CONSULTATION PAPER

Application of Groundwater Heating/Cooling Schemes in Malta and Gozo

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Malta Resources Authority • Millennia • Aldo Moro Road • Marsa MRS 9065 • Malta

Tel:+ 356 2295 5153 • Fax: +356 2295 5200

E-mail: consultation@mra.org.mt

Application of Groundwater Heating / Cooling Schemes in Malta and Gozo

1. Introduction

1.1 There is growing interest in Malta on the use of groundwater for heating and cooling buildings, by means of heat exchange through a borehole system.

1.2 It is well known that the efficiency of any thermodynamic process depends in part on the availability of a heat sink at a sufficiently low temperature. Generally the lower the temperature, the greater is the process efficiency. Groundwater temperature roughly equates the average annual ambient temperature of a locality, unless geothermal anomalies are present. Hence it is perceived as a useful heat sink during summer and conversely a heat source in winter when ambient temperature is cooler. This characteristic may be exploited for the reduction of energy consumption required for the cooling or heating of building structures, and so may be in principle favourably looked upon.

1.3 However, the qualitative and quantitative impact of this practice on small aquifers may be disproportionate and needs to be carefully assessed especially where small strategic aquifers carry a significant socio-economic value. From an environmental, hydro-geological and economic perspective, Malta is a typical case of such an aquifer.

1.4 This paper is concerned with the associated impacts. It sets out some facts regarding the local hydrogeology and the impact of this practice on groundwater resources. It proposes basic policy and the procedures and criteria to be used by the Authority in regulating geo-thermal exchange schemes.

The procedures are designed to ensure that the assessments and decisions on any such proposals are arrived at in an informed manner and that if approved, such cooling systems will have a minimum negative impact on the groundwater resource.

1.5 The paper is also intended to invite public consultation on the use of this technology in Malta, in anticipation of Government's publication of policy guidelines.

2. Groundwater-Heating/Cooling – The Technology

2.1 The two main methods used in groundwater heating/cooling schemes are *open loop* and *closed loop* type.

2.2 An open loop scheme pumps groundwater to the surface, where it passes through a heat-exchanger, before disposal at a warmer temperature by re-injection through a second borehole.

Figure 1: Schematic representation of a groundwater source (open loop) system

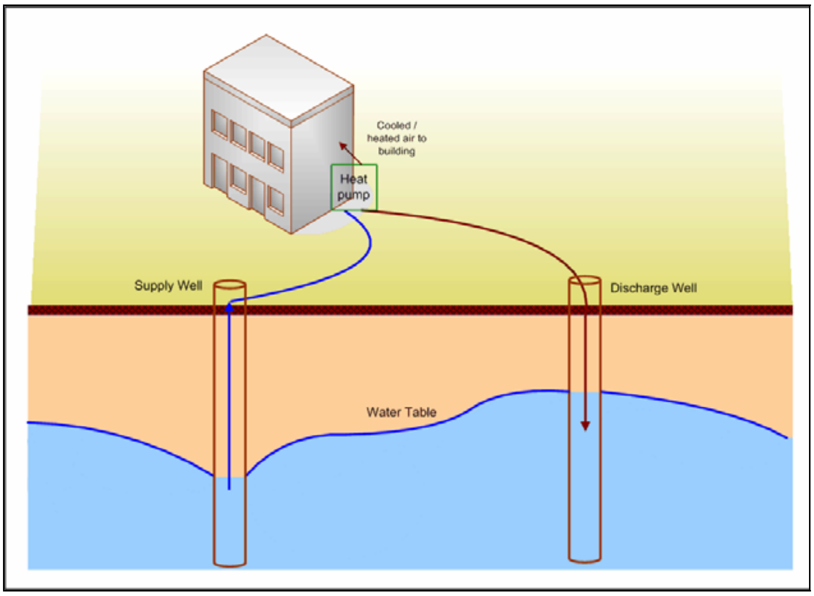
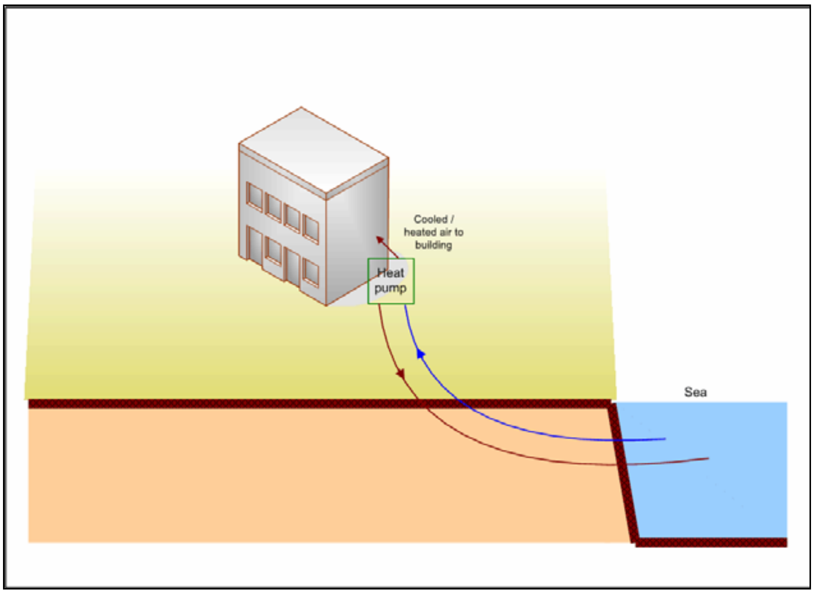
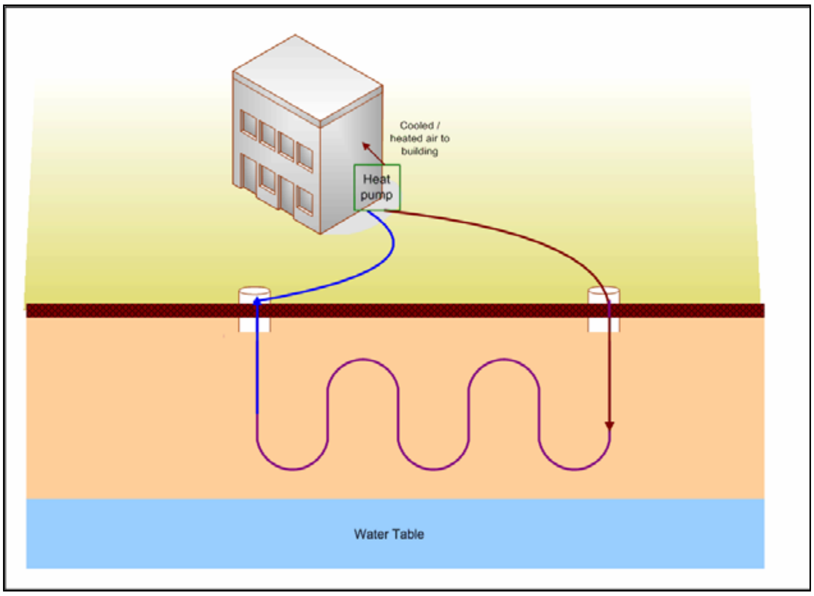


Figure 2: Schematic representation of a direct seawater (open loop) system



2.3 Closed-loop schemes circulate a coolant through a coil or loop of pipes buried in the ground, either vertically inside a borehole or buried horizontally under the soil. This design does not rely on groundwater abstraction, but on the circulation of fluid through a heat pump at the surface, followed by recirculation through a buried closed loop to exchange heat with the ground mass. Closed-loop systems generally have limited influence on groundwater close to the buried loop, thus limiting heating/cooling capacity which the system can support.

Figure 3: Schematic representation of a groundwater source (closed loop) system



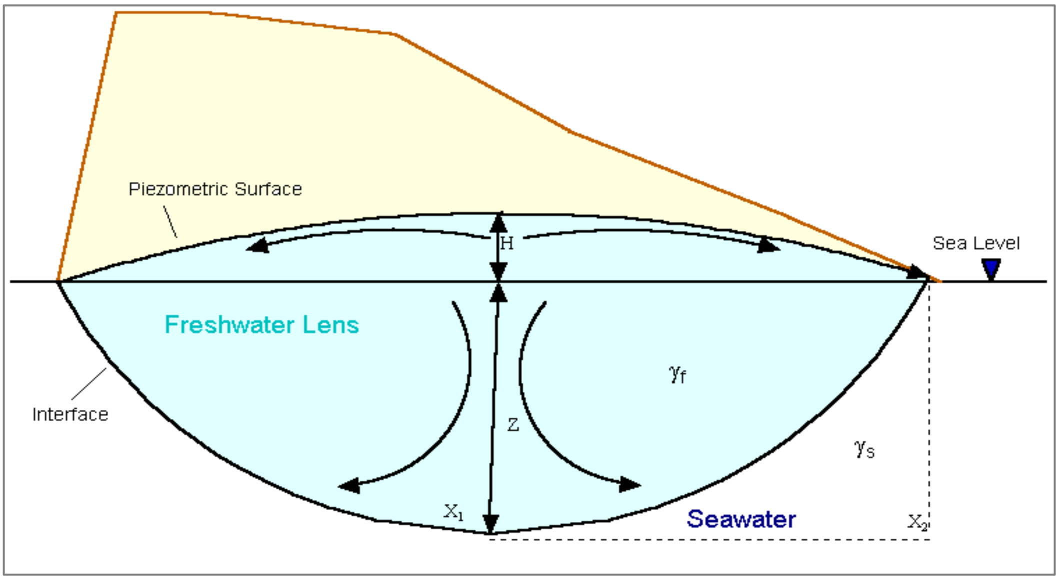
2.4 On the contrary, an open loop system will draw water from greater distances and can hence disturb greater volumes of groundwater, with a corresponding larger capacity to exchange heat with the ground. Open loop systems are commonly used for large scale developments on account of their higher heat exchange capacity. Unless the discharge well is sufficiently spaced from the abstraction well, open-loop systems may fail when the thermal plume from the hot well eventually reaches the abstraction well, an effect commonly referred as “thermal feedback”. Alternatively the plume may move along the hydraulic gradient away from the abstraction well, whilst shifting the risk to neighbouring groundwater sources.

3. Baseline Characteristics of Groundwater in Malta

3.1 The mean sea-level aquifers in Malta and Gozo are limited in surface area. The perched aquifers are even smaller.

3.2 The mean sea-level aquifer with its lens-shaped structure, is just 3m above sea-level at its highest point which corresponds to a depth of 120m below sea-level. Laterally it tapers to zero at the coast where the freshwater lens fades off into seawater.

Figure 4: Schematic representation of the Ghyben-Herberg lens



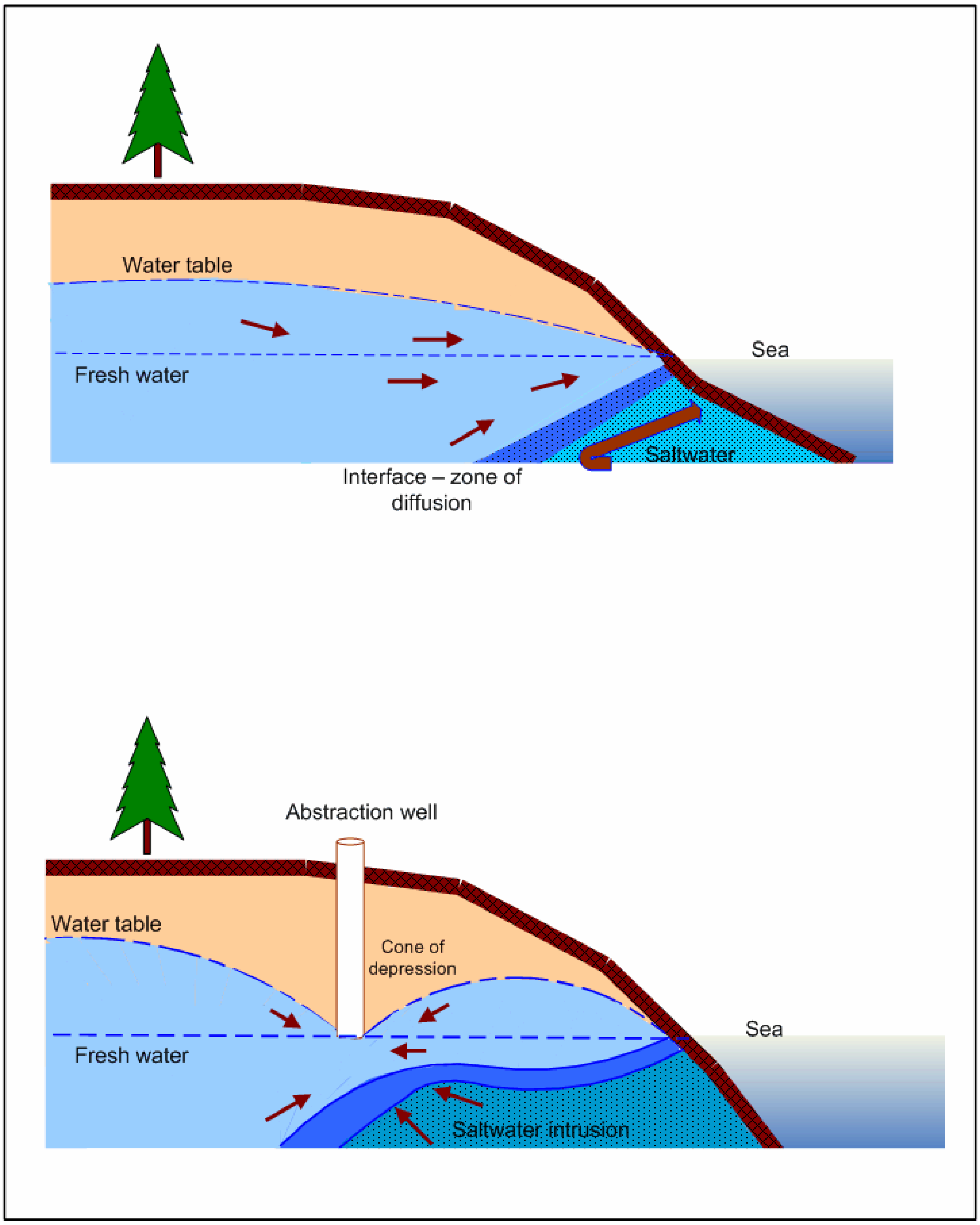
3.3 Physically the lens is not a uniform fresh-water mass, vertically across. On the contrary, its specific gravity, and hence salinity, increases gradually from the top (water table) to the bottom (interface) where seawater prevails. The lens is in fact in hydrostatic balance where fresh water floats over seawater within the rock formation.

3.4 Abstraction from the freshwater lens induces a drawdown of the water-table and conversely an up-coning of the interface by a simple physical process. This translates in the abstraction of a mixture of freshwater and brackish water. The higher the abstraction rate, the greater the drawdown and salinity of the abstracted water.

Figure 5: Schematic representations of:

(i) static conditions of water table

(ii) vertical upconing due to groundwater abstraction



3.5 BRGM quote the background level[1] for the chloride content in the sea level aquifer as 350mg/l. This level is an indication of the quality level which has to be achieved in this aquifer, if it is to attain good status as is required under the Water Framework Directive (Directive 2000/60/EC). Also, the new Groundwater Directive (Directive 2006/118/EC) expressly prohibits the discharge of effluents into the aquifers which might lead to a deterioration of its quality or jeopardise the continued use of this water by its most vulnerable receptors[2] or the achievement of good status under the Water Framework Directive.

3.6 As an indication of the expected quality of water abstracted from wells under continuous pumping conditions; Table 1 presents the abstraction rates and chloride content for a number of wells operated by the Water Services Corporation. These results show that although broadly increased abstraction results in an increased chloride content, local hydrogeological conditions (spatial location, fracturing, depth of the interface...) also have an important influence on the level of upconing and may act to limit or enhance the intrusion of saline waters and the subsequent deterioration in quality.

Table 1: Abstraction rates and resulting chloride content for selected wells operated by the Water Services Corporation

WSC Well	Abstraction (m^3/annum)	Abstraction (l/s)	Chloride Content (mg/l)
Harruba	29,670	0.9	125
Fiddien	43,488	1.4	440
Macedonia	40,738	1.3	80
Cawla	48,801	1.5	520
Torba	47,757	1.5	370
Iklin II	134,908	4.3	800
Ta Srina	151,976	4.8	430
Mentna	173,149	5.5	400
Bettina	174,736	5.5	1000
San Niklaw	169,563	5.4	1080

1 BRGM - Study of the Fresh Water resources of Malta, 1991. This report quotes the report drawn up by Dr Sutherland (1876) on the quality of the water resources in Malta. This is the earliest known report on water quality and as such can be taken to present the background quality level.

2 The most vulnerable receptor in the case of the Malta Mean Sea Level Aquifer is the supply of drinking water. It is noted that WHO and the EU Drinking Water Directive (Directive 98/83/EC) set an indicative limit of 250mg/l Chloride content for Drinking Water.

3.7 Under such conditions it has been appropriate to apply “skimming” techniques when abstracting groundwater from thin freshwater lenses in islands, such that the hydrostatic equilibrium is disturbed with the least possible drawdown. In Malta and Gozo such techniques are applied by a network of sea-level galleries which are purposely designed to draw water from the highest part of the freshwater lens, above sea-level

3.8 Galleries are preferred to boreholes because the floor of the gallery lies at sea level whereas the bottom of a borehole is normally around 10m below sea level, hence more susceptible to saline intrusions through vertical upconing.

3.9 Boreholes used for potable water supply are designed to keep drawdown to a minimum and at the same time obtain the lowest possible level of salinity. Under such regimes, the average flow from public boreholes is around 15m^3/h, as higher flow rates will surely yield water with higher salinities, and unsuitable for potable use.

4. Groundwater heating / cooling – local context

4.1 Groundwater resources in Malta and Gozo are heavily overdrawn by more than 43% over the sustainable rate. Government is committed to reduce groundwater abstraction rates from the current 34Mm^3/annum to a sustainable rate estimated at 23Mm^3 / annum. Geo-thermal applications, in particular open-loop systems, will undoubtedly increase the demand for groundwater abstraction, exposing the aquifer to additional pressures. In other words allocation of groundwater abstraction for cooling will have an impact on abstraction rates used by other users (potable water supply, industry, agriculture etc.) and on sensitive ecological sites by reducing the availability and quality of the groundwater.

4.2 In Malta the temperature of the mean sea-level aquifer is around 20^{o}C. In central and northern Europe groundwater is often cooler, between 8^{o}C and 12^{o}C.

4.3 In view of the relatively warmer temperature of groundwater in Malta,, heat-exchange will inevitably rely on high pumping rates and turn-around to obtain a reasonable thermal conditioning effect. As a result the impact on the local aquifers is expected to be higher than in others overseas. Moreover, world-wide, such systems are known to draw on substantial amounts of water.

4.4 In Malta, high pumping rates would entail drilling deep into the mean sea-level aquifer to ensure the highest saturated thickness of the aquifer enabling high transmissivity. Under similar pumping regimes, the hydrostatic equilibrium of the freshwater lens is subjected to a heavy dewatering process resulting in a severe mixing of seawater with freshwater within the area of influence of the well. The net result of such abstraction practice would lead to a depletory process which would depress the water table below sea-level, drawing it closer to the interface. Gradually this effect spreads laterally over a wide area affecting with a sharp rise in salinity, boreholes operated by the Water Services Corporation (WSC) for potable water supply as well as irrigation boreholes.

4.5 WSC and formerly WWD followed the practice of maintaining the water table to around 0.5m above sea-level by throttling flow from boreholes to optimise flow and salinity. Likewise, galleries in the mean sea level aquifer are fitted with penstock gates to raise the water level as high as possible, above sea-level, and to abstract only the overflow from the upper sections. This practice gave good results.

4.6 It needs to be pointed out that due to spatial limitations, the injection of warmer water (around 6°C over the abstracted water) through the discharge well will inevitably increase groundwater temperature which would with high probability affect both public and private wells in the vicinity. This increase in groundwater temperature would in the long term have an impact on the cooling capacity of the system whilst altering the quality of the groundwater, in particular its biological loading.

4.7 Discharge issues. A discharge well is generally expected to absorb around 75 % of water abstracted from a borehole with similar hydro-geological characteristics. This would imply that more than 1 discharge well would need to be constructed at appropriate distances or alternative discharge systems would need to be developed.

4.8 Blockage of the discharge well by the deposition of calcite and/or increased biological growth on the well face may further limit the absorption capacity of the discharge well.

4.9 Since the abstraction of groundwater in the mean sea level aquifers will invariably involve a certain degree of seawater intrusion, discharging the processed water at the upper layers of the aquifers would entail the introduction of higher levels of salinity at the least saline layers, hence depleting the more pristine section of the freshwater lens.

5. Cased boreholes

5.1 To overcome the local groundwater constraints, it has been suggested to drill deep boreholes through the aquifer to depths of around 300m below sea-level, and seal off the “aquifer” section by appropriately cemented casing. The process involves the sinking of steel casing (or other heavy duty material) to the bottom of the borehole followed by the reverse injection, under high pressure, of special cement slurry into the annulus, from the bottom of the casing.

5.2 While theoretically such a process can mitigate the effects on groundwater indicated above, this proposal has its limitations.

5.3 Cementation of well casing is a specialised and a costly technique which requires heavy equipment and trained personnel. Similar drilling operations, when conducted onshore in Malta, employed heavy drilling rigs equipped with a high pressure slurry pump.

5.4 Local drillers normally “pour” cement into the annulus from the top of the well, with no guarantee of proper bonding between the rock face and the casing. Reports of casing failures are not uncommon.

5.5 Borehole casing quickly deteriorates with time unless proper heavy-duty material is used and grouted with high quality cement slurry particularly when the saturated zone is below sea-level. In a fractured limestone environment, however, deep cased wells, crossing the aquifer, do not guarantee aquifer isolation, albeit the initial high capital cost.

6. Policy proposals

6.1 The benefits of geothermal heating/cooling in reducing green-house gases is undeniable. As the risks to groundwater are high a number of policy proposals are being launched for further discussion through public consultation.

6.2 The Malta Resources Authority will consider all applications in areas that are not designated as "no-go" areas *a priori* and is therefore proposing the adoption of the following policy measures:

6.2.1 Developers must provide the required information and carry out the necessary studies to feed the assessment procedure by the Authority in order to determine:

(i) the effect of the proposal on the quantitative and qualitative status of the aquifer where it is located especially for *open-loop* systems. It is to be ensured that the sustainability of the aquifer and respect to rights of third parties within the area of influence are maintained.

(ii) the proposed separation of the wells, impacts on any nearby groundwater sources, efficiency of the system and any effects associated with thermal feedback;

(iii) temperature evolution of the abstracted waters, temperature-breakthrough times and thermal effects of the discharge on the chemical and microbiological quality of groundwater;

(iv) effect on abstractions by third parties.

6.2.2 On the basis of knowledge available to date, "no-go areas" which are *high-risk* will be established and the Authority will not process any applications for geo-thermal heating/cooling using *open-loop* systems. Such no-go areas may include:

(i) areas located inland at a distance of more than 50m from the shoreline;

(ii) areas where small coastal aquifers occur and which are presently used for irrigation;

(iii) areas within 500 m used by WSC as RO well-fields.

6.2.3 Application for closed-loop systems will be processed by the Authority and will be subject to an assessment taking into account:

(i) Location of proposal and impact on areas of influence of groundwater sources used for potable water supply;

(ii) Depth of the closed loop system in relation to the depth to the saturated zone;

(iii) Proposed coolant and its properties as well as mitigation measures to ensure against groundwater contamination in the event of any accidents.

6.2.4 The Authority will, assess applications for geothermal heating/cooling based on other alternatives such as direct intake of deep seawater. Similar criteria for assessment as in 6.2.3 above are being proposed to be used.

6.2.5 Breach of conditions set by the Authority will be subject to severe fines and penalties as provided by Article 26 of the MRA Act, following enactment of ad hoc regulations

6.3 Detailed Proposal for the Assessment Procedure

6.3.1 Any prospective applicant will be required to submit an '*initial application*' to the Authority in which basic information on the proposal will be provided. This will enable the Authority to make a preliminary assessment of the proposal, clearing those applications which do not threaten the sustainability of the aquifer and its ability to sustain existing users, but refusing others.

6.3.2 In this initial application the following information and documentation will be requested by the Authority:

(i) Personal Details of Applicant.

(ii) Details of the Engineer/Civil Engineer supervising the project.

(iii) Outline description of the proposal clearly identifying the proposed cooling methodology (closed-loop system or open-loop system).

(iv) Schematic diagram of the proposed cooling system

(v) Official MEPA site-plan outlining the exact location being proposed for the drilling of the borehole(s) which will be used in the cooling system.

(vi) Initial estimate of the groundwater abstraction rate which needs to be achieved for the operation of the proposed system at full capacity. (if applicable)

(vii) Assessment of the energy-efficiency measures which the applicant has already in place and which may reduce further pressure on groundwater.

6.3.3 Following the submission of this initial application, the Authority will publish details of the application and allow a fixed time period in which representations by third parties can be made. The Authority will then screen the application in order to determine the potential impact which the application will have on existing licensed (registered) users of the groundwater resource, the status of the resource itself and the natural environment sustained by groundwater. Due consideration will also be given to the proposed location, groundwater abstraction rate, with abstraction thresholds being set in order to protect the status of the aquifer system, particularly for applications in the minor perched aquifers. Through the initial screening a distinction will be made between *closed-loop* and *open-loop* systems. Closed-loop systems will be assessed on the basis of their specific design and location with the exception of the following protected areas:

(i) Zone for the protection of groundwater sources utilised for the abstraction of water intended for human consumption; defined by the 300m radius from each source.

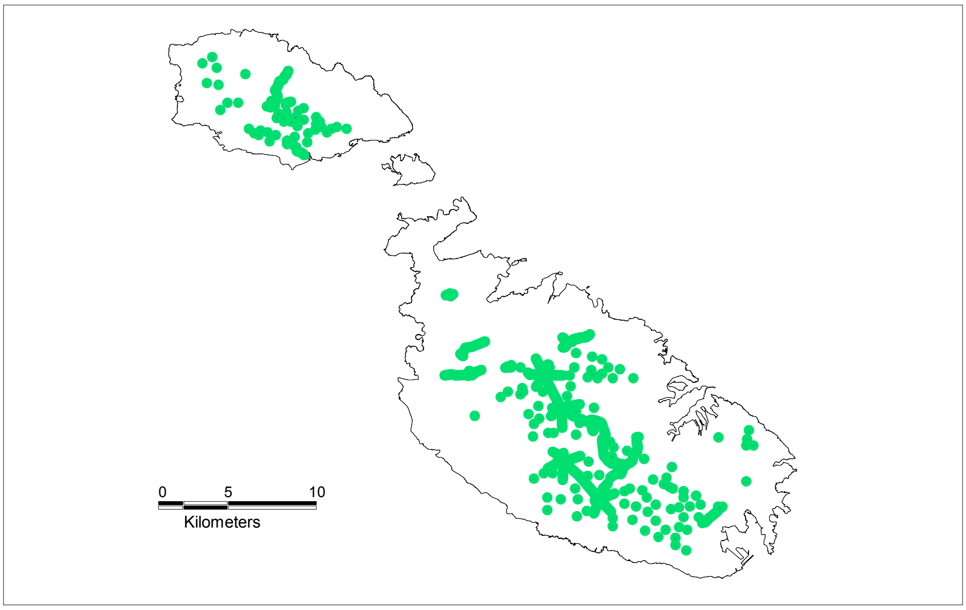
(ii) Zone for the protection of groundwater sources utilised for irrigation by registered farmers; defined by the 100m radius from each source.

(iii) Zone for the protection of groundwater dependent ecosystems, to be defined after consultation with MEPA.

(iv) Zone for the protection of existing permitted users of groundwater cooling system defined by the 300m radius from such wells.

6.3.4 It is also suggested that such no-go areas, once established, be publicly available on the Authority's web-site. Annex I provides further details on the establishment of these zones.

Figure 6: Protected area around groundwater sources utilised by the WSC for the abstraction of water for human consumption



6.3.5 Open loop systems ('hi-flow') will be also considered by the Authority provided that these are located along the coastal belt as they are heavily dependent on a consistent flow of water. Proponents will be required to submit a '*full application*' which will comprise a detailed assessment of the feasibility and the environmental impact of the proposal.

6.3.6 The following information (where applicable, depending on the typology of the proposed cooling system) will need to be submitted by the applicant at this stage:

(i) Full details on the construction of the wells to be drilled as required under LN 254/2008 entitled 'Borehole Drilling and Excavations Works within the Saturated Zone Regulations, 2008'.

(ii) Land use survey within a distance of 500m from the porposed well locations to identify the location of other established groundwater users and the presence of any groundwater dependent ecosytems.

(iii) Estimates of the annual volume of groundwater to be abstracted for cooling and the maximum rate of abstraction for the system to operate at full capacity. These estimates need to be supported by the necessary documentation.

(iv) Estimation of the maximum discharge rates to be achieved at the discharge point.

(v) An outline of the corrective and preventive actions which will be taken should there be a surface overflow at the discharge well.

(vi) An estimation of the expected increase in the temperature of the discharged water as compared to the temperature of the inflowing water and a study showing the effect of temperature increase on third party installations.

(vii) The construction of a heat-transfer model to estimate the flow-dissipation of heat around the discharge well and how this would be expected to impact the groundwater temperature at the abstraction well. Should this model indicate the distinct possibility of a significant impact, the developer would be required to provide estimates of the increased abstraction rates required to mitigate this impact on the efficiency of the cooling system.

(viii) Detailed design plans of and documentation on the proposed heat-exchange system which should clearly outline the risk of the abstracted water entering in contact with any effluents within the heat exchange system. Annex II provides the reasons why this information is being requested.

6.3.7 Following the successful consideration of the 'full application'; it is suggested that the applicant be granted a periodically renewable 'operational permit'. Such permit will have defined operational conditions which will have to be observed by the applicant throughout the whole operation of the cooling system. Such conditions will include (as applicable):

(i) Maximum abstraction rate;
(ii) Maximum level of salinity (electrical conductivity) of the abstracted water;
(iii) Maximum discharge temperature.

6.3.8 Under the conditions of the permit, the applicant will also be required to install automatic recording equipment to monitor the levels and trends in the value of these operational conditions. This data will need to be submitted on a regular basis to the Authority.

6.3.9 The Authority will also require to regularly monitor the operation of such approved cooling systems, and take the necessary enforcement action whenever the permit conditions are breached. Such enforcement action will include penalties/administrative fines and also the suspension of the permit should the non-compliance be found to threaten the sustainability of the resource and/or other registered/legitimate users of the resource.

6.3.10 It is also advisable that application fees, administrative/operational requirements and penalties/administrative fees be established through the enactment of a Legal Notice in order to provide a stronger backing to any enforcement action which might need to be taken by the Authority.

6.3.11 The Authority is proposing that any existing systems would have to be assessed in accordance with the abovementioned policy measures and procedures. Where systems are deemed to fail assessment due to negative impact on existing groundwater resources the proposed legislation will provide for the closure, sealing and decommissioning of the boreholes. It is further proposed that stiff penalties will be introduced as noted in 6.3.10.

The Authority invites comments and feed-back and/or amendments to the aforementioned policy proposals, from the general public and interested parties.

Comments for the consideration of the Authority can be sent by email at consultation@mra.org.mt or by post by not later than 15th October 2009 and addressed:

Chief Executive Officer
Consultation
Malta Resources Authority
Millennia 2nd Floor,
Aldo Moro Road,
Marsa
MRS 9065

ANNEX I

INITIAL APPLICATIONS FOR GROUNDWATER COOLING SYSTEMS

JUSTIFICATION FOR THE ESTABLISHMENT OF ‘NO-GO’ ZONES FOR AQUIFER COOLING SYSTEMS

Number	Proposed ‘no-go’ zones	Justification for the proposal
1	Zone for the protection of groundwater sources utilised for the abstraction of water intended for human consumption; defined by the 300m radius from each source.	The radius of influence of boreholes in the sea-level aquifers which are under continuous pumping conditions has been estimated as 300m through the application of the Dagan-Bear equation. All substances which are introduced into the aquifer-system within this zone will be diverted to the pumping well. In as much it is advisable that activities which could result in the release of contaminants (such as high abstraction rates which could entail the influx of saline waters and discharge of high salinity waters) not be allowed within this zone; and this in order to protect the quality of water which eventually is utilised for public (human) consumption.
2	Zone for the protection of groundwater sources utilised for irrigation by registered farmenrs; defined by the 100m radius from each source.	The discharge of high(er) salinity waters in the vicinity of irrigation wells will invariably result in an increase in the chloride content of the water abstracted for irrigation. This could have an immediate impact on crop productivity and on the sustainability of the agricultural sector. This protection zone around agricultural (irrigation) wells is aimed at the protection of the quality of the water abstraction from such wells.
3	Zone for the protection of groundwater dependent ecosystem, to be defined after consultation with MEPA.	An increase in the temperature of groundwater might have an impact on flora and fauna which depend on groundwater. The protection of such eco-systems is an obligation under the Water Framework Directive which idenitifies MEPA as the competent authority for such surface and coastal waters. In as much any such protected areas will need to be established in consultation with MEPA.
4	Zone for the protection of existing permitted users of groundwater cooling systems defined by the 300m radius from such wells.	Cooling systems depend on the temperature difference between the surface and the subsurface environments. An increase in the temperature of the groundwater will definitely reduce the efficiency of such systems entailing an increase in flow to restore the efficiency characteristics. This will result in an increased impact on the aquifers and a reduced energy efficiency of the system. The establishment of this zone is therefore aimed at the protection of existing permitted users.

	Proposed ‘no-go’ zones (open loop)	Justification for the proposal
5	Zones located inland at a distance of more than 50 m from shoreline	Subjecting the freshwater lens to additional pressure and depletion by way of heavy drawdown and abstraction
6	Zones within 500m of RO well-fields used by WSC	Protection of public facilities for the supply of drinking water

ANNEX II

FULL APPLICATIONS FOR GROUNDWATER COOLING SYSTEMS

1. JUSTIFICATION FOR INFORMATION REQUESTED IN THE CASE OF PROPOSALS INVOLVING CLOSED-LOOP COOLING SYSTEMS

Number	Information requested as part of the 'full application'	Justification for the request
1	Full details on the construction of the wells to be drilled as required under LN254/2008 entitled 'Borehole Drilling and Excavation Works within the Saturated Zone Regulations, 2008'.	Applicant still needs to abide with the provisions of LN254/2008 and apply with the Authority for the drilling of the heat-exchange well. This since the applicant would still be required to abide with all enacted National and European Legislation.
2	Land-use survey within a distance of 500m from the proposed well locations to identify the location of other established groundwater users and the presence of any groundwater dependent ecosystems.	This survey will enable the Authority to assess the potential impact of such a system on other established users, particularly those vulnerable to an increase in the temperature of groundwater. Moreover, in the case of installations in the perched aquifers or near-coastal areas, the impact of the installation on groundwater dependent ecosystems will have to be identified. Consultation with MEPA's Environment Protection Directorate will be required in such cases - MEPA being the national competent authority for such ecosystems.
3	Estimates of the annual volume of water to be abstracted from cooling and the maximum rate of abstraction for the system to operate at full capacity. These estimates need to be supported by the necessary documentation.	Not-applicable
4	Estimation of the maximum discharge rates to be achieved at the discharge point.	Not-applicable
5	An outline of the corrective and preventive actions	Not-applicable

Number	Information requested as part of the ‘full application’	Justification for the request
	which will be taken should there be a surface overflow at the discharge well.	
6	An estimation of the expected increase in temperature of the discharged water as compared to the temperature of the inflowing water.	Not-applicable
7	The construction of a heat transfer model to estimate the flow-dissipation of heat around the discharge well and how this would be expected to impact the groundwater temperature at the abstraction well. Should this model indicate the distinct possibility of a significant impact, the developer would be required to provide estimates of the increased abstraction rates required to mitigate this impact on the efficiency of the cooling system.	Not-applicable
8	Detailed design plans of and documentation on the proposed heat-exchange system which should clearly outline the risk of the abstracted water entering in contact with any effluents within the heat exchange system.	In closed-loop cooling systems a heat-transfer fluid is cycled in a tube-system absorbing heat at the surface and discharging the heat at the aquifer. Although such fluid does not at any time enter in direct contact with groundwater, there is still the distinct possibility that a rupture in the tubing system would result in this fluid to leak to the aquifer. In as much, any heat-transfer fluid utilised in such systems should be such as not to contain potentially polluting substances. Moreover, the applicant would be required to provide a contingency plan outlining how a rupture would be identified and the immediate actions which would be taken to reduce the volume of the leak and to ensure the recovery of the fluid which would have been leaked.

2. JUSTIFICATION FOR INFORMATION REQUESTED IN THE CASE OF PROPOSALS INVOLVING OPEN-LOOP COOLING SYSTEMS

Number	Information requested as part of the 'full application'	Justification for the request
1	Full details on the construction of the wells to be drilled as required under LN254/2008 entitled 'Borehole Drilling and Excavation Works within the Saturated Zone Regulations, 2008'.	Applicant still needs to abide with the provisions of LN254/2008 and apply with the Authority for the drilling of the heat-exchange well. This since the applicant would still be required to abide with all enacted National and European Legislation.
2	Land-use survey within a distance of 500m from the proposed well locations to identify the location of other established groundwater users and the presence of any groundwater dependent ecosystems.	This survey will enable the Authority to assess the potential impact of such a system on other established users, particularly those vulnerable to an increase in the temperature of groundwater. Moreover, in the case of installations in the perched aquifers or near-coastal areas, the impact of the installation on groundwater dependent ecosystems will have to be identified. Consultation with MEPA's Environment Protection Directorate will be required in such cases - MEPA being the national competent authority for such ecosystems.
3	Estimates of the annual volume of water to be abstracted from cooling and the maximum rate of abstraction for the system to operate at full capacity. These estimates need to be supported by the necessary documentation.	Standard design information which should be readily available.
4	Estimation of the maximum discharge rates to be achieved at the discharge point.	Standard design information which should be readily available.
5	An outline of the corrective and preventive actions which will be taken should there be a surface overflow at the discharge well.	One would tend to consider that the volume of water abstracted from a borehole would all be taken back by the return (discharge) well. However, this is often not the case as gravity feeding of the return water might not provide sufficient pressure to allow infiltration into the aquifer, and particularly so in aquifers where secondary permeability plays an important role. There is the distinct possibility that at high abstraction rates, the discharge well would not be able to accept the resulting high discharge

Number	Information requested as part of the 'full application'	Justification for the request
		rates and the discharged water would build in the well eventually discharging at the surface.
6	An estimation of the expected increase in temperature of the discharged water as compared to the temperature of the inflowing water.	Standard design information which should be readily available.
7	The construction of a heat transfer model to estimate the flow-dissipation of heat around the discharge well and how this would be expected to impact the groundwater temperature at the abstraction well. Should this model indicate the distinct possibility of a significant impact, the developer would be required to provide estimates of the increased abstraction rates required to mitigate this impact on the efficiency of the cooling system.	The efficiency of a heat-cooling system depends on the temperature difference between the surface and the underground environment. If the temperature of the abstracted water starts to increase (due to the influence of the discharged high temperature water), increased flows would be required to achieve the same heat-transfer capability. This would entail an increased impact of the system on the aquifer both from a qualitative (upconing) and quantitative (abstracted amounts) point of view. It is noted that various literature suggest a separation of several hundred meters between the abstraction and the discharge wells, which separation is difficult to achieve in Malta.
8	Detailed design plans of and documentation on the proposed heat-exchange system which should clearly outline the risk of the abstracted water entering in contact with any effluents within the heat exchange system.	In open-loop systems heat transfer at the surface could be achieved through the use of heat-conducting fluids. Since there is always the distinct possibility of such fluids entering in contact with the abstracted groundwater through ruptures in the system, the Authority needs to direct the developer towards the use of heat-conducting fluids which do not contain prohibited substances.