Water - A Crisis?

Gordon Knox

Traditional well exposed in quarry wall of The Limestone Heritage, Siġġiewi.

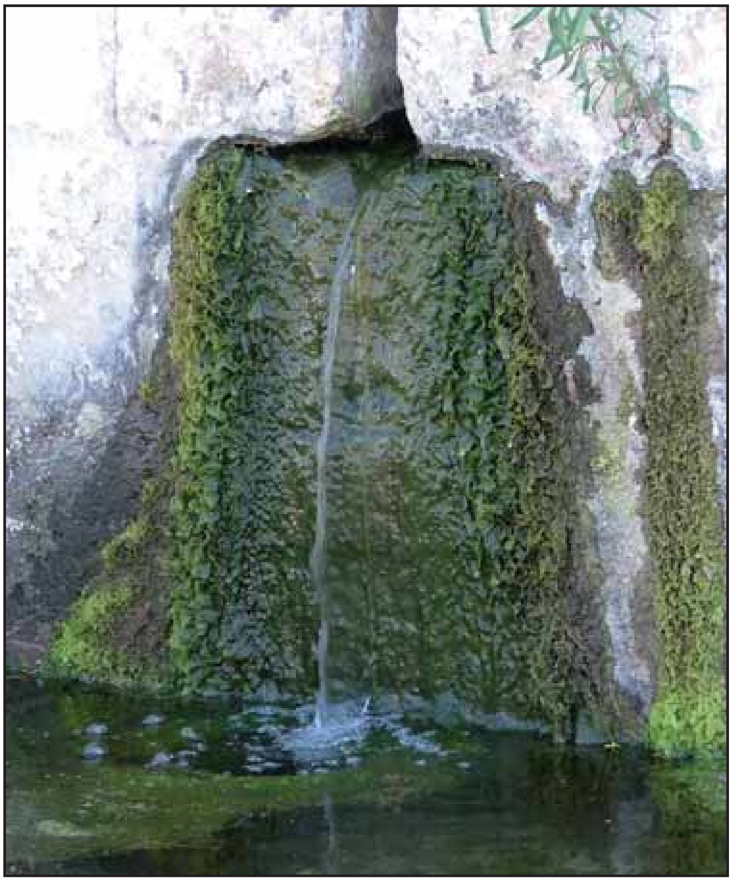
Photo Gordon Knox

Malta is heading for a crisis unless attitudes to water management and conservation change drastically. Natural water resources are over exploited and insufficient for the population of the islands, meaning that the shortfall is provided by expensive reverse osmosis (RO) desalinisation plants and virtual water.

Water is such a common substance that it is totally taken for granted – a public right at public expense, with seemingly inexhaustible quantities available at the turn of a tap. It is an essential component of life as we know it. It has many unusual properties and manifestations, which not only form the basis of myriads of natural processes but have continued to be fundamental to human society from prehistory to the present day. However, these properties, particularly water's use as a natural solvent, also mean that resources can be easily damaged or destroyed if they are not properly managed. Once water resources are lost by displacement or pollution, they are very expensive to replace.

Interplanetary probes have established that water is a common component of the Solar System and it is likely that Earth's original volume of water was inherited from condensation from the Solar Nebula around 4.5 billion years ago. Geological studies show that the Earth has had liquid oceans and a hydrological cycle for the greater part of its history. Today, most water – around 97.5 per cent – occurs on the surface of the earth as salt water and only a small proportion – 2.5 per cent – is in the form of fresh water, of which 68.9 per cent is locked up in ice, 30.8 per cent is in groundwater and 0.3 per cent is in lakes and rivers, with a further amount as vapour in the atmosphere. It is involved in an immense geodynamic cycle, largely powered by solar energy by which surface waters are evaporated and purified before condensing as precipitation. Exchange also takes place with ground waters and deep geology partially energised by the Earth's own thermal energy from the decay of radioactive elements. The biosphere constitutes an intimate part of the geodynamic cycle and consumes and excretes water on a vast scale.

Precipitation is not equitably distributed, and nor is usable ground water. Some countries have an abundance of water, but in others water is scarce. In many parts of the world water resources are under severe pressure. Precipitation often does not meet a population's needs and fossil ground water is extracted in an unsustainable manner. This is true on the Maltese Islands, where ground water is being extracted at a greater rate than the rate at which it is replenished.



Natural spring, Rabat.

Photo Gordon Knox

The main natural water resources in Malta and Gozo consist of the mean sea level water bodies or aquifers (MSLAs), which are essentially Ghyben-Herzberg fresh water lenses floating on denser seawater. The actual water is situated in fissures and pores mainly within the Lower Coralline Limestone Formation. Minor resources are situated in perched aquifers lying above the impermeable Blue Clay Formation. Perched water flows outwards above the Blue Clay Formation surface and springs are found where the Blue Clay and succeeding Upper Coralline Limestone Formation outcrop in the Maltese countryside. A very minor, transient, but potentially significant volume is trapped in runoff tanks, cisterns and wells. Run off capture has been important throughout Malta's history. Notable examples of this are the prehistoric Misqa Tanks, close to the Mnajdra Temple, and the cellar cistern of the Roman Villa site near Ghar Dalam. There are thousands of traditional flask-shaped domestic and agricultural wells, a good example of which can be seen on the quarry wall at The Limestone Heritage, Siġġiewi. Many are still in use today, and many houses have rectangular cisterns, covered with an arch-supported superstructure beneath ground level, to catch roof and street run-off. Along the main valleys there are small dams that assist the collection of storm run off and subsequent infiltration into the subsurface. Historically, Maltese society exploited the springs above the blue clay formation at a local level, and in the early 17th century the Wignacourt Aqueduct was built to carry water from the Mdina/Rabat area to Valletta. The MSLAs were largely unseen and unknown, apart from springs and brackish pools adjacent to the coast and only became exploited heavily during the 20th century. Today, around 60 per cent of Malta's water is supplied from the MSLAs via boreholes and pumping from a system of underground galleries.

The actual volume of water resources in place, and producible on a sustainable basis, cannot be measured directly. Geological modelling is required, plus a knowledge of the variation of rock porosity, such as geometrical properties and connectivity and permeability and related flow rates. Modelling is difficult because the host rock is limestone, which may not only have primary porosity between rock grains, formed when the limestone was deposited, but also secondary porosity caused by physical processes such as faulting and fissuring and/or by dissolution and reprecipitation of the limestone fabric to form voids that range in size from microscopic scales to caves. In the subsurface, water flows easily along fissures, but with less ease through microscopic pore spaces. While this phenomenon aids productivity from a borehole, it can also mean that salt water is sucked into the periphery of the borehole, thus damaging the aquifer.

A good understanding is needed of charge rates and depletion rates (natural + artificial). Estimates should never consist of a single figure, as there are many uncertainties inherent in the estimates – including the heterogeneity of the host limestones – and ideally should be modelled in a probabilistic manner. The volume of the fresh water lenses beneath the islands was estimated at two billion cubic metres several decades ago. However, it is not the water volume in place in the rock that is important, but the sustainable producible volume.

Fissure and water dissolved voids exposed in quarry wall of The Limestone Heritage, Siġġiewi.

Photo Gordon Knox

Charge comes mainly from precipitation but also includes leakages from the domestic water grid and also leakages from sewage pipes. Depletion depends not only on extraction but also on the natural dynamic flow of the water to the edges of the lenses along the coasts of Malta and Gozo, where brackish pools and springs can form.

Precipitation rates are related to rainfall, but infiltration to the ground water bodies is discounted by surface evaporation, plant transpiration and surface run-off to the sea. Precipitation can vary significantly from year to year, but collection of data over many decades gives a mean figure for the annual precipitation on the Maltese Islands. For example, annual rainfall is around 0.5 metres per year, meaning that about 160 million cubic metres of rain falls on the 316 square kilometres area of the Maltese islands, of which a range of about 22 to 40 million cubic metres infiltrates to the MSLAs on average (In a wet year 80 million cubic metres and in a dry year 16 million cubic metres may be added respectively). To this may be added about 5.5 million cubic metres from leakages in the water utility network and possibly an equivalent amount from sewage pipe leakages. Of the remainder, around

Run off flood water in Wied Hal Balzan, September 2003.

Photo Gordon Knox

6 per cent reaches the sea as direct runoff, although in built up areas this may reach and exceed 80 per cent. Some 70 to 80 per cent returns to the atmosphere by evaporation and transpiration and an unknown quantity is harvested by run off wells, cisterns and tanks.

In the MSLAs, natural depletion is a continuous process by flow to the periphery of the lenses at the coastlines. This may be in of the order of 23 million cubic metres per annum. Artificial depletion takes place through boreholes and pumping stations by the public utility with a relatively minor amount from springs and by both regulated and unregulated private boreholes. The map of the Malta Resources Authority (MRA) illustrates the historical density of the latter and includes old private hand-dug boreholes (blue dots), new boreholes (red dots), registered for the first time in 1997, and springs (green dots).

In 2007, the metered ground water extraction was of the order of 13.4 million cubic metres per annum, while to this should be added an unreported volume estimated at 16 million cubic metres, giving a total of around 29.4 million cubic metres per annum. Perched aquifers discharge naturally by springs and further extraction takes place from boreholes and wells. However, perched aquifers only supply a minor component of the Maltese Islands' water supply.

An aquifer has a maximum sustainable yield that includes natural as well as artificial depletion, beyond which it will suffer irreversible damage. In the case of the MSLAs, salinisation and invasion by seawater is the major threat. All Maltese aquifers are affected by pollutants such as fertilisers and infiltrating surface spills of miscellaneous liquids.

This means that they deteriorate for domestic consumption, so that remedial treatment is required to meet prevailing standards. An example of this are nitrates in the MSLAs, which are diluted by mixing with RO water before delivery to the consumer. In the case of the perched aquifers, fertiliser pollution has reached such levels that the water is no longer fit for human consumption.

The MSLAs have been estimated at different times to have different sustainable yields according to particular hydrological models. These have varied between 12 and 23 million cubic metres per annum. Whatever the correct value, it is clear that extraction beyond sustainable levels has, over decades in the case of the MSLAs of Malta, resulted in a contraction in the size of the fresh water lens while the salinity of extracted water has increased.

Public water production sources in the Maltese Islands.

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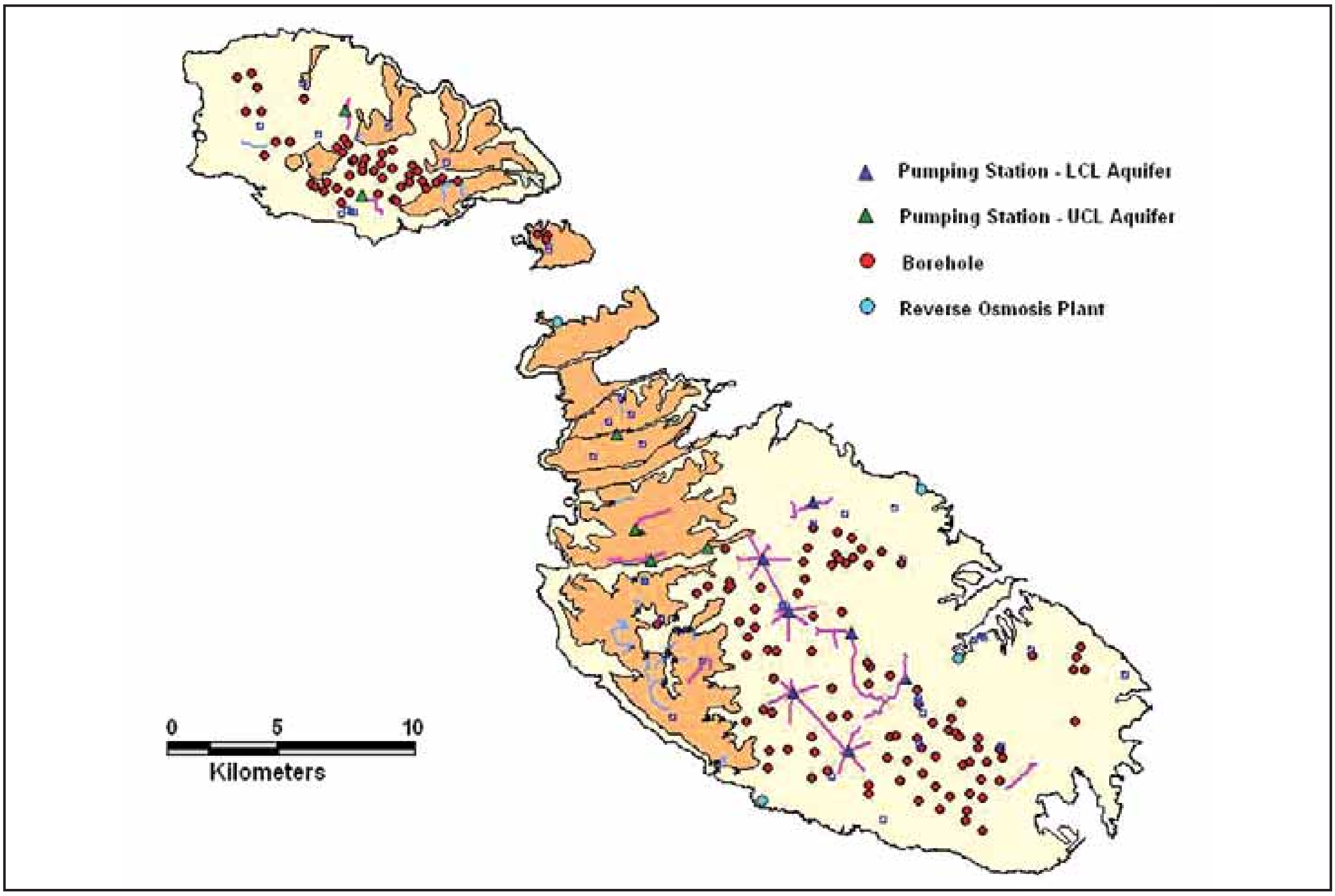

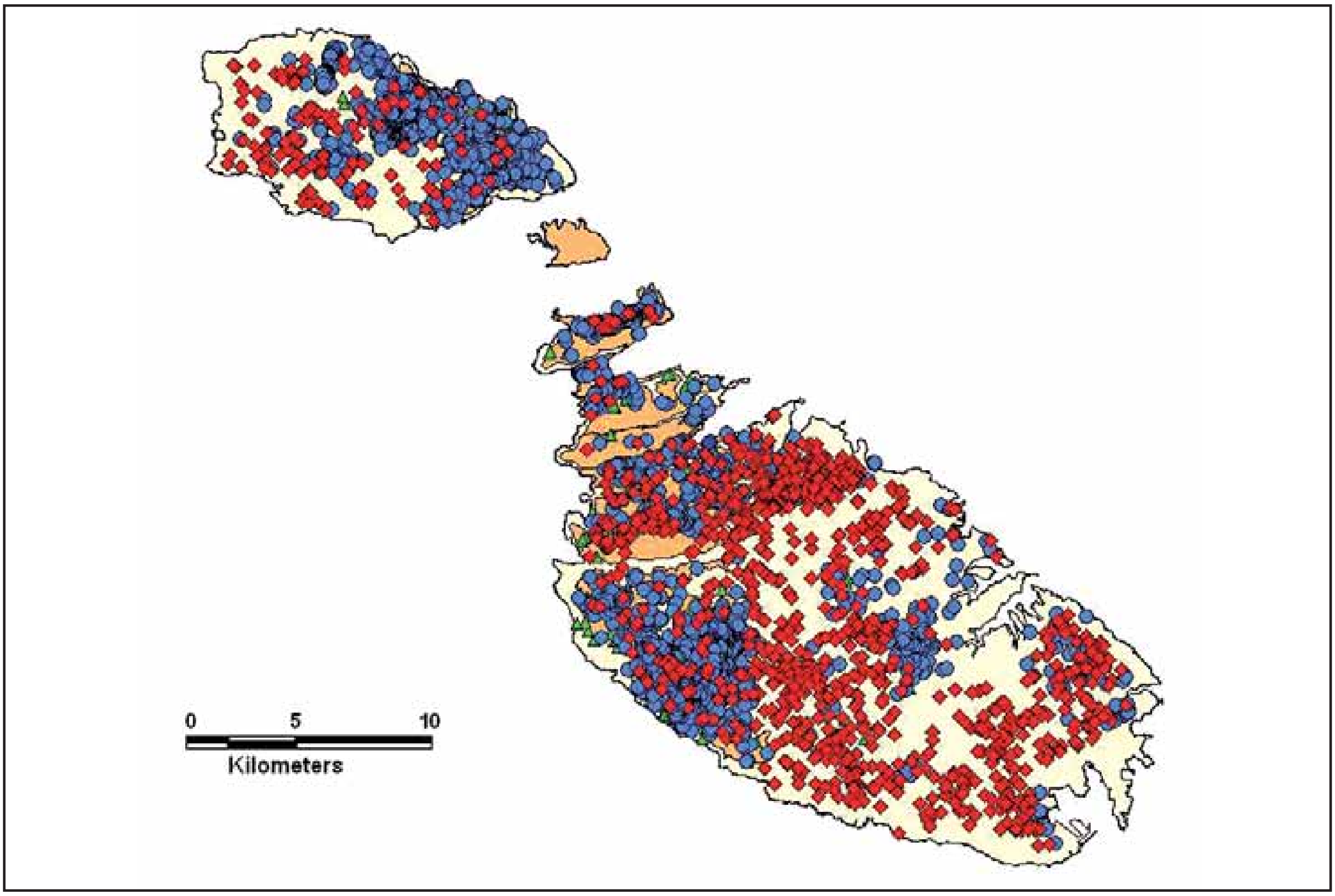

Location of Registered Private Groundwater Sources in the Maltese Islands.

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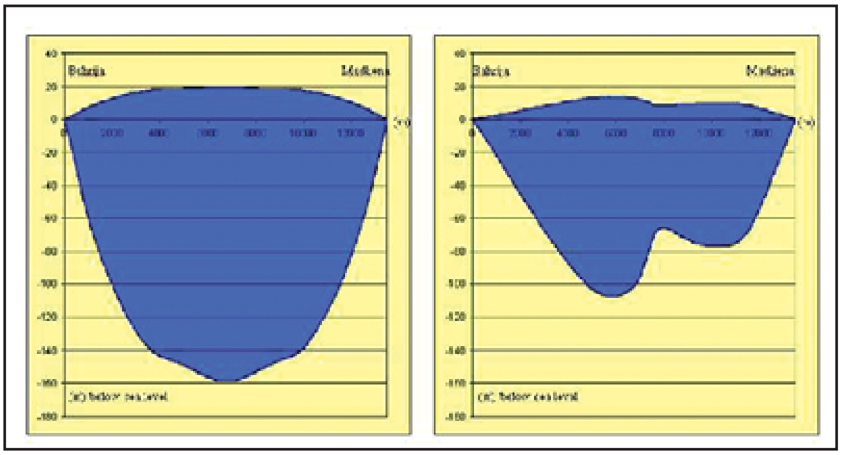
This contraction will continue with unsustainable extraction at present rates. In 2005, Mepa warned in a consultative document that water extraction without regard for the sustainability of the resource carries a severe risk of wiping out, for practical purposes, the underground fresh water storage capacity provided by the sea-level aquifers. Another document suggested that by 2015, seven years away, the MSLA under Malta would become unusable.

Total aquifer extraction in no way meets the shortfall for demand, as the RO plants provided about 17 million cubic metres per annum production in 2007. The sea water is mined to extract non-saline water. Desalinisation plants around the islands desalinate sea water and mix it with borehole water before feeding the national grid of water pipes and distribution to consumers. In 2007, around 56 per cent of the water utility's supply was generated from sea water, or about 37 per cent of Malta's total demand. The desalinisation process is expensive, which means that the public water utility is a major consumer of electrical power and thus contributes significantly to the amount of oil that Malta imports for power generation.

Malta consumes water in another way. It is basically an island city state surrounded by a large moat: the Mediterranean Sea. The "city" has a high population density and a very limited rural hinterland, which is far too small to support the population of around 400,000 people. Malta is, therefore, heavily dependent on others for food and industrial products, apart from energy from overseas. So the country imports large volumes of virtual water. This concept was introduced in 1993 by John Anthony Allan, who was awarded the 2008 Stockholm Water Prize. Virtual water is water that is embedded in commodities and is the volume of water used to produce agricultural and industrial goods. For example, the amount of water used to produce 1kg of wheat is 1,300 litres and for 1kg of beef is 15,000 litres. All products and goods have a virtual water content, so a country's exports and imports can be aggregated to obtain a virtual water balance. In addition, the export/import statistics of a country can be examined to estimate the water footprint, which is defined as the sum of total domestic consumption and virtual water imports, minus virtual water exports. According to a 2004 UNESCO-IHE publication, Malta imported about 644 million cubic metres per annum of virtual water in the period 1997 to 2001. This means that elsewhere in the world, around 30 times as much water as the sustainable yield of the Maltese aquifers was consumed to produce food and goods for import to the Maltese population. From this perspective, Malta is not in a sustainable situation.

On Malta, there are several issues related to water consumption: a dense population; a Western paradigm – water/sanitation is a public right provided at public expense; total demand of around 57 million cubic metres a year; overproduction from the aquifers; at least 5,000 private registered boreholes, the production of which is unknown; an unknown number of unregistered boreholes, with an unknown production; water use is energy/cost sensitive – water production requires six per cent of total power generation and RO water costs five times that of borehole water and has an impact on the balance of payments; meeting EU quality requirements; the limited recycling of water; the management and



Vertical section of the Ghyben-Herzberg Freshwater Lens in the Lower Coralline Limestone Aquifer;

(A) at the levels it would stand if there were no abstraction of groundwater and

(B) at the level it is today.

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capturing of storm water; pricing is a social and economic balancing act. While the above issues are well documented, and data and information is available on the websites of government and state organisations, public awareness is poor. The natural water bodies are out of sight, out of mind, and do not impact upon the public in the same way as, for example, air pollution, waste recycling and urban sprawl – which are public and media issues.

What are the consequences of not addressing these issues? Two extreme scenarios can be postulated, one of which I have called "Drift Scenario" and the other "Ruthless Conservation Scenario". The real future is likely to lie somewhere in between.

The Drift Scenario is a projection where little changes from the present and would describe a world with some or all of the following features: population density remains high or increases; the water wasteful paradigm is rooted in the population; unregulated private water production continues; there is minimum husbandry of rainfall and capture of storm water; limited recycling; depletion, salinisation and exhaustion of aquifers followed by the potential collapse of Maltese agriculture; near total dependence on desalinisation and energy/price fluctuations and the water supply being hostage to international crises.

On the other hand, the Ruthless Conservation Scenario would feature a world with much or all of the following characters: lower population density; a population that is highly sensitive to water conservation; highly regulated and sustainable production from aquifers; maximum husbandry/domestic use of rainfall; large to micro scale recycling – state, industry and domestic; redirection of horticulture and agriculture to incorporate virtual water concepts, desalinisation still prominent; reduced exposure to energy/price fluctuations and a more manageable future, with strategically preserved fresh water resources.

What might the Ruthless Conservation Scenario entail? According to the latest Eurostat Survey, in the short term the Maltese population is anticipated to rise to 429,000 by 2035. Assuming this projection is correct, it puts further demand on water, which makes a ruthless conservation world even more urgent.

A massive public relations campaign would be needed, to educate the population as to the scarcity and stress on water resources on the island, and the consequences of not changing the present wasteful attitude to water. The goal would be nothing less than to change the cultural attitude towards water of everybody on the islands, in preparation for the hard and difficult decisions to follow.

Opposite:

The tranquil waters of the fountain in the courtyard of Palazzo Falzon, Mdina

There would be the introduction of government policies and regulations to persuade and coerce the population, agriculture and industry – and government and state bodies – to water saving, conservation and water harvesting practices. Rainwater harvesting would be at a premium in wells/cisterns/tanks as a supplement/replacement for metered utility water or as water capture to be fed directly to the groundwater aquifers. The terraced nature of the Maltese countryside already minimises run off and aids water capture for infiltration. However, an increase in the number of well maintained dams in the valleys and storm water capture in the urban areas would all be in place.

Malta processes around 13 million cubic metres of sewage each year. Conservation in the home associated with the introduction of dual flush mechanisms would cut this volume significantly. Recycling would be the norm, from large scale reclamation of water from sewage to grey water-saving practices in hotels, homes, industry, agriculture and the public sector.

Meter pricing would maintain a socially sensitive element for basic personal volume needs, but the real cost of water would be charged, without subsidy. A full registry of private boreholes, including consumption and charging, would be in place, plus measures and resources for the prosecution and penalisation of water theft. Measures and technology would be put in place to detect and close down private and public boreholes where extraction is damaging the aquifers.

Production from the ground water aquifers would never exceed the natural recharge. In fact, planned measures would be in place to produce less than natural replenishment in order to rebuild the subsurface volumes as a long term strategic measure.

Virtual water practices would be in place, whereby industry and agriculture migrate to efficient water conservation methods and processes and also migrate to plant and animal products, which consume less water per kilogramme of product. This applies not only to commercial horticulture, agriculture and animal husbandry, but also to private and public gardens and parks.

A reversion to flora that is tolerant to summer drought and a Mediterranean climate would replace water-thirsty plants in constant need of water. The everyday scenes of bowsers and sprinklers watering public areas would disappear as climate-sensitive planting takes place, as, for example, on the airport roundabout. The last century has seen the movement to mainly water-thirsty ornamental plants and shrubs in gardens and the pendulum needs to swing back to the cultivation of plants that are at home in a Mediterranean climate.

Even if the Ruthless Conservation scenario becomes a reality, Malta would remain exposed. With major conservation measures in place, and more water-efficient local food production, the demand for virtual water imports would remain. Elsewhere, rising global population will add to competition for the virtual water consumed for export products to Malta, adding to global pressure on prices. Measures to stabilise and increase Malta's strategic ground water reserves imply some increased production from the RO plants and dependence on foreign oil imports and/or electricity imports by cable. The debate on alternative energy sources has been largely related to the global warming issue and the cutting of carbon dioxide emissions. However, in the Maltese context the debate should be redirected towards security issues and reducing dependence on foreign energy sources and, indirectly, their role in Malta's water dependency. Oil imports for energy and water production make Malta far more vulnerable to international price fluctuations and to unforeseen events in other parts of the world, over which Malta has no control. While Malta's high population density means that dependence on foreign oil and future cable imported electricity will remain for the foreseeable future, strategically planned moves towards the use of alternative energy sources using proven technology by utilities, the private sector and domestically by the private citizen, will help to mitigate Malta's water crisis, which is imminent long before the effects of global warming begin to impact upon the ground water bodies.

Acknowledgements and Further Reading

The writer acknowledges and is grateful to the MRA for permission for the reproduction and use of illustrations in their open files and to The Limestone Heritage in Siġġiewi for permitting the use of illustrations taken on their premises.

This article is based on a series of lectures I have been giving to non-government organisations in Malta since April 2005. Any reader who would like to delve further into the subject of water resources on the Maltese islands will find that a lot of material is available on websites of government and state organisations, and these organisations are to be complemented on the open file nature of this information. Many analyses and studies have been carried out and documented, and government is certainly aware of the issues, even if the general public is poorly informed.

The reader is directed to the websites of Mepa (*http://www.mepa.org.mt/*), MRA (*http://www.mra.org.mt/*), NSO (*http://www.nso.gov.mt/*) and the WSC (*http://www.wsc.com.mt/*). For an introduction to water footprints, the reader is directed to *http://www.waterfootprint.org/*.

In addition, I have listed below publications of both general and specific nature from which I have drawn some of the information in this article.

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