exactly similar conditions to those that could be expected for a Malta Gozo road tunnel.

The unit costs (for bored tunnels only) are summarised in Table 4.11, and have been obtained from a number of different sources. They have been adjusted to give an equivalent cost in Euros / km / bore in 2010 prices for comparative purposes.

The figures quoted should only be used to predict costs for future projects with caveats and caution. It is difficult and potentially misleading to compare case histories in detail as it is not always known exactly what the cost figures represent; and the commercial data is often confidential.

Table 4.11: Tunnel Cost Comparisons

Project	Brief Description	Equivalent Cost (Euro / km / bore) 2010 Prices
Complex Undersea or Under Land Tunnels – Tunnel Boring Machine Construction [Source; International Symposium on Technology of Bored Tunnels under Deep Waterways, Copenhagen, Denmark, 3-5 November 1993 & Mott MacDonald records]. [Costs factored to equivalent 13.5m ID tunnel]		
Great Belt Tunnel, Denmark	Road / Rail – twin bore under sea – 8km long	€59.2m
SMART Tunnel, Kuala Lumpur	Road / Storm Water – single bore under land, double deck – 9km long	€57.1m
Channel Tunnel, England / France	Rail / Service Road – triple bore under sea – 50km long	€90.7m
Norwegian Undersea Road Tunnels - Drill & Blast Construction [Source; Norwegian Sub-sea Tunnelling, Norwegian Soil and Rock Engineering Association, Publication No. 8, 1992.]		
Bømlafjord Tunnel	Single bore – 3 lane – 7.9km long	€7.7m

Project	Brief Description	Equivalent Cost (Euro / km / bore) 2010 Prices
Vardo	Single bore – 2 lane – 2.6km long	€18.8m
Alesund (Ellingsoy & Valderoy)	Single bore – 3 lane – 7.5km long	€14.5m
Godoy	Single bore – 2 lane – 3.8km long	€9.6m
Kvalsund	Single bore – 2 lane – 1.5km long	€9.6m
Norwegian Under land Road Tunnel - Drill & Blast Construction		
Laerdal Tunnel	Single bore – 2 lane – 24.5km long	€7.4m
European Union Road Tunnels - Drill & Blast /Road Header Construction [Source; JASPERS, Preparatory Studies and Financing Application for the Struma Motorway, Bulgaria, Task 5 Report August 2011.]		
Schottenberg Tunnel, Germany	Single bore – 3 lane – 0.7km long	€46.4m
Somport Tunnel, Spain	Single bore – 8.6km long	€50.3m
New Lioran Road Tunnel, France	Single Bore – 1.5km long	€59.0m
M6 Tunnels, Hungary	Twin Bore – 3km long	€33.3m
D1 Tunnels, Slovakia	Twin Bore – 7.5km long	€53.7m
Rennsteig Tunnel, Germany	Twin bore - 7.9km long	€16.3m
European Union (UK) Road Tunnel - Road Header Construction - Sandstone [Source; Mott MacDonald Records.]		
A3 Hindhead Tunnel, (2011)	Twin bore – 2 lane – 1.9km long	€43.8m
European Union (Greece) Road Tunnels - Road Header Construction – Elevated Ground- Limestone [Source; Mott MacDonald Records.]		
Maliakos Kleidi Tunnels (T1, T2 & T3)	Twin bore – 2 lane – 1.9, 5.9, 3.0 km long	T1 €32.0m, T2 €24.0m, and T3 €35.0m

Project	Brief Description	Equivalent Cost (Euro / km / bore) 2010 Prices
Hong Kong Road Tunnels – Drill & Blast Construction [Source; The Construction of Recent Tunnels in Hong Kong - unverified.]		
Tate's Cairn Tunnel (1991)	Twin bore - 2 lane – 3.6km long	€51.8m
Cheung Tsing Tunnel, Route 3 (1996)	Twin bore - 3 lane – 1.5km long	€44.1m
Tai Lam Tunnel, Route 3 (1997)	Twin bore - 3 lane – 3.7km long	€52.6m

Note: for comparative purposes it has been assumed that the twin bore road tunnel costs have been divided by a factor of 1.8 to obtain the single bore road tunnel equivalent.

The unit costs are also illustrated categorised into tunnels with similar geography and use in Figure 4.28. It can be seen there is a very large variation in unit costs. This can be explained by a number of factors including; geological conditions, tunnel length, contractual, economic and market conditions, regulatory requirements, working practices and local environmental conditions.

4.7.2 Analysis of Case History Construction Costs

A more detailed investigation of the rock strata, degree of faulting and geotechnical properties would be required to determine the optimum alignment, construction methodology, lining type and hence more accurate programme and cost estimate before a narrow range of construction costs can be identified.

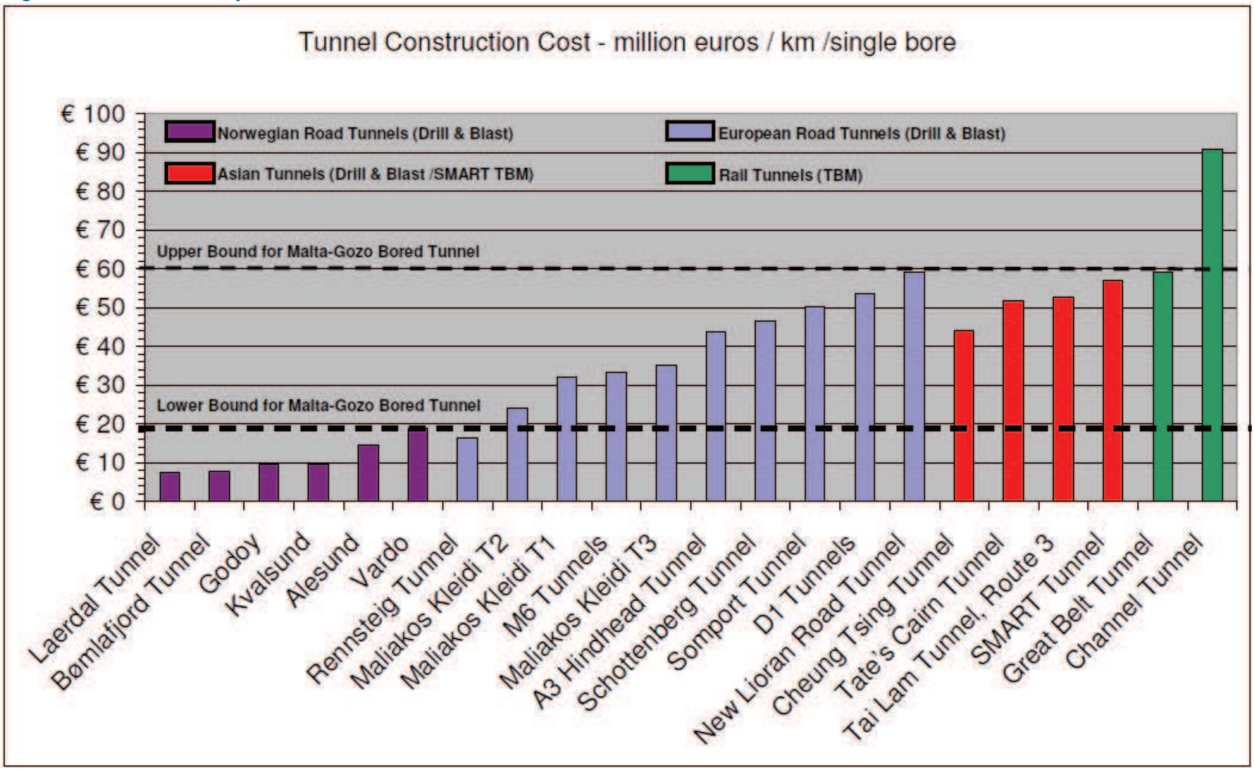
Further analysis of the case histories to narrow the range of expected construction costs for a proposed Malta Gozo tunnel has been undertaken as follows:

- The average cost of the Norwegian Undersea road tunnels is €12.0m / km /bore. This could be considered a lower bound estimate but would require the ground conditions to be very favourable. Based on the published geological maps, and analysis of them in the form of the geological sections in Appendix C, this is not thought to be the case for a tunnel from Malta to Gozo. There is also no evidence that the low Norwegian tunnelling costs have been achieved outside of Norway and a small number of northern European counties with comparable conditions. For this reason the lower bound of the range of estimated tunnelling costs for the Malta Gozo tunnel is taken to be at the higher end of the Norwegian tunnelling construction costs, and the lower end of other European tunnelling construction costs at €19m/km/single bore;
- The average cost of the European Union road tunnels (single and twin bore); Schottenberg Germany, Somport Spain, New Lioran France, M6 Hungary, D1 Slovakia, Rennsteig Germany, A3 Hindhead UK, the three Maliakos Kleidi Greece tunnels, is about €39m/km/single bore; and

- The Channel Tunnel costs have been discounted as this project is a high profile and complex rail tunnel project. A reasonable upper bound estimate could be taken as the high end of the other European tunnel examples at €60m/km/single bore.

The unit cost range following this is analysis is illustrated as the upper and lower bounds in Figure 4.28.

Figure 4.28: Summary of Tunnel Construction Costs



4.7.3 Construction Costs for Malta Gozo Road Tunnel

Based on the reviewed case studies (and further analysis in the case of the bored tunnel options) the range of costs in 2010 prices estimated for the construction of the fixed link is wide and would depend on ground conditions and other circumstances. From our analysis, it could be expected to be within the following ranges:

Option 1 (10km long)

- Single bore, 3-lane bi-directional tunnel - €190m to €600m; [€19m to €60m/km/bore];
- Twin bore, 2-lane unidirectional tunnel, with cross-passages - €342m to €1080m; and
- Single bore, 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel - €210m to €620m.

Option 2 (8.2 km long)

- Single bore, 3-lane bi-directional tunnel - €156m to €492m;
- Twin bore 2-lane unidirectional tunnel, with cross-passages - €280m to €886m; and

- Single bore 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel - €172m to €508m.

Option 3 (6km long – Immersed tube section only)

- For an immersed tube tunnel with a twin tube configuration - €438m to €684m. [€36m to €57m / km / bore] and with significant extra engineering costs to link to the existing road network – particularly on Gozo.

Option 4 (9.2km long)

- Single bore, 3-lane bi-directional tunnel - €175m to €552m;
- Twin bore 2-lane unidirectional tunnel, with cross-passages - €315m to €994m; and
- Single bore 2-lane bi-directional tunnel, with lay-bys at appropriate intervals and with regular escape passages to a smaller escape adit running parallel to the main tunnel - €193m to €570m.

Depending on the level of mechanical and electrical (M&E) equipment provided the M&E equipment costs would represent approximately 15-20% of the total capital costs.

Due to the lack of geotechnical information at this stage it would be inappropriate to evaluate detailed costs for each option as the geotechnical conditions could have a significant impact on these costs. In addition no differential has been made between the different types of bored tunnel construction techniques although for long tunnels (say greater than 5km) TBM construction would normally be less expensive for comparable ground conditions.

As excavation and ground support represents a significant proportion of the overall costs a detailed geotechnical investigation would be required before accurate cost estimates could be prepared and optimum alignments and construction methodologies selected.

It should be stressed that these costs are based solely on case histories and are indicative only. They are assumed to include the total capital cost of the tunnel project including civil works, material disposal costs, mechanical and electrical works, portal structures but not geotechnical investigations, design or land acquisition costs.

4.7.4 Operation and Maintenance Costs

Operation and maintenance costs would be made up from the following key elements:

- Maintenance costs (lighting, ventilation, electrical, fire systems, pumping, communications and traffic control);
- Energy costs (lighting, ventilation, pumping etc.); and
- Operating costs (staffing, cleaning general maintenance etc.).

In addition to these ongoing costs, at certain intervals (usually about every 20 years) the tunnel mechanical and electrical equipment may have to undergo significant refurbishment and replacement etc.

Based on work carried out for an estimate for the recently completed Hindhead tunnel in the UK (2km long twin bore highway tunnel under-land), the estimated annual operational and maintenance costs for the Malta Gozo tunnel have been estimated as follows:

- Maintenance and energy costs – a range of €2.2m to €3.0m – this estimate is applicable to an 8km to 10km tunnel, whether single or twin bore. At this stage the estimate for single or twin bore tunnel maintenance and energy costs are considered comparable as the degree of M&E equipment to be installed has not been determined; for example a single bore tunnel may need a more sophisticated ventilation system than a twin bore tunnel; and
- Operating costs – a range of €2.3m to €3.1m - this estimate is applicable to an 8km to 10km tunnel, whether single or twin bore.

A tunnel structure is normally designed for 120 years, although it can be expected to last for longer. This can be assumed as a practical lifetime. Maintenance requirements for civil work may include repairs to surface buildings, re-surfacing the carriageway and minor repairs to the tunnel lining finishes or repainting but all depending on the type of structure installed.

4.7.5 Other Costs

The geology of the project area is complex and not well documented. A comprehensive geological and geotechnical investigation is required to enable the optimum construction technique and alignment to be identified. This would be a significant undertaking taking about a year and costing in the order of about 3-5% of the anticipated capital cost.

Planning and design costs could be assumed to be in the order of 3% of the capital construction costs. This is in addition to geotechnical investigation costs.

Costs associated with any toll system installation, operation and maintenance need to be taken into account.

The cost of financing also needs to be considered depending on form of procurement, financing and funding.

In addition the client may be expected to incur costs related to land acquisition, legal fees, public relation and environmental costs and general project management costs during design and construction.

4.8 Construction Programme

4.8.1 Future Phases

Major construction projects typically follow various phases and steps. Table 4.14 below shows phases currently used by the UK Department for Transport. Processes within these are documented within their project control framework.

Table 4.12: Future Phases

Phase	Stage
1. Pre Options	1.1 Strategy, shaping and prioritisation
2. Options	2.1 Option Identification 2.2 Option Selection
3. Development	3.1 Preliminary Design 3.2 Strategy Procedures & Powers 3.3 Construction Preparation
4. Construction	4.1 Construction

Phase	Stage
	4.2 Handover and Operation

Within these phases, the following are likely to be necessary:

- Public exhibitions;
- Land searches;
- Traffic surveys;
- Feasibility studies (including cost benefit analysis);
- Marine investigation;
- Topographical surveys;
- Ground investigations;
- Environmental impact assessment; and
- Parliamentary Bill.

Regardless of the option chosen the construction programme would be in the order of 5-7 years with approximately 1 year for initial procurement and site set up, 3-5 years of tunnel construction and 1 year for testing and commissioning.

4.8.2 Bored Tunnel (TBM)

The average advance rate of a TBM could be expected to be in the order of 20m per day. A single bore 10km long tunnel would therefore take approximately 16 months to construct. For a twin bore tunnel either one TBM could be used (the first bore would be completed, the TBM would be refurbished and then the second bore completed) or two TBMs could be used to construct the bores concurrently.

4.8.3 Bored Tunnel (Road Header and Drill & Blast)

The average rate for a road header or drill and blast excavated tunnel could be expected to be in the order of 3-6m per day. The tunnels would be excavated from both sides. A single bore 10km long tunnel would therefore take approximately 24 to 48 months to construct. For a twin bore tunnel both tunnel would be constructed concurrently with headings at each portal.

4.8.4 Immersed Tube Tunnel (ITT)

A tunnel length of around 6km would require construction of about 35 to 40 tunnel elements. The length of time required to cast the tunnel elements would govern the overall project duration. For a single dry dock casting facility, similar in size to the Dock no.6 in Valletta, four elements could be constructed in one cycle. This would require 10 uses of the dock with a period of 6 months per cycle, leading to a construction period of around 5 years just for the tunnel elements. If two comparable dry docks are used the casting operation would take 2½ years. Towing out and sinking the elements can be done in a relatively short duration, typically about a day, but dependent on how far the elements have to be towed. Excavating the tunnel trench in the seabed can be done whilst the elements are being cast and would not impact on overall construction duration.

Construction of the tunnel cut and cover connections, finishing and fitting out work would extend this for at least a further 1½ years.

5. Environmental Assessment

5.1 Introduction

Three main alignments for a potential road tunnel crossing between Malta to Gozo have been considered.

The route alignments are shown on Environmental Constraint Plans in Appendix C and are summarised below.

- Option 1 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of Marfa Ridge on Malta and Route 2 west of Nadur on Gozo;
- Option 2 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of Marfa Ridge on Malta and near the junction of Route 2 and Route 110 north of Mgarr on Gozo;
- Option 3 – An immersed tube tunnel option from the Armier Bay area of Malta to the vicinity of Hondoq-Ir-Rummien on Gozo; and
- Option 4 - A bored tunnel beneath Comino, the portal on Malta being near Biskra in the Mellieha Bay Valley with a short connection to Route 1 on the northern slope of Mellieha Ridge; and the portal on Gozo being near the junction of Route 2 and Route 110 north of Mgarr.

For Options 1, 2, and 4 it has been assumed that the land surface of the Island of Comino would remain untouched due to it’s environmental sensitivity. The tunnel would be well below sea level as it crosses Comino, and ventilation or escape shafts are not expected to be essential, (although they could be considered if thought necessary for safety following a full risk analysis).

5.2 Relevant Environmental and Planning Legislation

5.2.1 Environmental Legislation

Malta has been a member of the European Union (EU) since 1 May 2004. Large infrastructure projects are subject to the European Union Directive (85/337/EEC) on Environmental Impact Assessments (known as the EIA Directive) as amended in 1997. This is enacted under Maltese legislation in the Environmental Impact Assessment Regulations, 2007. The Regulations list development types falling under the thresholds defined in Schedule I – which require a full EIA by preparation of an environmental impact statement; and Schedule II – which require a limited EIA by preparation of an environmental planning statement. The need for an EIA for developments with no threshold listed under Schedule II will be determined by the Director of Environmental Protection.

Applications for development permission for a proposed scheme, which may require an EIA, are required to be supported by a project description statement. The statement should contain details of the development and any likely environmental impacts. The Director of Environmental Protection, in the Malta Environment and Planning Authority (MEPA) determines whether an EIA is required. An environmental scoping statement can be submitted by the applicant describing the environmental characteristics of the project site and includes any baseline environmental surveys undertaken.

If a full EIA and environmental impact statement are required, this should describe the development and the extent of the environment affected by the development, identify and assess any effects on the environment and include any necessary mitigation measures. Monitoring and auditing requirements would also be included. A non-technical summary will also be required.

There are a number of internationally designated sites in Malta which make up part of the Natura 2000 network, designated under either the EU Habitats Directive or the EU Birds Directive. The designation ensures that management of the sites is ecologically and economically sustainable. If development is proposed within these sites, an appropriate assessment must be undertaken according to Article 6(3) of the Habitats Directive to address potential impacts on the qualifying features.

Before deciding to undertake a project that may give rise to significant effects upon a Natura 2000 site, the competent national authorities must make an appropriate assessment of the implications for that site in view of that site's conservation objectives. The carrying out of works will be subject to the general obligation of protection under Article 6(2) of the Habitats Directive i.e. avoiding deterioration of natural habitats and species' habitats and significant disturbance that affect the species for which the site has been designated. The competent national authorities must also consult with the relevant nature conservation agencies and have regard to any representations made by that body.

In making this assessment, it is important to recognise that it will be appropriate to the likely scale, importance and impact of the development. A key outcome of the appropriate assessment is to identify whether the integrity of the Natura 2000 site(s) is likely to be significantly affected by the project, and whether the conservation status of the interest features of the site could be impacted.

The requirement to undertake an appropriate assessment is not clear at this stage.

Legislation for environmental assessment in Malta in relation to road and tunnel infrastructure projects and the associated construction relating activities (including disposal of rock materials) is outlined below.

European and international legislation:

- Water Framework Directive 2000/60/EC;
- Habitats Directive 92/43/EEC (Conservation of natural habitats and of wild fauna and flora);
- Birds Directive 2009/147/EC (Conservation of wild birds);
- Marine Strategy Framework Directive 2008/56/EC;
- Directive 2007/60/EC on the assessment and management of flood risks;
- Directive 2008/50/EC on ambient air quality and cleaner air for Europe;
- Bathing Waters Directive 2006/7/EC;
- Ramsar Convention, 1971;
- Bonn Convention, 1979;
- Bern Convention, 1979;
- Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, 1995;
- Aarhus Convention1998;
- Environmental Impact Assessments 85/337/EEC; and
- Strategic Environmental Assessment Directive 2001/42/EC.

National legislation:

- Environment and Development Planning Act, 2010;

- Development Planning (Amendment) Act, 1997;
- Environment Protection Act (CAP. 435);
- Cultural Heritage Act, 2002;
- Fertile Soil (Preservation) Act;
- Environmental Impact Assessment Regulations, 2007;
- Strategic Environmental Assessment Regulations, 2005;
- Flora, Fauna and Natural Habitats Protection Regulations, 2010;
- Conservation of Wild Birds Regulations, 2007;
- Convention on Biological Diversity (Incorporation) Regulations, 2002;
- Trees and Woodland (Protection) Regulations, 2001;
- Marine Mammals Protection Regulations, 2003;
- Quality required of Shellfish Waters Regulations, 2001; and
- Quality of Fresh Waters Supporting Fish Life (Protection and Improvement) Regulations, 2001.

Government Notices and Legal Notices are issued under the auspices of the Development Planning Act (DPA) and the Environment Protection Act (EPA).

5.2.2 Planning Legislation

The Malta Environment and Planning Authority (MEPA) carries out development control which regulates the use of, and development of, land. MEPA considers planning applications and monitors development. MEPA will base its determination on structure plan policies, local plan policies and any other relevant policies or planning guidance.

In terms of strategic planning there is a Structure Plan for the Maltese Islands, which covers the twenty-year period to 2010. The Structure Plan addresses all aspects of social, economic and physical planning. A key requirement of this plan is to prepare more detailed plans for particular areas of the Maltese Islands.

There are two local plans which have been developed and apply to this project. The aim of the local plans are to, protect the natural and man-made environment and the scenic value of both rural and urban areas, provide for economic development needs, accommodate population growth, encourage leisure and tourism and sustain rural communities and agriculture (MEPA 2006).

The Gozo and Comino Local Plan (2006) sets out policies relating to:

- Flooding;
- Ecology, geology and hydrology;
- Landscape value;
- Coastal access; and
- Dark skies.

The Malta North West Local Plan (2006) sets out policies on:

- Transport;
- Landscape;
- Conservation;
- Garrigue;
- Woodland;
- Protected Areas; and
- Aquifers.

Table 5.1 lists the major designations of protected areas in Malta and their appropriate legal instrument.

Table 5.1: Major Designations of Protected Areas

Designation	Legal Instrument
Areas of Ecological Importance (AEI) & Sites of Scientific Importance (SSI)	National - DPA
Bird Sanctuaries	National - EPA
Nature Reserves	National - EPA
Special Areas of Conservation (national importance)	National - DPA & EPA
Special Areas of Conservation (international importance)	Form part of the Natura 2000 Network under the EC Habitats Directive National - DPA & EPA
Special Protection Areas	Form part of the Natura 2000 Network under the EC Birds Directive National - DPA & EPA
Ramsar Sites	Ramsar Convention
Specially Protected Areas	SPA & Biodiversity Protocol

Source: DPA - Development Planning (Amendment) Act, 1997
EPA - Environment Protection Act (CAP. 435)

The relevant designations under the Local Plans are discussed in Section 5.3, the environmental baseline and shown of Drawing 282725 – SK101.

5.3 Environmental Baseline

5.3.1 Introduction

The three populated islands of the Maltese archipelago are Malta, Gozo and Comino, located in the centre of the Mediterranean. Malta covers a land area just over 300 km², making it one of the world's smallest and most densely populated countries. Gozo has a land surface area which is over 60 km². Both Gozo and Comino are part of the country of Malta.

Malta and Gozo have a subtropical Mediterranean climate with mild winters and warm to hot summers. Rain occurs mainly in winter, with summer being generally dry.

Malta and Gozo are popular tourist destinations. Malta and Gozo are interdependent for commerce and the provision of services.

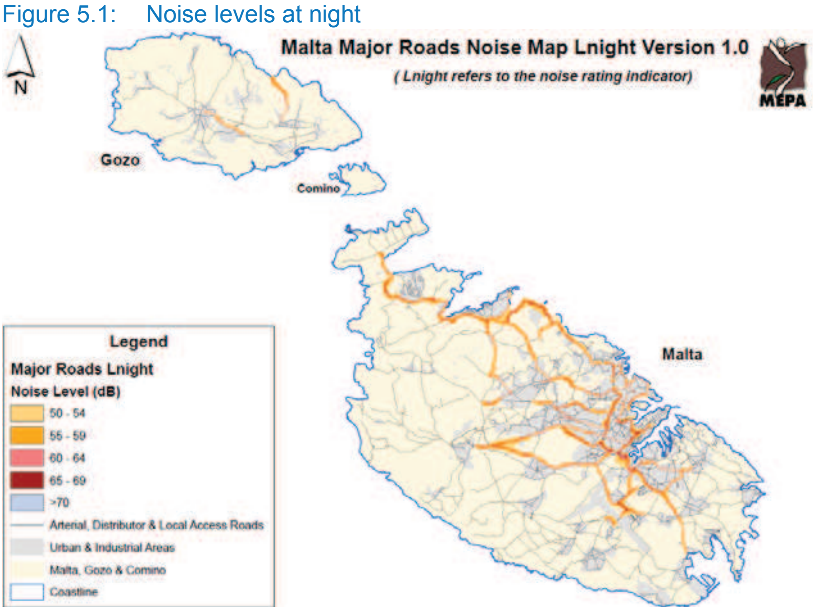
As outlined in the Inception report, the following environmental aspects are considered to present the greatest potential issues to delivering the options addressed in this report:

- Noise;
- Air quality;
- Landscape;
- Archaeology and cultural heritage;
- Biodiversity;
- Water resources;
- Journey ambiance;
- Soils and Land use;
- Marine users / navigation;
- Tourism and recreation; and
- Waste.

5.3.2 Noise

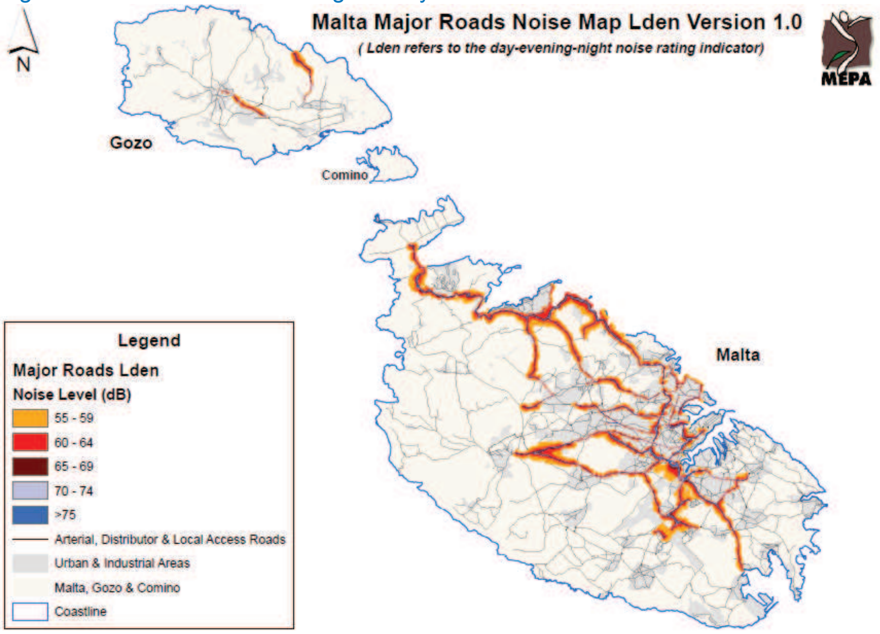
In 2007 as part of the reporting obligations of the Environmental Noise Directive (Directive 2002/49/EC) MEPA prepared strategic noise maps for Malta and Gozo. Traffic noise is considered to be one of the main sources of noise affecting the local residents in Malta and Gozo. Figures 5.1 and 5.2 indicate the noise levels at night and during the day time in close proximity to major roads.

Figure 5.1: Noise levels at night



Source: MEPA

Figure 5.2: Noise levels during the daytime



Source: MEPA

MEPA have also estimated the population exposure, total area exposed and numbers of dwellings that lie within 5dB noise level contour band for Lden and Lnight from major roads within Malta, details are provided in Tables 5.2 to 5.5.

Table 5.2: Estimate of population exposed to defined noise levels during the daytime

Noise band (Lden)	Population exposure
55-59	8800
60-64	6100
65-69	5700
70-74	2600
>=75	100

Table 5.3: Estimate of population exposed to defined noise levels during the night

Noise band (Lnight)	Population exposure
50-54	6300
55-59	5700
60-64	2800
65-69	100
>=70	0

Table 5.4: Area (km2) exposed to Lden > 55, Lden > 65 and Lden > 75

Area (km2) exposed to Lden > 55	Area (km2) exposed to Lden > 65	Area (km2) exposed to Lden > 75
29.1	9	1.4

Table 5.5: Area (km2) exposed to Lden > 55, Lden > 65 and Lden > 75

Dwellings exposed to Lden > 55	Dwellings exposed to Lden > 65	Dwellings exposed to Lden > 75
9700	3600	0

Prior and after to the adoption of the Environment Noise Directive 2002/49/EC by the Maltese Government there were no noise limit values in force or under preparation. The implementation of the Directive into Maltese law required action plans to be developed to reduce the populations exposure to noise. The draft action plan states that 'the proposed onset levels set by MEPA, for assessment of noise mitigation measures due to exposure to road traffic noise are (a) Lden = 65 dB and (b) Lnight = 55 dB'. Noise levels above these criteria may be considered to be contributing to adverse health impacts from environmental noise

In addition, World Health Organisation (WHO) guidelines for night noise recommend less than 40 dB(A) of annual average outside of bedrooms to prevent adverse health effects from night noise. It is likely that in certain locations where properties are immediately adjacent to the roads (that form part of the TEN-T network), noise levels at night may already be above 40 dB(A) (Lnight).

5.3.3 Air quality

Air quality is one of Malta's most important environmental concerns due to the direct link between human health and ecosystems (MEPA 2008). The Air Quality Framework Directive (1996/62/EC) and its four daughter directives, require member states to comply with limit values for all pollutants regulated under 1996/62/EC within specific timeframes. Directive 2008/50/EC on ambient air quality and cleaner air for Europe was adopted in May 2008. This latest directive merges the daughter directives into a single directive on air quality and sets new standards and target dates for reducing concentrations of fine particles.

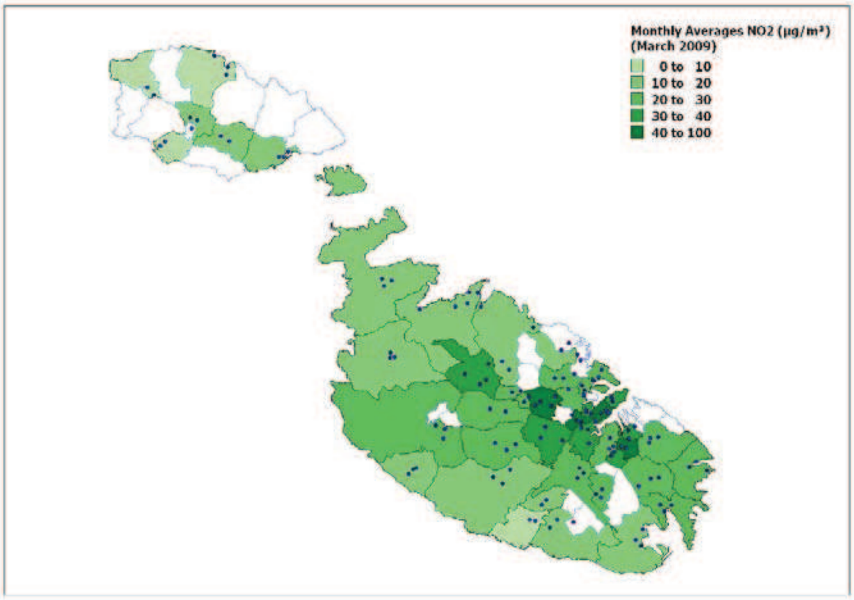
Table 5.6: Air Quality Objective from Directive 2008/50/EC

Pollutant	Averaging Period	Air Quality Objective	Where Applicable
		Concentration	
Nitrogen Dioxide (NO_2)	1-hour	200µg/m^3	All Locations accessible to the public.
	Annual	40µg/m^3	Locations of permanent residence.
Particulates (PM_{10})	24-hour	50µg/m^3	Locations where the public may be expected to be present for at least 8 hours per day (e.g. Residential properties, hospitals, care homes, etc).
	Annual	40µg/m^3	Locations of permanent residence.
Benzene	Annual	5µg/m^3	Locations of permanent residence

In 1999, the National Air Monitoring Programme was launched by the Environment Protection Department of MEPA. Annual surveys of sulphur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3) and hydrocarbons such as benzene, toluene, ethylbenzene and xylenes concentration in the air have been undertaken using diffusion tubes. MEPA also coordinates the automated real-time measurement of pollutants. However, none of the five monitoring stations are in close proximity to the road and tunnel options.

Figure 5.3 below indicates that the average NO_2 concentrations in March 2009 at all the potential portal locations were below the 40µg/m^3 value given in Directive 2008/50/EC.

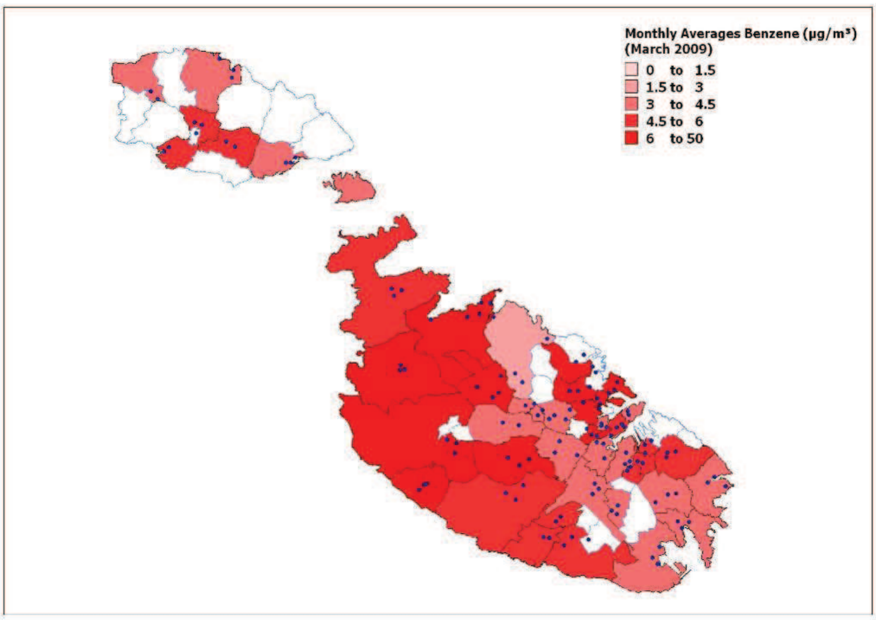
Figure 5.3: Average NO_2 concentrations (March 2009)



Source: MEPA

Figure 5.4 below indicates that the average benzene concentrations in March 2009 at all the potential portal locations were below the 5µg/m^3 value given in Directive 2008/50/EC.

Figure 5.4: Average benzene concentrations (March 2009)



Source: MEPA

Stacey and Bush (2002) suggest that in Malta and Gozo, the road transport sector is an important source of low level emissions for all pollutants, particularly lead, benzene and CO. Although for NOx, SO2 and PM10, the contribution from stationary sources, (combustion in energy and transformation and manufacturing) is significantly higher than that from road transport.

5.3.4 Landscape

The existing landscape characteristics are discussed separately for Malta and Gozo and Comino following the Local plan documents.

A specific Landscape Report for North West Malta was commissioned by MEPA for the Local Plan. The landscape assessment identifies regional landscape character areas and sub-divisions within them, which have been classified as local landscape tracts.

The relevant landscape character areas identified within the Local Plan area are:

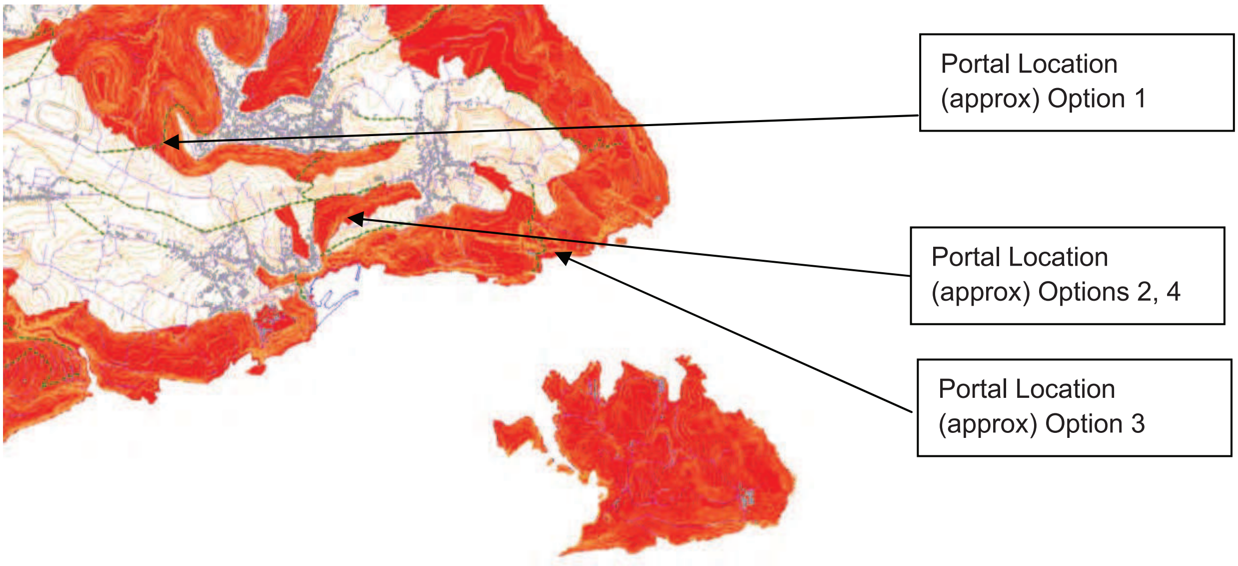
- Western Coast; and
- North East Coast.

On Malta, the portal locations for all options fall within a landscape characterised by low rounded hills with terraced fields bounded by limestone rubble retaining walls. The landscape is dominated by the large expanses of exposed bare rock, with sporadic areas Mediterranean scrub and woodland, with hotels and associated tourist activities along the northern coastline.

The locations of all tunnel portals on Malta are located outside the area of high landscape value and are not considered to be protected landscapes according the North West Local Plan. The approximate location of portals for Options 1, 2 and 4 on Malta are in areas defined as a pleasant but impaired landscape. The portal for the immersed tube option (Option 3) at Armier Bay is within an area defined in the Local Plan as a cluttered landscape.

The Gozo and Comino Local Plan defines areas of high landscape value. Figure 5.5 indicates the areas of high landscape value on Gozo. Again the landscape of Gozo is dominated by open views of low hills and valleys supporting terraced fields.

Figure 5.5: Areas of high landscape value on Gozo and Comino



Source: MEPA (Gozo and Comino Local Plan)

There is a local plan policy for Gozo and Comino that protects coastal views around the majority of the coast of Gozo. Dark sky heritage areas are also identified in the Local Plan, none of the portal locations are located within such areas.

Figure 5.6: Photograph of Gozo showing Route 2 and the general proposed location of the portal for Option 1

Source: Mott MacDonald

5.3.5 Archaeology and historic heritage

MEPA holds a scheduled property register which includes all legally protected heritage properties of the Maltese Islands. Many types of features have been scheduled including post boxes, telephone kiosks, towers, churches and shrines.

There are numerous 'Giren' located on the north west of Malta, very few are present in Gozo. Giren are stone 'huts' previously used for sheltering or herding livestock or for habitation. None are now believed to be permanently inhabited by people.

According the UNSECO there are six inscribed world heritage sites on the Maltese lands:

- Ġgantija;
- Haġar Qim;
- Hypogeum of Hal-Saflieni;
- Mnajdra;
- Megalithic Temples of Malta; and
- Valletta.

5.3.6 Biodiversity

5.3.6.1 Terrestrial

Designated sites

Thirty two sites with one or more designations lie within 2km of the proposed options (Table 5.7). Of these thirty two sites, sixteen are on Malta, ten on Gozo and six on Comino. There are eight European designated sites (Natura 2000) and one Ramsar wetland of international importance. Drawing 282725 – SK100 in Appendix B shows the locations of the Natura 2000 and Ramsar relative to the road tunnel options.

Table 5.7: Designated Sites within 2km of the Proposed Options

Site Name	Location	Designation
Kemmunett	Comino	AEI/SSI
Gebel ta' Bejn il-Kmiemen	Comino	AEI/SSI
Il-Qala Ta' Santa Marija	Comino	AEI/SSI/Nature Reserve
Kemmuna	Comino	Bird Sanctuary/IBA
Il Hazina	Comino	Nature Reserve
Kemmuna, Kemmunett, il-Hagriet ta' Bejn il-Kmiemen u l-Iskoll ta' Taht il-Mazz	Comino	SCI/SPA (Natura 2000)
Il Gebla Tal Halfa	Gozo	AEI/SSI
Wied Ta' Mgarr Ix Xini	Gozo	AEI/SSI
Ghajn Klin, Ix Xatt L Ahmar (Ghadajjar Ta' L Ilma Helu)	Gozo	AEI/SSI
Il Gebla Tac Cawl	Gozo	AEI/SSI/Special Area Of Conservation National Importance

Site Name	Location	Designation
Ta' Lambert (Heliport)	Gozo	Bird Sanctuary
Ta' Lambert	Gozo	Nature Reserve
Ix Xatt L Ahmar	Gozo	Protected Beach
Il Bajja Ta' Mgarr Ix Xini	Gozo	Protected Beach
L-Inhawi ta' Ta' Cenc	Gozo	SCI (Natura 2000)
Rdumijiet ta' Ghawdex: Ta' Cenc	Gozo	SPA/IBA (Natura 2000)
Rdum Mil Ponta Ta' L Ahrax Sa Rdum Il Hmar	Malta	AEI
Ir Ramla Tal Bir (Bur Salmastru)	Malta	AEI
Rdum Mic Cirkewwa Sa Benghisa	Malta	AEI
Tas Sellum U Wied Ghajn Zejtuna	Malta	AEI
Rdum Minn Rdum Tal Griebeg Sal Qala Tal Mistra	Malta	AEI
Ir Ramla Tat Torri (Gharam Tar Ramel)	Malta	AEI/SSI
L Armier (Gharam Tar Ramel)	Malta	AEI/SSI
Armier Bay	Malta	Protected Beach
Ir Ramla Tac Cirkewwa	Malta	Protected Beach
Anchor Bay	Malta	Protected Beach
Ghadira	Malta	Ramsar/Bird Sanctuary
Rdumijiet ta' Malta: Ir-Ramla tac-Cirkewwa sa Il-Ponta ta' Benghisa	Malta	SCI (Natura 2000)
Rdumijiet ta' Malta: Ir-Ramla tac-Cirkewwa sa Il-Ponta ta' Benghisa	Malta	SCI (Natura 2000)
L-Imgiebah / Tal-Mignuna Area	Malta	SCI (Natura 2000)
L-Ghadira Area	Malta	SCI/SPA (Natura 2000)
Ramla tat-Torri / Rdum tal-Madonna Area	Malta	SCI/SPA/IBA (Natura 2000)

Source: IBA – Important Bird Area

Habitats

The majority of habitats on Malta and Gozo are associated with disturbed or arable land and rocky ground. However, within the protected areas on Malta habitats listed on Annex I of the EU Habitats Directive e.g. Thermo-Mediterranean and pre-desert scrub, West Mediterranean clifftop phryganas and calcareous rocky slopes are dominant. On Gozo habitats also listed on Annex I of the EU Habitats Directive e.g. Thermo-Mediterranean and pre-desert scrub, and pseudo-steppe grassland are present. These habitats are protected under European legislation and support rare flora species. For example, the north western and southern cliffs of Malta and the cliffs of southern Gozo support the critically endangered (IUCN Red List) Maltese centaury (*Cheirolophus crassifolius*). The endemic Maltese salt tree (*Darniella melitensis*) can be found on coastal cliffs and hillsides on Gozo.

The less populated island of Comino is dominated by Thermo-Mediterranean and pre-desert scrub, and West Mediterranean clifftop phryganas (*Astragalo-Plantaginetum subulatae*). The remaining habitats comprise a mix of agricultural land, calcareous rocky slopes, pseudo-steppe grassland, marshland and sand dunes.

The Ghadira Nature Reserve (Figure 5.7) in Mellieha covers an area of about six hectares and occupies the floodplain between two ridges. More than 200 species of birds have been recorded at the reserve and many winter here. Little Ringed Plover only breed at the Ghadira Nature Reserve, where this species has been breeding annually since 1995 (Malta BirdLife). Ghadira Nature Reserve is located adjacent to the existing TEN–T network (Route 1) at Mellieha Bay.

Figure 5.7: Photograph looking down onto the Ghadira Nature Reserve

Source: Mott MacDonald

Ghadira nature reserve is one of only two wetland areas and represents the largest free-standing sources of water in Malta.

An afforestation project known as Foresta 2000 is located on the Marfa Ridge close to the Ghadira Nature Reserve. Foresta 2000 has the aim to recover an area over 100ha in size and plant a Mediterranean forest. The location of the portal for Options 1, 2 and 4 are shown in a location that avoids this area.

Fauna

There are over 7,000 species recorded in Malta of which 12 species of beetles, 17 species of butterflies and moths, five species of flies, two species of ants, one species of grasshoppers and seven species of molluscs are known to be endemic. The subspecies of the Sicilian shrew (*Crocidura sicula calypso*) is the only endemic mammal and is only found on Gozo. The most abundant endemic is the Maltese wall lizard (Podarcis filfolensis) with five distinct subspecies within the archipelago. Designated sites support a wide range of species afforded protection under the EU Habitats and Birds Directives within and outside the designated sites.

Coastal cliffs support important numbers of breeding seabirds such as Cory's shearwater (Calonectris diomedea) most notably at Ta'Cenc cliffs, Gozo, and also Yelkouan shearwater (*Puffinus yelkouan*) especially at Rdum Tal-Madonna, Malta. Notable numbers of short-toed lark (*Calandrella brachydactyla*) and spectacled warbler (*Sylvia conspicillata*) are also known from the clifftops at Rdum Tal-Madonna. Trans-Saharan passerine migrants and birds of prey pass through the islands in significant numbers. Ghadira is an important resting and feeding site for waders and is the only breeding site in Malta for little ringed plover (*Charadrius dubius*) and black-winged stilt (*Himantopus himantopus*). The water around the islands, including the water within the area of the proposed options, support a number of seabird species during the breeding season and the source populations of these birds may be from protected sites beyond the 2km search area used to identify the designated sites above.

5.3.6.2 Marine

Designated sites

There are two marine potential Special Areas of Conservation close to the project. These are the Zona fil-Bahar fil-Grigal ta' Malta and the Zona fil-Bahar fi-inhawi ta' Mgarr ix-Zini (Ghawdex) (Natura 2000 Data Form). Both sites consist of marine areas and sea inlets and are designated for important seagrasses, invertebrates and algal species.

There are a number of the seagrass Posidonia species (sp.) sub-types present in the Zona fil-Bahar fil-Grigal ta' Malta, with beds providing connectivity in the region. The site covers a large area (15,519.4ha) with Options 1, 2 and 4 passing several metres below the seabed, and the immersed tube section of Option 3 altering the seabed and being entirely within the designated site. The large designated site has a varied seabed with different substrates and habitat types.

Zona fil-Bahar fi-inhawi ta' Mgarr ix-Xini (Ghawdex) is smaller at 30.56ha and is approximately 2km west of Option 1. Its substrate is also varied with a number of habitat types typical of those in the Maltese islands, including the Annex I habitat, Posidonia sp. beds.

Zona fil-Bahar fil-Grigal ta' Malta is vulnerable to:

- Boating activities and anchoring which damage rhizomes and shoots and disrupts Posidonia mats;
- Fishing activities;
- Coastal development and anthropogenic activities and associated run-off; and
- Quarrying.

Zona fil-Bahar fi-inhawi ta' Mgarr ix-Zini (Ghawdex) is vulnerable to:

- Boating activities and anchoring which damage rhizomes and shoots and disrupts Posidonia mats;
- Maritime traffic;
- Alien algal species;
- Land run-off causing an increase in nutrients and particulate matter; and
- Fishing activities.

Habitats and associated benthic communities

Posidonia beds

There are large areas of Posidonia sp. (seagrass) beds on the seabed in the project area. Posidonia beds are Annex I habitats. There are a number subtypes including Posidonia meadows on mat (consisting of organic material in sediment), Posidonia on rock, on sand, mosaics with different species and barrier reef meadows (Natura 2000 Data Forms). Posidonia meadows are important for their productivity, their role in sediment stabilisation and nutrient cycling, their high species richness, and their role as refuges, feeding and nursery grounds for marine species (MEPA, 2011a). Posidonia barrier reefs are restricted to the Maltese Islands (MEPA, 2011a).

Flora

Lithothamnion minervae

The coralline alga Lithothamnion minervae is found within the Zona fil-Bahar fil-Grigal ta' Malta, Natura 2000 site and the citation notes that it is of national interest. Its conservation requires designation of SACs as it can form the Annex I (under the Habitats Directive) habitat mearl beds.

Fauna

Fish

Thirty two species of marine fish are listed as threatened by Fishbase (Fishbase, 2011). These are shown in Table 5.8.

Table 5.8: Threatened marine fish species in Malta (Fishbase, 2011; IUCN, 2011)

Species	Status	Red List Status	Common name	Maltese Name
*Acipenser sturio**	native	Critically Endangered	Sturgeon	Sturjun
Alopias superciliosus	native	Vulnerable	Bigeye thresher	Big eye thresher shark
Alopias vulpinus	native	Vulnerable	Thresher	Pixxivolpi
Anguilla anguilla	native	Critically Endangered	European eel	Sallura
Carcharhinus plumbeus	native	Vulnerable	Sandbar shark	Kelb griz
Carcharias taurus	native	Vulnerable	Sand tiger shark	Tawru
Carcharodon carcharias	native	Vulnerable	Great white shark	Kelb il - Bahar Abjad
Centrophorus granulosus	native	Vulnerable	Gulper shark	Zaghrun
Cetorhinus maximus	native	Vulnerable	Basking shark	Gabdoll
Dipturus batis	native	Critically Endangered	Blue skate	Rebekkin skur
Epinephelus marginatus	native	Endangered	Dusky grouper	Cerna
Galeorhinus galeus	native	Vulnerable	Tope shark	Mazzola
Gymnura altavela	native	Vulnerable	Spiny butterfly ray	Farfett
Isurus oxyrinchus	native	Vulnerable	Shortfin mako	Pixxitondu
Labrus viridis	native	Vulnerable		Tirda
Lamna nasus	native	Vulnerable	Porbeagle	Pixxiplamptu
Leucoraja circularis	native	Vulnerable	Sandy ray	
Leucoraja melitensis	native	Critically Endangered	Maltese ray	Raja ta' Malta
Mobula mobular	native	Endangered	Devil fish	Baqra

Species	Status	Red List Status	Common name	Maltese Name
Mustelus mustelus	native	Vulnerable	Smooth-hound	Mazzola bla xewka
Odontaspis ferox	native	Vulnerable	Smalltooth sand tiger	Silfjun
Oxynotus centrina	native	Vulnerable	Angular roughshark	Pixxiporku
Pagrus pagrus	native	Endangered	Red porgy	Hawwad
Pristis pristis	native	Critically Endangered	Common sawfish	Sija
Rhinobatos cemiculus	native	Endangered	Blackchin guitarfish	Kuntrabaxx
Rhinobatos rhinobatos	native	Endangered	Common guitarfish	Vjolin
Rostroraja alba	native	Endangered	White skate	Hamiema
Sphyrna tudes	native	Vulnerable	Smalleye hammerhead	Kurazza rasha zghira
Sphyrna zygaena	native	Vulnerable	Smooth hammerhead	Kurazza komuni
Squalus acanthias	native	Vulnerable	Picked dogfish	Mazzola griza
Squatina oculata	native	Critically Endangered	Smoothback angelshark	Xkatlu ta' l-ghajnejn
Squatina squatina	native	Critically Endangered	Angelshark	Xkatlu komuni

Source: *Protected species under the Habitats Directive

Sea Turtles

Two species of sea turtle are known to nest in the Mediterranean, the green turtle, *Chelonia mydas*, and the loggerhead turtle, *Caretta caretta*. These species nest in Tunisia and Greece, to the west and east of Malta respectively. Leatherback turtles, *Dermochelys coriacea*, are also commonly found in the Mediterranean but are not thought to nest there (Euroturtle, 2011). Turtles last nested in Malta in the 1960s (Nature Trust Malta, 2011). Loggerhead turtles are listed as endangered on the IUCN Red List and are protected by CITES Appendix I. Green turtles are listed as endangered on the IUCN Red List and are protected by CITES Appendix I. They are also listed in Appendices I and II of the Convention on Migratory Species. Leatherback turtles are listed as critically endangered on the IUCN Red List.

Sea Mammals

Seven species of marine mammals are known in Maltese waters and listed on the IUCN Red List (IUCN, 2011). The fin whale, *Balaenoptera physalus*, is listed as endangered, the sperm whale, *Physeter macrocephalus*, is vulnerable, the short-beaked common dolphin, *Delphinus delphis*, Risso's dolphin, *Grampus griseus*, and the common bottlenose dolphin, Tursiops truncates, are of least concern. The long-finned pilot whale, *Globicephala melas*, and the false killer whale, *Pseudorca crassidens*, data defined as deficient and can not be classified.

Sea birds

There are seven Annex I bird species listed in the Natura 2000 Data Sheet for Kemmuna, Kemmunett, Il-Hagriet ta' Bejn il-Kmiemen, L-Isholl ta' That il-Mazz SAC. Two of these are sea birds: Mediterranean shearwater, *Puffinus yelkouan*, and Cory's shearwater, *Calconectris diomedea*.

Invertebrates

Pinna nobilis, the nobel pen shell, *Centrostephanus longispinus*, a sea urchin, and *Scyllarides latus*, a slipper lobster are all found in Zona fil-Bahar fi-inhawi ta' Mgarr ix-Zini (Ghawdex) and are noted as being important.

5.3.6.3 Biodiversity summary

In summary both Malta and Gozo are populated by a diverse range of species and habitats, some of which are endemic to the Islands. The most important terrestrial and marine sites have been protected and are part of the Natura 2000 network. The immersed tube tunnel will sit just below the existing seabed level, this option is within the Zona fil-Bahar fil-Grigal ta' Malta marine SPA. All the other tunnel options and portal locations avoid marine and terrestrial Natura 2000 sites.

5.3.7 Water resources

5.3.7.1 Surface water

Natural freshwater resources in the Maltese Islands are scarce and depend entirely on rainfall.

Malta has no large river systems. River valleys, or widien, tend to be seasonally dry and very few permanently hold water. As such, there are no water bodies identified under the Water Framework Directive. However, ten water bodies designated as water-dependent, Natura 2000 sites have been identified and these are managed under both the Habitats Directive and the Water Framework Directive. One of these sites is within northern Malta - lake L Ghadira – and is less than one kilometre from Options 1 2 and 4 (MEPA, 2011b). All of the Maltese islands are considered to be Nitrate Vulnerable Zones.

The coastal waters of north Malta and south of Gozo are classified as good ecological and chemical status under the Water Framework Directive.

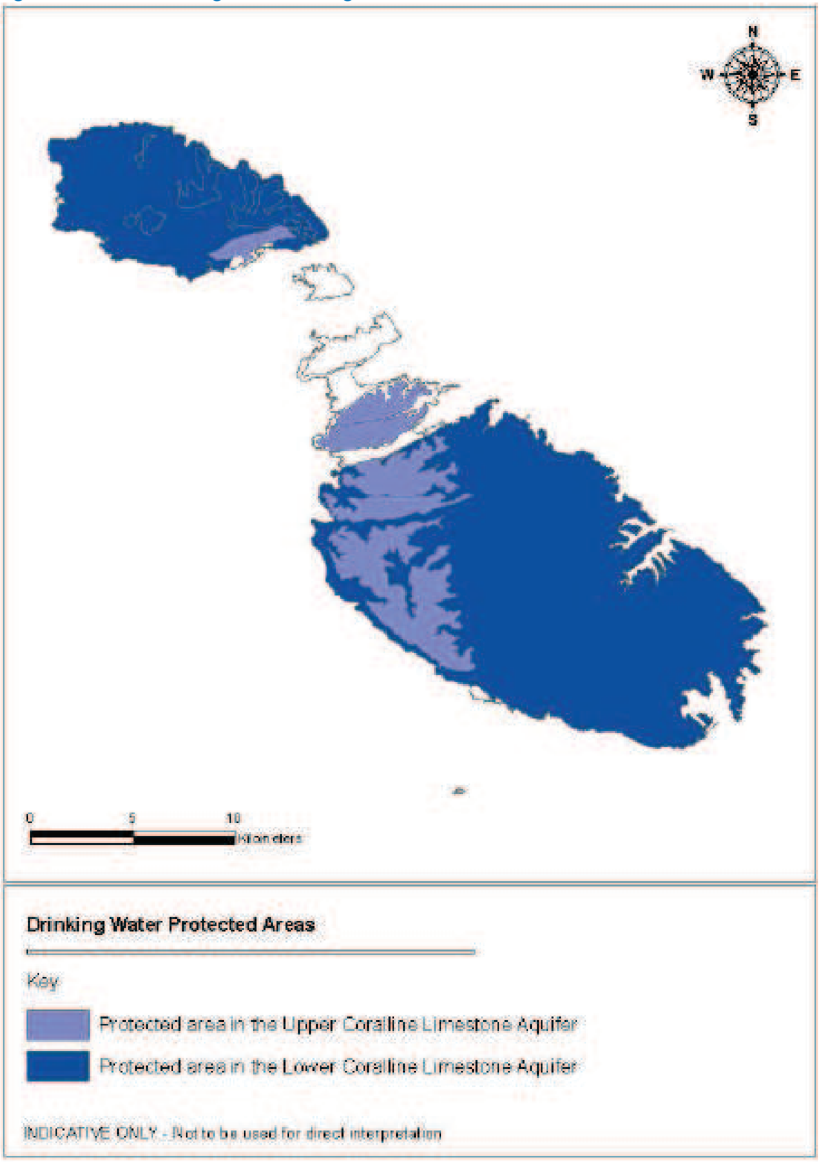
5.3.7.2 Groundwater

The Maltese islands obtain their potable water supply from groundwater and seawater desalination in equal proportions. Aquifers are the primary source of natural water. The groundwater from these aquifers is also used for agriculture.

The groundwater in the vicinity of the tunnels options and portal locations is within the Upper Aquifer or Perched Aquifer. This is in the Upper Coralline Limestone formation, above the Blue Clay formation. The aquifer in northern Malta is in contact with seawater. The northern part of Malta and Comino where the tunnel portals are proposed are not in drinking water safeguard zones, however all the portals on Gozo are within such a Zone. Figure 5.8 is taken from the Water Catchment Management Plan for the Maltese Islands and shows the extent of the drinking water safeguard zones.

Groundwater is currently impacted by saline intrusion due to over-pumping from irrigation wells and by various forms of domestic and agricultural pollution, including nitrate contamination. The most important issue affecting groundwater quality in Malta is nitrate contamination (MEPA, 2011b).

Figure 5.8: Drinking water safeguard zones



Source: MEPA 2011

There are perched aquifers on both Gozo and Malta, which consist of rainwater trapped in the permeable Upper Coralline Limestone due to the underlying layer of impermeable Blue Clay. Water seepage from the perched aquifers occurs wherever the Upper Coralline Limestone/Blue Clay interface is exposed, giving rise to springs which drain into widien watercourses. These perched aquifers play an important role for irrigation of agricultural crops.

5.3.8 Journey ambiance

Journey quality can be affected, positively or negatively, by travellers themselves and by the road network. The measures can affect three journey ambience factors:

- Traveller care;
- Travellers' views; and
- Traveller stress.

The most effective way to improve journey quality is to reduce travellers' journey times and/or the variability of these journey times by, for example, improving the transport infrastructure.

Car travellers using the approach road to the ferry on Malta are of mostly open views of the sea, and the views extend over many miles to Comino and Gozo. The view during the ferry journey is generally open and the ferry experience leaves travellers with a feeling of well being.

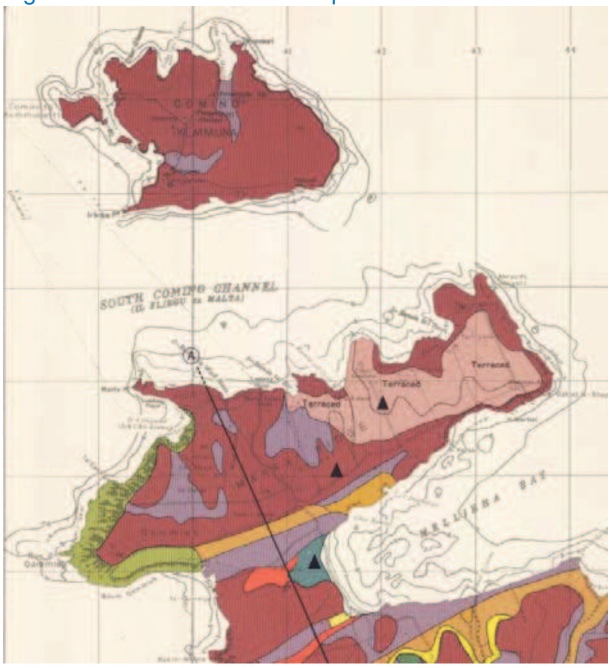
There are three main factors that influence traveller stress; frustration; fear of potential accidents; and route uncertainty. Currently it is believed that some driver stress is experienced at the ferry terminals on both Malta and Gozo, this occurs when travellers arrive at the ferry terminal just to see the ferry leaving.

5.3.9 Soils and land use

Fifty one percent of the land cover of Malta is agricultural. Approximately 22% is characterised by urban development, and an additional 7% is covered by industrial and commercial sites and activities.

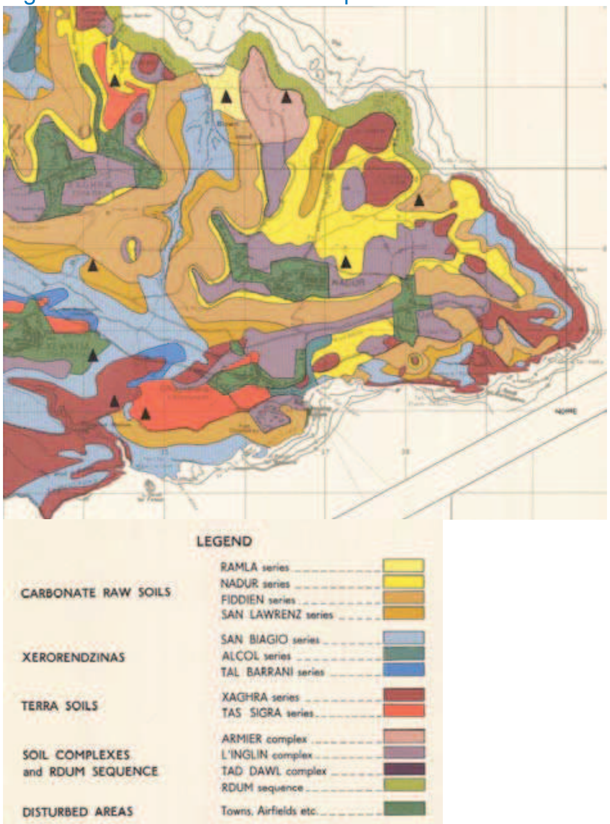
The only soil map of the Maltese Islands is that published in 1960 on a scale of 1:31,680 as a result of the study of the Maltese soils by D.M. Lang in 1956-57. Two extracts are provided in Figures 5.9 and 5.10.

Figure 5.9: Extract of soil map – Malta and Gozo



Source: http://eusoils.jrc.ec.europa.eu

Figure 5.10: Extract of soils map Gozo



Source: http://eusoils.jrc.ec.europa.eu

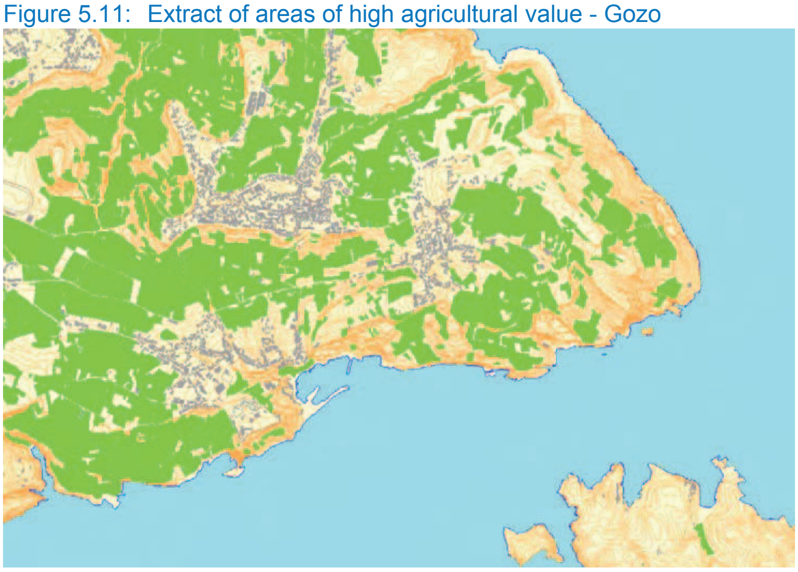
The depth of the soil and soil material is very variable the soils are very shallow ranging in depth from less than 20cm to about 60cm, deeper soils occur only in isolated pockets (Vella). Using the Kubiena classification system, Maltese soils are of three main types:

- Terra Soils which are relic soils formed during the Pleistocene and which are little affected by the present climate. They are mature and extensively weathered, have a low calcium carbonate content, and are also low in organic matter. Terra soils develop on karstland;
- Xerorendzinas which are immature soils with a high calcium carbonate content and low in organic matter. These develop on weathered Globigerina Limestone and on valley deposits; and
- Carbonate Raw Soils which are also immature and which have a very high calcium carbonate content and are very low in organic matter. These develop on weathered quaternary sandstones, Greensand, the lower beds of the Upper Coralline Limestone, Blue Clay and on Globigerina Limestone.

Malta's agricultural sector is small; most farms are small and privately owned. The majority of the crops and foodstuffs produced are consumed domestically. The main crops are potatoes, cauliflower, grapes, wheat, barley, tomatoes, citrus, and green peppers. A lack of sufficient water and soil quality is believed to be an obstacle to large scale agricultural production. Areas of High Agricultural Value are shown on Drawing 282725-SK101 in Appendix B.

Areas of high agricultural value are identified in the Gozo and Comino Local Plan and shown in Figure 5.11 below.

Figure 5.11: Extract of areas of high agricultural value - Gozo



Source: MEPA

Woodland communities are extremely rare in the Maltese Islands and remnants of such ecosystems are found in only four localities: Il-Ballut tal-Wardija, Il-Ballut ta' L-Imgiebah, Wied Hazrun and Il-Bosk (Buskett) These woodlands are characterised by large evergreen trees that are adapted to the Mediterranean climate such as the Holm Oak (Quercus ilex) (Balluta) and the Aleppo Pine (Pinus halepensis) (Znuber).

All locations of portals on both Malta and Gozo are sited outside woodlands.

5.3.10 Marine users/Navigation

5.3.10.1 Commercial fisheries

The fishing industry in Malta is relatively small. More than 65% of landings by weight are taken up by large pelagic species. However, at local level, the social and cultural importance of fisheries far out weighs their economic output.

A Census of Fisheries was undertaken in 2006 to obtain information on the structure of the fisheries sector. Malta's fishing industry has transformed itself from one made up of artisanal fishing with a sale value of 4 million liri in 1996 to an industry with approximately 22 million liri in sales in 2005. Liri was the currency of Malta until 2008.

Fishing with nets and spears takes place in the area and is known within the Zona fil-Bahar fi-inhawi ta' Mgarr ix-Zini (Ghawdex) for catching large fish and cephalopods (Natura 2000 Data Sheet). Eleven marine fish species are listed as commercial fish by Fishbase in Malta (Fishbase, 2011), as shown in Table 5.9.

Table 5.9: Commercial marine fish in Malta (Fishbase, 2011)

Species	Status	Common name	Maltese name
Acantholabrus palloni	native	Scale-rayed wrasse	Tirda rara
Alopias vulpinus	native	Thresher	Pixxivolpi
Boops boops	native	Bogue	Vopa
Conger conger	native	European conger	Gringu
Epinephelus costae	native	Goldblotch grouper	Goldblotch grouper
Epinephelus marginatus	native	Dusky grouper	Cerna
Naucrates ductor	native	Pilot fish	Fanfru
Scorpaena scrofa	native	Red scorpionfish	Skorfna hamra
Sphyraena sphyraena	native	European barracuda	Lizz
Trachipterus trachypterus	native	Mediterranean dealfish	Fjamma
Zeus faber	native	John dory	Pixxi San Pietru

The aquaculture industry in Malta started in the late 1980s, with culture of marine finfish in offshore cages, one of which is located in the Comino channel. Production built up to a maximum of about 2000 t/year in the late 1990s, but fell to about 1000 t/year by 2000, with most farms switching to tuna penning operations. The production of Bluefin tuna (*Thunnus thynnus*) through penning has been increasing over the past few years. Maltese aquaculture produce is almost entirely exported to European and Asian markets.

5.3.10.2 Shipping and Navigation

Malta has three large natural harbours on its main island, these include the Grand Harbour in Valletta and Marsamxett Harbour in close proximity. The third is Marsaxlokk Harbour at Marsaxlokk on the south-eastern side of Malta and is the main cargo terminal.

There are two man-made harbours that serve the passenger and car ferry service that connects Cirkewwa Harbour on Malta and Mgarr Harbour on Gozo. The ferry operates daily, 24 hours a day. The terminal at the Grand Harbour serves ferries that connect Malta to Pozzallo & Catania in Sicily, these services run two times a week.

Malta is in the centre of Mediterranean shipping routes and so received traffic for supplies, transhipment, cargo, repair and bunkering (MMS Shipping Agency, 2011). Over 1,500 merchant vessels fly the Maltese flag.

According to 2005 data, Malta ranked as the 8th largest register in the world and the 2nd largest in Europe. There are over 100 shipping agents and brokers in Malta servicing shipping companies. They employ 3,000 workers full time (EU Maritime Policy).

Shipping and the associated economic benefits are important to the Maltese economy. Road tunnel options 1 and 2 are located several meters below the seabed, hence current shipping practises would not need to be altered. For the immersed tube option, local shipping may have to avoid the immediate vicinity of construction activities.

5.3.11 Tourism and recreation

Tourism is important to the economy of Malta and Gozo. The pressures associated with tourism when concentrated around festivals or holiday periods are more acutely felt in Gozo, particular as many Maltese travel to Gozo during these periods.

5.3.11.1 Diving

There are several diving schools and centres on both Malta and Gozo. A large number of scuba dive sites around the Maltese islands are used for viewing sea life and many ship and aeroplane wrecks (Aquatica, 2011a). There are various dive sites around the coast of Comino concentred on the caves; on Gozo near Mgarr Ix-Xini there are three wreck sites and a cave complex and on the north west of Malta, Paradise Bay, Ahrax Point and Cirkewwa Arch are all popular dive sites.

5.3.11.2 Bathing beaches

There are a number of designated bathing beaches under the Bathing Waters Directive and also undesignated swimming zones. These are along the northern coast of Malta, the northern coast of Comino and the southern coast of Gozo (MEPA, 2011b). Armier Bay is designated as a ‘protected beach’ by MEPA in the local plan due to importance as a tourist attraction. The start of the immersed tube tunnel, Option 3 is located in close proximity to Armier Bay (Figure 5.12).

Figure 5.12: Photograph of Armier Bay

Source: Mott MacDonald

5.3.11.3 Fishing

Shore fishing takes place in the Maltese islands from bays and piers. Sea bream, wrasse, comber, mullet and parrotfish are known to be caught. Offshore sea fishing also takes place around Malta and many fish including bonitos, barracudas, amberjacks and dentex are caught (Aquatica, 2011b).

5.3.11.4 Footpaths/cycling

The are several footpath and cycle routes on Malta and Gozo, most but not all are along existing arterial roads. On Malta, there is a footpath in close proximity to the location of the portal for Options 1 and 2.

5.3.12 Waste

Construction and demolition waste constituted approximately 85% of waste generated in Malta in 2000 (MEPA 2006).

Waste disposal sites on the islands of Malta and Gozo are very limited and mainly comprise of redundant quarry sites. Currently, there is only one offshore disposal site, in the sea off the north of Malta.

5.4 Assessment of Options

5.4.1 Introduction

The high level environmental review of the both the construction and operation of the three road tunnel options is summarised in the following tables. This high level of review is considered to be appropriate based on the current understanding of the feasibility of the tunnel options. The review outlines the main advantages and disadvantages associated with each route option.

Options under consideration are as follows:

- Option 1 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of Marfa Ridge on Malta and Route 2 west of Nadur on Gozo;
- Option 2 - A bored tunnel beneath Comino, the portals being on Route 1 on the southern slope of Marfa Ridge on Malta and near the junction of Route 2 and Route 110 north of Mgarr on Gozo; and
- Option 3 – An immersed tube tunnel option from the Armier Bay area of Malta to the vicinity of Hondoq-Ir-Rummien on Gozo.
- Option 4 - A bored tunnel beneath Comino, the portal being near Biskra in the Mellieha Bay Valley with a short connection to Route 1 on the northern slope of Mellieha Ridge on Malta, and near the junction of Route 2 and Route 110 north of Mgarr on Gozo;.

It has been assumed that the Island of Comino would remain undisturbed due to it's environmental sensitivity.

5.4.1.1 Potential environmental impacts

The construction and operation of a new road tunnel link between Malta and Gozo is likely to give rise to a number of environmental impacts. An impact can be described as something which causes environmental changes or effects. Impacts may be direct, such as the loss of habitat arising from land-take, or indirect, such as the disturbance experienced due to construction traffic travelling to the construction site. Impacts can be short, medium, long term or permanent. They may be negative, reducing the value of an environmental resource or positive, increasing its value.

Below is a summary of the key potential environmental impacts associated with a road tunnel link between Malta and Gozo:

- Improvement/reduction in air quality along the existing road network and/or at portal locations due to increased emissions from increased vehicles numbers and their distribution;
- Increase/decrease in noise levels at sensitive receptors along the existing road network and/or at portal locations due to increases in vehicles numbers and their distribution;
- Noise and vibration impacts resulting form the construction of the tunnel, particularly if blasting is the preferred construction methodology;
- Change in the landscape character and visual quality of the islands of Malta and Gozo due to the introduction of large engineering structures in a largely natural landscape;
- Unknown archaeological or cultural heritage assets may be uncovered;
- Loss and disturbance of important and protected natural habitats and the species they support, either on land or in the marine environment;
- Pollution or reduction in quality of surface water and/or groundwater;
- Changes to shipping and navigational practices, including commercial fisheries operations;
- Changes in the volume and distribution of tourism between Malta and Gozo, varying economic benefits to the local communities; and
- Indirect impacts associated with the requirement for the reprocessing/disposal of large volumes of waste rock materials (such as additional land take, noise, dust, additional traffic, impacts on the landscape, impacts on the marine environment).

The potential impacts identified could result from activities either during construction and/or operation. The construction impacts may only be temporary but the construction activities are estimated to last between 3 and 5 years, possibly up to 7 years. Construction related impacts could therefore be significant and potential disturbing for the local communities near the portal locations.

Tables 5.10 – 5.12 highlight the potential environmental impacts associated with each of the road tunnel options.

Table 5.10: Environmental Review for Option 1

Environmental topic	Advantages	Disadvantages	Comments
Noise	Traffic noise would be much reduced at the ferry terminals on both Malta and Gozo as people are likely to be more attracted towards the tunnel option rather than using the ferry.	During operation traffic and the associated noise levels are likely to increase along the main TEN–T network leading to the portal locations causing increased disturbance of residences and other sensitive receptors close to the road. Noise associated with increased numbers of HGV during construction is likely to be disturbing to nearby sensitive receptors. This is likely to be more of a concern if large volumes of waste rock materials are required to be hauled along the TEN-T network for disposal away from the portal locations.	Overall traffic numbers are expected to increase as the road tunnel would become a more attractive transport mode than the ferry. Overall increases in noise levels along the existing network are therefore likely. Detailed calculations would be necessary to fully understand if the noise levels would increase above guidance levels during the operational phase. Construction noise (from equipment/ site compound/welfare facilities and rock materials reprocessing) may be a concern at the portal locations for nearby tourists using the beaches, hotels and local residents.
Air quality	Vehicle queuing at the ferry terminals is likely to be reduced overall – improvements in air quality associated with vehicle emissions may improve.	Ventilation of the tunnel at the portals is likely to give rise locally to increased traffic related air pollutants. Increase in overall volume of vehicle movements along the TEN–T network are predicted with the operation of a road tunnel. Indirect effects on flora and fauna, particularly those located adjacent to roads where there is a increase in the overall traffic numbers – locations include Ghadira Nature Reserve. Disturbances and generation of dust from construction activities.	Increased emissions associated with vehicle traffic including carbon dioxide, benzene, nitrogen and carbon monoxide and particulates may make it more difficult for Malta to meet its air quality targets.
Landscape	The location of the portal on the southern side of Marfa ridge on Malta helps to reduce the visual impact on the north Malta coastline. The portal location is located outside the areas identified as high landscape value.	Portal locations, partially the one on Gozo would be very visible on the hill side and falls within a designated area of high landscape quality.	All portal locations are all located on existing major roads to minimise the amount of new road to be created and the associated visual impacts.
Archaeology and cultural heritage	Any possible prehistoric deposits or artefacts on the seabed would remain undisturbed. Portal locations are located away from known archaeological and world heritage sites on both Malta and Gozo.		Unknown sites may be uncovered.

Environmental topic	Advantages	Disadvantages	Comments
Biodiversity (terrestrial)	Less terrestrial land take associated with the bored (D&B) tunnel options.	Portal location is very close to the Natura 2000 sites and to the Ghadira Nature Reserve, a designated Ramsar site. Potential disturbance to bird colonies is likely from construction activities and additional traffic movements associated with the operation of the tunnel. Potential habitat loss at portal locations due to control building and changes to the highway layout. Additional artificial lighting creating hazard to seabirds and adverse effects on bats.	Potential direct and indirect impacts on the Ramsar site and on the Natura 2000 sites are likely to require further more detailed studies and assessment.
Biodiversity (marine)	Seabed remains undisturbed by the tunnel construction therefore no impacts are envisaged.	Substantial volumes of waste rock will require disposal, this may be at sea.	No direct impacts are envisaged as a result of options 1 and 2, although disposal at sea may adversely impact upon marine biodiversity, depending on the location of the disposal site.
Water resources		Tunnel would be partially located/pass through the aquifer. The portal on Gozo is located within a drinking water safeguard zone.	Design and construction of the tunnel would need to consider the aquifer, generally this would be a fully water tight tunnel. A construction of drill and blast tunnel may be difficult within the aquifer.
Journey ambiance	The stresses associated with queuing and missing a ferry should be reduced.	When comparing to the existing journey ambiance on the passenger ferry the road tunnel option traveller views are likely to change significantly. Likely to be some adverse impacts to journey ambience due to frustration, fear of potential accidents and route uncertainty.	Similar for all road tunnel options, although Option 1 is a slightly longer tunnel than Option 2.
Land Use	On Gozo the portal location is located in an area identified as of high agricultural value.	Land take will be required at each of the portal locations for the supporting infrastructure such as tunnel service buildings. Temporary land take will be also necessary for the site construction offices, site compounds and material storage etc.	
Marine users / navigation	Location of the portals on land and the tunnel below the seabed will not affect the marine environment and marine users. No collision risk to marine traffic is predicted.		Unknown sites may be uncovered during construction.

Environmental topic	Advantages	Disadvantages	Comments
Tourism and recreation	The road tunnel link will improve access between the two islands, potentially improving the transfer of tourism between Gozo and Malta. No impact on known dive sites as the seabed would not be disturbed. May promote an increase in tourism on Gozo.	The portal location on Malta is close to Mellieha Bay, this area is a popular tourist beach. Construction of the portal is likely to make the beach areas less attractive for tourists.	
Waste		Construction of the tunnel will generate a significant volume of rock material, which will require reuse or disposal.	Waste materials generated during the construction of option 1 or 2 would mainly be composed of limestone. The materials may be usable raw materials similar to that within the limestone extraction industries. Disposal on land is unlikely due to the limited availability of landfill sites. Disposal at sea is therefore a more realistic solution.

Summary of Option 1

The environmental review of Option 1 has highlighted the potential for adverse offsite air quality and noise impacts along the existing road network on both Malta and Gozo, associated with the additional volumes of traffic crossing between Malta and Gozo during the operational phase of the road tunnel link. The position of the portal on Gozo is in an area of high landscape value, measures to minimise and mitigate adverse impacts on landscape character and visual impacts would be necessary. The portal location on Malta is in a very cluttered area; with holiday homes, the beach and associated hotels, the Ghadira Nature Reserve and the Forest 2000 site are all in close proximity to the proposed portal location. During the construction phase at the portal location on Malta the construction activities may make the Mellieha Bay beach area less attractive for tourists, adversely affecting the tourist industry in this location. Careful consideration would also need to be given when identifying areas of land for construction site compounds at each portal location. Direct land take from the Ghadira Nature Reserve, a Ramsar site, and from other Natura 2000 sites may be required at the portal location. Potential impacts on Natura 2000 sites are likely to require an appropriate assessment under the EU Habitats Directive.

Table 5.11: Environmental Review for Option 2

Environmental topic	Advantages	Disadvantages	Comments
Noise	Traffic noise would be much reduced at the ferry terminals on both Malta and Gozo as people are more likely to be attracted towards using the tunnel option rather than the ferry.	During operation traffic and the associated noise levels are likely to increase along the main TEN–T network leading to the portal locations causing increased disturbance of residences and other sensitive receptors close to the road. Noise associated with increased numbers of HGV during construction is likely to be disturbing to nearby sensitive receptors. This is likely to be more of a concern if large volumes of waste rock materials are required to be hauled along the TEN-T network for disposal way from the portal locations.	Overall traffic numbers are expected to increase as the road tunnel would be a more attractive transport mode than the ferry. Overall increases in noise levels along the existing network are therefore likely. Detailed calculations would be necessary to fully understand if the noise levels would increase above guidance levels during the operational phase. Construction noise (from equipment/ site compound/welfare facilities and rock materials reprocessing) may be a concern at the portal locations for nearby tourists using the beaches, hotels and local residents.
Air quality	Vehicle queuing at the ferry terminals is likely to be reduced overall – improvements in air quality associated with vehicles emissions may improve.	Ventilation of the tunnel at the portals is likely to give rise locally to increased traffic related air pollutants. Increase in overall volume of vehicle movements along the TEN–T network are predicted with the operation of a road tunnel. Indirect effects on flora and fauna, particularly those located adjacent to roads where there is a increase in the overall traffic numbers – locations include Ghadira Nature Reserve. Disturbances and generation of dust from construction activities.	Increased emissions associated with vehicle traffic including carbon dioxide, benzene, nitrogen and carbon monoxide and particulates may make it more difficult for Malta to meet its air quality targets.
Landscape	The location of the portal on the southern side of Marfa ridge helps to reduce the visual impact on the north Malta coastline. The portal location on Malta is located outside the areas identified as high landscape value.	Portal locations on Gozo would be prominent on the hill side and fall within a designated area of high landscape quality. Although overall impact less than for option 1 as there is some vegetation screening on the hill side.	All portal locations are all located on existing major roads to minimise the amount of new road to be created and the associated visual impacts.
Archaeology and cultural heritage	Any possible prehistoric deposits or artefacts on the seabed would remain undisturbed. Portal locations are located away from known archaeological and world heritage sites on both Malta and Gozo.		Unknown sites may be uncovered.

Environmental topic	Advantages	Disadvantages	Comments
Biodiversity (terrestrial)	This option avoids the most sensitive designated nature conservation sites. The amount of land take would be the same or very similar to Option 1.	On Malta the portal location is very close to two Natura 2000 sites and to the Ghadira Nature Reserve a designated Ramsar site. Potential disturbance to bird colonies. Potential habitat loss at portal locations due to control building and changes to the highway layout. Additional artificial lighting may create a hazard to seabirds and adverse effects on bats.	Potential direct and indirect impacts on the Ramsar site and on the Natura 2000 sites are likely to require further more detailed studies and assessment.
Biodiversity (marine)	Seabed remains undisturbed both during construction and operation and therefore no impacts are envisaged.	Substantial volumes of waste rock will require disposal, this may be at sea.	No impacts are envisaged as a result of this bored tunnel option, although disposal at sea may adversely impact upon marine biodiversity, depending on the location of the disposal site.
Water resources		Tunnel would be partially located/pass through the aquifer. The portal on Gozo is located within a drinking water safeguard zone.	Design and construction of the tunnel would need to consider the aquifer, generally this would be a fully water tight tunnel. A construction of drill and blast tunnel may be difficult within the aquifer.
Journey ambiance	The stress associated with queuing and missing a ferry should be reduced.	When comparing to the existing journey ambiance on the passenger ferry the road tunnel option traveller views are likely to change significantly. Likely to be some adverse impacts to journey ambience due to frustration, fear of potential accidents and route uncertainty.	Similar for all road tunnel options although Option 2 is a slightly shorter tunnel than Options 1 and 4.
Land Use	On Gozo the portal location is located in an area identified as of high agricultural value.	Land take will be required at each of the portal locations for the supporting infrastructure such as tunnel service buildings. Temporary land take will be also necessary for the site construction offices, site compounds and material storage etc.	Full and appropriate reinstatement of temporary land take areas should ensure all soils are retained.
Marine users / navigation	Location of the portals in land and the tunnel below the seabed will not affect the marine environment and marine users. No collision risk to marine traffic.		
Tourism and recreation	The road tunnel link will improve access between the two islands, potentially improving the transfer of tourism between Gozo and Malta.	The portal location on Malta is close to Mellieha Bay, this area is a popular tourist beach. Construction of the portal is likely to make the beach areas less attractive for tourists.	

Environmental topic	Advantages	Disadvantages	Comments
	No impact on known dive sites is predicted as the seabed would not be disturbed.		
Waste		Construction of the tunnel will generate a significant volume of rock material, which will require reuse or disposal.	Waste materials generated during the construction of either of the bored tunnel options would mainly be composed of limestone. The materials may be usable raw materials similar to that within the limestone extraction industries. Disposal on land is unlikely due to the limited availability of land fill sites. Disposal at sea is therefore a more realistic solution.

Summary of Option 2

The environmental review of Option 2 has highlighted the potential for adverse offsite air quality and noise impacts along the existing road network on both Malta and Gozo, associated with the additional volumes of traffic crossing between Malta and Gozo during the operational phase of the road tunnel link. These impacts would be very similar for both options 1 and 2. The portal location on Malta is in a very cluttered area; with the holiday homes, the beach and associated hotels, the Ghadira Nature Reserve and the Forest 2000 site, all are in close proximity to the proposed portal location. Again, this is comparable to option 1. Direct land take from the Ghadira Nature Reserve, a Ramsar site, and from other Natura 2000 sites may be required at the portal location. Potential impacts on Natura 2000 sites are likely to require an appropriate assessment under the EU Habitats Directive.

Table 5.12: Environmental Review for of Option 3

Environmental topic	Advantages	Disadvantages	Comments
Noise	Traffic noise would be much reduced at the ferry terminals on both Malta and Gozo as people are likely to be attracted towards the tunnel option.	Traffic and the associated noise levels are likely to increase along the main TEN–T network leading to the portal locations causing an increase in disturbance to residences close to the road. The location of the portal at Armier Bay is particularly sensitive to noise as the area is a popular beach resort.	Overall traffic numbers are expected to increase as the road tunnel would be a more attractive transport mode than the ferry. Overall increases in noise levels along the existing network are therefore likely. Detailed calculations would be necessary to fully understand if the noise levels would increase above guidance levels during the operational phase. Construction noise may be a concern at the portal locations for nearby tourists using the beaches, hotels and local residents.
Air quality	Vehicle queuing at the ferry terminals is likely to be reduced overall – improvements in air quality associated with vehicles may improve.	Ventilation of the tunnel at the portals is likely to give rise locally to increased traffic related air pollutants. Increase in overall volume of vehicle movements along the TEN–T network are predicted with the operation of a road tunnel. Indirect effects on flora and fauna, particularly those located adjacent to roads where there is a increase in the overall traffic numbers – locations include Ghadira Nature Reserve. Disturbances and generation of dust from construction activities.	Increased emissions associated with vehicle traffic including carbon dioxide, benzene, nitrogen and carbon monoxide and particulates may make it more difficult for Malta to meet its air quality targets.
Landscape		Both portal locations would be prominent creating substantial changes in the existing landscape character in the short to medium term due to the cut and cover works. Building sections of the immersed tube would require additional land take in close proximity to the roads and the sea the visual impact of this construction could be significant.	Extensive cut and cover works and deep cuttings would be required through the steep cliffs on Gozo. Screening and/or design of the portal would be required to make the portal more in keeping with the landscape setting. Building sections of the immersed tube would require additional land take in close proximity to the roads and the sea. The visual impact of this construction could be significant.
Archaeology and cultural heritage	Any possible prehistoric deposits or artefacts on the seabed would remain undisturbed. Portal locations are located away from known archaeological and world heritage sites on both Malta and Gozo.		Unknown sites may be uncovered.

Environmental topic	Advantages	Disadvantages	Comments
Biodiversity (terrestrial)		Large land take requirements particularly for the cut and cover works potentially resulting in habitat loss and fragmentation. Potential disturbance to seabird colonies using Natura sites located adjacent to the TEN-T network. Additional artificial lighting may create a hazard to seabirds and adverse effects on bats.	Indirect impacts on Natura 2000 sites may require an appropriate assessment under the EU Habitats Directive.
Biodiversity (marine)		Significant physical disturbance to the seabed during the construction of the immerse tube which could result in significant adverse effects such as habitat degradation, decrease in water quality and increase in noise and vibration on internationally designated sites, habitats, flora and fauna. Permanent loss of marine habitat (Posidonia beds) and the supporting benthic communities are likely with this option.	Seabed and associated marine habitats are internationally protected. Direct effects on Natura 2000 sites require an appropriate assessment and mitigation measures to be implemented. Compensatory measure may also be necessary.
Water resources		Cut and cover tunnel would be partially located/pass through the aquifer. The portal on Gozo is located within a drinking water safeguard zone.	Design and construction of the cut and cover tunnel would need to consider the aquifer and the drinking water safeguard zone.
Journey ambiance	The stresses associated with queuing and missing a ferry should be reduced.	When comparing to the existing journey ambiance on the passenger ferry the road tunnel option traveller views are likely to change significantly. Likely to be some adverse impacts to journey ambience due to frustration, fear of potential accidents and route uncertainty.	Similar for all road tunnel options – Option 3 is a shorter tunnel but has longer link roads connecting to the existing road network.
Land Use		High value agricultural land would be lost as a result of the cut and cover working method. Land take will be required at each of the portal locations for the supporting infrastructure such as tunnel service buildings. Temporary land take will be also necessary for the site construction offices, site compounds and material storage etc.	Full and appropriate reinstatement of temporary land take areas should ensure all soils are retained.

Environmental topic	Advantages	Disadvantages	Comments
Marine users / navigation	May impact on commercial fisheries as there is a fish fattening cage located within the Comino channel in close proximity to this option. No collision risk to shipping is predicted as the tube would be covered.	Location of the portals on land and the tunnel above the seabed could potentially affect the marine environment and marine users during construction and operation.	
Tourism and recreation	The road tunnel link will improve access between the two islands, potentially improving the transfer of tourism between Gozo and Malta. No impact on known dive sites is predicted as the seabed would not be disturbed in the vicinity of the known dive sites.	Significant impacts are likely at Armier Bay, a popular beach resort. The beach at Armier Bay is a protected beach, an immersed tube in this location would be significant degradation to the quality of the beach area for tourism and recreational activities.	
Waste	Little waste rock materials will be generated; it is likely the seabed material would be locally redistributed naturally by sea currents.		Disposal of rock materials is less of a concern with this option as the volumes involved are small in comparison to the other options.

Summary of Option 3

Based on the level of engineering detail currently presented, the construction of an immersed tube tunnel through a marine Natura 2000 site is likely to cause substantial disturbance of the seabed and damage to protected habitats and their benthic communities. An immersed tube tunnel is likely to adversely affect the integrity of a European designated site, although in the long term re-vegetation of the listed features (i.e. seagrass) may occur.

In addition the cut and cover tunnels required on land at each of the portals would cause disturbance to the local community, particularly at Armier Bay where the setting and quality of the protected beach is likely to change. One advantage of this option is that there is the expectation that less volume of waste rock material would be generated during the construction activities that would require later reuse or disposal. Other main factors separating this option from the others is a requirement for suitable locations for the construction of sections of immersed tube tunnel sections, and the significant environmental impact of changes to the existing road network and associated structures on the Gozo and Malta sides of the channel, particularly the 2.5km link road on Gozo, and a link road potentially across agricultural land on Malta.

Table 5.13: Environmental Review for of Option 4

Environmental topic	Advantages	Disadvantages	Comments
Noise	Traffic noise would be much reduced at the ferry terminals on both Malta and Gozo as people are more likely to be attracted towards using the tunnel option rather than the ferry.	During operation traffic and the associated noise levels are likely to increase along the main TEN–T network leading to the portal locations causing increased disturbance of residences and other sensitive receptors close to the road. Noise associated with increased numbers of HGV during construction is likely to be disturbing to nearby sensitive receptors. This is likely to be more of a concern if large volumes of waste rock materials are required to be hauled along the TEN-T network for disposal way from the portal locations.	Overall traffic numbers are expected to increase as the road tunnel would be a more attractive transport mode than the ferry. Overall increases in noise levels along the existing network are therefore likely. Detailed calculations would be necessary to fully understand if the noise levels would increase above guidance levels during the operational phase. Construction noise (from equipment/ site compound/welfare facilities and rock materials reprocessing) may be a concern at the portal locations for nearby tourists using the beaches, hotels and local residents.
Air quality	Vehicle queuing at the ferry terminals is likely to be reduced overall – improvements in air quality associated with vehicles emissions may improve.	Ventilation of the tunnel at the portals is likely to give rise locally to increased traffic related air pollutants. Increase in overall volume of vehicle movements along the TEN–T network are predicted with the operation of a road tunnel. Indirect effects on flora and fauna, particularly those located adjacent to roads where there is a increase in the overall traffic numbers – locations include Ghadira Nature Reserve. Disturbances and generation of dust from construction activities.	Increased emissions associated with vehicle traffic including carbon dioxide, benzene, nitrogen and carbon monoxide and particulates may make it more difficult for Malta to meet its air quality targets.
Landscape	The location of the portal on the southern side of Marfa ridge helps to reduce the visual impact on the north Malta coastline. The portal location on Malta is located outside the areas identified as high landscape value.	Portal locations on Gozo would be prominent on the hill side and fall within a designated area of high landscape quality. Although overall impact less than for option 1 as there is some vegetation screening on the hill side.	All portal locations are all located on existing major roads to minimise the amount of new road to be created and the associated visual impacts.
Archaeology and cultural heritage	Any possible prehistoric deposits or artefacts on the seabed would remain undisturbed. Portal locations are located away from known archaeological and world heritage sites on both Malta and Gozo.		Unknown sites may be uncovered.

Environmental topic	Advantages	Disadvantages	Comments
Biodiversity (terrestrial)	This option avoids direct impacts on the most sensitive designated nature conservation sites. The amount of land take would be the same or very similar to other options.	On Malta the portal location is very close to two Natura 2000 sites and to the Ghadira Nature Reserve a designated Ramsar site. Potential disturbance to protected bird colonies. Potential habitat loss at portal locations due to control building and changes to the highway layout. Additional artificial lighting may create a hazard to seabirds and adverse effects on bats.	Potential direct and indirect impacts on the Ramsar site and on the Natura 2000 sites are likely to require further more detailed studies and assessment.
Biodiversity (marine)	Seabed remains undisturbed both during construction and operation and therefore no impacts are envisaged.	Substantial volumes of waste rock will require disposal, this may be at sea.	No impacts are envisaged as a result of this bored tunnel option, although disposal at sea may adversely impact upon marine biodiversity, depending on the location of the disposal site.
Water resources		Tunnel would be partially located/pass through the aquifer. The portal on Gozo is located within a drinking water safeguard zone. The tunnel passes underneath the Natura 2000 sites and the Ghadira Nature.	Design and construction of the tunnel would need to consider the aquifer, generally this would be a fully water tight tunnel. A construction of drill and blast tunnel may be difficult within the aquifer. Design of the tunnel underneath the Natura 2000 sites and the Ghadira Nature will need to ensure that water levels within theses protected sites can be maintained to ensure the habitat remains suitable to support the bird colonies.
Journey ambiance	The stress associated with queuing and missing a ferry should be reduced.	When comparing to the existing journey ambiance on the passenger ferry the road tunnel option traveller views are likely to change significantly. Likely to be some adverse impacts to journey ambience due to frustration, fear of potential accidents and route uncertainty.	Similar for all road tunnel options although Option 4 is a slightly longer tunnel than Option 2.
Land Use	On Gozo the portal location is located in an area identified as of high agricultural value.	Land take will be required at each of the portal locations for the supporting infrastructure such as tunnel service buildings. Temporary land take will be also necessary for the site construction offices, site compounds and material storage etc.	Full and appropriate reinstatement of temporary land take areas should ensure all soils are retained.
Marine users / navigation	Location of the portals in land and the tunnel below the seabed will not affect the marine environment and marine users. No collision risk to marine traffic.		

Environmental topic	Advantages	Disadvantages	Comments
Tourism and recreation	The road tunnel link will improve access between the two islands, potentially improving the transfer of tourism between Gozo and Malta. No impact on known dive sites is predicted as the seabed would not be disturbed. The portal location on Malta is away from Mellieha Bay, when compared to options 1 and 2, this area is a popular tourist beach.	Disturbance during construction is likely to impact on the tranquil holiday designations near the proposed portal location on Malta.	
Waste		Construction of the tunnel will generate a significant volume of rock material, which will require reuse or disposal.	Waste materials generated during the construction of either of the bored tunnel options would mainly be composed of limestone. The materials may be usable raw materials similar to that within the limestone extraction industries. Disposal on land is unlikely due to the limited availability of land fill sites. Disposal at sea is therefore a more realistic solution.

Summary of Option 4

The environmental review of Option 4 has highlighted the potential for adverse offsite air quality and noise impacts along the existing road network on both Malta and Gozo, associated with the additional volumes of traffic crossing between Malta and Gozo during the operational phase of the road tunnel link. The portal location on Malta is away from the Mellieha Bay beach area and associated hotels, although disturbance during construction to these tourist spots is still likely, although less that that associated with Options 1 and 2 on Malta. The tunnel goes underneath the Ghadira Nature Reserve and the portal entrance is in close to the Reserve boundary. Direct land take from the Ghadira Nature Reserve, a Ramsar site, and from other Natura 2000 sites are unlikely, although noise disturbance to birds and other wildlife is likely during construction. The design and construction of the tunnel underneath the Natura 2000 sites and the Ghadira Nature Reserve will need to ensure that water levels within theses protected sites can be maintained to retain the habitat suitable to support the bird colonies. Potential impacts on Natura 2000 sites are likely to require an appropriate assessment under the EU Habitats Directive. Link roads to join into the existing network will need to cross agricultural land.

5.5 Typical Mitigation Measures

A series of typical mitigation measures are outlined below to reduce the potential impacts associated with the types of road tunnel options considered in this environmental review.

5.5.1 Avoidance Measures/Design

Avoidance is always a key factor in minimising significant environmental effects. Specific measures should be identified early in a project development to avoid adverse impacts. For example, an option that minimises disturbance to the marine environment, that is, a bored tunnel rather than an immersed tube tunnel would be preferable. However, should the immersed tube tunnel be selected then the specific route should aim to avoid highly sensitive areas.

5.5.2 General Mitigation Measures

It is unclear at the present time which construction methods would be adopted therefore a series of general mitigation measures are proposed; these include:

Noise:

- Integrate noise barriers (if required) with visual screening and landscaping proposals;
- Implement measures to minimise the movement of construction vehicles;
- Restrict working hours to mitigate the potential noise related impacts at sensitive receptors; and
- Keep construction traffic to a minimum, particularly during the night.

Air Quality:

- Ensure compliance with EU air quality standards;
- Reduce the risks and effects of dust by using water as a dust suppressant; and
- No loads entering or leaving site uncovered.

Landscape:

- Minimise the size of the construction areas;
- Temporarily screen long term site compounds and storage areas;
- Avoid areas of high landscape value; and
- Design above ground structures to minimise visual intrusion including the incorporation of soft screening (i.e. planting).

Archaeology and cultural heritage:

- Avoid direct physical impact, land take or severance to known features, sites of archaeological and historic interest; and
- Development of a written scheme of investigation to set out the design and implementation of mitigation with regard to any known sites and any as yet undiscovered sites or materials encountered.

Tourism and recreation:

- Minimise the loss of cycleways, footpath and public open space;
- Specify working practices and traffic management measures to minimise local disturbance (i.e. maintain existing accesses and traffic movements); and
- If possible avoid particularly noisy or disturbing construction activities during the main tourist periods.

Biodiversity:

- Promote nature conservation within landscaping proposals, with the aim to strengthen and extend existing habitats and increase the overall diversity of species;
- Construction techniques would be adopted that minimise the mobilisation of sediments (in the sea) and the footprint of the trench and minimise water quality and ecological impacts (Option 3 only);
- Sediment dispersion would be limited by selecting the most appropriate dredging rate and timing during tidal cycles (e.g. excavation during the ebb tide) (Option 3 only);
- Construction materials would be carefully selected so as to minimise potential environmental impact where possible;
- Wherever possible construction works would avoid highly sensitive areas and minimise the amount of land / sea take;
- Good practice measures may be required to minimise potential impacts to marine mammals, some of these include (Option 3 only);
  - Produce an agreed mitigation protocol which could include the employment of a qualified Marine Mammal Observer (MMO);
- Wherever possible construction works should aim to minimise noise levels;
- Noisy works should avoid sensitive times when sensitive marine mammals and other species are usually engaged in susceptible activities such as mating, breeding, calving, pupping, feeding and / or migration. Should this not be possible because of changes in the programme becoming uneconomic, alternative methods should be considered if appropriate (Option 3 only);
- Avoid impacts on designated and protected sites such as Natura 2000 sites; and
- Design the scheme to minimise the amount of land take.

Water:

- Control discharges for the road and tunnel to avoid surface and ground water pollution;
- Impacts on water quality would be minimised through use of good construction practices; and
- Installation of preconstruction drainage.

Land use:

- Minimise the extent of permanent and temporary landtake and disruption to commercial activities;
- Ensure that soils are stripped, handled, stored and reinstated using best practice procedures; and
- Ensure procedures are in place to ensure contaminated soils if encountered during construction are dealt with appropriately.

Waste:

- Development of waste minimisation strategy including how soils and other materials are managed on site and also reused / disposed of off site.

5.5.3 Construction Environmental Management Plan

To implement and effectively manage environmental issues during the construction period, it is essential that Construction Environmental Management Plan (CEMP) is prepared. A CEMP would set out the following:

- Roles and responsibilities for environmental management;
- The regime for regular environmental monitoring visits both on site and off site;
- Requirements for record keeping;
- The approach to construction waste management;
- Arrangements for formal auditing for environmental compliance;
- Communications procedure for discussions with relevant authorities and the public; and
- Procedure for the responses to environmental incidents.

A CEMP should also describe the control measures that should be implemented to eliminate or reduce the potential environmental impacts.

5.6 Environmental Constraints and Recommendations

Any future development of a road tunnel link between Malta and Gozo should consider the following constraints and recommendations.

5.6.1 Strategic Environmental Assessment (SEA) requirements

The Strategic Environmental Assessment Directive 2001/42/EC requires the assessment of the effects of certain plans and programmes on the environment. It requires environmental effects to be taken into account by authorities during the preparation of plans and programmes in the fields of land-use, transport, waste and water management, energy, and a range of other sectors. Consideration should be given to the need to undertake an SEA associated with the improvement of the infrastructure links between Malta and Gozo.

5.6.2 Environmental Planning Statement

All road tunnel options considered in the report would require the preparation of Environmental Planning Statement (EPS) or Environmental Statement. It is highly likely that any option to link Gozo with Malta would require an EPS.

5.6.3 Assessment of plans and projects significantly affecting Natura 2000 sites

In accordance with Article 6 paragraphs (3) of the Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) an appropriate assessment is required where a plan (or project) not directly connected with or necessary to the management of the site may give rise to significant effects upon a Natura 2000 site (SAC/SCI/SPA). An appropriate assessment (Stage 1

Screening) will be required as a result of the proximity of the all three option routes to Natura 2000 sites. Subsequent stages may be required if the conclusions of the Stage 1 Screening indicates significant effects upon a Natura 2000 site(s) or that there is insufficient data to be able to make a conclusion whilst applying the precautionary principle. Stage 2 may require extensive survey work and data collection. In the event Stage 2 concludes that there will be significant effects upon a Natura 2000 site then in accordance with Article 6 paragraphs (4) alternative solutions, imperative reasons of overriding public interest, compensatory measures, overall coherence and the opinion of the European Commission will need to be addressed. Should any option likely to adversely affect the integrity of a Natura 2000 site substantial further environment assessment would be required, as well as clear and logical reasoning as to why this was the only alternative.

5.6.4 Carbon and Climate Change

Climate change issues have risen up the national and international agenda over recent years. It is now widely accepted that emissions of greenhouse gasses must be reduced to reduce the contribution to climate change. Emissions from the domestic transport sector have grown over the past two decades due to the increasing numbers of cars being used and despite progress in reducing emissions from vehicle emissions. It is recommended that carbon emissions and climate change considerations – covering the life cycle of the project from design, construction, operation to dismantling and/or refurbishment – form an integral part of any future project development.

5.6.5 Public and stakeholder engagement

Consultation should form part of the project development. It will be important to fully understand the different interests and stakeholders, and depending on their location in relation to the project the concerns and issues raised are likely to differ. Public and stakeholder engagement during the feasibility and preferred option development will be essential to identifying, managing and minimising the environmental and social impacts of the project and ensuring the project gains relevant approvals to proceed to the construction phase.

5.6.6 Social Impact Assessment

Social impact assessment is a systematic process for identifying and managing the effects of infrastructure projects on local communities, and is increasing a requirement of private investors (through the Equator Principles) and donor organisations.

Key social issues are likely to include the effects of improved accessibility and reduced journey times on communities in both Malta and Gozo, including economic development benefits, tourism, access to education and access to healthcare. The direct benefits of generating employment during the construction phase would also be considered. The views of stakeholders and communities (captured through consultation and engagement) are collated and analysed as part of the assessment.

The options for transport linkages will contribute to socio-economic objectives in different ways and future project development should consider the differential performance of each option.

5.6.7 Health Impact Assessment

The effects of infrastructure projects on human health can be formalised into established assessment frameworks. Human health can be considered as part of Strategic Environmental Assessment or Social Impact Assessment.

If more detailed examination is required, Health Impact Assessment (HIA) is an effective and efficient way to ensure that the direct and indirect implications for human health are addressed. The World Health Organisation sets out processes and standards relevant to transportation projects and quantitative, qualitative and participatory techniques for assessment.

HIA aids decision-makers when making choices about alternatives and enhancements for health protection and health improvement.

5.6.8 Construction methodology and materials

Depending on the final selection of the road tunnel link option and the construction methodology differing volumes of waste rock material would be produced by the construction of a tunnel. It will be important to fully understand and investigate the reuse options for the waste rock materials. Should reuse of the materials not be feasible due to environmental, cost or engineering reasons then disposal opportunities need to be considered including disposal on land and at sea. There are a few small existing disposal sites on land, however should substantial amounts of the waste require disposal at sea new sites may have to be identified. Any future environmental assessment should consider in detail the environmental impacts associated with reprocessing and transport of waste/rock and its disposal either at sea or on land. If large quantities of rock material requires haulage along the existing road network this could give rise to significant adverse environmental effects. Alternatives to haulage by land should be considered such as conveyer belts direct into barges prior to disposal at sea.

5.6.9 Utilities, services and road alignment changes

The scope of this environmental review is preliminary and therefore it is difficult to fully understand the potential impacts associated with the ancillary infrastructure such as service buildings, impounding sumps, drainage systems, energy provision, safety infrastructure as road alignment changes that would be required as part of the overall design for a road tunnel and associated link roads. Hence, further more detailed studies should include an environmental assessment of these aspects, which would allow a more complete understanding of the overall environmental impact of the proposal.

5.6.10 Temporary land take during construction

Further environmental studies are required once the requirements for temporary land take for site compounds, storage of rock materials and other construction related equipment are known as this could cause significant environmental impacts particularly on Malta where the portal location for Options 1 and 2 are within an already ‘cluttered’ area. A detailed environmental impact assessment of a preferred option would need to fully consider the impacts associated with temporary land take during construction.

5.6.11 Revegetation /translocation of seagrass

Seagrass assemblages are naturally very dynamic and both spread and contract at significant rates due to natural events. The reestablishment and translocation of terrestrial habitat is a well-established technique, however, it is relatively new in the marine environment. The reestablishment of seagrasses is now being actively investigated at a number of sites around the world, methods are being developed and continually improved.

The most important factors for seagrass reestablishment include water quality and depth, light levels and sediment chemistry. Seagrass revegetation is perceived as a management tool for the future rather than an experimental endeavour, however the success rate of many re-vegetation projects still remains low (Fonseca et al., 1998).

Assuming conditions were suitable, it is likely that in the relative short term (5-10 years) seagrass would expand to cover areas of disturbed seabed, however it would be a significantly longer period of time before the associated benthic communities would return to allow a fully function marine ecosystem.

Further research and investigation would be required to understand if seagrass reestablishment would be considered to be a viable option in the seas between Malta and Gozo. Careful planning and effective implementation of any reestablishment project will be required to achieve successful seagrass revegetation.

6. Key Issues and Conclusions

6.1 Summary of key issues

The feasibility of tunnelling options is highly dependent on geological and technical conditions. Because of the high cost per metre length of a tunnel, the tunnel should be as short as possible for economic reasons. For bored tunnel options, a single-bore would be feasible, and less expensive than dual tunnels, but also less safe. For immersed tube options, the environmental impact of construction is within a Marine Natura 2000 site, and whether this is acceptable has to be considered. The construction stage for a tunnel would be approximately 5-7 years which includes 1 year initial procurement and site set up, 3-5 years tunnel construction, and 1 year mechanical and electrical testing and commissioning. Prior to construction there would be a need to identify other options for linking the islands, selecting the most appropriate option, preliminary design and a variety of surveys.

6.1.1 Economics and Traffic Forecasts

The key points from the economic assessment may be summarised as follows:

- Between 2000 and 2010 the number of vehicles crossing the channel between Malta and Gozo has increased at 4.1% per annum and the number of people crossing the channel has increased at 2.8% per annum. In 2010 there were 1,500 vehicles/day/direction and 5,500 people/day/direction;
- The proposed tunnel is likely to reduce average journey times between the islands of Gozo and Malta by at least 40 minutes;
- Indicative traffic and revenue forecasts for the proposed tunnel have been developed based on the growth in GDP, number of cars and number of tourists;
- Base case forecasts assuming a similar level of toll to the ferry are 2,700 vehicles/day/direction in 2021 rising to 6,400 vehicles/day/direction in 2051. The tunnel increases traffic by about 25% compared to traffic levels without a fixed link. Without a toll on the tunnel the traffic levels would be 34-43% higher than the levels with a similar toll to the tunnel.
- Toll revenue (2011 prices including VAT) would be in the range €13-23m in 2021 increasing to €32-68m in 2051, depending on the toll rate that is set for the tunnel;
- High growth forecasts have been calculated and are 3,400 vehicles/day/direction in 2021 increasing to 9,200 vehicles/day/direction if the toll is set at a similar level to the ferry. Without a toll traffic would exceed 10,000 vehicles/day/direction in 2041;
- The effect on the current ferry service is likely to be high if a tunnel is built;
- The tunnel would also have a wider socio-economic impact which includes the benefits to business of faster and more reliable journey times between Malta and Gozo, benefits to the Gozo economy of more visitors to the island and Gozo being perceived as a more attractive place to live and work; and
- More robust forecasts would require surveys to be carried out to determine the times of travel, trip purposes, vehicle occupancies, route choice preferences and the willingness to pay tunnel tolls. The impacts on the local and national road networks also needs to be fully considered.

6.1.2 Tunnelling and Geotechnical

The key points from the tunnelling assessment may be summarised as follows:

- There is potentially extensive rock faulting in north Malta and south Gozo and in the channel between and this may be more extensive than shown on the geological maps. It is possible that some fault zones remain active. The Upper Coralline Limestone Formation is prone to karsts (underground caves). Karstic formations in the Globigerina and Lower Coralline Limestone formations are less likely, but further geotechnical investigation should be carried out to verify the nature of these karstic formations;
- Excavation rates and support requirements and their related costs are greatly dependent on the ground conditions and quality of the rocks;
- The bored tunnel alignment Options 1,2 and 4 are considered the most favourable and should be considered in further feasibility studies. Option 2 is shorter and therefore less expensive;
- The immersed tube tunnel Option 3 is feasible but has significant environmental impacts. This option should only be considered further if the environmental challenges to a long link road on the coastal slope of Gozo can be overcome;
- Both single bore (3-lane bi-directional traffic) and twin bore (2-lane) unidirectional traffic with cross-passages) tunnel configurations should be considered further. A single bore option is less expensive. However, the twin bore option is preferable with regards to fire life safety issues. For the single bore option, the provision of an escape gallery acceptable to the emergency services, may be difficult to achieve;
- An option comprising a single bore (2-lane bi-directional traffic) tunnel with lay-bys and an escape adit running parallel to the main tunnel should also be considered further;
- There would need to be a study of the detailed maintenance needs of the tunnel including costs and impacts, which could include temporary closures; and
- This study has not included any detailed technical surveys such as geotechnical, geophysical, marine or topographical. Further topographical, site and geotechnical investigations are required to further develop the project. A key element of this would be in order to better understand the bedrock conditions beneath the sea crossing.

6.1.3 Environmental Assessment

The key points from the environmental assessment may be summarised as follows:

- Overall Options 1, 2 and 4 are likely to have similar environmental concerns as all 3 are bored tunnel options and are likely to have similar environmental characteristics at portal locations;
- The location of the portals on Malta for all of Options 1, 2 and 4 are likely to have indirect impacts on the Natura 2000 site;
- Options 1 and 2 have portal locations outside the Natura 2000 site on Malta, but all traffic would have to travel through the site (as now), and construction activities are likely to significantly impact the site;
- Option 4 has a portal location south of Mellieha Bay Beach and the adjacent Nature Reserve removing through traffic from this important tourist location;
- Design and construction of Option 4 would need to ensure there is no dewatering issues within the protected Natura 2000 site to maintain the habitat of the protected bird colonies;

- All of the options are likely to give rise to impacts related to changes in air quality and noise as these effects are linked to the predicted increase in traffic numbers associated the provision of a road tunnel link between Malta and Gozo. These impacts are unlikely to be restricted to the portal locations but extend along the TEN–T network;
- The requirements for temporary land take for site compounds, storage of rock materials and other construction related equipment need further consideration. Temporary land take could cause significant environmental impacts particularly on Malta where the portal location for Options 1 and 2 is within an already ‘cluttered’ area;
- Based on the information available and summarised in this environmental review the immersed tube tunnel, Option 3, is likely to be the most environmentally damaging as it is located within a proposed marine Natura 2000 site. The construction of this option is likely to disturb and permanently change the seabed and the habitats and communities that are present;
- Depending of the final selection of the road tunnel link option and the construction methodology, differing volumes of waste rock material would be produced by the construction of a tunnel. It will be important to fully understand and investigate the reuse options for the waste rock materials as there may be significant environmental effects; and
- Following more detailed baseline surveys and data collection and with greater levels of engineering detail it may be possible to define more clearly the potential environmental impacts associated with the options for a road tunnel link between Malta and Gozo. With a greater level of understanding of the environmental concerns, measures could be developed to reduce any significant environmental impacts, however a project of this scale this is likely to be a difficult and complex task.

6.2 Conclusions

- With regards to the overall length, depth, configuration and size of tunnels an undersea tunnel link between Malta and Gozo would be feasible and doesn’t exceed the capability of current technology;
- The geology of the project area is potentially complex and not well documented. A detailed geological and geotechnical investigation is required to determine the optimum tunnel alignment and construction methodology;
- Tolls from a tunnel could cover the operating cost with a significant surplus, but would not cover all costs;
- A road tunnel could be considered with EU / national grants and / or private sector funding;
- Tunnel Boring Machine, Road Header and Drill and Blast construction options should all be considered further for bored tunnel options;
- The cost of an immersed tube tunnel option is estimated to be similar per metre length, but as the length is shorter, should be considered further if cost (rather than environmental impact) is the controlling factor;
- The environmental impact of an immersed tube tunnel on the seabed and associated link road on Gozo would make the immersed tube tunnel option challenging;
- The exact location and impact of tunnel portal positions on both Malta and Gozo need considering carefully taking into account geology as well as environmental conditions; and
- The output of this study can be used as input into a future feasibility study considering all options for a link between Malta and Gozo.

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Appendices

Appendix A. References

A.1. Tunnelling References

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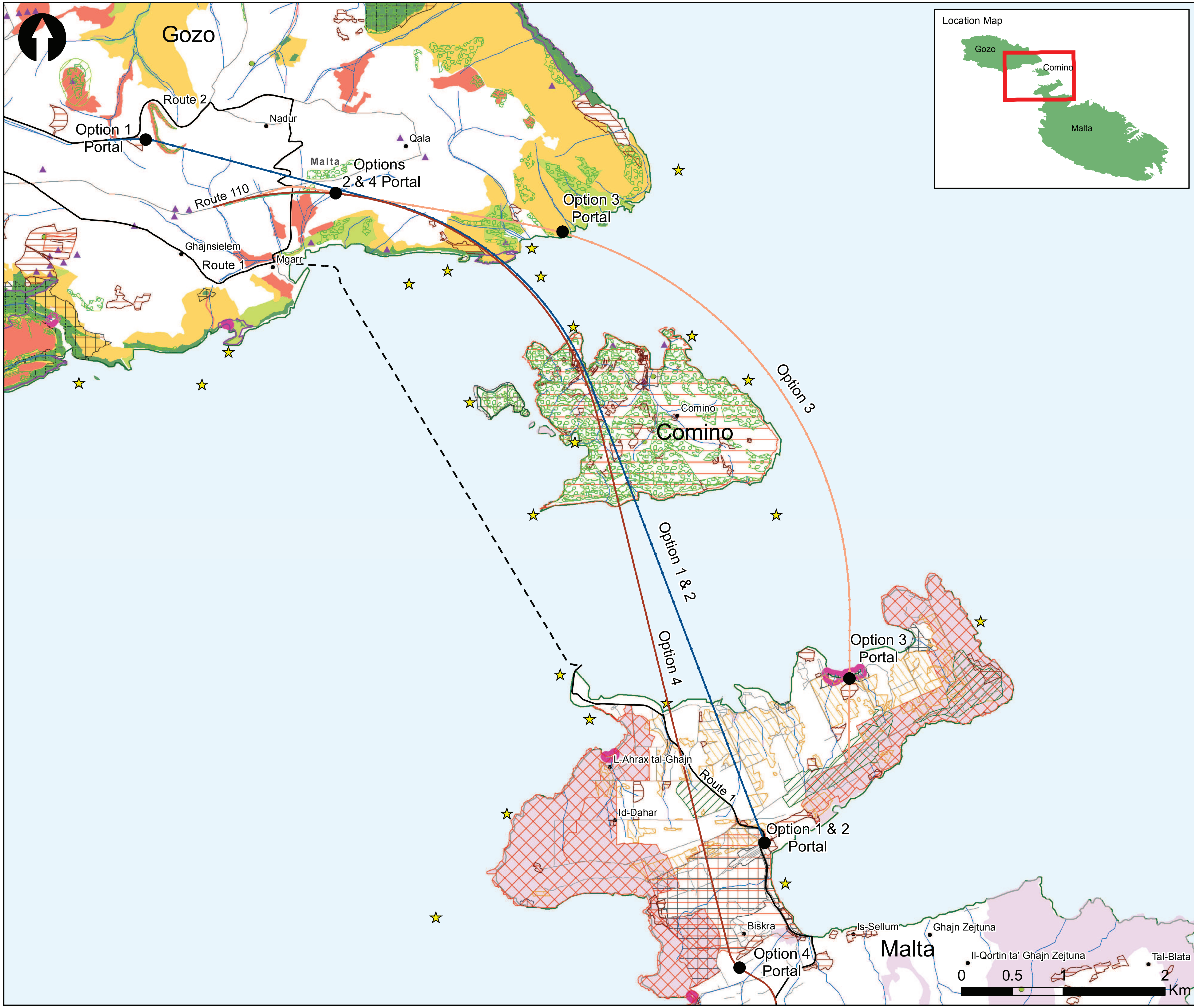
Appendix B. Environmental Constraints

List of Drawings

282725-SK101 Environmental Constraints Plan – Overview

282725-SK100 Environnemental Constraints Plan – Natura 2000 Sites



Notes

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Contains, or is based on, information supplied by Malta Environment & Planning Authority (MEPA).
Areas of landscape value are shown on the island of Malta only.
For areas of landscape value on Gozo and Comino see Figure 5.5 of the Final Report.

Position of portals and tunnel routes are indicative only.

Key to symbols

- Main Settlement
- TEN T Network (Existing/Proposed)
- TEN T Network (Existing Ferry)
- Arterial Local Roads
- Watercourse

Sites of Interest
- Diving Site
- Archaeological Site

Land Use
- Area of Agricultural Value (Malta)
- Woodland (Malta)
- Landscape Value (Areas of Ecological Importance/Site of Scientific Importance) (Malta)

Protected Areas and Habitats
- Protected Beaches (Tourism) (Malta)
- Garrigue (Gozo & Comino)
- Disturbed Habitats
- Nature Reserve (Islands) (Malta)
- Nature Reserve (Trees) (Gozo & Comino)
- Birds Sanctuary
- Special Area of Conservation - National Importance
- Site of Scientific Importance (Geology) (Gozo & Comino)
- Areas of Ecological Importance/ Site of Scientific Importance (Malta)
- Areas of Ecological Importance (Malta)

Ecological Levels of Protection (Gozo & Comino)
- 1 (High Value)
- 2
- 3
- 4 (Low Value)

Route Options
- Option 1
- Option 2
- Option 3
- Option 4

Rev	Date	Drawn	Description	Ch'k'd	App'd
P4	19/03/2012	SJP	For Information	EL	TG

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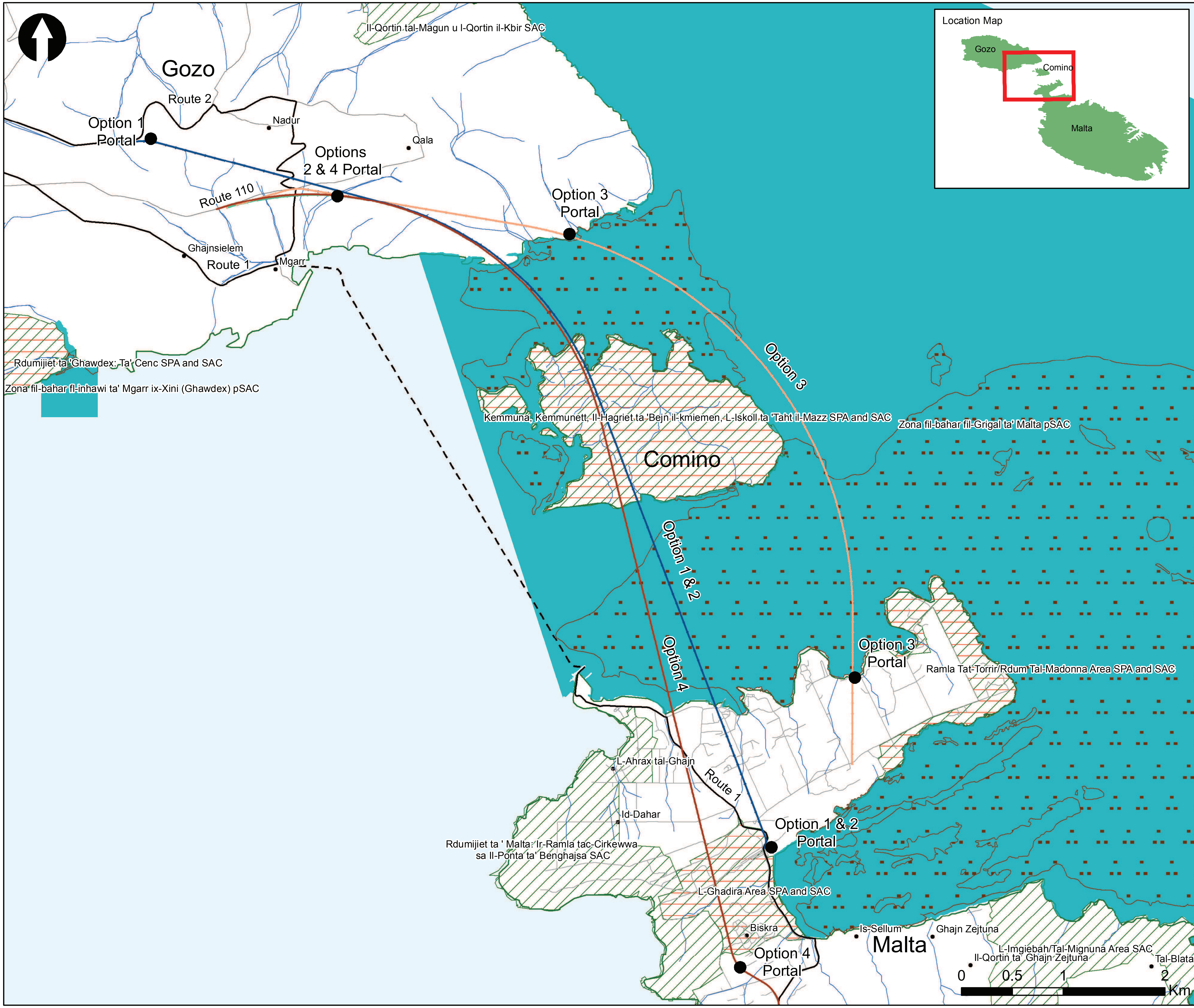
Title

Malta Gozo Tunnel Environmental Constraints Plan Overview

Designed	—	Eng Check	—
Drawn	SJP	Coordination	EL
Dwg Check	EL	Approved	TG
Scale at A3: 1:35,000	Project: 282725		Status: PRE
Drawing No.: 282725-SK101			Rev: P4



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Position of portals and tunnel routes are indicative only.

Key to symbols

- Main Settlement
- Watercourse
- Arterial Local Roads
- TEN T Network (Existing/Proposed)
- TEN T Network (Existing Ferry)
- Special Area of Conservation (Natura 2000 sites)
- Potential Special Area of Conservation - Marine (Natura 2000 sites)
- Special Protection Areas (Natura 2000 sites)
- Posidonia Beds

Route Options
- Option 1
- Option 2
- Option 3
- Option 4

Rev	Date	Drawn	Description	Ch'k'd	App'd
P4	19/03/2012	SJP	For Information	EL	TG

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Title
Malta Gozo Tunnel
Environmental Constraints Plan
Natura 2000 sites

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Drawn	SJP	Coordination	EL
Dwg Check	EL	Approved	TG
Scale at A3: 1:35,000	Project: 282725		Status: PRE
Drawing No.: 282725-SK100			Rev: P4

Appendix C. Options Plan, Longitudinal and Geological Sections

List of Drawings

282725-SK102 Route Options Plan

282725-SK002 Option 1 Bored Tunnel – Longitudinal Section

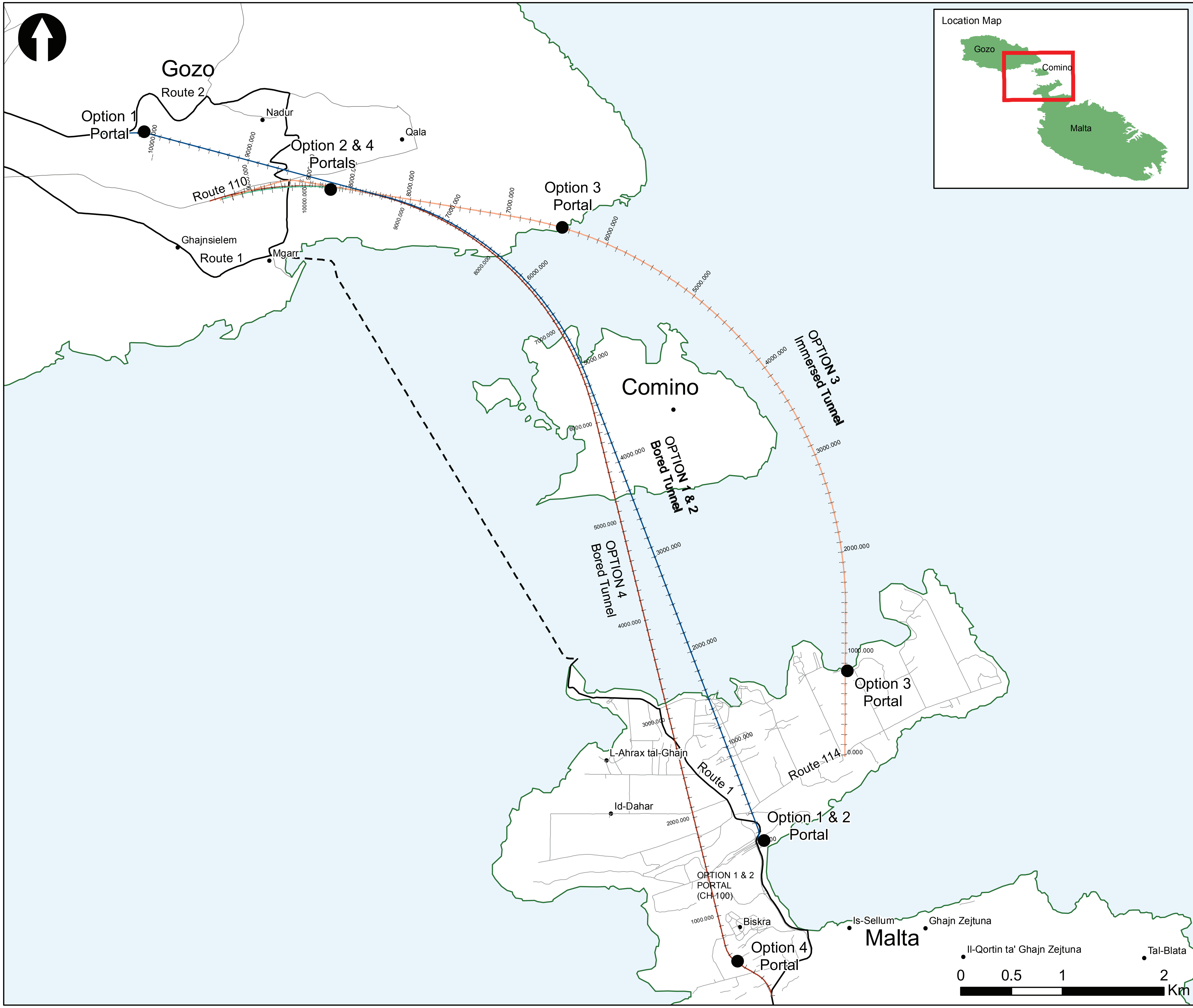
282725-SK003 Option 2 Bored Tunnel – Longitudinal Section

282725-SK020 Options 1, and 2 – Geological Section

282725-SK005 Option 3 Immersed Tube Tunnel – Longitudinal Section

282725-SK009 Option 4 Bored Tunnel – Longitudinal Section

282725-SK021 Option 4 – Geological Section



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Position of portals and tunnel routes are indicative only.

Key to symbols

- Main Settlement
- TEN T Network (Existing/Proposed)
- TEN T Network (Existing Ferry)
- Arterial Local Roads

Route Options
- Option 1
- Option 2
- Option 3
- Option 4

Rev	Date	Drawn	Description	Ch'k'd	App'd
P2	20/03/2012	SJP	Included in the Final report	CR	TG

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Title

Malta Gozo Tunnel
Route Options Plan

Designed	—		Eng Check	—
Drawn	SJP		Coordination	CR
Dwg Check	CR		Approved	TG
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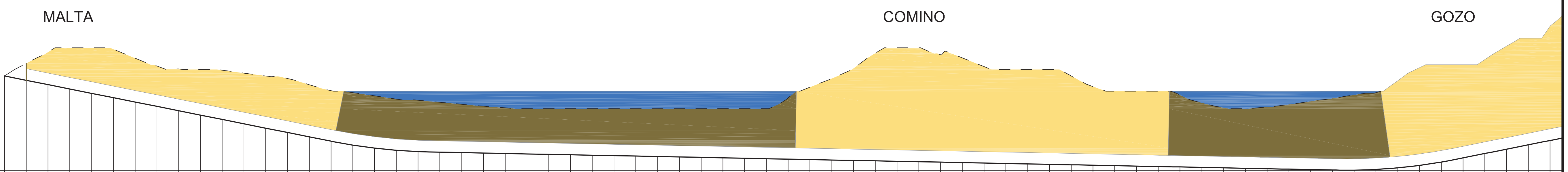
Drawing No.: 282725-SK102			Rev: P2	



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Longitudinal section along Design Option 1 - Bored tunnel

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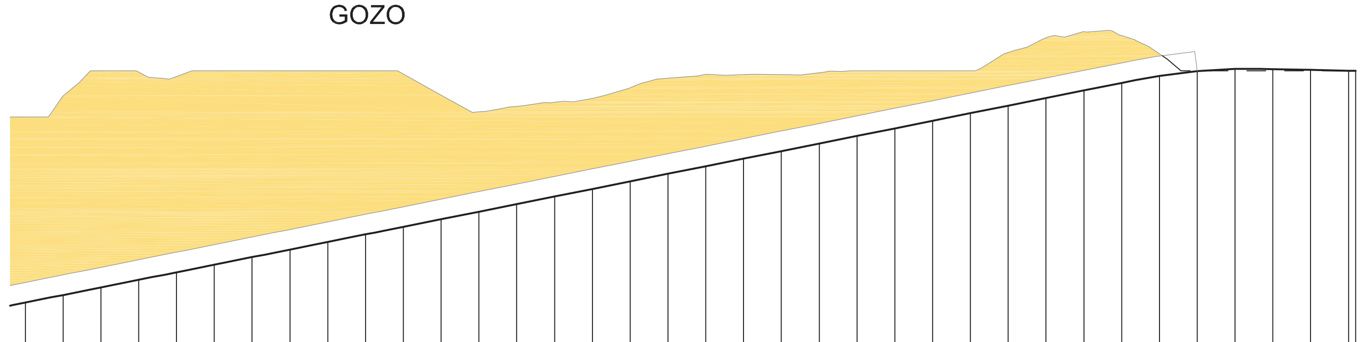

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7900.000	-16.560	91.440
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8100.000	-6.560	75.455
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Notes:-

1. Refer to drawing 282725/SK/102 for horizontal alignment.

2. Sea bed and land levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	10.11.11	CR	Included in the Final Report	NT	NG
P2	29.09.11	CR	Horizontal and vertical alignment revised	NT	TG
P1	12.08.11	CR	Drawing Created	NT	TG

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Drawing Title
Malta Gozo Tunnel
Route Feasibility Option 1 Bored Tunnel
Longitudinal section

Designed	C.Rajaraman	Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.	D.Pentland	Approved	T.Groves
Scale: As shown	Project: 282725		Status: PRE
Drawing No: 282725/SK/002			Rev: P3

Plotted by pen01428, on Nov 14, 2011 - 3:40pm

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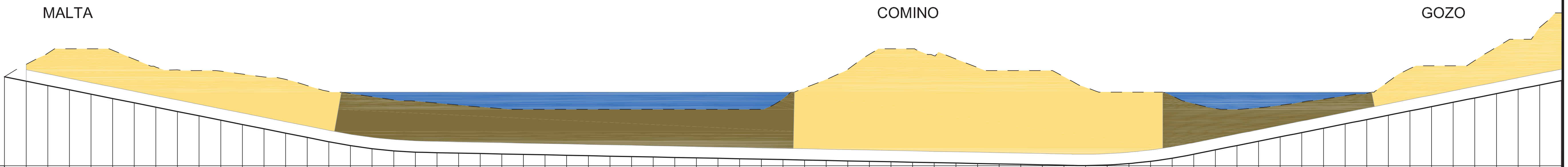

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700.000	-17.405	28.961
800.000	-22.405	25.667
900.000	-27.405	24.994
1000.000	-32.405	24.211
1100.000	-37.405	20.868
1200.000	-42.405	17.525
1300.000	-47.405	14.714
1400.000	-52.405	7.534
1500.000	-57.405	0.672
1600.000	-61.898	-1.564
1700.000	-65.391	-5.275
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2600.000	-73.000	-19.995
2700.000	-73.500	-19.995
2800.000	-74.000	-19.995
2900.000	-74.500	-19.995
3000.000	-75.000	-19.995
3100.000	-75.500	-19.995
3200.000	-76.000	-19.995
3300.000	-76.500	-19.995
3400.000	-77.000	-19.995
3500.000	-77.500	-19.995
3600.000	-78.000	-7.639
3700.000	-78.500	4.662
3800.000	-79.000	14.568
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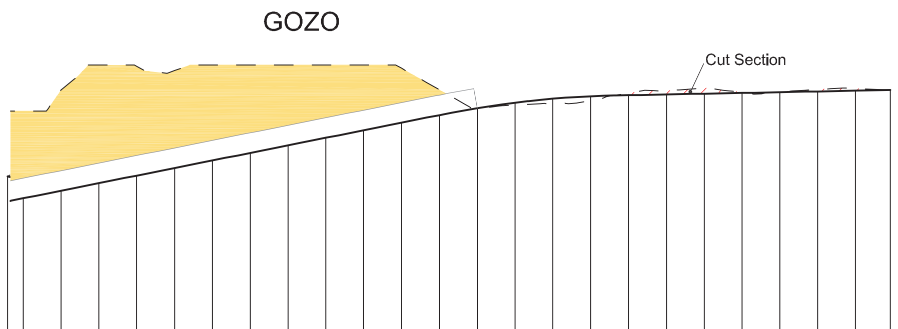
5200.000	-82.582	0.010
5300.000	-79.967	0.010
5400.000	-76.352	-4.330
5500.000	-71.744	-13.360
5600.000	-66.744	-18.942
5700.000	-61.744	-19.995
5800.000	-56.744	-18.110
5900.000	-51.744	-15.227
6000.000	-46.744	-11.534
6100.000	-41.744	-8.151
6200.000	-36.744	-4.270
6300.000	-31.744	-1.551
6400.000	-26.744	12.106
6500.000	-21.744	27.148
6600.000	-16.744	30.480
6700.000	-11.744	30.480
6800.000	-6.744	36.461
6900.000	-1.744	51.880
7000.000	3.256	60.960
7100.000	8.256	74.868
7200.000	[illegible]	[illegible]

Longitudinal section along Design Option 2 - Bored Tunnel

scale H:10000 V:2500



VERTICAL: K=-100.000 L=450.000 | P=0.500% L=730.604

HORIZONTAL:) L=4467.684

CHAINAGE	DESIGN OP2	EXISTING LEVEL
7000.000	3.256	60.960
7100.000	8.256	74.868
7200.000	13.256	91.440
7300.000	18.256	90.565
7400.000	23.256	87.734
7500.000	28.256	91.440
7600.000	33.256	91.440
7700.000	38.256	91.440
7800.000	43.256	91.440
7900.000	48.256	91.440
8000.000	53.256	89.240
8100.000	58.256	75.087
8200.000	62.867	62.762
8300.000	66.484	64.817
8400.000	69.101	65.925
8500.000	70.718	67.803
8600.000	71.409	72.808
8700.000	71.909	74.240
8800.000	72.409	76.069
8900.000	72.909	73.279
9000.000	73.409	73.666
9100.000	73.909	75.212
9200.000	74.409	75.817
9292.329	74.870	74.870

Notes:-

1. Refer to drawing 282725/SK/102 for horizontal alignment.

2. Sea bed and land levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	10.11.11	CR	Included in the Final report	NT	TG
P2	29.09.11	CR	Horizontal and vertical alignment revised	NT	TG
P1	12.08.11	CR	Drawing Created	NT	TG

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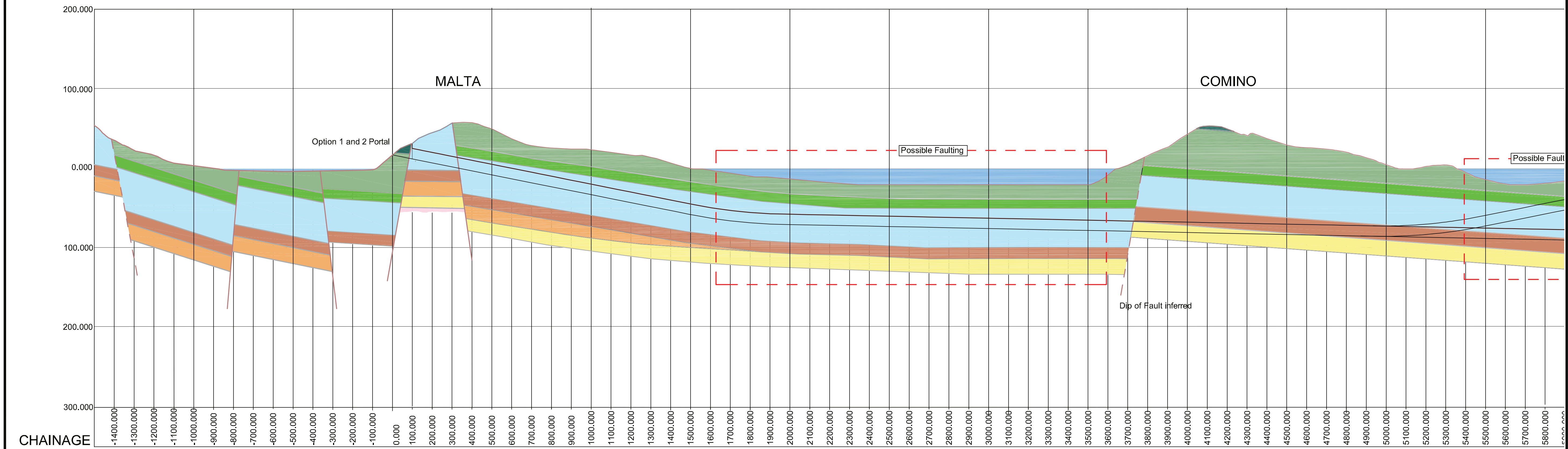
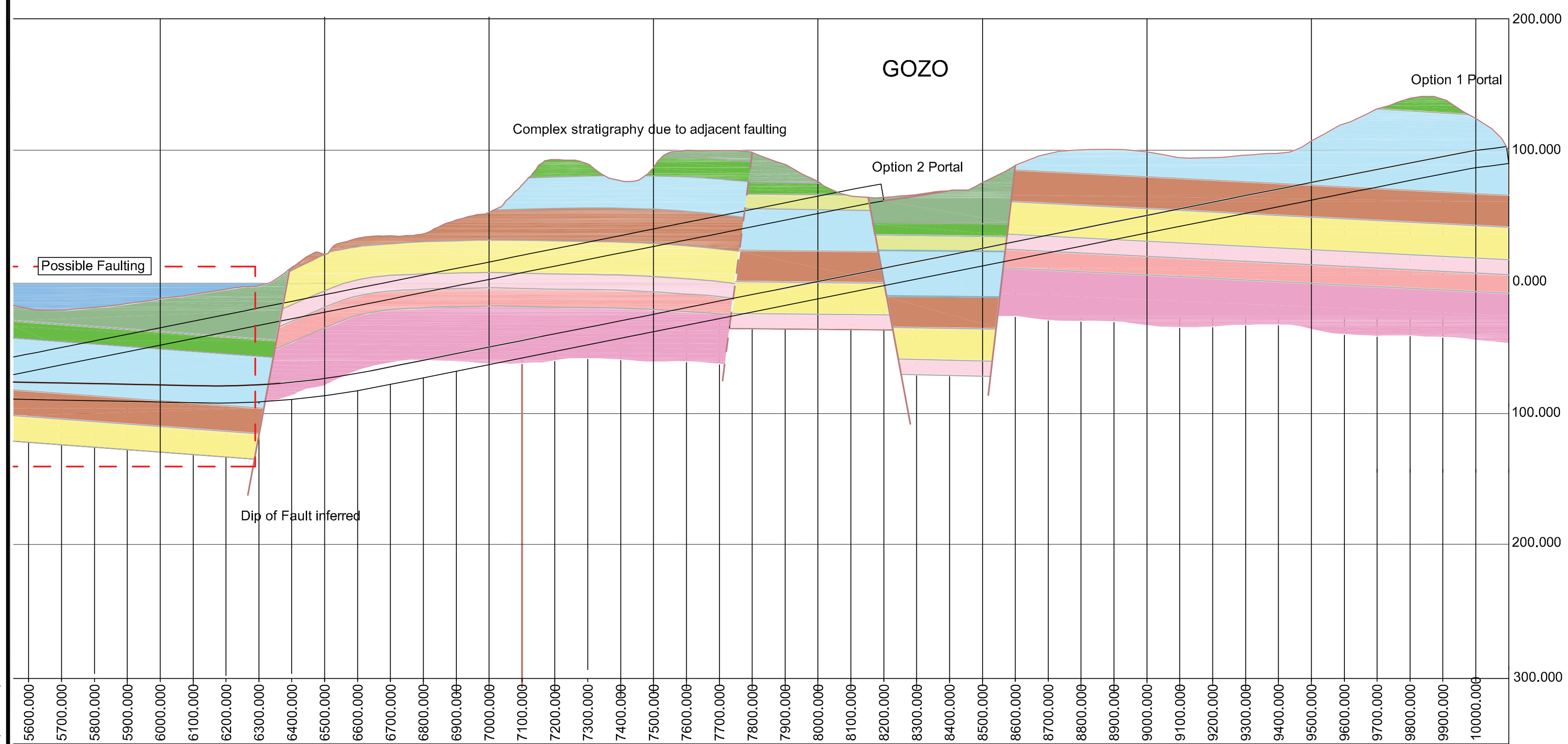
Joint Assistance to Support Projects in European Regions

Drawing Title
Malta Gozo Tunnel
Route Feasibility Option 2 Bored Tunnel
Longitudinal section

Designed	C.Rajaraman	Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.	D.Pentland	Approved	T.Groves
Scale: As shown	Project: 282725	Status: PRE	
Drawing No: 282725/SK/003		Rev: P3	



Longitudinal section along Design Option 1 - Bored tunnel
scale H:10000 V:2500



Notes:-

1. Refer to drawing 282725/SK/102 for horizontal alignment.
2. Sea bed levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.
3. Land levels are approximate based on contours on the 1:25,000 Geological Map of the Maltese Islands, dated 2003.
4. Dips of bedding and faults are based on the limited information included on the geological map and take into account the relative alignment of the tunnel and the exaggeration of the vertical scale. There may be additional faulting in the Comino Channel areas.

KEY TO GEOLOGICAL MEMBERS

MIOCENE

UPPER CORALLINE LIMESTONE FORMATION

- Mgl — Gebel Imbark Member: Thickness 4 - 25m.
- Mp — Tal - Pitkal Member: Thickness 30 - 50m.
- Mm — Mtarfa Member: Thickness 12 - 16m.
- Mgm — Ghajn Melel Member. Thickness 0 - 13m.

BLUE CLAY FORMATION

- Mbc — Blue Clay Formation: Thickness 15 - 75m.

GLOBIGERINA LIMESTONE FORMATION

- Mug — Upper Globigerina Limestone Member: Thickness 8 - 26m.
- Mmg — Middle Globigerina Limestone Member: Thickness 15 - 38m.
- Mlg — Lower Globigerina Limestone Member: Thickness 0 - 80m.

OLIGOCENE

LOWER CORALLINE LIMESTONE FORMATION

- Ox — Xlendi Member: Thickness 0 - 22m.
- Oa — Attard Member: Thickness 10 - 15m.
- Owm — Maghlaq Member: Thickness >38m.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	07.03.12	JB	Geological Section	NT	NG
P2	29.09.11	CR	Horizontal and vertical alignment revised	NT	TG
P1	12.08.11	CR	Drawing Created	NT	TG

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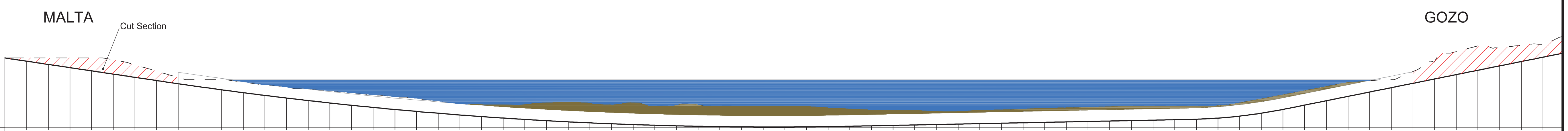
Drawing Title
Malta Gozo Tunnel
Route Feasibility Option 1 and 2 Bored Tunnels
Geological section

Designed	J.Bradley	Eng.Chk.	
Drawn	J.Bradley	Coordination	
Dwg.Chk.	S.Chilton	Approved	T.Groves
Scale: As shown	Project: 282725		Status: PRE
Drawing No: 292725/SK/020			Rev: P3

Plotted by bra47825, on Mar 08, 2012 - 11:39am

CAD file: C:\Documents And Settings\bra47825\Desktop\Malta\Plan & Long Sections_JB3_1.dwg



DATUM=-55.000

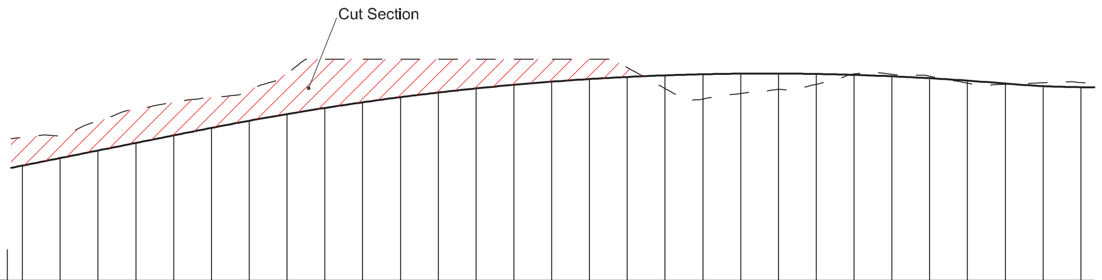
CHAINAGE	DESIGN OP3	EXISTING LEVEL
0.000	24.994	24.994
100.000	21.294	24.994
200.000	17.594	24.994
300.000	13.894	24.994
400.000	10.194	24.994
500.000	6.494	23.020
600.000	2.794	16.822
700.000	-0.906	9.840
800.000	-4.578	2.569
900.000	-8.126	0.010
1000.000	-11.542	0.010
1100.000	-14.827	-2.774
1200.000	-17.980	-5.785
1300.000	-21.002	-8.643
1400.000	-23.892	-10.456
1500.000	-26.650	-12.749
1600.000	-29.277	-15.076
1700.000	-31.772	-17.270
1800.000	-34.136	-19.702
1900.000	-36.368	-21.506
2000.000	-38.469	-24.707
2100.000	-40.438	-27.607
2200.000	-42.275	-28.469
2300.000	-43.981	-28.776
2400.000	-45.556	-28.309
2500.000	-46.998	-26.376
2600.000	-48.309	-25.451
2700.000	-49.489	-27.006
2800.000	-50.537	-28.654
2900.000	-51.453	-26.201
3000.000	-52.238	-29.993
3100.000	-52.891	-29.067
3200.000	-53.413	-28.535
3300.000	-53.803	-29.993
3400.000	-54.062	-30.227
3500.000	-54.189	-30.582
3600.000	-54.184	-30.447
3700.000	-54.048	-30.716
3800.000	-53.780	-31.979
3900.000	-53.380	-33.403
4000.000	-52.885	-34.597
4100.000	-52.385	-34.934
4200.000	-51.885	-35.082
4300.000	-51.385	-36.185
4400.000	-50.885	-36.307
4500.000	-50.385	-34.763
4600.000	-49.885	-34.271
4700.000	-49.385	-33.591
4800.000	-48.885	-32.398
4900.000	-48.385	-31.898
5000.000	-47.885	-31.328
5100.000	-47.385	-30.679
5200.000	-46.885	-29.993
5300.000	-46.385	-29.993
5400.000	-45.885	-29.993
5500.000	-45.336	-29.993
5600.000	-44.024	-29.527
5700.000	-41.712	-26.283
5800.000	-38.400	-21.651
5900.000	-34.088	-16.970
6000.000	-29.105	-12.244
6100.000	-24.105	-7.476
6200.000	-19.105	-2.755
6300.000	-14.105	-1.160
6400.000	-9.105	0.010
6500.000	-4.105	9.466
6600.000	0.895	21.119
6700.000	5.895	32.275
6800.000	10.895	39.002
6900.000	15.895	36.710
7000.000	20.895	39.582
7100.000	25.895	40.969

VERTICAL: P=-3.700% L=734.456 | K=760.000 L=3192.000 | P=0.500% L=1542.333 | K=100.000 L=450.000 | P=5.000% L=1550.320

HORIZONTAL: D=1446.410 | R=-3900.000 L=5501.515

Longitudinal section along Design Option 3 - Immersed Tunnel

scale H:10000 V:2500



DATUM=-55.000

CHAINAGE	DESIGN OP3	EXISTING LEVEL
7000.000	20.895	39.582
7100.000	25.895	40.969
7200.000	30.895	50.347
7300.000	35.895	58.254
7400.000	40.895	62.744
7500.000	45.879	66.001
7600.000	50.609	70.815
7700.000	55.006	81.993
7800.000	59.070	91.440
7900.000	62.800	91.440
8000.000	66.197	91.440
8100.000	69.261	91.440
8200.000	71.991	91.440
8300.000	74.388	91.440
8400.000	76.452	91.440
8500.000	78.182	91.440
8600.000	79.579	85.764
8700.000	80.643	71.938
8800.000	81.373	64.980
8900.000	81.770	68.616
9000.000	81.834	71.369
9100.000	81.564	74.704
9200.000	80.961	81.523
9300.000	80.025	81.315
9400.000	78.755	80.108
9500.000	77.152	75.489
9600.000	75.232	74.775
9700.000	73.528	75.723
9800.000	72.797	75.841

VERTICAL: K=-300.000 L=2099.999 | P | K=1 L=5

HORIZONTAL: D=2142.160 | R | D=1

Notes:-

1. Refer to drawing 282725/SK/102 for horizontal alignment.
2. Sea bed and land levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P2	10.11.11	CR	Included in the Final report	NT	TG
P1	05.10.11	CR	Drawing Created	NT	TG

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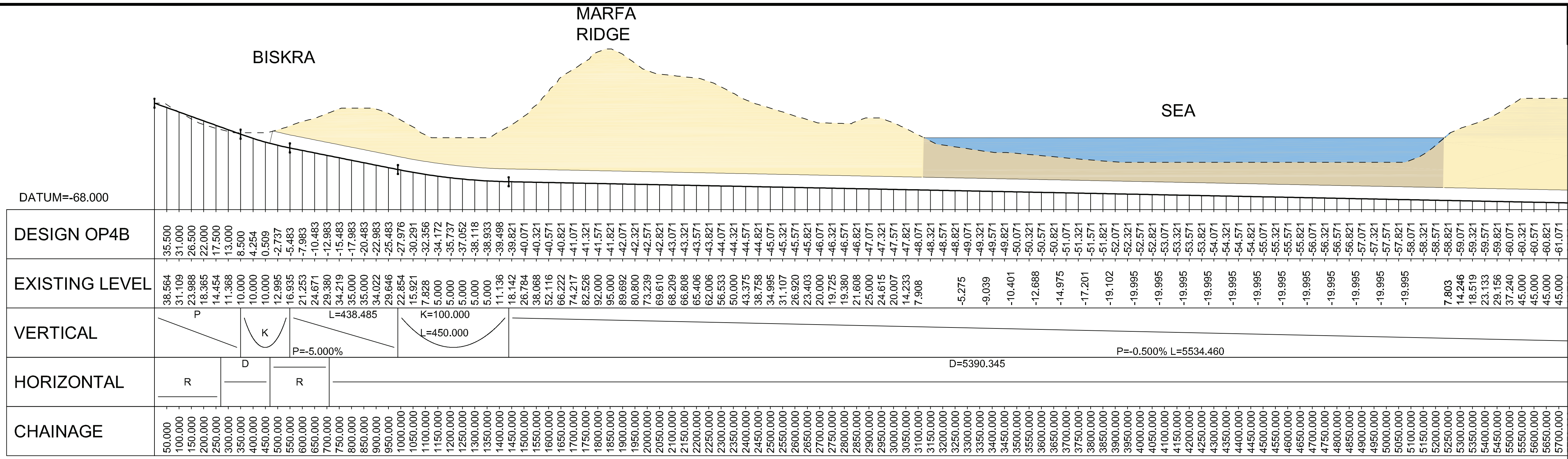
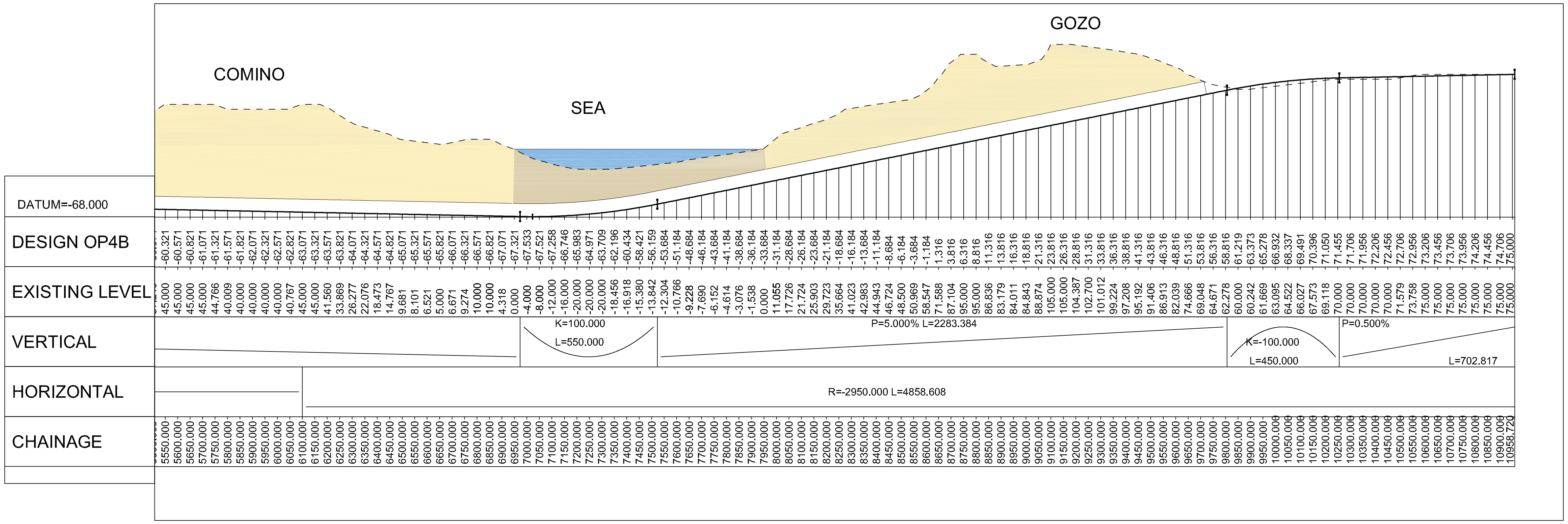
Drawing Title
Malta Gozo Tunnel
Route Feasibility Option 3 Immersed Tunnel
Longitudinal section

Designed	C.Rajaraman	Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.	D.Pentland	Approved	T.Groves
Scale: As shown	Project: 282725		Status: PRE
Drawing No: 282725/SK/005			Rev: P2





Notes:-

1. Refer to drawing 282725/SK/101 for horizontal alignment.

2. Sea bed and land levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	06.03.12	CR	Drawing Created	NT	TG

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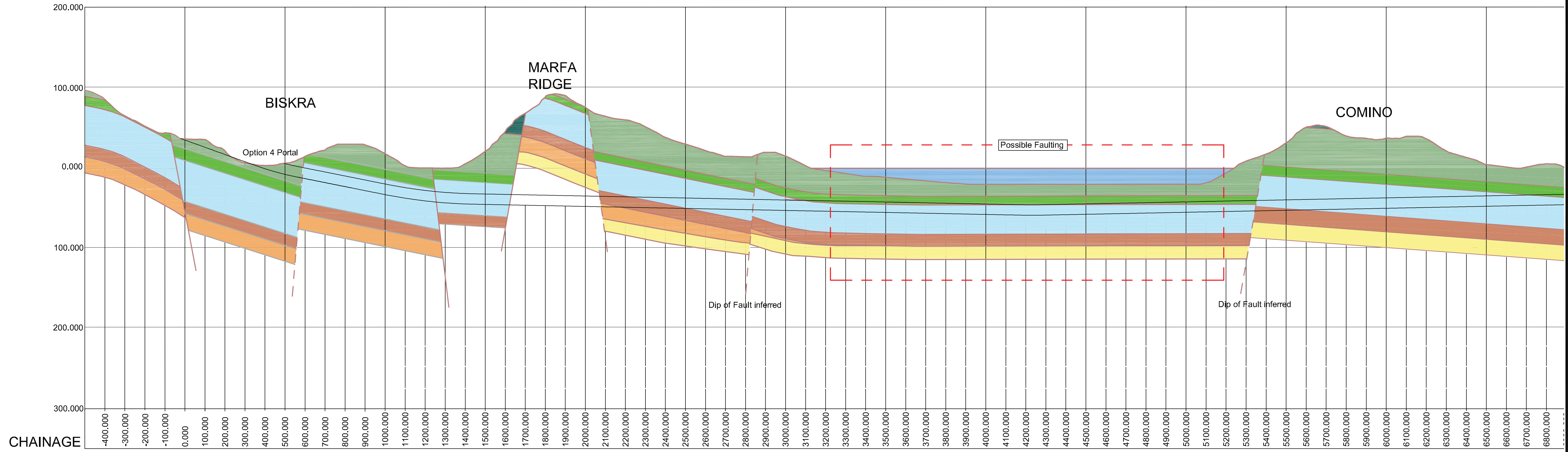
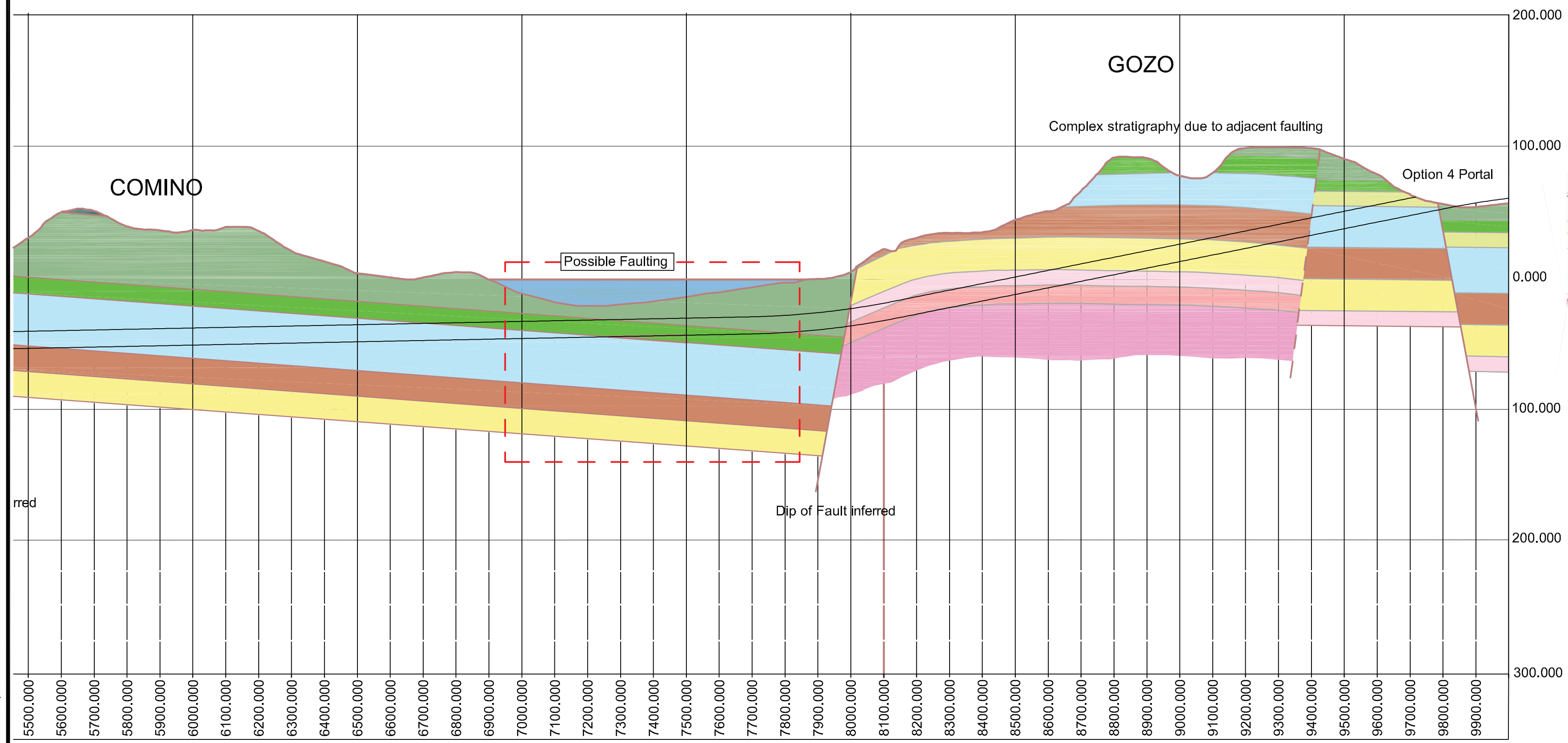
Drawing Title
Malta Gozo Tunnel
Route Feasibility Option 4 Bored Tunnel
Longitudinal section

Designed	C.Rajaraman	Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.	D.Pentland	Approved	T.Groves
Scale: H:10000 V:2500 @ A1	Project: 282725		Status: PRE
Drawing No: 282725/SK/009			Rev: P1



Longitudinal section along Design Option 4 - Bored tunnel

scale H:10000 V:2500



Notes:-

1. Refer to drawing 282725/SK/008 for horizontal alignment.
2. Sea bed levels are approximate based on contours on the Admiralty Chart "Plans in the Maltese Islands" dated 23rd January 2003.
3. Land levels are approximate based on contours on the 1:25,000 Geological Map of the Maltese Islands, dated 2003.
4. Dips of bedding and faults are based on the limited information included on the geological map and take into account the relative alignment of the tunnel and the exaggeration of the vertical scale. There may be additional faulting in the Comino Channel areas.

KEY TO GEOLOGICAL MEMBERS

MIOCENE

UPPER CORALLINE LIMESTONE FORMATION

- Mgl — Gebel Imbark Member: Thickness 4 - 25m.
- Mp — Tal - Pitkal Member: Thickness 30 - 50m.
- Mm — Mtarfa Member: Thickness 12 - 16m.
- Mgm — Ghajn Melel Member. Thickness 0 - 13m.

BLUE CLAY FORMATION

- Mbc — Blue Clay Formation: Thickness 15 - 75m.

GLOBIGERINA LIMESTONE FORMATION

- Mug — Upper Globigerina Limestone Member: Thickness 8 - 26m.
- Mmg — Middle Globigerina Limestone Member: Thickness 15 - 38m.
- Mlg — Lower Globigerina Limestone Member: Thickness 0 - 80m.

OLIGOCENE

LOWER CORALLINE LIMESTONE FORMATION

- Ox — Xlendi Member: Thickness 0 - 22m.
- Oa — Attard Member: Thickness 10 - 15m.
- Owm — Maghlaq Member: Thickness >38m.

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	08.03.12	JB	Geological Section	NT	NG
P2	29.09.11	CR	Horizontal and vertical alignment revised	NT	TG
P1	12.08.11	CR	Drawing Created	NT	TG

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Drawing Title

Malta Gozo Tunnel
Route Feasibility Option 4 Bored Tunnel
Geological section

Designed	J.Bradley	Eng.Chk.	
Drawn	J.Bradley	Coordination	
Dwg.Chk.	S.Chilton	Approved	T.Groves
Scale: As shown	Project: 282725		Status: PRE
Drawing No: 292725/SK/021			Rev: P3

Appendix D. Example Tunnel Cross Sections

List of Drawings

282725-SK012 Twin Bore Unidirectional Bored Tunnels

282725-SK014 Immersed Tube Twin Tunnels

282725-SK015 Single Bore 3-lane Bi-Directional Tunnel

282725-SK016 Single Bore 2-lane Bi-Directional Tunnel with Lay-Bys and Escape Adit

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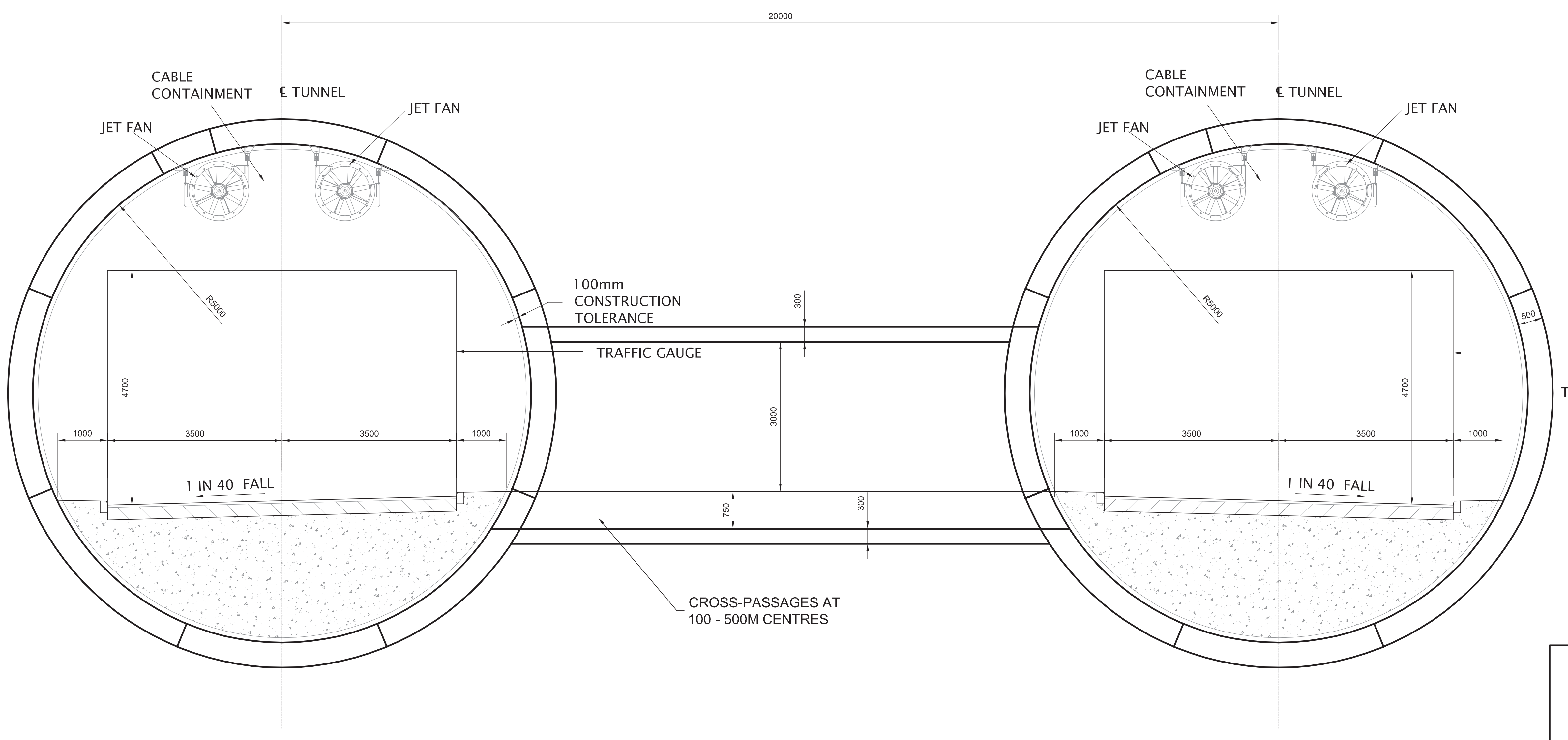
1. Lane width = 3.5m (ref: PIARC Cross Section Geometry in Unidirectional Road Tunnels, V.4).
2. Maintained headroom (C) = 4.5m. Allowance (E) as safety zone for signs, luminaires, fans = 0.2m.
3. Verge width = 1.0m (BD 78/99 Table 4.5)



Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	10.11.11	DKP	Included in the final report	NT	TG
P2	28.09.11	CJW	Tunnels moved, notes added and fire main deleted.	NT	TG
P1	03.10.11	CR	Drawing Created	NT	TG

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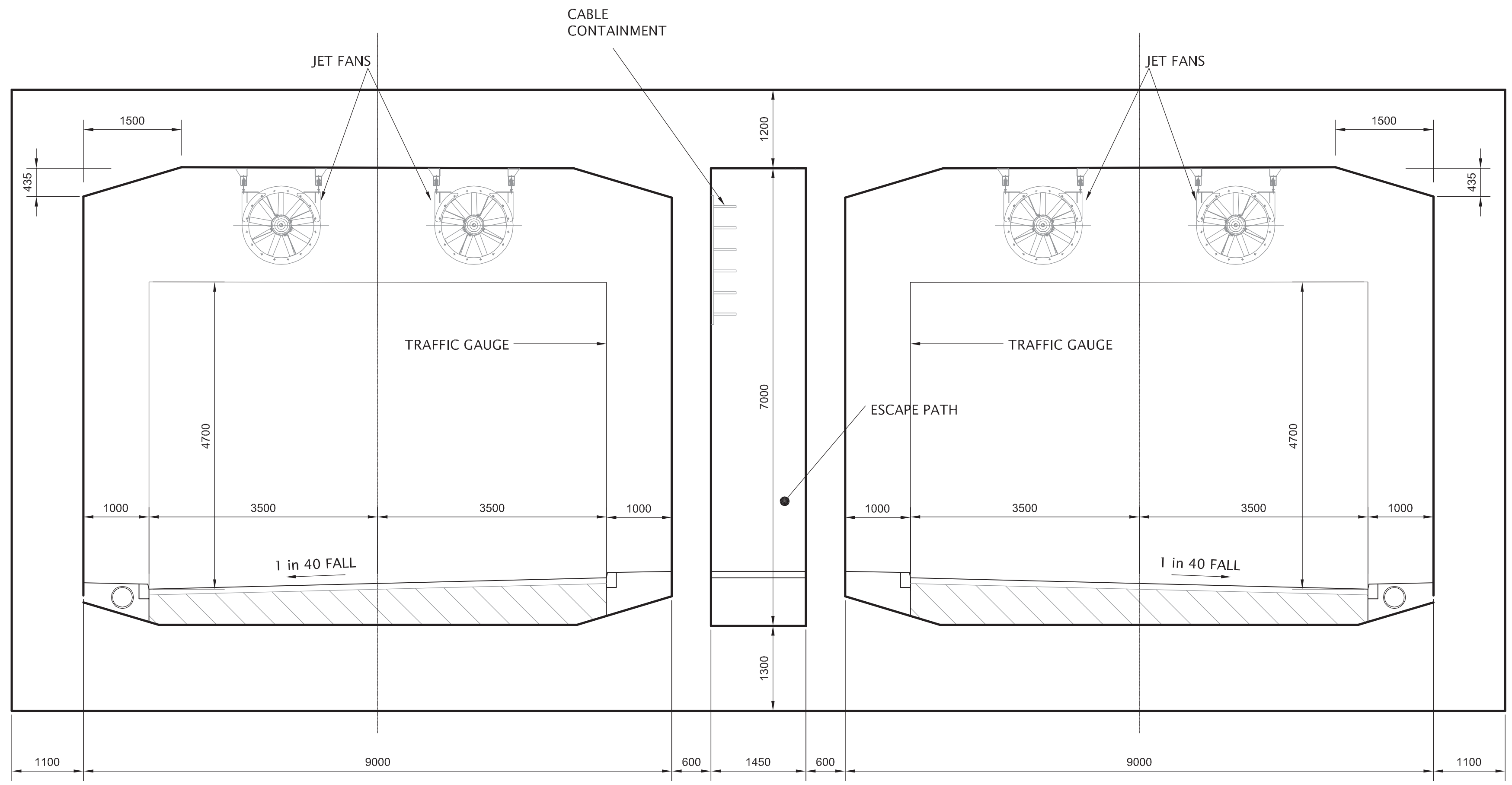
Drawing Title
Malta Gazo Tunnel
Route Feasibility Option
Twin Bored Uni-Directional Tunnel

Designed		Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.		Approved	T.Groves
Scale 1:50	Project 282725		Status PRE
Drawing No 282725.SK012			Rev P3

CAD file: P:\Southampton\ITW\Projects\282725 Malta\Acad\Typical Tunnel Section.DWG

Plotted by pen01428, on Nov 10, 2011 - 3:10pm

1. Lane width = 3.5m (ref: PIARC Cross Section Geometry in Unidirectional Road Tunnels, V.4).
2. Maintained headroom (C) = 4.5m. Allowance (E) as safety zone for signs, luminaires, fans = 0.2m.
3. Verge width = 1.0m (BD 78/99 Table 4.5)



Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	10.11.11	DKP	Included in the final report	NT	TG
P2	28.09.11	CJW	Dims changes, notes added and fire main deleted	NT	TG
P1	03.10.11	CR	Drawing Created	NT	TG

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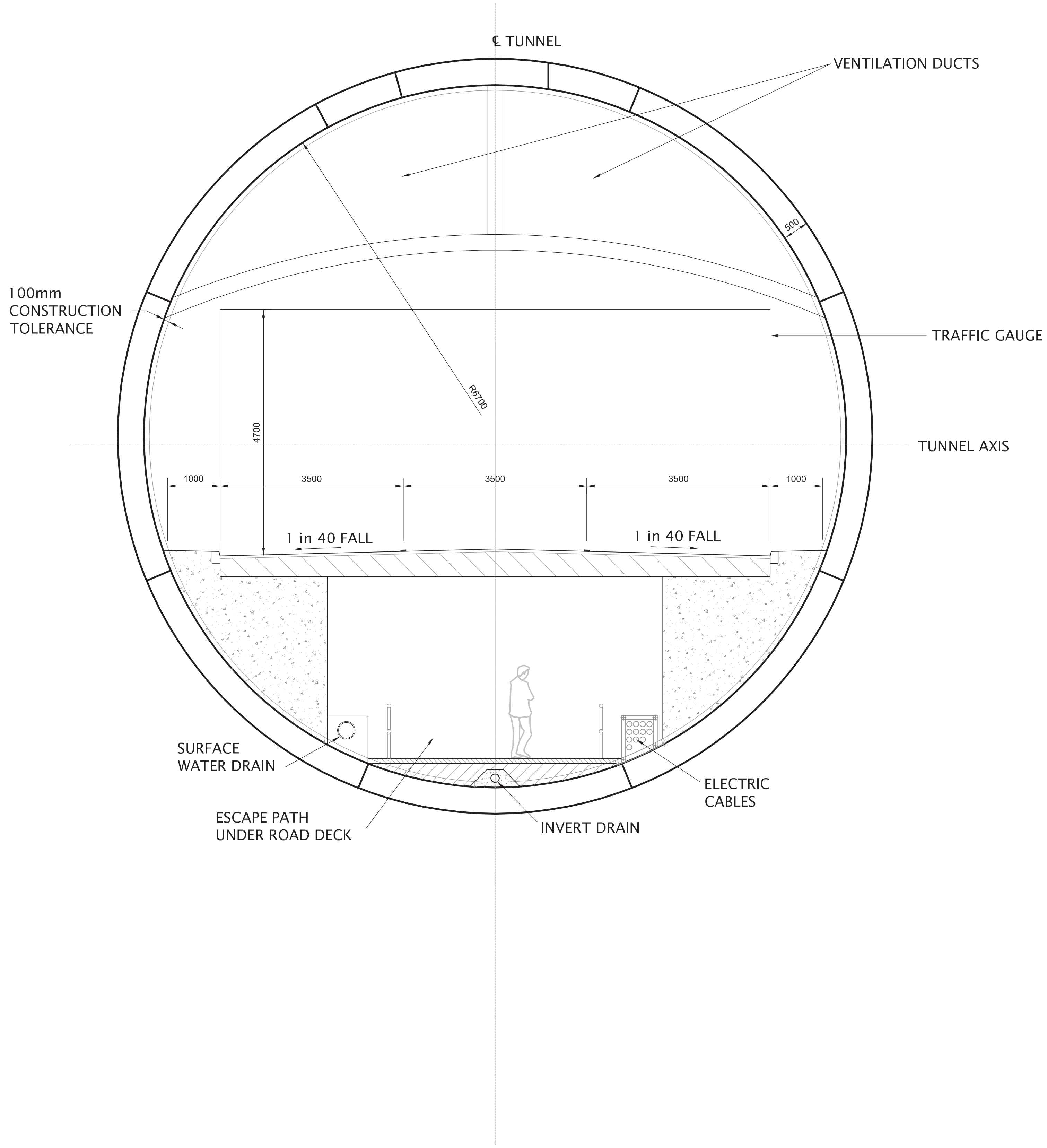
Drawing Title
Malta Gazo Tunnel
Route Feasibility Option
Immersed Tube Tunnel
Twin Tube Uni-Directional

Designed		Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.		Approved	T.Groves
Scale 1:50	Project 282725		Status PRE
Drawing No 282725.SK014			Rev P3



1. Lane width = 3.5m (ref: PIARC Cross Section Geometry in Unidirectional Road Tunnels, V.4).
2. Maintained headroom (C) = 4.5m. Allowance (E) as safety zone for signs, luminaires, fans = 0.2m.
3. Verge width = 1.0m (BD 78/99 Table 4.5)

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	10.11.11	DKP	Included in the final report	NT	TG
P2	28.09.11	CJW	Jet fans and dimensions removed. Note added.	NT	TG
P1	03.10.11	CR	Drawing Created	NT	TG

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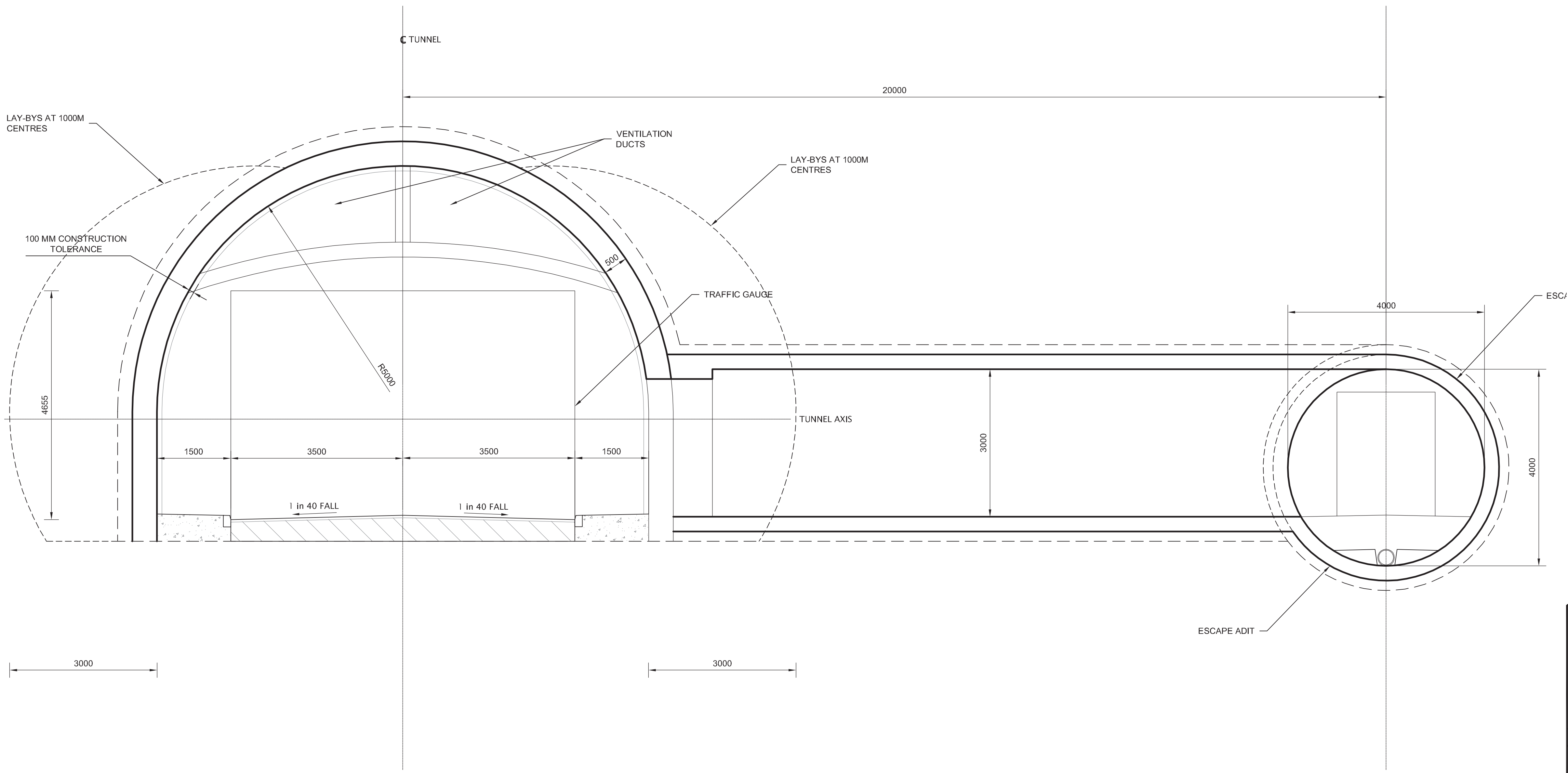
Drawing Title
Malta Gazo Tunnel
Route Feasibility Option
Bored Tunnel,
Single Bore, 3 - Lane,
Bi-Directional Tunnel

Designed		Eng.Chk.	
Drawn	C.Rajaraman	Coordination	
Dwg.Chk.		Approved	T.Groves
Scale 1:50	Project 282725		Status PRE
Drawing No 282725.SK015			Rev P3

1. Lane width = 3.5m (ref: PIARC Cross Section Geometry in Unidirectional Road Tunnels, V.4).
2. Maintained headroom (C) = 4.5m. Allowance (E) as safety zone for signs, luminaires, fans = 0.2m.
3. Verge width = 1.0m (BD 78/99 Table 4.5)



Rev	Date	Drawn	Description	Ch'k'd	App'd
P2	10.11.11	DKP	Included in the final repot	NT	TG
P1	03.10.11	MDL	Drawing Created	NT	TG

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Drawing Title
Malta Gazo Tunnel
Route Feasibility Option
Drill and Blast
Single Bore Bi-directional Tunnel
with Laybys and Escape Adit

Designed		Eng.Chk.		
Drawn	MD Laurent	Coordination		
Dwg.Chk.		Approved	T.Groves	
Scale 1:50		Project 282725		Status PRE
Drawing No 282725.SK016				Rev P2