WATER RESOURCES

6.0 Executive Summary

The IPCC FAR observes that between 1900 to 2005 precipitation quantities declined in the Mediterranean with the global area affected by drought likely to have increased since the 1970s. It is also very likely that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is also likely that heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide. Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1300 years.

Lowering of annual volumes, high rainfall intensity events and increased temperatures will all tend to exert additional pressures on the strains currently experienced by Malta's water resources. Lower annual precipitation volumes contribute to lower capacity volumes whilst higher rainfall intensity events generate greater amounts of runoff and lower volumes available for percolation and subsequent recharge. Temperature rises in themselves lead to increased transpiration and evaporation rates thereby pronouncing losses. It is in this context that vulnerability, which is defined as the effects of shocks emanating out of climate change on human welfare, needs to be seen as well as to attempt to establish the degree and causes of identified vulnerabilities with a view to proposing adaptation strategies.

A proper adaptation strategy is one which takes climate change considerations into account, to the extent feasible, in social, economic and environmental policies, practices and actions by all stakeholders. Adaptation will be required to reduce the costs and disruptions, alter behavioural patterns and give an additional context to decision making to acknowledge those causes derived from climate change, particularly from extreme weather events like storms, floods and heat waves. In this sense, due important is associated with the availability of the right data to ensure monitoring and modelling of future scenarios in order to enable a number of potential scenarios to be identified and addressed accordingly. Adaptation measures will entail adjustments and changes at every level - from local to national and international. These include changes in behaviour, in design consideration, in policy formulation, in public and private initiatives and service delivery and in the development and use of technology. This is the essence of adaptation planning.

Government has, over the past years, shown a commitment towards improving the water resources of the Maltese Islands as evidenced in various strategic documents that have been published. Adaptation to the potential effects of climate change on water resources is proposed to be addressed through improved governance, building

capacity to handle the prevailing issues, increased research and development efforts, strengthening education and communications and looking at ways to prevent certain impacts by adapting our behaviours.

6.1 Introduction

Climate change may influence the hydrological cycle in a way that it will impact water availability and water quality. This is of particular concern to the Maltese Islands in view of the already limited water resource which make the country dependent on desalinated water for around 57% of its total water production.

The impacts of climate change on water resources were preliminary analysed in Malta's First National Communication (FNC) in 2004. The FNC concluded that the Maltese Islands are expected to experience a decrease in the natural water resources mainly due to increased evapotranspiration rates, alteration in subsurface water movements and sea level rise. Malta's FNC described the climate of the Maltese Islands as being typically Mediterranean, with a mild wet winter invariably followed by a long dry summer. In fact the main parametric differences which were identified and which consequently have an impact on the availability of water resources were summarised as follows:

- an increase in the mean annual air temperature of about 0.5 °C in 77 years in line with the regional value over the Mediterranean during the last century. The maximum local temperature increased by 1.5 °C, while the minimum decreased by 0.8 °C over the same period. Observed extremes in the maximum and minimum temperatures are typical of desert regions;
- rainfall patterns show a relatively high spatial variability over the Maltese territory and no definite trend in the observed precipitation. Since 1923, there has been little change in rainfall during winter and summer, whereas there has been a decrease of 0.14 mm per year during spring and an increase of 0.8 mm per year during autumn;
- during the rainy season, the number of days per year with thunderstorms has increased by nine since 1950;
- the existence of convective rainfall is corroborated by the positive trend in the daily maximum rainfall between 1923 and 2000, since this type of rainfall is of short duration and often heavy;
- an increase in the daily maximum rainfall is observed notwithstanding the fact that, over a full year, the absolute number of days with rainfall in the range 1-50 mm is decreasing;
- the recorded decrease in the mean annual cloud cover over Malta amounts to –0.3 oktas since 1965;

- the duration of bright sunshine has decreased by an average of 0.6 hours per day since 1923. This decrease is attributed to changes in atmospheric composition, predominantly due to the higher atmospheric loading by suspended particles. The trapping of pollutants and dust in the lower atmosphere is favoured by anti-cyclonic situations that are accompanied by lower level inversions and slack pressure gradients, thereby lacking sufficiently strong air currents that could disperse particles. This would necessarily increase the incidence of haze, especially at low elevations of the sun.

6.2 Climate Trends and Scenarios

The IPCC FAR [255] clearly states that warming of the climate system is unequivocal as evidenced from observations of increases in global average air and ocean temperatures and average sea level amongst other parameters. The report states that eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850) with a one-hundred year linear trend (1906-2005) of 0.74 [0.56 to 0.92] °C which is larger than the corresponding trend of 0.6 [0.4 to 0.8] °C (1901-2000) given in the IPCC TAR. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear.

The FAR observes that between 1900 to 2005 precipitation quantities declined in the Mediterranean with the global area affected by drought likely to have increased since the 1970s. It is also very likely that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is also likely that heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide. Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1300 years.

Using MAGICC/SCENGEN version 5.3 it was possible to come up with projections extending over the next one-hundred years for important climate parameters. Without delving too deeply into the uncertainty associated with the results (which are described elsewhere described in Chapter 5) it is interesting to note the following results which are summarised in Table 5.8. It can be pointed out very briefly that while models for temperature increase are quite robust, those for precipitation and sea level rise are associated with high degrees of uncertainties.

Climate Variable	Observed Change	Projected change (without mitigation)
Temperature	Global: increase 0.76 °C in last 100 years 1990s warmest decade for 150 years; 1998 and 2005 warmer than any individual year since 1850 Europe: increase 1.1°C, winters increase more than summer, largest increase over Iberian Peninsula, south-east Europe and Baltic States	Global: Best estimated increase 1.8-4.0°C during this century (range 1.1-6.4°C) Europe: mean increase 2.1-4.4°C by 2080 (range 2.0-6.2°C) with larger increases in eastern and southern Europe
Precipitation	Global: trends highly variable in space and time have been observed during the last century Northern Europe: 10-40% more precipitation South and East Europe: 20% less precipitation	 Northern Europe: annual precipitation increase 1-2% per decade. Decrease in summer precipitation Southern Europe: Overall decrease in annual precipitation, 5% decrease in summers
Extremes	Temperature extremes are more intense and more frequent than some decades ago Globally more intense, and longer dry periods Significantly more wet days in mid and northern Europe, fewer wet days in southern Europe More heavy rain events in most parts of Europe, strongly linked to North Atlantic Oscillation	Heat waves are expected to increase in frequency and severity in a warmer world More frequent extreme precipitation events in entire Europe Northern Europe: more frequent summer droughts, despite more intense precipitation events during these periods Southern Europe: More droughts in all seasons
Sea Level	Seal level rose by 0.17m during the 20th century 1.8 mm/year 1961-2003 3.3 mm/year 1993-2003	0.2-0.6m by 2100, increased Greenland-Antartic melt may add 0.1-0.2m to this Larger values can not be excluded (due to factors not yet sufficiently understood)

Table 6.1: Observed and Projected Changes in Climatic Conditions. [Adapted from [191])

Table 6.1 above summarises the observed and projected changes in climatic conditions [191] which, in a nutshell captures and crystallizes how the main climatic parameters are expected to change and provides an ideal background for assessing vulnerabilities and determining ways of adaptation.

On a local scale, the trends analysis carried out as part of the Second National Communication as well as that carried out by the Physical Oceanography Unit of the University of Malta confirms the trends in the climate parameters as identified in the First National Communication:

- in respect of temperature, the rise in annual average temperature will be in the range 0.53-1.32 ^{o}C by 2030 which is in the main greater that the global mean change. This is expected to result in less cold winters and warmer summers.
- the change in annual mean precipitation is projected to be around –5.5% per ^{o}C global mean warming which can be translated into a drop from the current observed value of 568 mm/yr to 552 mm/yr by 2030 and 507 mm/yr by 2100.
- winds are projected to be slightly weaker during autumn and winter and slightly stronger during spring and summer thereby contributing to higher evaporation rates in the higher incidence of drought periods;
- cloud cover is expected to decrease by about 3% over current annual values resulting in more cloudless skies during winter and autumn;
- in respect of sea level, contrary to expectations Maltese waters have experienced a fall at an average rate of 0.5 $\pm$ 0.15 cm/yr. However to maintain a precautionary approach, projections should be made on the 2002-2006 period during which sea level rise averaged 0.45 $\pm$ 0.15 cm/yr whilst still maintaining appropriate levels of observations in order to determine any changes in trends and the resulting projections into the future that might result therefrom.

It is important to note that, with regards to precipitation, the models put forward scenarios which are associated with high degrees of uncertainties. The observed data (or trends analysis) implies that total rainy days with 0.1 mm or more of rainfall are decreasing while total yearly days with 10 mm or more of rain is increasing. This may be interpreted as a decrease in the total amount of volumetric precipitation but an increasing trend for convective type rainfall or heavy rainfall intensities which in itself characterizes impacts on water resources. Whilst the uncertainties with respect to predictions on precipitation still prevail, the trends identified from data observations are in line with regional scenarios (vide IPCC) with regards to both decrease in precipitation and increase in extreme weather events for the Mediterranean region.

In terms of sea level rise the uncertainties are also high and it is to be noted that for the purposes of this report, although there has been no sea level rise in Malta since the last 15 years, a precautionary approach has been adopted by choosing to use global sea level rise rates or the more recent rates observed in Malta.

Despite the variations that might exist between various sets of projections there is still a justification to start thinking in terms of the realities that might prevail if these parameters were to materialise. In the context of water resources in Malta, where there is a high dependency on desalination for water production, all measures which are climate change friendly and which synergise with the attempt to protect freshwater resources bring with them a symbiosis which is warranted.

All this needs to be placed in the context of continued monitoring of climatological parameters as well as the ensuing forecasting which needs to be maintained in order to obtain early warning signals of trends which may prevail and for which long term action needs to be catered for in order to guard against the predicted outcomes.

6.3 Vulnerability and Adaptation

Vulnerability is defined as the effects of shocks emanating out of climate change on human welfare. This section will attempt to establish the degree and causes of identified vulnerabilities with a view to proposing adaptation strategies to assess such. Climate change can be a driver to alter the quantitative and qualitative status of water resources. Through climate change phenomena, the hydrological cycle can be altered to cause a change in:

- the intensity and frequency of extreme rainfall events (floods and droughts);
- the amount of water available and the demand exerted thereon;
- water quality (e.g. temperature and nutrient content).

Malta's Water Resources Review [80] makes some interesting observations. It warns that whilst there is no compelling statistical evidence of climate change affecting the water resources of the Maltese Islands, there is a risk that climate change will become a serious issue in the future. This comprehensive review states that in a scenario where the sea level of the Mediterranean Sea is expected to rise by up to 96 cm by 2100 a consequential rise in the freshwater lens will occur which will have a negative effect on the abstraction stations in the sea-level aquifers. The climate modelling exercise undertaken as part of this second communication presents further data to reinforce, or otherwise, these claims and further modelling will be required over time to keep the situation under close scrutiny in order to direct Malta's responses to the evolving consequence arising out of climatological changes. It is to be noted that for the purposes of this report, although there has been no sea level rise in Malta since the last 15 years, a precautionary approach has been adopted by choosing to use global sea level rise rates or the more recent rates observed in Malta.

A recent paper by [79] identifies Malta as one of those countries that will suffer mostly from climate change. It makes the case for the potential economic loss that Malta might have to bear as a result of climate sensitive tourists who might shy away from the prevailing conditions. This research also foresees a strong potential for the

decrease of water resources which, although linked to the tourism potential, continues to reinforce the sensitivity of water resources to the onset of climate change.

The Malta Resources Authority which is the competent authority in Malta for water resources has undertaken an initial characterization of Malta's groundwater bodies in line with the provisions of the Water Framework Directive (WFD). In respect of the Malta Main Mean Sea Level Aquifer, this Groundwater Body is at risk of failing to achieve the Environmental Objectives of the Regulations both from the point of view of criteria related to the achievement of the quantitative and qualitative status. It should be noted that the groundwater body is also at risk of failing to achieve the objectives set in the Nitrates Regulations. This also applies to other aquifers such as the Rabat-Dingli Perched, Mġarr-Wardija Perched, Pwales Coastal, Mellieħa Perched Groundwater Body, Gozo Mean Sea Level Groundwater Body, Għajnsielem Perched Groundwater Body.

The Miżieb Mean Sea Level Aquifer shows a 'water balance' estimate that has a slightly positive outcome, whilst recorded nitrate levels are lower than the 50 mgl^{-1} parametric limit and saline intrusion is limited. Further in-depth investigations are needed to determine current and future trends with respect to the attainment of good 'status' as required by the WFD.

As regards the Mellieħa Coastal groundwater body, owing to the fact that no chemical data exists for the Mellieha coastal groundwater body, the condition of the body should be assessed on the basis of similar groundwater bodies such as that at Pwales. These considerations lead the groundwater body to be considered as 'probably at risk' of failing to achieve the WFD's objectives. Similar methodologies are required for the Marfa Coastal Groundwater Body.

The Mqabba-Żurrieq perched groundwater body has been found to be probably at risk of failing to achieve the objectives related to its qualitative status, particularly due to the high nitrate content, most probably arising from the agricultural activities in its catchment area. The characteristics of the groundwater body should however be further investigated and if necessary verified with results obtained from chemical analyses on the groundwater.

In Gozo, the Nadur perched groundwater body is probably at risk of failing to achieve the environmental objectives of the Water Framework Directive particularly those concerning its qualitative status. The Xagħra perched groundwater body is probably at risk of failing to achieve the environmental objectives of the Water Framework Directive related to its qualitative status due to an expected high nitrate content due to the two main land-use types. This also generally applied to the Żebbug Perched and Victoria-Kerċem Perched groundwater bodies. The Comino (which is barely inhabited and has limited activity upon it) Mean Sea Level groundwater body is probably not at risk of failing to achieve the environmental objectives of the Water Framework Directive both from the view of the achievement of criteria related to its quantitative and qualitative status. The groundwater body is however prone to

localized seawater intrusion in response to abstraction from wells, even at low abstraction rates.

Further details on this initial characterisation can be found in [260] from which the above assessments have been reproduced. Therefore it is also very clear that the vulnerability of our water bodies is also dependent on the current state of water resources.

Changes in these variables have a potential impact on socio-economic and environmental goods and services that depend on these variables directly or indirectly (health, agriculture, biodiversity, public safety and industry). Examples of possible impacts of climate change on water resources due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century are summarized hereunder. These do not take into account any changes or developments in adaptive capacity.

It is in this context that the potential outcomes that might prevail are to be seen to have the following potential effects on water resources in Malta namely:

a) any lowering in annual rainfall volumes will mean a decreased contribution to volumes of freshwater resources thus consolidating Malta's dependence on desalinated water;

b) variability in inter-annual and intra-annual rainfall will have corresponding effects on demand as well on the amount of water potentially available for recharge;

c) seasonal scarcity of precipitation when the water requirements of the agriculture and tourism sectors are highest (normally from June to August) could contribute to increased pressures on freshwater resources;

d) high rainfall intensity events, with shorter durations, will have a lower contributing effect to recharging groundwater resources;

   - frequent occurrence of low rainfall years when groundwater recharge is likely to be low;
   - frequent occurrence of high rainfall years when runoff is likely to be high;

e) increased demand for water resources to combat the effects of higher temperatures;

f) higher evapotranspiration rates that will demand increased water volumes for cultivated areas;

g) a potential increase in the salinity of groundwater resources if sea water levels rise with salty water replacing freshwater sources.

Phenomenon and direction of trend	Likelihood of future trends based on projections for 21st century	Impact
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights.	Virtually certain	Effects on some water supplies
Warm spells/heat waves. Frequency increases over most land areas.	Very likely	Increased water demand; water quality problems, e.g. algal blooms
Heavy precipitation events. Frequency increases over most areas.	Very likely	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved
Area affected by drought increases	Likely	More widespread water stress
Increased incidence of extreme high sea level	Likely	Decreased freshwater availability due to saltwater intrusion and higher levels of seawater infiltration in freshwater and sewage galleries

Table 6.2: Possible Vulnerabilities of Water Resources from Global/Regional Climate Change Scenarios [adapted from [255].

The problems that are envisaged to cause water shortages as a result of changes related to climate are identified hereunder.

Lower Annual Rainfall Volumes

The total amount of annual rainfall is a measure of the total potential annual water resources that may be derived from precipitation. Hence, any changes to annual rainfall amounts will have a direct effect on the amount of water that is subsequently directed towards the recharge of groundwater aquifers hence consolidating desalinated water as an important resource for Malta's water production. Despite the capacity that Malta has in terms of producing desalinated water one must bear in mind that this kind of production method has a higher emission level than that produced from groundwater. Lower annual rainfall volumes will alter the water budget with the consequent result that there will be lower volumes of water available for recharge thus lowering the overall contribution of groundwater resources to potable water production, this apart from the potential alteration of existing ecosystems as a result of changing freshwater patterns.

High Rainfall Intensity

A shift towards less frequent and more intense storms is likely to have a twofold negative effect on natural freshwater supplies. As the intensity of a storm increases, the amount of water percolated through pervious areas decreases. This occurs as a result of both the quicker satisfying of any soil moisture deficits as well as a result of the compaction of the upper permeable soil portions through the force generated by the impact of rainfall. From a hydrological perspective such phenomena will in turn lead to an increase in storm water runoff volumes. This will in turn result in lower groundwater recharge volumes and hence lower harvesting volumes. At the same time, high intensity rainfall would increase the risks associated with flooding and civil protection measures. Moreover, increased intensities will automatically lead to increases in peak discharges consequently demanding the need for larger infrastructure to handle such volumes if these are to be in any way harnessed.

Higher rainfall intensities will also give rise to a quicker exhaustion of saturation deficits leading to increased runoff and consequently erosion of the topsoil layers that could cause a cumulative soil loss to the agricultural community.

Changes in Meteorological Parameters

Changes in climate will undoubtedly have a knock on effect on the demand for water both in terms of consumption as well as for supporting agriculture and animal husbandry for the purpose of food production. A simple increase in temperature alone will be responsible for an increase in water demand from the current estimated levels of around 70-80 litres per capita per day. For example, an increase of 5 litres per capita per day, in terms of demand, would translate into an additional 2000 m^3 of production per annum from the domestic sector only. Similarly, such condition would also affect tourists who consume around 150 litres per capita per day excluding water sources derived from beyond public water supplies, as well as animals reared in the animal husbandry sector.

Losses of water through evapotranspiration are usually related to a number of climatic parameters. Evapotranspiration generally increases with increases in temperature, sunshine and wind speed and with a decrease in humidity with a close relationship existing between net solar radiation and evapotranspiration. Actual evapotranspiration rates for Malta have been calculated at 63% of precipitation, which indicates that over half of our potential natural freshwater resources from precipitation are eventually returned to the atmosphere. Climate change scenarios which predict increases in temperature are likely to fuel an increase in evapotranspiration rates. This would mean that more water would be required in order to sustain current agricultural practices.

Sea Water level Rise

A rise in sea water level of over 40 cm by 2100 will make water's groundwater supplies more vulnerable to salinization as the degree of saltwater intrusion is

directly dependent on the distance between the bottom of the well and the freshwater-saltwater interface. The Water Resources Review [80] quotes recent results as having shown that in the central regions of the Islands, particularly around major pumping stations, the freshwater-seawater interface has reached levels close to the mean sea level. This means that any relative future change in sea level will have more pronounced effects in these regions in terms of deteriorating the quality of water extracted from groundwater sources.

The expected annual reduction in rainfall, which may amount to between 10 to 40% by 2100 over much of Africa and southeast Spain, with smaller but significant changes in other places, will do little to maintain the current sea water-freshwater interface with potential increased salinization of the freshwater aquifer. This is because the degree of saltwater upconing is directly dependent on the distance between the bottom of the well and the freshwater-saltwater interface. The rainfall pattern is also expected to change, resulting in a shorter rainy season with shorter but higher-intensity storms. The materialisation of these projections on a local level for these two factors are most likely to cause a decrease in the amount of water infiltrating to recharge groundwater systems and a potential increase in flooding due to higher storm water volumes generated. Conductivity logs for the Ta' Kandja and Mrieħel GBH show the interface standing at –10 m for the Ta' Kandja GBH, located near the Ta' Kandja pumping station and at –80 m for the Mrieħel GBH, which is not located particularly close to any pumping station. The state of the aquifer in the Ta' Kandja region makes it more prone to adverse effects from sea-level changes [80]. This situation would affect both aquifer types but would be expected to have a drastic and immediate effect on the perched aquifers where the annual recharge forms a large percentage of the aquifer storage. This can have a knock on effect on the principal users of such perched aquifers with a major impact on farmers.

In the case of the mean sea-level aquifer, a reduction in precipitation coupled with a sea-level rise would not only cause a decrease in the volume of freshwater available but would also be expected to reduce the groundwater storage capability of the freshwater lens. This is basically because the height of the piezometric head at any point in the island is proportionally dependent on the amount of infiltrating recharge; and the storage capability of the groundwater body for a given set of geological conditions depends exclusively on the hydraulic head.

Sea water level rises would also give rise to a further salinization of our water resources. In the case of water supplies from groundwater, a rise in sea level would have a negative effect on the galleries and pumping stations as these will be subject to increased infiltration of seawater as a result of its consequent rise. Therefore the balance required from reverse osmosis production needs to be greater in order to retain the same blend, or 'desalinization treatment' would have to be applied to extracted water or significant investment would be required in order to modify the existing infrastructure.

Similarly for sewage, parts of the system which are channelled through galleries cut in rock will experience greater seawater intrusion unless any infrastructural

interventions are undertaken. This would lead to increased salinity of wastewaters and deterioration in the quality of the treated effluent which would have to be polished in order to eliminate its excessive salt content.

The aforementioned vulnerabilities also need to be seen in the context of other work, of an environmental dimension, which Malta is pursuing. This is particular in respect of the impact of water resources on biodiversity as well as the impact of agriculture on water resources in particular where the use of nitrates as fertiliser is concerned. Similarly, the actions being taken by Malta also need to be seen in the light of what it is achieving through the transposition of the environment acquis into local legislation.

6.3.1 Adaptation Strategy

A proper adaptation strategy is one which takes climate change considerations into account, to the extent of being feasible, in social, economic and environmental policies, practices and actions by all stakeholders. Adaptation will be required to reduce the costs and disruptions, alter behavioural patterns and give an additional context to decision making to acknowledge those causes derived from climate change, particularly from extreme weather events like storms, floods and heat waves. We are witnessing a variety of climatic phenomena which are working in tandem to potentially impact water resources. A fall in annual rainfall volumes coupled by more intense events augment the losses of freshwater and therefore impinge upon the recharge potential of groundwater aquifers; lower rainfall amounts coupled with higher temperature not only make water scarce but also increase the demands from human consumption and evapotranspiration; lower rainfall volumes coupled with seawater level rises contribute to lower groundwater volumes.

Many a time the thought of reducing GHGs has stemmed as a frontrunner towards solving climate change and associated phenomena. Whilst all efforts to mitigate against GHG emissions are to be fully supported there is strong evidence that even if GHG levels were to be contained at current levels, increases in temperature and related impacts will persist for years to come. Hence it is important to focus, in parallel, on adaptation measures that will entail adjustments and changes at every level - from local to national and international. These include changes in behaviour, in engineering designs, in policy formulation, in public and private initiatives and service delivery and in the development and use of technology. This is the essence of adaptation planning.

Climate Change Risks	Potential Risks and Opportunities		
	Freshwater resources	**Wastewater**	**Land-related Processes**
Increase in summer temperatures	increased demand for potable water (M) increased pressures on groundwater (H) increased demand on reverse osmosis plants (M) increased evapotranspiration rates (H) potential public health and hygiene issues (L)	increased sewer dry weather flow (M) increased dry weather treatment volumes (M) increased treated effluent volumes (M)	reduction in groundwater recharge (H) more aggressive regime for agriculture (H) ground shrinkage (M)
Increasing winter temperatures	increased demand for potable water (M) increased pressures on groundwater (H) increased demand on reverse osmosis plants (M) increased evapotranspiration rates (M)	increased sewer dry weather flow (M) increased dry weather treatment volumes (M) increased treated effluent volumes (M)	productive regime for agriculture with opportunities for premium products maturing early (L)
Higher winter rainfall	increased volumes for recharge (M) existing water storage volumes might be insufficient (H) increased stormwater runoff (H)	higher volume of stormwater generated which may exceed infrastructure capacity (H) higher volumes of stormwater entering sewers – surcharge events increase (H) increased volumes of wastewater to treat at sewage treatment plants (M) increased volumes of treated effluent may remain unutilised (H)	increased flooding instances (H) increased damage to infrastructure (H) increase in soil erosion (M)
Lower summer rainfall	lower recharge volumes (H) increase in demand from agricultural sector (H)	lower sewage volumes and consequent treated effluent volumes (M)	ground shrinkage (M)
Higher intensity of rainfall	higher proportion of total rainfall might end up as runoff and not contribute to recharge volumes (H) higher level of pollutants in stormwater (H)	higher peak flows in sewers (H) increased possibility of sewer surcharge and overflows (H)	increased incidences of flooding (H) damage to infrastructure increases (H) increased soil erosion (M)
Sea level rise	reduced volumes of groundwater (H) increased salinity of groundwater (H)	increased seawater infiltration volumes (M) more saline wastewater and hence treated effluent (M)	loss of land (L) increased flooding of coastal areas (M) increased need for flood defences (M) new methods of construction (H) insurance premiums may increase (M)

Table 6.3: Observed and Projected Changes in Climatic Conditions - Level of Vulnerabilities and Opportunities.

Table 6.3 presents a Water Resources Impact Matrix that shows how the various changes in climatic parameters are expected to effect water resources. Notwithstanding it is important to consider Malta's ongoing developments in the water sector.

The WFD aims to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. In terms of the obligations under the WFD, Malta is currently working on assessing the status of water bodies (groundwater, terrestrial and coastal) and develop River Basin Management Plans including Programmes of Measures safeguarding the water bodies. The WFD provides an opportunity for climate change adaptation through the RBMPs and Malta should take into consideration climate change impacts in the implementation of the WFD [260].

The Government is currently working upon a Storm Water Master Plan which is aimed to address a number of issues related to the two paramount and juxtaposed issues of flood relief and water conservation. The Plan is intended to identify priorities to be adopted as policy, and projects for their implementation and is to include the results of an investigation and evaluation of the feasibility of the identified policies and actions, for:

a) management of the various impacts associated with storm water including flooding, road infrastructure deterioration and traffic management, civil protection and valley management in general and also with reference to particular flood prone areas and localities;
b) utilisation of storm water to augment the water resources of the Maltese Islands through harvesting, storage, use, re-use, recycling, distribution of storm water and proper disposal of excess.[262]

From an agriculture perspective, Malta's National Rural Development Strategy for the Programming Period 2007-2013 identified water resources as an important aspect for this sector and provides a thorough scenario of the resource implications as well as the climate change implications resulting from the sector (refer to Chapter 11). Moreover it puts forward eligible actions that aim to improve the impact of the agricultural dimension on water quality both in terms of surface and groundwater.

Equally important is Malta's current programme aimed at treating all sewage prior to disposal. At present two sewage treatment plants have been constructed, in Gozo (having a capacity of 6000 m^3 per day) and to the North of Malta (having a capacity of 7000 m^3 per day), with work underway on Malta's largest sewage treatment plan in the South of Malta which will have a capacity of 60000 m^3 per day.

Malta's Operational Programme I - Investing in Competitiveness for a Better Quality of Life also identifies water resources as one of the areas of intervention and cites the areas of intervention for the stormwater masterplan as well as for sewage

treatment in the south of Malta as permitted interventions to achieve the targets set out for this Programme.

The importance of water resources in connection with energy requirements is also evidenced in the Legal Notice 238/2006 "Minimum Requirements on the Energy Performance of Building Regulations, 2006" and its Technical Guidance (F) which provides for the conservation of rainwater from buildings by stating that this should not be allowed to drain into sewers but collected within cisterns within the area of the building. It also suggests that such water is reused for irrigation and toilet flushing with a view to maximising the demand side management of this resource.

It is therefore evident that Government recognises the problems it is facing in the sector as well as the high level areas of intervention which are required. Climate change scenarios with respect to water resources can synergise with other strategies aimed at improving the water status of the Maltese Islands and it is these synergies which make a cohesive approach towards addressing Malta's vulnerabilities, obligations, mitigation and adaptive stances in respect of water resources.

This section aims to put forward an adaptation strategy for the Maltese Islands that is based on the country's characteristics and which takes into account its main vulnerabilities with a view to embarking upon a process which, despite all other mitigation efforts, will ensure that the population and its visitors may be able to adapt to those changes which, irrespective of all other efforts, are likely to manifest themselves and effect all members of society.

6.3.1.1 Governance (Legislation, Policy, Regulation and Institutions)

Good governance for climate change needs to be factored as an integral part of policy making. It is important to ensure that the country is sensitised to the challenges that are being faced by ongoing changes in climatic conditions and to safeguard the population against such phenomena as far as possible. Adaptation measures include:

Revise Existing Regulations

Existing planning regulations should be revised to factor in the likely effects of climate change. These would include the delineation of areas which might become prone to flooding with a view to ensure that development of such areas takes these factors into consideration and provides adaptive measures that combat such phenomena. It is important that this would be combined with extensive sea level monitoring and forecasting techniques such that no unnecessary action is taken particularly in the light of the variations in data that exist for the region including Malta.

One must bear in mind that the collection and treatment of storm water that is generated from urban developments presents a very high costs to make it economically and financially viable. This points towards an increased relevance of

demand side management practices aimed to integrate water conservation and reuse features at the point of generation. The minimum requirements on the Energy Performance of Building Regulations, 2006 already stipulate the need for cisterns as well as the need to have a draw off point for use for toilets and landscaping. Consideration should be given to amplify building regulations that stipulate mandatory requirements or that support good practice for new developments. These would include the obligation to foster the use of dual flush toilets and water conservation fittings in all public buildings amongst other initiatives.

Moreover, existing and future plans, policies and projects should seek to integrate adaptation measures as an integral component of their environmental dimension.

Integrated Water Management Plans

Government should task the Malta Resources Authority to develop Integrated Water Management Plans that amongst other issues would tackle climate change induced reduction in water availability and analyses the effects of such reductions on the environment and society. This is in line with the provisions of Subsidiary Legislation 423.20 - Water Policy Framework Regulations - and which transposes the provisions of the WFD, which obliges the competent authority to develop water catchment management plans.

Local legislation already stipulates that water catchment management plans are to be published by the end of November 2009 and reviewed and updated by the end of November 2015 every six years thereafter.

Provision of Fiscal Measures

Amongst the provisions of the Water Policy Framework Regulations is that the competent authority shall ensure that measures are taken to prevent the deterioration of the status of all bodies of groundwater, and to take the necessary measures to protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status by the end of November of the year 2015.

In order to encourage energy efficiency and renewable energy initiatives, Government had issued schemes which offered financial incentives on such initiatives. The recent scheme that offered a 50% rebate on PV panels, 66% rebate on solar water heaters and a 33% rebate on certain other energy saving materials such as roof insulation are all steps in the right direction to instill an adaptive cultural change. On the same lines, fiscal incentives such as tax credits or VAT waiving on works or fittings that permit water conservation should be considered. These could be aimed at both existing and new dwellings. Similarly, fiscal penalties should be in place for those abusing of water resources.

The value of the water resource should be actively analysed in order to make the full wealth of our water resources appreciated by the whole of society and to legislate in

favour of metering authorised boreholes in order to ensure that abstraction is effectively controlled. This requires a national consensus with targets for cost recovery set accordingly.
In this context a pricing regime for the promotion of safe uses for second class water is advisable as this would otherwise end up discharged to the marine environment. Lessons learnt from the wastewater treatment experience which has prevailed since the early nineties could prove of value together with increased research on the issue.

Green Government

Government has a duty to lead by example. The Green Leader concept that was introduced by Government was a first step in sensitising the public administration towards the need for a greener approach towards the use of resources. It is perhaps time to step up a gear by securing that the Green Leader concept is strengthened to ensure that an Adaptation Plan for the Public Administration is drawn up and implemented and contributes towards our national targets. This plan should be subject to consultation, made available to all public employees and monitored for results. This plan should be publicised as a best practice model for other organisations to be enticed into adopting similar initiatives.

Furthermore, Government is in a unique position to use its status of being the single largest procurer of goods and services to send a strong message that promotes the sustainability of resources by entrenching green public procurement concepts within its procurement systems. A draft of the Green Public Procurement document had been produced by Government and it is advisable that this issue is revived and brought to fruition.

Water Governance

Water Governance is the key to sustainable use of water resources. Water Governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society (UNDP definition).

It is in this sense that Malta would have to develop abstraction and permitting schemes which together with other regulatory measures would improve the sustainability of the resource which has been deteriorating as a result of the prevailing abstraction practices and which have a knock on effect on the sustainability of the groundwater resource.

In the context of Government's declared moratorium for the drilling of new boreholes there is a call for the introduction of a complementary dedicated and strict enforcement regime aimed at tackling unauthorised extraction of groundwater.

Awards

Government should introduce a system of rewards which is subsequently linked to a remuneration as well as publicity on Malta's efforts abroad be they of a tourism or enterprise nature.

Data

Data regarding water resources and climatic parameters are collected by different entities. Often enough the lack of the availability of such data, in its raw format, does not encourage research in this field. The setting up of a Climate Change Observatory would be able to collate all data inputs and make them available for researchers whilst at the same time it would liaise with the competent authorities with a view to producing national databases with reliable data on water use. A special mention goes to the uncertainties of the rise or fall of Maltese waters which show the need for monitoring in greater detail to ascertain trends.

The NSO is Malta's central competent authority responsible for statistics. Notwithstanding there are other entities who collect data. Within the business and citizen environment, data sharing concepts are promoted as part of Malta's better regulation agenda. The creation of an inventory of data collecting sources and the consolidation of such data in a manner that can be accessed from a single platform is called for. This would facilitate research as well as provide useful information for those wishing to embark upon climate and water related projects and research.

Furthermore Malta's experience in the MEDHYCOS project warrants the potential investigation of the proposed Observatory to form part of a wider Mediterranean based Observatory in order to foster research amongst the Mediterranean partners as well as to ensure that climate and desertification modelling may be carried out on a sizeable catchment.

Insurance

Directive 2007/60/EC on the assessment and management of flood risks obliges Member States to undertake preliminary flood risk assessments as well as to subsequently prepare flood hazard maps and flood risk maps.

Any rise in sea water level, whether it results in the forecast modelled by MAGICC/SCENGEN or even if it is worse as suggested by other sources, could have a potential knock on effect on low lying areas. With a preamble of ensuring that there is sufficient evidence that indicates the certainty of loss of land as a result of such phenomena, it is important that, in collaboration with the financial services sector, the issue of insurance implications of properties/activities in flood prone areas should be explored with a view to determining whether there is cause for differentiating between various zones whilst at the same time offering protection to those who may still wish to operate in vulnerable areas.

Land Value

Linking on to the aforementioned issue of insurance, land value is another issue that needs to be looked into. The construction sector in Malta has always been very active with the industry itself having a significant effect on the Maltese economy both in terms of its contribution to GDP as well as its direct and indirect employment creation potential. Any area that risks fulfilling its full development potential would be accompanied by a revaluation. This could have a significant effect on the investment returns of individuals. Through sustained monitoring and forecasting techniques, it is important at this stage to assess the extent of the likelihood of such scenarios with a view to determine potential scenarios and impacts for the construction and real estate sectors in this respect.

The revision of the Structure Plan for the Maltese Islands is also seen as an enabler towards policy making in this area.

6.3.1.2 Capacity Building

Strengthening Public Capacity

The competent authority responsible for water resources should be strengthened with a view to enable it to develop the capacity to research, act and educate on the need to adapt to a scenario of limited freshwater resources. This also needs to be complemented with the attraction of specialists to study and subsequently work in the sector and hence the educational dimension needs to ensure such results.

Development of Schemes for the Unemployed

Government had undertaken a project whereby some people who were on the unemployment register were trained in waste management and subsequently deployed to train households in this area. Malta's human resources are one of its main assets and such initiatives should be replicated with a view to utilise such resources whilst at the same time enriching their learning experience. Schemes could be developed for persons currently on the unemployment register to be trained to understand the pressures of climate change on water resources and to tour the various commercial and residential premises in order to offer free advice on how to adapt to anticipated scenarios.

6.3.1.3 Research and Monitoring

Encourage Research Initiatives

Research into the variation of various parameters in response to climate change needs to be encouraged. For this purpose, it is vital that Government, through its research institutions, gives priority to such actions. The University should try and attract various students to undertake their dissertations in this area whilst EU funding instruments should, where possible, place climate change initiatives at the

forefront of national priorities. This is also in line with Malta's R&I Strategy which places great emphasis on popularising and incentivising Science and Technology disciplines.

Undertake Research for Adaptation

Adaptation is not an option - hence establishing ways and means of adapting to phenomena beyond our control as quickly as possible is imperative. As climate change will undoubtedly exert an influence on water resources, one of the areas which may be suitable for research relates to research for agriculture wherein, the best economic-financial-water use matrix that results in win-win strategies and solutions could be identified.

In line with Malta's R&I Strategy, research on areas such as drought occurrence and the maximisation of the recharge potential of our aquifers need to be encouraged in order to be able to better adapt to the upcoming circumstances.

Similarly, research into crop tolerance to drought and increased salinization is required in order to offer the local agricultural sector concrete advice on potential diversification to less water demanding crops and crops which can better adapt to foreseen climatic condition thereby ensuring the sustainability of this sector.

Monitoring

The setting up of a Climate Change Observatory which would have access to all data that is required and that is currently collected through national resources has already been referred to. This observatory could be formed in conjunction with the support of the Meteorological Office, the Agricultural, Water, Environmental and Energy authorities. It should however have a separate persona from these entities in order to enable it to conduct audits of performance by private and public stakeholders.

Treated effluent

As part of Malta's obligations under the Urban Wastewater Regulations which transpose the Urban Wastewater Directive, three new sewage treatment plans are required in order to treat all of Malta's sewage prior to disposal. The two plants at Ras il-Ħobż and at iċ-Ċumnija already generate around 13,000 m^3/day of treated effluent whilst the new treatment plant at Ta' Barkat will have a capacity of about 60000 m^3/day. These are substantial volumes of a water resource which could spell a new opportunity for Malta's water resources.

Research into possible utilisation of treated effluent should be encouraged. This could extend to as many sectors as possible with construction, agriculture and tourism being possibly the prime candidates for intervention. Malta's experience in the use of treated effluent dates back to the early eighties. Additional research that explores possible safe use of this resource should be considered.

6.3.1.4 Education and Communications

National Minimum Curriculum

The current revision of Malta's National Minimum Curriculum should seek to combine the emergence of environmental issues in a more holistic manner taking into account the need to learn about the management of our environment in a sustainable manner throughout all the stages of compulsory education.

Strengthening Environmental Studies

Environmental Studies should not be dominated by the environmental issue of the day but should seek to integrate aspects such as climate change, sustainable development, water, energy, waste, biodiversity and the like into an integrated curriculum. Moreover, great importance should be attached to this subject with due consideration being given to the possibility of making this subject a compulsory requirement for progression on to higher education as it is a cross cutting subject that will effect each and every individual throughout his/her life independent of the career chosen.

Educate and Communicate

Education should not be limited to compulsory education or to the formal education system. The environment is our heritage and we have an obligation to manage it in a sustainable manner such that we may bestow it in a similar or better state to our successors. Therefore it is important for the competent authority to identify the various target groups that form our entire society and to target educational campaigns in order to raise their awareness. Such campaigns could include courses, adverts, brochures, onsite visits and demonstrations possibly in conjunction with stakeholder representatives - constituted bodies, local councils and NGOs.

Outreach activities should be designed with a view to targeting those sectors or groups which are at greatest risk from the changes resulting from climate change. A particular group is farmers and those involved in the agricultural sector. This sector has turned out to potentially be that which exerts the highest demand on groundwater resources and as such an outreach programme would transmit the educational knowledge of the best adaptation measures for the sustainability of the sector which could include crop diversification strategies, improved irrigation methods and the like.

Within the communications dimension, Government has a role to play. Through its horizontal role in society it can send key messages to all actors in favour of behaviours which are in synch with climate change good practice. This needs to be done creatively and in a manner that it uses the right message to reach out to the various audiences that characterise society.

Changes in Behaviour

The sensitisation of people towards better behaviour in their use of water needs to be embarked upon. This involves informing people about the water consumption properties of everyday life such as showering instead of bathing; dishwashing against washing crockery in a basin or under running water; the non potable potential of certain activities to replace that currently satisfied through potable supplies. Efficient appliances such as dual flush toilets should also be promoted. This level of education needs to be transmitted to all strata of society with a tailored message.

The same applies to those involved in the commercial or public administration sector that needs to be 'educated' into making their enterprises more efficient.

A 'Water Wisdom' initiative would be opportune with the aim of helping the Maltese make informed and wise decisions about their own water resources. Such an initiative needs to be independent from Government with no political allegiance but only with the best water interests at heart. The main aim of this initiative would be to provide objective information about water resources and how they are being used, at the same time providing conclusions and consequences based upon objective evidence, on the consequences of change or *status quo* scenarios. This initiative would also serve to communicate water resource information in an effective and timely manner and to show its presence in an active manner in the appropriate fora.

Efficiency in Design

Buildings that house people or activities in themselves lead to the consumption of water. The Minimum Requirements on the Energy Performance of Building Regulations, 2006 are a step in the right direction to foster the use of runoff from the building's footprint for secondary uses. Moreover, courses being organised for assessors are in themselves a complementary positive initiative to secure the greener performance of buildings. It is therefore paramount to 'educate' professionals into adopting efficient design practices. These include initiatives such as water supply systems with short runs of pipes from water heaters to avoid long lengths of 'cold water' being wasted particularly in the cooler months as well as the use of water efficient fittings. Such training needs to be targeted at architects and civil engineers; building services engineers and plumbers and electricians in particular.

6.3.1.5 Acceptance of Certain Impacts

Coastal Areas

There is still an amount of uncertainty on the outcome of sea water rise vis-à-vis how this will impact, if at all, Malta. Notwithstanding, it is important to understand the potential scenarios that might result. In this respect Malta may need to develop scenarios that identify those coastal areas which are likely to be subject to constant

flooding as a result of various climate change outcomes. This would give an indication of the extent of areas which could be earmarked for redevelopment. This would offer the opportunity for specialists in planning, architecture and engineering to develop proposals and concepts for such areas which in turn employ design and engineering methods that adapt to such phenomena. These might include, but not be limited to, raised building levels that can accommodate a degree of flooding without rendering the site wasteland.

Notwithstanding, Malta is obliged under Directive 2007/60/EC on the assessment and management of flood risks to undertake preliminary flood risk assessments as well as to subsequently prepare flood hazard maps and flood risk maps. The synergies between the impacts of climate change on land use as well as the provisions of the Floods Directive are considered synergistic and contribute to reinforce each other.

Increase of Treated Effluent Volumes

Treated effluent volumes are bound to increase and will amount to around 73000 m^3/day. The fact that Malta's sewage is not yet fully treated is in itself already a catalyst for change as significantly higher volumes of treated effluent are expected in 2009 which are far beyond those experienced currently. The use of treated effluent within the groundwater protection zone is to be avoided and hence it is worth studying the possibility of reclaiming disused land outside the groundwater protection zone for the development of controlled agricultural parks which would be able to benefit from plentiful quantities of treated effluent and which possibly, in a controlled environment, can offer a premium organic product that will increase the country's competitiveness in the sector. All this would have to be undertaken taking into account all health and safety guidelines that have been developed and recommended so far by leading institutions such as WHO and others.

6.3.1.6 Prevention

Leakages from Infrastructure

The WSC is looked upon as a "Best Practice" example of leakage control by other water companies. Apparent water losses include both the actual leakages from the distribution infrastructure as well as the water being consumed but which is unaccounted for due to inaccuracies in the billing system. Total apparent water losses in 2005 stood at 47.65% of total water production whilst total actual losses (leakages) stood at 21.59% of total water production. Actual leakages were reduced from 2002 to 2005 with the leakage amount of 2005 standing at 32.87% less than the amount of 2002. Whilst recognising that water supply systems have an economically viable leakage index one should ensure that levels are maintained as close as possible to such benchmarks whilst focusing on securing the reduction of unaccounted for water.

Improving Infiltration Potential

Ground water recharge depends entirely on the ability of the terrain to percolate sufficient water before it is lost through evaporation or surface runoff. Prevention of fresh water losses are multidimensional and include proper demand side management where storm water generated at a local level would be retained and reused instead of being discharged as runoff. Subsequently the improvement of soil infiltration needs to be studied - this includes the preservation of permeable surfaces and the enhancement of other surfaces.

Irrigation Systems

The introduction of drip irrigation systems has contributed towards the water efficiency of the agricultural sector. However, a proper understanding of crop water requirements is required to ensure that farmers are well aware of the correct amount of water to direct to the various species and that water usage is determined as much as possible on scientific grounds to assist the farmer in optimising his crop.

Any changes in volumetric or intensity characteristics of rainfall will undoubtedly have a knock on effect on the water available for irrigation. Whatever the outlook and whatever changes may occur, the situation today is already at critical levels with a considerable amount of groundwater being abstracted directly for agricultural purposes. If the current situation is afflicted by the changes in precipitation, temperature and sea water level rise, the demand versus availability balance is sure to become even tighter as increased crop water requirements become necessary but with lower amounts of groundwater and storm water available to satisfy such increases in demand.

Cognisance must also be given to the types of landscaping that is used to embellish public areas. Central and local government must be aware of the landscaping demands exerted by certain plant types (e.g. turf, certain flowering plants etc) and to move towards a more indigenous form of landscaping which could optimise on current irrigation water consumption volumes.

Infrastructure

Existing infrastructure is bound to suffer from increased volumes of water to handle during flash floods. Consequently, where possible, the existing systems should be modified to take into account such phenomena. Practical examples include the construction of, or the use of existing infrastructure to act as, detention basins in order to protect sewerage infrastructure against flooding with the resultant contamination to land. Moreover, new infrastructure should already factor into the loading calculations the impact of climate change.

The use of dams to prolong retention times of stormwater in valleys should also be considered so as to enhance the recharge potential to groundwater.

It is expected that the Storm Water Master Plan currently being formulated will address these issues but should also take into account climate change perspectives in developing its proposals.

Water supply systems should be designed as intelligent water distribution systems with pressure balancing to improve water efficiency and reduce the amount of losses from the system.