Water Scarcity in the Maltese Islands: Geopolitics and Management Issues

Volume 1

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ABSTRACT

The Maltese Islands have a history of water resource problems. A high proportion of the Maltese population has suffered over the past few years from water scarcity caused mainly by: (a) a shortage in water production and escalating water demands; (b) rising salinity levels in groundwater and tap water; (c) an undersized and deteriorating distribution system; and (d) increasing levels of groundwater pollution.

There is a spatial variation in the intensity of these problems. They are greatest in the south of Malta and it has been suggested that this is due to geopolitical, as well as social, economic and physical, factors. This inequity in water supply has, for many years, been blamed on the politicisation of water.

The causes of the water problems are presented and the problems, themselves, are analysed. The link between the water problems and the politicisation of water and conflicts over water resources, is established and discussed. Finally, solutions, through water management and future planned developments, are presented.

Social and geopolitical information was gathered mainly through qualitative interviews with water consumers, water suppliers, decision makers, academics and members of non-Governmental organisations, in Malta. Quantitative data on hydrology and the entire water management system was collected and analysed. An extensive literary search to support the physical, social, economic and geopolitical aspects of the research and to obtain legal information, was also undertaken.

In conclusion, although the water problems have been enhanced by unsustainable management, they are a part of a wider geopolitical problem, especially the inequitable water supply. In particular, settlements with an affiliation to the political party in Government are better supplied than settlements that support the Opposition. In addition, water conflicts, at all scales, arise due to water scarcity and a lack or absence of water sharing regulations and, of course, human nature.

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LIST OF ACRONYMS

AD - *Alternattiva Demokratika*.
DA - Department of Agriculture.
ECO - Malta Ecological Society.
EIA - Environmental Impact Assessment.
ETP - (Real) evapotranspiration.
EU - European Union.
FIS - Foundation for International Studies.
MDC - Malta Development Corporation.
MLP - Malta Labour Party.
MSF - Multi-stage flash.
NP/PN - Nationalist Party.
NTOM - National Tourism Organisation - Malta.
PA - Planning Authority.
PETP - Potential evapotranspiration.
PPM - parts per million.
RO - Reverse osmosis.
SASTP - Sant' Antnin Sewage Treatment Plant.
TIE - Theatre in Education.
UNEP - United Nations Environment Programme.
UNESCO - United Nations Educational, Scientific and Cultural Organisation.
UK - United Kingdom.
US - United States.
WHO - World Health Organisation.
WSC - Water Services Corporation.
WWD - Water Works Department.

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".... it is evidently true that humans do not just fulfil their biological subsistence needs but, through the process of socialization, accept and strive to reach the level of living defined as desirable by the social environment.... Within a given context individuals will, to some extent, behave according to the principle of *enlightened interest*, cooperating with each other when it can further their interests, and struggling with each other when it seems appropriate. Some scientists believe that technology will be able to increase the availability of resources. According to others, social mechanisms limit access even when the resources are made available" (Falkenmark and Suprapto, 1992, p.32).

CHAPTER 1

INTRODUCTION

1.1. <u>WATER RESOURCE PROBLEMS</u>

Water is one of the most vital substances for life:

"Water, nature's special vitalizing substance is a prime stimulus for the manifestation of life, and a necessary factor for sustaining life and productivity in both natural and man-made systems. It is crucial for the fight against under-development and for promoting those conditions that favour the development of a satisfactory quality of life. Water is a driving force in development. It is an essential element for the maintenance of a viable human environment. There is no substitute for water." (Obeng, 1980b).

Water resources are becoming increasingly scarce in many parts of the world. Originally the problem was thought to be restricted to arid and semi-arid regions, but even temperate regions are experiencing increasing water scarcity. The 1995 drought in Britain illustrates this. It has been argued that anthropogenic climate change, or the 'greenhouse effect,' is the cause. However as yet it is uncertain whether climate change is occurring and if it does occur, its impact on weather and water resources could be a long time ahead.

The causes of water scarcity are much more far-reaching than just year to year variations in climate. Principle causes include population increases, development pressures/demands and poor water management. In developed nations like Malta and Britain, where population growth is relatively small, it is the water demands of development that cause water problems for many countries. In addition to increasing industrial and commercial (particularly from tourism (Sykes, 1995)) demands for water, standards of living have increased which include the demand for more water and water consuming appliances.

"For most of us, water scarcity conjures up visions of drought, those temporary dry spells that nature inflicts from time to time. But while droughts capture headlines and grab our attention, the far greater threat posed by our escalating water consumption goes largely unnoticed. In many parts of the world, water use is nearing the limits of natural systems; in some areas those limits have already been surpassed." (Postel, 1992, p.18).

Water is often provided by a Government body or private company or companies via piped supplies, which in some places are almost entirely derived from seawater by desalination (Walton, 1987). It is available at the turn of a tap and is taken for granted. Postel (1992) uses Phoenix in Arizona to illustrate what has happened in many dry developed cities and nations:

".... scarcity is masked by the damming, diverting, and pumping of water from near and far to make the city not only livable but lush. An illusion of plenty has been created in water scarce Phoenix - which leads to overconsumption and adverse consequences for the environment and future generations." (Postel, 1992, p.18).

Eventually supply systems become old and inefficient and are difficult and expensive to replace. Poor water management is usually the result of an unskilled task force, or misdirection where the actions of the water supplier are driven by politics or financial gain, at the expense of the consumer and the service itself.

To cope with consumer demands, surface and underground water sources are often extracted at highly unsustainable rates with little regard for the conservation of water quantity and quality for future supplies. This is partly due to the shortlived terms in Government of decision makers, during which time environmental sustainability is sacrificed to keep voters satisfied.

".... man's use of the resources has.... resulted in the modification of various components and sometimes adversely affected the dynamics of environmental systems and the satisfactory progress of development." (Obeng, 1980a, p.115).

As water quantity and quality decrease, then the competition for this essential resource increases. If enough is not available and, as often is the case, in the absence of equitable water sharing measures and regulations, conflicts may arise where individuals, groups, political and economic powers, economic sectors, regions and nations will readily fight for water (*The Guardian*, 8/8/95, section 2, pp.1-3; *Independent*, 7/8/95, p.6). Water becomes a geopolitical issue.

The problem is likely to be worse in small, dry and densely populated islands (like Malta) where it has, in many cases, reached crisis proportions (Okoye, 1990; Falkland and Custodio, 1991), partly due to their isolation (preventing long distance water transfers), the lack of perennial streams (Deguara, 1983), the low level of groundwater resources relative to population and large numbers of tourists, and the threat of seawater intrusion (ibid).

1.2. WATER RESOURCE GEOPOLITICS AND CONFLICTS

With water being a fundamental resource and its scarcity increasing globally, without adequate and agreed water sharing means and regulations the potential for conflict (not necessarily violent) between riparians, neighbours, etc., is also increasing. These conflicts are unfortunately the culmination of the geopolitics of water resources or, hydropolitics (a term used to describe the influence of water on the formulation of policy or individual and group decisions) (Anderson, 1992). The following examples illustrate how hydropolitics can occur at any scale, using evidence drawn from the Mediterranean region.

One of the most controversial cases of hydropolitics, on an international scale, is that between the riparian countries of the Levant. Water has been argued to be the next strategic resource replacing oil as the impetus for future armed conflict. Although to date there has been little evidence of this, water certainly plays a large part in the strategy and international discussions of some Middle Eastern countries. The River Jordan, for example, is shared by Israel, Jordan, Syria and Lebanon. However, it is the contentious issue of groundwater extractions in the region that has had the countries in disagreement over water. Before 1967 and Israel's occupation of the West Bank, it had no control over the eastern aquifer in the region. After 1967, Israel took control of groundwater supplies and the eastern aquifer now supplies at least 60% of Israel's water (to the loss of many West Bank communities), yet only 3% of the area of the Jordan Basin lies within the boundaries of pre-1967 Israel (Anderson, 1987). Israel's occupation of the Golan Heights also gave it control of the tributaries of the Jordan and part of the Yarmuk. Israeli extraction from the river upstream lowers the quantity and quality of water reaching Jordan. Hence, water is a vital component of the Middle Eastern peace process and possibly one that may hinder progress (Anderson, 1992).

On a national scale, although a much larger island (the second largest in the Mediterranean), like Malta, Cyprus is semi-arid with limited water resources (Cyprus is used here to illustrate the kind of hydropolitics that can exist not only in Mediterranean islands like Malta, but throughout the Mediterranean region where two or more opposing sides have vested interests in obtaining water). After the ceasefire between the Turkish controlled north and the Greek Cypriot south, the Turkish Cypriots held approximately 37% of Cyprus. The occupation divided hydrological regions with three important headsprings (Kythrea, Lapithos and Karavas) lying in the north, and cut across the course of all the major northward flowing streams (Grundy-Warr, 1984) (the flows of which are not very significant in terms of national water resources and not perennial (Hocknell, 1997)). Of the key economic sectors, agriculture is the largest consumer of water in Cyprus and 46.5% of the total irrigated land (including the richest in water resources) is in the occupied areas. The Greek Cypriots also lost important dam and water development projects. Due to the geopolitical situation,

"Since the partition, it has not been possible to integrate water development schemes on an island-wide basis...." (Grundy-Warr, 1984, p.165).

During the 1964 to 1974 period, Turkish-Cypriot enclaves experienced water shortages due to Government restrictions or due to the over-consumption and diversion of streams and groundwater resources shared by, and running into, both sides' territory. According to Drury (1977) Turkish Cypriots,

".... resented the way in which new wells were deliberately sunk adjacent to their own territory, thereby lowering their own water table to untappable depths...." (Grundy-Warr, 1984, p.165 from Drury, 1977).

Water resources clearly played a strategic role in the conflict. The 1974 partition improved the water situation of the Turkish-Cypriots but,

"..... the north could still be deprived of water from the south during dry summer months should the Greeks decide this is necessary for their own needs or as a political weapon." (Grundy-Warr, 1984, p.166).

Today, any water related disagreement usually consists of the Greek-Cypriots blaming the Turkish-Cypriots for their water problems in times of drought. Water would certainly be the primary topic of contention and more of a political issue were it not for the bigger issue of the Turkish occupation. Presently water stands as a point of conflict under the umbrella of the wider conflict (Hocknell, 1997).

The United Nations Peace Keeping force patrols the buffer zone between the north and south. In theory, the geopolitical nature of water requires the United Nations force to ensure that the water distribution system in the buffer zone is operated for the benefit of both communities (Grundy-Warr, 1984).

"The Buffer Zone has a peculiar hydropolitics with U.N.F.I.CYP. [United Nations Force in Cyprus] in charge of its water supply. Before a farmer can drill for water he must have proof of land ownership to obtain a drilling licence, then get U.N.F.I.CYP. permission." (Grundy-Warr, 1984, p.184).

Arguments do break out over water rights, with farmers pressing for access to wells where they have no proof of ownership (Hocknell, 1997).

Today, in the Greek Cypriot south, on a regional scale, the potential for competition and conflict over water is high since the region has outdated water legislation (from before 1960) which fails to define any authority to evaluate, inventorise, allocate and control the use of water resources. For the last twenty years Cyprus has been implementing a water master plan (UNEP, 1995). Unfortunately, this has presented difficulties in,

".... data availability, qualified and experienced staff shortage, legislation deficiencies and lack of administrative organizations capable to undertake such tasks." (UNEP, 1995, p.77).

The situation in Malta is not, basically, dissimilar, albeit far less extreme. Conflicts are not of a military nature or related to territorial divisions but specifically over water and are highly politicised. As Chapters 6 and 7 illustrate, water is used in Malta as a political weapon and not only are water conflicts caused by political and social differences but these conflicts reinforce and propagate these differences.

The extreme circumstances of Cyprus show that the production and enforcement of equitable and sustainable water use regulations is necessary to prevent water conflicts. This has not happened in Malta either and is one of the reasons water is a highly geopolitical issue there.

Recently, in 1995, Spain suffered from one of the worst droughts this century (Owen, 1995a), with reservoirs holding 10% of their capacity and water restrictions in most cities (Nowicka *et al.* 1995). Being one of the world's most popular tourist destinations, the tourist industry was severely affected by widespread water rationing (Owen 1995a).

Both sectoral and regional water conflicts arose. In one case, the regional parliament of Castilla-La Mancha, in arid central Spain, claimed that the central government acted illegally when it allowed the region's water to be transferred 185 miles south-east to supply drought-stricken Alicante, Murcia and Almeria. The regional parliament stated that it did not have enough water for its own population and accused the *murcianos* of wasting water (Owen, 1995b).

Inter-sectoral conflicts over water also frequently occur in times of water scarcity. In Cyprus (the Greek Cypriot south) the agricultural and private residential (domestic) sectors often blame the tourist sector for excessive water consumption and water scarcity (Hocknell, 1997), forgetting that while the latter was developed for the purpose of economic recovery (after precious agricultural and industrial land in the north was lost in 1974) and uses only 2% of the nation's water, the agricultural and domestic sectors are responsible for using 75% and 21%, respectively (Ministry of Finance (Cyprus), 1992). This situation of apportioning blame for water scarcity between sectors exists in Malta too.

Conflicts are greater in number on the smallest of scales because there are greater opportunities for them to break out. For an island the size of Malta there are an extraordinary amount within a variety of contexts. They are discussed in Chapter 6. Illustrating how these small scale conflicts can occur wherever water is in short supply and water allocations and regulations are inequitable, deficient, outdated (as they often are in traditional agricultural communities) or non-existent, the village of Akaki in Cyprus presents problems of water rights. Water extraction is from eight chains of wells called *laoumia*. Entitled owners use water according to their entitled share which is controversially based not on acreage, but according to the specific share registered in the Lands and Surveys Department. In many cases those that have fewer shares do not receive the amount of water they need, while others with less acreage but more shares receive more water than necessary. Furthermore, the fields of some water-owners are not near the outlets of the watercourses creating access problems and the possibility for conflict (Karouziz, 1980). A problem too familiar in many places in Malta and the rest of the world.

1.3. WATER SCARCITY IN MEDITERRANEAN ISLANDS

Problems associated with the water situation in most Mediterranean islands are remarkable and relevant to the Maltese experience in that many are dry and experience high levels of water demand during the summer (the driest period), mostly from the tourist sector but also all other sectors (Bonell, 1993). During 1995, water restrictions were in force throughout most of the Mediterranean region. The Italian islands suffered considerably from increasing water problems. Sardinia had its driest year since the 1920's with water storage down to 12% of capacity (Nowicka, 1995; Birdi, 1997)).

"This phenomenon is serious in the small Mediterranean islands (whose surface area is less than 1000km^2) because, unlike the bigger islands or mainland coastal districts, where water can be supplied from one area to another, they do not have a hinterland supply." (Aubriet, 1993).

The Mediterranean climate ranges from sub-humid to semi-arid. For many islands high summer temperatures coincide with minimal or no rainfall, leading to drought. Examples of extremes in average annual rainfall, in Table 1.1., are 1,340mm in Corfu (sub-humid) and 250mm in

Table 1.1. Approximate average annual rainfall (mm) in small Mediterranean Islands

Island	Rainfall	Country
Kerkennah	250	Tunisia
Aegina	300	Greece
Thira	370	Greece
Naxos	375	Greece
Ibiza	450	Spain
Malta	500	Malta
Gozo	520	Malta
Stromboli	580	Italy
Minorca	645	Spain
Nisyros	730	Greece
Hvar	760	Croatia
Samos	950	Greece
Corfu	1340	Greece

Source: Aubriet, 1993.

Kerkennah (semi-arid). Summer is a dry period, when, as previously stated, water demands are at their highest (Aubriet, 1993).

The main factors affecting rainfall are latitude, longtitude (distance from the Atlantic Ocean) and the degree of exposure or shelter. Generally, in the summer, sub-tropical high pressure systems prevent cyclonic disturbances from entering the Mediterranean basin. These high pressure systems come from the south and so the southern regions are better protected than the northern Mediterranean and so are drier. The east is drier than the west because most depressions (bearing rain) come from the west. Most islands located east of the peninsulas are sheltered while the ones to the west are exposed. Hence these two factors (latitude and degree of shelter) give rise to two extreme (southern latitudes and eastern fronts) and two intermediary positions (northern latitudes and western hilly fronts) of islands in terms of aridity. Hence, because Kerkennah is sheltered by the mass of the Tunisisan uplands and is located at latitude 34 48'00" north, it only receives an average annual rainfall of 250mm. The most favoured islands in terms of rainfall are those in the north (the Hyères Islands in France, the Toscan Archipelago in Italy, the Northern Sporades, Thassos, Samothrace and Lemnos in Greece) and those located on the west (windward) side of mountainous regions (all the Adriatic and Ionian Islands and the eastern Aegean islands). The least favoured islands are the southern islands close to the continent (Aegina and the Tunisisan islands of Kerkennah and Djerba) (ibid). Finally, the longtitudinal position of an island will affect its rainfall to some extent. The further away an island is from the Atlantic and associated rainfall bearing low pressure systems, the drier the weather it experiences.

Climate alone does not determine the availability of water resources in the Mediterranean islands. The terrestrial environment, including catchment characteristics and geology, are also important. Many islands have steep slopes facilitating rapid run-off (pp.85-88) losses to the sea. This is the case with islands located inside the peri-Mediterranean Alpine ranges (not the Maltese and Tunisian islands). Some (the Balearics, Sicily, the Adriatic and Ionian Islands, Crete, Karpathos and Cyprus) are the peaks of Alpine mountain chains separated by tectonic (the movement which affects the features of the Earth's crust, resulting from movements of the Earth's plates) change and the incursion of the sea. The Plio-Quaternary neotectonic period (1.6. million years ago) caused uplifts giving rise to mid-Aegean islands and uplifting the external Aegean arc (Kythera, Crete, Karpathos, Kassos and Rhodes) (ibid).

The volcanic islands, which consist mainly of the Aeolian archipelago and the internal volcanic arc of the Cyclades, were the result of two zones of subduction in the Mediterranean. The volcanic cones are relatively young and some more than 900m high with slopes much steeper than on the continental islands (Stromboli reaches 926m on a surface area of 12.6km^2). This greatly facilitates run-off losses and consequently less water is available for surface and groundwater storage. Similarly, in the Hyères Islands, at Port-Cros, which is very hilly, run-off constitutes 20% of rainfall while at Porquerolles, with a large area consisting of smooth and flat plains, run-off is only 2% of rainfall (ibid).

Vegetation cover is also an important determinant of water resources, reducing run-off, facilitating infiltration (pp.127-132) but also increasing evapotranspiration (pp.88-90). Forests still cover a number of Mediterranean islands (The Hyères Islands, Rab, Mljet, Cres, Losinj, Korcula, Cephalonia, the Northern Sporades and Thasos, for example) due to the greater rainfall. Elsewhere maquis and garrigue, which are scant in cover, predominate, often due to the destruction of the original vegetation by overgrazing (p.65). Scant soil cover on many islands has a negative affect on water retention and this is strongly associated with scant vegetation cover (ibid).

Geology dominates all the other factors, discussed so far, in determining the abundance of water. For example, heavy rains in the Adriatic islands flow into fissures which are then lost as sub-surface discharges at sea level for most of the time. Metamorphic rocks like those of Paros are almost non-porous (impenetrable to water) and so very little water penetrates the surface. In contrast, the layers of ash at Nisyros are highly permeable (pp.127-128) so that very little water is lost to the sea, despite the relatively high rainfall and steep slopes. If water infiltrates the soil and bedrock it is saved from evapotranspiration as well as run-off. But as in the case of some karstic limestone islands (p.130) it may not be stored underground but continue to filter down and into the sea (the Adriatic islands, for example). The extent of alluvial plains, i.e. the coastal plains, which are highly water retaining, is the most important determinant of water availability. Islands with sizeable coastal plains, or watersheds, have the highest quantity of stored water. Aubriet (1993) states that islands of more than 200km^2 are self-sufficient (Naxos, Andros in the Cyclades, and Kos in the Dodecanese) (ibid) although this cannot by any means be interpreted as a general rule, nor even a guide since many small islands, Gozo for example, are, or have been, self-sufficient due to a variety of factors other than size.

Droughts aside, it is the unsustainable water consumption by society, mainly by domestic consumers and tourists (the agricultural and industrial sectors are not significant consumers of water in most small Mediterranean islands) that creates problems for most Mediterranean islands. This can vary from island to island. For example, domestic consumption is no more than

80 litres/capita/day in most of the small Greek islands while it is approximately 250 to 300 litres/capita/day in France. But in most islands, standards of living are increasing and consequently, the demand for water (Chapter 4). Tourist demand can reach 400 to 600 litres/capita/day in some hotels (including washing, the watering of grounds and golf greens, and the filling of swimming pools). Population increase is also a significant factor in the increasing demand for water, particularly because of the number of workers needed in the tourist sector, especially during the summer (ibid).

Most Mediterranean islands tend to rely on tourism to a greater extent than the mainland and reach and exceed the carrying capacity rapidly. This is probably due to the comparative advantage they have in tourism related activities and the desire to exploit them as much as possible (Briguglio, 1995). Due to their small size many have fragile ecosystems and face environmental dangers such as water scarcity and pollution (ibid). Through excessive extraction many Mediterranean islands have exceeded the sustainable yield of their groundwater stores and consequently, seawater intrusion has resulted in the salinisation of supplies. They tend to experience water scarcity to a greater extent than most mainlands. For example, the Adriatic coast of former Yugoslavia is supplied by two rivers (Neretva and Cetina) as well as having the possibility of piped water transfers from the non-karstic interior. But water supply is critical on the Adriatic islands which have no permanent water flows. In most cases the development of tourism and industry is not possible without water transfers from the mainland and, to this end, a sea-bed pipeline to the mainland has enabled the development of the islands of Brac, the Peljesac peninsula (which has all the morphological characteristics of an island), and Šolta (Klarić, 1989). It should be noted, however, that in the case of Cyprus, Malta and possibly some of the Greek islands, where the nearest mainland is foreign, reliance on a foreign source of water can be a politically unsafe and insecure option. The islands of Silba, Hvar and Korcula in the Adriatic Sea have also been linked by a pipeline to their mainland. Examples from elsewhere include the islands in the bay of Naples, Salamina in Greece and Djerba in Tunisia, all connected to their respective neighbouring mainlands (Aubriet, 1993).

Šolta is only 9 miles from the coastal municipality of Split on the Croatian mainland. Like Malta, Šolta consists mostly of porous limestone and has no permanent springs or surface flows. Even before 1986, when a water link was made with Split, despite rationing on the island, it was necessary to import water by water carrying ships (tankers). However the lack of water was causing depopulation almost to the point of desertion. Fortunately, a water pipeline has allowed Šolta to develop, particularly its tourist industry, and reverse the process of depopulation. Tourism has not been a problem in terms of water supply thanks to the importation of water and has in fact helped to populate the island by generating tourism related employment (ibid).

Silba, also in the Adriatic and consisting of calcareous rocks with no surface water flows, is approximately 35km off the coast of former Yugoslavia. Depopulation has left only 200 residents but during the summer a total of up to 2,400 tourists have been known to visit the island. This puts enormous pressures on water supply which is already in short supply, hindering development. Water has been imported by tankers (the most common solution for water transfers to islands in the Mediterranean) during the tourist season in the past but since the filling points for the tankers are about 150km away, this is costly. Unlike Šolta but like Malta, Silba is unable to construct a pipeline supply to the mainland due to the distance and cost involved while transfers by tankers are also expensive, unreliable in adverse weather conditions, vulnerable to contamination and only worthwhile if an island has sufficient water storage facilities which most small islands do not (it has been suggested that rain water harvesting (pp.609-611) be the solution to the shortage in Silba) (Aubriet, 1993; Falkland and Custodio, 1991).

"We live in a time when it is impossible to provide the financial means for the construction of expensive regional systems of water supply using water piped or tanked from the main land." (Falkland and Custodio, 1991, p.399).

Falkland and Custodio's observation is an important consideration for many small islands. Self-sufficiency is, or should be, of utmost importance for many Mediterranean islands in order for them to ensure water security. This has certainly been the case in the Maltese Islands, not just because they are physically isolated, but also politically isolated.

The Maltese Islands presented a unique possibility for study for a number of reasons. Like Cyprus, climatically they are some of the most disadvantaged of the Mediterranean islands in terms of rainfall (pp.76-85), lying east of the Tunisian uplands and experiencing the dry high pressure conditions from the south for much of the year. Thankfully they have a topography and geology that favours water storage. They are typical of many of the Mediterranean islands, in terms of water problems and their causes, but are unique in that they have experienced advanced stages in the development of these problems and have gone on and tried to tackle them with non-conventional methods that other islands have not tried or only experimented with.

A consequence of being independent has been that the Maltese Islands are one of the most politically, as well as physically, isolated of the small islands in the Mediterranean for which pipeline transfers are out of the question and water tankers uneconomic and impractical (imports by tanker were tried in the 1980's but abandoned, while some islands are still contemplating this option). They are the most densely populated of the Mediterranean islands and have experienced mass tourism, industrialisation and an increase in standards of living relatively early. Hence, water demand has already increased substantially. As a result, Malta has had to resort to the third option (after pipelines and tankers) small islands adopt when facing extreme water scarcity: desalination (its first desalination plant was the largest in the world at the time of installation (1982)).

"The only way for the islands to become relatively independent as far as water is concerned is to invest money in the building of water desalination plants. That is what Malta has done resolutely, because it was a question of national independence [*sic*]." (Aubriet, 1993, p.38).

Unlike any of the other Mediterranean islands, however, Malta has adopted desalination technology on such a large scale that more than half of the public water supply is derived from the sea (pp.174-184). Cyprus has four thermal distillation plants and eight reverse osmosis (pp.184-190) units (which accounts for a small amount of water supply) (Theodosiou, 1986) and wider use of desalination technology is under consideration for times of prolonged drought and for conventional use beyond 2000 (Republic of Cyprus, 1994). Only the Italians have as much experience as the Maltese with desalination technology but in trying to reduce the high energy costs involved,

"The experiments of sea water desalination, using solar energy, carried out on the Italian islands of Lampedusa and San Nicola.... are, unfortunately, not quite convincing from the operational as well as from the cost of installation points of views." (Aubriet, 1993, p.38).

Malta has been running a sewage recycling plant to produce water for irrigation since 1984 (learning from the extensive and successful Israeli experience) and has plans for more, something that some small islands have not even considered. This, and the widespread adoption of RO technology ahead of most other Mediterranean islands, is probably, to a large extent, the result of the independent status of the Maltese Islands. Most other Mediterranean islands would be dependent on their mainlands for financing and allowing the adoption of expensive water supply technologies. These mainlands, where almost all national policies and financial decisions are made, are unlikely to allow the kind of expense spared in Malta to occur in their own sovereign islands.

In addition to their unique situation, the Maltese Islands were chosen for this study because despite the large scale use of desalination technology and a history of water resource problems they still have not managed to solve existing problems (radical attempts to do so are occurring and some are planned (Chapter 8)) while new ones have emerged and are emerging (Chapter 5). Hence, they may represent the stage to come for many other Mediterranean islands and provide a blueprint for what not to do or more importantly what should be done if other islands experience (or are experiencing) similar problems.

Furthermore, the small size of the Islands allowed the complete investigation and analysis of the water issue in terms of supply, demand, problems, conflicts and politics, from the local to the national scale. Most

Maltese speak English and accessibility to decision makers and those who supply water, as well as consumers, could therefore be achieved, although political barriers sometimes denied me access to certain information. Most of the research was undertaken in mainland Malta, mainly because most of the problems, conflicts and politics over water existed there, while in Gozo, Malta's 'sister' island (where the water problem is less pronounced but is increasing), research concentrated mostly on cases which mirrored the problems in Malta. The population of the two islands is estimated in 1993 to have been 363,000, with almost 93% resident in Malta (Lockhart, undated unpublished draft).

1.4. AUTHOR'S BACKGROUND

The study was undertaken as a progression of my personal interests and academic work. My previous research included the study of human perception of, and preparedness for, the earthquake hazard in Fremont, San Francisco, for my undergraduate dissertation. The study made recommendations for making people more aware of the real consequences of the hazard and non-technological adjustments to reduce risk, from the individual to the regional level.

This interest in natural hazards led me to undertake a study of a more recently emerging and topical climatological hazard for my MSc dissertation: the risks of overexposure to ultraviolet radiation. The study compared North American and British perceptions of stratospheric ozone depletion and the health risks associated with sunbathing. The North Americans interviewed were better informed of the risks than the British and recommendations were made of a similar education campaign in the UK to those undertaken in North America and parts of Australia, where the state of

Victoria was dubbed the skin cancer capital of the world.

This progression from the study of risk from a hazard with a sudden onset to one with a much longer time scale, led me to gain interest in drought and its societal impacts. Of particular interest was the way water shortages can lead to conflict and for my MSc I studied international water conflicts between the riparians of particular rivers in the Middle East and Africa. This introduced me to the work of Professor Ewan Anderson, my supervisor, and the aims of this study. I became interested in the effects of drought induced by anthropological factors, more than climatic factors, and its effects at various scales (from the local to the nation/state level) in the Maltese Islands.

1.5. METHODOLOGY

The approach to this study was a progressive one. The main body of research was undertaken during the drought in July, August and September 1993. This is referred to as Research Period 1 in the text. Subsequent research was undertaken in March/April 1994 and March/April 1995, Research Periods 2 and 3, respectively. The purpose of these was to investigate if the water problem and its consequences existed outside of the drought conditions in 1993 and the summer months (July to September which are the driest), and also to update the study, since the water situation in Malta was rapidly changing. All the primary research was of a qualitative nature based upon semi-structured interviews.

During Research Period 1, initially, a pilot study was undertaken with five water consumers and two officials in order to obtain an idea of the water problem and to finalise an exploratory survey. The aim of the exploratory survey was to determine the nature and extent of the water problem, if it existed at all, and if any scarcity caused any social and political conflict. Hence, it was directed at water consumers, who would know if there was a problem and who would be least likely to deny it if there was one (as opposed to water suppliers, who would be least likely to admit that there was a problem). These consumers consisted of local residents, farmers, hoteliers and industrialists.

For the exploratory survey of domestic consumers a random stratified sample was obtained by choosing 50% of settlements from each the five main regions of Malta, i.e. 7 settlements from the Inner Harbour region of 14 settlements (or more where there are an odd number in a region, i.e. 6 from the 11 in the South-Eastern region) (Tull and Albaum, 1973; Dixon and Leach, undated, *c*.1978). Table 1.2. lists the settlements in each region (sample settlements are followed by an asterisk) and Figure 1.1. shows the location of settlement regions by census localities. Care was taken to choose settlements of varying (population) size and with some distance from each other, since it was hypothesised that the water problem is geographically related. The pilot survey strongly suggested this. The survey was also extended to Gozo to see if a water problem also existed there.

Since the interviews were to be qualitative and potentially lengthy, two respondents were randomly chosen from each settlement. Because of the qualitative nature of the survey, a representative sample of each settlement's population was not a consideration. My main goal was to understand the social processes underlying the problems, politics and conflicts associated with water (Gilbert, 1993). Given the small size of most settlements, and the Islands themselves, and the close-knit nature of the community, it was assumed that each respondent would have sufficient knowledge of these issues on a settlement-wide and even island-wide scale. All respondents in the pilot survey justified this assumption. Children were excluded from the survey since

Table 1.2. Settlements in the Maltese Islands by census localities.

1. Inner Harbour region:

   Valletta
   Floriana
   Sliema *
   Gzira/Ta' Xbiex *
   Msida *
   G'Mangia/Pieta
   Hamrun
   Marsa *
   Paola
   Cospicua *
   Senglea
   Vittoriosa *
   Kalkara
   St. Lucia *

2. Outer Harbour region

   St. Julians *
   San Gwann
   Birkirkara *
   Sta Venera
   Qormi
   Luqa *
   Tarxien
   Fgura *
   Zabbar *

3. South-Eastern region

   Qrendi
   Mqabba *
   Zurrieq *
   Safi
   Kirkop
   Gudja
   Ghaxaq
   Birzebbuga *
   Marsaxlokk *
   Zejtun *
   Marsascala *

4. Western region

   Dingli *
   Rabat *
   Mdina
   Siggiewi *
   Zebbug
   Attard
   Lija *
   Balzan

5. Northern region

   Mellieha *
   St. Paul's Bay *
   Mgarr
   Mosta *
   Naxxar
   Gharghur

6. Gozo

   San Lawrenz
   Gharb
   Ghasri
   Kercem *
   Munxar *
   Fontana
   Victoria *
   Zebbug *
   Xaghra *
   Xewkija
   Sannat
   Ghajnsielem *
   Nadur *
   Qala

* - denotes settlements sampled for the exploratory survey.

Source: Central Office of Statistics - Malta, 1994.

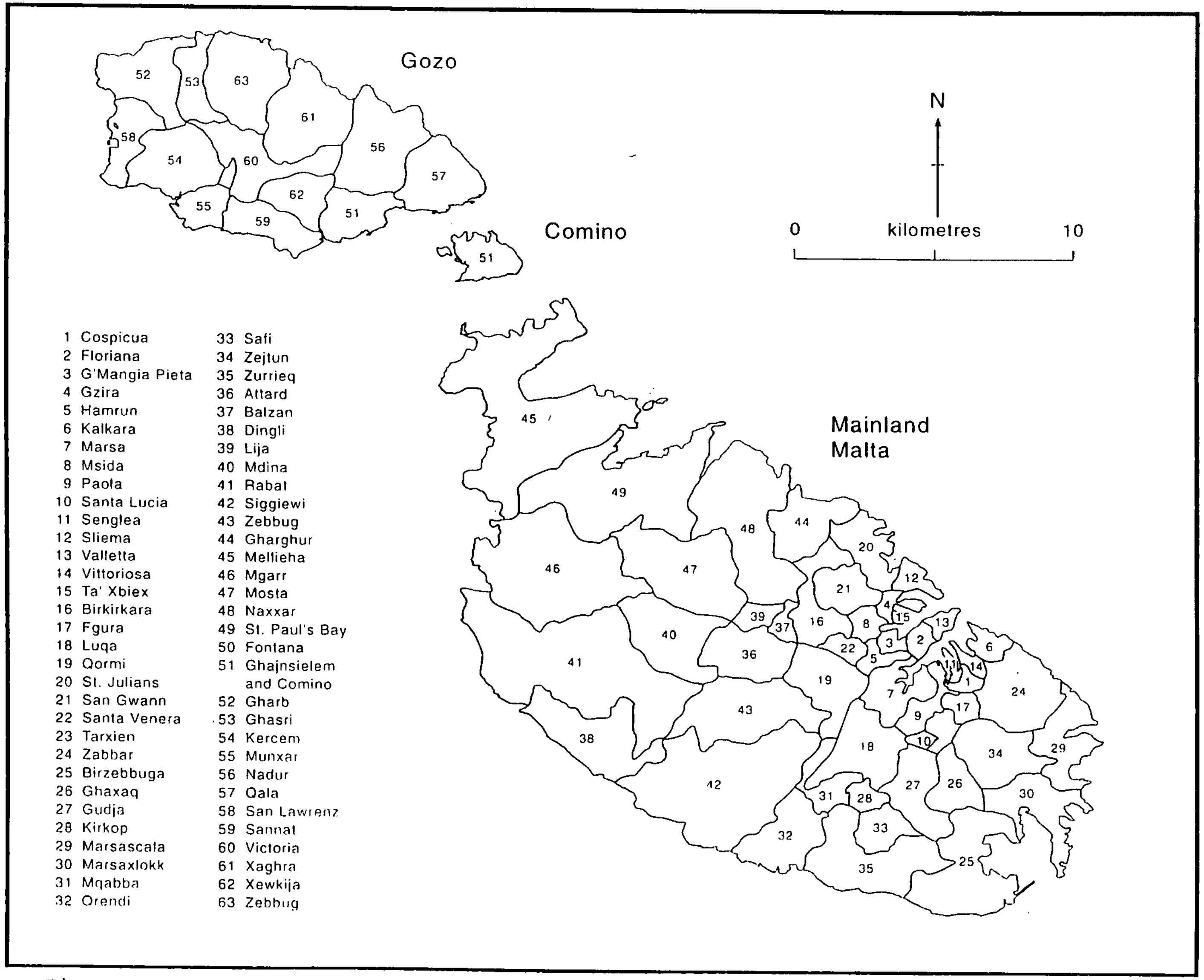

Figure 1.1 Settlement location by census localities in Malta and Gozo.
Source: Ministry for the Development of Infrastructure, 1990; 1991.

they are not the principal decision makers on consumption in a household.

On the advice of one official source, questions about political affiliation were avoided since this is a private and very sensitive topic, especially in relation to water. Since it had been suggested from the pilot survey that the water problem is greater in the south because it is predominantly Labour voting, and hence neglected by the Nationalist Government, it was assumed that those interviewed in the south (the line from Valletta to Siggiewi is considered to be the offical north-south divide) were likely to be Labour supporters, and those in the north and central regions, Nationalist supporters. Although this is highly presumptuous, political affiliations came strongly across in most interviews anyway.

All interviewees were willing to be interviewed although some refused to answer all my questions or gave up some way through, mostly when water was brought up in relation to politics and conflicts, because, I assumed, water is a politically sensitive issue. A total of fifty interviews were successfully completed. This was more than sufficient to gain a detailed insight into the water problem and water politics, providing a background of knowledge for the main body of research: the interviews with officials, academics, members of Non-Governmental Organisations (NGO's) and professionals (pp.36-37).

Very little detailed information exists on the distribution of irrigated agriculture in Malta. Hence, with the advice of a Department of Agriculture (DA) source, samples of six farmers were taken from each of the main irrigated agricultural regions in Malta: the south-east, central Malta, the west and the north-west and from various agricultural areas in Gozo (mainly the Lunciata Valley). The farmers were randomly selected within each region. However, I tried where and whenever possible to select interviewees with varying distances from water sources, i.e. varying accessibility to water, since it was hypothesised that with decreased accessibility, less water would be available for those at the periphery if water was scarce, hence leading to shortages and conflict.

Twenty hoteliers from the main tourist areas of Sliema/St. Julians, and Bugibba/Qawra in Malta, and Marsalforn and Xlendi in Gozo were interviewed so that equal representation was given to accommodation of 3 star and above, and those below 3 star. Although anonymity was assured, obviously some hotels may have been wary of giving details about any water problems or conflicts they experienced due to the adverse publicity they thought my work may give them. It should be noted for the purpose of this study that the tourist industry, although a part of the commercial sector, is discussed separately since its water requirements are much greater than the rest of the sector.

A total of eight managers of water consuming industries (MDC booklet; MDC, 1993) were successfully interviewed, but these interviews proved more difficult to undertake as many interviewees were unwilling to disclose information.

The questionnaires, upon which the interviews with each group of water consumers were based, are in Appendix 1. All the interviews were qualitative, designed to probe the interviewee about their perceptions of the water situation, any problems they (or their hotel/tourists and industries) have themselves and any source of conflict over water. Hence the interviews sometimes became purposely unstructured and sometimes questions were not asked, or new ones introduced, where appropriate. Questions were mostly free answer questions (Appendix 1) and in many instances the interview lapsed into conversation, especially with domestic consumers and farmers (Payne, 1951). Interviews lasted from as little as five minutes to over an hour and were tape recorded, except where the respondent refused. This was the case with all the industrialists interviewed and some hotelliers. In some domestic and agricultural cases interviewees spoke little or no English. I coped with some with my limited Maltese vocabulary, otherwise was assisted by translation from Maltese University students.

If people did not want to talk or withheld answers it seemed likely that it was because water is a political issue and some people were afraid of the consequences of any criticism they may make of the Government. Political opinions are not as anonymous in Malta and Gozo as they are in, say the UK, due to the very small size of the Islands. Several respondents believed that what they said might have negative consequences for them if those in or close to the Government knew. Indeed, albeit an extreme and example, I was able to openly approach and talk to the Prime Minister and the leader of the Opposition. The Islands are small and gossip easily spreads. This obstacle to my research is further discussed in Chapter 7. Many farmers were also suspicious of my intentions and who I was and only later in my research did I discover that the theft of water amongst farmers was commonplace. Certainly, many farmers were secretive and sometimes hostile. Someone with a clipboard and pen could easily be mistaken as someone from the water authority, the Government or the police. This was particularly the case in Gozo where interviews with farmers proved difficult. Furthermore, some respondents, farmers and householders, did not have time or were not interested.

In many cases problems were overcome by assistance from Maltese students who reassured interviewees of anonymity. Having their voices tape recorded was probably the most unnerving aspect for them. However, it was those that were suffering the most from water scarcity, poor water quality and water disputes, that were most keen to talk and wanted to ensure that their anger and views were known. Some even asked me to take their case to the newspapers.

The exploratory survey proved more valuable and informative than I thought it would. Analysis went hand in hand with the fieldwork allowing a rapid appreciation of water problems and geopolitics. As well as a general overview of the water problem, more specific problems and water conflicts were made apparent to me. Many of these were then followed up with further investigation and individually tailored qualitative interviews in specific areas with specific people, the main participants in a certain water conflict, for example. Some interviewees were interviewed more than once and a few became regular sources of information, updating me on particular developments (mostly conflicts) (Riley, 1990). The exploratory survey and follow up interviews are drawn upon many times in the text, particularly to illustrate water conflicts. Also, given that my main fieldwork method was the interview, the use of quotations from interviews is very extensive in this study. Quotations from other authors are also extensively used. Since much of the evidence presented by the study is encapsulated in quotations (that are best presented in their own words), this justifies their extensive use.

One of the most important aspects of my research and methodology was my own participation and observation in the field. In terms of participant observation I was both detached and involved (Shipman, 1972). I observed peoples' everyday water use, hardship and measures to cope with water shortages. I experienced water cuts and poor water quality myself and participated in protest marches against water shortages, in political/media discussions and in conferences and roundtables about the water problem. Living there I obtained a feel for the frustration and inconvenience of not having water or having poor quality water. Through my own experiences I developed my ideas and research.

Once the exploratory survey of consumers was complete, the main body of research was undertaken. This involved interviewing and consulting academics, officials, professionals and members of NGO's. Sixty sources were interviewed and consulted, some several times. They are listed under their respective institutions and organisations in the acknowledgements.

Access to these sources was obtained mostly through a snowball effect, where one or two sources, initially provided by my supervisor, led to more and more sources. The sources were pre-selected for me by existing sources and interviews planned so that the most useful sources were consulted and interviewed.

They were interviewed using a list of questions and topics of discussion specifically tailored to probe their individual specialised knowledge on water issues, problems, politics and conflicts. The questions were varied depending on who the interviewee was and some were omitted and/or new ones introduced. A list of all topics/queries is in Appendix 1. Again, the interviews often lapsed into general conversation which provided, as with the exploratory survey, more qualitative information than with a structured interview. The interviews lasted from as little as fifteen minutes to over two hours. They were not tape recorded since much of the information being given was politically sensitive and may not have been made available, or been as truthful, if it were known that a recording was taking place. For this reason almost all sources listed are anonymous, as many had requested. This is a feature of the thesis and all verbal sources are referenced according to the institution or organisation they belong to and the year of the Research Period in which they were interviewed.

My research has accidental similarities to the methodology known as Transaction Cost Economics (TCE) (Willamson, 1985) (articles on TCE were discovered after research was undertaken), which is a component of the New Institutional Economics and,

".... attempts to apply economic reasoning to problems not conventionally addressed by standard neoclassical economics. For example, rather than assuming the existence of markets or, as in cost-benefit analysis, attempting to calculate surrogate market values (shadow prices) where none exist, TCE asks the more fundamental question of why some transactions take place in a market, while others are governed through other structures, notably a hierarchy (e.g. by the state or within a firm), or sometimes do not occur even though an exchange would be of mutual benefit to the transacting parties. In the context of water use, why are conflicts not resolved on the open market?" (Nickum, 1991, p.iv).

Why, for example, do many consumers in the north of Malta, including swimming pool owners, have ample water, while many in the south have no water at all for several weeks?

The TCE is an interdisciplinary framework,

".... based on neoclassical economics but more open to other disciplines like sociology, anthropology, and decision sciences." (ibid, p.viii).

It has been used to try and analyse and understand water use, water management and water conflicts in Seoul (Shin, 1991), Manila (Francisco and Fellizar, 1991), Madras (Venugopal, 1991), Samut Prakarn Province, Thailand (Srivardhana, 1991), Osaka (Oka, 1991), Honolulu (Moncur, 1991) and Kunming (Zhang, 1991).

Many of the issues and questions raised by these studies have also been raised in this study, including: water distribution mapping from source to discharge; determining all water sources and consumers and their objectives; geographical and income variations in water use; the role of private water vendors; water use conflicts over water of adequate quantity and quality;

the state of water resources management; controversies over the quality of tap water; allocation and charging principles; sectoral priorities; pricing systems; centralised vs. decentralised water supply; water rights; relationships within and between organisations involved in water-related transactions; institutional conflicts; water demand management; decentralised decision making; the role and effect of special interest groups (Nickum, 1991; Nickum and Easter, 1991).

Qualitative research should be reiterative and all interviews and conversations were analysed during the process of data collection. This 'progressive focussing' allowed me to return to sources and ask about new topics and ideas I had thought of since the first meeting, or ask more focused questions, or to probe further an issue that I thought was being previously withheld (Riley, 1990). With subsequent interviews many sources revealed more than they had previously divulged.

Hence, many sources were interviewed more than once in the same Research Period or in subsequent Research Periods. Their responses ranged from being very helpful to those that were hostile, secretive and defensive, although some of these became more open and co-operative in subsequent visits as a rapport and trust was developed through persistence, which several sources seemed to admire. A few sources became mentors and advisors, and some were willing to give me tours and guides of various installations, such as the Pembroke reverse osmosis plant and the Sant' Antnin Sewage Treatment Plant. Given the politically charged atmosphere surrounding the water situation and the secrecy surrounding the Water Services Corporation, at times my research almost descended to investigative journalism.

In addition to this, an extensive literature search was undertaken, mostly at the University of Malta library in Msida and the National Library in Valletta. This is one of the few studies that presents and makes references to press cuttings very extensively. The press cuttings, included in Appendix 3, are a central part of my research's findings. The inclusion of so many is justified because the press is the forum for which water conflicts, water politics and public information on water (and indeed all aspects of Maltese life) are publicly discussed.

Figures and Plates are also extensively used to illustrate the study as fully as possible. Along with the press cuttings, these provide easy access, for the reader, to relevant material that might otherwise be difficult to access without actually visiting Malta itself.

1.6. <u>ORIGINAL CONTRIBUTIONS</u>

The research undertaken and the entire thesis is original in the respect that there has been no other study as large and as comprehensive on the water situtation in Malta. It is a complete nationwide study of all aspects: physical, economic, social and political, of a key problem.

All scales and aspects of water derivation, provision, access, consumption and problems are discussed. Interviews were undertaken from the householder to the Prime Minister. All geographic regions and sectors of the economy in Malta, concerned with water use, were studied.

By spending a total of five months in Malta I managed to live like the local residents and experience the same patterns of water use and hardship as they did, as well as being able to observe and study their problems.

Given that through my research I have been in contact with the whole spectrum of Maltese society, it is likely that my work, as early as at the research stage, has influenced key players involved in water supply and management and water consumers. Interaction with these players, through my interviews, may have made decision makers, water suppliers and water consumers think and act more carefully (resourcefully and equitably) when it comes to water managament, water supply and water consumption, respectively. The questions I have asked them have made them think about issues that they may never have considered otherwise. More directly, my participation in a national radio debate on the water problem (pp.585-587) and a roundtable discussion on the need for adequate water management (p.597), at which members of Parliament and the WSC (key decision makers and water suppliers, respectively) attended, could well have already influenced national water policy. I have discussed and given information, gathered through my research, to members of environmental pressure groups (the Malta Ecological Society and *Moviment ghall-Ambjent*). This has affected the content and possibly, the strength and direction of their lobby for better water management in the Islands. In this aspect my research has been unique. It has influenced people even before the thesis was written (of which the WSC and *Moviment ghall-Ambjent* have requested a copy, when complete).

Finally, the thesis is not a one stage study. Before discussing the water problems and the geopolitics of water, the causes that underly them, including supply and demand problems, are presented. Once the problems have been discussed, solutions and future planned developments, to remedy them, are assessed and proposed.

1.7. RESEARCH AIMS

It was already known to me that Malta has a history of water problems. It has suffered from water shortages and poor quality water. The aim of this study was to try and determine the social and political consequences of these problems. Most central to the study was the aim to establish if water scarcity in terms of quantity, quality and access (Pearce, 1994) has led to conflict, both social and political. Such a premise came about through my background reading of water problems and water conflicts.

In order to establish this, subsidiary aims had to be fulfilled. Firstly, it was necessary to establish that there was a water problem and if so, what caused it. Unfortunately for many Maltese (but fortunately for this study), 1993 was a drought year. That year had very low rainfall, which is a significant factor in determining water supply. However this was not the only cause of the problem and other causes, past and present, were investigated, including those of a socio-economic and political nature. Once the water problem and its causes were established, water conflicts and politics were investigated to see if there was a causative link.[1]

This approach has dictated the structure of this thesis. Chapter 2 is an introduction to the physical and historical background to water resources in Malta, discussing mainly geology, climate, hydrology and water resources development. Chapter 3 presents the unique and complex nature of the water supply system. The demand for water, a significant cause of the water problem, is discussed in Chapter 4.

Chapter 5 brings together the water problems caused

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[1] Few specific presumptions/hypotheses were made, since this is the nature of qualitative research. I entered with few preconceptions to try and understand the processes underlying the problems, geopolitics and conflicts and see what their consequences, if any, were. This approach was highly rewarding producing a large amount of qualitative information, much of which I had no idea existed.

mostly by, unsustainable development policies, pollution, the nature of water supply and distribution, and the rising demands for water. Chapters 6 and 7 discuss the relationship between the water problems and conflicts over water, and water politics, respectively. Politics are indirectly a cause of the water problem, by exacerbating the inequity of water supply. The problem then becomes politicised and water conflicts arise between the haves and have nots, and between political parties and their respective supporters.

Finally in Chapter 8 water management and future (and some present) planned developments to solve the problem are discussed. Recommendations are also made in Chapter 8.

CHAPTER 2

A PHYSICAL AND HISTORICAL BACKGROUND TO WATER RESOURCES IN THE MALTESE ISLANDS

2.1. PHYSICAL BACKGROUND: INTRODUCTION

The Maltese Islands form an archipelago consisting of the islands of Malta, Gozo, Comino, the uninhabited smaller islands of Filfla and St. Paul's Island and other islets (Riolo *et al*, 1993).

They are located approximately in the centre of the Mediterranean Sea between 36 00'00" and 35 48'00" north-south latitude and 14 35'00" and 14 10'30" east-west latitude. The nearest land masses are Sicily, 93 km north, and North Africa, 290 km to the south-west (ibid). Figure 2.1. is a map showing the location of the Islands. They comprise a total area of 315.6 km^2. Table 2.1. lists the land area of each island (ibid; Chetcuti *et al*, 1992).

Initial sections of this Chapter discuss the geology, hydrogeology and climatology of the Maltese Islands. These three aspects of the Islands' physical geography are the most important in determining natural water resources. Section 2.2. (pp.135-153) discusses the history of water resources development to give the study a historical context.

2.1.1. Geology

The Maltese Islands are composed, geologically, almost entirely of marine sedimentary rocks deposited in

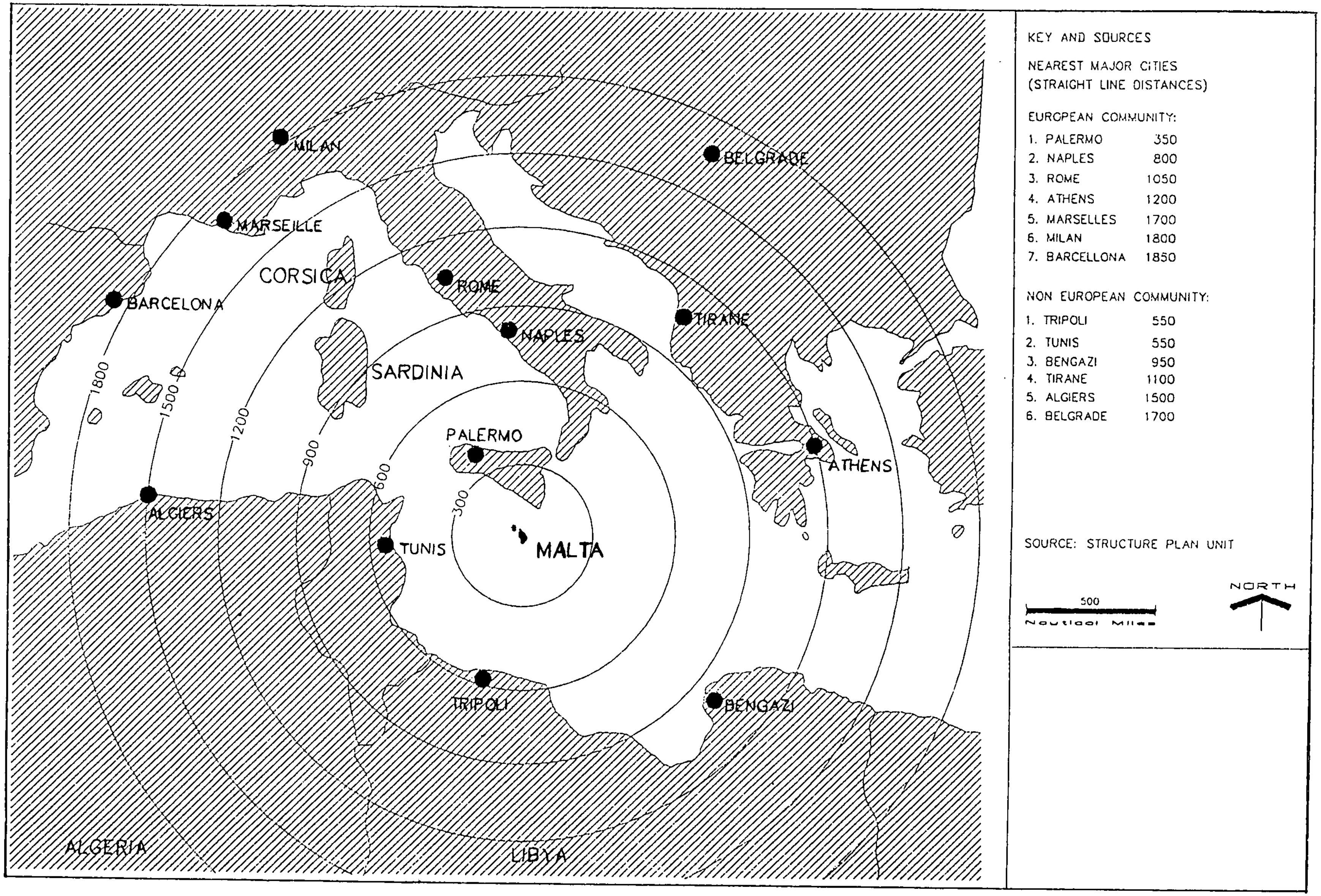

Figure 2.1. Malta's location within the Mediterranean region.
Source: Ministry for the Development of Infrastructure, 1990a.

Table 2.1. Land area of the Maltese Archipelago

Island	Area Km2
Malta	245.7
Gozo	67.1
Comino	14.5
St. Paul's Islands	10.1
Cominotto	9.9
Filfla	2.0
Fungus Rock	0.7
Gebla tal-Halfa	0.4

Sources: Chetcuti et al, 1992; Riolo et al, 1993.

various shallow marine environments about 25 million years ago during the Oligo-Miocene period (Schembri, 1993). In the two main islands, Malta and Gozo, the five main rock types take the form of a simple layered cake gently tilting to the north-east. These layers are, with the youngest first: Upper Coralline limestone, Greensand, Blue Clay, Globigerina limestone and Lower Coralline limestone. This 'cake' has been greatly affected by faulting and Karst solution resulting in relatively good conditions for rainwater percolation and groundwater storage (Debono, undated, *c*.1993). The geological map of the Islands (Figure 2.2.) together with the cross-section (Figure 2.3.) of Malta illustrate the different geological strata. Figure 2.2. shows that there is a predominance of Blue Clay and Upper Coralline limestone in the west and north-west, while the Globigerina limestone stratum has been exposed extensively in the rest of the Island. The importance of this to water resources is discussed on pp.94-101. Figure 2.3. shows that Malta's geology is an important determinant of hydrology which will be discussed later in this section (pp.54-57). The different geological strata are described later in this section (pp.52-54).

The Islands have numerous fault lines, however, two principle faults, tending north-east to south-west, divide them into two distinct tectonic regions. These are the Victoria Lines Fault, or Great Fault, in Malta and the South Gozo Fault in Gozo. The former bisects Malta from Fomm ir-Rih on the western coast to Madliena on the north-east coast. The South Gozo Fault lies parallel to the Victoria Lines and runs from Ras il-Qala on the east coast to Mgarr ix-Xini on the south-east coast. Figure 2.2. shows the location of these main faults (Schembri, 1993).

In between these two main faults is a system of upthrown and downthrown blocks which form horsts (ridges) and graben (valleys) caused by faulting probably

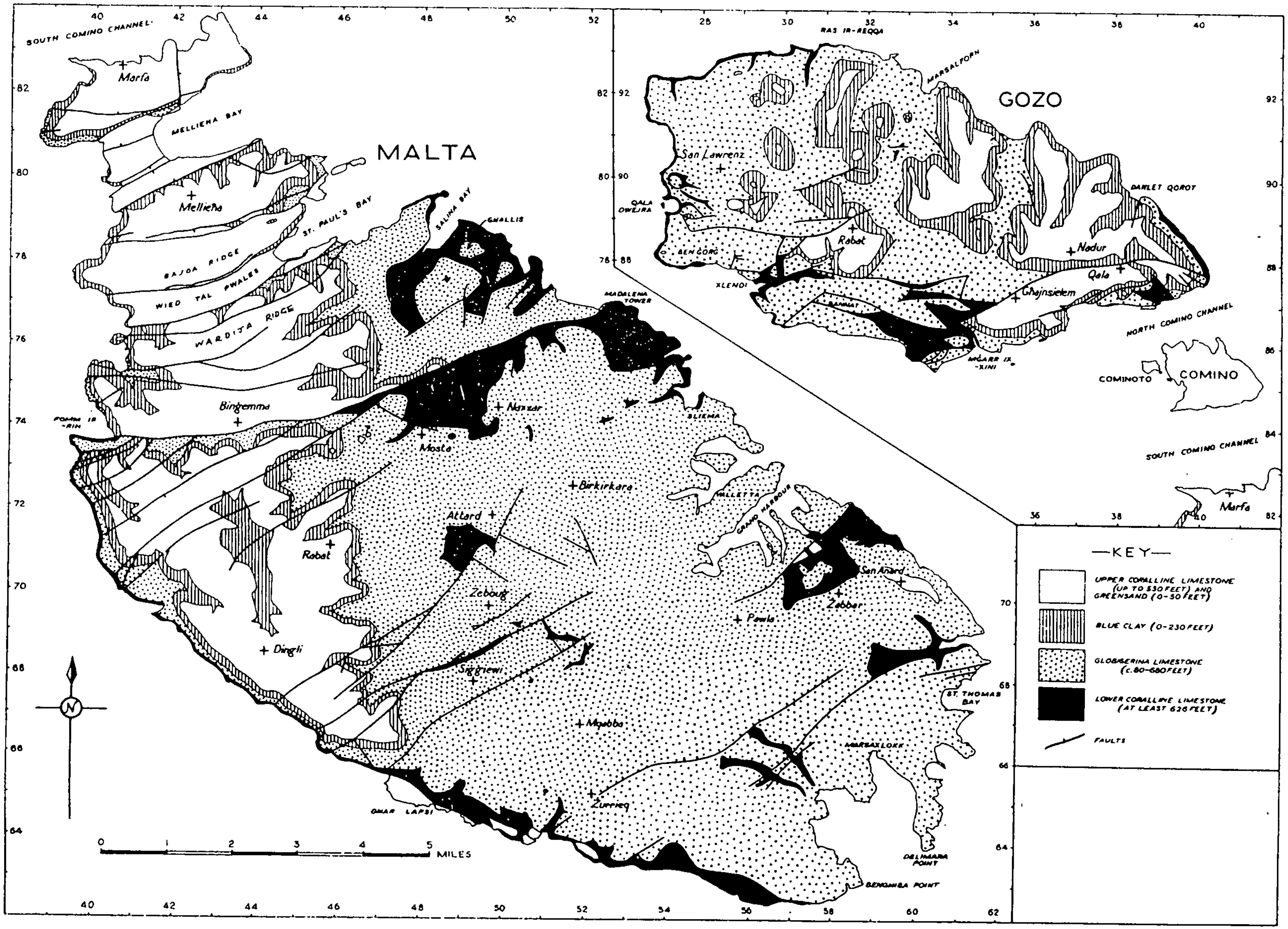

Figure 2.2. The geology of Malta and Gozo.
Source: Bowen Jones *et al*, 1961.

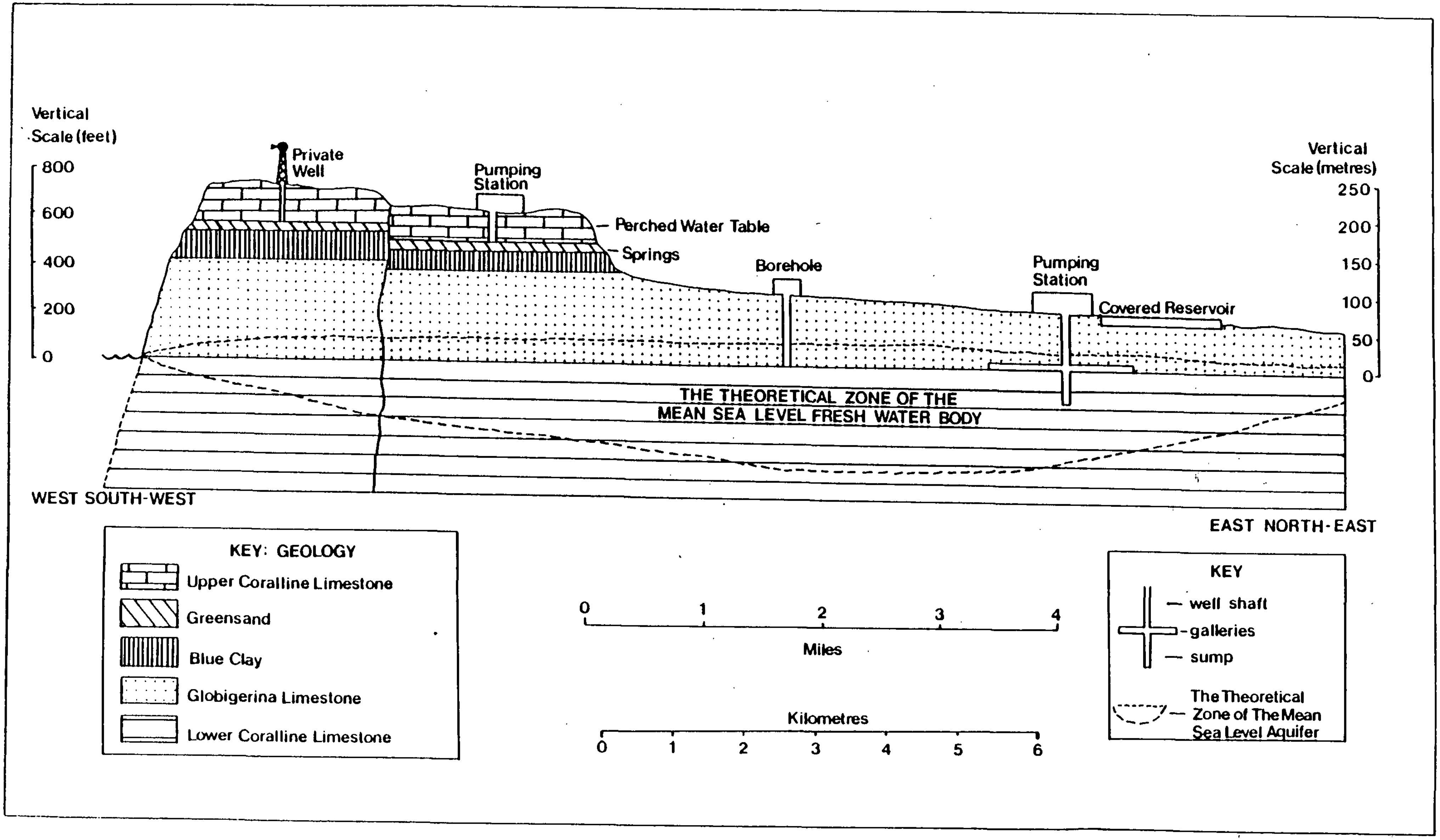

Figure 2.3. A generalised cross-section of Malta.
Source: Oglethorpe, 1982.

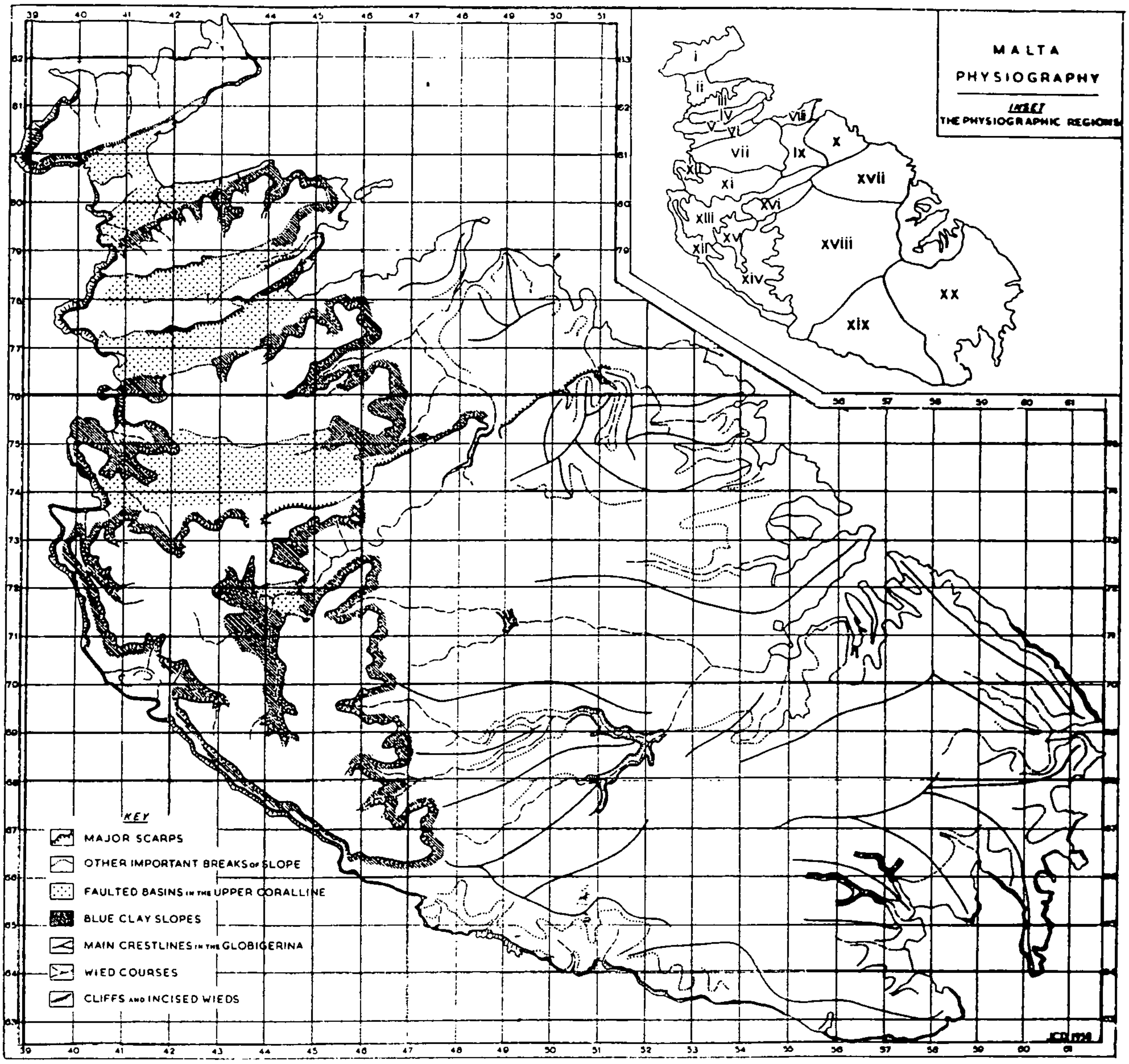

Figure 2.4. The physiography of Malta.
Source: Bowen Jones *et al*, 1961.

initiated in the Pleistocene period (Newberry, 1969).

Figure 2.4. shows the horsts and graben which are, proceeding from the Victoria Lines (represented by the inland line of cliffs): (see inset in Figure 2.4.) the Bingemma Basin (xi), Wardija Ridge (vii), Pwales Valley (vi), Bajda Ridge (v), Mistra Valley (Mizieb Valley) (iv), Mellieha Ridge (iii), Ghadira Valley (Mellieha Valley) (ii) and Marfa Ridge (i). The next graben in this sequence is inundated by the sea and forms the South Comino channel which separates Malta from Gozo (Debono, undated, *c*.1993).

Gozo, in contrast to Malta, is not tilted and is characterised by a series of hills topped by an Upper Coralline limestone plateau with slopes covered with clay taluses. These hills are separated by gently rolling low lying plains that are the result of erosion down to the Globigerina limestone stratum (Schembri, 1993).

The region south of the Victoria Lines is divided into the Rabat-Dingli Uplands and the (mostly unfaulted) Plains and Hills (Ransley and Azzopardi, 1988). Figure 2.4. illustrates this, with the Victoria Lines fault marked by a line of cliffs and the Rabat-Dingli Uplands (see Figure 2.4. inset: xiii, xii, xv and xiv) bounded by these cliffs and Blue Clay slopes.

On the Plains and Hills, because of the tilt of the whole Island towards the north-east, most of the three upper strata, the Upper Coralline limestone, Greensand and Blue Clay, have been eroded away leaving the next stratum, the Globigerina limestone, predominantly exposed (Debono, undated, *c*.1993; Schembri, 1993). The land undulates with gentle folds and it is only on the Rabat-Dingli plateau that all five strata remain (Ransley and Azzopardi, 1988).

The thickness of each stratum is extremely difficult to measure and varies across the Islands. A stratum often appears to be a certain thickness in cliff faces, when in fact it may simply be disguising another stratum by covering it, for example, the Blue Clay stratum in the cliff face at Gnejna Bay. Hence, in the following discussion varying measurements from different sources are given.

The strata are discussed in order of decreasing age and depth: the Lower Coralline limestone stratum, the Globigerina limestone stratum, the Blue Clay stratum, the Greensand stratum and the Upper Coralline limestone stratum (Figure 2.3.).

2.1.1.1. Lower Coralline limestone

The Lower Coralline limestone stratum is the oldest rock type in the Maltese Islands and its deposition began betweeen 30-25 million years ago. According to Schembri (1993) it is exposed to a thickness of 140m, while Ciocardel (1972) states that its thickness ranges from 150m to 225m and Ransley and Azzopardi (1988) give an average thickness value of 129m. Similar to the Upper Coralline limestone, it is semi-crystalline but harder. It can be found exposed on cliff sides like on the western coast of Malta and the cliffs south of Sannat in Gozo (ibid).

2.1.1.2. Globigerina limestone

Globigerina limestone rock stratum is subdivided into Lower, Middle and Upper Globigerina limestones by two pebble beds. Schembri (1993) states that this layer varies in thickness from 23m to 207m. Ciocardel (1972) gives a similar thickness range of 30m to 230m. Ransley and Azzopardi (1988) estimate an average thickness of 75m. Maximum depths have been recorded at Marsaxlokk (Ciocardel, 1972). Good examples of exposed Globigerina limestone can be seen in the cliffs south of Fomm ir-Rih, at Mtahleb and at Dingli.

2.1.1.3. Blue Clay

The Blue Clay stratum is so named because of its bluish colour before exposure to weathering. Ransley and Azzopardi (1988) argue that it averages from 6m to 9m in thickness but in some places it is absent. Generally speaking the Blue Clay stratum decreases in thickness from west to east Malta while in Gozo it is thicker (Newberry, 1968). Ciocardel (1972) places its thickness range at 0m to 65m and has observed a thickness of 55m in the western region of Fomm ir-Rih. According to Schembri (1993) it is exposed to a thickness of 162m.

2.1.1.4. Greensand

Greensand is actually a fragmented limestone. It is named so because before exposure to weathering it is green due to its high content of glauconite grains (Newberry, 1968; Ransley and Azzopardi, 1988). This stratum is exposed to a maximum thickness of 12m, for example, at Dingli. Commonly it varies from 0.5m to 1.5m and in some places it is absent (Ciocardel, 1972; Schembri, 1993). Ransley and Azzopardi (1988) argue that in some places its thickness is greater than 15m.

Greensand actually occurs as two types. One is a green glauconite marl and the other a rust coloured sandy limestone. Newberry (1968) argues that,

"From the stratigraphic and especially from the hydrogeological point of view, the marl should be included with the Blue Clay below; the sandy limestone with the Upper Coralline limestone above." (Newberry, 1968, p.557).

Good examples of exposed Greensand can be seen around Victoria in Gozo and in parts of western Malta.

2.1.1.5. Upper Coralline limestone

The Upper Coralline limestone stratum is composed of a complex conglomeration of limestones (Schembri, 1993). It is generally semi-crystalline as can be witnessed in places where it is exposed, for example in the area surrounding Paradise Bay. It was deposited on the surface of the Islands when they were still submerged about ten million years ago (Ransley and Azzopardi, 1988). This rock layer is exposed to a thickness of 162m according to Schembri (1993); Ciocardel (1972) states that the thickness varies from 80m to 100m with a maximum depth recorded at Bingemma; and on the highland areas where it is most abundant it averages a thickness of 30m, according to Ransley and Azzopardi (1988).

In many areas in Gozo this layer has been eroded away. Some of it remains, especially as outcrops capping several hills on which lie some of Gozo's large settlements: Nadur, Xaghra, Zebbug, Qala and parts of Victoria (Macelli, 1990).

2.1.2. Hydrogeology

The geology of the Maltese Islands blesses this otherwise uninhabitable land with a natural water resource base. The Islands' natural water resources depend on rainwater infiltrating and percolating through the permeable limestone layers to accumulate and be stored in aquifers, underground stores of freshwater within the rock strata. It then either seeps out or is pumped out for human exploitation. There have been numerous studies of the hydrogeological situation of the

Maltese Islands (Ciocardel, 1972; Morris, 1952; Newberry, 1968; Debono, undated, *c*.1993). Various estimates of aquifer recharge state that between 16% and 25% of the annual rainfall infiltrates (penetrates through) the ground to reach the aquifers (Morris, 1952; Newberry, 1968; Chetcuti *et al*, 1992; Debono, undated, *c*.1993; Schembri, 1993).

There are two main aquifers separated by an aquiclude, consisting of the Blue Clay stratum: the perched aquifer above it, and the mean sea level aquifer in the limestone strata below.

2.1.2.1. <u>The perched aquifer</u>

The upper water table is generally referred to as the 'perched aquifer' because it rests upon the aquiclude formed by the Blue Clay stratum. Water collects in the Upper Coralline limestone and the Greensand strata that overly the Blue Clay. It seeps out as high level springs where the Blue Clay is exposed (Briguglio, 1994). The fissured nature of the limestone results in a number of underground springs in the aquifer.

To refer to the upper water table as a whole as the 'perched aquifer' is in fact a misnomer since several of these perched aquifers exist (pp.57-58). They lie approximately 100m above sea level and are the result of faulting which has broken the upper water table into a series of blocks (Bowen-Jones *et al*, 1961; Ransley and Azzopardi, 1988). Altogether the perched aquifers occupy about 56.5 km^2 of the Maltese surface (Briguglio, 1994). Their storage capacity is limited due to the fact that they are mostly thin (Bowen-Jones *et al*, 1961). Large outcrops of Upper Coralline limestone denote perched aquifers.

The largest of the perched aquifers lies south of the Victoria Lines Fault on the Rabat-Dingli plateau in Malta (Figure 2.4. inset: xiii and xiv). This aquifer is the most commonly referred to, after the larger 'mean sea level aquifer', in Maltese water resources literature and is commonly known as the 'perched aquifer'. Perched aquifers are more numerous per km^2 in Gozo than in Malta due to the greater predominance of Blue Clay.

2.1.2.2. The mean sea level aquifer (MSLA)

The lower water table lies in the pores and fissures of the Globigerina and Lower Coralline limestone strata and consists of the mean sea level aquifer (MSLA). This aquifer is the most important since it accounts for 98% of all groundwater (Debono, undated, *c*.1993). Most of the southern plains and hills of Malta and some of southern and eastern Gozo, where Globigerina and Upper Coralline limestones have been exposed (two-thirds of Malta's surface and a half of Gozo's) are the main catchment areas (Chetcuti *et al*, 1992).

Rainwater falling on this surface infiltrates it and percolates down to sea level, mostly via fissures, joints and the bedding plains of the limestones, until it comes to rest on seawater (Ransley and Azzopardi, 1988). This is theoretically a 'Ghyben-Herzberg' lens of freshwater that floats upon the denser saline water in the limestone at sea level, with the base of the lens being below sea level at 36 times its height above sea level (Debono, undated, *c*.1993).

Piezometric levels[1] are highest in the central parts

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[1] The piezometric level, or surface, of an aquifer is,

".... an imaginary surface that everywhere of Malta and Gozo and various estimates in the past have stated that for Malta the level reaches from 2.0m to 3.5m above sea level (Ciocardel, 1972; Ministry of Works and Sports, 1980). A more recent estimate by Debono (*c*.1993) puts this height at 4m above sea level. This height is gradually reduced from the central region towards the coast where it tapers off to zero (Debono, undated, *c*.1993). The MSLA is the largest body of groundwater in Malta and Bowen-Jones *et al* (1961) have defined its limits as follows:

"The area occupied by this water table is bounded by (a) the coast where the Lower Coralline outcrops and (b) the line along which the junction of the Lower Coralline with the Globigerina lies at sea level. The area thus defined occupies 37.5 square miles south of the Victoria Lines and 4.3 to the north.... The water body is replenished for the most part through the extremely limited outcrops of Lower Coralline since the Globigerina, especially where it is soil covered, forms a region of very slow percolation." (ibid, p.43).

2.1.2.3. Other aquifers

Several other aquifers occur north of the Victoria Lines in the horst and graben described earlier (Figure 2.4.). These are smaller aquifers and are not considered as important as the mean sea level aquifer or the perched

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coincides with the static level of water in the aquifer. Generally, however, the aquifer is characterized by more than one piezometric surface." (Domenico, 1972, p.166).

Measuring a piezometric level involves the precise location of the water surface in a well or borehole that penetrates the aquifer (Ward, 1975).

aquifer of the Rabat-Dingli plateau. Most are semi-confined because they are in partial contact with seawater since they are located in the Upper Coralline limestone at sea level, while the Blue Clay lies below. Examples of these (Figure 2.4.) can be found at Marfa Ridge (i), Ghadira Valley (Mellieha Valley) (ii), the Pwales Valley (v) and the Mizieb Valley (iii). There are also small perched aquifers at Mellieha Ridge and Mgarr-Wardija Ridge.

2.1.3. Hydrology

The availability of a natural supply of freshwater in any locality depends on the local hydrological cycle. The cycle is the main determinant of the processes that allow the inflow and outflow of water and is itself determined largely by the local climate and local catchment characteristics (Debono, undated, *c*.1993).

As already discussed, the favourable hydrogeological characteristics of the Maltese Islands compensate in part for the low rainfall. Despite their superficial arid appearance, the Islands have favourable catchment characteristics, which in the past, along with the hydrogeology, contributed to and determined the location of early settlers. The resulting water reserves in the water tables presently account for approximately 40% of the water supply (Debono, undated, *c*.1993).

The dynamic aspects of the hydrological cycle involve the processes of rainfall, run-off, evapotranspiration, infiltration/aquifer recharge and aquifer discharge (ibid). These are discussed after catchment characteristics.

2.1.3.1. Catchment characteristics

Catchment characteristics are largely determined by topography and surface features such as geology, soil, vegetation, and the level of urbanisation and hydraulic structures. The most notable topographic feature of the natural Maltese landscape are the *widien* or dry valleys. These are discussed here as well as soil and vegetation cover, surface features which greatly influence the amount of water retained and lost. Figure 2.5. shows the the 69 water catchment areas in Malta (and respective pumping stations (pp.201-205)) of which the largest and most central are used to draw water from, via respective pumping stations. Slope characteristics are illustrated by Figure 2.4. which shows that the steepest slopes are those that bound the Rabat-Dingli Uplands.

2.1.3.1.1. *Widien*

On a local scale probably the most important topographic feature in terms of water supply are the *widien* (singular *wied*). These are dry valleys that act as drainage channels. They were formed by either stream erosion during a previous wetter climate, or by tectonism, or by a combination of these two processes. Figure 2.4. shows the location of major *widien* (Schembri, 1993).

Today, most only carry water during the wet season usually for a few days after heavy rainfall, which tends to be concentrated in short storms (Plates 2.1., 2.2., 2.3. and 2.4.). A few, however, do drain perennial springs and some have water flowing through their watercourses all year round and so are like miniature river valleys. Given their water supply and the shelter provided by their sides they are very productive habitats and are consequently extensively cultivated (ibid).

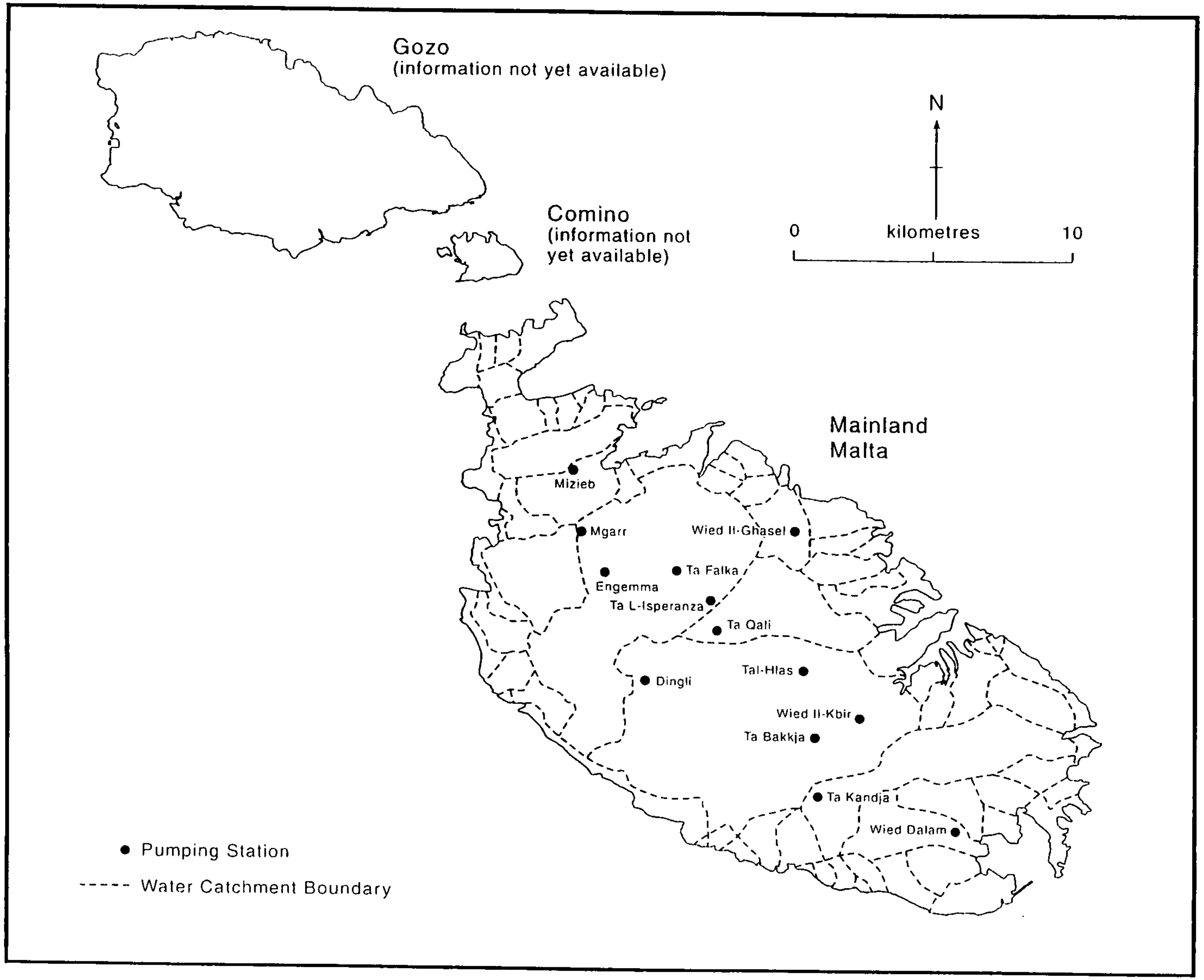


Figure 2.5. Water catchment areas in Malta.
Source: Ministry for the Development of Infrastructure, 1990b.

Plate 2.1. Wied il-Ghasel (Ta' l-Isperanza Valley).

Plate 2.2. Wied il-Ghasel (near Mosta).

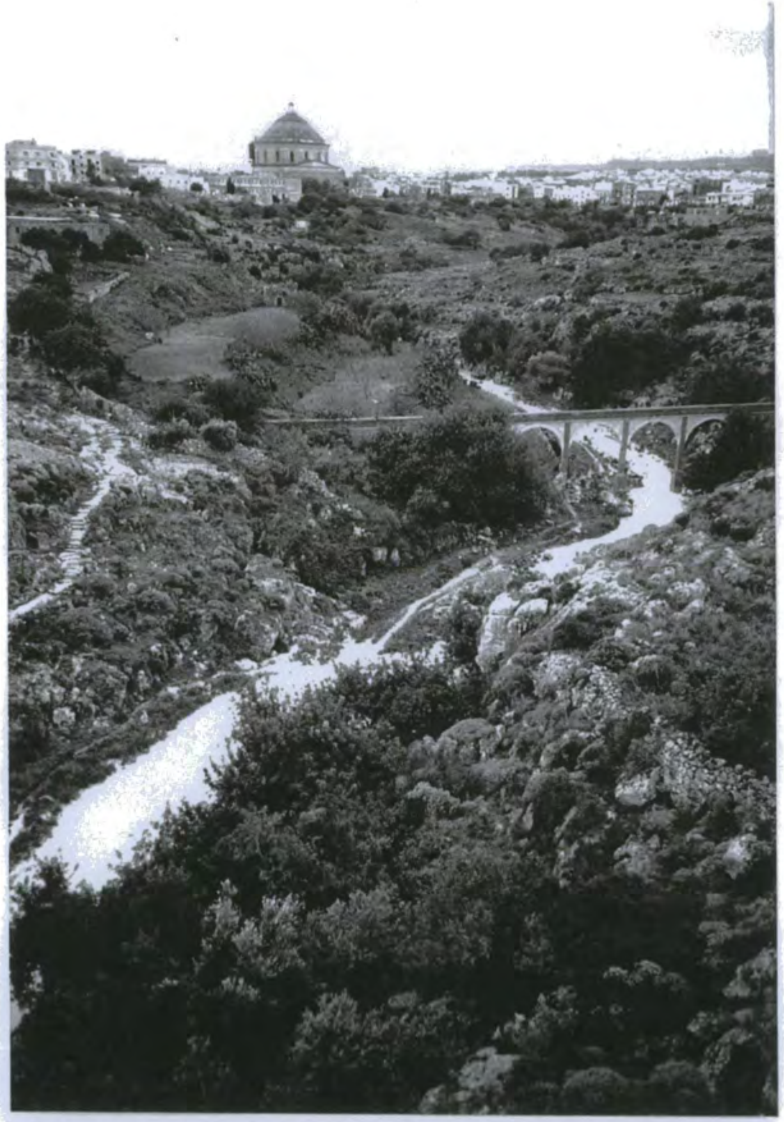


Plate 2.3. Wied il-Ghasel (near Mosta).

Plate 2.4. Wied il-Ghasel (Fiddien Valley).

There have been deliberate attempts to modify catchment characteristics to aid water conservation by the construction of hydraulic structures. Dams were erected in the Ta' l-Isperanza and Qleigha Valleys which gave rise to the Chadwick Lakes (Park, 1977). The *Risq-il widien* project involved the construction of more dams in several *widien* and their maintenance.

2.1.3.1.2. Soil cover

Soils in the Maltese Islands are similar to the parent rock material. They are relatively young and underdeveloped mainly due to the ineffectiveness of the climate in producing soil horizon development and due to their modification by human activities. Many areas consist of bare rock with little or no soil cover. Consequently soil moisture storage is of little significance in the water balance of the Maltese Islands, particularly in terms of exploitable resources (Chetcuti *et al*, 1992; Schembri, 1993). However, the influence of the water retention capacity of different soils is important in influencing the amount of water evapotranspirated back into the atmosphere:

"Soil holding capacity for water is an important factor for recharge generation. High retention favours evaporation and transpiration of infiltrated rain, thus reducing effective precipitation. Coarse soils with low water retention capacity allow rainfall to quickly penetrate below root depth in vegetated areas, thus decreasing evaporative losses.... Soil is an effective agent in the abatement of groundwater pollution and, hence, in the protection of aquifers. This is an important factor in water resources management and protection." (Falkland and Custodio, 1991, p.42).

When soil becomes saturated it has reached its maximum storage capacity (Chetcuti *et al*, 1992). This state is held temporarily until the soil's field capacity (U) is reached, which is its capacity to hold water when,

".... the amount of water held in soil after excess water has drained away [after saturation or near saturation] and the rate of downward movement has materially decreased." (Ward, 1975, p.143; Veihmeyer and Edlefsen, 1949).

The field capacity (U) is measured in millimetres and given by the relationship:

$$U = 0.46\ Cc.h$$

Cc = field capacity index
h = depth of penetration of roots (Chetcuti *et al*, 1992).

The field capacity index of a soil is determined mostly by its texture. Hence, coarse sandy soils have a very small storage capacity and fine clayey soils have a large capacity. The field capacity index for the Maltese Islands is 0.5 (ibid), which means that Maltese soils, collectively, are neither very fine nor very coarse. This is fortunate for it allows some water to infiltrate into the ground and recharge aquifers before it can be evapotranspirated (evaporation and infiltration are explained on pp.88-94 and pp.127-132, respectively).

2.1.3.1.3. Vegetation cover

With regard to vegetation the main ecosystems of the Maltese Islands are *maquis*, *garrigue* and *steppe*. There are other minor ones that include, woodland, coastal wetlands, sand dunes, freshwater and rupestral communities and those of caves (ibid).

However, due to agrarian change much of the original natural vegetation of the Maltese Islands has been destroyed. At one time the landscape was dotted with olive trees. However with Arab occupation these were virtually all destroyed in favour of pastoral farming. Chetcuti *et al* (1992) have stressed the importance of human influences in shaping the contemporary landscape:

".... the most obvious and probably the most significant force in the destruction of the Mediterranean landscape is grazing. The effects of over-grazing may be seen throughout the basin: degraded soils, active erosion and plant denudation are apparent almost everywhere. Generations of over-grazing by goats have stripped great tracts of land of the plants which hold the soil together, churning the top soil to powder. Wind and rain complete the devastation, transforming great expanses to arid wasteland.... the human pressure on the natural environment of the Maltese Islands has been and continues to be very intense. Development commenced some 7000 years ago with the arrival of the first colonists. These early settlers radically modified the landscape by clearing the native forests and natural vegetation for agriculture, construction and fuel, and by the introduction of grazing animals, mainly goats which prevented the trees from regenerating." (Chetcuti *et al*, 1992, p.91).

Population explosions and the associated growth of agriculture and settlements since the reign of the Knights of St. John have further modified the natural landscape. More recent urbanisation has also displaced vegetation cover:

"Development of the Maltese Islands has been particularly rapid during the last 40 years. Land area occupied by buildings has increased from 5 percent in 1957 to 16 percent in 1983. Quarrying to provide stone for these buildings has already caused the extinction of some important plant species, for example the Ciculo-Maltese endemic orchid.... Another aspect of this intense development was increased road construction from 893km in 1957 to 1842km in 1987, modifying the countryside and leading to settlement in previously inaccessible areas. The tourist industry also increased the utilization of more country areas particularly in the coastal regions." (Chetcuti *et al*, 1992, p.92).

The urbanisation of the Maltese Islands has rendered much of the surface impermeable resulting in increased run-off loss of water to the sea and surface ponding/storage (where land is flat) increasing losses via evaporation (pp.319-325).

In terms of water resources, vegetation is particularly important, given the Maltese climate where rainfall is concentrated in short heavy downpours, since it reduces run-off and soil erosion and aids percolation and soil development. In terms of water loss, vegetation greatly facilitates the evapotranspiration of water, even that stored at great depths, by the action of roots. Vegetation draws water up via the roots and this is transpired via the stomata. For example, much of the Maltese vegetation species associated with freshwater flourish in the *widien* and so help to slow down the run-off of water to the sea and consequently aid percolation of this water for aquifer recharge (pp.127-132) (Schembri, 1993). However, evapotranspiration from *widien* is great and although total losses are not known, the relatively high level of humidity in *widien* can be felt on a hot day if moisture is present. The loss of vegetation over the past 7000 years will certainly have had a significant effect on these water gains and losses.

"Vegetation cover in small islands, of both the low and high type, is desirable from many viewpoints.... but its desirability is not so clear from the viewpoint of water resources. Even in cases where net losses of water occur, such as where vegetation transpires water directly from groundwater, the negative effect of vegetation on water resources may be outweighed by other positive effects." (Falkland and Custodio, 1991, p.43).

There is no detailed information on the overall effect of vegetation in the Maltese Islands on water gains and losses. Even with regard to the role of vegetation in the hydrological cycle in general, little is known:

"In many cases there is controversy about the net effect of vegetation on the quantity of water resources. Results of studies depend on local circumstances, and sometimes the processes involved are not well understood. For example, fog interception by trees is a well known phenomena [*sic*] and provides a source of water for forests, but few quantitative studies exist. Very little is known about its possible effect on surface runoff and groundwater recharge." (ibid, pp.42-43).

It would be useful for a study of vegetation and water resources to be undertaken in Malta. Certain imported species, such as the Eucalyptus tree, are extremely water consumptive and not suited to the Islands. Native species that have been lost or drastically reduced in number are likely to have been more suited to, and in equilibrium with, the hydrological and pedological conditions.

"Thus, it can be seen that the plants found in the Mediterranean environment are not those best suited to edaphic and climatic conditions, but those best able to withstand biotic pressures.... Repeatedly in the long history of settlement, the balance between man and his needs, and the resources available to meet these needs, has been lost. Each time equilibrium has been regained, but each time at a progressively lower level." (Chetcuti *et al*, 1992, p.92).

2.1.3.2 The water balance and dynamics of the hydrological cycle

Figure 2.6. shows the water balance for the MSLA in Malta (more detailed figures for water inflow, aquifer recharge and water outflow are given in Tables 2.10. and 2.11.). It can be seen that of the total rainfall that falls, some will be evaporated back into the air. Of that which reaches the surface, some will infiltrate into the substratum or be lost as run-off or via evapotranspiration. Where rainwater infiltrates the soil, some will immediately evaporate and be transpired by vegetation back into the atmosphere, the rest will infiltrate into the limestone rock below to recharge aquifers. In addition, seawater intrusion into the limestone occurs as surface and subsurface inflows.

If the rate of rainfall exceeds the infiltration rate (as is the case with much of the Islands' rainfall) it cannot pass completely through the soil and the rock layer, this excess water will flow as run-off into ditches, small surface reservoirs, cisterns for surface storage, but mostly into the sea via *widien* and off urban surfaces.

Once water has infiltrated groundwater and recharged aquifers, it can be lost as subsurface discharge along the coast as diffused flow or extracted for water consumption (Chetcuti *et al*, 1992).

The following sections discuss these processes in the Maltese Islands.

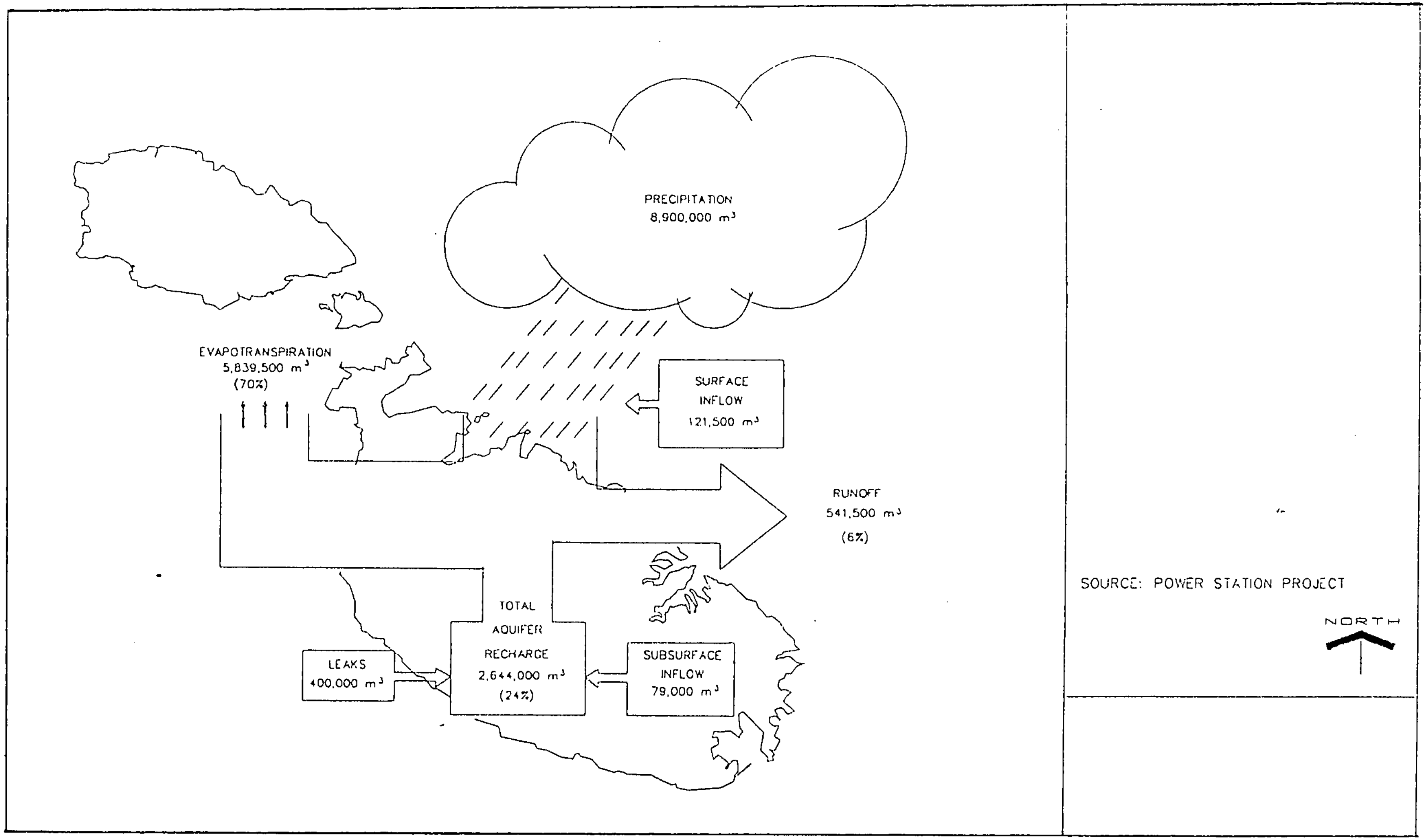


Figure 2.6. Water balance of the MSLA in Malta.
Source: Ministry for the Development of Infrastructure, 1990b.

2.1.3.2.1. Classification of the climate of the Maltese Islands

Figure 2.7. shows that the Maltese Islands are classified as a part of a drought prone area (1981-2). This may be too general a classification, however. A number of methods have been proposed to classify climates of places from extreme aridity to extreme humidity. The most commonly employed paramaters to determine these are mean annual values for precipitation, potential evapotranspiration and temperature. These parameters and their values for the Maltese Islands are discussed on pp.76-85, pp.90-94 and p.102, respectively.

The climatic index used by Koppen (1931) relates temperature and precipitation to vegetation (Agnew and Anderson, 1992):

Arid boundary = $P/T < 1$
Semi-arid boundary = $1 < P/T < 2$
P = mean annual precipitation (cm)
T = mean annual temperature (°C)
(after Yair and Berkowicz, 1989).
(ibid).

Koppen's classification gives the Maltese Islands a climate index of 2.8, which is neither arid or semi-arid.

Thornthwaite's (1948) water balance approach to climate classification is an index of aridity considering moisture available to plants (ibid):

Arid boundary $I_m = < -66.7$
Semi-arid boundary $-33.3 > I_m > -66.7$
$I_m = 100[(P/P_e)-1]$
P = mean annual precipitation (mm)
P_e = mean annual potential evapotranspiration (mm)
(after Mather, 1974) (ibid).

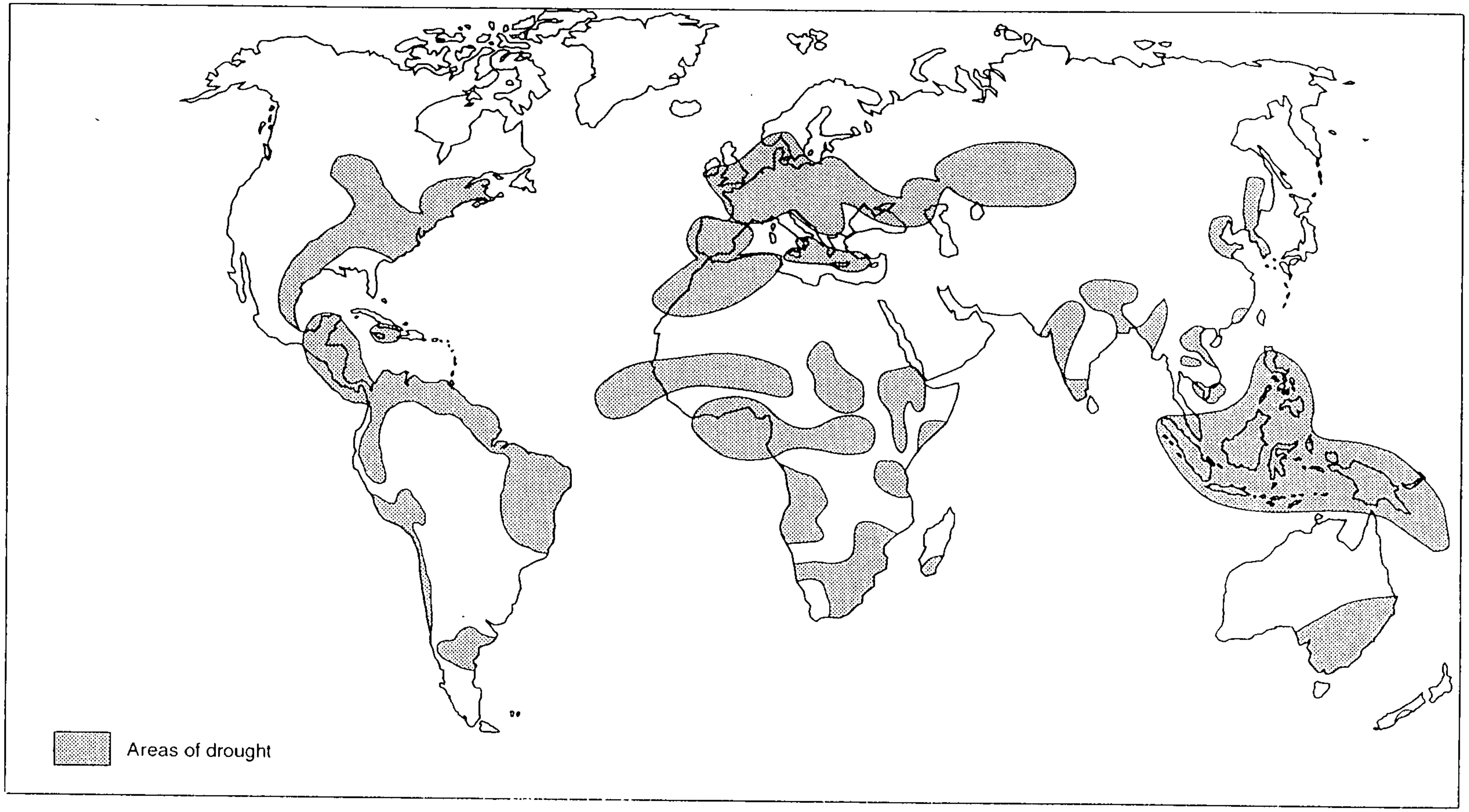


Figure 2.7. Areas of drought 1981-2, after Wilhite and Glantz (1985). Source: Agnew and Anderson, 1992.

His classification gives the Maltese Islands an aridity index of -43.8 which classifies them as semi-arid.

Both classifications have been criticised by others. The former for not adequately considering water supply and only generally relating temperature and precipitation to vegetation (Mather, 1974), and being only applicable to large areas (Wallen, 1976). The latter for overestimating moisture supplies (ibid; Agnew and Anderson, 1992).

Given this Meigs (1953) developed Thornthwaite's method for the United Nations Environmental, Scientific and Cultural Organisation (UNESCO) to assess the potential for global food supplies. This classification was reinterpreted by Mallet and Ghirardi (UNESCO, 1977) by using Penman's (1948) formula for evaporation to become the 'standard' classification of global arid regions (Agnew and Anderson, 1992):

Arid and hyper-arid boundary	P/ET_p = less than 0.20
Semi-arid boundary	P/ET_p = 0.50 to 0.20

P = mean annual precipitation (mm)
ET_p = mean annual potential evapotranspiration (mm)
(after UNESCO, 1977).

The UNESCO classification gives the Maltese Islands an aridity index of 0.56, just outside the boundary for semi-arid classification.

Chetcuti *et al* (1992) have used a method devised by de Martonne (in Colinvaux, 1986) to classify the Maltese climate. de Martonne used an aridity index (I) to describe six climatic regions (Table 2.2.). The index is the ratio of the mean annual rainfall to the mean annual temperature:

$$I = P_m/(T_m+10)$$

P_m = mean annual precipitation (mm)
T_m = mean annual temperature (°C).

Using the aridity index, the Maltese Islands have a figure of 18.5, classified as semi-arid.

The temperature-precipitation diagram in Figure 2.8. illustrates the period of aridity for the Maltese Islands. Mean monthly precipitation is at twice the scale of mean monthly temperature. A dry month is defined when precipitation is less than twice the temperature, i.e. when the rainfall curve falls below the temperature curve in Figure 2.8. The dry period extends from April to September with the area between the two curves representing the duration and intensity (the extent of the aridity) of the dry period (Chetcuti *et al*, 1992).

2.1.3.2.2. <u>Atmospheric pressure</u>

The weather of the Maltese Islands, as with any place, is related to atmospheric pressure, which is,

".... the force per unit area due to the weight of an imaginary column of air extending from the earth's surface up to the outer limits of the atmosphere. Normal atmospheric pressure is usually quoted as equivalent to the pressure of a mercury column 760mm high. Using modern units, normal atmospheric pressure is equal to 101,300 Pascals or 1013.0 hecto Pascals." (ibid, p.62).

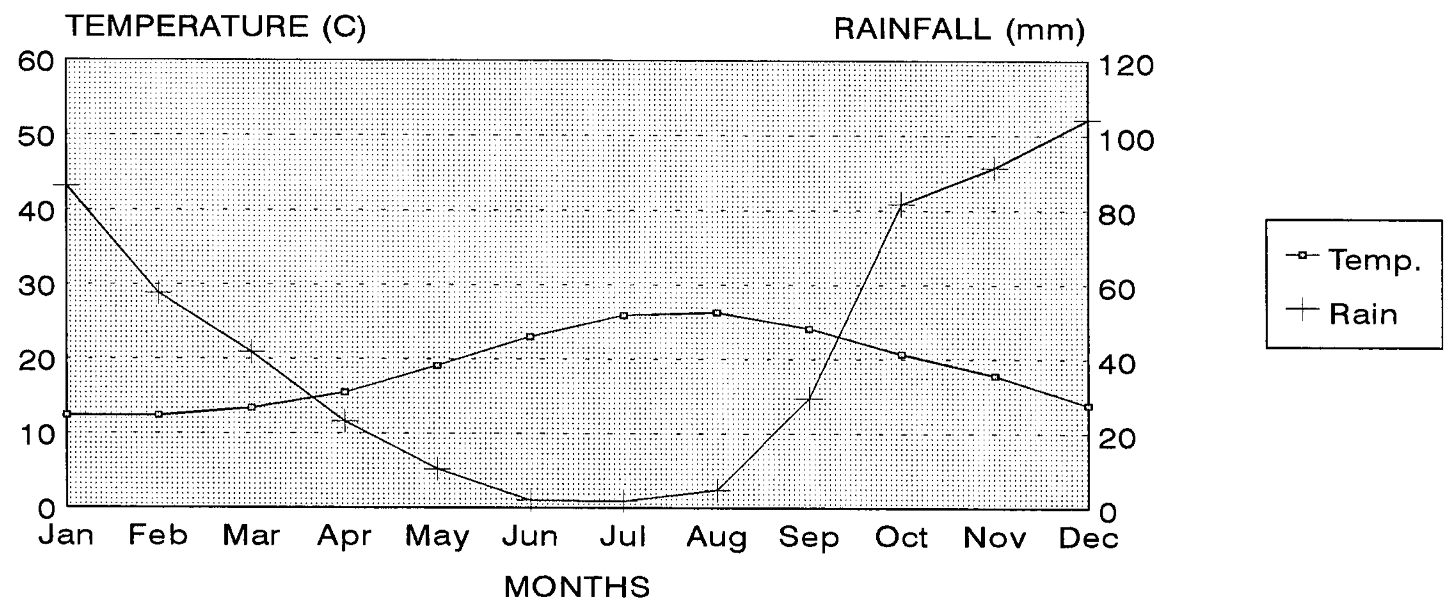
Table 2.2. de Martonne's classification of climate

Type of climate	Aridity index (I)
Extreme aridity	0- 5
Arid	5-15
Semi-arid (Mediterranean)	15-20
Semi-Humid	20-30
Humid	30-60
Extreme humidity	>60
Malta	18.5

Derived from Chetcuti et al, 1992.

Figure 2.8. Temperature and precipitation curve of the Maltese Islands

The shaded area represents the duration and intensity of the arid period



Source: Chetcuti et al, 1992.

In the Maltese Islands, high pressure usually causes fine and calm weather while low pressure is associated with stormy and windy weather.

"The mean monthly values of atmospheric pressure for the Maltese Islands range from medium to high, typical of fine weather." (ibid, p.62).

From Figure 2.9. it can be seen that, for the period 1951 to 1980, mean monthly pressure values between 1015 hPa and 1019 hPa are most frequent, which are above normal atmospheric pressure (*c*.1013.0 hecto Pascals (hPa)). Figure 2.10. shows that the greatest variation in atmospheric pressure occurs between October and March, while in the summer pressure is relatively constant. Maximum variability occurs in February (ibid).

These monthly pressure patterns result in weather that is fine during the summer months from June to August causing hot, dry and calm conditions (ibid).

The winter months, particularly October, November and December, when the pressure can drop suddenly, frequently experience strong winds (pp.109-113) and violent thunderstorms (Figure 2.11.) due to the extreme variability in pressure and associated steep pressure gradients. Comparison of Figure 2.11. with Figure 2.10. shows that these storms are strongly associated with the greater incidence of low pressure from September to February (ibid).

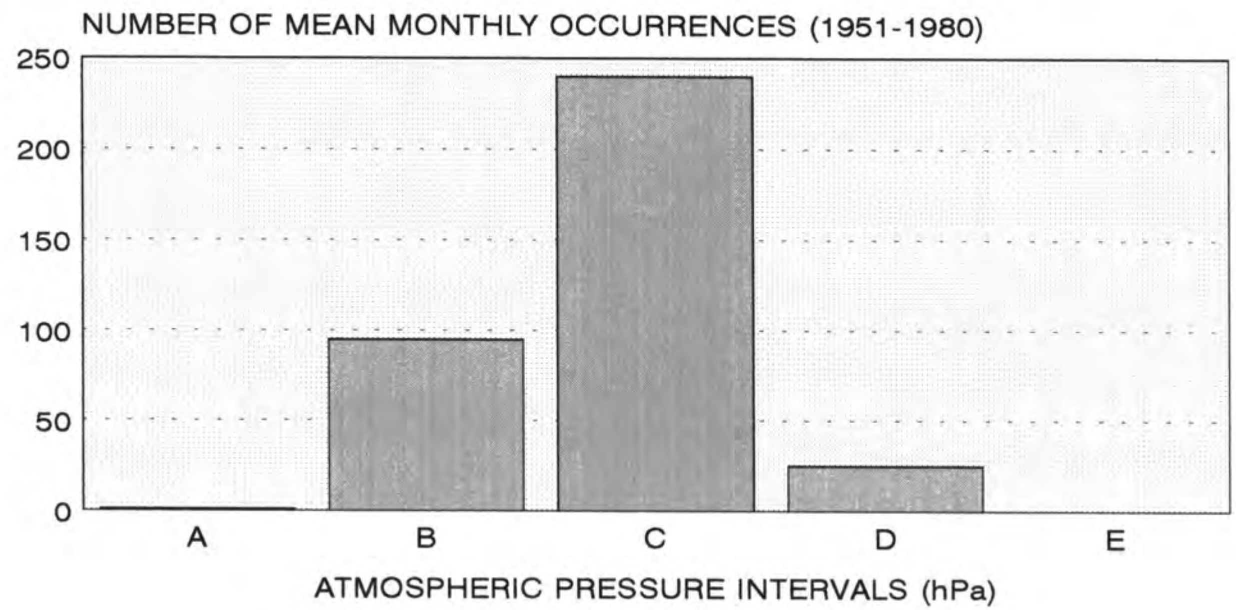
The rest of the year is generally mild but rainy with occasional fine periods (ibid).

2.1.3.2.3. <u>Rainfall</u>

Rainfall is the main source of water in the hydrological cycle. Malta has a Mediterranean type climate with a well defined seasonal rhythm consisting of a mild wet winter and a long, hot and dry summer (Debono,

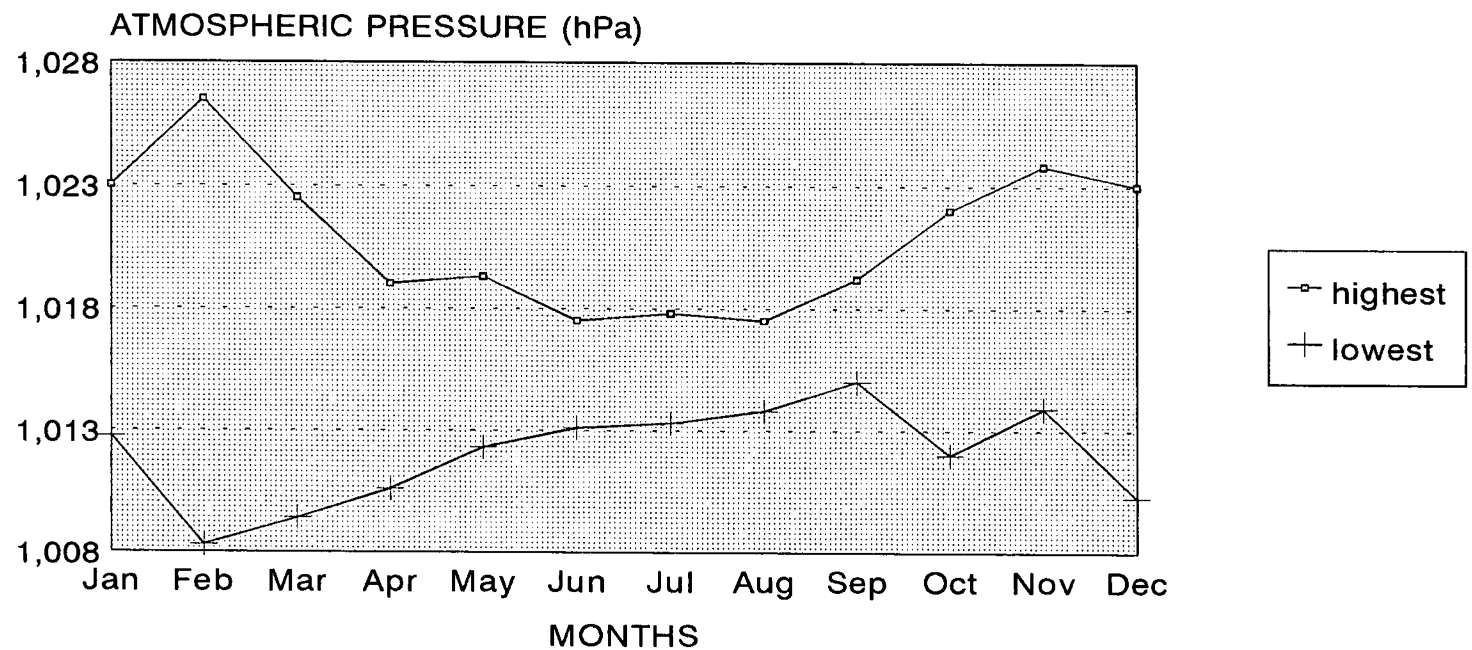
Figure 2.9. Frequency distribution of the mean monthly atmospheric pressure for the period 1951-1980

A=1005.0-1009.9hPa; B=1010.0-1014.9hPa; C=1015.0-1019.0hPa; D=1020.0-1024.9hPa; E=1025.0-1029.9hPa.



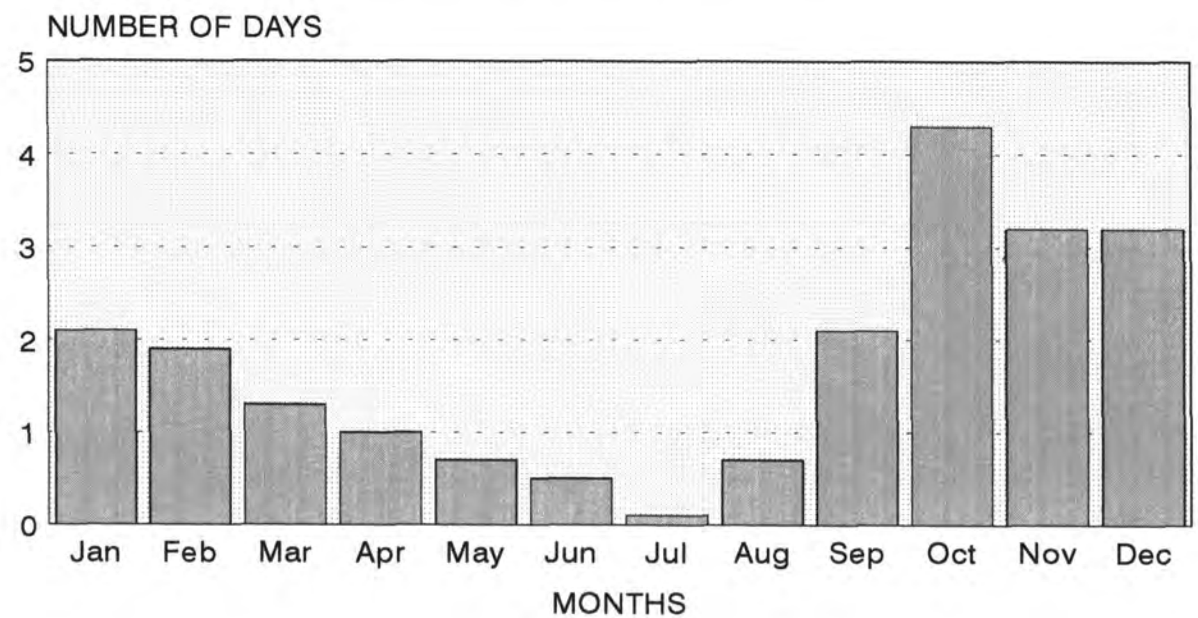
Derived from Chetcuti et al, 1992.

Figure 2.10. The mean highest and mean lowest atmospheric pressure for each month for 1951-1980
Based on data obtained from the Luqa Meteorological Office



Derived from Chetcuti et al, 1992.

Figure 2.11. Average number of days per month with thunderstorms for the period 1951-1986
Based on data from the Luqa Meteorological Office



Derived from Chetcuti et al, 1992.

undated, *c*.1993).

"The end of the summer drought and the beginning of the wet season are triggered off in September by cold fronts which pass over the hot humid air of the Mediterranean. This releases enough energy to cause instability which gives rise to intense rainfall, especially during October. A characteristic of the Mediterranean climate at this time of year is the occurrence of a number of violent storms accompanied by heavy rainfall and by thunder." (Chetcuti *et al*, 1992, p.84).

The total annual rainfall for the 133 year set of rainfall averages 529.57mm (ibid). Table 2.3., which is derived from Chetcuti *et al*'s analysis of raw climate data (from 1854 to 1986), shows that there is a total of 16 wet years and 18 dry years. This means that excessively wet or dry years rarely occur and without any degree of regularity (ibid).

Table 2.4. and Figure 2.12. show mean monthly rainfall, which is highest during the winter and lowest in the summer. December has the highest mean rainfall, however all the months between October and March may be considered as being wet months. June, July and August are extremely dry and only account for 1.6% of the total annual rainfall. July is the driest month with absolute drought being recorded in 115 out of 133 Julys during the period 1854 to 1986 (ibid).

There is a significant amount of variation in rainfall across the Islands. It can be seen from Figure 2.13. that the greatest amount of annual rainfall is in the west and north-west, particularly in the Naxxar-Gharghur area, reaching a maximum of 550mm/annum at Bingemma. This occurs mostly from January to March as orographic rainfall, where the hills in this area force moist air upwards to cool, condense and precipitate.

Table 2.3. Intervals between successive drought and wet years for the period 1854-1986

(h=rainfall; s.d.=standard deviation)

Drought year $h<1$ s.d.	Interval (years)	Wet year $h>1$ s.d.	Interval (years)
1. 1855		1. 1858	
1866	11	1859	16
2. 1867		2. 1874	
1872	5	1875	23
3. 1888	16	3. 1889	30
4. 1894	6	1928	
1895		4. 1931	3
5. 1897		5. 1934	4
1903		1938	
6. 1922	19	6. 1942	4
7. 1945	23	7. 1951	9
1947		8. 1965	14
8. 1952	5	9. 1969	4
9. 1960	8	10. 1976	7
1961		11. 1983	7
10. 1963	11	12. 1986	3
1974			
11. 1979	5		

Source: Chetcuti et al, 1992.

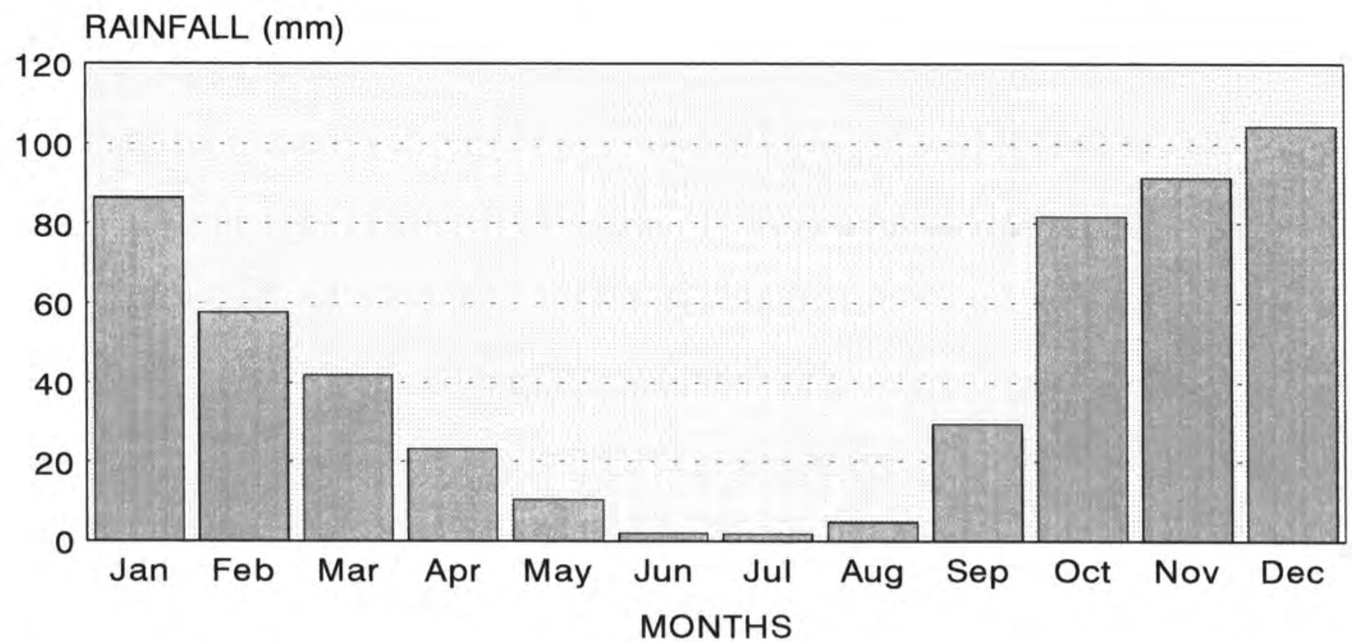
Table 2.4. Mean monthly rainfall (mm)

Based on data from Valletta for 1854-1950 and from the Luqa Meteorological office for 1951 to 1986

Month	Mean Rainfall	Standard Deviation
January	86.4	53.7
February	57.7	43.8
March	41.8	35.5
April	23.2	22.7
May	10.4	15.4
June	2.0	5.4
July	1.8	10.1
August	4.8	12.9
September	29.5	38.0
October	81.7	74.2
November	91.4	57.1
December	104.3	69.8
Total	529.6	153.3

Source: Chetcuti et al, 1992.

Figure 2.12. Mean monthly rainfall (mm) for the Maltese Islands
Based on data from the WWD (1854-1950) and the Luqa Meteorological Office (1951-1986)



Source: Chetcuti et al, 1992.

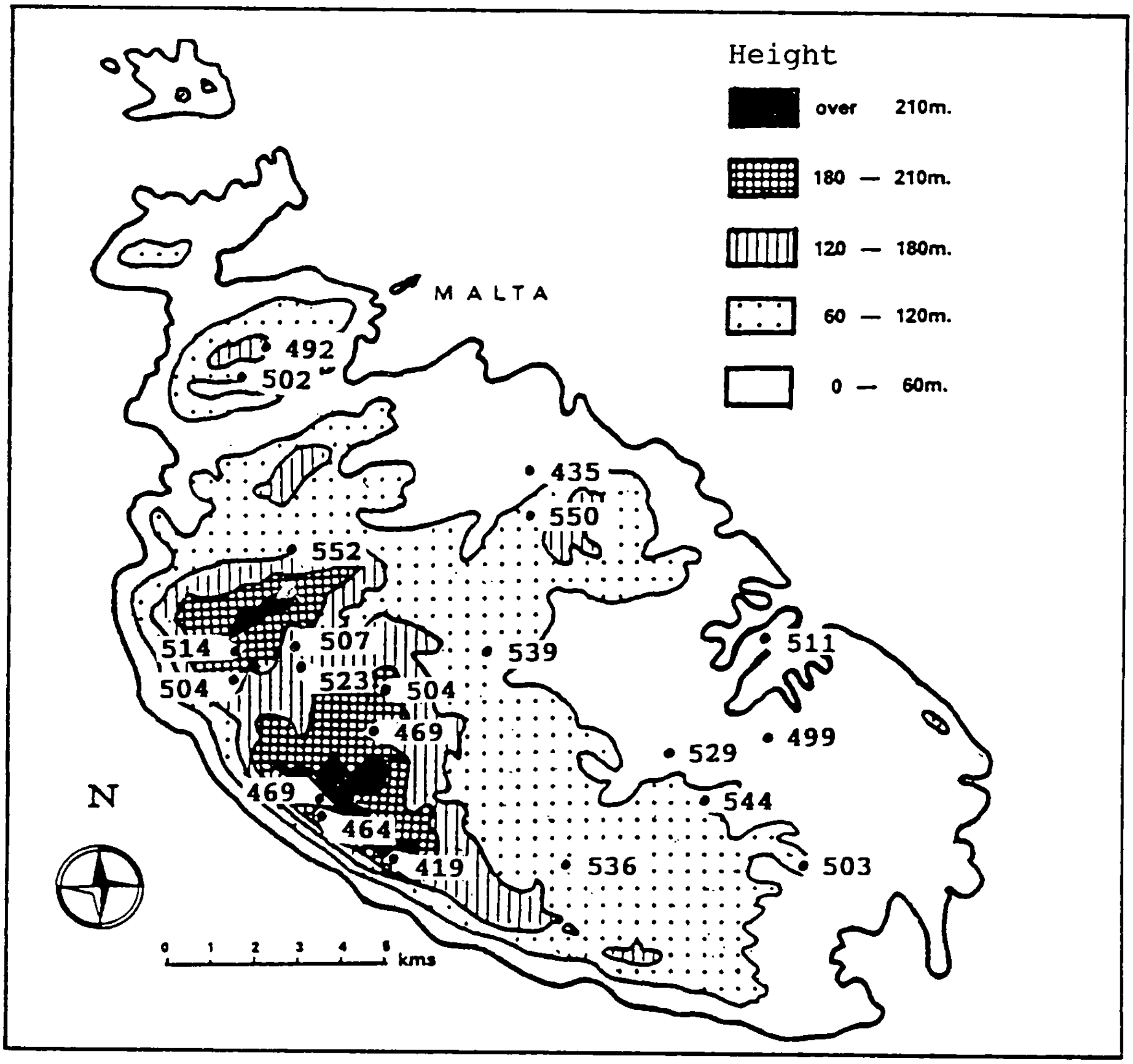


Figure 2.13. Distribution of total annual rainfall, in millimetres, at the locations of the various rain gauges (see Figure 2.16.) for the period 1956-1986.
Source: Chetcuti *et al*, 1992.

Rainfall is lowest in the Dingli area with the least amount falling at Gebel Ciantar (419mm/annum) (ibid).

As a percentage this variation from the mean, although significant, is relatively small and appears to be large only because rainfall is generally low in the Islands. Were the same percentage of variation to occur in a temperate climate such as the UK's, then the difference would be significantly large.

2.1.3.2.4. Run-off

Run-off is the movement of water over the land surface, also known as overland flow. There are three types of overland flow: Hortonion overland flow, saturation overland flow, and subsurface flow (Falkland and Custodio, 1991).

Hortonion (surface) overland flow is caused by a rainfall excess (*i-f*) when rainfall intensity (*i*) exceeds the infiltration capacity (*f*) of the soil (ibid). This occurs mostly after intense rainfall during winter storms, particularly over the Upper Coralline limestone plateau and the impermeable urban fabric.

Another type is called saturation (sub-surface) overland flow where areas adjacent to stream channels become saturated and produce saturated overland flow from rainfall in these areas (ibid). This can occur in the land adjacent to *widien* after heavy rainfall.

A third type of run-off is subsurface flow down a hillslope and into a stream channel at the base of the slope (ibid). In Malta this is common in the hills of the Rabat-Dingli Uplands and the Naxxar-Gharghur region.

All these run-off types are accentuated where urbanisation has taken place due to the impermeable nature of the urban surface.

"Surface runoff occurs only on islands with favourable topographical and soil/geological conditions.

On those islands where it occurs, considerable variation can occur between catchments due to variations in catchment parameters and orographic effects on rainfall distribution. In many small islands perennial surface runoff is non-existent or reduces to small baseflows fed by springs from perched aquifers [as in the case of the Maltese Islands]. Few small islands have permanent rivers.... Generally surface runoff is a relatively small proportion of the long-term water balance on small islands. However, over short time periods during storms, the percentage of rainfall that becomes runoff can be quite high." (ibid, p.51).

According to various estimates, run-off in the Maltese Islands constitutes only a small percentage of total annual rainfall (Debono, undated, *c*.1993; Spiteri Staines 1987). Most of this occurs after heavy downpours mainly in the *widien*. Debono (undated, *c*.1993) states that only,

".... 6% is lost directly to the sea as surface run-off. Geology, topography, urbanisation and hydraulic structures determine the extent of this run-off which contrary to public opinion is only of minor significance." (Debono, undated, *c*.1993, p.2).

Indeed, to many it does seem a rather small amount considering the large volumes of water that can be observed flowing into the sea via *widien*. Given that areas of infiltration have been decreased due to soil development by farmers and urbanisation, it is reasonable to assume that run-off is greater than 6% of rainfall.

However, on the conservation side, the construction of numerous small dams, cisterns and reservoirs has helped significantly reduce run-off to the sea. Debono also attributes the small run-off rates to the favourable topography, the good storage capacity of the thin soil layer, very good infiltration properties of the rock strata, and the fact that,

"Structurally, Malta tilts gently to the east giving rise to a topography that is high along the western shores. This implies that the surface drainage lines cross the entire width of the Island from their source close to the western shore before entering the sea on the east. This gives the surface water maximum time to seep into the ground and thus minimizes run-off losses to the sea." (Debono, undated, *c*.1993, p.4).

The problem in measuring run-off is that not all the discharge points on the Islands are monitored. This is particularly the case with subsurface run-off in limestone caverns such as Ghar Dalam and Ghar Hassan, and where run-off becomes diffused before it is lost to the sea. This subsurface loss is sometimes called aquifer discharge and normally considered separately from run-off (pp.132-135).

Presently run-off is recorded only at the exit points of major drainage areas such as Burmarrad, Msida and Marsa. More dated estimates put the figure for run-off at even less. The former Ministry of Works and Sports (1980) for example stated that,

"Readings taken by means of runoff recorders indicate that the discharge towards the sea from the central catchment areas is about 3 per cent of the annual precipitation. This figure excludes the fringe areas where the runoff percentage is much higher." (Ministry of Works and Sports, 1980, p.8).

This and other areas need to be considered. Furthermore, urban run-off needs to be assessed to determine the extent to which the growth of the urban surface has caused water loss via run-off.

2.1.3.2.5. Evapotranspiration

Evaporation is the process by which water is converted from liquid to vapour. Evapotranspiration is the term given to this evaporation of moisture directly from the thin superficial layer of soil across most of the Islands, together with the emission of water into the atmosphere via transpiration from vegetation (Chetcuti *et al*, 1992).

The soil is responsible for the vast majority of loss from the hydrological cycle and rainwater infiltration into the rocks below only occurs once the soil is saturated (Debono, undated, *c*.1993).

Evapotranspitation is primarily determined by solar radiation. It is also dependent upon the ability for the atmosphere to accept and transport water away, which depends upon relative humidity, temperature and wind.

The zone between the soil surface and water table is called the unsaturated zone or vadose zone. This zone is divided into a soil water (or moisture) zone and an underlying intermediate zone which constitutes the unsaturated zone above the water table. When rainfall occurs, a small surface layer becomes saturated with water and there is a zone behind the advancing (infiltrating) wetting front which is close to saturation. If there is no evaporation the soil's moisture content reaches equilibrium. Once evaporation begins from the soil or from vegetation, water content and water potential reduces and consequently there is an upward gradient allowing for the movement of water upwards from the water table to the surface, or the evaporation zone. There is a maximum rate at which water can be conducted to the surface and if atmospheric demand exceeds this rate then the surface dries out and the rate of supply reduces. Once this occurs it is possible to have the real evaporation rate inversely related to atmospheric demand, or the potential evaporation rate (pp.90-94) (Falkland and Custodio, 1991).

"A water content can be reached below which water effectively ceases to move under the gravity gradient because hydraulic conductivity is an inverse exponential function of water content. This empirical observation has been called field capacity (*FC*) and corresponds to a soil suction of about 0.5 atmospheres. As soil dries below *FC*, strong suction gradients are set up which still allow some water movement to occur particularly in the steep, short range gradients around roots which extract water for plants. Once the bulk soil water potential reaches a suction value of about 15 atmospheres virtually all movement ceases and this is defined as the wilting point (*WP*). Herbaceous plants wilt and possibly die, and permanent plants stop or drastically reduce transpiration.... When vegetation cover is sparse, direct soil evaporation can occur, but there is a depth below which evaporative losses are not possible or are negligible. At a given time, there is a neutral or zero-flux plane, above which soil water moves upwards and below which only downward movement, or recharge, occurs. This plane rises to the surface as rainfall fills the soil moisture zone to field capacity and falls progressively until the next rain event." (ibid, pp.49-50).

In the Maltese Islands, wilting point is reached in July and evapotranspiration rates are at their lowest until September. Various estimates place losses via evapotranspiration at 70% to 80% of total precipitation (Chetcuti *et al*, 1992; Debono, undated, *c*.1993; Ministry of Works and Sport, 1980; Oglethorpe, 1982; Spiteri

Staines, 1987). This is a very large loss of freshwater and calls into question the need for a study into the role of vegetation and different types of vegetation in the water balance equation. For example, it would seem that shallow rooted plants would be most beneficial so that they could help to intercept rainfall, reduce run-off and aid infiltration in the rainy season, while they would wilt or not be able to draw up water from aquifers outside the rainy season. Water thirsty plants, particularly those with deep roots, are less favourable.

2.1.3.2.5.1. Potential and real evapotranspiration

Potential evapotranspiration is the amount of water that would be evapotranspirated from a fully moist and vegetated surface if availability of moisture was not a limiting factor. Real or actual evapotranspiration is the true or real rate of water vapour lost back to the atmosphere (Chetcuti *et al*, 1992).

It is fortunate for the Islands that most of the rainfall occurs in the relatively colder and cloudier winter months. The fact that this rainfall falls in short bursts during heavy storms also helps to minimise real evapotranspiration (although increasing run-off loss). If rainfall was more evenly distributed over time, then exposure to evapotranspiration would be increased.

Chetcuti *et al* have calculated that the potential evapotranspiration for the Maltese Islands to be 942mm (Table 2.5.) which is much higher than the mean total annual rainfall which is only 530mm. Total real evapotranspiration is 377mm for a soil moisture retention capacity of 100mm (Table 2.6.), which, as previously stated, is more than 70% of the mean annual rainfall.

Table 2.5. and Figure 2.14. show that potential evapotranspiration levels are highest during the summer

Table 2.5. Mean monthly values of potential evapotranspiration (ETP)

Calculated by the method of Thornthwaite. Based on data from the Luqa Meteorological Office

Month	ETP (mm)
January	25
February	26
March	37
April	50
May	84
June	124
July	160
August	156
September	119
October	81
November	48
December	31
Total	942

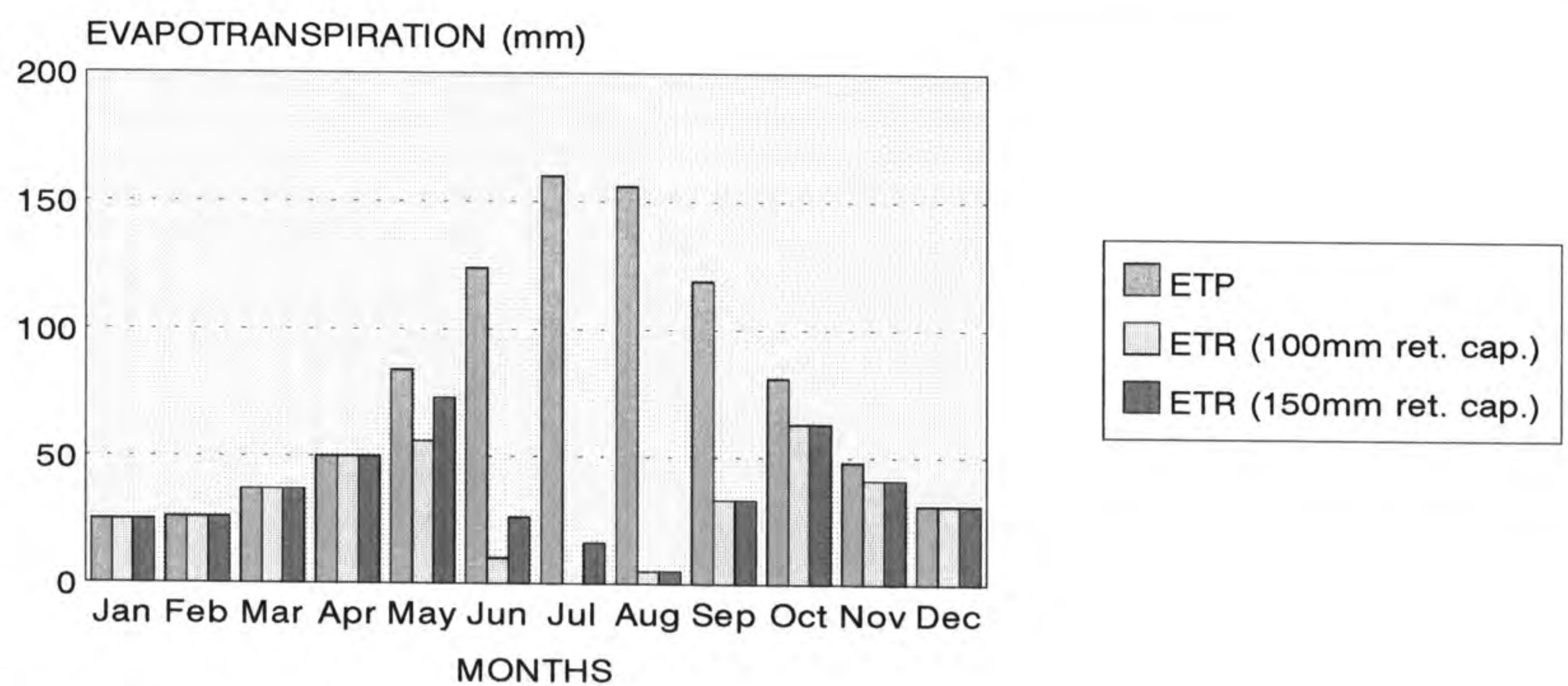
Source: Chetcuti et al, 1992.

Table 2.6. Mean monthly real evapotranspiration (ETR) for 100mm and 150mm retention capacities.
Calculated by the method of Thornthwaite

Month	Mean Real ETR for a 100mm ret. cap.	Mean Real ETR for a 150mm ret. cap.
January	25	25
February	26	26
March	37	37
April	50	50
May	56	73
June	10	26
July	0	1
August	5	5
September	33	33
October	63	63
November	41	41
December	31	31
Total	377	411

Source: Chetcuti et al, 1992.

Figure 2.14. Mean monthly potential evapotranspiration (ETP) and real evapotranspiration (ETR)
for retention capacities of 100mm and 150mm



Derived from Chetcuti et al, 1992.

months (peaking in July) when higher temperatures mean that the potential for losses is high. Conversely, potential evapotranspiration is lower during the winter months (lowest in January) due to the relatively lower temperatures, but it is during these months when real evapotranspiration is at its highest (Table 2.6. and Figure 2.14.) due to the higher levels of rainfall, run-off and surface ponding, which are virtually non-existent in the summer. These patterns are illustrated in Figure 2.14.

Real evapotranspiration varies according to the water retention properties of different soils and soil cover. For example, from Table 2.6. and Figure 2.14. it can be seen that in July soils with a moisture retaining capacity of 150mm are able to evapotranspirate, while those with a capacity of 100mm cannot due to a water deficit (pp.117-127) (ibid).

2.1.3.2.5.2. Geographical variation in evapotranspiration

Evapotranspiration (real) loss is not uniform across the Islands. It varies with topography, soil characteristics, exposure (mainly to wind) and land use. For example, shallow water-table zones exist where the aquifer lies just below the root zone, such as those at Marsa and Burmarrad. Here evapotranspiration is relatively high. Such areas are few since the topography of the Islands is relatively high. At the other extreme there are large areas of land with barren rock outcrops or a thin gravel layer and sparse vegetation. Percolation in these areas is direct and rapid with little retention and hence relatively less evapotranspiration.

Vegetated areas have relatively high evapotranspiration and agricultural cultivation accelerates this loss especially with the widespread use of poor irrigation and water storage methods (pp.458-459)

(Debono, undated, *c*.1993).

Those parts of the Islands exposed to dry winds will have greater levels of evapotranspiration. This is particularly the case in the north-west and west where strong north-westerly and westerly winds blow all year round (Chetcuti *et al*, 1992).

As previously introduced, one of the most important factors accounting for geographical variation in evapotranspiration is the water retention capacity of the soil. The more water is retained in the soil, the more is available for evapotranspiration. Chetcuti *et al* have calculated mean monthly values of real evapotranspiration for different soil retention capacities of 100mm and 150mm. The results can be seen in Table 2.6. and Figure 2.14.

As already stated, for soils with a retention capacity of 100mm, total real evapotranspiration is 377mm. This is over 70% of the mean annual rainfall. However, for soils with a retention capacity of 150mm, 411mm will be evapotranspirated from the surface, which is more than 77% of the mean annual rainfall (ibid).

Geology and the corresponding infiltration of rainfall is the most significant factor affecting regional variations in evapotranspiration. Figure 2.15. (introduced here rather than earlier to make convenient comparison with Figures 2.16., 2.17. and 2.18.) shows the location of weather stations in Malta while Figure 2.16. shows the regional variations in infiltration into the substratum in Malta and gives the amount of water (mm) infiltrated at each of the stations. When compared to Figure 2.17 and 2.18., it can be seen that evapotranspiration is lowest at those stations where infiltration is high and consequently there is a higher water surplus (the difference between rainfall and real evapotranspiration) in that area, and vice versa.

By superimposing the infiltration values on a geological map (Figure 2.19) it can be seen that the

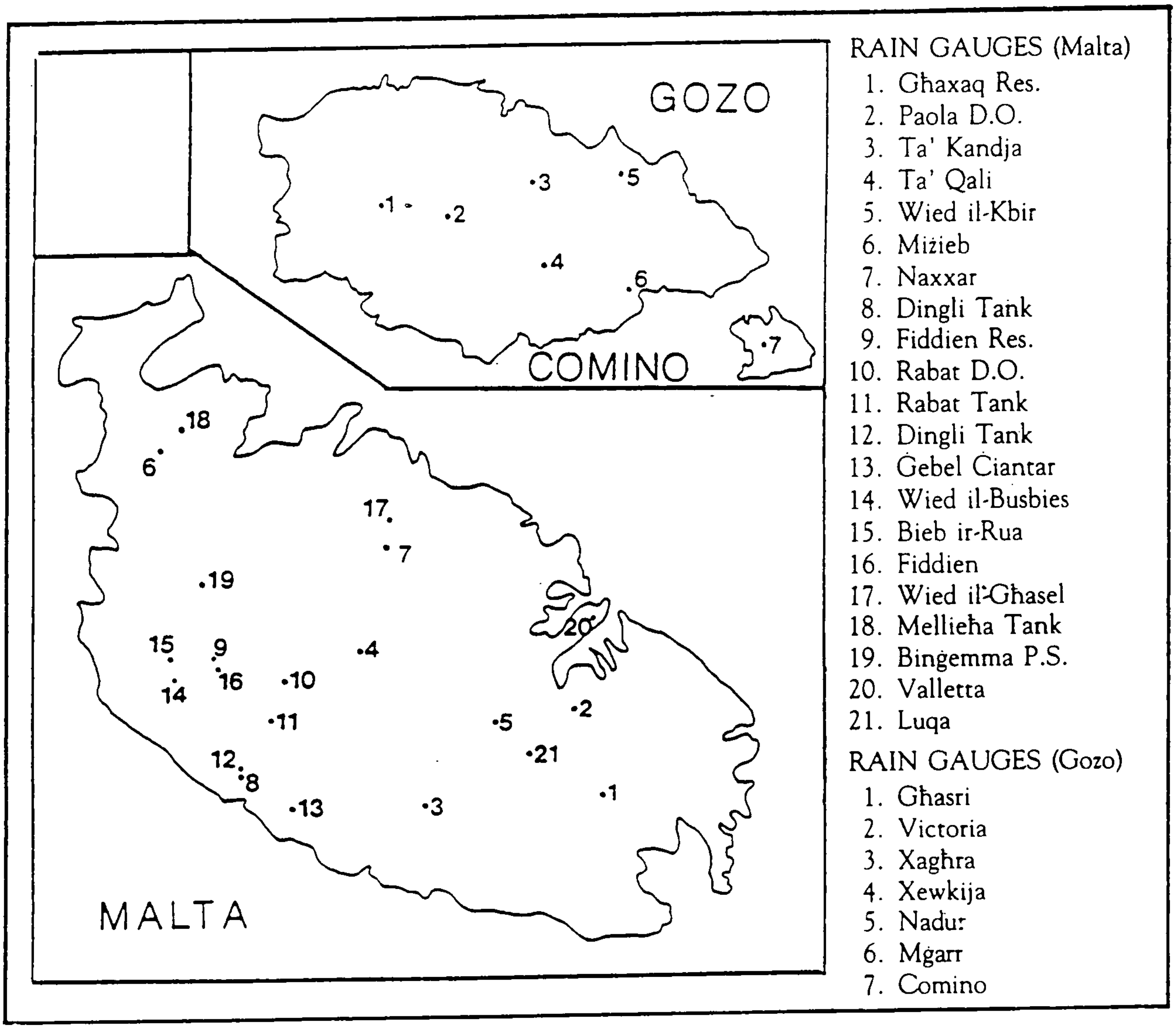


Figure 2.15. Distribution of Water Works Department rain gauges over the Maltese Islands.
Source: Chetcuti *et al*, 1992.

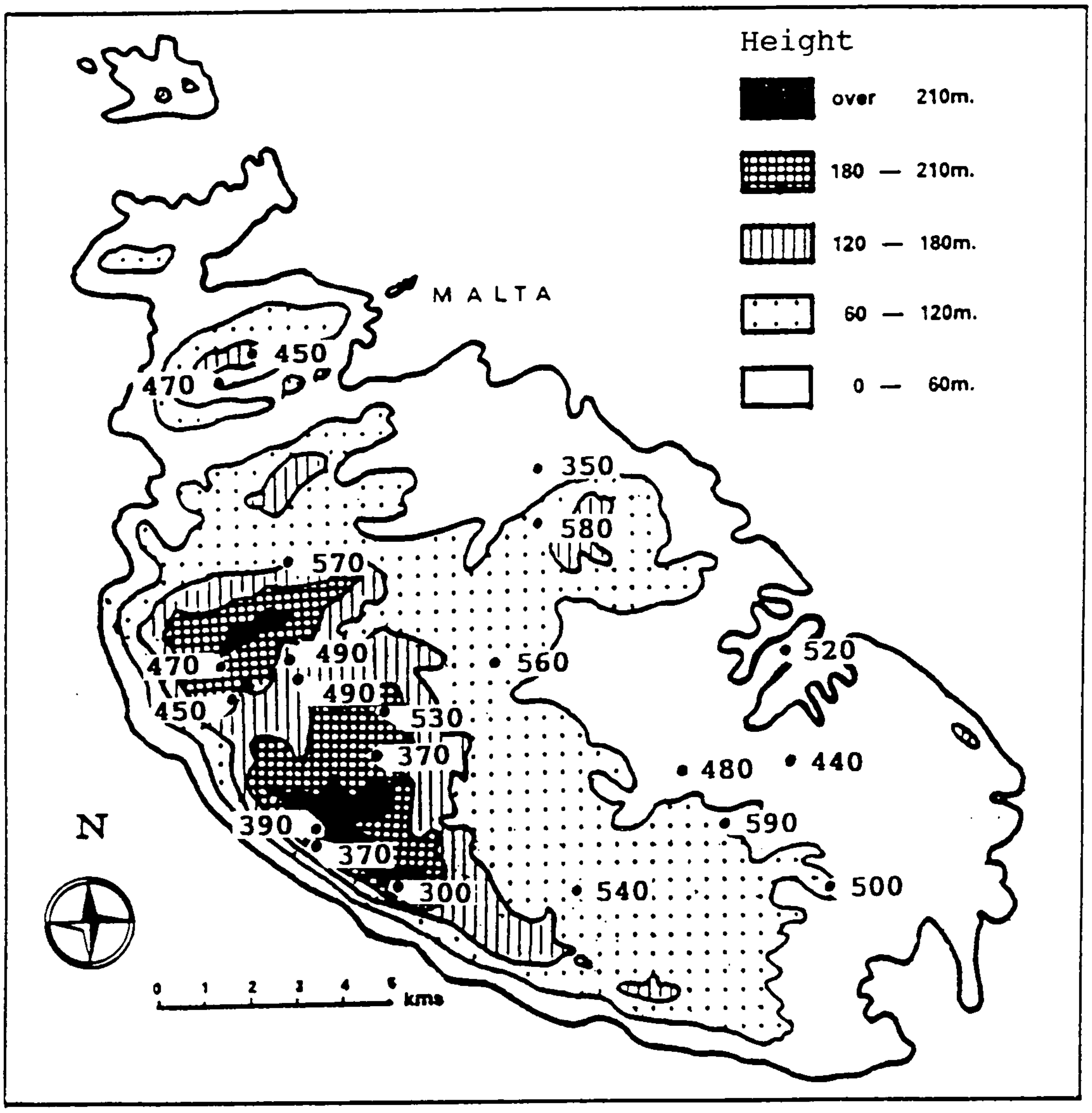
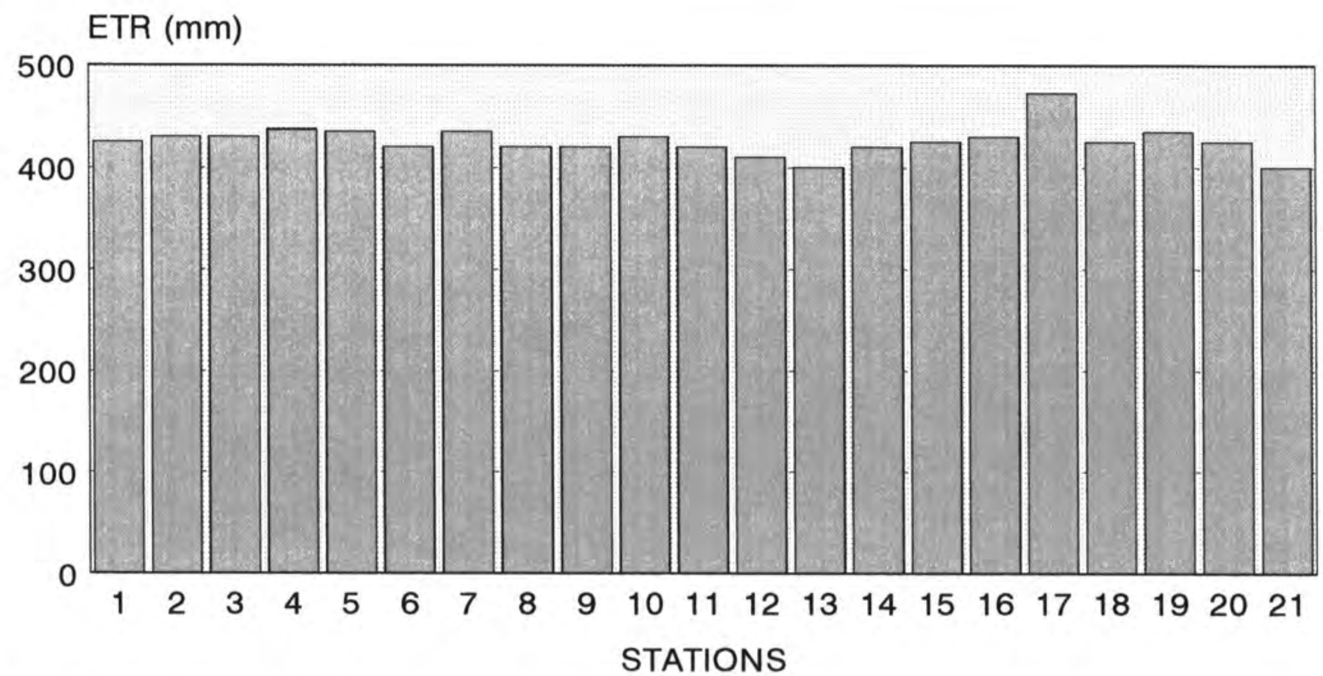


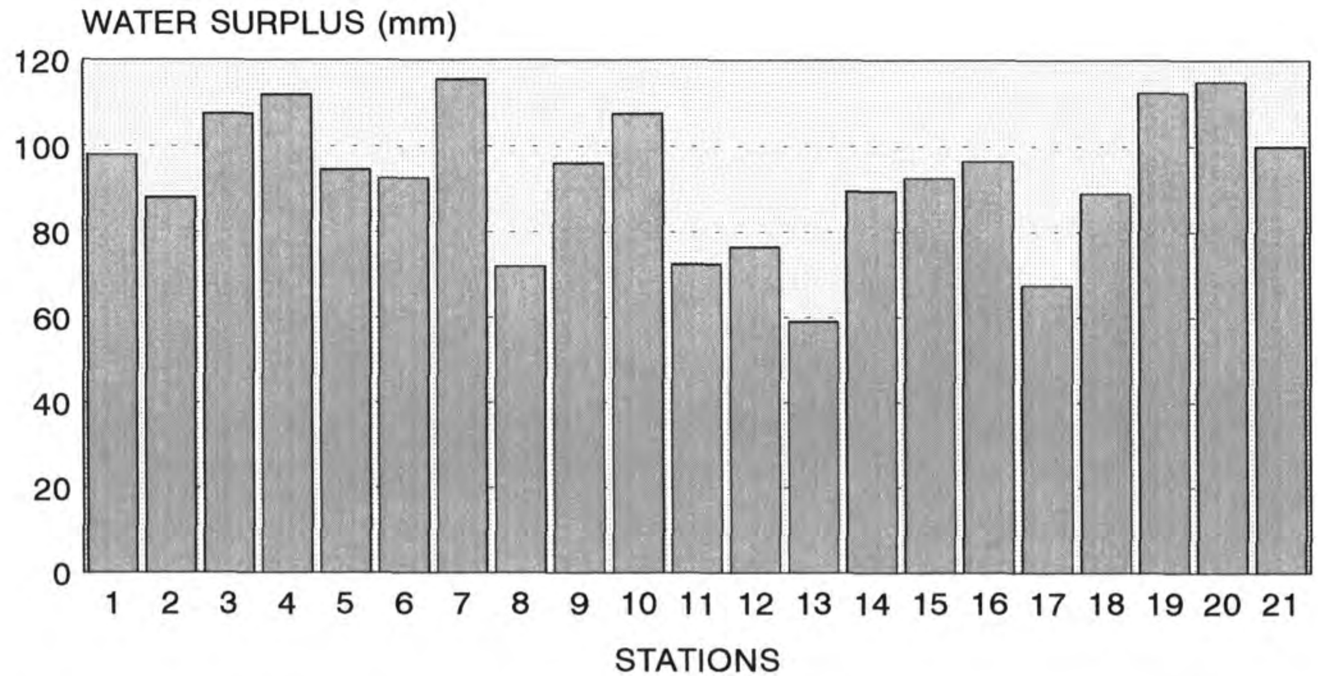
Figure 2.16. The regional distribution of water, in millimetres, infiltrated into the substratum at the different weather (rain gauge) stations in Malta.
Source: Chetcuti *et al*, 1992.

Figure 2.17. Mean real evapotranspiration (ETR) for the different stations in Malta in Figure 2.15.
Calculated by the method of Thornthwaite



Derived from Chetcuti et al, 1992.

Figure 2.18. Mean water surplus values for the different stations on Malta shown in Figure 2.15.
Calculated by the method of Thornthwaite



Derived from Chetcuti et al, 1992.

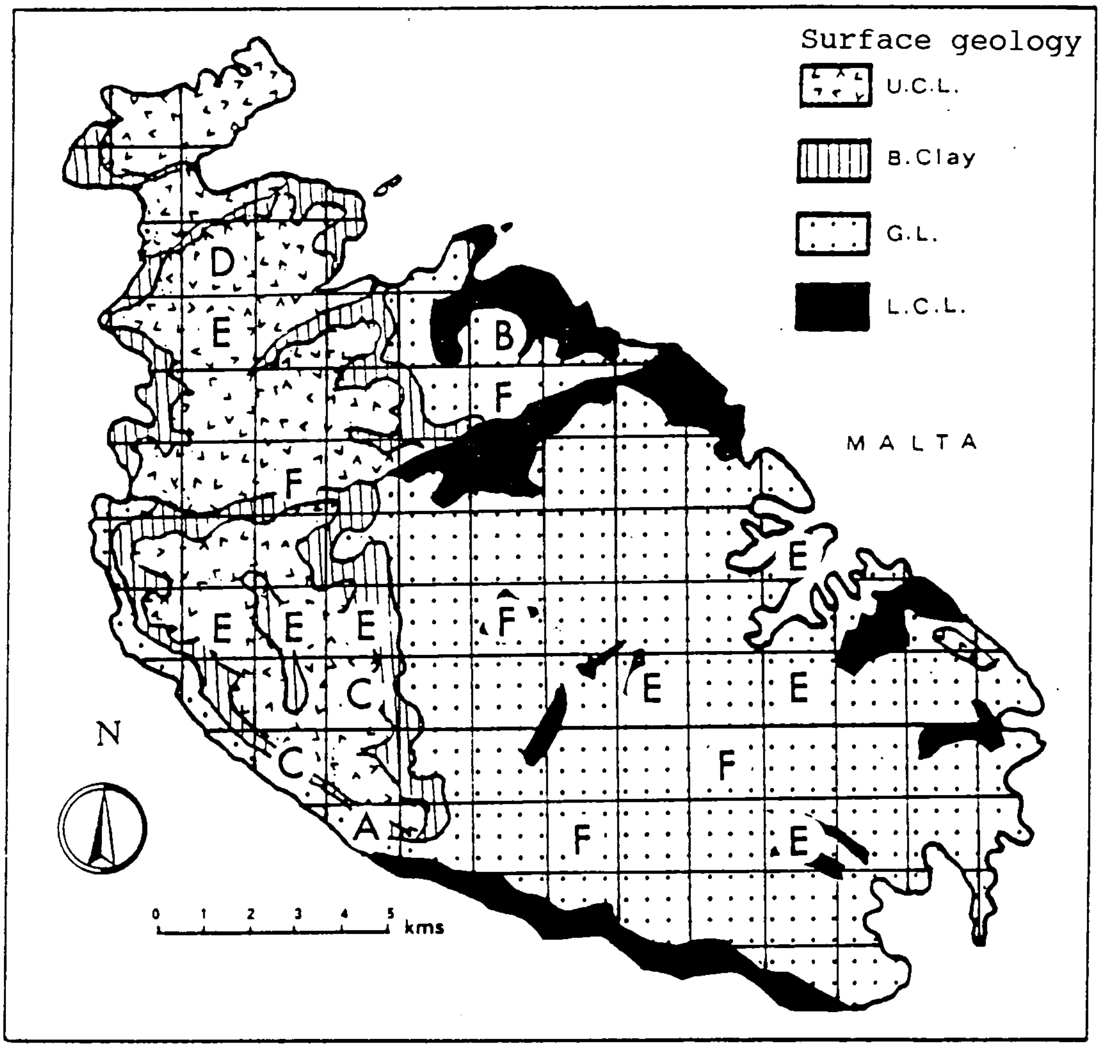


Figure 2.19. Distribution of the amount of water, in millimetres, infiltrated into the rock strata of Malta. A=300mm; B=350mm; C=400mm; D=450mm; E=500mm; F=550mm. U.C.L.= Upper Coralline limestone; B.Clay= Blue Clay; G.L.= Globigerina limestone; L.C.L.= Lower Coralline limestone.
Source: Chetcuti *et al*, 1992.

least amount of water is infiltrated in the north-west especially in the Rabat-Dingli Upper Coralline limestone area and that more infiltrates on the Globigerina limestone plains to the south of the Victoria Lines. This means that a greater availability of water on the surface and in the soil and upper substratum in the north-west allows for more water to be evapotranspired.

Other factors in this area also contribute to the higher levels of evapotranspiration. There is a higher level of rainfall in this area than elsewhere and so more water available. The area has a greater abundance of highly water retaining Blue Clay and an abundance of low level springs that flow at or near the surface. These themselves have produced or accentuated a large number of *widien*, many lined with Blue Clay and some containing water, at or near the surface, even during the summer (due to the presence of Blue Clay and dams giving rise to long term ponding) while elsewhere in Malta *widien* are relatively dry.

This region also contains most of Malta's vegetation especially in *widien* which are more fertile than elsewhere due to the water they retain. It also contains the Buskett Gardens, Malta's only remaining forest. The area is also directly exposed to the strong north-westerly wind, and its greater elevation exposes it to wind in general, much more so than the sheltered southern region. The effect of wind on evapotranspiration is discussed on pp.109-113.

Anomolies to this pattern exist. For example, at station number 17 at Wied il-Ghasel. Here, because the water table is shallow and the aquifer lies just below the root zone, infiltration into the substratum is only 350mm per annum since saturation of the substratum can occur rapidly. Consequently evapotranspiration losses are highest here resulting in a relatively low annual water surplus (ibid).

2.1.3.2.5.3. The effect of temperature on evapotranspiration

The high level of water loss via evapotranspiration is largely due to the relatively high temperatures most of the year. The mean annual temperature is 18.6°C. Mean monthly temperatures range from 12.3°C to 26.3°C with January and February being the coldest months and July and August the hottest as illustrated by Table 2.7. and Figure 2.20. (ibid).

Variations from the mean are important as a comparison between daily mean, minima and maxima temperatures in Table 2.7. (and between Figures 2.20. and 2.21.) shows that, for example in August, the hottest month, while the mean temperature is 25.4°C, the mean daily maximum is 30.6°C. In January and February, which are the coldest months, the mean temperature is 12.4°C. However, in January the mean daily minimum is 9.2°C, and 9.3°C in Februrary. The extreme temperatures in Table 2.7. illustrate the limits of variability in temperature, the highest being 42.7°C in July 1988 and the lowest, 1.4°C in January 1981 (ibid).

2.1.3.2.5.4. The effect of radiant energy on evapotranspiration

The amount of radiant energy reaching the surface is determined by the daylength, which is determined by the latitudinal position of the Islands and the position of the sun in the sky. On a daily basis the sun may shine brightly in clear skies or may be obscured by clouds or atmospheric haze. Hence the amount of radiant energy is determined mostly by the hours of sunshine and the amount of cloud cover.

The Islands have a sunny climate with an annual mean of 8.3 hours of bright sunshine a day. Figure 2.22. shows

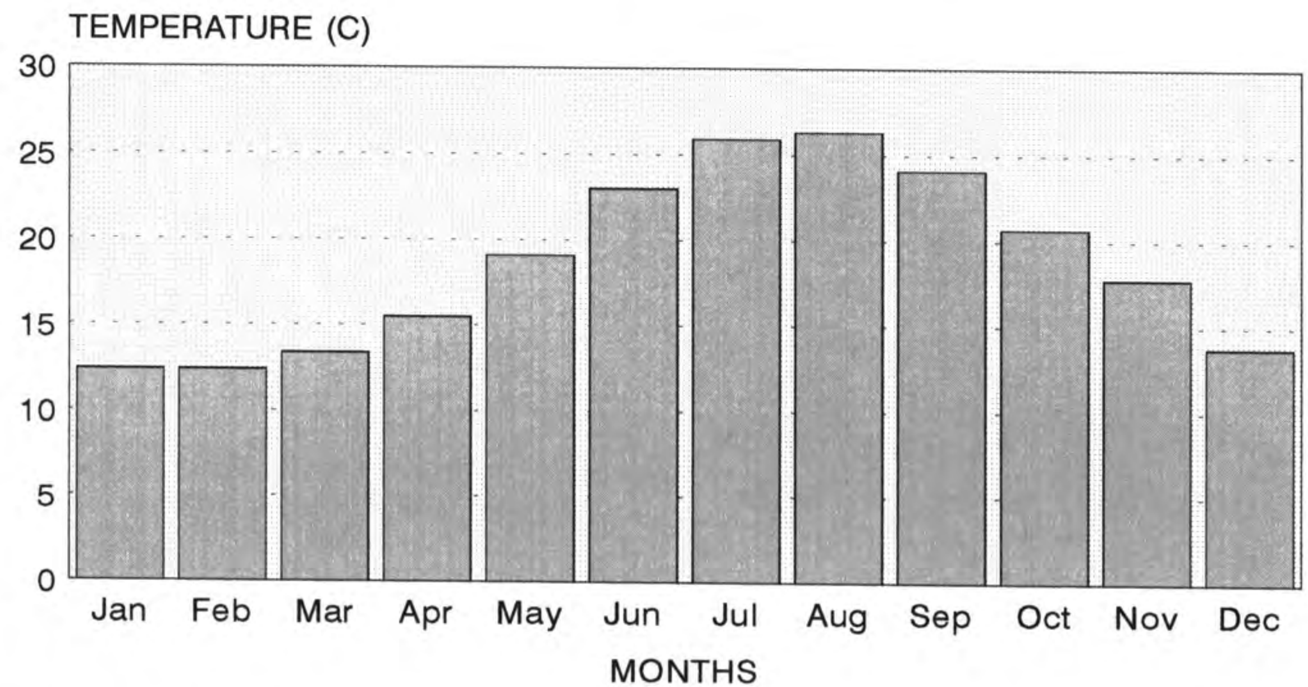
Table 2.7. Temperature data (degrees celsius) for 1951-1980 (extremes from Sep. 1947 to Dec. 1990)

Based on data obtained from Luqa Meteorological Office

Month	Mean monthly	Mean daily max.	Mean daily min.	Average highest	Average lowest	Extreme highest	Year	Extreme lowest	Year
Jan	12.4	15.2	9.2	18.8	4.4	22.2	-82	1.4	-81
Feb	12.4	15.5	9.3	19.3	4.5	26.7	-60	1.7	-56
Mar	13.4	16.7	10.1	21.4	5.6	28.9	-52	2.2	-49
Apr	15.5	19.1	11.9	24.2	7.8	30.7	-85	4.4	-56
May	19.1	23.3	14.9	28.9	10.8	33.9	-73	8	-70
Jun	23	27.5	18.4	32.9	15	39.5	-82	12.6	-75
Jul	25.9	30.7	21	36.5	18	42.7	-88	15.5	-80
Aug	26.3	30.7	21.8	35.1	18.8	39.8	-87	15.9	-72
Sep	24.1	28	20.1	32.2	16	37.4	-90	13.2	-69
Oct	20.7	24.2	17.1	28.5	12.2	33.6	-90	8	-78
Nov	17.8	20.1	13.9	24.9	8.9	27.1	-90	5.9	-71
Dec	13.8	16.7	11	20.8	6.3	24.3	-63	3.6	-67
Year	18.6	22.3	14.9						

Source: Chetcuti et al, 1992.

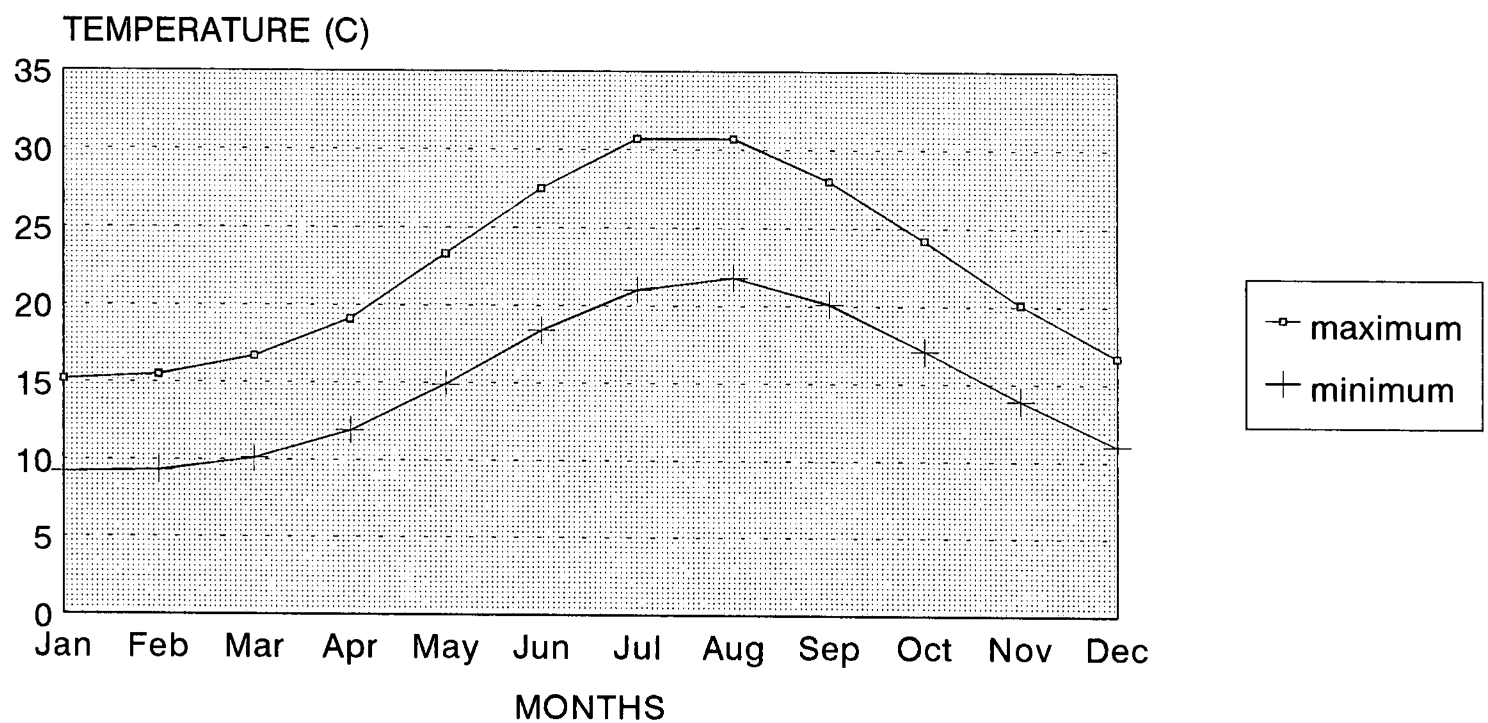
Figure 2.20. Mean monthly air temperature in the Maltese Islands for the period 1951-1986
Based on data obtained from Luqa Meteorological Office



Source: Chetcuti et al, 1992.

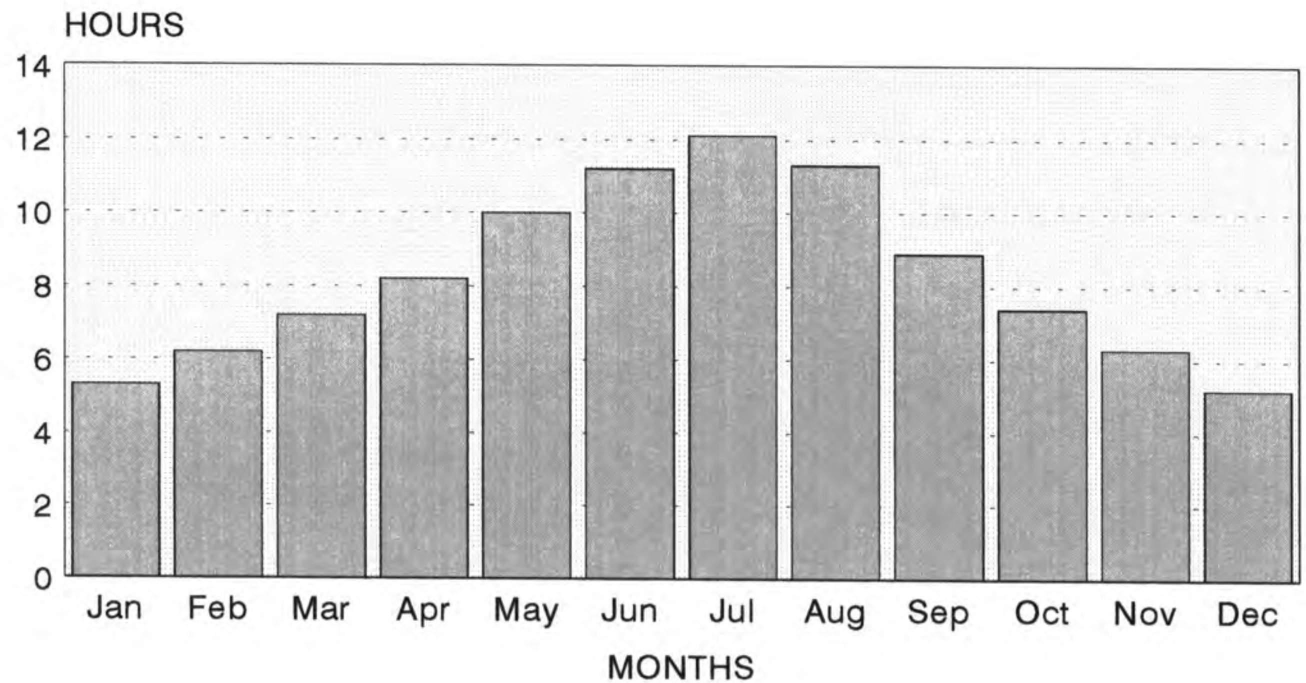
Figure 2.21. The mean daily maximum and minimum temperatures for each month for the period 1951-1986

Based on data from the Luqa Meteorological Office



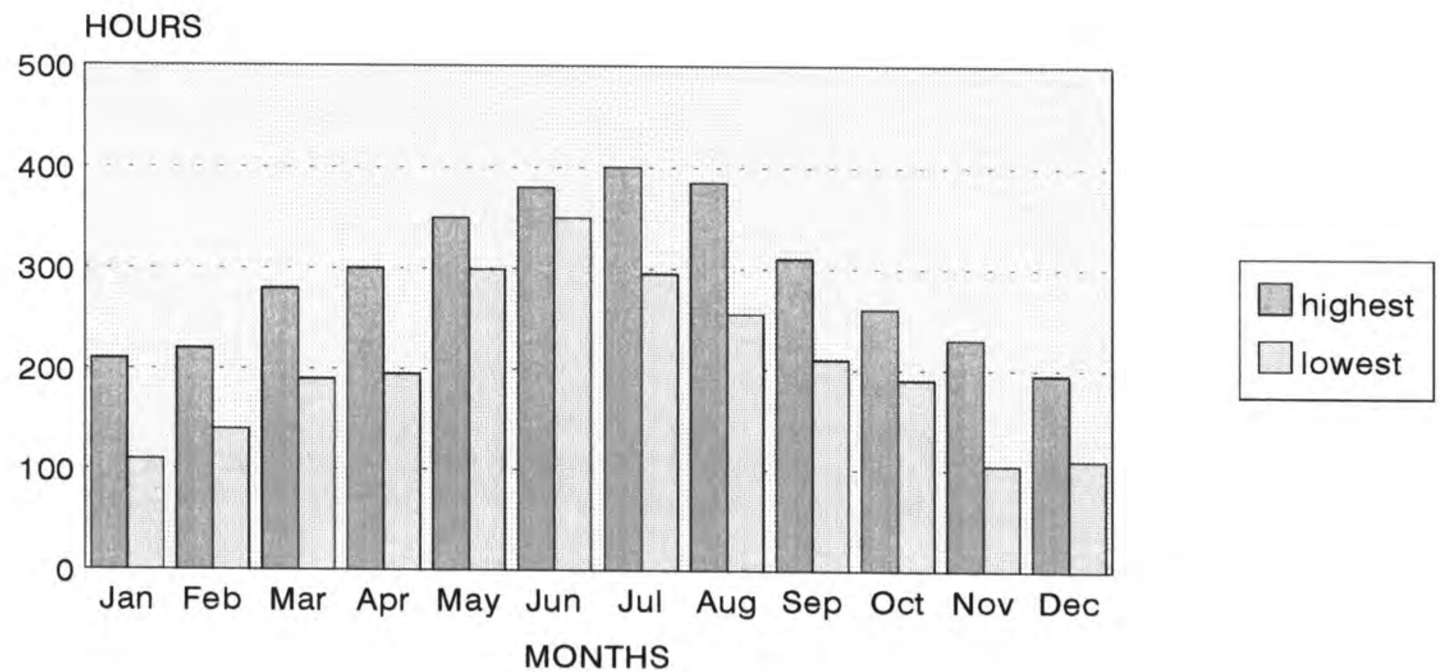
Source: Chetcuti et al, 1992.

Figure 2.22. The mean number of daily hours of sunshine for the period 1951-1980
Basd on data obtained from the Luqa Meteorological Office



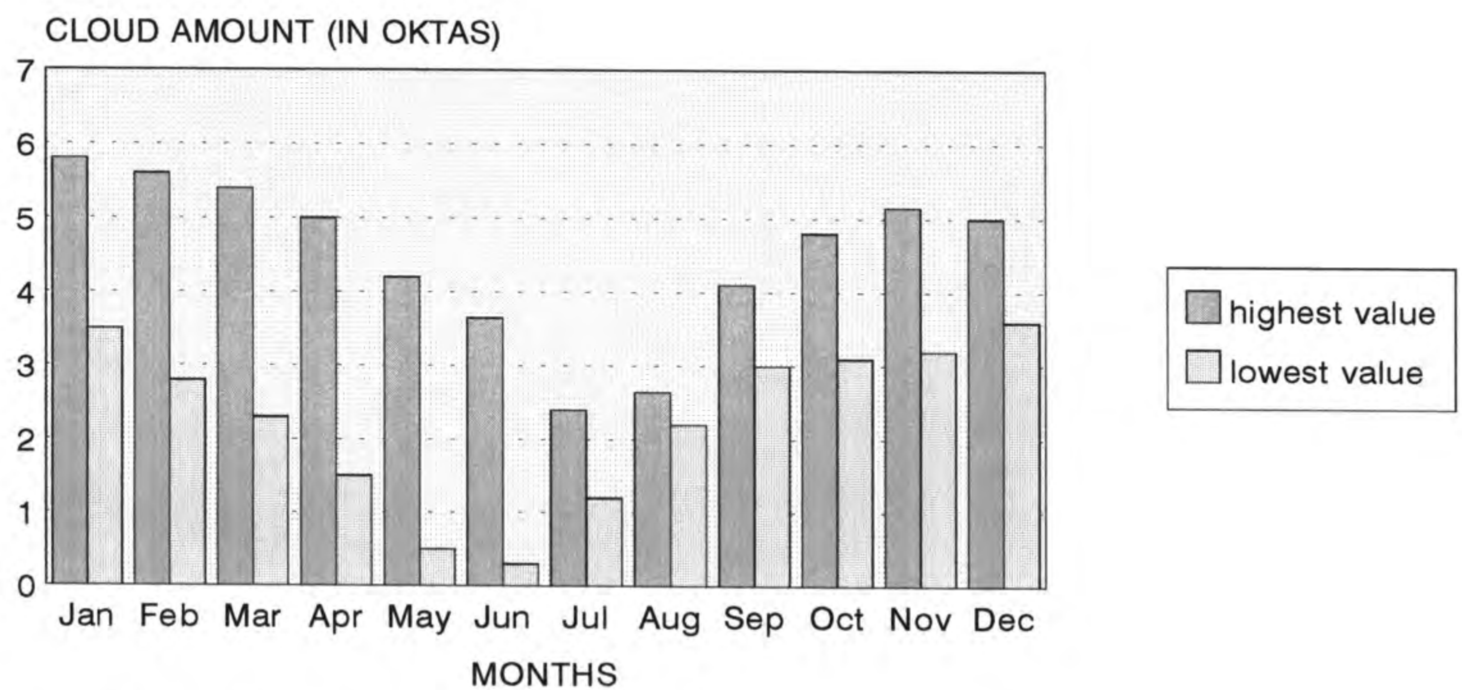
Derived from Chetcuti et al, 1992.

Figure 2.23. The monthly highest and lowest amount of sunshine hours for the period 1951-1980
Based on data obtained from the Luqa Meteorological Office



Derived from Chetcuti et al, 1992.

Figure 2.24. Mean monthly high and low values of cloud cover in oktas for the period 1951-1980
Based on data obtained from the Luqa Meteorological Office



Derived from Chetcuti et al, 1992.

that mean daily hours of sunshine are highest in July with a mean of 12.11 hours in a day and lowest in December with a mean of 5 hours per day, due to seasonal changes in the sun's position. Figure 2.23. shows that there is a considerable difference in the monthly highest and lowest levels of sunshine over the period 1951 to 1980. This difference is smallest during the summer months, particularly for June. A high level of sunshine hours during the summer, when the difference between highest and lowest sunshine hours is relatively small, contributes to the high level of potential evapotranspiration (ibid).

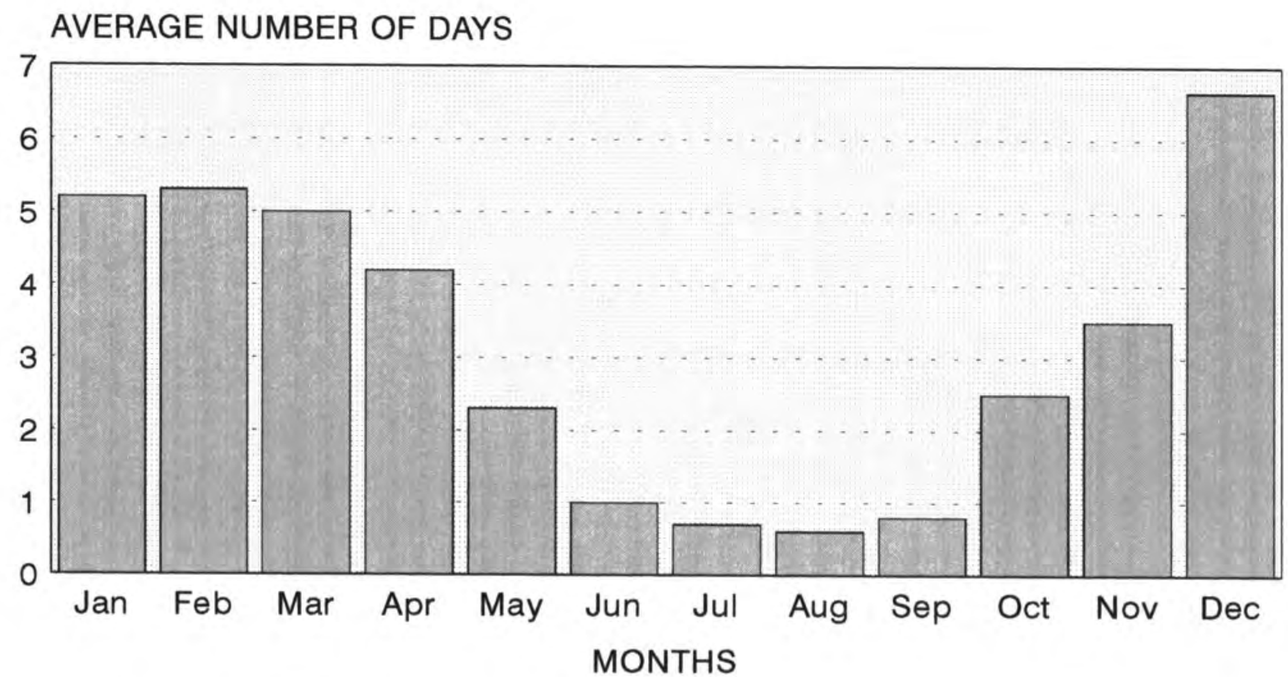
As well as influencing rainfall, cloud cover determines the amount and length of time of bright sunshine. Cloud cover is measured in oktas, one okta representing an eighth of the sky being covered with clouds. Figure 2.24. shows that the mean monthly high and low values for cloud cover are highest in January and lowest in July. This pattern is inversely related to insolation. Cloud cover reduces radiant energy and hence the potential for evapotranspiration. The difference between the high and low values are smallest in July, August and September, giving almost consistently clear skies (ibid).

2.1.3.2.5.5. The effect of wind on evapotranspiration

The fact that the Islands are windy, with only an average of 7.7% of the days of the year being calm, accelerates evapotranspiration (ibid; Schembri, 1993). Figure 2.25. shows that days with gusts of wind greater than 63 km/hr, which are gale force, occur mostly in the winter months and are most frequent in December. These winds coincide with the winter rainfall, maximising their effect on real evapotranspiration (Chetcuti *et al*, 1992).

For most other days the wind speed is between 1.8 and 39 km/hr. In the summer, July, August and September,

Figure 2.25. Mean number of days per month with gusts of wind of speeds over 63 km/hr for 1951-1980
Based on data obtained from the Luqa Meteorlogical Office



Derived from Chetcuti et al, 1992.

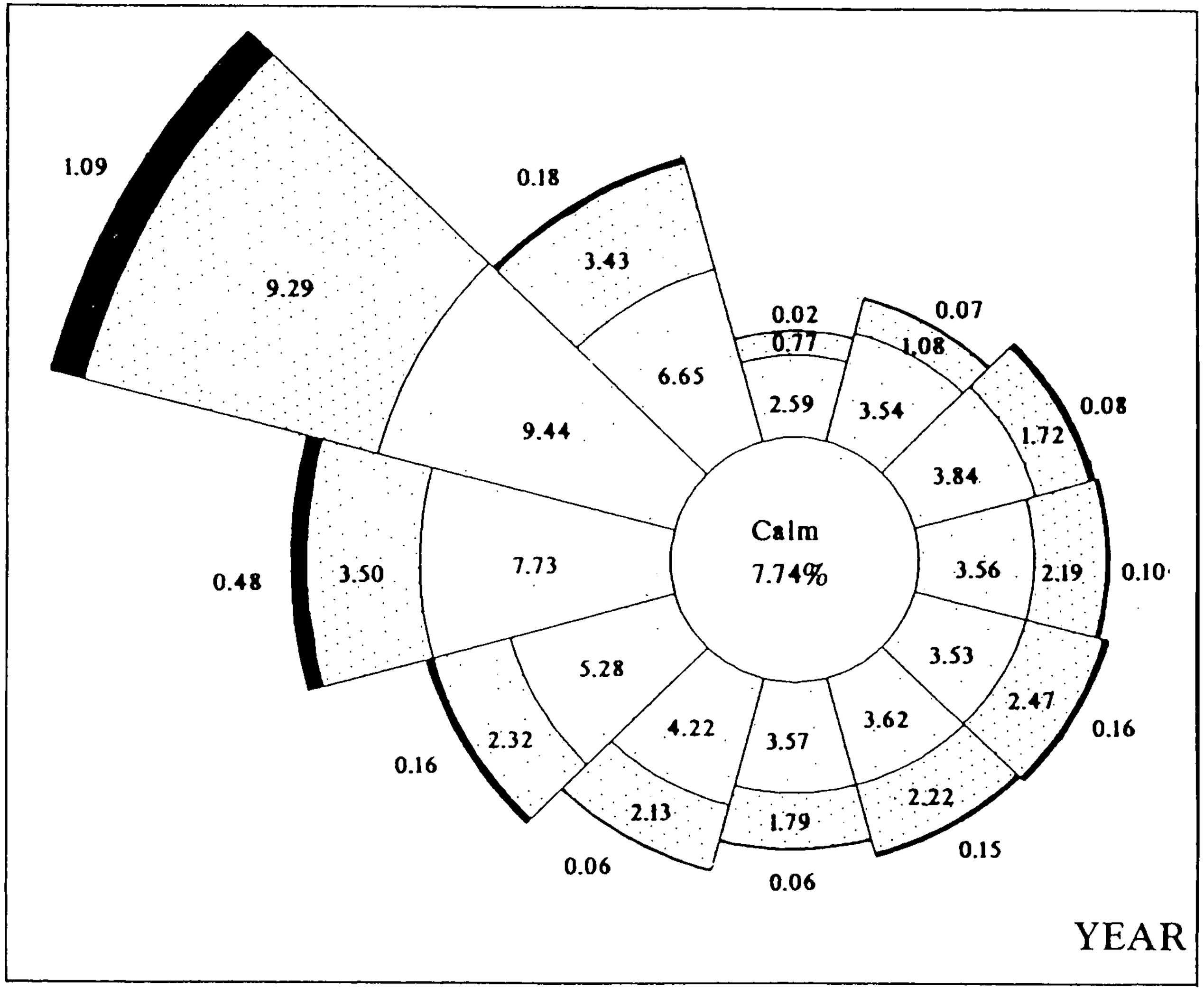


Figure 2.26. Annual percentage frequencies of wind speeds and directions.
Source: Chetcuti *et al*, 1992.

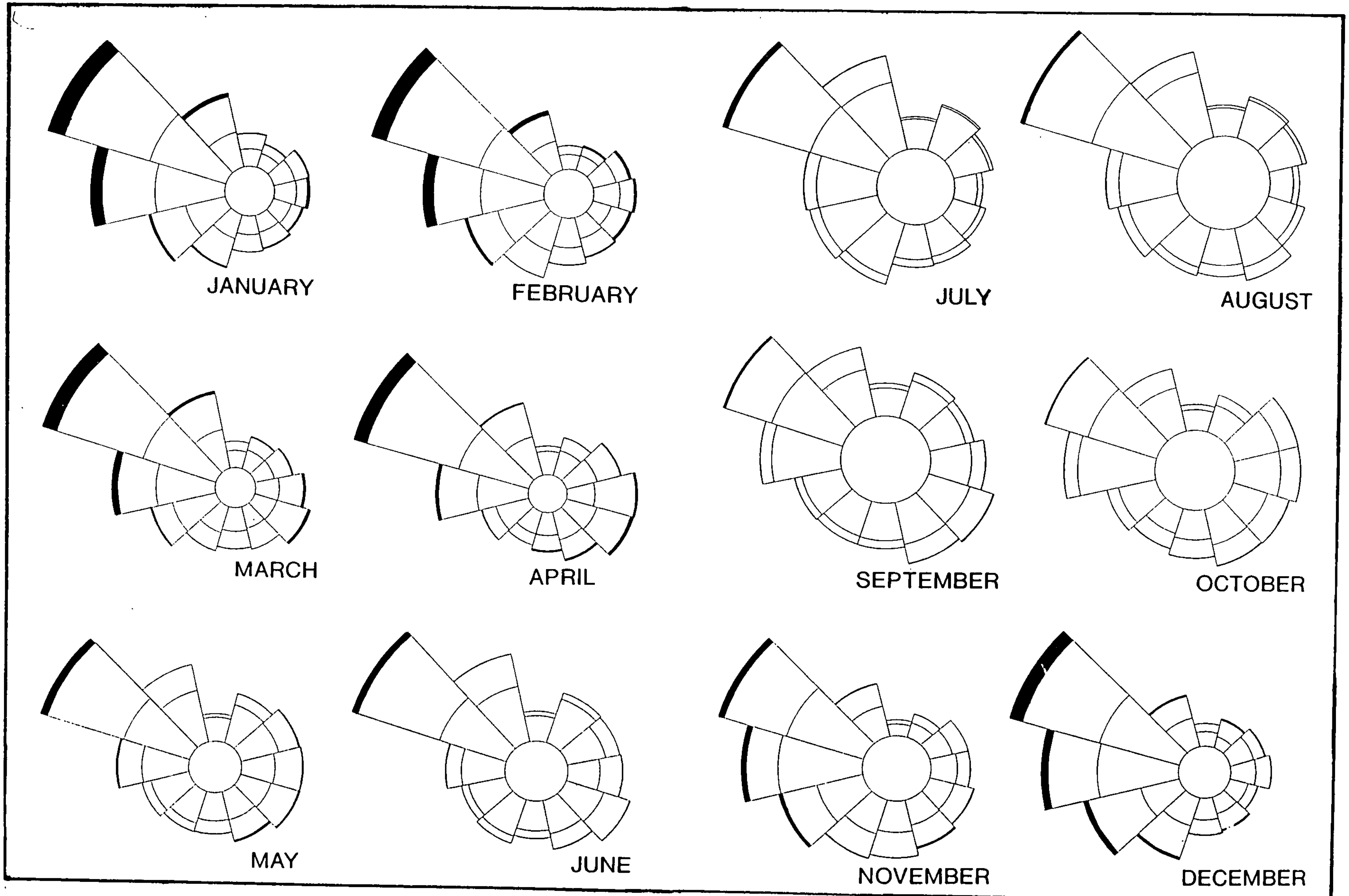


Figure 2.27. Monthly percentage frequencies of wind speeds and directions.
Source: Chetcuti *et al*, 1992.

the proportion of calm days is greater reaching 11.6 percent in August. Figures 2.26. and 2.27. show the wind roses of the percentage frequencies of wind speeds and directions for the whole year and for each month of the year, respectively. Wind frequency is represented by the length of each radiating arm and the diameter of the circle in the centre of each rose represents the number of calm days. It can be seen that the north-westerly *Majjistral* is the most common wind, blowing for an average of 19% of the days in a year. This blows most intensely in the winter months and most directly effects that part of Malta which experiences most rainfall, the west. January has fewer calm days than August and greater wind speeds, mostly from the west and north-west (ibid).

2.1.3.2.5.6. Relative humidity and evapotranspiration

Humidity and evapotranspiration are intrinsically related and both influence each other. With evapotranspiration at 70-80% of total annual rainfall, real humidity is consistently high throughout the year at 65-85% (Chetcuti *et al*, 1992).

Relative humidity, however, is the percentage of the maximum amount of water vapour that the air is capable of holding at a given temperature.

Relative humidity influences evapotranspiration since the amount of water vapour that a volume of air can hold is determined by temperature. Warm air holds more water vapour than cold air with a doubling of this capacity with every increase of 11°C in temperature. Chetcuti *et al* (1992) state:

"Relative humidity is important, particularly in terms of water resources, since if the relative humidity is low, evaporation is high and vice versa." (ibid, p.63).

Hence relative humidity has a diurnal variation which is related to the diurnal variation in temperature, which both influence the diurnal variation in evapotranspiration. From Figure 2.28. it can be seen that the mean percentage relative humidity decreases to a low range of between 50% and 70% at 12.00 hours throughout the year. This is mostly because of higher midday temperatures and allows for the highest evaporation rates at this time. At other times, relative humidity is high at levels between 65% and 85% reaching a maximum around midnight. Correspondingly, evapotranspiration is lowest at this time (ibid).

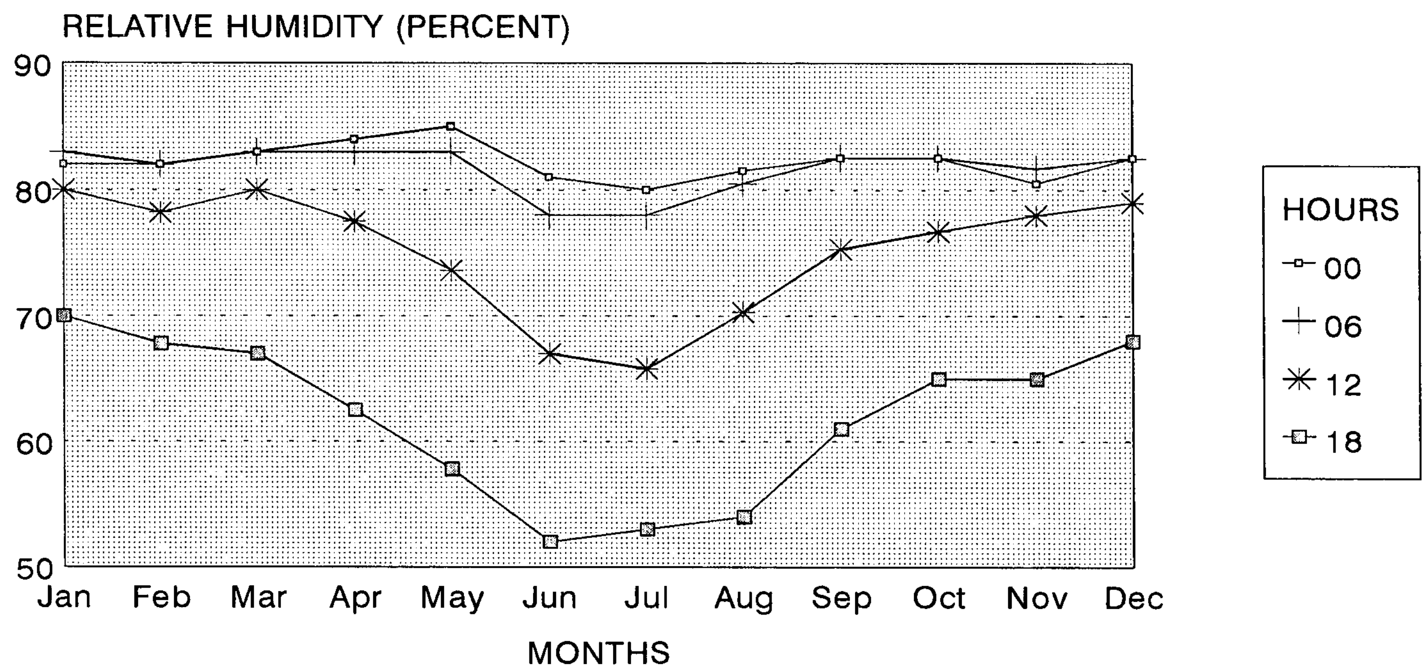
The higher summer temperatures mean that mean percentage relative humidity is lowest from June to August (Figure 2.28.).

2.1.3.2.5.7. Vapour pressure and evapotranspiration

The water that is evapotranspired into the atmosphere causes an increase in atmospheric pressure by an amount called the partial pressure of water vapour and is known as the 'vapour pressure'. Vapour pressure gives a more representative indication than relative humidity of the amount of water vapour in the atmosphere. A comparison of the mean monthly values for 00 hours and 1800 hours in Figure 2.29., shows that there is a small increase in vapour pressure during the day due to evapotranspiration and a decrease at night due to condensation. It can be seen that the mean monthly vapour pressure in summer is almost twice that in winter (ibid).

Figure 2.28. The mean percentage relative humidity at different hours of the day for 1951-1980

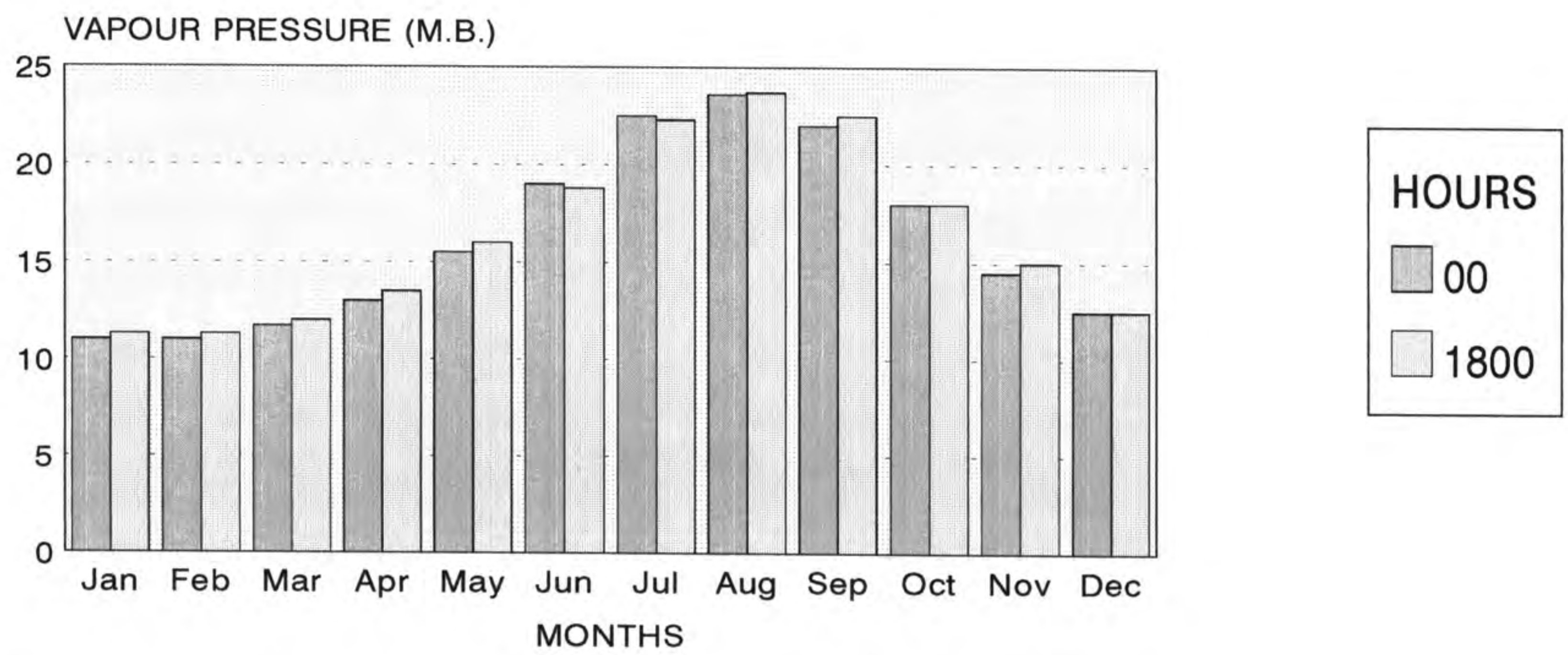
Based on data obtained from the Luqa Meteorological Office



Derived from Chetcuti et al, 1992.

Figure 2.29. Mean monthly vapour pressure for 00 and 1800 hours for the period 1951-1980

Based on data obtained from the Luqa Meteorological Offce



Derived from Chetcuti et al, 1992.

2.1.3.2.6. Water surplus and water deficit

There is a marked monthly variation in water availability which creates a water surplus when aquifer recharge occurs and a water deficit when aridity occurs.

Whether a water surplus or a water deficit exists depends on the soil water balance. The soil water balance has been determined by Chetcuti *et al* using the method of Thornthwaite (1948) based on potential evapotranspiration and real evapotranspiration (ibid).

They define the water surplus as the difference between rainfall and real evapotranspiration. Table 2.8. shows the mean monthly values of water surplus for soil retention capacities of 100mm and 150mm. It shows that a water surplus occurs only between October to March, with values reaching a maximum in January and February (ibid).

The total average annual water surplus is 181mm for a retention capacity of 100mm. Since this is only 34% of the total annual rainfall, the arid nature of the Islands is evident. Furthermore, where the retention capacity is 150mm, greater levels of real evapotranspiration mean that the water surplus is 128mm, just 24% of the total annual rainfall. The relationship between rainfall, evapotranspiration and water surplus for retention capacities of 100mm and 150mm is illustrated in Figures 2.30. and 2.31., respectively. It can be seen that for a retention capacity of 150mm, the water surplus is lower than that for one of 100mm, particularly for the months November and December due to higher evapotranspiration levels during those months (for a 150mm retention capacity) (ibid).

Chetcuti *et al* define water deficit as,

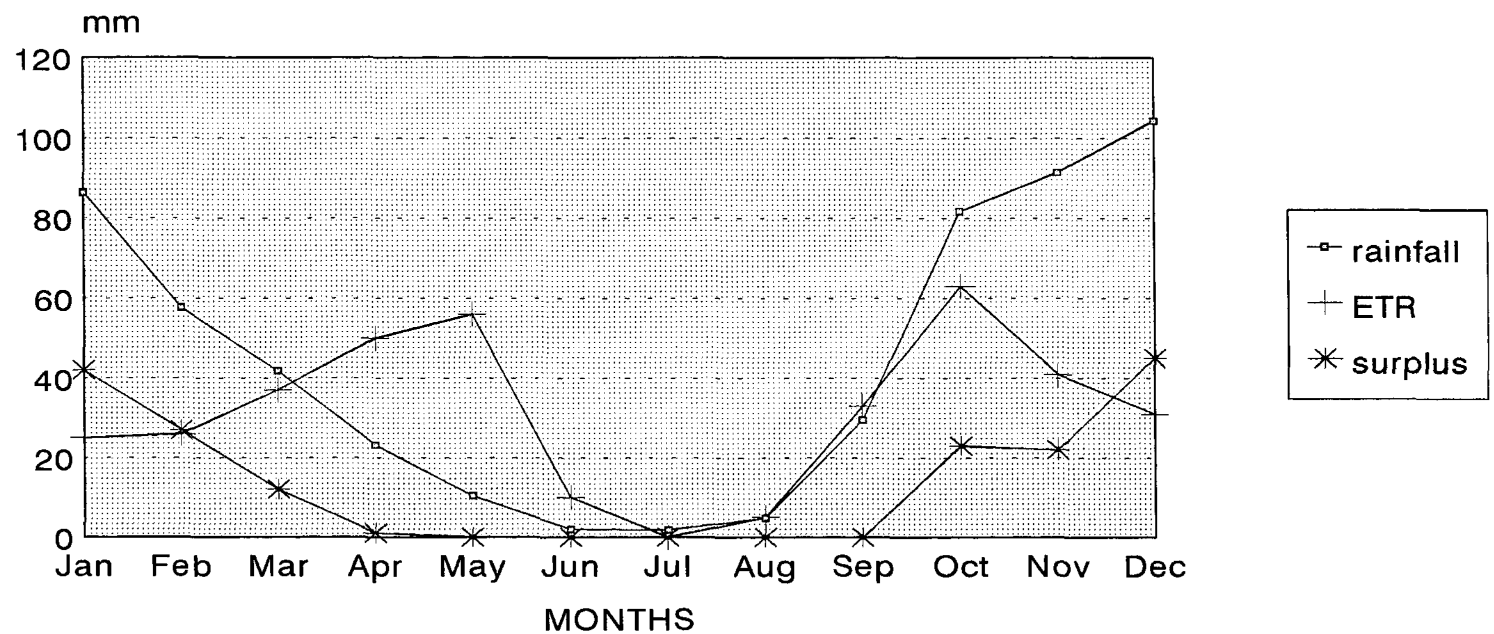
".... the difference between potential evapotranspiration and real evapotranspiration...." (ibid, p.74).

Table 2.9. Mean and standard deviation (SD) values of water surplus per month
for 100mm and 150mm retention capacities

Month	Mean water surplus 100mm ret. cap.	SD 100mm ret. cap.	Mean water surplus 150mm ret. cap.	SD 150mm ret. cap.
January	42	50	26	44
February	27	43	24	42
March	12	19	8	17
April	1	4	1	4
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	32	129	27	118
November	22	44	12	32
December	45	65	30	57

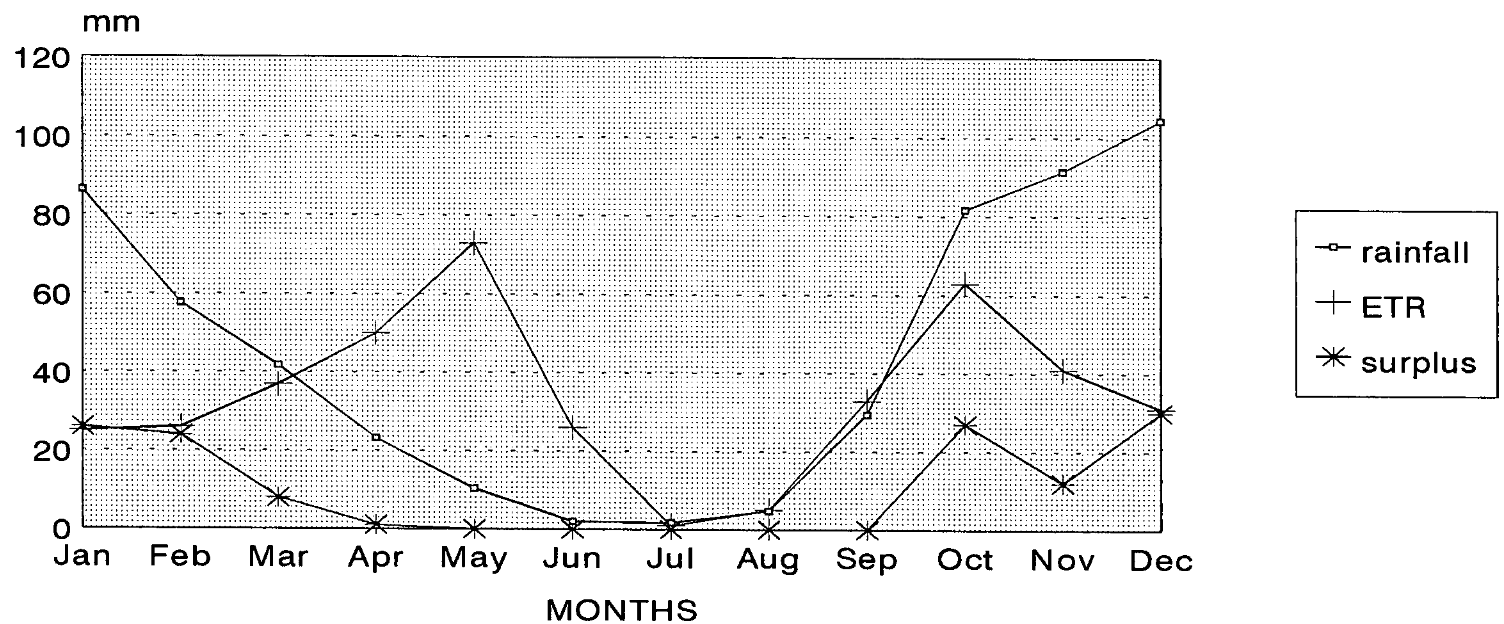
Source: Chetcuti et al, 1992.

Figure 2.30. Mean monthly pattern of rainfall, evapotranspiration (ETR), and water surplus
for a retention capacity of 100mm



Source: Chetcuti et al, 1992.

Figure 2.31. Mean monthly pattern of rainfall, evapotranspiration (ETR), and water surplus
for a retention capacity of 150mm



Source: Chetcuti et al, 1992.

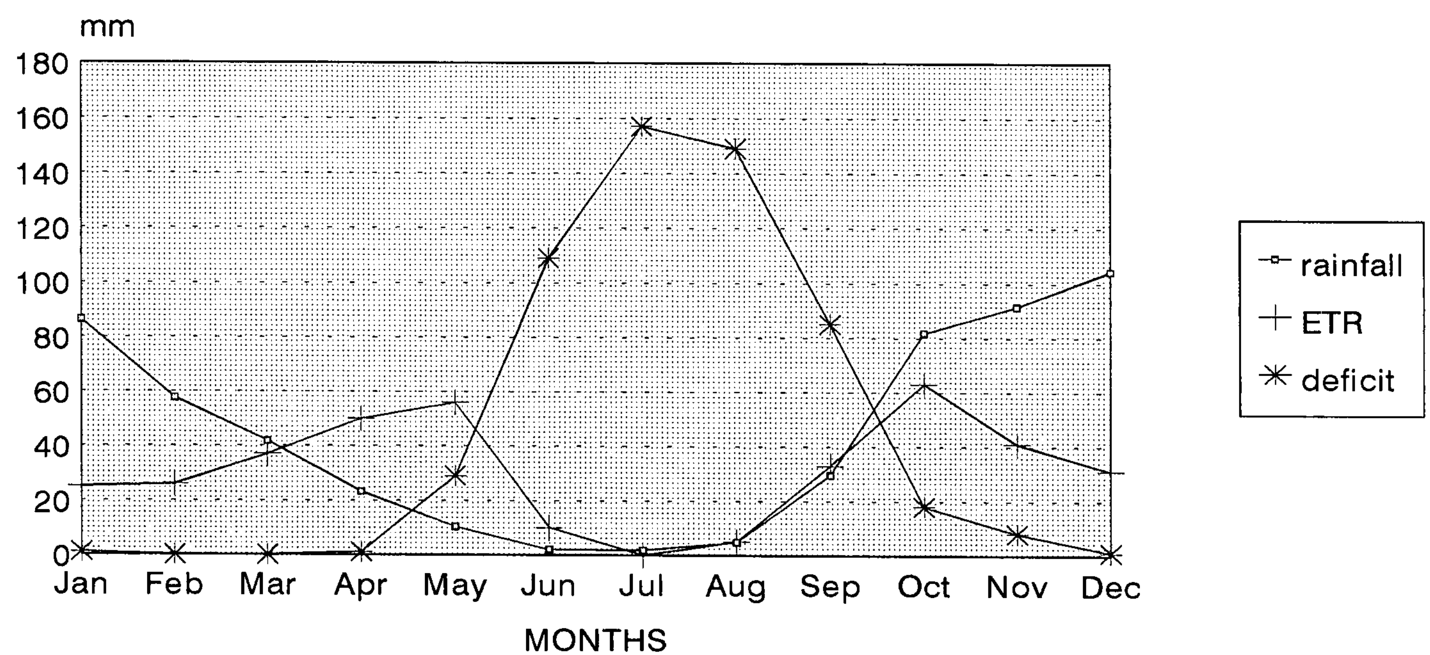
Table 2.9. Mean and standard deviation (SD) values of water deficit per month
for 100mm and 150mm retention capacities

Month	Mean water deficit 100mm ret. cap.	SD 100mm ret. cap.	Mean water deficit 150mm ret. cap.	SD 150mm ret. cap.
January	1	3	1	3
February	0	0	0	0
March	0	0	0	0
April	1	3	1	6
May	29	24	12	20
June	109	26	94	34
July	157	16	156	17
August	149	24	151	23
September	85	31	84	31
October	18	25	18	25
November	8	16	8	16
December	1	2	1	2

Source: Chetcuti et al, 1992.

Figure 2.32. Mean monthly pattern of rainfall, evapotranspiration (ETR), and water deficit

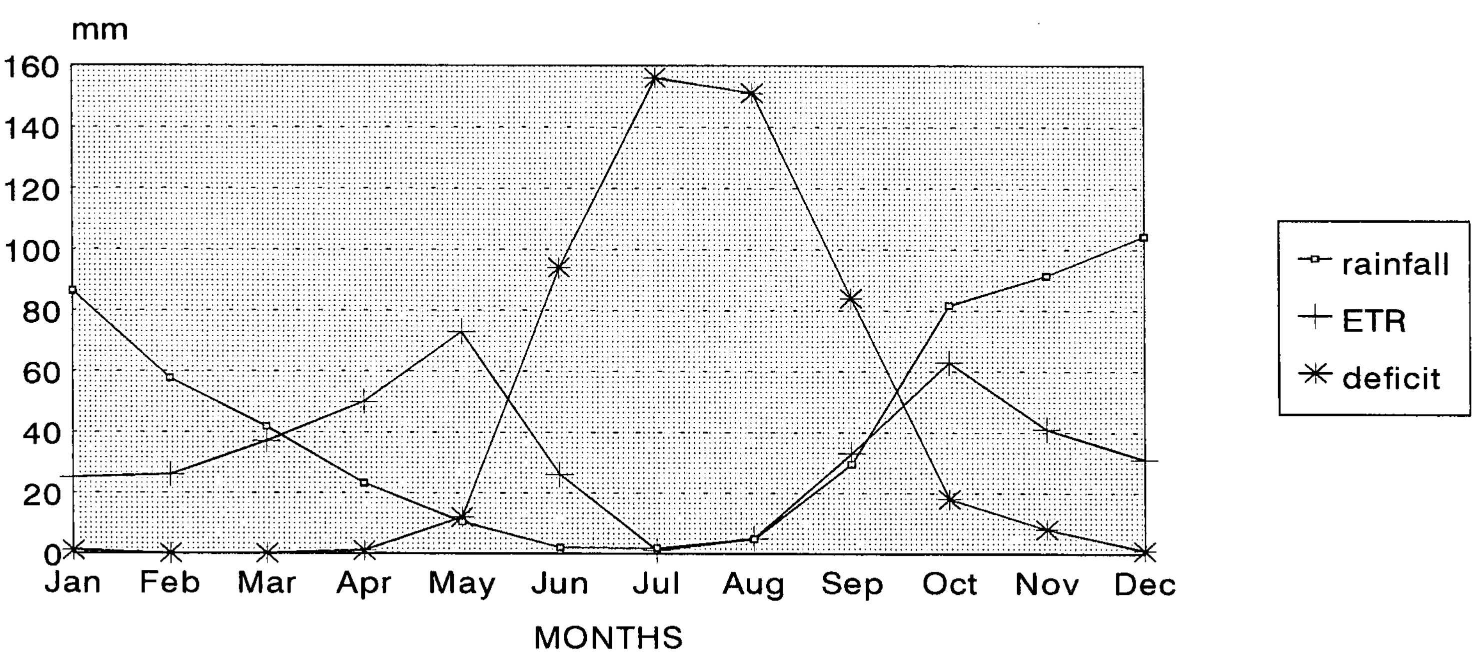
for a retention capacity of 100mm



Source: Chetcuti et al, 1992.

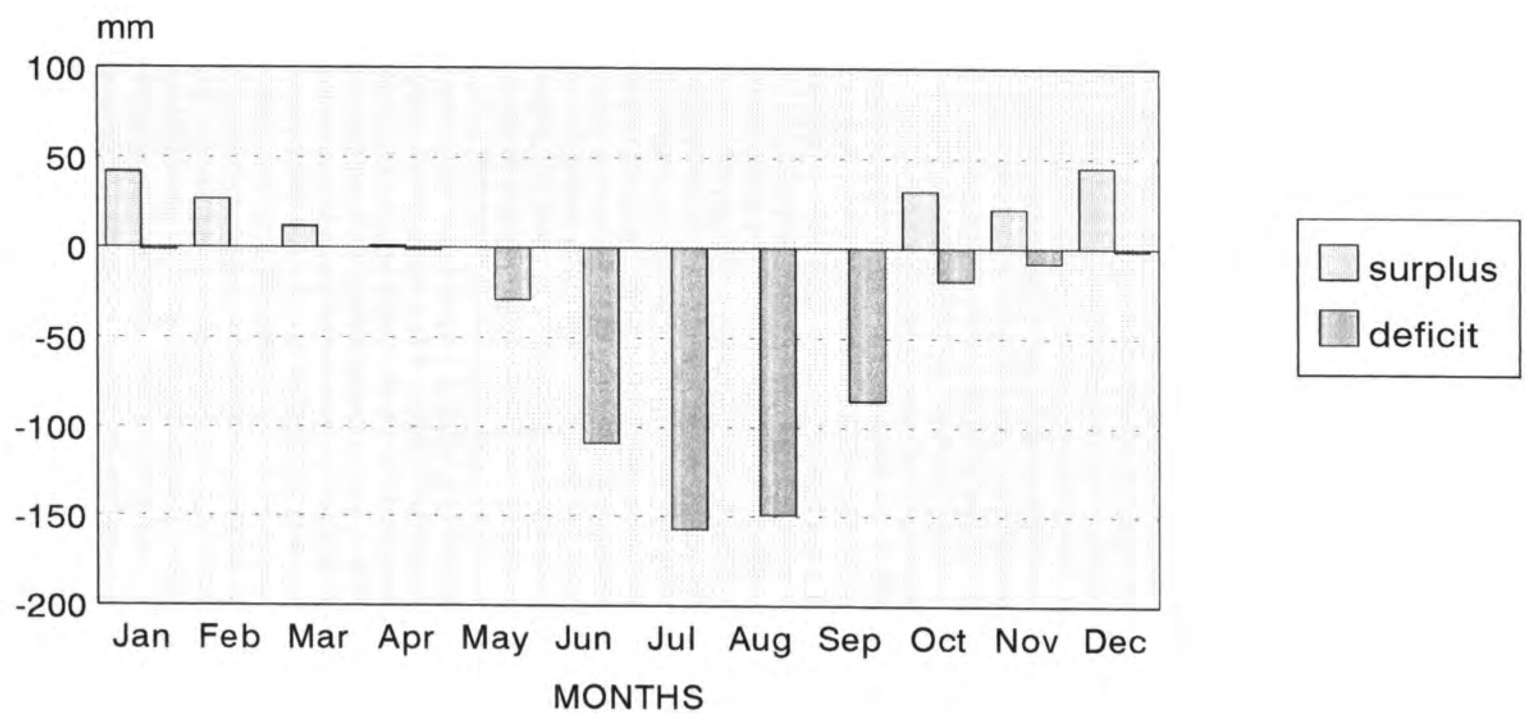
Figure 2.33. Mean monthly pattern of rainfall, evapotranspiration (ETR), and water deficit

for a retention capacity of 150mm



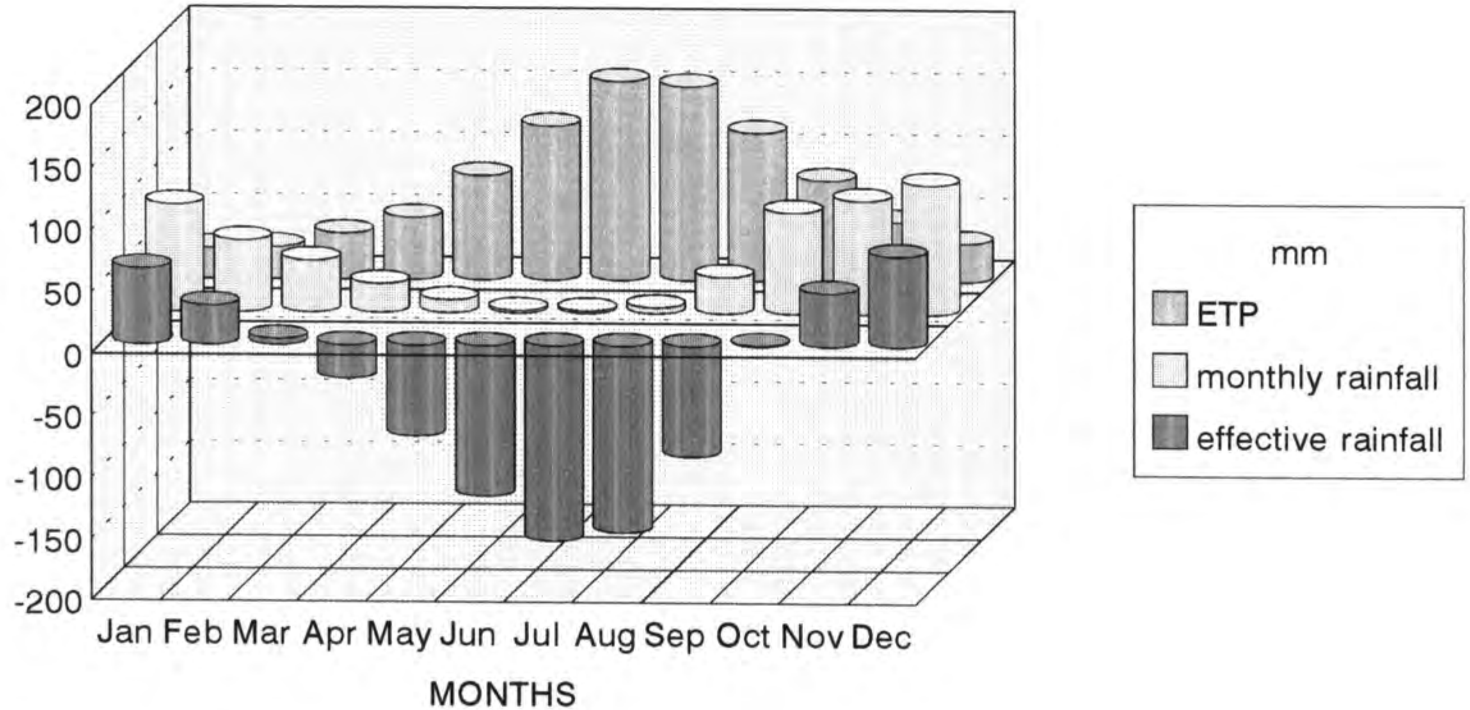
Source: Chetcuti et al, 1992.

Figure 2.34. The mean water balance for the Luqa rain gauge showing water surplus and water deficit
for a water retention capacity of 100mm



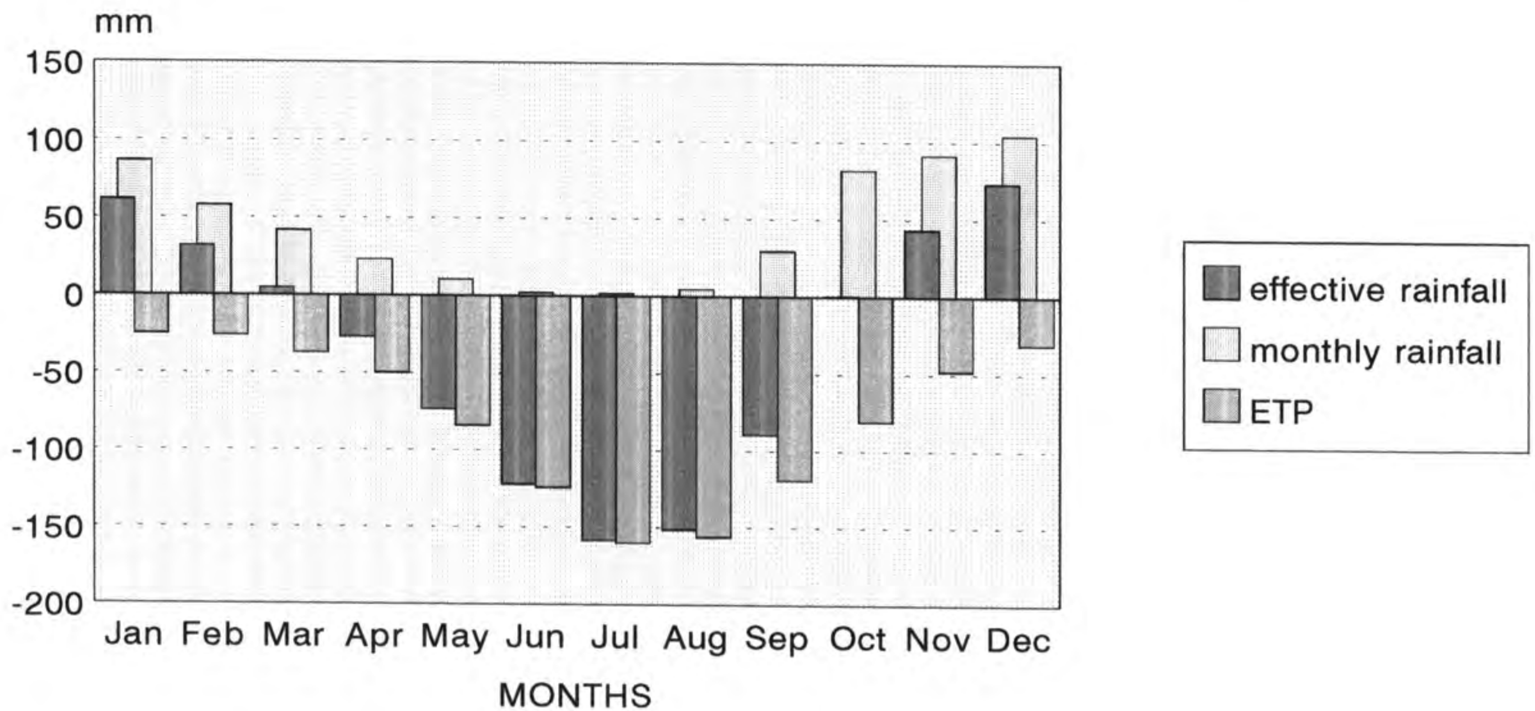
Source: Chetcuti et al, 1992.

Figure 2.35. Mean monthly water excess (mm) for the rainfall station at Luqa



Source: Chetcuti et al, 1992.

Figure 2.36. Mean monthly water excess (mm) for the rainfall station at Luqa



Source: Chetcuti et al, 1992.

Table 2.9. shows the values for mean monthly water deficit for soil retention capacities of 100mm and 150mm. The relationship between these values and rainfall and evapotranspiration can be seen in Figures 2.32. and 2.33. The water deficit is highest from June to September due to aridity during these months. The deficit is greater for soils with a retention capacity of 150mm (ibid).

In the water balance of the Maltese Islands, the water deficit far exceeds the water surplus in each year and this is illustrated by Figure 2.34. This has a direct effect on water resources, which are largely dependent on the effective rainfall (ibid). Chetcuti *et al* define the effective rainfall as,

".... the difference between the mean monthly rainfall and the potential evapotranspiration." (ibid, p.74).

Since the latter far exceeds the former for most of the year, the effective rainfall is negative from April to September. Figure 2.35. illustrates this pattern compared to the pattern of rainfall and potential evapotranspiration. Figure 2.36. shows potential evapotranspiration (ETP) as a negative value to illustrate its close relationship with effective rainfall during the dry period. By October, not all the rainfall is being evapotranspirated and so a surplus exists. The rainfall recharges the soil so that the effective rainfall is positive, enabling aquifer recharge (ibid).

2.1.3.2.7. <u>Rainwater infiltration and aquifer recharge</u>

Infiltration is the penetration of water into the soil surface and its percolation through the soil. Soil permeability is the rate at which water is capable of moving through the soil, if it were saturated. Movement is initially through pores in the soil and the rate of infiltration depends on,

".... the capillary tension at the air-water interface and the opposing frictional force between the advancing water (wetting front) and the pore. As pores are filled with water the rate of advance of the wetting front, and consequently the infiltration rate, decreases exponentially. The infiltration rate also depends on the initial soil moisture content, with the rate decreasing more rapidly at higher moisture contents." (Falkland and Custodio, 1991, p.48).

A number of factors determine the maximimum infiltration rate of a soil, called the infiltration capacity (*f*) or 'ponded infiltration rate'. These include soil type, moisture content and the presence of organic matter and vegetation. The deposition of weathered material such as Blue Clay, particularly in the *widien* near the Blue Clay slopes in the west of Malta and much of Gozo, reduces the permeability of the surface. However, when these clay covered surfaces are dry, cracks in the clay act as macropores and allow significant amounts of infiltration, initially. The swelling of the clay upon wetting rapidly reduces the level of infiltration capacity (ibid).

"The infiltration capacity of the soil and the rainfall intensity (*i*) in a storm directly affect the amount of depression storage and surface runoff. For a given soil type, if $f>i$ then depression storage and surface runoff will be nil. However, if $f<i$ then excess water will pond or runoff. The difference between *f* and *i* is termed 'rainfall excess'. Ponded water will either be evaporated or infiltrate after the storm." (ibid, pp.48-49).

Once water has moved through the soil layer, which is relatively thin in the Maltese Islands, it then must travel through the underlying rock layer, via pores, fractures and fissures, before groundwater recharge of the aquifers can take place. Infiltration depends upon the rock type.

"Groundwater recharge can occur naturally from soil water percolating below the root zone and from infiltration of streamflow along watercourses. Recharge can also occur from man-induced sources such as return irrigation flows, leaking pipes and specifically designed artificial recharge areas. In all cases, groundwater recharge is essentially in the vertical direction." (ibid, p.51).

Infiltration capacity is the most important determinant of aquifer recharge. For the Maltese Islands, estimates of aquifer recharge by rainwater infiltration state figures of 16% to 25% of rainfall (Morris, 1952; Newberry, 1968; Chetcuti, 1988; Chetcuti *et al*, 1992). Maintenance of both water tables relies on an annual recharge almost exclusively by the winter rains.

Regional differences in infiltration amounts have already been discussed. There are differences in the percolation time for water travelling down through the ground for the two main aquifers. The yield of springs from the perched aquifers show evidence of being directly related to the amount of rainfall (Briguglio, 1994). Aquifer recharge of this upper water table is rapid, taking a few days, since the depth traveled by percolating water on average is only approximately 15m (University source, 1993).

In contrast recharge of the lower water table takes longer. There is a longer lag time between the time of rainfall and total aquifer recharge, two to three years, mostly due to the distance travelled by percolating water which is, on average, approximately 100m in depth (ibid).

The formation of karsts[2] during sea level changes in the past have had an important bearing on aquifer recharge. The sea last retreated approximately 14,000 years ago and it has risen about 100m since then (due to the still active Flandrian Transgression). Geochemical changes related to seawater movement and groundwater flow towards the coast occurred during this retreat. This resulted in a series of karsts which can be observed today at different levels above sea level. Their form of development and distribution are also related to the tectonic and stratigraphic background of the Maltese Islands. Debono (1994) argues that,

"The horizontal configuration of karsts in Malta would suggest that their development started along bedding planes and paleo-sealevels where flow of groundwater towards the coast caused dissolution of the limestone." (Debono, 1994, p.9).

He notes the underground limestone cave complexes of Ghar Hassan and Ghar Dalam on the southern coast of Malta as examples of this dissolution.

"These karsts bring about a marked anistropy which

---

[2]"Ground water creates landforms in regions with a soluble bedrock, notably in regions underlaid by limestone and dolomite. Ground water dissolves the more soluble portions of the bedrock first and creates sink holes, blind valleys, underground caverns, and residual hills, greatly altering the surface configuration of the land. In regions where solution becomes the dominant process in landform development a unique type of topography is produced known as *karst*. The term *karst* is applied to limestone or dolomite areas that exhibit a topography peculiar to and dependent on underground solution." (Vann, 1971, p.30).

together with the fractures and fissures act as conduits and regulate the general direction of groundwater flow to and within the aquifers." (ibid, p.9).

Bowen-Jones *et al* (1961) have also noted that:

"The presence of bedding planes, joints and fissures is of far more importance in controlling the underground movement of water than are porosity and permeability of the rocks themselves. The Globigerina though it contains important limestones, is composed largely of thick and relatively impervious marly beds, through which percolation is slow and from which run-off is correspondingly rapid." (Bowen-Jones *et al*, 1961, p.43).

It must be stressed again that the estimated 16% to 25% of annual rainfall that infiltrates the surface to recharge the aquifers is not evenly distributed across the Islands' surface. Figures 2.18. and 2.19. have illustrated this uneven distribution of percolation in Malta which is largely attributed to varying surface infiltration properties of different rock types, land use, and topography.

Furthermore, most estimates of aquifer recharge do not account for artificial recharge leaking from water pipes. Spiteri Staines (1987) states that artificial recharge amounts to 3.9% of total annual rainfall and puts the figure for total aquifer recharge at 28% of total annual rainfall (Spiteri Staines, 1987).

Complicating the issue further is the fact that approximately 60% of water supply (and so leakage) is desalinated seawater (p.174) and so is not directly derived from precipitation and hence not a part of the natural hydrological cycle. Furthermore, 17% of Malta's wastewater, 60% of which is derived from seawater desalination, is recycled and used for agriculture (pp.226-241) which reaches the aquifers eventually. Given that all wastewater is to be recycled by 2010 (pp.612-615) and to be used mainly for irrigation and possibly artificial aquifer recharge, and that the percentage of water supply derived from seawater is increasing, this introduces a significant human input into the water balance of the Maltese Islands.

2.1.3.2.8. Aquifer discharge

Aquifer discharge occurs mostly as subsurface discharge. Water that enters the aquifers flows away mostly horizontally. That which is not exploited for human activities continues its lateral flow towards the coast where it discharges into the sea. Debono (undated, *c*.1993) argues that,

"This outflow of freshwater into the sea takes place all around the coast of the Islands in the form of diffused outflow. More concentrated discharge... is conducted through fault planes such as at White Rocks or through karst cavities such as at the Blue Grotto." (Debono, undated, *c*.1993, p.11).

He identifies Burmarrad, Marsa, Msida, Marsaxlokk Bay, the Blue Grotto, Fomm ir-Rih, St. Paul's Bay, Mistra and Mellieha Bay as the major discharge points in Malta. Furthermore, there is an upward flux of freshwater at the freshwater-saltwater interface of the MSLA which discharges along the coast as submarine springs (ibid).

It is a commonly held misperception that freshwater loss to the sea is very small because it is construed to embody only the 6% or so as run-off. As a result, sub-surface discharge is often not included in water balances, such as those by Spiteri Staines (1987) and Riolo *et al* (1993), shown in Tables 2.10. and 2.11., respectively. The Tables which show values for water inputs and aquifer recharge, only show outputs as

Table 2.10. Groundwater balance for the Maltese Islands in 1986

WWD = Water Works Department

Input/Output	Volume 000m3/annum	Percentage
A. Precipitation	124000	100.0
B. Surface run-off	7400	5.9
C. Evapotranspiration	87400	70.0
D. Natural recharge	30000	24.1
E. Recharge from leaks	4900	3.9
F. TOTAL RECHARGE (E+F)	34900	28.0
		Percentage of recharge:
G. WWD gallery extraction (MSLA pumping stations)	11186	32.0
H. WWD borehole extraction	6471	18.6
I. WWD gallery (perched aquifer springs)	562.9	1.6
J. Total public extraction by WWD (G+H+I)	18219.9	52.2
K. Private extraction	3600	10.3
L. TOTAL GROUNDWATER EXTRACTION (J+K)	21819.9	62.5

Source: Spiteri Staines, 1987.

Table 2.11. Groundwater Balance for the Maltese Islands in 1990

WWD = Water Works Department

Input/Output	Volume 000m3
A. Precipitation	85217.3
B. Surface inflow	1164.099
C. Surface water (A+B)	86381.390
D. Surface run-off	2591.441
E. Actual evapotranspiration	68957.780
F. Surface losses (D+E)	71549.220
G. Infiltration into aquifer (C-F)	14832.180
H. Subsurface inflow	752.020
I. Artificial recharge from leakage (30% of N)	5429.478
J. TOTAL AQUIFER RECHARGE (G+H+I)	21013.680
K. WWD gallery extractions	10525.950
L. WWD borehole extractions	7060.995
M. WWD extraction from springs	521.320
N. Total public extractions by WWD	18098.260
O. Private extraction	3000.0
P. TOTAL EXTRACTION (N+O)	21098.260

Source: Riolo et al, 1993.

run-off, evapotranspiration and extraction by humans.

Debono (undated, *c*.1993) appreciates subsurface discharge and puts its contribution to freshwater losses at 12% of total annual rainfall, a relatively significant loss.

However, Spiteri Staines's and Riolo *et al*'s water balances include groundwater extraction for human consumption, which constitutes a much greater output than aquifer discharge. This extraction from the aquifers has rapidly increased as the development of the Islands has demanded the development of water supply (pp.201-202).

2.2. HISTORICAL DEVELOPMENT OF WATER RESOURCES

Without a natural water supply the Maltese Islands would probably not have been colonised on more than a temporary basis. This section discusses the development of water resources and the water supply system since colonisation to the present day.

It has been suggested that on reaching the shore, the very first settlers in the Maltese Islands must have moved inland and settled in areas where natural springs provided fresh water for everyday uses (Hatt *et al*, 1977; Zammit, 1931).

Digging cisterns into the ground is one of the earliest methods of water storage. There is evidence that it has been used throughout Maltese history providing water during dry months and is still used today (p.226), though far less than it could or should be (pp.317-319). The remains of historical cisterns can be found all over the Islands alongside the archaeological remains of these earliest settlements and can be traced back to Medieval, Roman, Punic and Neolithic times.

"Even going back as far as the neolithic period, one can trace man-made cisterns dug in the rock for the storage of rain-water for use during the hot dry months of the year - a necessity for survival. These cisterns may still be seen at the Tarxien Temples [Plate 2.5.] and ol-Misqa, a few metres away from Mnajdra." (Riolo *et al*, 1993, p.3).

Plate 2.5. shows the cisterns at the Tarxien Temples and Plate 2.6. shows a cistern as part of Roman remains on the extreme south-west tip of Gozo (Trump, 1971).

This appreciation of the importance of water is shown by the long tradition of naming every individual spring (*ghajn*) in the Maltese Islands: clear evidence of the importance assigned to each of them (Riolo *et al*, 1993).

".... every little one, guarded and treasured by their owners. Ghajn Tuffieha, Ghajn Dwieli, Wied il-Ghajn in Malta and It-Triq ta'l-Ghajn, and Ghajnsielem in Gozo are today sites of thriving communities. All have got their names and have grown around natural springs." (ibid, p.3).

Not only locals, but incomers realised the crucial importance of water supplies:

In 1530, the Knights of the Order of St. John of Jerusalem, with their need for a fortified outpost, settled in Malta with their soldiers and attendants (Zammit, 1931). Before they arrived, a document was drawn up by a Commission of the Knights sent to Malta to report on the Islands. A translation in Riolo *et al* (1993) reads:

"The water is salty and sedimentary; and the sweeter springs in the island I think come mostly from wintry showers. Their source is not deep, for in Summer they frequently dry up and diminish. Drinking water comes from rain (when there is any) which is preserved in cisterns

Plate 2.5. Underground cisterns at the Tarxien Temples.

Plate 2.6. A Roman cistern in Gozo.

and more frequently in ditches." (ibid, p.3).

At that time the local population, about 25,000 persons (Bowen-Jones *et al*, 1961), were located around these springs (Riolo *et al*, 1993). Mdina was then the only fortified city and the Knights found it dependent on rainwater that was collected and stored in underground tanks, deep wells and springs on the Rabat-Dingli Uplands (Zammit, 1931).

However, when Grand Master La Vallette took charge of the Islands in October 1530, the Knights located themselves at Vittoriosa (Birgu) because their activities were mostly maritime and the natural harbours in the south-east were deemed the most suitable settlement foci (Riolo *et al*, 1993).

The Marsa springs constituted the most important water supply for the Knights; in Vittoriosa, for example, spring water was diverted into cisterns cut into the ground under houses and in the streets. The springs were especially important to, and widely used by, ships in the harbour and by the galleys of the Order (Zammit, 1931).

Probably the first ever recorded conflict over water resources (but certainly not the first conflict) in the Maltese Islands came about with the invasion of the Turks in 1565 and the Great Siege. A strong force was ordered to gain control of Marsa and to secure the springs, invaluable to their military operations. Grand Master La Vallette foresaw that the Turks would try to occupy Marsa on account of its water and knew that he would be unable to prevent them from doing so. Strategically, he asked the chief physician, Camillo Rocco, to make the water unfit for use by the enemy. According to Zammit,

"It is a fact that steps were taken to poison the water of the Marsa, the great tank at Cala di San Giorgio, the well of Cala di San Tomaso and other fountains, by means of a mixture made from hemp, wheat, arsenic and other ingredients. The water thus treated is said by Bosio to have caused great trouble and mortality among the barbarians until they discovered how to purify the supply." (Bosio, 1695; Zammit, 1931, p.7).

During the Great Siege, the fact that Vittoriosa did not have an adequate water supply caused many problems. These were resolved on the 21st of July 1565 when a cistern was discovered under a house that was found to be connected to a spring which, although brackish, was fully used by the public (Zammit, 1931).

During the construction of the city of Valletta, one of La Vallette's greatest concerns was the provision of water. At the time, water was being transported from Marsa by boat, employing thousands of workmen. A large number of tanks were therefore excavated to store rainwater. The discovery of a spring in the city was interpreted as a miracle by Christians of the time (ibid). A fountain was erected on the spot, called the Grand Fontana, but unfortunately the spring soon declined to a dribble which was, presumably, not seen as equally miraculous (ibid).

By 1596 the question of water supply had become yet more serious. Consequently, Grand Master Garzes called Padre Giacomo (a consultant) to help. Giacomo devised a scheme to carry spring water from the west to Valletta, but due to the lack of funds work was postponed (ibid).

The years 1608 and 1609 were exceptionally dry and water became a priority as droughts became common. In 1610, Grand Master Wignacourt, following the drought years, acquired the services of Padre Natale Tomasucci, a water engineer. As a result, water from a number of springs in the west of Malta was conducted, via stone channels, to a tank in the Fiddien Valley (today water from these springs is still collected at the Fiddien reservoir for public supply). The water was conveyed east to Valletta via an aqueduct. On the outskirts of Attard the aqueduct was made to pass over two series of arches and was for some part buried underground. Remains of these arches can still be seen in Attard (Plate 2.7.). The total length of this aqueduct from Rabat to Valletta was 13km. Another aqueduct from Fawwara Spring was constructed in 1840 to serve Mqabba, Luqa, Tarxien, Paola, Cottonera, Gudja, Ghaxaq, Zejtun and Zabbar (Cassar, 1988; Spiteri Staines, 1987; Zammit, 1931).

The Gozo aqueduct, also constructed in 1840, was one of the first developments in the integration of Gozo's water supply and involved the uniting of the Ghar Abdul and Ghar Ilma springs and the water being carried in a stone channel aqueduct over stone arches and a tunnel through the Mixta Hill, to discharge into a reservoir at Santa Lucia. This like the Wignacourt aqueduct has long been unused and left to ruin (Plate 2.8.) (Zammit, 1931). Such rapid abandonment of developments like these is symptomatic of what happens in the Islands as soon as new developments are introduced (as was the case with small scale open reservoirs (p.182), introduced in the 1970's and 1980's).

From the second half of the nineteenth century, when the population grew rapidly, both spatially and absolutely, special scientific attention at last began to be given to the water supply of Malta. Early writers of Maltese hydrogeology had believed that the springs owed their existence partly due

".... to the rain which fell on the high land to the west of the Island, and, quite wrongly, partly due to the sea water which was purified and sweetened by filtering through the rock." (ibid, p.14).

In 1854, Dr. Nicola Zammit's essay on, "The Water Supply of Malta" was offered a prize by the Literary and Scientific Institute of Malta. In agreement with Zammit's views it was proclaimed that Malta's springs

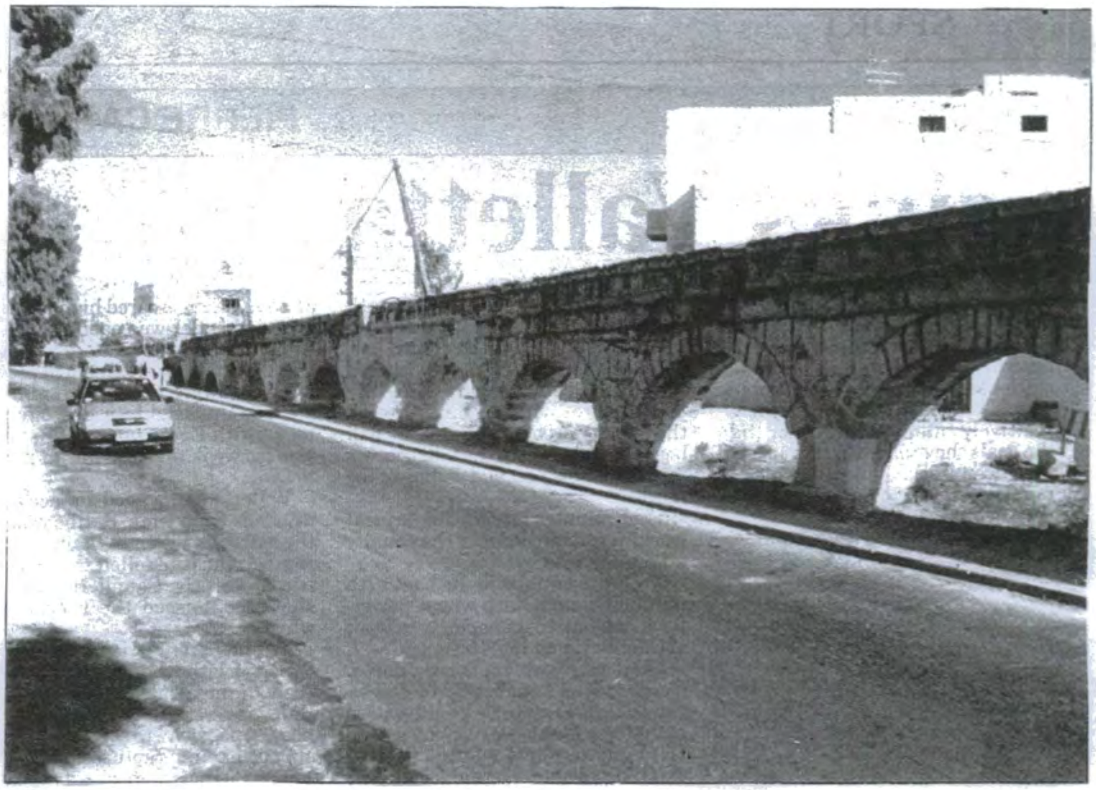


Plate 2.7. The Wignacourt aqueduct in Attard.

Plate 2.8. The ruins of the aqueduct in Gozo.

".... were branches of a vital current of water running through the globe totally independent of local circumstances, and they considered the fact that our springs lost so little of their volumes after the two years of drought in 1839 and 1840, to be a conclusive argument in proof of this." (Zammit, 1931, p.17).

On the basis of this gross misconception it was decided that this 'subterranean stream' would be tapped via artesian wells. The first such well was sunk in 1851, on Zammit's recommendation, at Armier (Spiteri Staines, 1987; Zammit, 1931).

Until the mid-nineteenth century 80% of potable and other non-irrigation water demands had been met by the perched aquifer (Tricker, 1977). The MSLA was first exploited in 1856 near Marsa to provide water for the shipping and naval establishments on the south side of Grand Harbour (West, 1975). Tricker (1977) stated that,

"Since 1856 the total water demand in Malta has outstripped the supply potential of the Upper Water Table [perched aquifer] and there has been a systematic exploitation of the Lower Water Table [MSLA]." (Tricker, 1977, p.119).

For instance, by 1864 extensive works had been undertaken by the Government to drill shafts and drive horizontal galleries (underground tunnels for collecting percolating groundwater) in the rock of the Rabat-Dingli Uplands and beyond the Fiddien Valley to collect groundwater (Zammit, 1931).

Again, according to Zammit, from 1864 to 1866, 175 wells were sunk and 7,590m of connecting galleries were constructed in the perched aquifer, mostly around Rabat. This added 680m^3 (150,000 gallons) per day to the supply, about one half of the aqueduct supply at the time. The belief that Maltese springs were independent of local conditions, i.e. were fed by submarine aquifer flow from surrounding mainlands, had to be discarded when the geology of the Islands was better understood and rainfall records improved (ibid).

The cholera epidemic of 1865 led sanitation experts to stress the lack of ample provision of water. The first ever comprehensive chemical analysis was undertaken that year. Valletta's main source was still the Bingemma Hills via the Wignacourt aqueduct (providing 2,440m^3/day (537,000 gallons/day) in 1861), while Cottonera was being supplied by the Fawwara aqueduct with water from more springs at 420m^3/day (92,000 gallons/day). Also a well had been sunk at Marsa to supply the shipping and upper end of Grand Harbour (Spiteri Staines, 1987; Zammit, 1931).

In 1867, Charles Andrews was the first to suggest a plan to improve water supplies by damming some valleys and ravines to give rise to small reservoirs (Zammit, 1931).

In the 1870's it was warned that rainfall had become very scarce in recent years and criticism was made of the fact that no effort had been made to store the winter excess. In response, the Government, in 1866, had to buy water flowing in two gardens owned by the Bishop and distil seawater (pp.182-184) to supply Cottonera.

In 1876, Dr. Adrian Dingli proposed a scheme to make the water supply more reliable and plentiful. His emphasis was on storage and the construction of several tanks and also the laying of iron pipes to carry excess to the south of the Island. For Gozo, he proposed similar storage arrangements. That same year, Mr. Unsworth, a consultant, proposed to the Government the construction of an uncovered reservoir with a storage capacity of 318,220m^3 (70,000,000 gallons) of water. Neither Dr. Dingli's nor Mr. Unsworth's proposals were taken up (ibid), but other works did continue: in 1878, for instance, a large tank, called the 'Bouverie', was constructed on Corradino hill which was connected with the Fawwara aqueduct (ibid).

1881 was a very dry year, adding weight to earlier warnings, and as a result of this a distillation plant was quickly constructed in Sliema, on the Tigne Road, to try and alleviate the water shortage. Distillation was, however, considered an expensive luxury and had previously only been used once in the Three Cities (Cottonera) (ibid).

The population increases in Malta and Gozo and several droughts made the water question more and more urgent each year. In 1883, Mr. Osbert Chadwick, who was to be remembered in Malta not least for his "Lakes", was asked to advise the Government. He undertook a comprehensive study of the water situation in the Islands including calculations of water production from springs, run-off losses, the upper water table and the distribution and collection of water (Spiteri Staines, 1987). The Government used his advice extensively and substantial amounts of money were spent in order to act upon some of his recommendations, which included the start of work on the Wied il-Kbir, St. Anton and Wied is-Sewda pumping stations (Brincat, 1979). Until 1885, except for the maintenance of the aqueduct, only small amounts of money had been spent annually on the water service. At the start of 1885, a substantial amount of money was voted by the Council for the reorganisation of the water supply (Spiteri Staines, 1987; Zammit, 1931).

Under Mr. Chadwick's proposals, the Dingli pumping station was constructed (West, 1975) and associated galleries were cut at sea level in 1885. They had a total length of 700m (2,300 feet) and were connected by 14 shafts sunk between Rabat and Dingli. The aim was to reach the freshwater body lying over salt water (Riolo *et al*, 1993). These developments led to a significant improvement in hygienic conditions in most parts of Malta (Cassar, 1988).

The Santa Maria reservoir, with a storage capacity of 54,550m^3 (12 million gallons), was completed in 1886 at Ta' Qali. Today it is known as the Ta' Qali reservoir. Its location at 90m (300 feet) above sea level gave sufficient head to supply districts east of Attard. It is cut out in the rock, completely covered and is enclosed by a high wall (Zammit, 1931). Before this, public water storage only occurred in small domestic cisterns which were required, by law (a law unfortunately no longer in force), for each household to collect water in winter (pp.161-162) (Riolo *et al*, 1993).

In 1885-1886, a dam, 4.2m (14 feet) high, was constructed across the Qleigha Valley, to the west of Mtarfa Hill. For a few years this satisfactorily provided irrigation water for agriculture and the orange gardens in Attard. However in 1902, a severe epidemic, believed to be water-borne, broke out in the valley. The impounded water served as a breeding ground for the malaria mosquito which fed on the ague, became infected and carried the disease, affecting most people living in the valley. Consequently, the water was, for a while, allowed to run off into the sea (Zammit, 1931).

In 1887, the galleries and pumping station at Wied il-Kbir started to produce water. Water was provided via a water main distribution system to Valletta, Floriana, Sliema, Birkirkara, Zebbug, Siggiewi, Rabat and Mdina. 1887 also saw the beginning of water metering in domestic premises (Spiteri Staines, 1987).

By 1890 piped domestic water supply was common and according to Cassar (1988), until the introduction of bathrooms in the 1920's and 1930's, personal cleanliness was generally rare. Personal cleanliness is something that is relative in time and space and his view should be disregarded. Just because people did not have bathrooms did not mean that they were unclean.

Between 1887 and 1893, the Government spent large sums of money to ensure a reliable water supply for the Maltese Islands. The improvement of the water supply in

Gozo closely followed that of Malta (Zammit, 1931).

In 1896, Chadwick produced a report on the water supply of Gozo and acting on his recommendations, a series of shafts were sunk and galleries driven to develop the island's water supply. A pumping station was erected at Mgarr Ix-Xini and major reservoirs constructed at Mgarr, Victoria, Nadur, Ta' Cenc and Sannat (Zammit, 1931). Small dams were also constructed in the Wied il-Qleigha to conserve run-off, giving rise to the Chadwick Lakes (West, 1975).

As a result of an outbreak of typhoid in 1909, Sir Temi Zammit, the Government water analyst, introduced the chlorination of potable water supplies (Spiteri Staines, 1987).

During the war years, 1914 to 1918, no money was spent on new gallery construction but production from the MSLA did increase to meet the heavy demands of the war, especially from military hospitals. This involved the construction of a new pumping station near Tal-Hlas (West, 1975).

In 1916 the urgency of war time demand for water and the need to increase supplies led Lord Methuen to seek the advice of Colonel J.C. Robertson, a sanitary officer in the Malta Command. He recommended the chlorination of high level springs so that shallow springs, which had been cut off from the public supply, could be used again because there was no longer the danger of contamination. He also stressed the need to stop the theft[3] of water via

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[3]Water theft had increased mainly due to the legislation of water access rights. Whereas previously private extractors of water (mostly farmers) need not have obtained permission to drill boreholes and could extract as much water as they wanted, now such activities were increasingly regulated by the Government and any breach of these regulations constituted theft.

private wells and shafts from nearby Government galleries (ibid). In the same year, Colonel Raban, a civil engineer, was asked to suggest improvements to meet military demands. On his advice a 45,500m^3 capacity reservoir was constructed to the west of Luqa village, to receive water from Wied il-Kbir pumping station, before it was conveyed in iron pipes to Grand Harbour (Zammit, 1931).

During the 1920's, numerous water works were undertaken in Malta and Gozo. These included the sinking of new shafts, extensions of the gallery system and the laying of 50km of new pipe mains. Under Roberton's recommendations, two galleries and pumping stations were built at Wied Dalam (between 1920 and 1925) and Wied il-Ghasel (between 1925 and 1938). The former failed because it yielded very little and highly saline water (West, 1975).

In 1931 Sir Temi Zammit recommended that there needed to be more concentration on the development of the MSLA, because it was the easiest and most economic solution to Malta's water supply difficulties. However, he stressed the need for conservation and equity in water resources management (ibid, Zammit, 1931). He warned:

"The water works engineer cannot stand still and smile at the past, he must find out if more water can be had and how it is possible to increase the supply. It is his duty to show how to avoid any waste of the precious element and how to ensure that all the available water be managed, stored and distributed for the use of all, and not allowed to become the monopoly of a few. An element of the first necessity of life should be common property and under strict public supervision." (Zammit, 1931, p.47).

Zammit's caution has not been heeded in practice and today many of the water problems in the Maltese Islands are to a large extent caused by the over-reliance on the MSLA, the inequitable distribution of water supply and its wasteful consumption (water problems are discussed in Chapter 5).

The period 1934-36 saw the holding of two committees on water production and water supply: the Agricultural Committee and the Water Supply Committee. They were the result of the increasing lack of direction in the outlook of the Water Department, no longer guided by Chadwick who had left Malta. Unfortunately, suggestions made by both committees were fraught with contradictions and the Agricultural Committee was particularly disregarded by the Government. By 1938 the Wied il-Ghasel pumping station was complete as well as 2000m (6,600 feet) of associated gallery. Unfortunately, the salinity of the water rapidly rose to the point where it was unfit for consumption. The Water Pumps Ordinance was passed in 1938, prohibiting the modification of existing wells and the drilling of new ones over a large part of the Upper Coralline areas and subjecting the use of water pumps to the authority of the Water Board (West, 1975; Spiteri Staines, 1987).

As a result of this exploitation and ever-increasing demand, by 1945, 80% of total piped water supplies was supplied by the MSLA (Tricker, 1977). The heavy water demands of the Second World War, from shipping, British troops and hospitals, had resulted in the drilling of numerous boreholes, the construction of the Ta' Qali pumping station and investigations into water derivation schemes at Bingemma, Ta' Falka and Mizieb (Brincat, 1979). However towards the end of 1943, the Water Department suffered setbacks in well-boring because of the war-time conditions and was also seeing bad results in terms of quantity and quality of water supply (West, 1975). Malta had to resort to importing water from Sicily at an average rate of 22,730m^3 (5 million gallons) per month to tackle a water shortage created by low rainfall and the demands of the large number of British military personnel (Riolo, 1985). No doubt this was a difficult task given that the water tankers would have been attacked by German war planes. The war time exodus from the harbour towns to the Rabat and Zebbug areas increased water demand there, which was met by the installation of a booster pump at Ta' Qali to bring water from the Tal-Hlas station. By 1944, the realisation that the MSLA was depreciating in quality prompted a return to extraction from the perched aquifer. Consequently, by 1947, extensions had been made to the Wied il-Ghasel galleries, adding approximately 136m^3 (30,000 gallons) of water per day. By 1949, further gallery works were undertaken at Tal-Lunzjata in the perched aquifer and in 1951, the Ta' Bakkja pumping station and associated shafts and galleries were constructed in the MSLA (West, 1975).

The need to increase water supply and make it easily accessible to the main areas of consumption prompted T.O. Morris to devise a scheme, in 1944, for the construction of a new gallery system in the MSLA and a large central pumping station at Ta' Qali. A further large pumping station was constructed at Ta' Kandja. These two schemes were implemented between 1944 and 1957 and yielded much more water than had been anticipated and of lower salinity than the other stations (ibid). Unfortunately, this poor level of prediction often worked in the opposite direction, with many instances where the yield of water was expected to be relatively good, in terms of quality and quantity, and proved not to be so. Such poor anticipation of likely yields illustrates just how little hydrological surveyors of the time knew about the groundwater they were trying to study.

In 1952, T.O. Morris completed a historical survey on the water resources and hydrology of the Maltese Islands (Briguglio, 1994). To a large extent it formed the basis of water supply development policies for the next two decades (ibid). Under Morris's recommendations, Ta' Qali, Ta' Kandja (as previously stated), Ta' Bakkja and Ta' l-Isperanza pumping stations were constructed in the MSLA and Bingemma, Ta' Falka, Mgarr and Mizieb pumping stations in the perched aquifer (Brincat, 1979). However, he warned that the MSLA had already been over-exploited and that supplies would soon be unfit for consumption if the rate of extraction was not reduced (Tricker, 1977).

During 1955-56, plans for the construction of 45 small dams to conserve run-off in *widien* were undertaken, primarily to provide water for irrigation. By 1975, 60 such dams had been constructed (ibid). Between 1955 and 1961, as a part of a vast water development programme and largely due to Morris's recommendations, shafts and galleries were sunk at Bingemma, Falka, Mgarr, Mizieb and Ta' Zerb, machinery was installed at new pumping stations, the Fiddien and Qrendi reservoirs were constructed, plans for new galleries at Ta' l-Isperanza and Ta' Bakkja were drawn and large diameter mains were laid (Newbery, 1968; Spiteri Staines, 1987).

By 1958, Malta's water supply network consisted of approximately 725km of trunk and distribution pipelines with diameters up to 24 inches. By 1978 the network had reached 863km, a 16% increase in as many years. Supply pipes of three and four inches in diameter formed the bulk of this system. Only pipes conforming to so-called British standards were used, which were considered to be a marked improvement on older pipes. After 1964 (Independence year), further improvements in pipe quality were made including an internal and external coating of bituminous solution, the latter with a cement lining to try and prevent encrustations (Naudi, 1979).

From 1959 to 1964, the main water strategy outlined in the first Development Plan was to intensify borehole drilling in the MSLA, a policy of the (Maltese) Labour

Government which rejected desalination as too costly. The plan also stressed the need to lay trunk mains, develop pumping stations, complete galleries, construct irrigation dams and reservoirs, renew mains and undertake hydrological research. A substantial sum of money was spent on achieving these aims (Brincat, 1979).

During the period 1965 to 1969, the Atiga Consortium was commissioned by the World Health Organisation (WHO) to conduct an in-depth study of the activities and records of the Water Works Department (WWD) and survey the potential for wastewater treatment. As a result of this there was a drive towards reducing wasted water by leakage detection in the distribution network. It was claimed that by the end of 1978, leakages had gone down from 47% of the equivalent of consumption to about 28%, an impressive saving, given the absolute rise in consumption during this period. Many faulty meters (pp.438-439) were also replaced (Brincat, 1979; Spiteri Staines, 1987; Briguglio, 1994).

Also during this period four multi-stage flash distillation units were installed in Malta to convert seawater to potable water with a total production capacity of 20,000m^3 per day (pp.182-184) (Briguglio, 1994). This was the result of the realisation that the yield from the perched aquifer was being curtailed by private extraction, while there was a need to reduce pumping from the MSLA due to its rising salinity. The first distiller went into operation in 1967, followed by three others in 1969. In a political context they were the result of a change in Government and the second Development Plan for the years 1964 to 1969 which, drawn up under the new Nationalist Government, advocated desalination and hence contradicted the first (Labour) plan. The (still Nationalist) Development Plan for 1969-1973 continued this policy and in 1971 the Gozo distillation plant was inaugurated. In the same year, the Labour Party, back in Government, made major policy changes in the plan for 1973-1980, particularly with regard to the distillation plants, reminiscent of their 1959-1964 plan. In 1973 the plants were deemed uneconomic due to the oil price increase that year and distillation was phased out (Brincat, 1979; Spiteri Staines, 1987).

A number of water experts were commissioned during the early 1970's to report on various aspects of the water production problem, most prominently, Ciocardel (Brincat, 1979). He recommended the drilling of two lines of boreholes (15 in total), one parallel to the Ta' Kandja/Ta' Bakkja gallery and one in a south-easterly direction from Ta' Kandja to Zurrieq. He warned that in the event of a sudden increase in the salinity of a borehole's water, it should be blocked or used only as a gauging hole. He also suggested the sinking of two or three boreholes in the central part of Gozo to increase the supply there and the exploration of the aquifer north of the Victoria Lines and of what he thought were "deeper aquifers" below sea level. He warned, like Morris before him, that despite the drilling of new boreholes, the total extraction from the MSLA should not be exceeded because it had reached its maximum limits (Ciocardel, 1972).

After Ciocardel's report in 1972 and the reduction in distillate, under the aims of a seven year (as opposed to five) Development Plan for 1973-1980, an intensive borehole drilling programme, in line with Labour policy, was commenced to increase water production. Groundwater production increased from the mid-1970's throughout the 1980's (pp.201-202) (Brincat, 1979; Briguglio, 1994). Malta's close relations with Libya led to the latter donating a Massarenti Rotary Percussion Rig in 1974 to help with Malta's borehole drilling programme (Spiteri Staines, 1987), although indirectly far from helpful because of its contribution to the decline in the condition of the MSLA. Between 1973 and 1978, 81 new boreholes were drilled in the MSLA, despite Ciocardel's cautionary advice (Tricker, 1989).

The 1973-1980 plan also aimed to reduce water losses (Brincat, 1979) and the conservation of water in catchments was a strategy which led to the building of more small dams in *widien* (Park, 1977).

Between 1976 and 1977 a number of water surveys were undertaken in Malta, including a study by Professor G. Serrini (EC) of the chemical composition of water and the growing nitrate pollution problem (pp.374-393) and Dr R. Dijon (UN) whose report stressed the need for a national water policy (Spiteri Staines, 1987).

In 1978, a seminar, under the Economic Commission for Europe, was held to determine the optimum management of groundwater and its relation to surface water, groundwater quality, desalination and wastewater re-use. In the same year, Swedish consultants drew up a report, based on the work of the Atiga Consortium and initiated a study into wastewater recycling (which culminated in the operation of the Sant Antnin Sewage Treatment Plant in 1984) (Brincat, 1979; Tricker, 1989).

The Ta' Cenc reservoir in Gozo was completed in 1979. In 1980, two Percussion Boring Rigs and spare parts were donated by the United Arab Emirates. Also that year, the *Risq il-Widien* project was implemented to erect more dams in *widien* and reduce run-off losses. In 1981, the Xaghra reservoir in Gozo was completed and a polythene submarine pipeline was laid to convey water from Gozo to Malta (Spiteri Staines, 1979). In the same year a pilot water treatment scheme was initiated to bring run-off water up to potable standards. A treatment plant was constructed at Corradino. A combination of this and the water catchment schemes helped ease the demand on the MSLA by producing 22,000m^3 of water per annum. By 1984, two other water treatment schemes were in operation, at Santa Lucia and Siggiewi (Tricker, 1989).

Developments in the laying of mains, detection of leaks in pipes and drilling of boreholes has taken place on an annual basis. There certainly must be, or should be, a finite limit to the number of boreholes that can be drilled and operated but astonishingly, this did not seem apparent at the time. Between 1974 and 1991, 560km of new mains were laid (including the Malta-Gozo submarine pipeline in 1981), 358km of mains were renewed or replaced and over 40,000 leaks were detected and repaired (Briguglio, 1994).

The 1980's saw the start of a trend towards heavy investment in desalination technology using the process of reverse osmosis (RO) (pp.184-191). This continued into the 1990's and by 1993, five reverse osmosis plants and twelve pumping stations were in operation. Sewage recycling technology was introduced in 1984 with the inauguration of the Sant Antnin Sewage Treatment Plant to provide irrigation water.

This rapid development and application of water resources technology and production techniques in the Maltese Islands illustrates just how important water is to the Islands' economic and social development and survival. Although discussion has been limited to just a few, several large water storage reservoirs were constructed to cope with the increasing water supply and its distribution. Further reference to these is made on pp.242-244.

2.3. CONCLUSION

The Maltese Islands are small with a semi-arid climate characterised by relatively low rainfall and high temperatures. Evapotranspiration rates, which vary significantly across the Islands mainly due to variations in surface catchment characteristics, are high. Rainfall is concentrated in short bursts which lead to a significant loss to the sea, but, fortunately, also reduce exposure to evapotranspiration. Water is also lost via subsurface discharges. The result is a water deficit during the summer months and a water surplus for the rest of the year.

Fortunately, the Islands' physiography and geology favour the interception and storage of rainfall, giving rise to the MSLA (a freshwater lens resting on seawater), the perched aquifer and several subsidiary perched and semi-confined aquifers. Aquifer recharge occurs mainly during the winter due to the infiltration and percolation of rainfall. To facilitate this and to create surface water supplies, several dams have been constructed in *widien*, which along with perched aquifer springs, are the only watercourses on the Islands.

Collected rainfall in cisterns and perched aquifer springs were the first sources of water supply to be tapped, followed by the large scale extraction from the MSLA this century. This development was rapid and involved the drilling of boreholes and the construction of pumping stations, galleries, reservoirs and a public water distribution system. Desalination technology became a necessity when it was realised that the increasing demand for water could not be met by conventional sources of water supply.

What is disturbing about the course the development of water resources in the Maltese Islands has taken, is the fact that it has been so rapid, with what seems like very little planning and control. Most of the many developments since the mid nineteenth century seem to have been based on a rapid response philosophy, rather than a long term plan. Spring water and rainfall that had sufficed for centuries soon became insufficient with the onset of modern life. Groundwater extraction was seen as the all embracing and endless solution to the increasing demand for water associated with modernity (Chapter 4). Yet even this was insufficient, in terms of quantity and supply, and desalination technology is now embraced as the Islands' saviour. Being surrounded by water, there is obviously a tendency to believe that in the mid term, if not the short term, it is this water which can be converted into a permanent supply for the Maltese islanders. To try and control demand itself has only recently become a serious consideration. Pumping stations, boreholes, etc. just seem to have been installed wherever and whenever it was convenient to do so. Of course, there has been the advice and warnings given by a number of water experts and one would assume that water development would have been the best it could have been, in terms of sustainability and resource economics, under their wisdom and guidance. Unfortunately, left to their own devices and authority, the developers of Maltese water resources have developed too much too quickly with the result that the natural resource base has deteriorated almost to the point of exhaustion in terms of both water quantity and quality (Chapter 5). This seems somewhat ironic, or even tragic, given that they were given so much help and advice over such a long period. Along with other complex factors, dealt with in this study, mismanagement has resulted in water scarcity, which has given rise to a variety of related problems: physical, institutional, social, and geopolitical, the subject matter of this thesis.

CHAPTER 3
WATER SUPPLY

3.1. INTRODUCTION

Water supply in the Maltese Islands is of two kinds - first class and second class - the former being potable and the latter of a relatively inferior quality. This division of the water supply is very different to, and an advance on, many other countries where water supply is either solely first class water or solely second class water.

The Government mains supply is first class water and is the responsibility of the Water Services Corporation (WSC). Second class water is obtained and distributed on a completely different principle but is also under the WSC's jurisdiction.

This Chapter discusses the role of the WSC and its legislative responsibility with regards to water supply; the legal aspects of water supply and use (given the meticulous and concise way in which legal documents are couched it is difficult to summarise them. Hence, legal statements concerning the WSC and water supply are selectively quoted); the price of water; sources of first and second class water and their respective uses in each sector of the economy; and the distribution of water.

3.2. THE WATER SERVICES CORPORATION

The WSC was established in January 1992 by the Nationalist Government. Previously it was known as the Water Works Department (WWD). The change from WWD to WSC has involved a reorganisation of the public service sector in general to allow the Government to improve its management (WSC sources, 1993).

Appendix 2 is the WSC's portfolio which shows the structure and division of the WSC and details the duties of each section. In summary:

"The Financial Services Branch caters for groundwater exploration and management (including pollution control), desalination, water treatment and second class water.

The Distribution Branch caters for distribution system works - pipelaying, maintenance and water conservation - and manages the district offices.

The Engineering Services Branch provides engineering back-up to the Organisation.

There is also an Information System Division. The Institute of Water Technology, whose mission is consultancy, education, training and development, is run on an autonomous basis.... [pp.643-645]." (WSC, 1993b, p.1).

The Production Branch is responsible for water production.

The WSC's duties and powers are laid down in Part 2, Section 18 of the Water Services Corporation Act (House of Representatives, Parliament, 1991):

"(1) (a) ....the Corporation shall, in so far as it is able to do so:-

(i) supply water to such persons, in such a manner and under such conditions as, in the opinion of the Board, are calculated to satisfy reasonable demands for water;

(ii) take such steps from time to time as may be necessary for ascertaining the sufficiency, pressure and wholesomeness of water supplies;

(iii) take all such actions as it may from time to time consider necessary or expedient for the purpose of conserving, redistributing or otherwise augmenting water resources and of securing the proper use of water resources." (House of Representatives, Parliament, 1991, pp.793-794).

The Act also gives the WSC the power to suspend or cut supplies:

"(4) (a) The Corporation may reduce as it thinks fit the quantity of water supplied to any customer, if, by reason of any unforseen circumstances beyond the control of the Board, it appears that the supply of water is insufficient to enable the full quantity to be conveniently supplied [for example where drought conditions or unexpected demands cause shortages, or where deliberate water cuts are introduced to try and ration groundwater supplies when shortages are envisaged (pp.330-346)].

(b) Where:-

(i) The supply of water to specified premises is insufficient or unwholesome to the extent of causing a danger to health [pp.356-358], and

(ii) the supply of wholesome water by the Corporation for domestic purposes is required for these premises and it is not practicable to provide such a supply in pipes, but is practicable to provide such a supply otherwise, at a reasonable cost,

it shall be the duty of the Corporation to provide a supply of wholesome water otherwise than in pipes for domestic purposes to those premises." (ibid, p.794).

This "supply of wholesome water" is often provided by bowsers (water trucks referred to on p.242 and Plate 3.23.) but since this service is limited and inefficient, usually, water of very un-"wholesome" quality is drawn locally and directly from the ground and supplied to several settlements suffering from shortages (pp.371-374).

It is envisaged that the whole water cycle from supply to discharge will be eventually managed by the WSC. The WSC Act places duties such as the treatment, re-use and disposal of sewage water under the responsibilities of the WSC, but presently they are preoccupied with the difficult task of supplying water alone. Beyond the consumption stage, the water cycle is still under the Drainage Department's jurisdiction (ibid; WSC source, 1993).

The WSC headquarters are at Luqa and on the same site is the Institute for Water Technology, established to train employees.

The Corporation has to consider all the relevant criteria in order to determine production levels. Most importantly it needs to consider variations in water demands, particularly the location, time and duration of peak demands (WSC source, 1993).

3.3. WATER RESOURCES LEGISLATION

Legislation regarding water consumption in the Maltese Islands reflects the scarce nature of water and the need to conserve it and protect it from pollution and misuse. Unfortunately, enforcement of these laws has been almost non-existent (p.318). Legislation is aimed mostly at the prevention of water misuse and theft (WSC, 1990).

The most important legislative instruments are the Water Services Corporation Act 1991, the Water Supply Ordinance 1886, and the Water Supply Regulation 1948. The latter two enact regulations in respect of house services and the distribution of water to the public (House of Representatives, 1948; 1991).

Each household in Malta is required by law to have a water meter to measure consumption, which is charged accordingly via a billing system. The Water Supply Regulation 1948 states:

"All constant supplies shall be measured by a meter... Meters shall be sealed by the Department, and the consumer shall be held responsible should the seals be found broken or tampered with at any time" (Falzon, 1973, p.258).

The other main legislative instruments include the following laws:

Section 113 of The Code of Police Laws states:

"Every house shall also have a cistern in good condition of a capacity of at least sixty cubic feet for every thirty square feet of the surface of the floor of each room of such house.... The cistern.... shall be made to communicate with the roof of the house, by means of pipes sufficient for the passage of the rain water falling on the said roof." (Legal (Publishing) Enterprises, 1984, Chapter 10, 339).

In addition, Section 117 of the Code states that,

"The owner of any building shall keep in a good state of repair, the cistern.... " (ibid, p.347).

And in Section 97 that,

".... the cistern.... shall be made to communicate with the roof of the house, by means of pipes sufficient for the passage of the rain-water falling on the said roof." (ibid, p.335).

This reflects the scarce nature of water in the Maltese Islands and the need for decentralised rainwater collection.

The Underground Water Ordinance 1943 was amended in 1958 (section 12) in order to conserve groundwater supplies from private extraction through boreholes, which could previously be sunk without permission:

" (1) The sinking by mechanical means anywhere in Malta, of any bore or shaft in search of underground water by any person or body of persons other than the Government is prohibited except by a special permit of the Minister responsible for water supply.

(2) The Minister responsible for water supply shall have, at all times, the power to vary or revoke in his discretion any permit previously given by him...." (ibid, Chapter 114, p.6).

The Irrigation Ordinance 1939 states the same in section 6, part 1, but being older is limited to irrigated land:

"No person may, in any irrigation area, without the permission of the board, sink any well, or borehole, or dig any trench for the purpose of obtaining underground water, or carry out any work whatever which reduces or interferes with the Government supply of water in the area." (ibid, Chapter 105, p.681).

The Underground Water Ordinance updates this law to include all areas, not just irrigated areas, due to what was the rapidly growing number of boreholes in previously non-irrigated areas and for industrial and commercial use (WSC source, 1995).

The Building Permits (Temporary Provisions) Act 1988, Policy for the Erection of Buildings Outside a Developed Area concerns itself with the protection of groundwater from pollution:

"Outside developed areas, overriding consideration is to be taken of.... the conservation of the water table, of other sources of water and other natural resources...." (Legal (Publishing) Enterprises, 1984, Chapter, 322, p.197).

The Act also only allows the location of agricultural/farm buildings where:

".... the building is intended for the purpose of animal breeding or farming provided that such use is not liable to contaminate a water catchment area and the site is distant by at least 200m from an inhabited area or an area which is intended for residential or touristic development." (ibid).

This Act reflects the need to protect groundwater sources from pollution, particularly given the close proximity of pollution sources and groundwater extraction points in these small islands.

The Food, Drugs and Drinking Water Act is a more recent and comprehensive law that protects water supplies from any polluting source and not just buildings. Section 24, part 1 states:

"It shall not be lawful for any person to contaminate or pollute the water of any source of supply being water which is used, or is likely to be used, for drinking purposes, in the preparation of food for human consumption, or in the growing of crops for use as food for human consumption." (ibid, Chapter 231, p.404).

Laws that exist to prevent the misuse and theft of first class water supplies are important since it should not be used where second class water will suffice:

"Moreover, it is forbidden to use first class water for such uses as irrigation, for which second class water may be used. First class water is here defined as water that is suitable for human consumption, in contrast to second class water, which is not." (Ministry for Development of Infrastructure, 1991b, p.46)

Section 283 of The Code of Police Laws governs the theft of water:

"In the cases set forth in the second paragraph of subsection (1) of section 264, the theft aggravated by 'means' shall be deemed to be completed when the communication therein mentioned is effected, and the offender shall be liable to the punishment laid down in subsection (4) of section 278, unless it is proved that the value of the water, gas or electric current stolen exceeds ten liri[1]" (Legal (Publishing) Enterprises, Chapter 9, p.166).

Subsection (1) of section 264 states that,

"'Breaking' shall include.... any breaking, twisting, wrenching, or forcing of the pipes of the public water service.... or of the meters therof or of any seal of any meter made for the purpose effecting an

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[1]Maltese liri = Lm; Lm1 = *c.*£1.75 in 1993.

unlawful communication with such pipes.... or the existence of artificial means as are mentioned in subsection (2) of this section, shall also be deemed to be 'breaking'" (ibid, p.161).

Subsection (2) states that,

"In the case of breaking of pipes of the public water service.... or of the meters therof, or of any seal of any meter or in the case of the existence of artificial means capable of effecting the unlawful use or consumption of water.... or capable of preventing or altering the measurement or registration of the quantity used or consumed, shall, until the contrary is proved, be taken as evidence of the knowledge on the part of the person.... of the said use or consumption of water...." (ibid, p.161).

As mentioned in section 283 the punishment for water theft aggravated by 'means' is laid down in subsection (1) section 278:

"Whosoever shall be guilty of theft aggravated by 'means' only shall be liable to imprisonment for a term from five months to three years" (ibid, p.164).

This is so except where the value stolen is ten liri or less as laid down in subsection (4) of section 278:

"Where, however, the value of the thing stolen does not exceed ten liri, the court may... apply in each case the punishment of imprisonment for a term from five to nine months" (ibid, p.165).

The importance of these laws falls into significance in Chapter 5 (pp.440-445) where their poor enforcement and breaching are discussed.

3.4. WATER TARIFFS

With the exception of recycled sewage effluent (pp.226-241) charges are placed only on first class water supplies in the Maltese Islands. Water tariffs vary according to the type of water consumption. Factors include the financial situation of the consumer, the importance of attracting industrial investment and curtailing the use of first class water where second class will suffice.

The different water rates for each sector and activity are shown in Table 3.1. The lowest water tariff, and hence the most heavily subsidised, is the industrial tariff. The tariff for boathouses, gardens and fields is relatively high to discourage the use of first class water for the watering of fields and gardens and the washing of boats. Since the use of first class water for irrigation is illegal, this tariff is intended to act as a disincentive to do so (WSC source, 1993).

With regard to extensive everyday use of first class water, the water tariff for the tourist sector (hotels, tourist flats and associated nightclubs, bars and restaurants) is the highest (NTOM source, 1993).

Up until 1994, the domestic water tariff was heavily subsidised since water is very expensive to produce in the Maltese Islands due to the costly nature of desalination (pp.184-191). For every Lm1.00 paid by the customer, the Government paid Lm9.00 (PA source, 1993; *The Times*, 4/5/93, p.5). The tariff is still subsidised but to a lesser extent.

While no changes in the tariff for the tourist sector were planned, it was announced in 1993 that the industrial rate would be increased in 1995 (*The Times*, 23/11/93, p.1), although by Research Period 3, no change had occurred.

Table 3.1. Current water tariffs in the Maltese Islands

Type of consumer	Service charge/ 4 months cyce	Block 1	Block 2	Block 3	Block 4
Domestic	Lm 1.20	0-5.5m3/person at 7c5/m3	5.511m3/person at 18c7/m3	> 11m3/person at 75c/m3	
Commercial i.e. night clubs bars/restaurants, garages	Lm 1.20	0-10m3 free	10-57m3 at 70c/m3	> 57m3 at Lm 1.00/m3	
Industrial/farms	Lm 0.60/0.80	0-227m3 at 4c5/m3	> 2270 m3 at 12c/m3		
Tourist flats	Lm 0.60	0-84m3 at 70c/m3	> 84m3 at Lm 1.00/m3		
Hotels	Lm 0.60/0.80	0-14m3/bed at 70c/m3	> 14m3/bed at Lm 1.00m3		
Laundries	Lm 0.60/0.80	0-2270m3 at 70c/m3	> 2270/m3 at Lm 1.00m3		
Sea craft	Lm 0.60	Lm 1.10/m3			
Government departments	Lm 0.60/0.80	4c5/m3			
Boat-houses, gardens, fields, etc.	Lm 1.50	0-5 m3 free	5-10m3 at 80c/m3	10-42m3 at Lm 1.00/m3	> 42m3 at Lm 1.25/m3
Others (including churches, banks, shops, etc.)	Lm 5.00	0-57m3 free	> 57m3 at 12c/m3		

Source: WSC, 1995a.

3.4.1. Revision of the domestic water tariff

The old domestic tariff for every billing period of 4 months was as follows:

Lm 1.20 meter rent.	
The first $27m^3$ consumed per account	free
Consumption between $27m^3$ and $42m^3$	$12c/m^3$.
Consumption between $43m^3$ and $57m^3$	$16c5/m^3$
Consumption greater than $57m^3$	$25c/m^3$.

The tariff was introduced in 1981 when groundwater accounted for 85% of water production. Its main failing was that it:

".... awarded $27m^3$ per household per 4 months, independent of the number of persons in that household. Thus it failed to recognise that subsidies should be properly addressed to persons not households. This tariff unnecessarily awarded too much 'free water' to smaller families while not sufficiently supporting the larger families. The general low level of the charges masked all the inadequacies since a low bill invariably resulted." (WSC, 1995a, p.3).

Inflation, the changing ratio of groundwater/ desalination production sources (p.174) and the need to curb rising consumption justified an increase in the domestic water tariff (*The Times*, 4/12/93, p.1). It was announced by the Government, in the summer of 1993, that the price of water was to increase from January 1st 1994 to reflect the true cost of water (ibid; *The Malta Independent*, 25/7/93, p.1; 19/9/93, p.68).

It is also seen that revising the tariff was a,

"…. feasible and satisfactory way of securing whatever distribution of wealth is desired (Briguglio, 1994, p.48).

During Research Period 1 the new price of water was very confidential and it was only known that the new water tariff would more closely reflect the cost of production (75c/m^3) (*The Times*, 23/11/93, p.1; WSC source, 1993).

For social and health reasons the WSC had to give a certain amount of water free. The tariff had to be stepped so that any consumption above 'normal' requirements is penalised. The problem facing the WSC in 1993 was what exactly constituted 'normal' consumption (ibid).

On the 1 January 1994, the price of water increased and the new tariff was made public. Table 3.1. shows the new tariff. The rates and subsidy were based upon the premise that 11m^3/person/4 months (20 gallons/person/day) is a reasonable amount for social needs and deserved to be subsidised (WSC, 1995a).

The subsidy was decided by analysing the theoretical and practical consumption patterns of consumers in the Maltese Islands and abroad. Also, sample water accounts of households with working meters were analysed and consumption correlated to the number of people in each. It was concluded that consumption averaged 0.08m^3/person/day (18.6 gallons/person/day). Hence, 0.09m^3/person/day (20 gallons/person/day) would be subsidised in two equal blocks at 90% and 75% (ibid).

"Thus the tariff and subsidy scheme distinguished between the social use of water, and the less important and luxury use of water which do not deserve to be subsidised." (ibid, p.5).

Above this subsidised rate the tariff reflects the actual cost of water.

The size of bills is determined by the new tariff, the amount consumed and any error in billing. Table 3.2. shows what a bill should work out to for a given consumption, for a given number of persons per household based on a 4 month (120 days) cycle, under the old and new tariffs (ibid). In terms of the number of people in a household, the new tariff is much more equitable than the old tariff (Babys, unpublished interview). The more that is consumed per person, the higher the bill. While a two person household may consume $15m^3$ and pay Lm2.78, a single person consuming the same will have to pay more since he or she is consuming over and above what is considered a reasonable amount ($11m^3$/person/4 months).

The new tariff did not come into effect for billing until the 4 month cycle of May to August 1994 (*The Malta Independent*, 16/1/94, p.1). This delay was due to the fact that not all the data on the number of persons per household was available until mid-1994 (WSC source, 1995). The first new bills were received in autumn 1994. From these the WSC were satisfied that the subsidised level was sufficient. Table 3.3. shows the average consumption, subsidy and size of bill, depending on the number of persons in a household under the old and new tariffs. Bills are much higher under the latter with percentage increases being higher for households with fewer people. From Table 3.4. it can be seen that the maximum subsidy increases with increasing number of persons in a household, since it applies to $11m^3$/person/4 month cycle. Furthermore, the Table shows that the number of households consuming less than the subsidised volume is 69%. More reassuring for the WSC is that 74% of individuals have been billed for consumption below the subsidised $11m^3$/cycle. Average consumption per person was between $7m^3$ and $13m^3$/person/cycle (WSC, 1995a).

Table 3.2. Magnitude of water bills under the old and new domestic water tariffs

Amount consumed (m3)	Bills with old tariff (Lm)	Bills with new tariff (Lm):	1 PERSON	2 PERSONS	3 PERSONS	4 PERSONS	5 PERSONS	6 PERSONS
0.0	1.20		1.20	1.20	1.20	1.20	1.20	1.20
5.0	1.20		1.58	1.58	1.58	1.58	1.58	1.58
10.0	1.20		2.46	1.95	1.95	1.95	1.95	1.95
15.0	1.20		5.65	2.78	2.33	2.33	2.33	2.33
20.0	1.20			3.72	3.10	2.70	2.70	2.70
25.0	1.20			6.34	4.04	3.42	3.08	3.08
30.0	1.56				4.98	4.36	3.74	3.45
35.0	2.16				7.04	5.30	4.68	4.05
40.0	2.76				10.79	6.24	5.62	4.99
45.0	3.50					7.74	6.56	5.93
50.0	4.32					11.49	7.50	6.87
55.0	5.15						8.44	7.81
60.0	6.23						12.19	8.75
65.0	7.48							9.69

Source: WSC, 1995a.

Table 3.3. Average, consumption, subsidy and bills per four month cycle for each household type

Number of persons	Average consumption (rounded) (m3)	Maximum amount subsidised (m3)	Bill for average consumption with new tariff (m3)	Subsidy included in bill for average consumption (Lm)	Bill for average consumption with old tariff (Lm)	Percentage increase
Empty	15	11	5.78	6.67	1.20	382
1	13	11	4.28	6.67	1.20	257
2	20	22	3.74	12.46	1.20	212
3	27	33	4.43	17.02	1.20	269
4	32	44	4.77	20.43	1.80	165
5	36	55	4.90	23.30	2.28	115
6	40	66	5.05	26.15	2.76	83
7	40	77	4.43	26.77	2.76	61

Source: WSC, 1995a.

Table 3.4. Maximum subsidy and consumption under the subsidised volume for each household type

Number of persons	Total number of households	Maximum subsidised volume per cycle (m3)	Maximum subsidy (Lm)	Net bill at maximum subsidy (Lm)	Number of households consuming less than subsidised volume	% households consuming less than subsidised volume	% persons consuming less than subsidised volume
Empty	48119	11	6.67	2.78	31045	65	--
1	15825	11	6.67	2.78	9713	61	3.2
2	20950	22	13.42	4.28	13616	65	9.1
3	21305	33	20.10	5.85	14846	70	14.8
4	24961	44	26.84	7.36	18848	76	25
5	11230	55	33.52	8.92	9180	82	15
6	3870	66	40.26	10.44	3346	86	6.6
Total	146260	--	--	--	100594	69	73.7

Source: WSC, 1995a.

3.5. SOURCES OF FIRST CLASS WATER SUPPLY

Malta and Gozo's public tap water supply is currently derived from the MSLA's groundwater resources via pumping stations and boreholes and desalinated water from five reverse osmosis (RO) plants. A small amount is derived from perched aquifer springs and boreholes. Figure 3.1. shows the location of these sources, while Figure 3.2. shows the relative amounts boreholes, pumping stations and RO plants contribute to total water production. From Figure 3.1. it can be seen that there is a greater concentration of boreholes in the south of Malta while all but one of the RO plants are located in the north. The implications of this in terms of regional water availability and quality are discussed on pp.246-252.

Figure 3.3. shows that water production has been increasing since 1961 and particularly dramatically since 1982 when the first RO plant was commissioned. This increase has been to meet increasing demands for water from all sectors (p.263), except agriculture which relies on second class water for irrigation (pp.210-216) and only a small amount of subsidised tap water for the washing of hands, tools, etc.

Figure 3.4. shows the relative proportions of first class water production by source at the start of 1994. It can be seen that RO plants collectively account for the largest proportion of water production (60% (*The Times*, 22/10/93, p.40)). These proportions have not always been like this. At one time first class water was almost completely derived from groundwater sources and the earliest water supply was derived solely from springs which have become insignificant. Table 3.5. shows the contribution of each source since 1970 and the RO contribution is broken down to show the amount produced by each plant. Both this Table and Figure 3.5. illustrate how groundwater production has gradually increased,

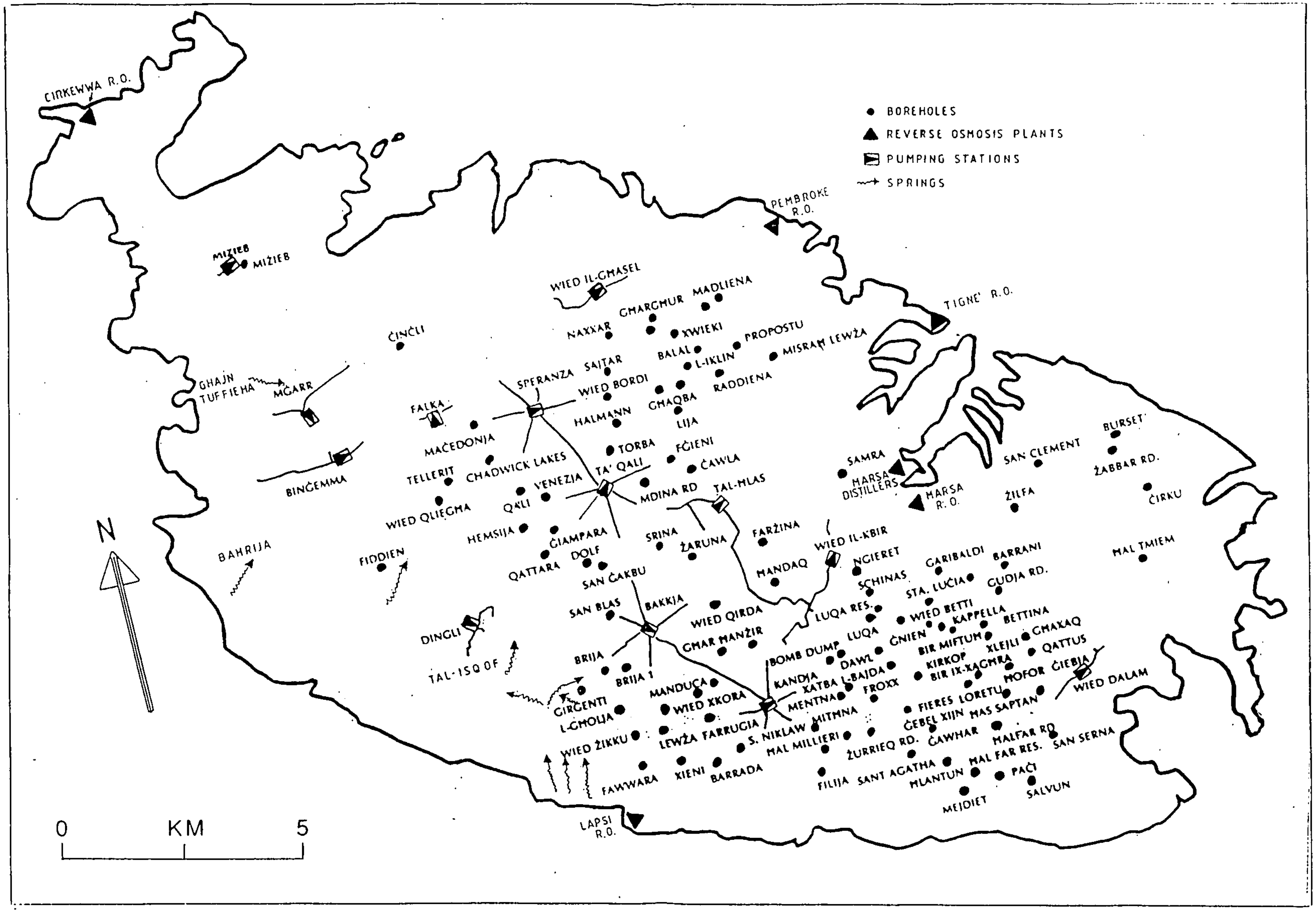


Figure 3.1. The location of production sources in Malta.
Source: WSC.

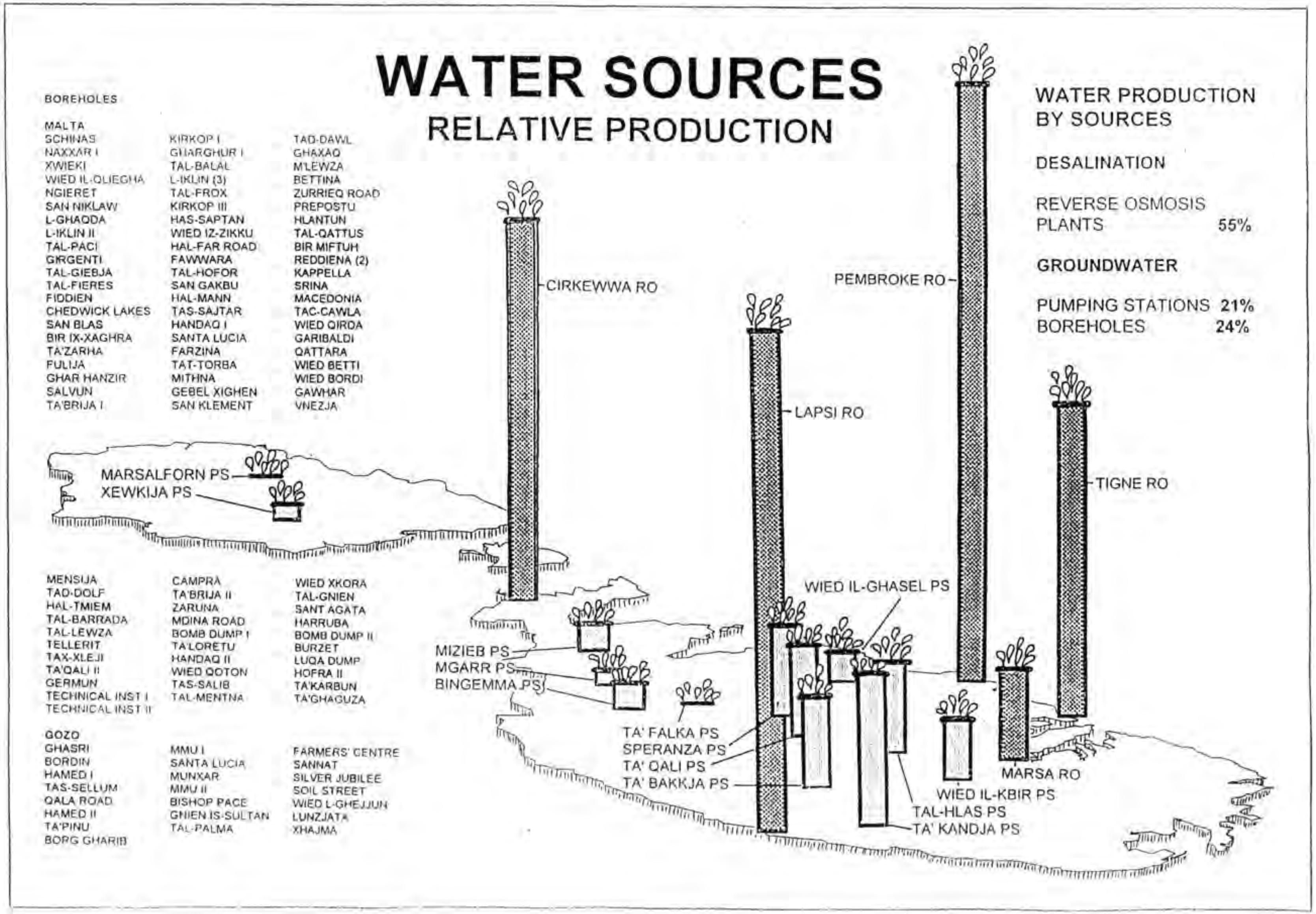
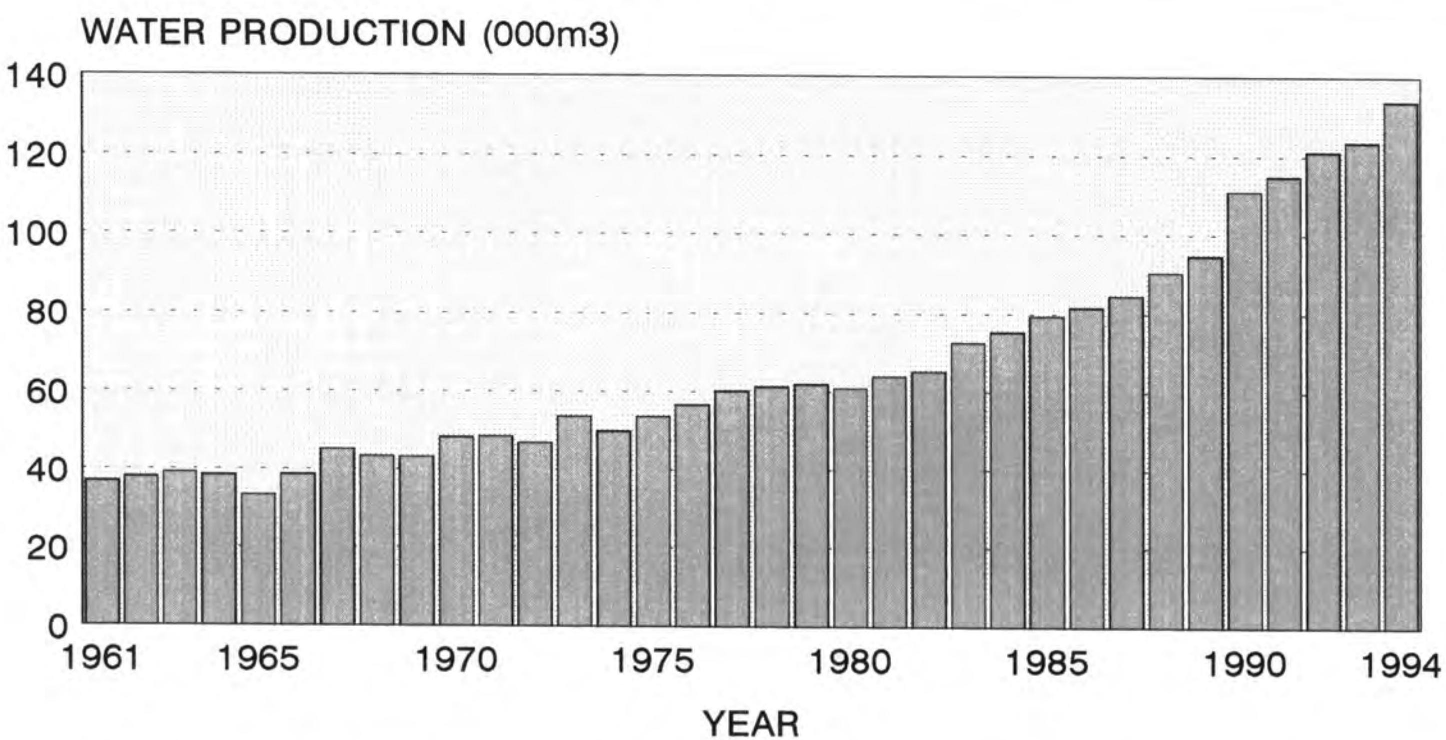


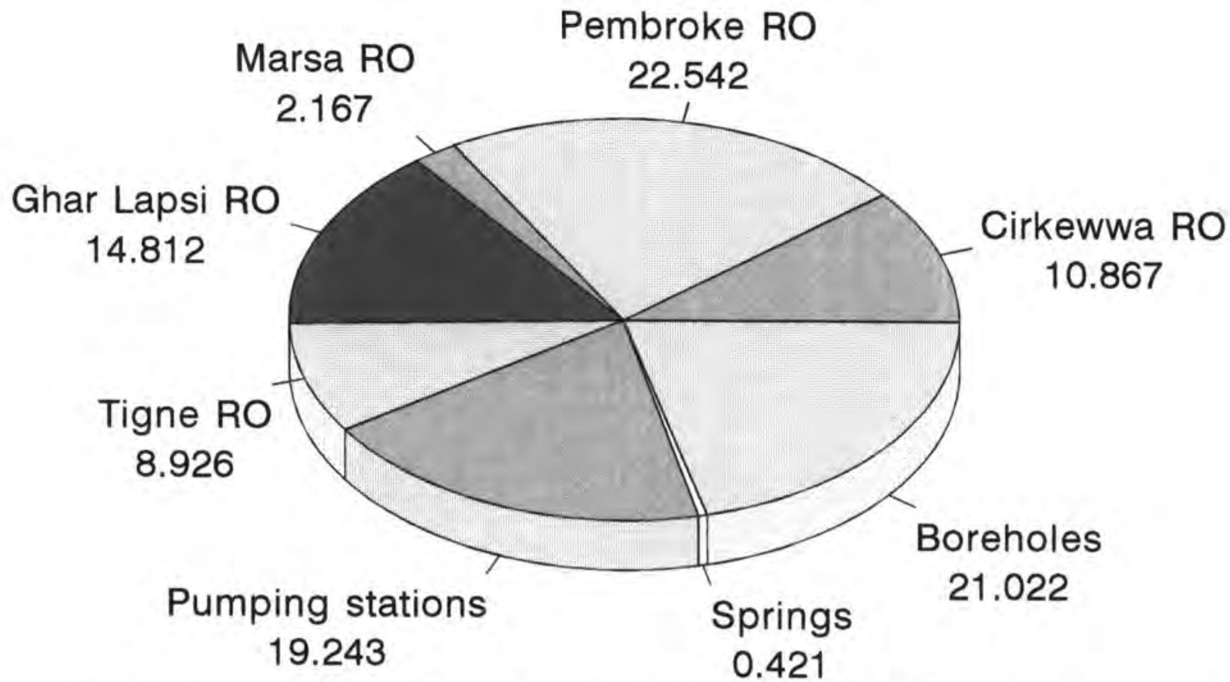
Figure 3.2. Relative production from water sources in Malta and Gozo for 1993.
Source: WSC.

Figure 3.3. Total mean daily first class water production for the period 1961 to 1994



Note: Values are only for water production for the supply of first class mains water.
Sources: Briguglio, 1994; Debono, 1994; WSC unpublished data.

Figure 3.4. Mean daily first class water production by source in the Maltese Islands for 1994



Percentage of water from the different sources of water production

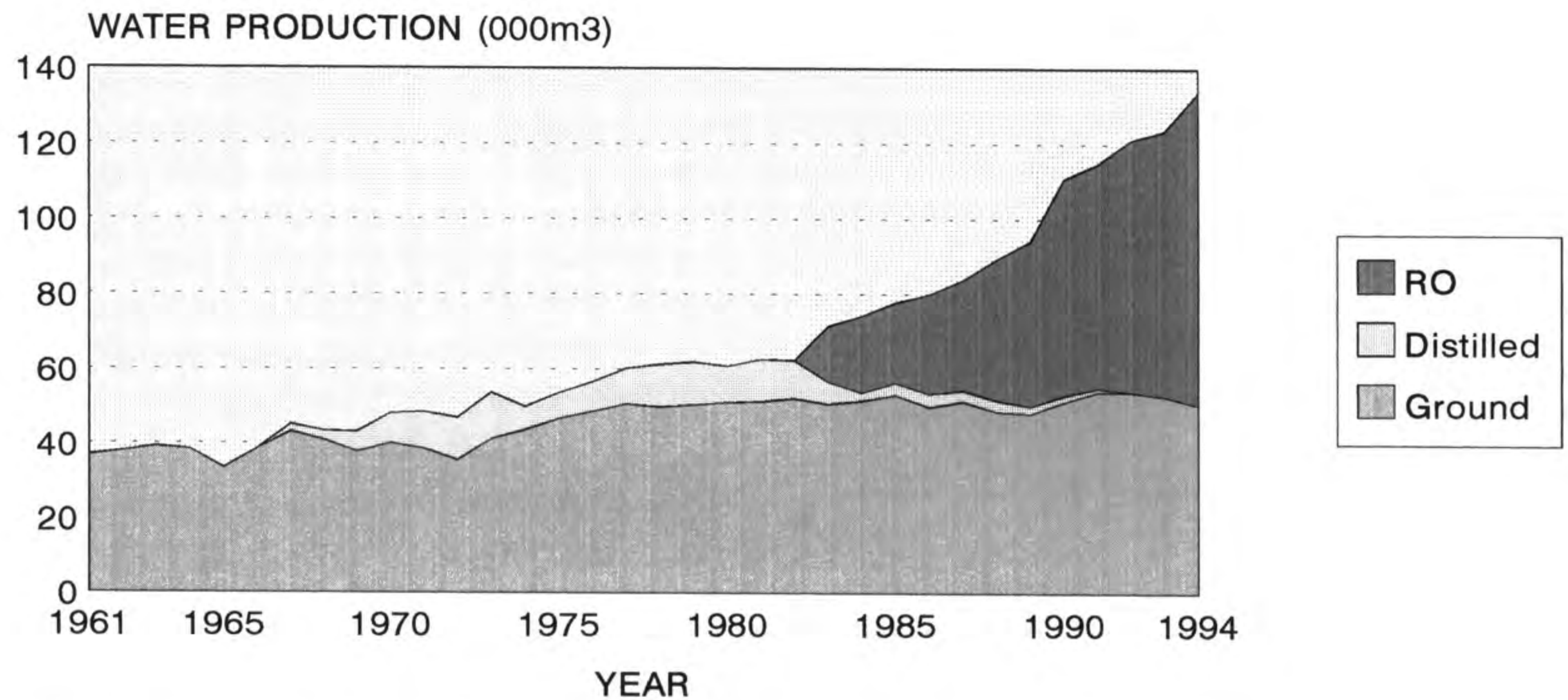
Source: WSC unpublished data.

Table 3.5. Mean daily first class water production/supply (m3) in Malta for the period 1970 to 1992

Year	Springs	Pumping stations	Boreholes	Total groundwater production	Distillation	Ghar Lapsi RO plant	Marsa RO plant	Tigne RO plant	Cirkewwa RO plant	Pembroke RO plant	Total RO production	Total desalination	Treatment plants	Gozo pipeline	Total production
1970	1568	34329	4171	40068	8136							8136			48203
1971	1628	33175	3737	38540	9956							9956			48496
1972	2210	29907	3395	35512	11365							11365			46877
1973	1746	35838	3642	41227	12411							12411			53637
1974	1013	37200	5393	43607	6222							6222			49829
1975	1272	35507	9931	46710	6913							6913			53623
1976	2000	35112	11568	48680	7892							7892			56572
1977	1106	35857	13684	50646	9495							9495			60141
1978	940	34117	14860	49917	11357							11357			61275
1979	1421	33001	15986	50408	11462							11462			61870
1980	1107	34028	15954	514090	9755							9755			60844
1981	1148	32882	17351	51381	11268							11268		1235	63884
1982	1434	33585	17148	52167	10260							10260		2793	65220
1983	1284	32867	16585	50736	5963	13503	1329				14832	20795		1055	72587
1984	1357	34687	15473	51517	2257	17378	3059				20437	22694		1023	75234
1985	1532	33675	17849	53057	3310	18296	3141				21437	24746		1552	79355
1986	1542	30649	17730	49921	3530	20693	2606	3270			26569	30099		1497	81518
1987	1743	31777	17885	51405	2887	20872	3741	4943			29556	32444		639	84487
1988	1290	29253	18108	48652	3048	21017	2808	10106	3773		37704	40752	36	966	90405
1989	1601	29915	16591	48108	2000	21215	3073	11755	6102		44146	46146	28	409	94690
1990	1428	30542	19320	51291	1659	21219	2895	21214	10769		57792	59487	23	193	110994
1991	1345	31290	21281	53916	976	20353	3325	13970	13232	8001	59857	60833	3	31	114783
1992	946	30479	22525	53950	0	20521	3056	13726	15614	14244	67160	67160	0	0	121110

Source: WSC unpublished data.

Figure 3.5. Mean daily water production by groundwater, distillation and RO sources for 1961 to 1994



Note: Values are only for water produced for the supply of first class mains water.
Sources: Briguglio, 1994; Debono, 1994; WSC unpublished data.

Plate 3.1. A disused open reservoir in Msida.

Plate 3.2. The Cirkewwa RO plant.

distillation has (after being introduced in 1967) been phased out and RO production has rapidly increased since its introduction in 1982 to dominate production today.

3.5.1. Small scale open reservoirs and treatment plants

During the 1970's and 1980's many open reservoirs were constructed across Malta to collect surface run-off at major convergence points. Alongside some of them were treatment plants to render the water potable. These are no longer used and the location of many, astoundingly, has been long forgotten (University source, 1995; WSC source, 1995). Plate 3.1. shows the one in Msida. A few of the treatment plants were brought back into use between 1988 and 1991 (WSC unpublished data).

3.5.2. Distillation

Seawater is composed of a number of different salts and minerals which are dissolved. The most prevalent is sodium chloride (NaCl) and other dissolved materials include the elements and radicals, calcium (Ca_2), magnesium (Mg_2), bicarbonate ($HCO3^{-1}$) and sulphate (SO^{-2}). These dissolved materials are called the Total Dissolved Solids (TDS). This provides a method of expressing the salinity or concentration of salts in milligrams per litre (mg/l) or parts of salt per million parts of solution, expressed as parts per million (ppm) (Pembroke RO plant data; Pembroke RO plant source, 1993).

Desalination is the process by which most of the salt in seawater is removed to leave a product that is relatively low in salts so that it is potable. Distillation is one process of desalination in which large amounts of energy are consumed to evaporate seawater. The salts are left behind and the vapour condensed to obtain the distilled water which is of superior quality, in terms of salinity, than the potable water produced by reverse osmosis, although generally a more expensive process.

Seawater salinity averages 35,000ppm with variations of 5,000 ppm on a global scale. Salinity is higher in warm areas where evaporation is high (ibid). Hence, the feedwater for desalination plants in Malta has been found to have a salinity of 39,200ppm (except where brackish springs of much lower salinity are used) (Andrews, 1985).

The first distillation plant, installed at Tigne in 1881, produced potable water on the principles described above. Later plants used a process called Multi-Stage Flash (MSF) distillation in which seawater is prevented from boiling by maintaining conditions above the solutions' saturation pressure. It is then passed into a flash chamber at a lower temperature causing rapid evaporation. The water vapour released is then condensed. The thermal energy from the brine and the distillate are used to produce more distillate via a number of linked chambers (Agnew and Anderson, 1992).

MSF distillation plants were installed in 1964. There were originally four MSF distillers in Malta and one in Gozo. With the exception of the plant at Marsa, they have not been used or maintained for many years (WSC source, 1993). The cost of water produced in this way was approximately Lm2.50/m^3 (ibid). The Marsa plant makes use of surplus steam generated at the Marsa power plant to drive the turbines that produce the distilled water (ibid).

A WSC source (1993) stated that the other distillers were closed down because technically their life was over. However, another WSC source (1993) informed me that rising fuel prices, after the 1973 oil crisis, made running costs too expensive for the 'low spend' policies of the Labour Government (p.588) and this is the generally admitted and accepted explanation.

Figure 3.6. shows that there was a steady increase in desalination (by distillation) until 1974 when it was reduced by more than half. There was no significant increase in desalinated production until 1983 but this was not due to distillation, which by then was a dying method of production, but the introduction of RO technology at the end of 1982.

Table 3.5. and Figure 3.5. show the decline in distillation. The Labour Government tried to bring the distillers back on line in the late 1970's (there is a small rise after 1974) but the lack of maintenance meant that they did not function properly (WSC source, 1993). Today, RO plants can produce water at half the cost the distillers could before 1973 (ibid). In 1992 the Marsa distiller did not produce any water for the first time (Table 3.5.) and it has not done so since (WSC unpublished data).

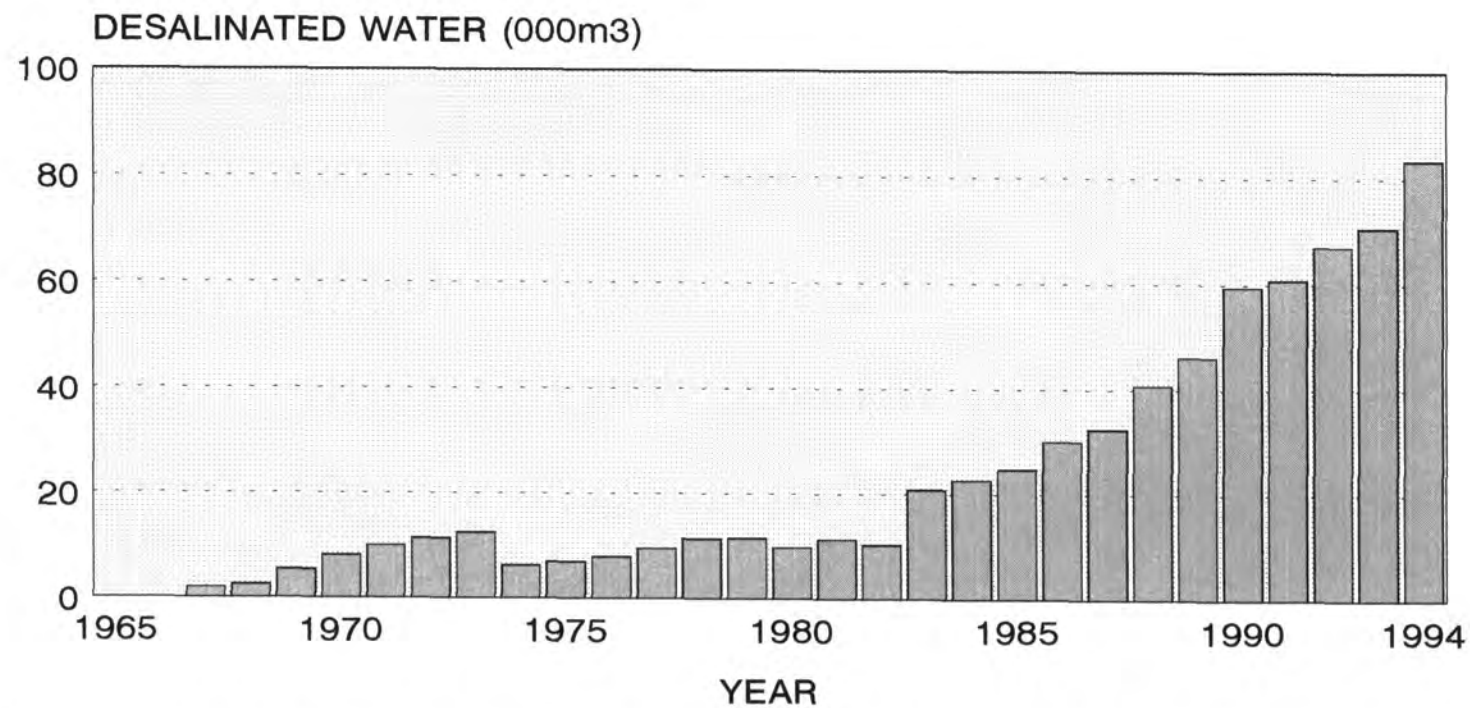
3.5.3 Reverse osmosis (RO)

Desalinated water produced by RO plants accounts for approximately 60 per cent of water supply, although total maximum production capacity in 1994 was 103,900 m^3/day, capable of covering 67% of total water production (Debono, 1994). What is remarkable about water supply in the Maltese Islands is the speed with which RO technology has come to dominate production since 1982. In the 1990's there has been an even more dramatic increase with the introduction of new plants and expansions of existing ones. Table 3.5. and Figures 3.5. and 3.6. illustrate this.

Figure 3.7. shows Government capital expenditure on water supply. Years with large expenditure are due to the capital costs of RO plants when constructed or expanded.

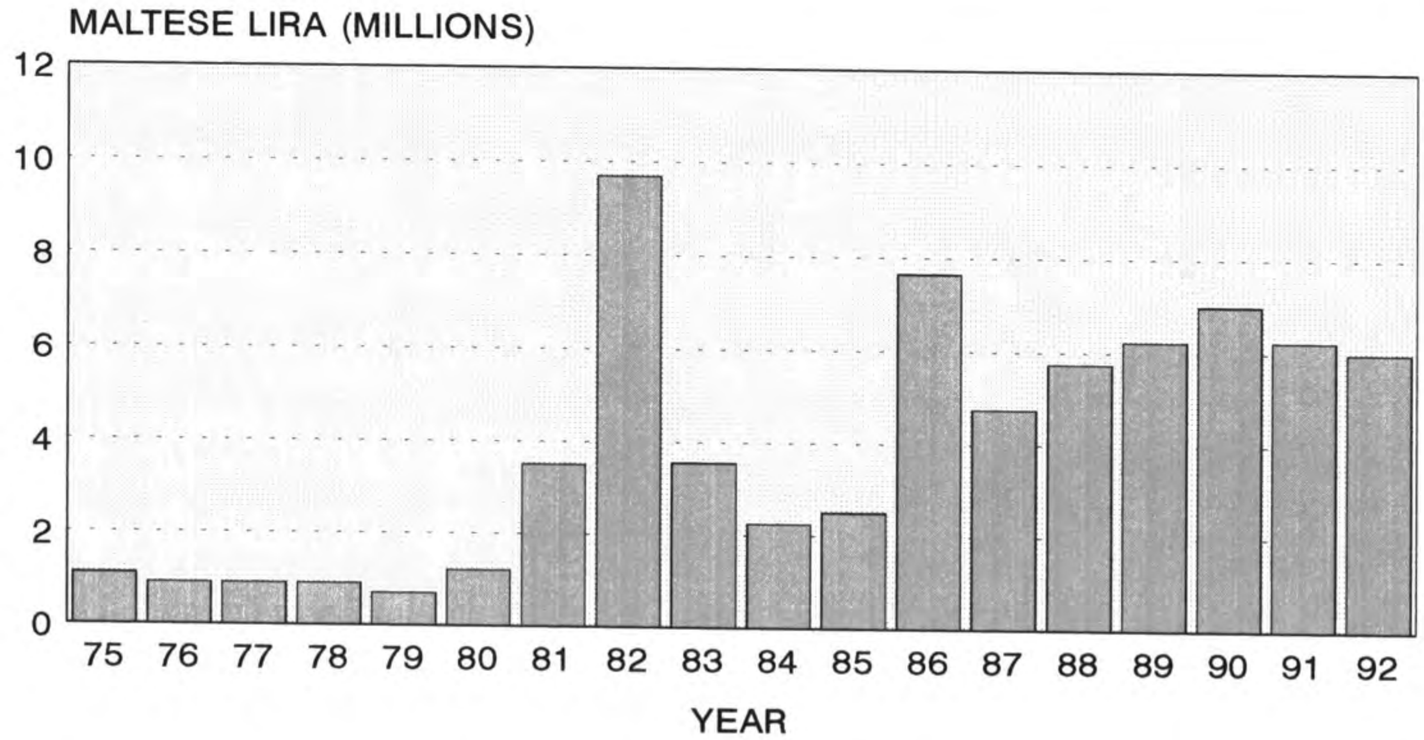
RO plant operations are illustrated by Figures 3.8.

Figure 3.6. Total mean daily water production by desalination for the period 1965 to 1994



Note: Values are only for desalinated water production for the supply of first class mains water.
Sources: Briguglio, 1994; Debono, 1994; WSC unpublished data.

Figure 3.7. Government capital expenditure on water supply for the period 1975 to 1992



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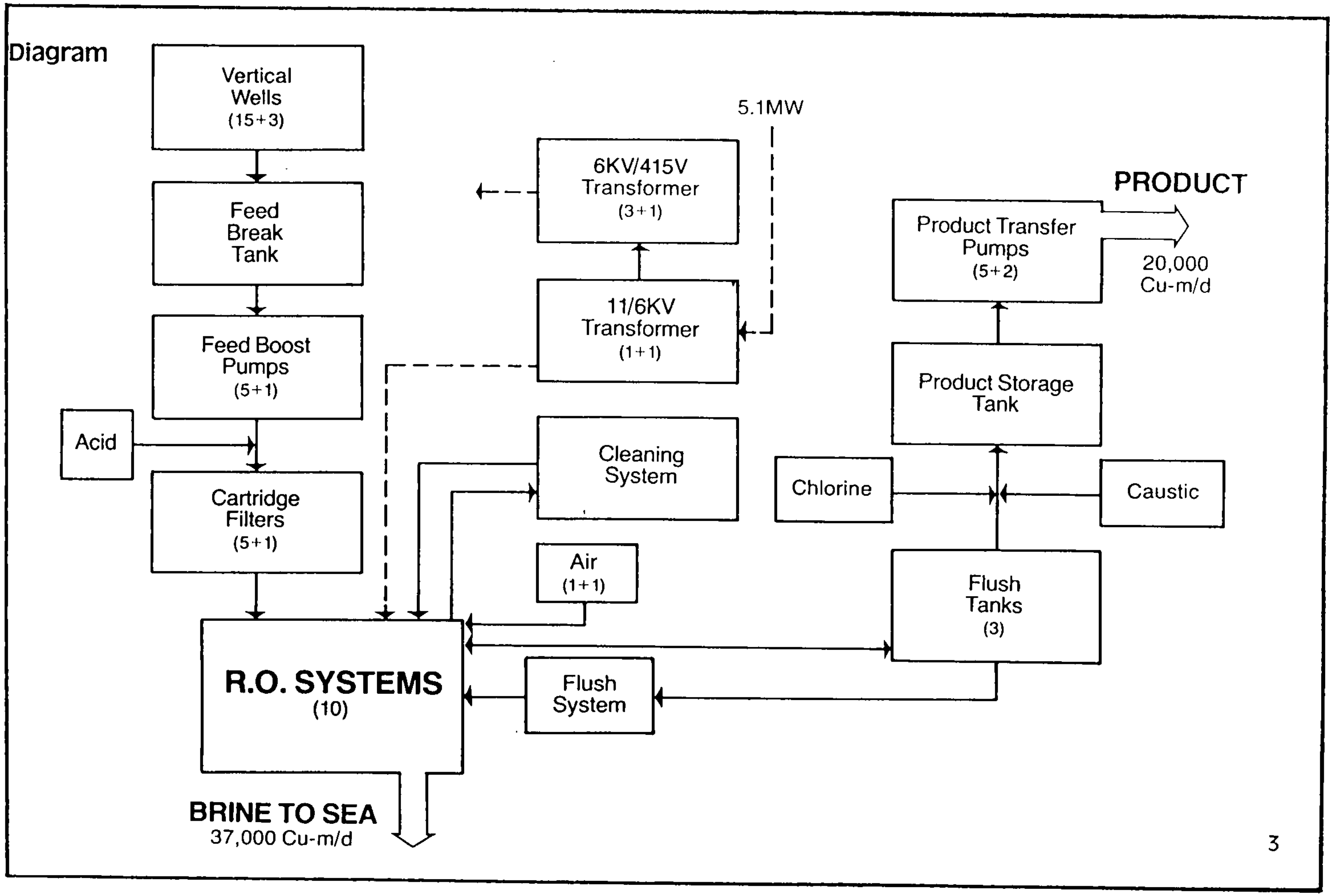


Figure 3.8. RO water production operations for the Ghar Lapsi RO plant.
Source: Du Pont, 1985.

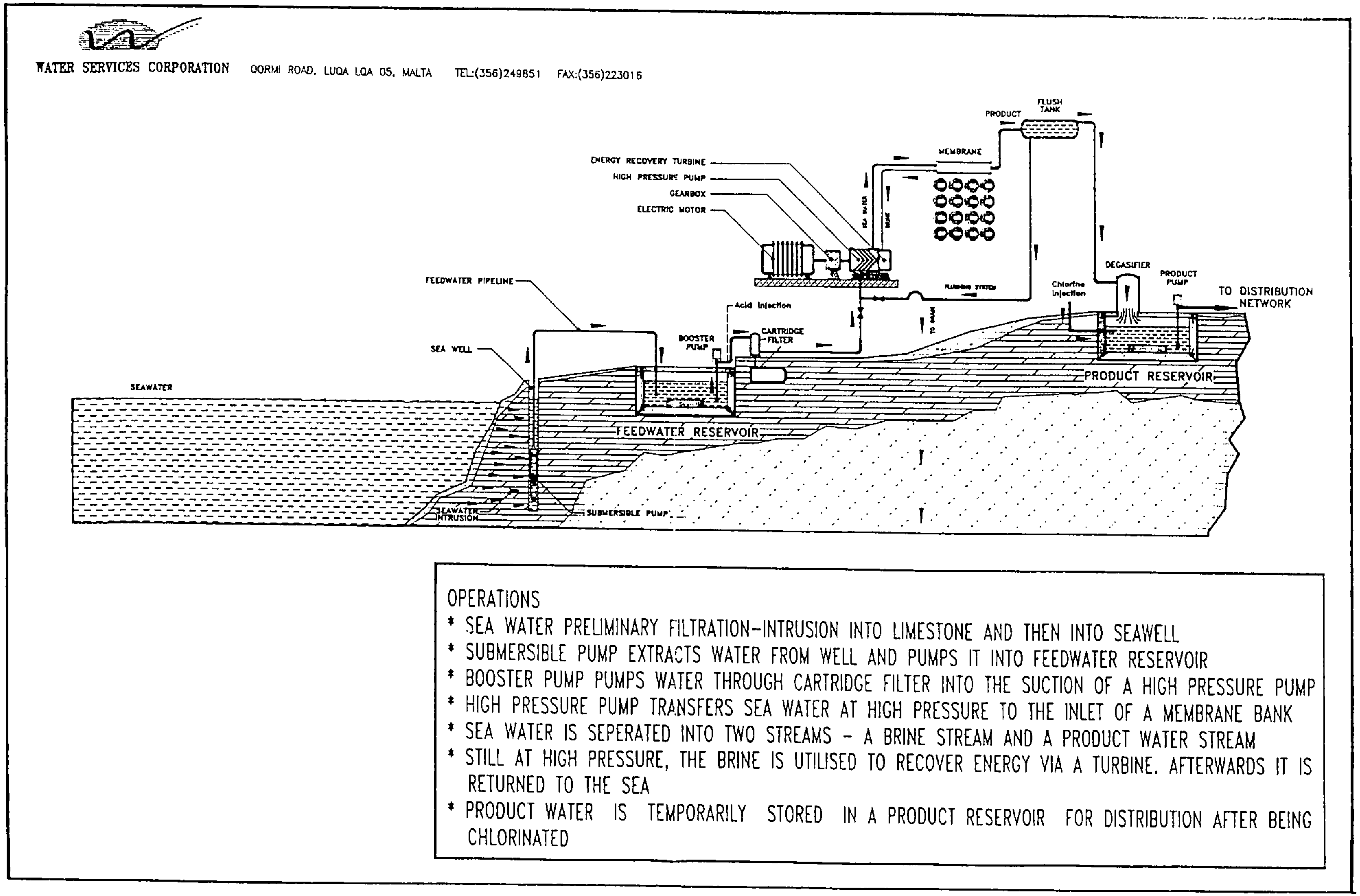


Figure 3.9. RO plant operations in cross section.
Source: WSC.

(for the Ghar Lapsi plant) and 3.9. Both Figures show that the process of producing water in RO plants is relatively simple and one that is considered an,

".... efficient system which performs all of its desalting operations in a single pass." (Du Pont, 1985, p.1).

Seawater is pumped up from 18 wells at Ghar Lapsi to go into a breaktank from where it is sent to the RO system by booster pumps. The seawater is injected with acid to prevent scaling and passed through cartridge filters to remove particulate material. Then the seawater is pumped by high pressure pumps to banks of permeators for desalting. Each bank can produce up to $2000m^3$/day of potable water via reverse osmosis. Finally, the product water is passed through three parallel draw-back tanks and automatically pH adjusted and chlorinated (ibid).

Osmosis is the net diffusion of water through a membrane separating two solutions as a result of a concentration gradient. This means that when two solutions of different salt concentrations are separated by a semi-permeable (selective in what is allowed to pass through) membrane, there is a natural flow of water from the area of low concentration, through the membrane, into the area of high salt concentration, in an attempt to dilute it (ibid).

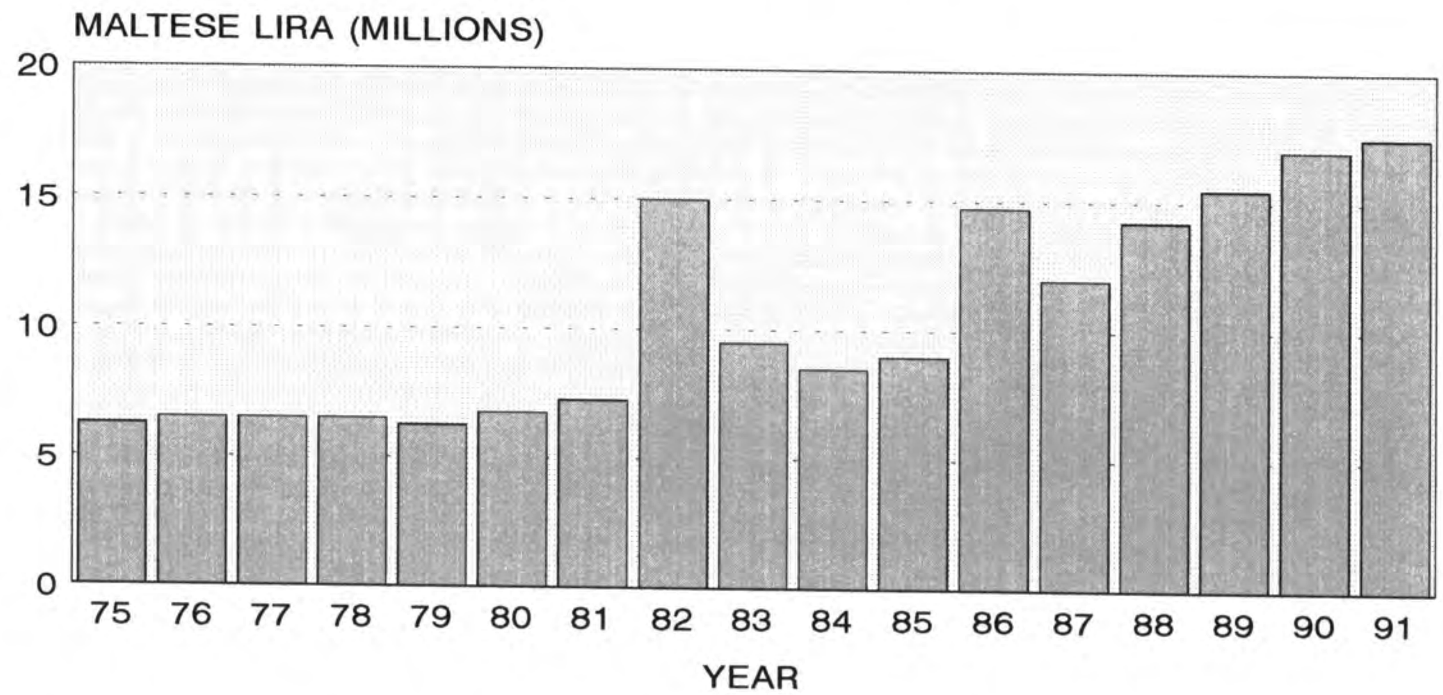
Reverse osmosis is flow in the opposite direction: from the area of high concentration, through the membrane, into the area of low concentration. This can only be done if pressure is applied on the solution with the higher salinity, with a piston or a pump, so that there is a net flow of water through a semi-permeable membrane towards the area of low salinity. The salt is left behind in a brine solution which is discarded into the sea, while on the other side of the semi-permeable membrane the filtered water or 'permeate' collects and this is the product (ibid). The product water has a salinity of less than 500ppm which is acceptable by World Health Organisation (WHO) standards, but not by European Union (EU) standards (ibid). The product water is potable. A WSC source (1993) stated that, ".... it must be borne in mind that RO water is not some sort of 'super water'. It's simply a mean level of potable water." (pp.419-420).

Reverse osmosis requires large amounts of electricity (5.89Kw/m^3) (Andrews, 1985). In Malta, 18% (Debono, 1994) of generated power is consumed by the RO plants. With a production cost of Lm1.04c/m^3 (ibid), it is this requirement for large amounts of power that makes RO water the most expensive source of freshwater in the Maltese Islands. In 1994 it was expected that the cost of power to the RO plants would reach Lm6 million for that year (*The Times*, 6/5/94, p.1). As stated previously, up until 1994 the Government heavily subsidised water. This is mostly because of the high running costs for RO production. Figure 3.10. shows the Government subsidy on water. Peaks correspond closely to Government expenditure on water supply (Figure 3.7.) and the construction and expansions of RO plants. The subsidy has been increasing since 1982 not only because of capital costs of the RO plants, but their running costs as well (WSC source, 1993).

Production at the RO plants stops only for maintenance, breakdowns or whenever there is a power cut (pp.329-330). Otherwise the RO plants produce approximately the same amount of water every day (ibid).

As previously stated most RO plants are located along the northern coast of Malta (Figure 3.1.), which, according to a PA source (1993), is due to the population being densest in the north of Malta. Some have also argued that their location is politically motivated (pp.563-564).

Figure 3.10. Government subsidy on water supply for the period 1975 to 1991



Derived from data obtained from the PN library, Pieta.

3.5.3.1. Ghar Lapsi RO plant

The Ghar Lapsi RO plant was commissioned in December 1982 (Debono, 1994) by the Labour Government to meet increasing demands in the south of Malta. At that time it was the largest RO plant in the world, in terms of production which was 13,500m^3/day (Andrews and Bergman; 1983; PA source, 1993; WSC unpublished data).

Its location, according to PA sources (1993), was decided upon largely by the fact that it is an area unaffected by sewage discharges to the sea which might otherwise pollute the feedwater to the plant. Today, the Ghar Lapsi plant produces 21,550m^3/day (Debono, 1994).

3.5.3.2. Marsa RO plant

The Marsa RO plant was a part of the Ghar Lapsi plant contract (WSC source, 1993). Commissioned soon after the Ghar Lapsi plant in August 1983 (Debono, 1994) it produced 1,350m^3/day (WSC unpublished data). Today it produces 3,300m^3/day (Debono, 1994). This is marginal when compared to the output of the other plants and is mainly for the industrial area around Valletta. Its feedwater is a brackish spring with a salinity of 13,000ppm chlorides (Riolo, 1985; PA source, 1993).

3.5.3.3. Tigne RO plant

The RO plant at Tigne was rapidly commissioned in August 1986 (Debono, 1994; *The Times*, 20/5/86, p.3; 23/5/86, p.3) to relieve water shortages in Sliema. As a consequence, the plant was housed in an old military building at Tigne, near Sliema. At that time it produced 3,270m^3/day (WSC unpublished data). Since then it has been upgraded (*The Times*, 3/8/87, p.1) and today it produces approximately 14,000m^3/day (WSC source, 1995).

3.5.3.4. Cirkewwa RO plant

The 1980's saw a continuation of the increasing demand for water in the northern and central areas of Malta, following the tourist building boom there during the 1970's (p.277). This growth necessitated greater water production and consequently the RO plant at Cirkewwa (Plate 3.2.) was commissioned in September 1988 (Debono, 1994) producing 3,800m^3/day. The site was chosen because there was an existing pipeline from Cirkewwa to the central reservoirs (to import water from Gozo), which saved infrastructural costs (WSC source, 1993).

Today the plant serves as the source of two important lifelines: it can supply Gozo, the northern coast and the central reservoirs in Malta (p.250) (ibid). It has been upgraded and presently produces 16,000m^3/day (Debono, 1994).

3.5.3.5. Pembroke RO plant

The RO plant at Pembroke (Plate 3.3.) was constructed to meet the growing demands of the northern and central areas. When it was commissioned in May 1991 (ibid) it produced 8,000m^3/day (WSC unpublished data) under two trains (production units) (WSC source, 1995) and was left with scope for expansion (the addition of more trains) (PA source, 1993). Plate 3.4. shows the feedwater inlet and brine reject pipes at the plant, which convey the initial and final stages of RO water production.

An extension of the plant occurred during 1992 with the addition of two trains increasing production to approximately 16,300m^3/day by the end of that year. It was

Plate 3.3. The Pembroke RO plant.

Plate 3.4. The feedwater inlet and brine reject pipes at the Pembroke RO plant.

extended again in the summer of 1993 from 4 to 6 trains, adding around 8,600m^3/day, to produce a total of approximately 25,000m^3/day, and again in the spring of 1994 to 12 trains, reaching its maximum capacity of 50,460 m^3/day (Debono, 1994; ibid).

3.5.3.6. Locational factors

The most important factors in locating an RO plant are geology and hydrogeology since these determine the quality and quantity of the feedwater, since feedwater is pumped from adjacent coastal ground which acts as a primary filter (WSC source, 1993).

Areas of seaborne pollution need to be avoided to prevent feedwater contamination (ibid). The large volume of noise generated by operations should necessitate location away from residential areas.

The availability of space can be a problem, since the plants need to occupy large areas of flat land. Malta, being very small, has a large number of competing land uses and conflicts often arise. The RO plant must not be far from the sea in terms of distance inland and its height from sea level, in order to minimise feedwater pumping costs (ibid; Cilia, 1993).

The existence of an appropriately sized infrastructure (pipelines and electricity) would be beneficial, as was the case at Cirkewwa, but not Tigne which was set up in an emergency near Sliema and under better planned circumstances, would have been located elsewhwere (ibid).

With the introduction of the *Malta Structure Plan* (Ministry for Development of Infrastructure, 1990a,b&c; 1991a&b) (a five year national plan for the Islands adopted by the Planning Authority (PA) in 1992 (Galea, 1995) to evaluate and implement a physical planning system in Malta (Camilleri, 1993)), the construction of each RO plant in the future will have to be subject to an Environmental Impact Assessment (EIA). This would include the effect on ecology, both marine and land based, microclimate, groundwater, soils and humans. None of the existing RO plants were subject to EIA's (ibid).

Previous locational mistakes have included the RO plants at Ghar Lapsi (Plates 3.5. and 3.6.), in an area of outstanding natural beauty, and Pembroke, near a residential area (WSC source, 1993). Plates 3.5. and 3.6. show that the pipeline to the Qrendi reservoir is the only part of the Ghar Lapsi plant that aesthetically blends with the surroundings.

3.5.3.7. Tourist, industrial and agricultural RO plants

A number of hotels, that can afford to do so, have reduced their dependence on the public mains supply by purchasing their own small RO systems. This was largely a reaction to the water shortages of the late 1970's and throughout the 1980's. The hotels are the Jerma Palace in Marsascala, the Hilton in St. Julians, the New Dolmen in Qawra, the Seabank in Mellieha, the Ramla Bay in Marfa and the Suncrest in Qawra. They are all large hotels of 4 or 5 star rating and located on the coast enabling easy access to feedwater. Panta Lesco is the main supplier of mini RO systems in Malta. Figure App.3.3.1. shows the advertisement they placed in the national press when the New Dolmen hotel installed one of their RO systems.

The Jerma Palace in Marsascala actually preceded the WSC in adopting RO technology and their RO system was the first in the Maltese Islands (*The Times*, 22/8/81, p.11). It is similar to those used by the WSC and used seawater as its source. Today it uses tap water but still passes the water through its RO system because of the relatively high salinity of tap water in the south (pp.369-374)

Plate 3.5.
The Ghar Lapsi
RO plant.

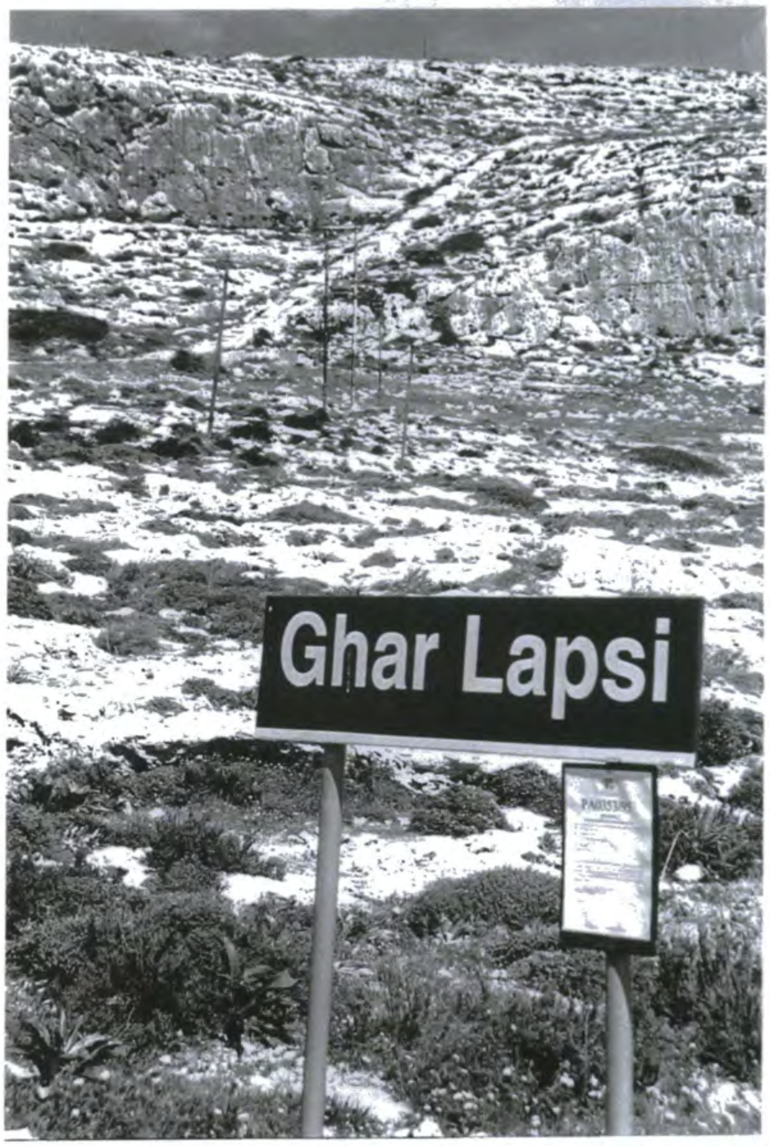


Plate 3.6.
The pipeline
from the Ghar
Lapsi RO plant
to the Qrendi
reservoir.

(*Moviment ghall-Ambjent* source, 1995).

A number of industries have installed RO systems mostly because the quality of tap water is not always reliable in terms of salinity. For example, almost all of the beverage manufacturers have their own RO systems to treat tap water and/or groundwater. For example, Portanier (the producers of *7 Up* and *Aquadot*) and Simmonds-Farsons Cisk (producers of Maltese beer and *San Michel* and *Elan* bottled waters) receive water from the Government RO plant at Marsa, yet have two RO plants themselves to treat the water further. The General Soft Drinks Co. (producers of *Coca-Cola* and *Kristal* bottled water) treat water from their borehole because it is nitrate rich (pp.382-387) as well as saline.

There are two farmers in Malta that own small RO systems to treat saline groundwater. They grow high grade crops, like strawberries, which require a certain standard of water quality, and these farmers receive Government grants to do so (DA source, 1993).

One farmer in the Pwales Valley told me that he needs water of superior quality for his strawberries. Plate 3.7. shows the RO plant which cost him Lm12,000. In addition he collects rainwater in winter from the roofs of the glasshouses (Plate 3.8.) in which the strawberries grow by drip irrigation application (Plate 3.9.) (pp.721-722). He also applies second class water to field crops using traditional ridge and furrow irrigation (Plate 3.10.). His case is a rare one in Malta since most farmers use water of one quality level and usually irrigate in open furrows (ridge and furrow irrigation) only.

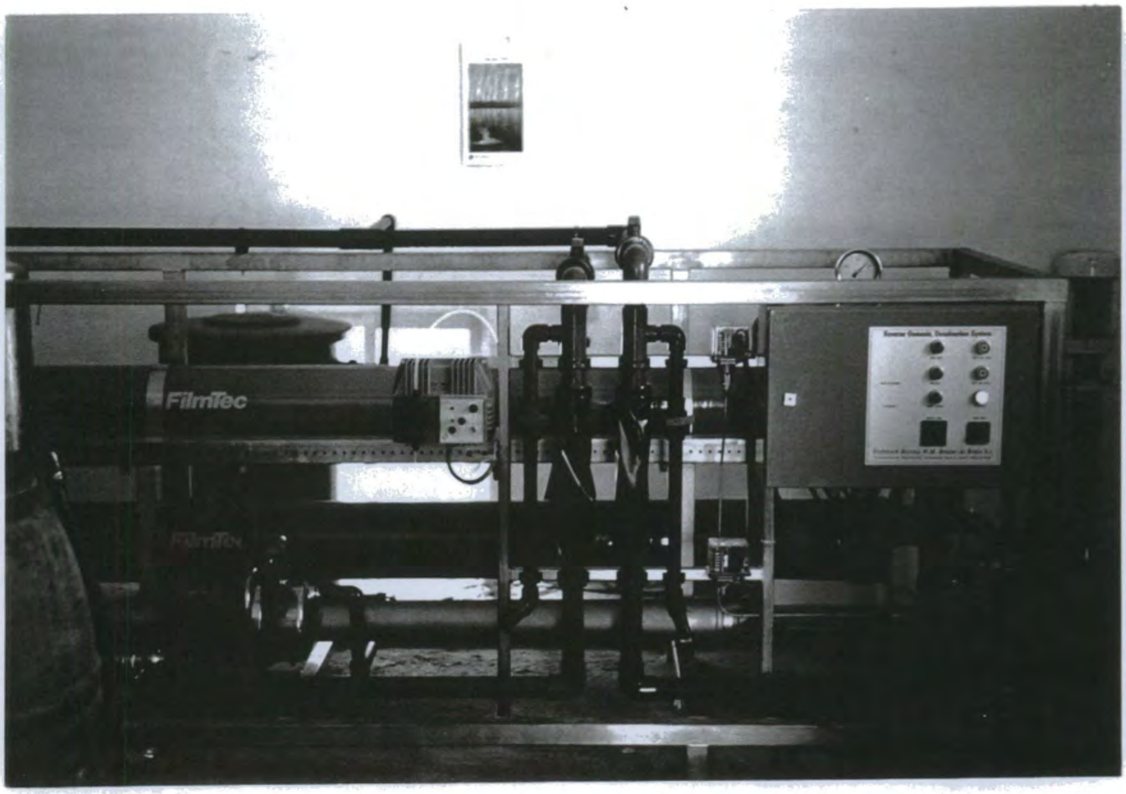


Plate 3.7. A mini-RO system used to produce high grade irrigation water.

Plate 3.8. Rainwater harvesting from glasshouse roofs into a reservoir.

Plate 3.9. Irrigation of high grade crops (strawberries) inside glasshouses with RO water and harvested rainwater.

Plate 3.10. Second class groundwater application to field crops using traditional ridge and furrow irrigation.

3.5.4. Groundwater from Government pumping stations, boreholes and springs

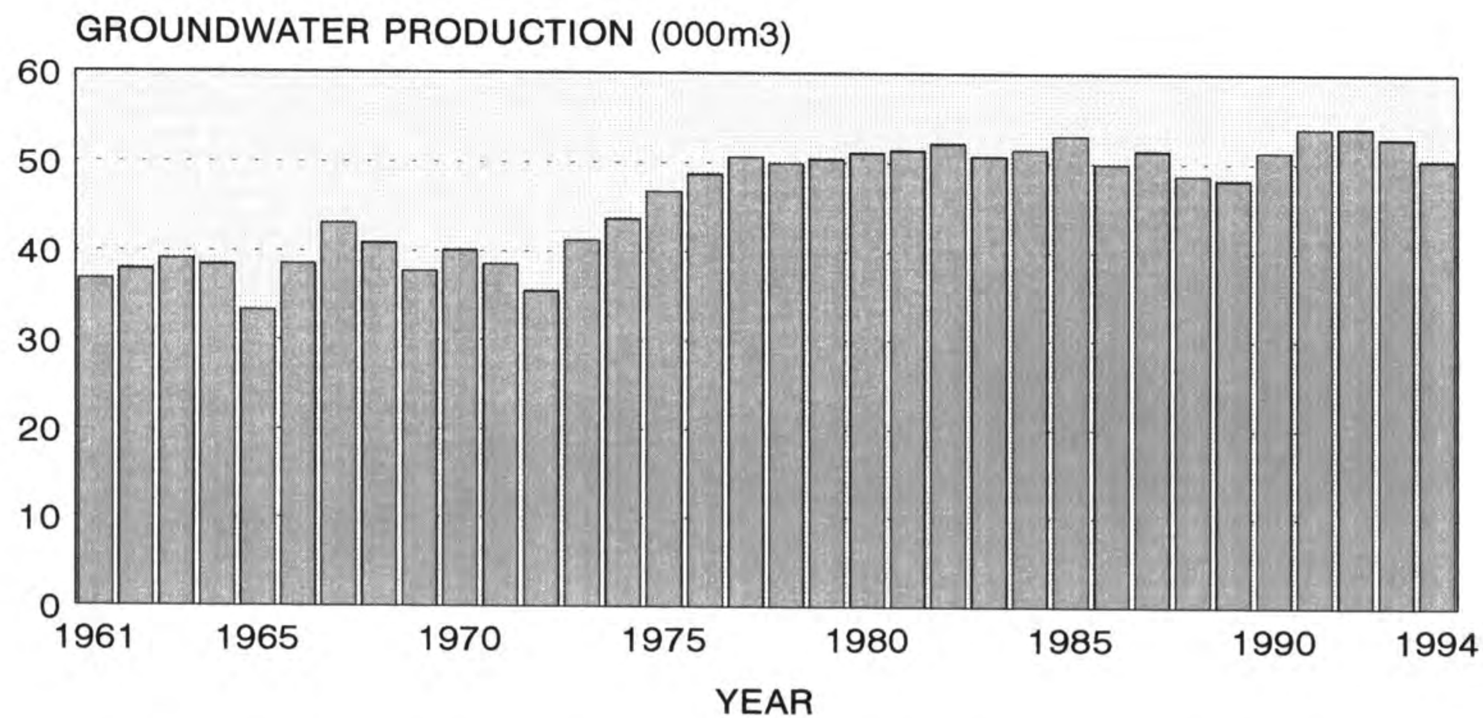
Water production via extraction from aquifers and springs accounts for approximately 40% of the nation's water supply. Figure 3.11. shows groundwater production from 1961 to 1994. Since 1961, production has increased significantly and extraction has been approximately at the maximum allowable (due to aquifer capacity limits in terms of salinity) since 1975, after the drive to increase groundwater extraction due to the 1973 oil crisis. Figure 3.12., which shows rainfall since 1980, illustrates the relationship and importance of rainfall to groundwater recharge and extraction. For example, the low rainfall (Figure 3.12.) due to the drought in 1993 necessitated a reduction in groundwater extraction during 1994 (Figure 3.11.).

The drop in extraction in 1988 and 1989 (Figure 3.11.) was partly due to the water policies of the new Nationalist Government and the fact that 1987 had exceptionally low rainfall. However, increasing demands meant that groundwater production increased again until 1994.

Figure 3.13. shows the percentage extraction from all groundwater sources. There are nine springs used by the WSC for potable supplies. From Figure 3.13. (and Table 3.5.) it can be seen that their contribution is small and by 1992 their use was being phased out. The majority of groundwater is extracted from MSLA boreholes and pumping stations. The latter are connected to and extract water from galleries, the underground conduits which collect percolating water. A relatively small amount is extracted by perched aquifer pumping stations, also from galleries.

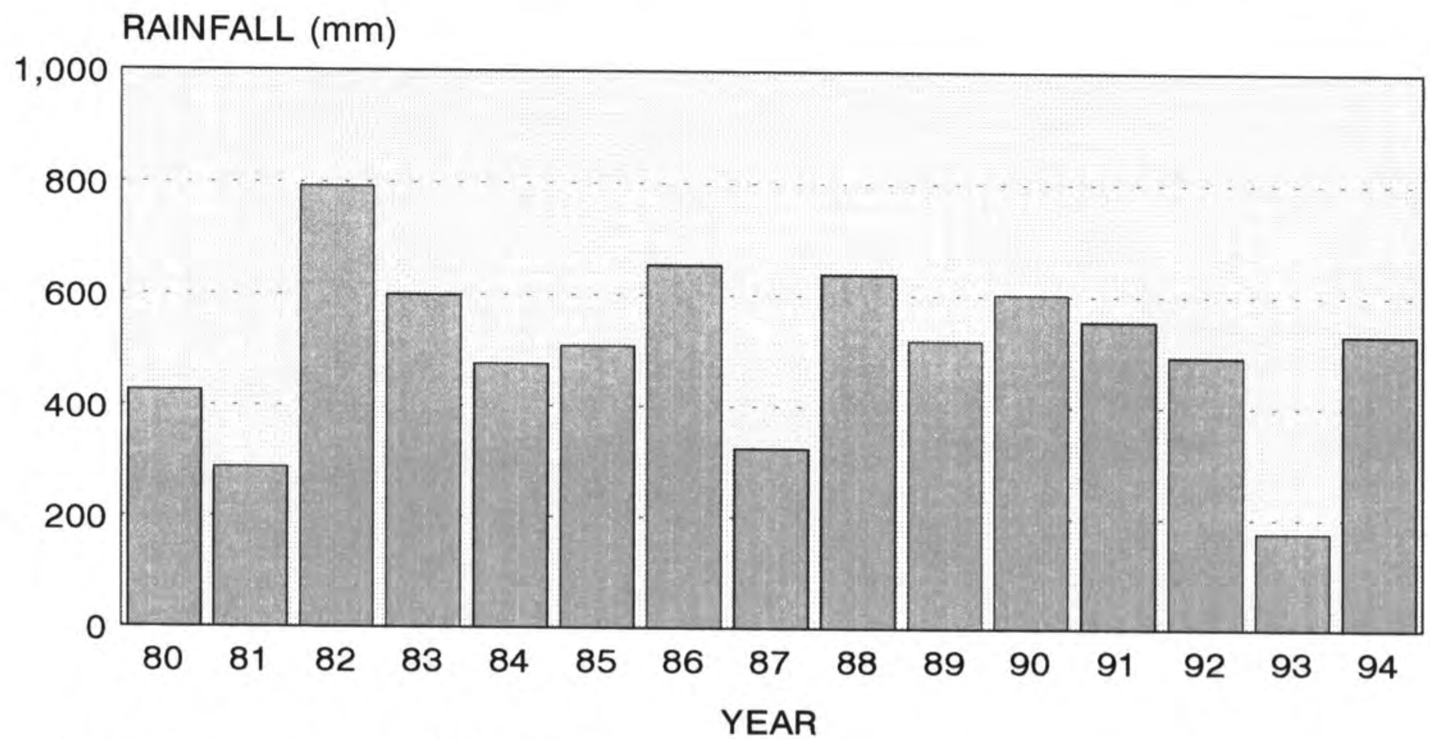
There are 11 ground pumping stations extracting 29,100m^3/day and 94 active 1st class boreholes extracting 22,400m^3/day (Debono, 1994). Groundwater is the cheapest

Figure 3.11. Total mean daily groundwater production for the period 1961 to 1994



Note: Values are only for water extracted for the supply of first class mains water.
Sources: Briguglio, 1994; Debono, 1994; WSC unpublished data.

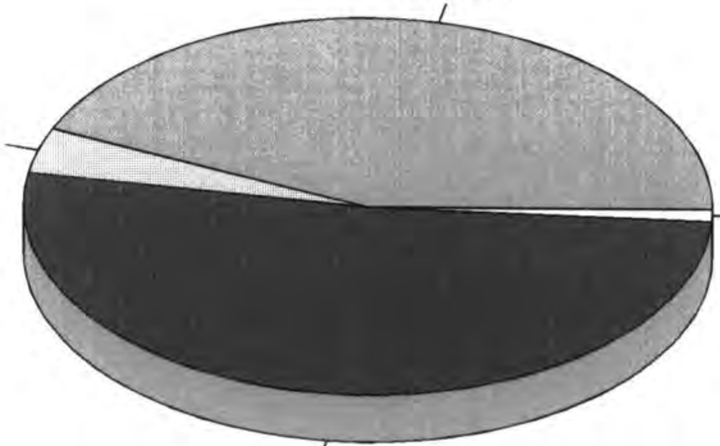
Figure 3.12. Annual rainfall in the Maltese Islands for the period 1980 to 1994



Source: WSC unpublished data.

Figure 3.13. Groundwater sources of first class water supply for 1994

PA = Perched aquifer; MSLA = Mean sea level aquifer



Percentages of water extraction from each groundwater source

Source: WSC unpublished data.

source of freshwater in the Maltese Islands costing 46 cents/m^3 to deliver to the consumer (ibid).

Boreholes can be recognised by the bright blue door on the huts they are housed in (Plate 5.15.). Pumping stations are larger structures which draw water from the galleries (WSC source, 1995). The greater concentration of boreholes in the south (Figure 3.1.) has serious implications for tap water quality in this region (pp.356-374).

Gozo's hydrogeology is different from that of Malta's consisting of much more Blue Clay and many more perched aquifers than Malta. As a result its mains water supply is derived almost completely from groundwater (FIS source, 1993).

3.5.5. Bottled water

Bottled water has been made widely available by several beverage manufacturers by treating springs, groundwater and tap water. It is popular for drinking and cooking and in extreme cases, during lengthy water suspensions, for washing. Bottled water is expensive relative to tap water. The average price of a 1.5 litre (0.0015m^3) bottle of table water is 18c.

3.5.6. Provision of a minimum quantity of first class water

The World Bank defines 40m^3 to 80m^3 per capita/annum (0.11m^3 to 0.22m^3 per capita/day) to be a reasonable quantity of water supply (Briguglio, 1994). However, given the relatively wide range of these figures a more precise figure to satisfy needs is required.

According to a WSC source (1993), all members of the public are provided with 0.12m^3 per capita/day and everyone is satisfied. However, the *Malta Structure Plan*

(Ministry for Development of Infrastructure, 1991b) states that daily consumption per capita for 1989 was $0.25m^3$. This figure is only an average. Other sources (WSC sources and WSC data) and more importantly interviews with members of the public refute this statement. Water supply to consumers varies from ample to none for several weeks at a time (pp.330-336).

In questioning the WSC's statutory obligation with regard to water supply, another WSC source (1993) stated that statutory policy was passed in 1948 requiring the water supplying authority to provide each person with 3 gallons ($0.01m^3$) of water per day (a small amount but almost every household had, and used, a well then). However, the policy contradicts itself by stating that the water authority has a right to suspend the water supply as it sees fit. Described as "ridiculous", this statute is not only self-contradictory, but out of date, and is expected to be revised. Unfortunately, in its revised state it will make no reference to the amount of water the WSC should supply (ibid).

Since the WSC is supposed to operate like a corporation providing a service that customers pay for, there should be some legal obligation for them to supply a fixed quota of water/capita/day or otherwise offer compensation to those who do not receive an adequate amount. This argument has been put forward in the United Kingdom (UK) where water shortages and rationing during the summer of 1995 led to accusations of negligence on the part of the water companies and demands for compensation, many of which were met (*Independent*, 18/8/95, p.6, 20/8/95, section 2, p.14, 24/8/95, p.10; *The Times* (UK), 24/8/95, p.2).

However, even the WSC Act 1991, discussed earlier, has similar conditions which mean that under particular circumstances the WSC does not have to supply water to certain customers:

The act requires the WSC to provide water of acceptable quantity and of "wholesome" quality. If this cannot be done through piped supplies it must be done through some other means which are "practicable" and "at a reasonable cost." (House of Representative, 1991, p.794). The only other means are by water tankers (bowsers) and from local boreholes. However, as previously mentioned, supplies by the former are hardly sufficient in quantity without considerable cost and the supplies from the latter are far from "wholesome".

"Where the quantity of water has been reduced as aforesaid in this section, no liablity shall be incurred by the Corporation in respect of any loss or damage caused by such reduction." (ibid, p.794).

3.5.7. First class water supply prioritisation

It is a fact of Maltese life that during the summer when supplies are at their lowest and demands at their highest, supplies are rationed by means of water cuts. Under these circumstances, the WSC, according to sources at the Malta Development Corporation (MDC) (1993), the National Tourism Organisation - Malta (NTOM) (1993) and WSC (1993), prioritises water supply so that hospitals and tourist areas are least likely to have their water supply cut off.

However, a University source (1993) told me that industry, especially that which has a large number of employees, is given the highest priority since although tourism may be economically important, it is not exportable as are industrial products. The low cost of water to industry reflects this:

"The need of water for directly productive activites necessitates that Government provides it below cost;" (Zahra, 1979, p.119).

In the past industrial estates have experienced water supply problems but since the Government has assisted several by increasing the capacity of their supply, they are relatively satisfied. The construction of the RO plants has helped considerably (WSC source, 1993) but a few are still short of water (pp.300 and 344-346).

Tourist areas are of a very high priority (ibid). For example, Buggiba was supplied with a larger nine inch main as soon as there was a severe shortage in 1987 and Sliema was provided with its own RO plant at Tigne in 1986 (ibid).

At a hotel in Sliema I was told that, "....especially in Sliema, we don't get so many water shortages. That is the best served area.... the tourist resorts on the Island, they are sort of always well supplied.... we have an RO system in Sliema [at Tigne] supplying it alone.... we have a water cut when we have a power cut...."

At a hotel in St. Julians, I was told how the WSC will arrive quickly to remedy a problem at a tourist establishment, while they have a reputation of not responding to calls from the public (domestic consumers) for longer (up to several months in some cases). The manager told me that, "If something is wrong with the pipes they come running.... Once I had a fault in a tap and they came instantly.... at home it'd be a few more hours."

A WSC source (1993) informed me that it is a myth that water cuts do not exist in tourist areas. All the hotel managers I spoke to in Bugibba, Qawra, Sliema, Xlendi and Marsalforn had said that they had experienced water cuts on a regular basis during summer 1993, usually once a week (pp.341-344).

Valletta, being the administrative and parliamentary centre is also considered important (WSC sources, 1993).

Residential areas are given a lower priority and some frequently experience water cuts, but if a residential area incorporates industry, tourism or a hospital it is of higher priority (ibid).

When water supply becomes problematic in residential areas, due to shortages, then supply in agricultural areas is reduced or cut off (ibid). Agriculture is lowest on the list of priorities since it relies mainly on second class water (ibid).

".... the demands on the water supply for domestic and industrial use exceed the natural potential and farmers certainly are not the first in the order of priority to be served out of expensive artificial sources." (Gatt, 1993).

It is interesting to note the perception of sources at the Department of Agriculture (DA) (1993) who considered the domestic sector as having the highest priority, for what reason is not clear.

The perceptions of most interviewees tended to draw on the same conclusion: that the tourist and industrial sectors are given priority. Only one WSC source (1993) stated that no particular sector is given a priority and that the WSC's concern is an equitable supply all round.

In addition, my own observations discovered that residential areas that are not already suffering from water shortages are most likely to bear the burden of water rationing, while those supplied solely by RO plants are least likely (since it is groundwater that is being rationed) (p.337).

Finally, influential politicians and contacts can often guarantee supply to whom they wish (pp.590-591).

3.6. SOURCES OF SECOND CLASS WATER

Second class water is that which is not considered fit for human consumption. Treatment varies from none at all, as in the case of water from boreholes for irrigation in agriculture (except by a few farmers with RO systems), to large investments to ensure strict standards, as in the case of recycled sewage effluent. There are a variety of sources and second class water is used in all sectors in some way.

Agriculture is the largest utiliser of second class water and is supplied by various sources for irrigation purposes.

It has been argued that,

"Local climatological characteristics make water resources the most important and at the same time limiting factor in agriculture." (Micallef, 1994, p.30).

The west and north receive on average more rainfall than the drier south. However, water availability and the type of agriculture in each region has been determined mostly by local soils and geology. For example, the soils in the south-east, irrigated by recycled sewage effluent, are very shallow, from 0.5m to 1m in depth (Haiste International Limited, 1990) and so the ground rapidly absorbs any moisture. This and local geological conditions have made water less abundant than in the west and north.

As a result, with respect to infiltration rates, the land in the south-east is considered marginally suitable for irrigation in small basins or short furrows given an instantaneous infiltration rate of 74 mm/h^{-1} (ibid). Before recycled wastewater for irrigation was introduced there, the region was either under dry farming or barren (SASTP source 1995).

Irrigated agriculture is in general a very small percentage of total agriculture which in turn is a declining sector. From Table 3.6. it can be seen that there has been a 42% decrease in total agricultural land between 1956 and 1994 from 20,433ha to 11,902ha (Meli, 1993). However, the decrease in dry agricultural land (by 41%) and wasteland (by 54%) has been far greater than that of irrigated and semi-irrigated land (11%) (ibid) mostly because of legislation protecting irrigated land from being taken over by development, and the introduction of the SASTP (SASTP source, 1993). Figure 3.14. shows the distribution of irrigated and semi-irrigated agriculture in Malta and Gozo. It can be seen that irrigated and semi-irrigated land is concentrated in the north-west, the west and the south-east in Malta, simply due to the availability of water in these regions.

The total number of farmers have been decreasing (Meli, 1993). In addition Table 3.7. shows that the number of part-time farmers has increased while the number of full-time farmers has decreased. The number of holdings has increased due to the division of land as it is handed down by retired farmers to their sons.

Given these circumstances, irrigation is not a common practice or considered important for a semi-arid country and is practised over only 4% of the registered agricultural land (Micallef, 1994). Meli (1993) states that this figure is 6%, including semi-irrigated land.

The most common irrigation techniques are surface/furrow (Plate 3.10.) and sprinkler irrigation (Plate 3.11.). Many farmers own small water reservoirs to store water when it is available, for use when it may not be. Cultivation is intensive and the main crops are vegetables, including potatoes and onions, which are exported to EU countries (Micallef, 1994).

Rainfall is usually sufficient most of the time (eight years out of ten) for a good winter crop, but not for a spring sown crop which, in the case of most fruit and vegetables, cannot be grown without irrigation.

Table 3.6. Agricultural land (ha) in the Maltese Islands (1956-1991)

Year	Dry			Irrigated			Waste			Total		
	Malta	Gozo	Total	Malta	Gozo	Total	Malta	Gozo	Total	Malta	Gozo	Total
1956	13,392	3,676	17,068	704	112	816	2,304	246	2,550	16,400	4,033	20,433
1961	11,864	3,132	14,996	615	78	693	2,120	198	2,318	14,599	3,408	18,007
1966	10,885	2,867	13,752	632	61	693	1,794	234	2,028	13,314	3,162	16,476
1971	9,984	2,641	12,625	568	59	627	1,740	198	1,938	12,292	2,898	15,190
1976	9,777	2,390	12,167	648	43	691	1,636	224	1,860	12,061	2,657	14,718
1981	8,938	2,093	11,031	552	34	586	1,424	191	1,615	10,914	2,318	13,232
1986	7,958	1,920	9,878	627	37	664	1,282	162	1,444	9,867	2,119	11,986
1991	8,454	1,544	9,998	681	42	723	1,030	151	1,181	10,165	1,737	11,902

Source: Meli, 1993.

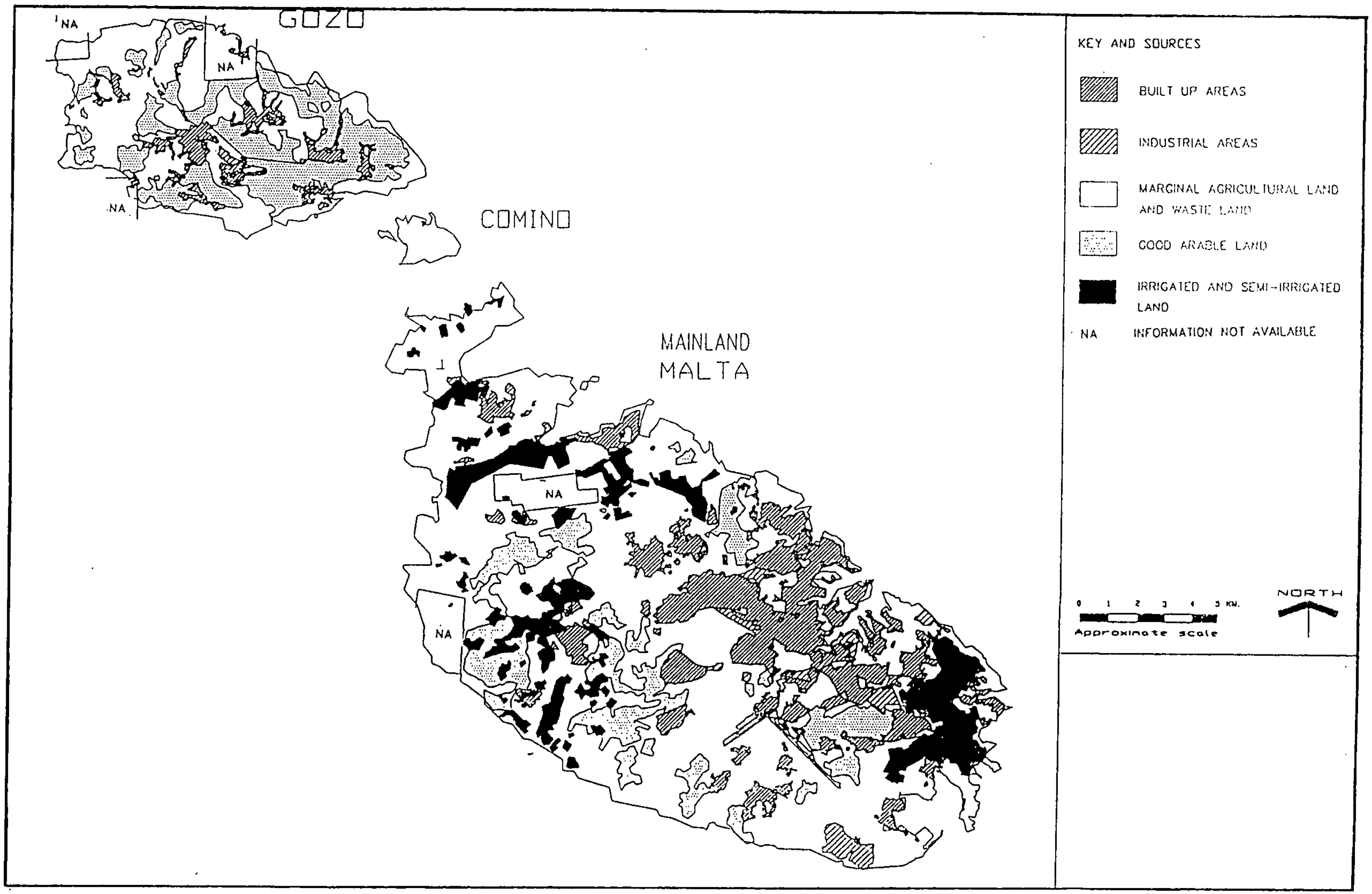


Figure 3.14. The location of irrigated and semi-irrigated agricultural land.
Source: Spiteri, 1992a.

Table 3.7. Farming population and the number of holdings in the Maltese Islands (1956-1991)

Year	Whole-time farmers			Part-time farmers			Total farmers			Agricultural holdings		
	Malta	Gozo	Total	Malta	Gozo	Total	Malta	Gozo	Total	Malta	Gozo	Total
1956	5,468	2,025	7,493	7,573	2,176	9,749	13,041	4,201	17,242	9,123	3,517	12,640
1961	5,114	2,216	7,330	7,174	1,641	8,815	12,288	3,857	16,145	8,340	3,184	11,524
1966	4,486	1,797	6,283	6,772	1,843	8,615	11,258	3,640	14,898	7,867	3,089	10,956
1971	4,027	1,609	5,636	6,538	1,786	8,324	10,565	3,395	13,960	7,690	2,909	10,599
1976	4,710	1,309	6,019	8,144	2,634	10,778	12,854	3,943	16,797	8,737	3,083	11,820
1981	3,376	976	4,352	8,562	2,361	10,923	11,938	3,337	15,275	8,805	2,937	11,742
1986	1,933	585	2,518	9,558	2,716	12,274	11,491	3,301	14,792	8,930	2,921	11,851
1991	1,248	225	1,473	10,865	2,942	13,807	12,113	3,167	15,280	10,157	2,801	12,958

Source: Meli, 1991.

Plate 3.11. Old and new technology outside Rabat: a traditional wind pump (background) and a sprinkler irrigation system (foreground).

Plate 3.12. Drip irrigation near Siggiewi where locally available water is scarce.

The *Malta Structure Plan* (Ministry for Development of Infrastructure, 1991b) summarises the present role of water in farming:

"Water availablity is one of the bottlenecks for agriculture. Apart from about 300ha in the South East Region which are supplied with reclaimed irrigation water from Sant'Antnin Sewage Treatment Plant (SASTP), irrigated land is concentrated over the perched aquifer in the North West Region of mainland Malta. Water is extracted from privately owned wells, using wind powered and fuel driven pumps.... Rainfed agriculture occurs on about 95% of the arable land.... From May to August there is practically no rain.... The vegetative period lasts about 210 to 230 days, from October to May.... In several holdings runoff water is collected from roads, stored in ponds, and used as supplementary irrigation in the springtime." (Ministry for Development of Infrastructure, 1991b, p.15).

3.6.1. Groundwater extraction

The exact number of boreholes owned by farmers, industry and private suppliers of water is not known, but approximately 5.5 million m^3/annum of groundwater is extracted by farmers through vested rights (Jaccarini and Degaetano, 1993). Illegally extracted water (pp.443-445) is not known.

This water is mostly used with little or no treatment. In some cases it is treated by industry, private suppliers and a few farmers to upgrade its quality. Once this has happened it may still be considered second class water depending on the level and type of treatment. For example, two bottled water producers extract water from underground springs in the west of Malta and treat it to potable standards. The

Tessons-Sullivan company, that produces *Flavia* bottled water, obtains water from an underground spring in the Girghenti Valley. The Marsovin company obtains spring water from the Bahrija Valley for their bottled water, *Fontana*.

Water extracted by private suppliers for commercial purposes, although strictly an illegal activity, is usually sold (at approximately Lm 11/5.5m^3) to hotels and domestic consumers during tap water suspensions, owners of swimming pools (farmers sold water to fill up the national swimming pool in Msida for the 1992 Small Nations Games) and also to farmers without local supplies. Farmers may also buy water from the DA (at Lm3/5.5m^3) (DA source, 1993).

Many private suppliers are farmers themselves selling water to traditionally dry farming areas like those around Siggiewi, Safi, Kirkop and Zebbug. The main crops grown in these relatively waterless regions are potatoes and onions, needing relatively little water. During the summer, farmers that purchase water can grow melons by using drip irrigation (Plate 3.12.).

A farmer between Zebbug and Siggiewi told me, "Water we don't have over here.... There's a well.... it will fill once in winter and that's that.... its empty.... This area there is no supply of water.... Its always been like that.... That's why I have these trees because its not necessary to water them. If I water them it will give you much more than this.... There's a guy at San Blas he sells water.... he's got a borehole.... he's a full timer and he supplies water to other farmers."

Farmers that have a local supply of water may also need to buy water towards the end of the irrigation season as supplies run out. A farmer in the Bahrija Valley told me that if he needs more water, then he has to buy a bowser: ".... during the summer because it's very dry.... people who have potatoes have to buy because it uses a lot."

As one DA source (1993) put it, "We call it gold. When one owns a borehole he owns gold." However, the extraction of groundwater is mostly undertaken by farmers for their personal needs:

3.6.1.1. Groundwater extraction in agriculture

Groundwater extraction for irrigated agriculture is limited to the west, from the perched aquifer and the north-west region of Malta, from the smaller perched aquifers and semi-confined sea level aquifers of the Upper Coralline limestone. There used to be some extraction in the area south of Qormi before it was urbanised. Extraction in the south-east area is limited by the high salinity of the groundwater there, prone to seawater intrusion and varying from 2,294 to 44,957 ppm chlorides (Haiste International Limited, 1990).

Wind pumps, which can still be seen standing derelict (Plate 3.11. and Plate 6.18.), have been long replaced by diesel and electric pumps, although wind pumps are still used sometimes alongside new pumps.

The groundwater in the semi-confined aquifers of the Pwales Valley, Ghadira Valley (Plates 3.13. and 3.14.) and Mizieb Valley is very saline (up to 7,000ppm chlorides) due to contact with seawater, but abundant in supply.

In the Pwales Valley I was told by farmers that they had a plentiful supply mostly from perched aquifer springs and saline boreholes (Plate 3.15.). They were aware that other areas had less water: "For this area it's enough. Beyond the hills [Rabat-Dingli Uplands] there is no water at all," I was told. Not a single farmer interviewed in this area said that they did not have enough water.

In Gozo, the greater abundance of Blue Clay ensures that water supply from springs and groundwater is more

Plate 3.13. The Ghadira Valley. Agricultural land is at sea level and hence extracted irrigation water is very saline.

Plate 3.14. Salt lakes in the Ghadira Valley, which are used for irrigation.

Plate 3.15. Cultivation in the Pwales Valley. Clay rich slopes and associated springs provide a relatively good quality alternative to saline groundwater.

Plate 3.16. Blue clay slopes in Gozo.

Plate 3.17. A diesel pump extracting groundwater in Gozo.

abundant than in Malta (Plates 3.16. and 3.17.), but shortages can occur in several places (pp.339-341).

Water supply from the perched aquifers is relatively low in salinity but, as these farmers stated, limited in supply. Extraction is usually directly from the water table by deep boreholes or interception of underground springs. In the past, farmers there were allowed to extract extensively (University source, 1993). However, pumping permits that were issued freely to farmers and the extraction of groundwater by sinking new boreholes was legal, but now this is no longer the case:

"There exists a 'Water Ordinance' according to which one requires a licence to pump groundwater. The enforcement of the ordinance is less than satisfactory. Presently, a limit is imposed on the pumps capacity whenever new pumps replace older ones. New drilling by private owners is prohibited. Pumping from old boreholes (usually drilled before 1945) is continued." (Riolo *et al*, 1993, p.38).

Very often farmers are not able or not allowed to pump for about twenty four hours, as is the case, for example, on land around Rabat (DA source, 1993).

3.6.2. <u>Surface run-off water</u>

The storage of winter run-off behind dams in *widien* (Plates 3.18. and 3.19.) gives rise to agricultural supplies that can last well into the summer. The most extensive grouping are behind the dams in the Ta' l-Isperanza and Qleigha Valleys, called the Chadwick Lakes. Figure 3.15. shows the location of dams in Malta.

Run-off is also collected from some rural roads. For

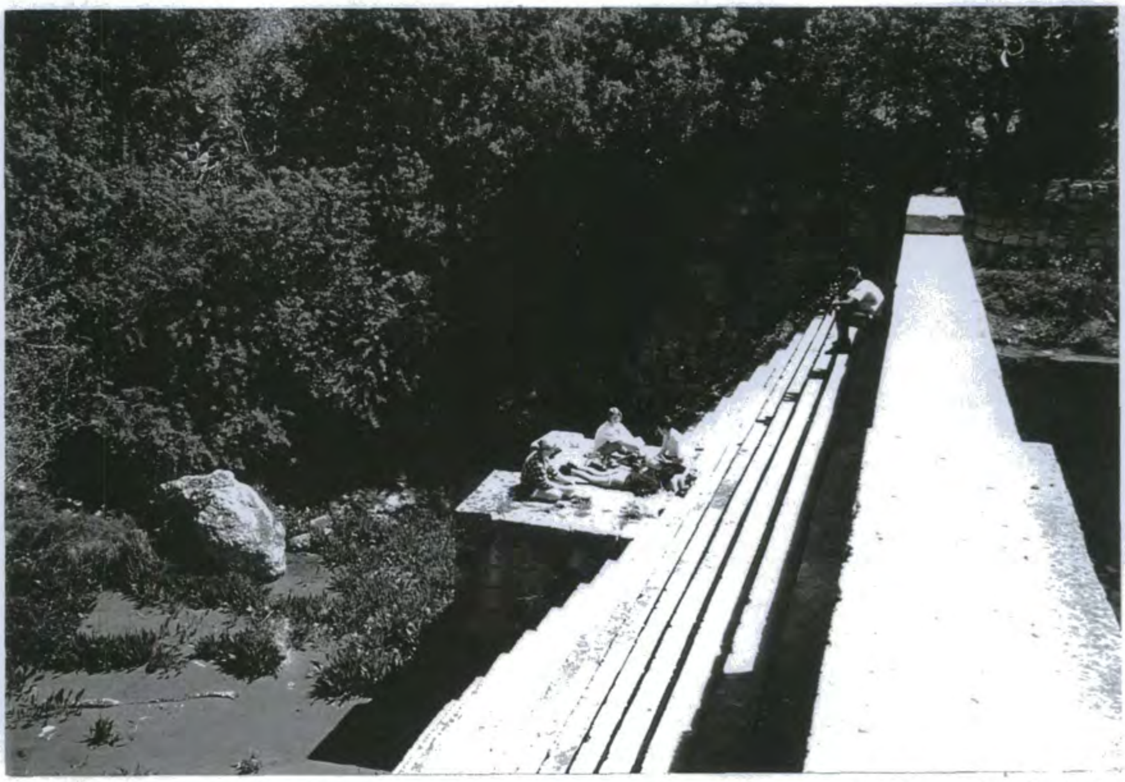


Plate 3.18. A dam in Wied il-Ghasel (part of the Chadwick Lakes in the Qleigha Valley).

Plate 3.19. Surface ponding behind a dam in a *wied*.

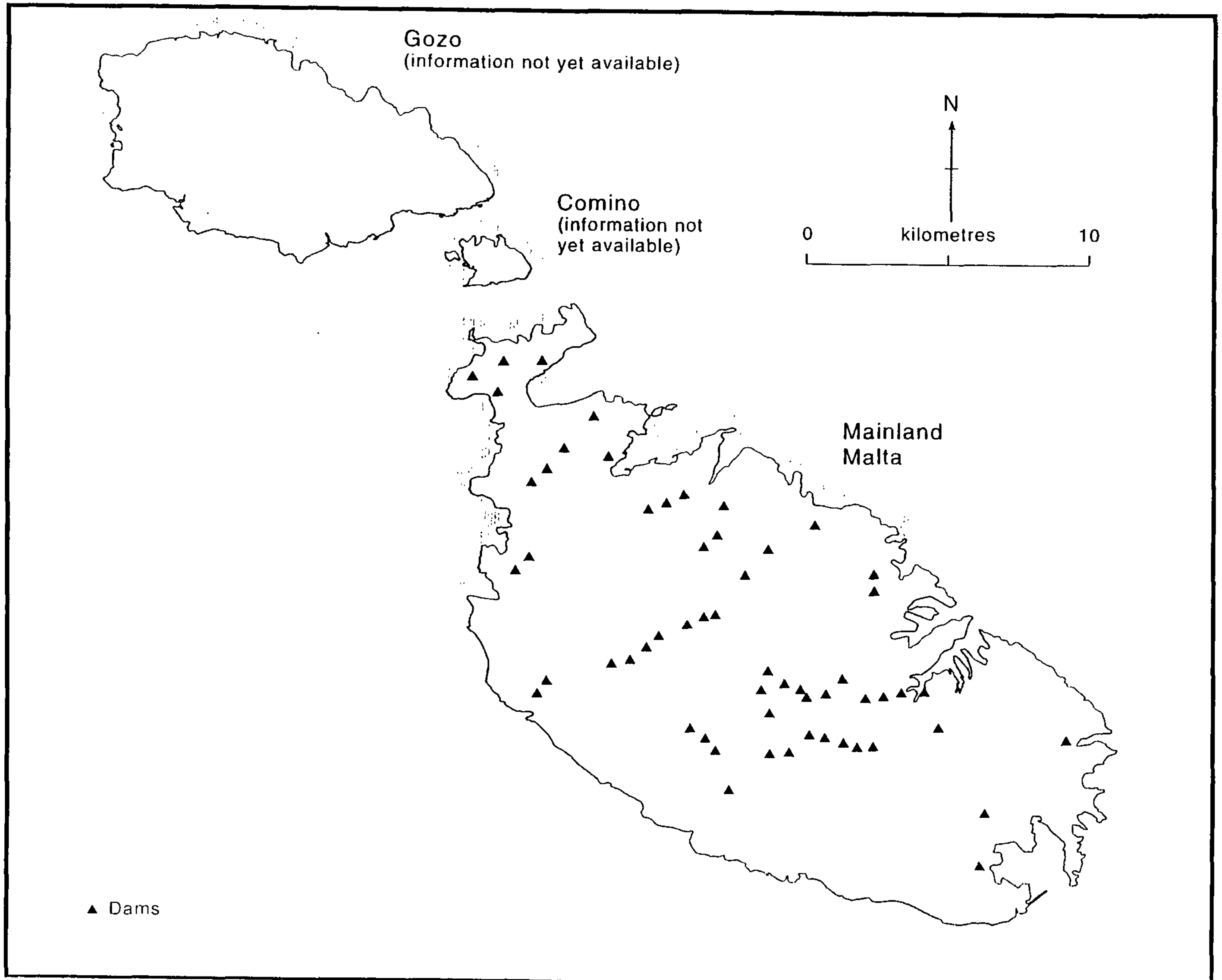


Figure 3.15. The location of dams in Malta.
Source: Ministry for the Development of Infrastructure, 1990; 1991.

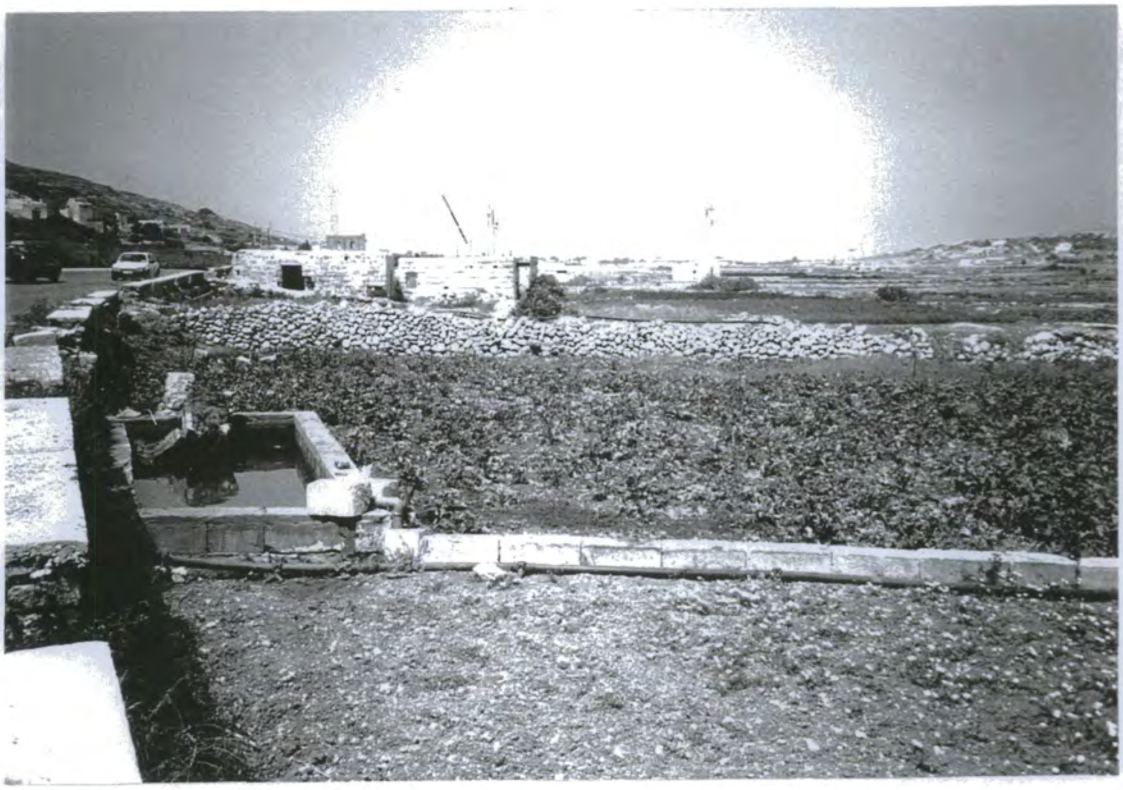


Plate 3.20. A water storage tank (Pwales Valley).

Plate 3.21. A disused quarry in Mqabba, used as a second class water reservoir.

example roads in Mtahleb, have diversion ridges across them to channel water to the side for collection in small tanks (Plate 3.20.). This is used by local farmers and transported away by others.

Water is also collected from the runways at Luqa airport, the roofs of farm buildings and glasshouses (Plate 3.8.), and stored in ponds, small tanks (reservoirs) (Plate 3.20) and some quarries (Plate 3.21.). A number of farmers also make use of surface springs, especially in Gozo and the west of Malta.

3.6.3. Domestic cisterns

As already discussed, by law each domestic residence should have an underground cistern to store rainwater collected from roof tops (Falzon, 1973). Exactly how much exists or is used is not known. However, WSC sources (1993) stated that it is potentially a very significant amount since at one time this was the only source of water for those living away from the springs in the west. It is mostly used for watering gardens and washing, especially in the summer.

3.6.4. Recycled sewage effluent

Approximately 80% of total domestic water consumption ends up in the public sewers (Debono, 1994). Since 1980, the Sant' Antnin Sewage Treatment Plant (SASTP) (Plate 3.22.) has been recycling 17% of this wastewater to provide irrigation effluent for agricultural land in the south-east of Malta.

"The Sant' Antnin scheme was planned in the 1980's in response to some of the island's pressing problems. In particular, it addresses those of a growing volume of

Plate 3.22. The Sant' Antnin Sewage Treatment Plant.

Plate 3.23. WSC bowsers stationed outside the Luqa reservoir.

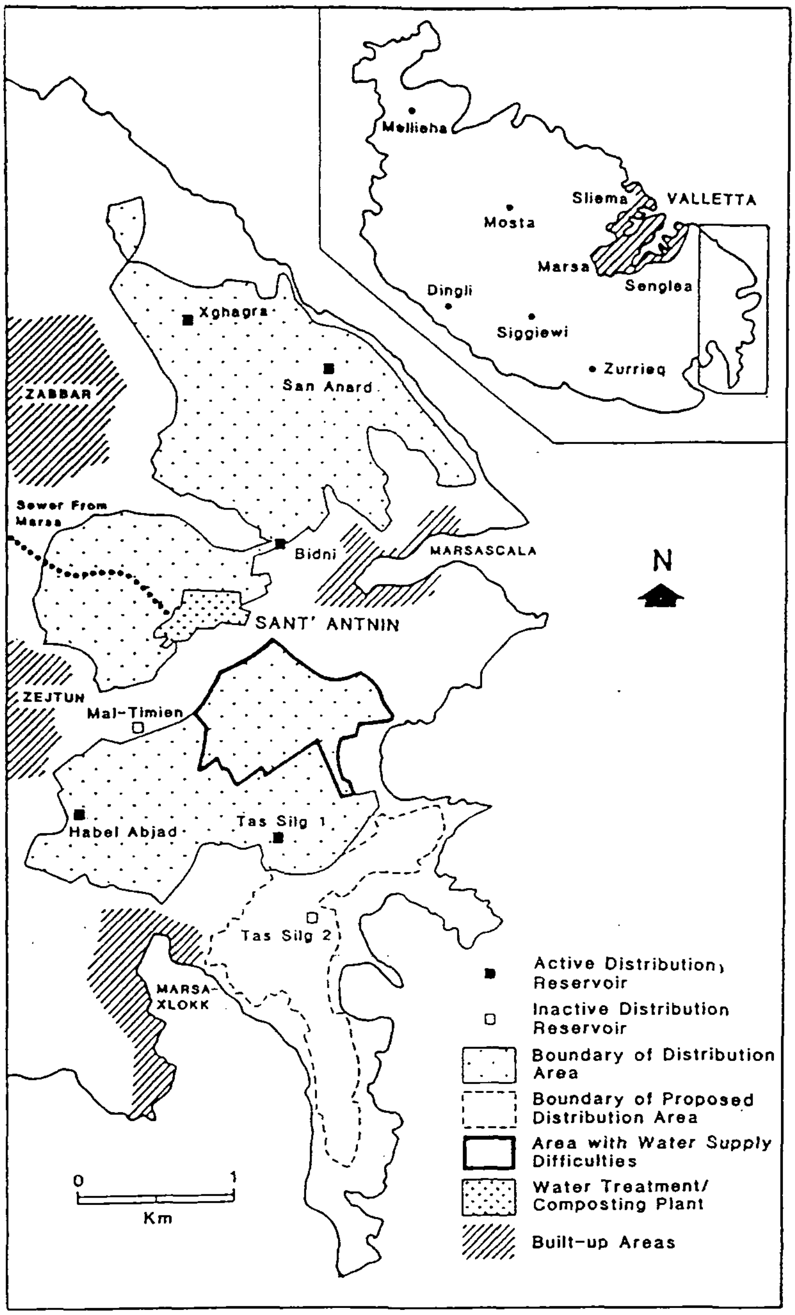


Figure 3.16. Location of the SASTP and satellite distribution reservoirs and their respective distribution areas.
Source: Short and Ticker, 1994.

wastes from the urban system, increasingly intense competition for water (for example between potable, industrial and agricultural applications), and weakening farm sector performance in the context of industrialization and a declining food balance." (Short and Tricker, 1994, p.213).

Figure 3.16. shows the location of the SASTP (further reference to this map is made later and in subsequent chapters). The plant cost Lm5.8 million (Gauci, 1993) and began operation in 1984 solely to supply recycled irrigation effluent to help meet the goals of Malta's agricultural development policy:

"..... The Sant' Antnin scheme appears to offer opportunities to fulfil such objectives through the application of advanced resource conservation and recycling technology. Although primarily about introducing modern irrigation to a number of small family farms, the project articulates with several of Malta's social, economic and environmental concerns, notably increasing integration of rural and urban lifestyles, the place of part-time farmers in agricultural change and a search for agriculture's role in Malta's future development.... The physical extent of the scheme depends in part on issues of definition. There are early references to a 630 ha project.... an area which would have effectively doubled Malta's irrigated land resource. In practice, the net area irrigable under the scheme is smaller. Some land within its perimeter is inherently inaccessible or unsuited to irrigation - roads, buildings, steep slopes, marginal soils. Some farmers have responded to the flat-rate area based water charges [see p.236] by having part of their farm declassified for irrigation, usually on grounds of 'bare rock'. There have also been technical limitations which have curtailed the scheme's capacity. Once these factors are discounted, the potential irrigated area falls to around 400 ha." (Short and Tricker, 1994, pp.212-213).

For their raw sewage, the managers at the SASTP have a choice of source region to use since the salinity varies from place to place (SASTP source, 1993). Figure 3.17. shows the sewage master zones of Malta and Gozo, sewage flows and the discharge points for these flows.

Ideally the sewage effluent with the lowest salinity is best for recycling, since the process does not remove salts. Hence, sewage from the 'Marsa Land' drainage (sewage supply) area (Table 8.3. (p.620)) in the northern half of the 'Marsa South' sewage master zone (see Table 8.3. for salinity values of drainage supply areas in the sewage master zones), 'D' in Figure 3.17., is used because the area has relatively good quality tap water and is away from coastal seawater intrusions and brine reject from hotels which, otherwise, would make the wastewater more saline. However, the recycled water is still considered too saline for some crops (p.424) (ibid).

The sewage converges at the Marsa (sewage) Pumping Station from where wastewater is pumped to the SASTP to undergo treatment to tertiary level. Table 3.8. gives the treatment components and specifications of the SASTP. Figure 3.18. is a plan of the SASTP. Figure 3.19. shows the various stages in the treatment process. Reference to these will help to illustrate the following discussion on wastewater treatment at the plant.

The wastewater is biologically treated to secondary level using the Activated Sludge Technique, and then passed through a rapid sand filtration process and finally chlorinated (Gauci, 1993). The main treatment applications are those necessary to remove ammonia and organic matter since these two contaminants interfere with disinfection (Riolo *et al*, 1993). The processes involved in each treatment stage are as follows:

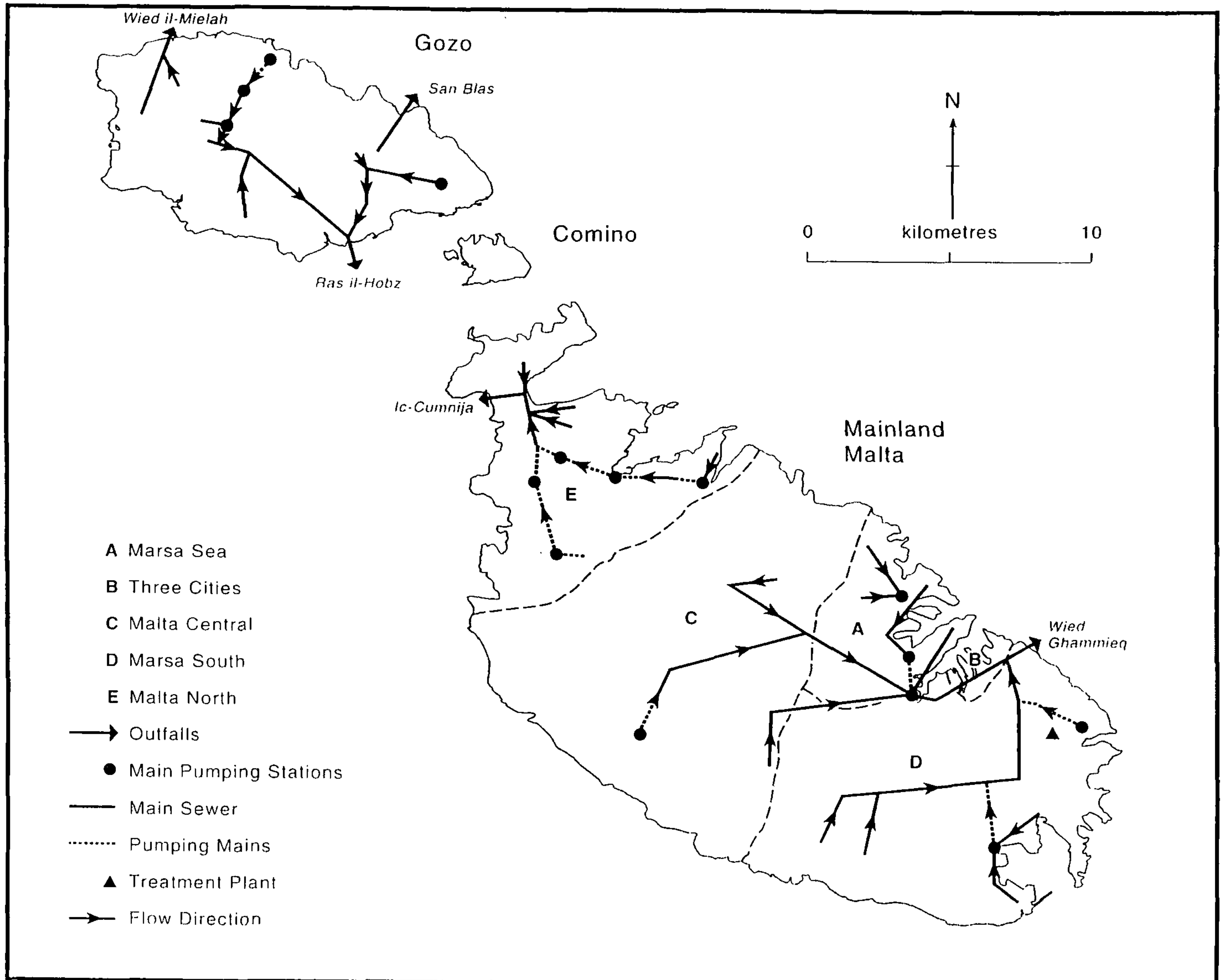


Figure 3.17. Sewage master zones (A,B,C,D and E), flows, pumping stations, and outfalls.
Source: Ministry for the Development of Infrastructure, 1990b.

Table 3.8. Sant' Antnin Sewage Treatment Plant (SASTP) treatment components and specifications

Component	Volume m3	Surface area m2	Capacity m3/hour	Comments
Oil and grit chamber	72			
Primary sedimentation	2 x 540	2 x 180		
Aeration tanks/aeration capacity	4 x 1,656 / 6 x 3,500			
Secondary sedimentation	2 x 1,414	2 x 707	1 x 400 / 1 x 240	
Sludge thickener	2 x 100			Not in use
Centrifuge				Never used. Make: Alfalval - 1981
Sand filtration		4 x 25 / 3 x 34	Backwash pump: 4 x 135	Backwash blowers: 2 x 1,200 m3/h
Chlorination			Dosage: 12 mg/l (Cl) / Residual: 1 mg/l (Cl)	

Source: Ministry for the Environment, 1992.

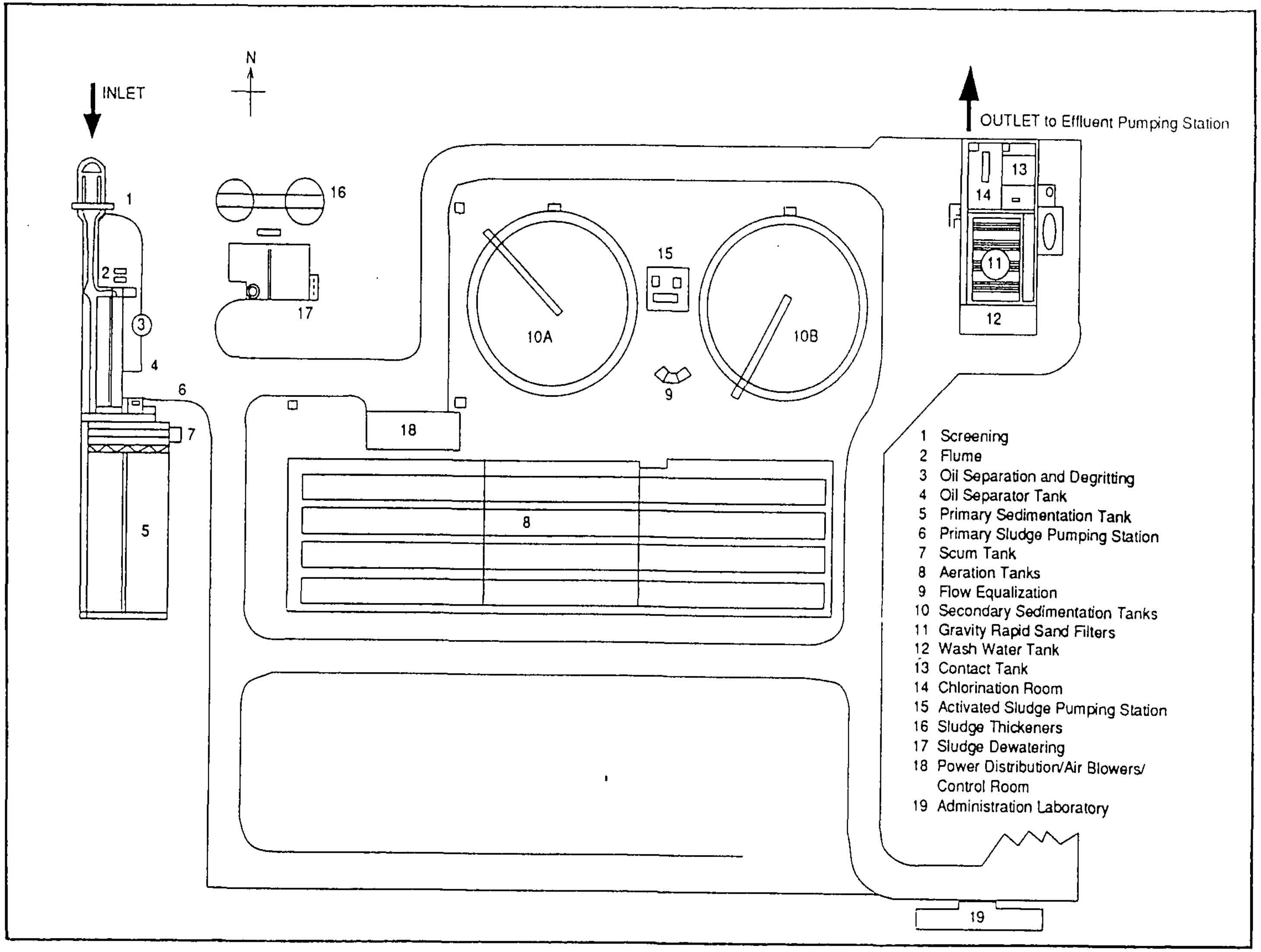


Figure 3.18. Plan of the SASTP.
Source: Gauci, 1993.

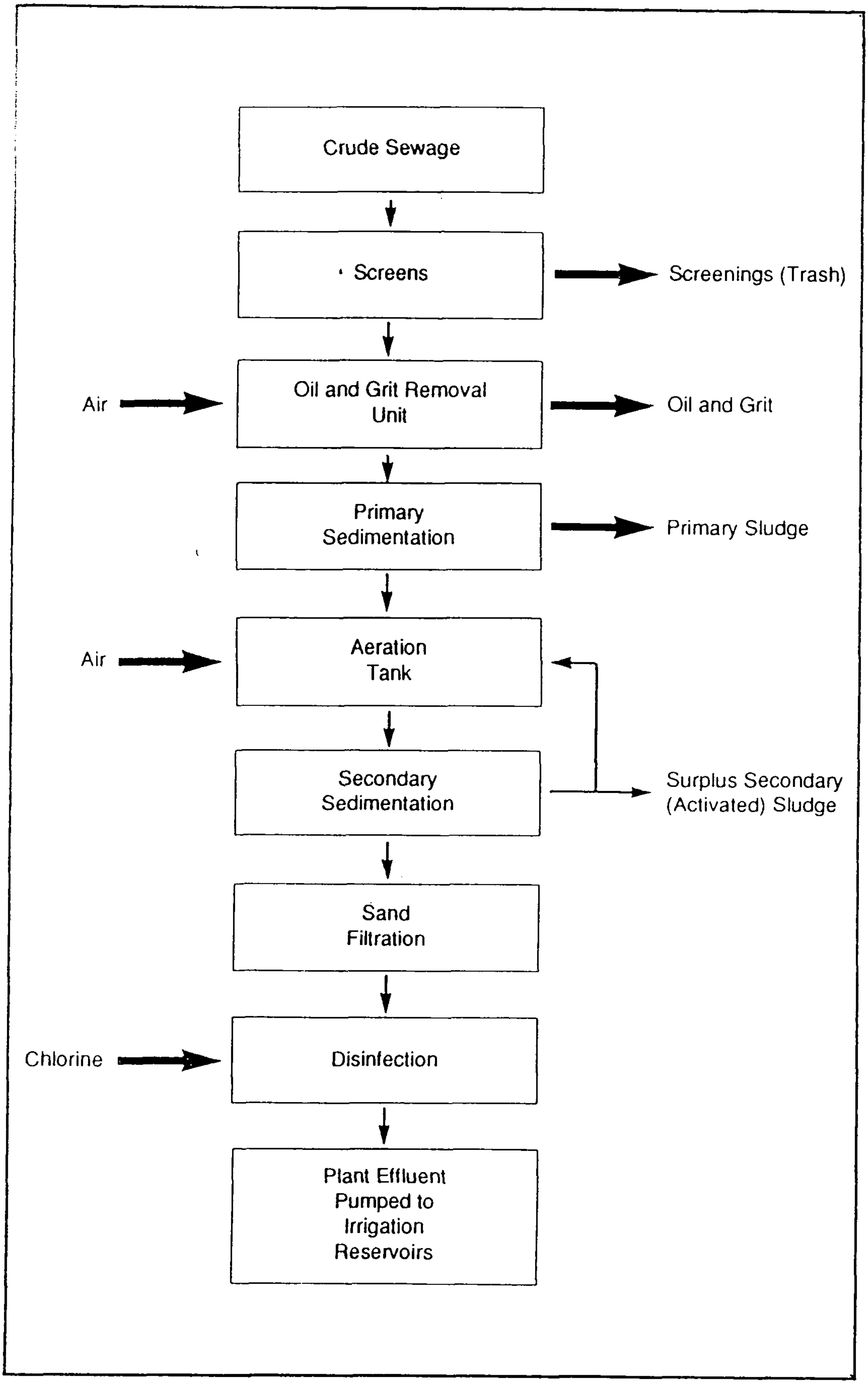


Figure 3.19. Summary of sewage treatment stages at the SASTP. Source: Gauci, 1993.

1. Preliminary Treatment: Screening and oil/grit removal.

At this stage materials that may cause mechanical problems in later stages are removed. The sewage is then screened through iron bars, 2.5cm apart. Heavy settleable solids (grit) are removed by passing the screened sewage through an aerated channel. Once the solids settle they are removed. Oil is removed as a scum off the surface (Ministry for the Environment, unpublished paper).

2. Primary treatment: Settling.

This stage removes lighter, mainly organic, settleable solids by passing the sewage through a tank, allowing them to settle and discarding them as a sludge (ibid).

3. Secondary treatment: Biological oxidation in an aeration tank and settling.

During this stage air is blown via diffusers through the settled sewage in a tank to encourage the growth of aerobic micro-organisms. Some of these bacteria consume organic pollutants in the sewage, while another group oxidises ammonia to nitrate. This process converts pollutants into biomass.

The second part of this stage involves the separation of the biomass from the water. The effluent is passed through a secondary settling tank where biomass settles in the form of Activated sludge, some of which is discarded and some which is recycled to the aeration tank. Clear effluent, overflowing the circumference of the tank, is the end product of this stage (ibid).

4. Tertiary treatment: Sand filtration and disinfection.

The effluent is filtered through sand to remove small particles of biomass and, finally, chlorinated (ibid).

The production cost of the treated effluent is 12c/m^3 (Gauci, 1993). The water is supplied to the farmers throughout the irrigation season, from March to November, at an annual nominal fee of Lm36.00/ha/annum (ibid). The revenue collected is only 4% of the effluent cost, the consequences of which are discussed in Chapter 5 (p.458).

During winter when the irrigation season is over, the SASTP reduces its capacity mainly for the type of maintenance that cannot be undertaken without shutting the plant down (SASTP source, 1994).

The plant employs approximately 35 people, including laboratory staff, mechanical engineers, foremen, electrical and mechanical fitters and several skilled and unskilled labourers (Gauci, 1993).

Table 3.9. and Figure 3.20. show that annual production of recycled wastewater has been increasing since 1984. From Figure 3.21. (and Table 3.9.), which shows monthly production for 1991, it is clear that production is greatest from March to November which reflects the demand for irrigation (pp.296-297).

The SASTP was treating approximately 6000m^3 of sewage per day during spring 1994. The maximum effective output is presently 7,000m^3/day which only enables it to produce enough water to theoretically irrigate 240ha (Ministry for Development of Infrastructure, 1991b).

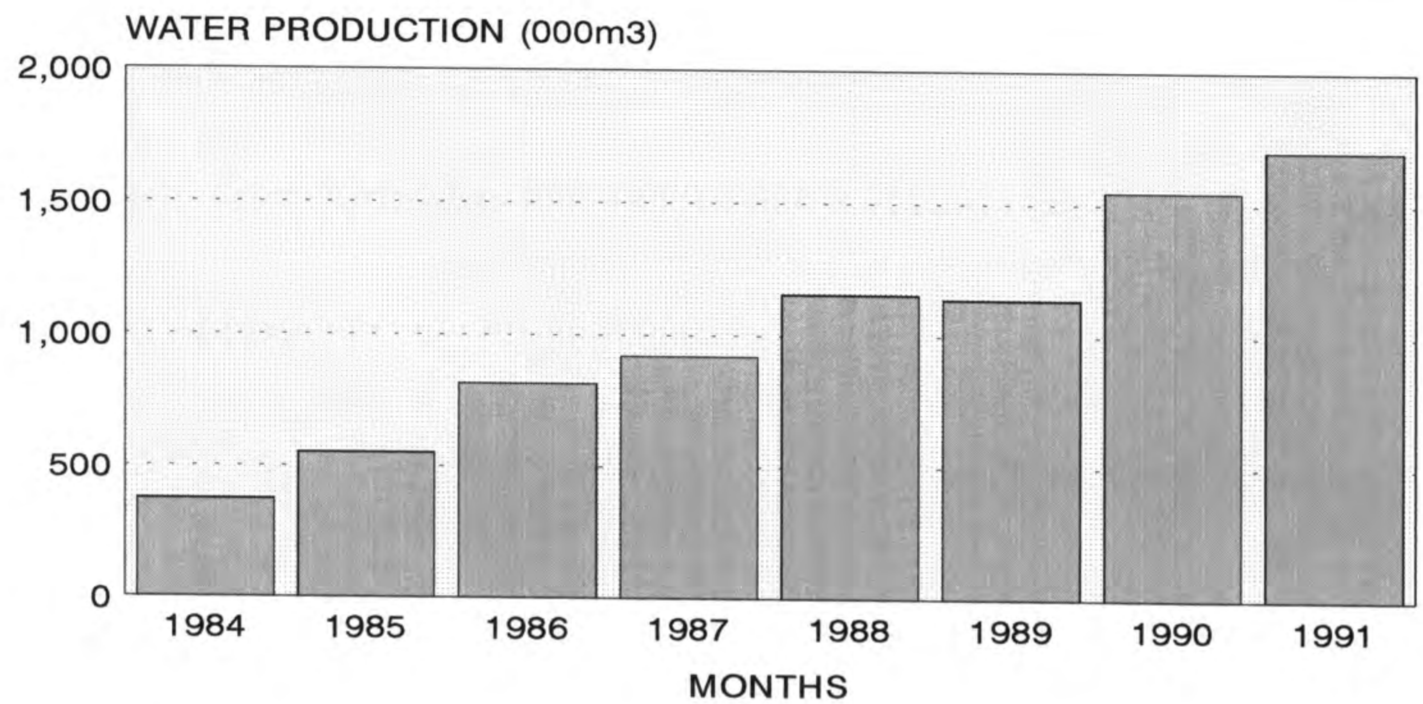
The total capacity of the plant is to be extended to 12,000m^3/day with the installation of newly installed components (Ministry for Development of Infrastructure, 1991b). With the necessary upgradings, the plant will be capable of treating 17,000m^3/day, a capacity for which it can accommodate within the present boundaries (Ministry for the Environment, 1992, p.6.29; SASTP source, 1994).

Table 3.9. SASTP recycled wastewater production (000m3) for the period 1984 to 1991

Month	1984	1985	1986	1987	1988	1989	1990	1991
January	0	0	0	0	17	0	0	13
February	5	0	0	0	62	0	0	27
March	4	34	64	3	77	90	180	90
April	45	58	98	60	139	153	189	202
May	48	65	89	112	131	130	158	178
June	43	65	98	99	129	145	149	162
July	43	71	131	140	155	145	201	221
August	60	71	127	136	168	165	199	213
September	77	73	116	130	113	157	192	225
October	47	62	83	129	136	73	171	195
November	0	52	9	68	28	73	84	124
December	0	0	0	45	0	8	27	53
Total	372	550	920	920	1156	1139	1548	1703

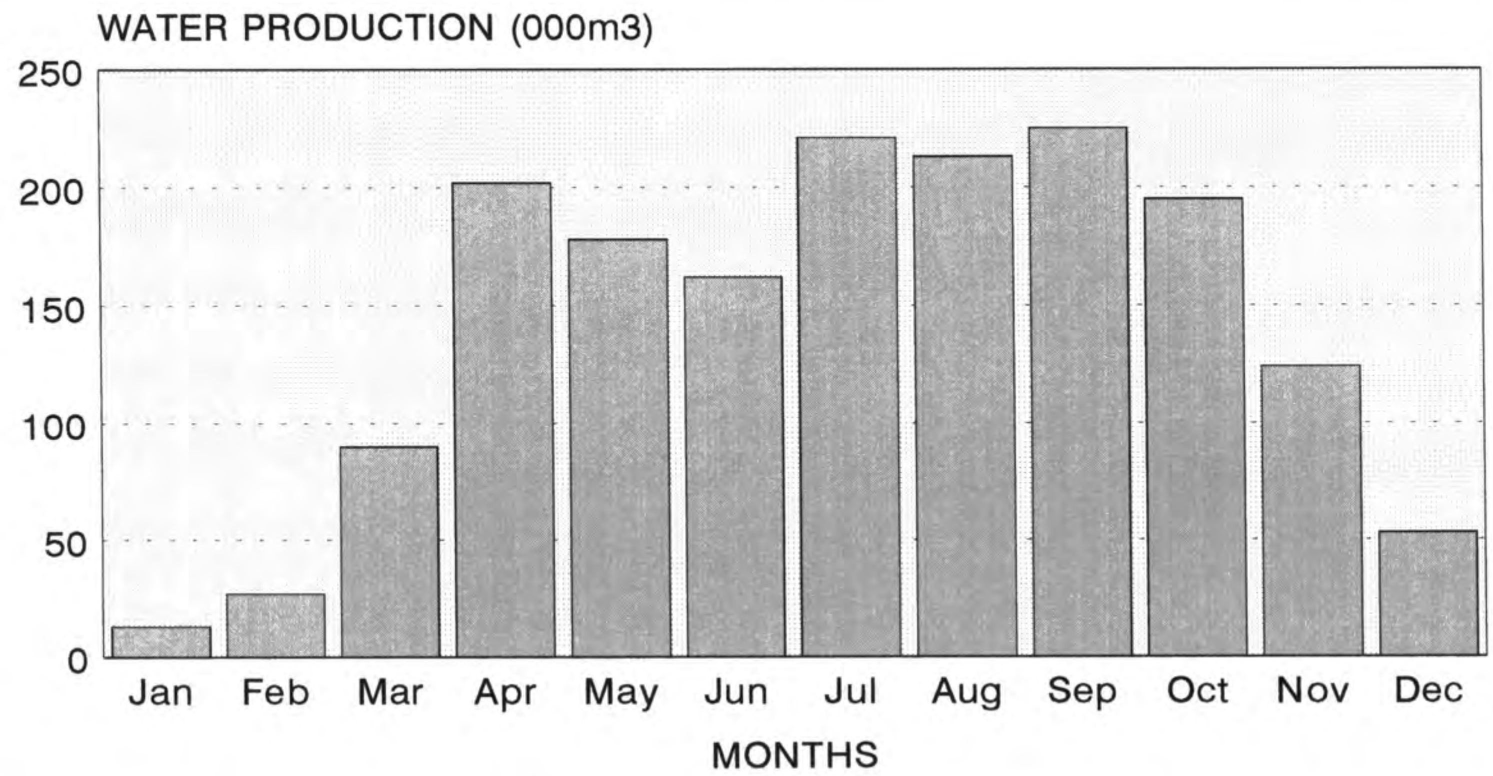
Source: Ministry for the Environment, 1992.

Figure 3.20. Total annual production of recycled wastewater at the SASTP for the period 1984 to 1991



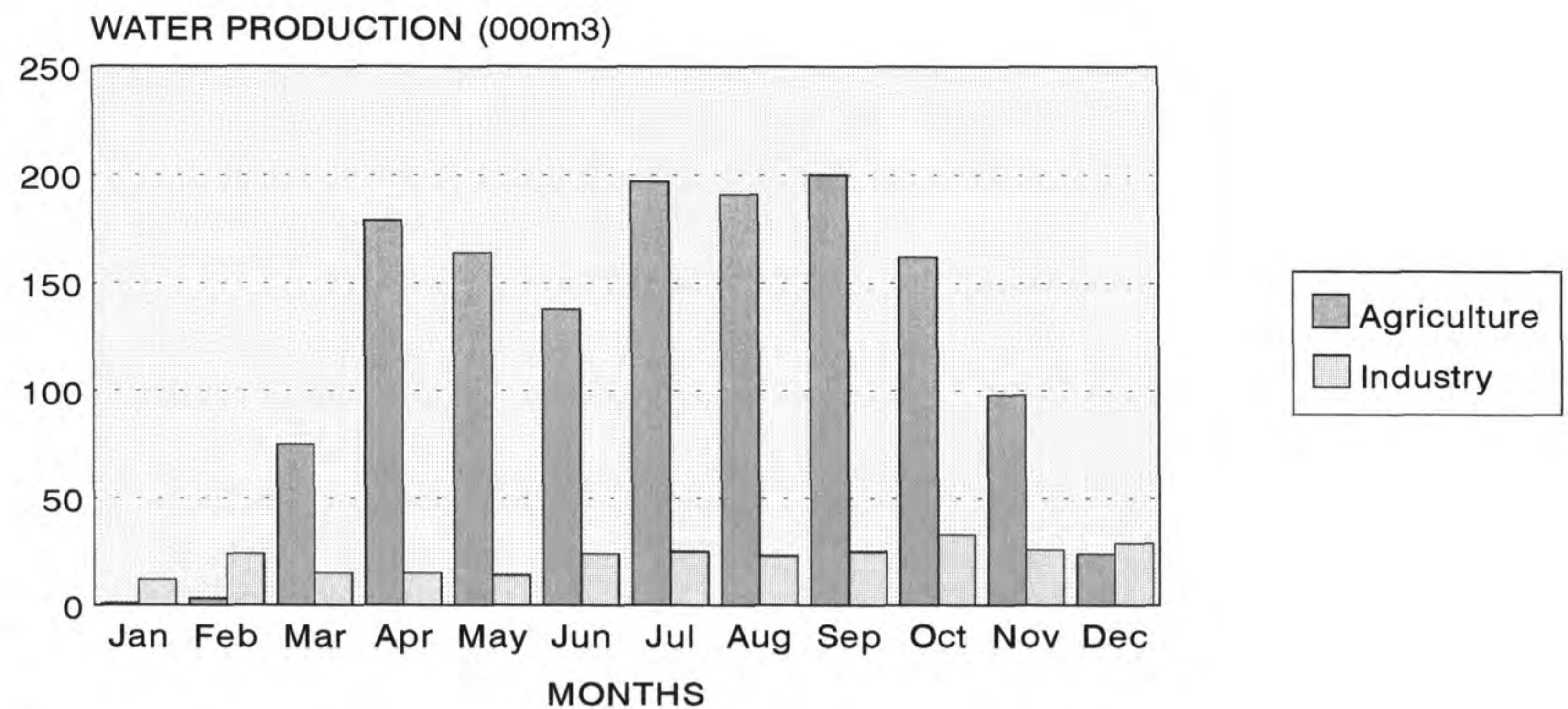
Source: Ministry for the Environment, 1992.

Figure 3.21. Monthly production of SASTP recycled wastewater for 1991



Source: Ministry of Environment, 1992.

Figure 3.22. SASTP recycled wastewater production for agriculture and industry for 1991



Source: Ministry for the Environment, 1992.

The plant is expected to continue operating for the rest of its lifespan of fifty years (DA source, 1993). It is supported by Government funds, since the revenue obtained from the effluent is hardly enough (SASTP source, 1994).

The SASTP supplies approximately 10% of its output to an industrial estate at Bulebel near Zejtun (DA source, 1993; Ministry for the Environment, 1992). Industrial demand is fairly constant throughout the year and so is production for the industrial estate. This production pattern is illustrated by Figure 3.22. It shows that there is a slight increase in wastewater production for industry from September to December since agricultural demand is low then.

Specifically, the water is used mostly by two laundry/washing factories and a leather processing factory (Micallef, 1994; Debono, 1994). The water can be diverted to irrigate turf at a football ground near Paola (DA source, 1993).

"Generally the plant only operates at the capacity and time required by the users of the produced second class effluent water, i.e. from March/April to November. During the months December to February the plant only treats the nominal requirements for industry, i.e. during winter most of the sewage will be conveyed to the outfall at Wied Ghammieq where it is discharged untreated." (Ministry for the Environment, 1992, p.6.27).

3.7. WATER DISTRIBUTION

The division of water supply and distribution, according to first and second class water, in the Maltese Islands is unique given the size of the Islands but reflects the need to utilise as many available sources and to allocate water so that first class water, which is expensive to produce, is not used where second class water will suffice.

The distribution of first class mains water is via an extensive distribution system consisting of pipes of varying size. Occasionally (frequently in times of water shortages) first class water is distributed in mobile tankers called bowsers (Plate 3.23.).

Second class water has several means of distribution since there is more than one source. Each of these are discussed. Cistern water is not discussed since its distribution is relatively simple: from the tank to the household under which it lies.

3.7.1. Government distribution of first class water supply

The national water distribution system in Malta is very complex. Some regions may get purely RO water while others get borehole water only. Some regions are supplied with a blend of RO and borehole water, mixed in reservoirs, and this blend may vary so that some regions will have mostly (or solely) RO water and some will have mostly (or solely) borehole water (WSC source, 1993).

In Malta, water reserves beyond, at the most, two days are insignificant, since reservoir storage capacity is not large enough (ibid). The surface storage capacities for Malta and Gozo are approximately 454,600m^3 and 90,900m^3, respectively. Figure 3.23. shows the location of all reservoirs in Malta. A comparison with Figures 3.24. and 3.26. shows that most of the reservoirs are conveniently located close to pumping stations and RO plants, their main sources of water, as well as centres of high water demand. Reservoirs (Plates 3.23., 3.24. and 3.25. show three of the largest) bridge the gap between production and consumption, particularly for blending RO and groundwater: "Our main reservoir is the sea," (ibid) I was told (and the MSLA aquifer, the other).

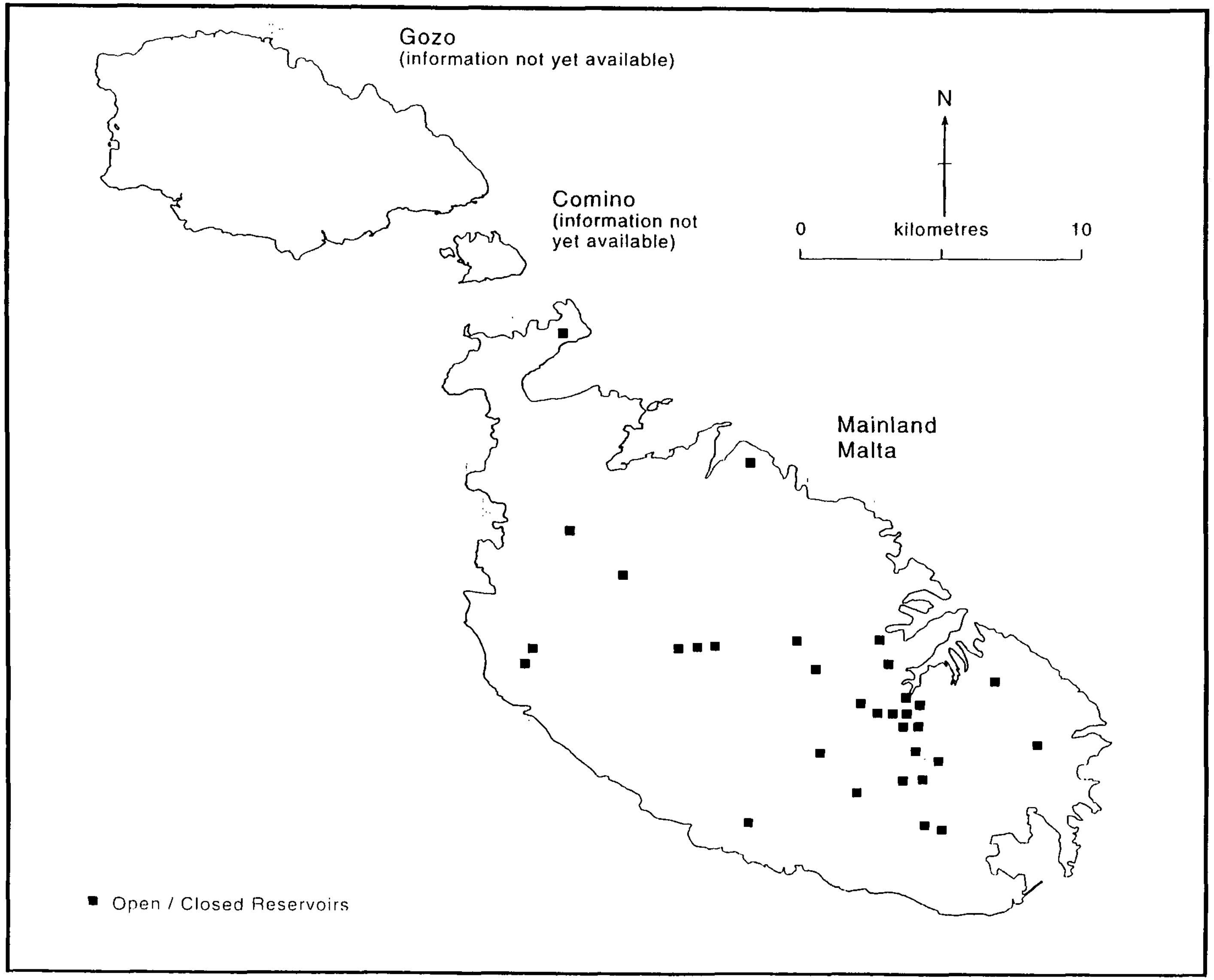


Figure 3.23. The location of reservoirs in Malta.
Source: Ministry for the Development of Infrastructure, 1990; 1991.

Plate 3.24. The Qrendi reservoir.

Plate 3.25. The Fiddien reservoir.

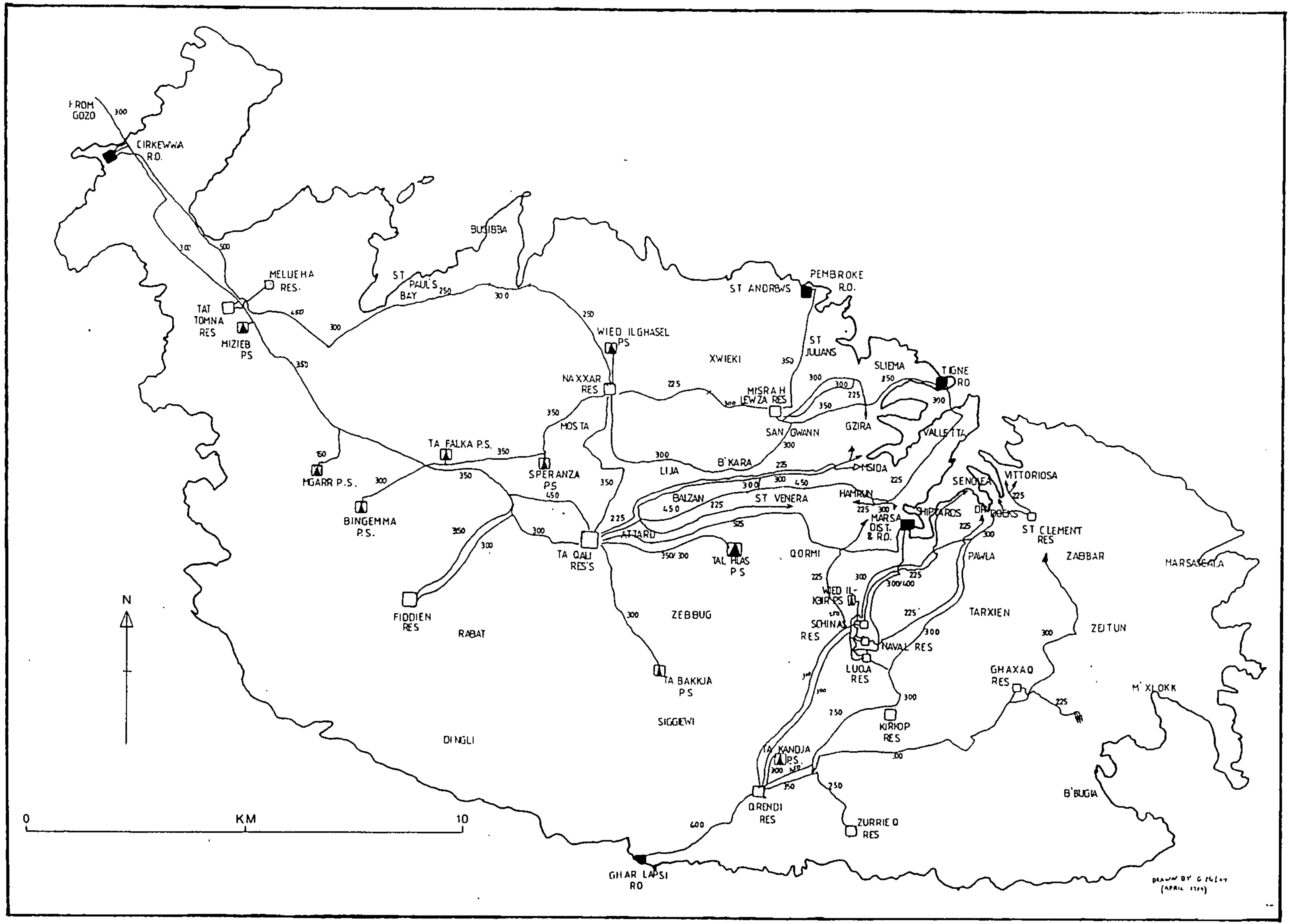


Figure 3.24. Malta water supply major distribution system (PS = pumping station; Res = reservoir; RO = RO plant.
Source: WSC.

3.7.1.1. Distribution patterns

Figure 3.24. shows the distribution network as it existed before September 1993 (Figure 3.26. is a general diagramatic representation). This distribution system is based upon the growth of settlements in Malta, some of which have grown and merged. As can be seen from the map the system is mostly linear with trunk mains supplying settlements directly from either RO plants, boreholes /pumping stations or reservoirs (Riolo *et al*, 1993).

"The distribution system is just as complex as the production system if not more so. It consists of 160 distribution zones which are defined by natural features such as topography and village boundaries, and by distribution system components such as [25] reservoirs, [17] distribution pumps, [*c*.600] shut valves and [137] flow meters. The [distribution] zones vary from small zones with either few consumers or small area to very large zones that include either numerous consumers or cover a wide area. In terms of consumption, they [zones] vary from as small as $20m^3$/day to about $3,500m^3$/day. About a third of the zones are monitored for consumption; the rest require additional meters." (ibid, p.19).

Figure 3.25. shows the high level of division of Malta into sub-zones and master zones. The largest zones are mostly rural while the smallest are mostly densely populated urban areas to make their management easier. Figure 3.26. shows a generalised diagram of flow directions of water in distribution from source to supply areas. Water is not always sent to reservoirs from boreholes, pumping stations and RO plants, but may be supplied directly from these sources.

Figure 3.27. is a flow diagram which complements Figure 3.24. to show the main water sources and reservoirs and their respective supply areas/settlements.

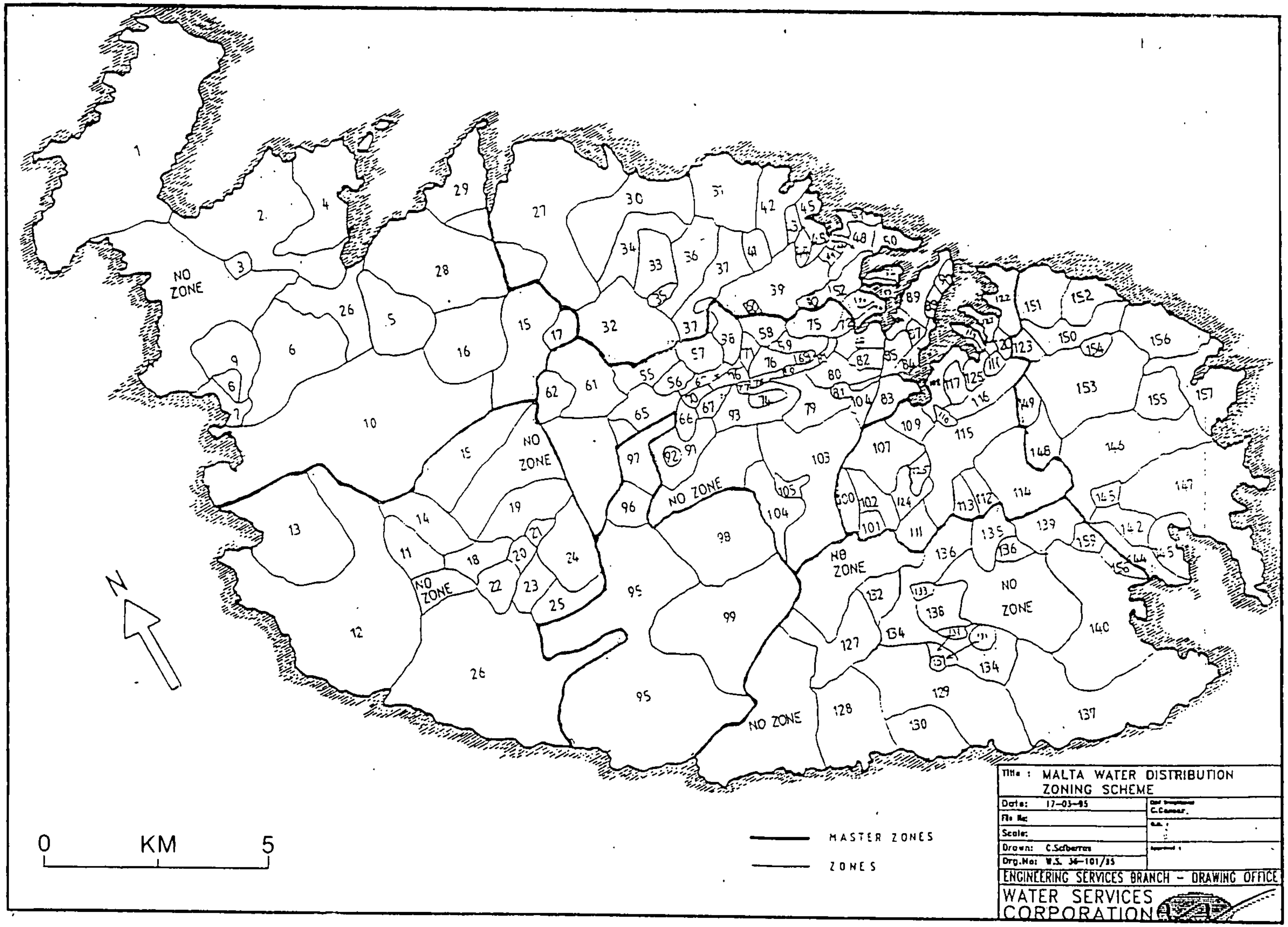


Figure 3.25. Water supply master zones and sub-zones in Malta.
Source: WSC.

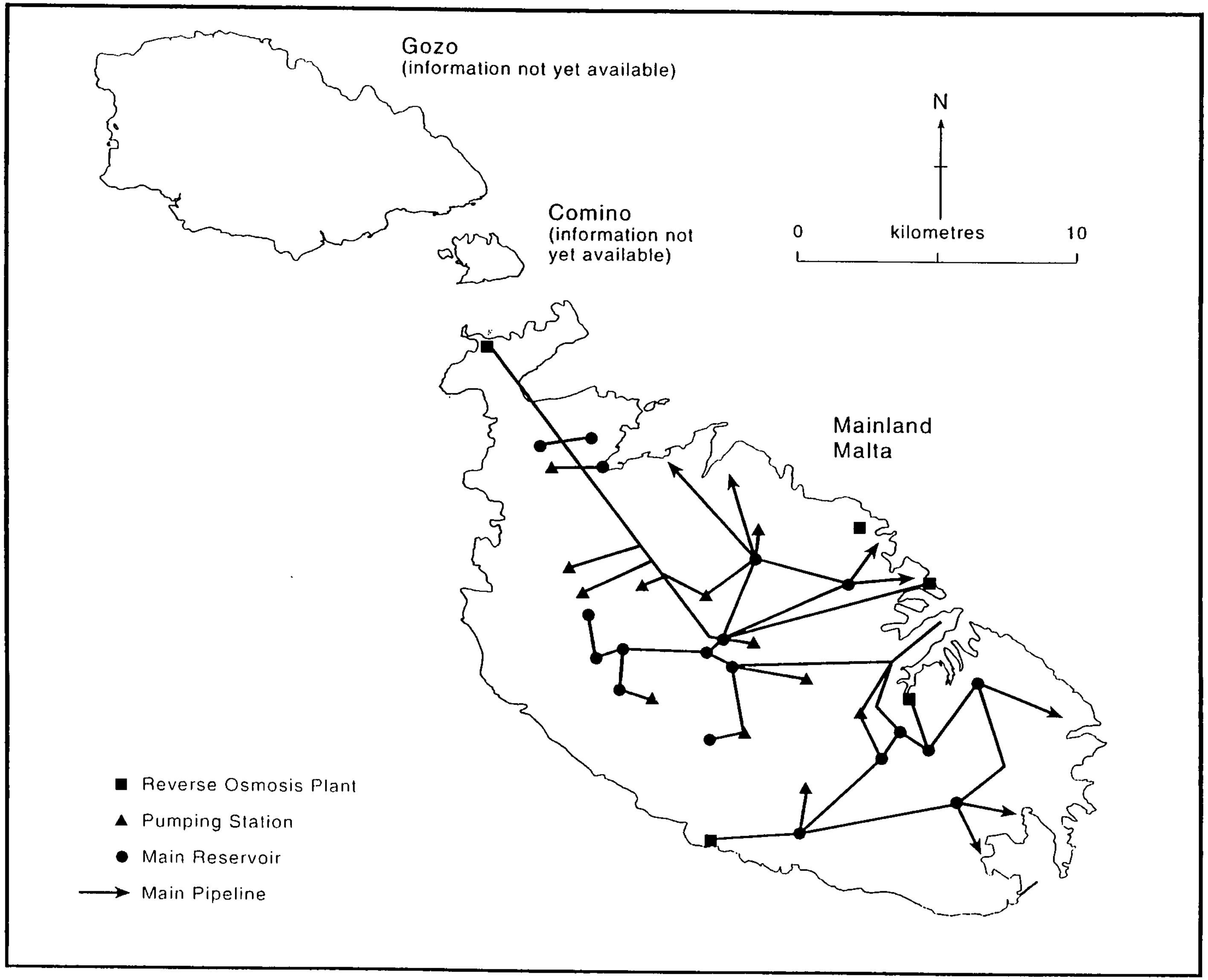


Figure 3.26. Main water sources and generalised water distribution flows.
Source: Ministry for the Development of Infrastructure. 1990; 1991.

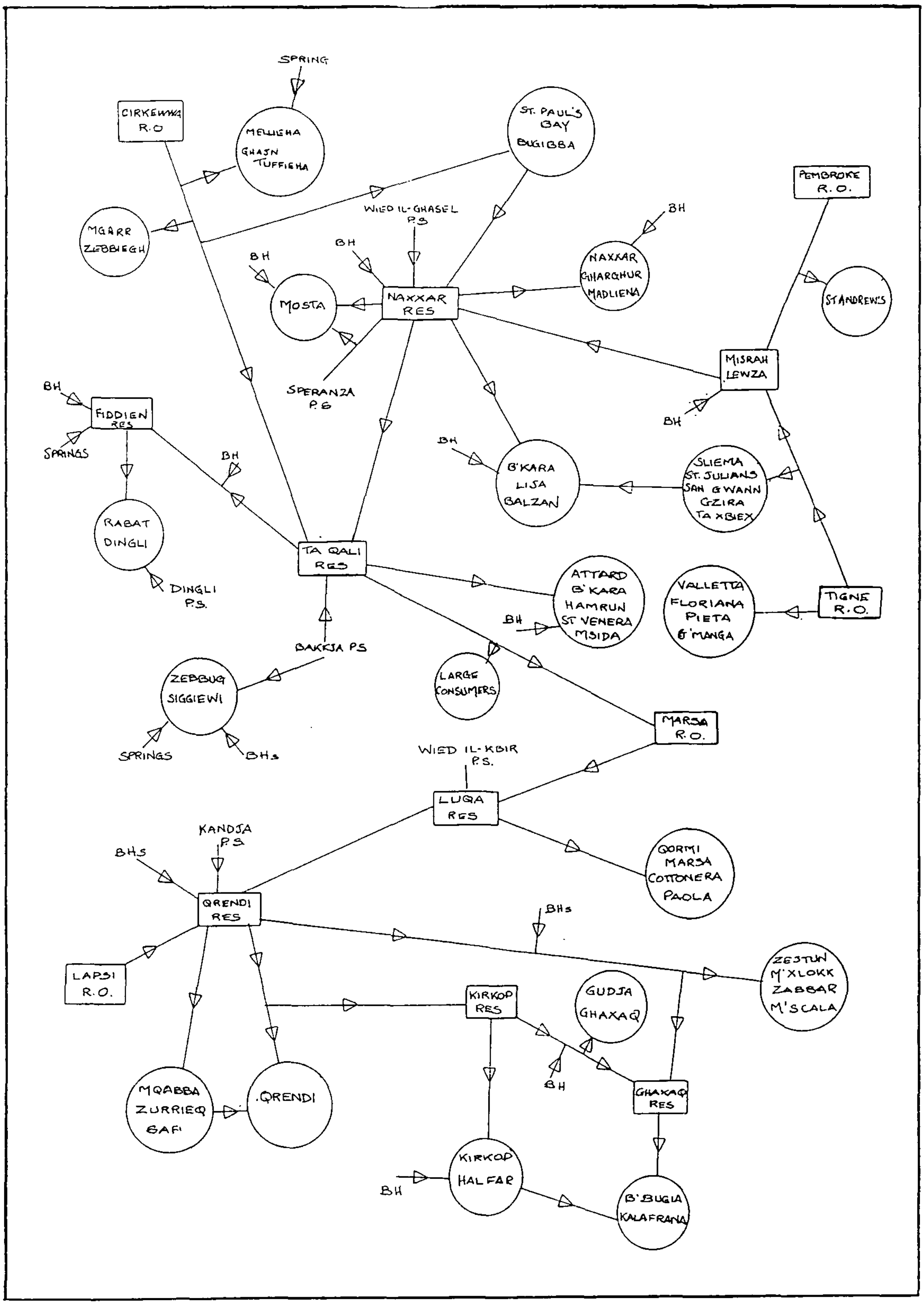


Figure 3.27. Water flows from sources to settlements in Malta. Source: WSC.

On the basis of this Malta can generally be divided into the following supply regions:

3.7.1.1.1. <u>The north-west</u>

Water produced at the Cirkewwa RO plant will, in transit to the Ta' Qali, Naxxar and Fiddien reservoirs, supply the settlements nearest to it, like Mellieha and Bugibba. The north therefore, is fed almost solely with RO water or a mix of mostly RO water with some groundwater. Once these settlements have been satisfied, only then will the remainder, if any, be transferred further along the distribution system to be blended with more groundwater in the central reservoirs and distributed to the central settlements (WSC sources, 1993).

3.7.1.1.2. <u>The south</u>

Southern settlements are supplied by the Qrendi reservoir. One source at the WSC (1993) told me that, "The area is overpowered by groundwater." This is because although the reservoir is fed with RO water from the Ghar Lapsi RO plant, there is significantly more groundwater in the reservoir from the Ta' Kandja pumping station and local boreholes.

Furthermore, as water goes along the southern pipeline from settlement to settlement, its volume and pressure in the pipe diminishes, so more and more water from local boreholes is added to the pipeline to augment supply and increase the pressure (Figures 3.24. and 3.27.) (University source, 1993). The coastal settlements tend to be supplied solely from boreholes.

Some of the water from the Qrendi reservoir also goes to the reservoir at Luqa, which also receives groundwater from local sources and some water from the north (WSC source, 1993).

3.7.1.1.3. <u>The central region</u>

The central reservoirs (Naxxar, Fiddien and Ta' Qali) supply the central settlements, like Mdina, Rabat and Mosta and those settlements east of the Ta' Qali reservoir: Attard, Birkirkara, St. Venera, Hamrun and Msida (ibid).

Spring water is collected at the Fiddien reservoir and some settlements, like Siggiewi, are fed directly with spring water. Groundwater from local (central) boreholes is fed to both the Fiddien and Ta' Qali reservoirs (ibid).

The Marsa RO plant feeds the Ta' Qali reservoir (Riolo *et al*, 1993) although most of its water is used to supply large industrial consumers surrounding the Valletta area (ibid). Valletta is mostly supplied by Tigne RO plant via a submarine pipe across Marsamxmett Harbour (WSC source, 1993).

Some RO water from Pembroke is also transferred to the Ta' Qali reservoir. Water is transferred between the Fiddien reservoir and the Ta' Qali reservoirs according to need (ibid).

3.7.1.1.4. <u>The north-east</u>

Densely populated settlements like Sliema, St. Julians, San Gwann and St. Andrews receive mostly RO water from the Tigne and Pembroke plants (Riolo *et al*, 1993; ibid).

Although some settlements in the north-east (Lija, Balzan and Birkirkara) receive a mixture of groundwater and RO water, the balance is more towards RO water due to the close proximity of the Pembroke and Tigne plants.

3.7.1.1.5. Gozo

In Gozo, water from springs and boreholes is collected and stored in large reservoirs, underground and at the surface, and then pumped to smaller local or village 'area' reservoirs such as those at Xaghra, Nadur and Zebbug. These local reservoirs are located on high ground from where water is distributed by gravity to respective settlements (FIS source, 1993).

3.7.1.1.6. Inter-island transfers

As previously stated, there is an underwater pipeline connecting Malta and Gozo. The pipe was commissioned in 1981 to relieve water shortages in Malta and is capable of transporting up to 9,000m^3 per day (WSC source, 1993). Despite this relatively large capacity, only approximately 546m^3 was pumped to Malta in 1981, usually during winter when Gozo had an excess, rising to 700m^3 in 1982 (Tricker, 1989). This amount was transferred each year until 1988 when, according to a WSC source (1993), transfers were stopped.

Up until 1993, Comino was supplied with water from Gozo, mainly for a 5 star hotel and pig farming. In 1993, due to water shortages in Gozo, Malta took over this task (WSC source, 1993). In the summer of 1994, the shortages in Gozo meant that Malta started supplying Gozo for the first time with RO water from the Cirkewwa RO plant (WSC source, 1995).

3.7.2. The distribution of water in agriculture

Water in agriculture is distributed in more than one way since there is more than one supply source. The most common source, groundwater, is pumped up and distributed in open furrows or via sprinklers, although drip irrigation is becoming common.

Boreholes and springs are often shared by a number of farmers by a rota in accordance to very old and traditional laws based on a Napoleonic code rather than Parliamentary legislation.

Sources at the DA (1993) informed me that over the past fifty years the ownership of boreholes, as with the ownership of land, has been subdivided into ludicrous levels as fathers pass their land and water on to their sons. Allocated pumping times must be divided and reduced. Because of this process of subdivision, the average size of a farm in Malta is only 0.8ha (DA source, 1993). I was told by farmers that water extraction times are divided according to the amount of land one has.

Once water has been extracted from a borehole or spring it is,

".... usually supplied to local (individual) small reservoirs from which it is delivered to the fields." (Riolo *et al*, 1993, p.38).

In the south-east of Malta water from the SASTP is pumped to five satellite reservoirs located at elevated heights (Plates 3.26. and 3.27.). Figure 3.16. shows their location, names and their respective distribution areas (hinterlands).

The water holding capacity of these reservoirs and the total volume of water supplied to each in 1993 are given in Table 3.11. The Table shows that supply does not always meet the total capacity of the reservoir, mostly due to production limitations which are discussed in Chapter 5 (pp.325-326).

Since the SASTP is presently only functioning at half its capacity there is not enough water produced to fill all the reservoirs everyday. So water is supplied on a rota basis to only three reservoirs a day (DA source, 1993).

From these reservoirs water is distributed by gravity to farmers' fields in open stone channels along the tops of rubble walls (Plates 3.28. and 3.29.) by the Zabbar Agricultural Extension Office (ibid).

It can take about two to two and a half hours for water to travel from the reservoir to the furthest end of the distribution channels. The level of the water in the reservoirs determines the water pressure and hence the rate of water flow in the channels. Once a full reservoir begins to distribute water it is usually empty within 3 to 4 hours (ibid).

Most farmers use the traditional ridge and furrow method for irrigating their crops in the south-east area. Water is siphoned off from the channels with a hose and applied to channels parallel to rows of crops. Some farmers use sprinklers and very few, drip irrrigation (ibid).

The majority of farmers have their own small reservoirs which are filled with water to use at other times when water is not flowing in the channels (ibid).

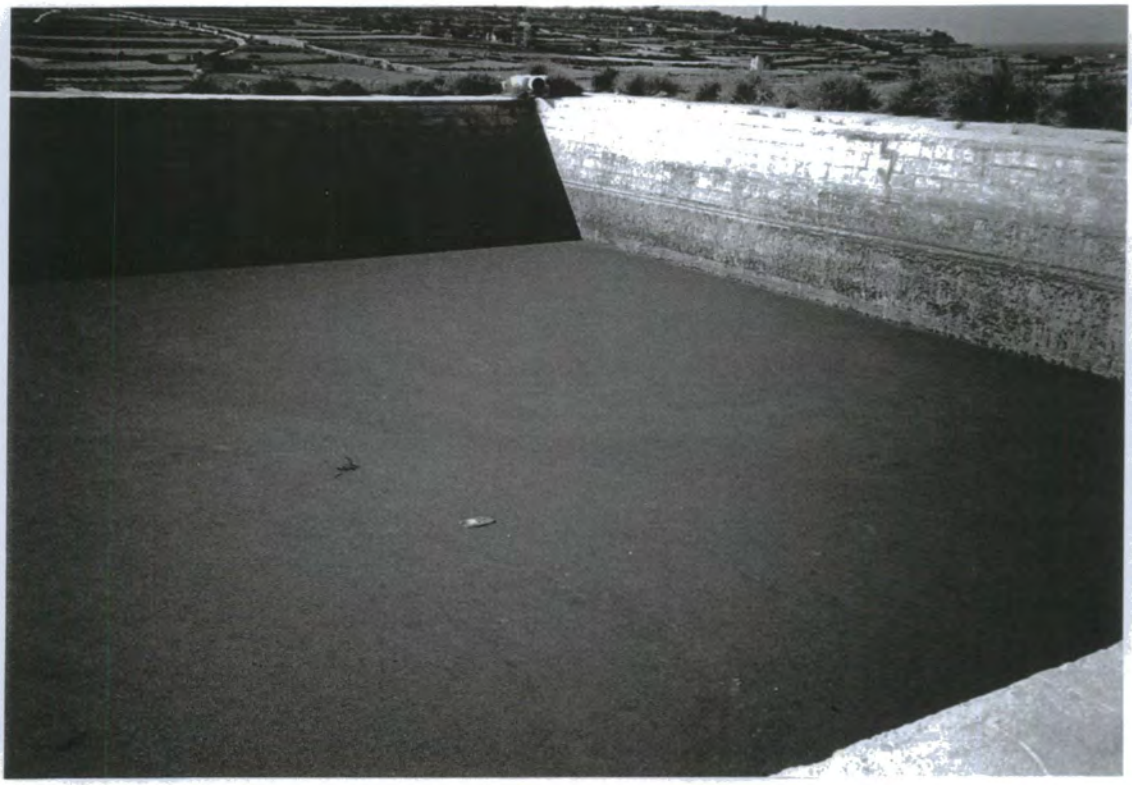


Plate 3.26. The Tas-Silg (SASTP) reservoir.

Plate 3.27. The Habel Abjad (SASTP) reservoir.

Table 3.11. SASTP satellite reservoir capacities and total supply for 1993.

Reservoir	Capacity (000m3)	Total supply in 1993 (m3)
San Anard	36368.80	269000
Habel Abjad	34095.75	340000
Bidni	22730.50	233000
Xghajra	11365.25	195000
Tas-Silg	11365.25	175000

Source: Department of Agriculture unpublished data.

Plate 3.28. An empty SASTP distribution channel.

Plate 3.29. Water flowing in a SASTP distribution channel.

3.8. CONCLUSION

The WSC has the difficult task of supplying water via a complex network consisting of a variety of water sources with varying levels of water quality, and several means of distribution. However, despite the apparent complexity of the system, it is a relatively efficient one that tries to maximise the potential of each water source, water type and mean of distribution.

Legislation governing the use and protection of water reflects the precious nature of the resource. The legislation is detailed, comprehensive and covers virtually every aspect of water use. However it is relatively ineffective without proper enforcement. The lack of enforcement is something that effects not only water resources but almost all aspects of Maltese society governed by the law. It is a major failing that has had an adverse effect on water resources and has made people less likely to fear and take notice of those laws that are not enforced. These consequences are discussed in Chapter 5 (pp.317-319; pp.402-410; pp.425-426; pp.440-445; and pp.446-456). Poor enforcement means that the only incentive to use water wisely is to charge effective water tariffs (which on its own may not be enough an incentive for consumers that can continue to afford to use as much water as they want). However, some tariffs are very low. This is particularly true of the domestic tariff which, given that the domestic sector is the largest water consumer, has recently been the focus of a long overdue revision to encourage people to use water more efficiently. However, the likely success of the new domestic tariff is contentious in that it may not actually encourage a significant reduction in consumption and may even lead to an inequity in water charges, greater than the one that exists presently. These effects are discussed in Chapter 8 (pp.683-686).

Of greater concern is the fact that the poor enforcement of water resources legislation extends to the cistern law. Cisterns are rarely built today and many of those that exist are, surprisingly, unused or misplaced (the location of many rural cisterns, in particular, has been forgotten) which is an enormous waste of what is collectively a potentially vast reservoir of water. This waste is discussed in Chapter 5 (pp.317-319). People have become less self-sufficient and increasingly over-reliant on piped water supplies, which is unfortunate since these supplies are unreliable and often of inferior quality (pp.356-358). The reason why people do not invest in cisterns is not just a question of cost, or the law being so lax. Rather, it seems to be indicative of their eagerness to rely on the Government for all their needs. Even if they are suffering from drought, many people would rather wait for the Government to help them than help themselves.

Piped Government supplies of potable water have, until the mid-1980's, consisted mostly of groundwater, with some run-off collected in small open reservoirs. Distillation was also used, phased out due to rising fuel costs and presently makes no contribution. RO technology, which manifests itself in Malta as five RO plants, has rapidly dominated first class water supply. RO technology, although expensive (in both capital and running costs), is actually a worthwhile investment because an over-reliance on a single source (the MSLA) is not a secure option given the importance of a consistently available water supply and also because the MSLA has deteriorated as a result of being solely relied upon and over-used (pp.362-369). The water authority should never have placed all its eggs in one basket, so to speak, but should instead have invested in several conventional (large reservoirs and cisterns for run-off collection) and non-conventional (RO and distillation plants) sources. However even then, given the low standard of water management in the past, there is no guarantee that the MSLA would not have been exploited to the extent it has been.

Despite the MSLA's critical condition, it is still being milked of what it currently has left to offer, which, as will become apparent in Chapter 5 (pp.362-369), in terms of quality, is very little. Groundwater is still a significant source but in many cases, even when put to use, it is not adequately distributed and blended with RO water, if at all, in the large closed reservoirs. The result is that, generally, the north receives mostly RO water while the central region and especially the south, receive mostly groundwater. This inequality in water supply is a major problem, given that RO water is of a far superior quality to groundwater (pp.369-374 and pp.387-392).

The poor quality of tap water in general is indicated by the fact that several industries, hotels and a few farms have installed RO systems, while the bottled water market has rapidly grown with leading Maltese brands being widely and increasingly used by both the tourist sector and domestic consumers. This is a problem since a large amount of effort and capital is spent to bring tap water to potable standards for it only to be either rejected or treated further by many consumers. A dual pipe system (first and second class water) or a solely second class system, with first class water supplied in bottles or through communal standpipes, would get round this problem and is an option discussed further in Chapter 8 (pp.637-639). The problems associated with water quality are discussed in Chapter 5 (pp.356-428).

Regrettably, there is no legal obligation for the WSC to supply water of a certain quantity and quality to consumers each day which, given the supposedly corporate nature of the WSC, should be legislated for. This also calls into question the monopolistic nature of the piped water supply in Malta. Possibly, if private suppliers were allowed a market share the service would be better than it presently is, in the face of competition.

Water supplies are prioritised so that hospitals, industries, tourist establishments and the commercial sector are provided for as fully as possible, which may seem like a worthwhile system given their relative economic and medical importance. However, given that the domestic and agricultural sectors are lower on the list of priorities, this is inequitable and unacceptable, particularly from the point of view of domestic and agricultural consumers and hence has become a potential source of conflict with other sectors and, more openly, with the WSC. Water conflicts are discussed in Chapter 6.

However this prioritisation of first class water does not make any significant impact on the agricultural sector since it relies mostly on second class (non-potable) water either as: collected rain and/or run-off water and/or groundwater from boreholes, usually applied via ridge and furrow irrigation or by sprinklers, mostly in the north, the west and in Gozo; or as recycled sewage effluent from the SASTP, which is distributed in open stone channels, from five main satellite reservoirs, to farmers working in the south-east. However, this reliance on second class water is only because farmers were denied their once substantial quota of subsidised first class water, because agriculture is considered a low priority sector. Today it receives only a negligible amount. Industries and private suppliers of water (some of whom are farmers) also extract significant amounts of groundwater.

Some recycled sewage effluent is supplied to industries at the Bulebel industrial estate. This redirection of what was originally solely agricultural water is an example of how even second class water is becoming prioritised, whereby the needs of the industrial sector have once again taken precedence over those of the agricultural sector. No doubt, if demand for second class water in the tourist and domestic sectors increases it will be to the detriment of the agricultural sector, unless supplies are increased.

CHAPTER 4

WATER DEMAND

4.1 INTRODUCTION

During the 1970's the demand for water from all sectors of the economy, except agriculture, was rapidly increasing (Park, 1977). The Government's response was to increase groundwater production. The number of private boreholes, legal and illegal, also increased (University source, 1993). Total water demand increased due to industrialisation, growth of tourism and, most importantly, increases in domestic demand:

"The country is small in size and has one of the highest national population densities in the world.... There is also a considerable increase in the number of households and a constant improvement in living standards, both of which require additional public utilities." (Ministry for Development of Infrastructure, 1991b, p.78; Central Office of Statistics - Malta, 1994).

This Chapter discusses the increases in water demand and consumption and the causes in each sector.

4.2. WATER CONSUMPTION

In 1991, the *Malta Structure Plan* (Ministry for Development of Infrastructure, 1991b) stated that,

"Practically all households and industrial and commercial establishments are served by a piped, metered water supply. Malta is experiencing a steady increase in water demand due to the increase in population, standards of living, tourism, and industrialisation." (Ministry for Development of Infrastructure, 1991b, p.15).

Water consumption is the best quantifiable measure of demand. However this does not necessarily reflect demand, but the amount supplied. For example, because many southern settlements can be without water for weeks, does not mean that demand there is nil.

From Table 4.1. it can be seen that between 1983 and 1988 there has been a significant increase in total water consumption in Malta and Gozo. The average per capita daily consumption has increased by 23% in Malta (from 0.225m^3 to 0.277m^3) and 26% in Gozo (from 0.188m^3 to 0.236m^3) (ibid). In 1990 average daily consumption per capita was approximately 0.255m^3 (Ministry for the Environment, 1992). This did not mean that there was a decrease in consumption but that the figure includes a 10% reduction to allow for water lost through leaks in the distribution system (pp.434-438), which were discovered to be greater than previously estimated (ibid).

Column 5 in Table 4.2. (and Figure 4.1.) shows that water consumption has been rapidly increasing from 1970 to 1992. Consumption changes in each sector of the economy are also shown and several references to these are made in this Chapter. The Table shows figures for first class consumption only and so does not represent agricultural consumption of second class water. Changes in tourist arrivals, population and manufacturing exports are also shown. While changes in the latter two have only partly caused increases in domestic and industrial water consumption, respectively, the former has had a significant impact on tourist consumption of water (Figure 4.7. (p.283)). Table 4.2. and Figure 4.1. show that consumption is higher in summer (July, August and September) and considerably higher on the day of peak consumption. This seasonal difference is also attributed

Table 4.1. Total water consumption (m3) for Malta and Gozo from 1983 to 1988

Year	Total for Malta (000m3)	Total for Gozo (000m3)	Average daily/capita consumption for Malta	Average daily/capita consumption for Gozo
1983	26463.99	1724.93	0.2249	0.1883
1984	27430.37	1652.81	0.2453	0.1910
1985	29126.20	1735.60	0.2589	0.1999
1986	29071.79	1825.78	0.2488	0.1963
1987	30959.93	2012.15	0.2630	0.2153
1988	32561.01	2206.10	0.2769	0.2358

Source: Ministry for Development and Infrastructure, 1991a.

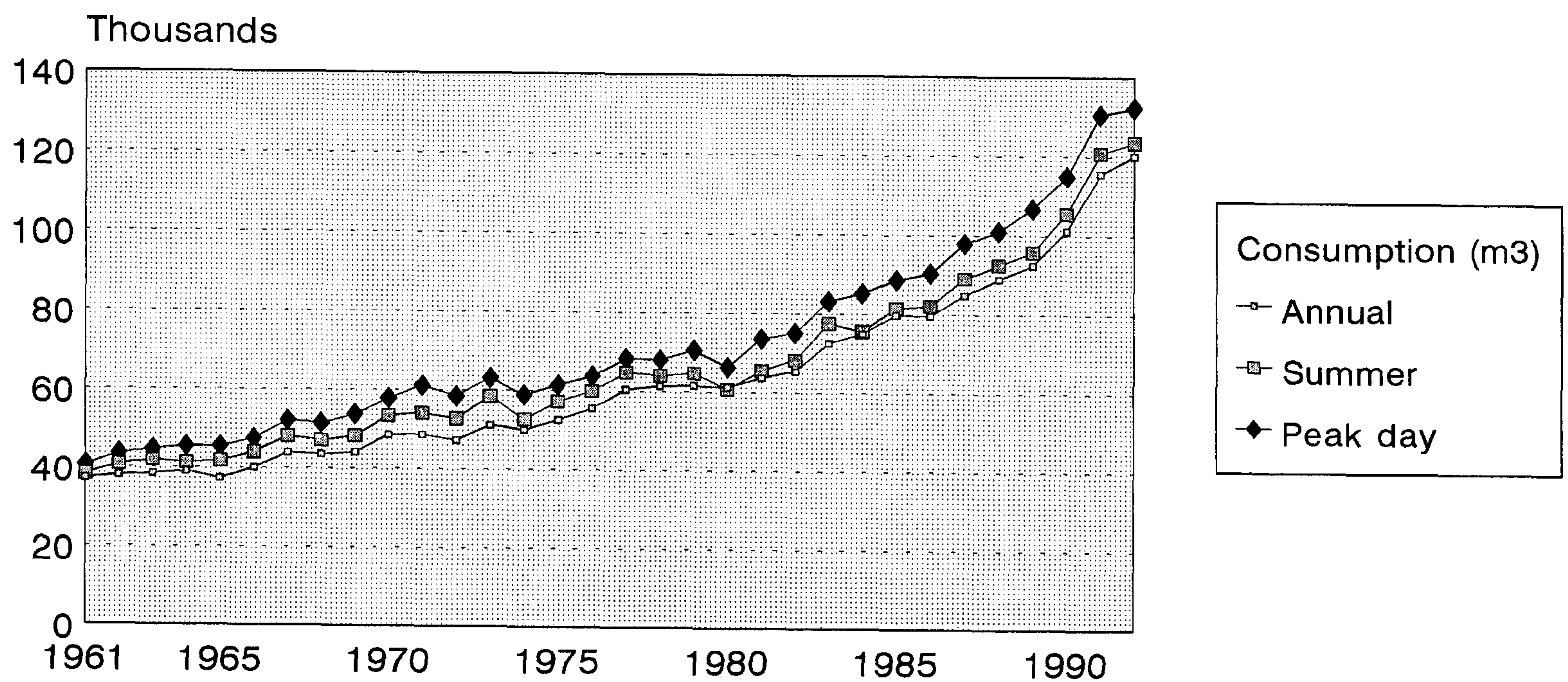
Table 4.2. Mean billed first class water consumption (daily averages in m3)

Blank spaces denote missing, unavailable or unrecorded data

Year	Population	Tourist arrivals	Manufacturing exports (Lm'000)	Annual consumption	Summer (Jul-Sep) consumption	Consumption for peak month	Consumption for peak day	Domestic consumption	Industrial consumption	Tourist consumption	Other consumption	Unaccounted for water
1970	277100	170853	10855	48502	53376	54280	57758	17593	4191	0	3669	23049
1971	277441	178704	14117	48598	54135	56822	61081					
1972	277845	149913	20804	47229	52798	53921	58513					
1973	279910	221196	30761	51166	58463	58876	63091					
1974	280093	272516	41334	50125	52698	53280	58945	12806	4487	854	3741	28236
1975	284621	334519	49543	52598	57244	58049	61463					
1976	288781	339537	79055	55567	59913	60331	63822	13165	5651	1300	4446	31004
1977	292766	361874	103100	60459	64805	65518	68428					
1978	295589	477741	117202	61463	64054	65305	68119					
1979	299470	618310	136830	61627	64655	66105	70569	17043	5996	2409	2577	33596
1980	302545	728732	149034	61195	60695	63222	66318					
1981	305261	705506	154239	63609	65427	67964	73619					
1982	308392	510956	150078	65418	68291	71128	75115	20248	5673	2209	1732	35555
1983	311525	490812	141650	72510	77606	78579	83239					
1984	314488	479747	164819	75025	75647	75988	85235					
1985	315913	517864	169244	79811	81480	82639	88658					
1986	318222	574189	180316	79661	82162	84012	90435	23935	8051	2609	3214	41851
1987	320474	745943	190700	84830	89053	89922	97897	29577	6624	3119	3419	42088
1988	323629	783846	217100	88985	92536	95263	101046	29431	7005	3119	5605	43820
1989	326655	828311	273600	92513	95832	97246	106856	27081	7078	3132	10851	44370
1990	329355	871776	328700	101196	105560	112470	114971	27386	7028	3164	3937	59681
1991	329421	895036	371600	115662	120835	121926	130564	31250	7037	3423	5082	68773
1992	330488	1002381	333500	120158	123577	124549	132269	32895	6769	3737	7892	68148

Sources: Central Office of Statistics - Malta, 1988; Ransley and Azzopardi, 1988; Ministry of Finance, 1992; Zammit Satariano, 1993; NTOM, 1995; WSC unpublished data.

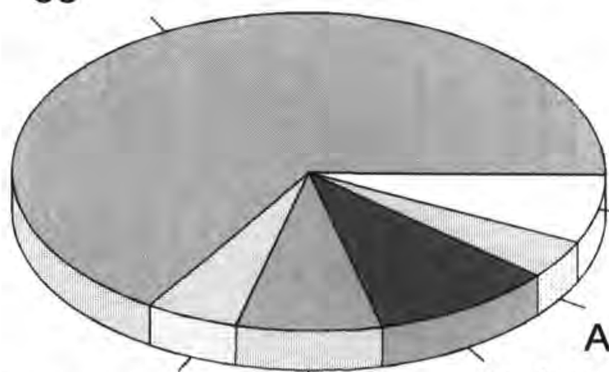
Figure 4.1. Mean daily billed first class water consumption patterns for the period 1961 to 1992: per annum, for the summer (July, August and September), and for the peak day of consumption.



Note: Consumption includes only that which has been billed; i.e. not including unaccounted for water (see pp.432-443).
Source: WSC unpublished data.

Figure 4.2. First class water consumption by sector in the Maltese Islands

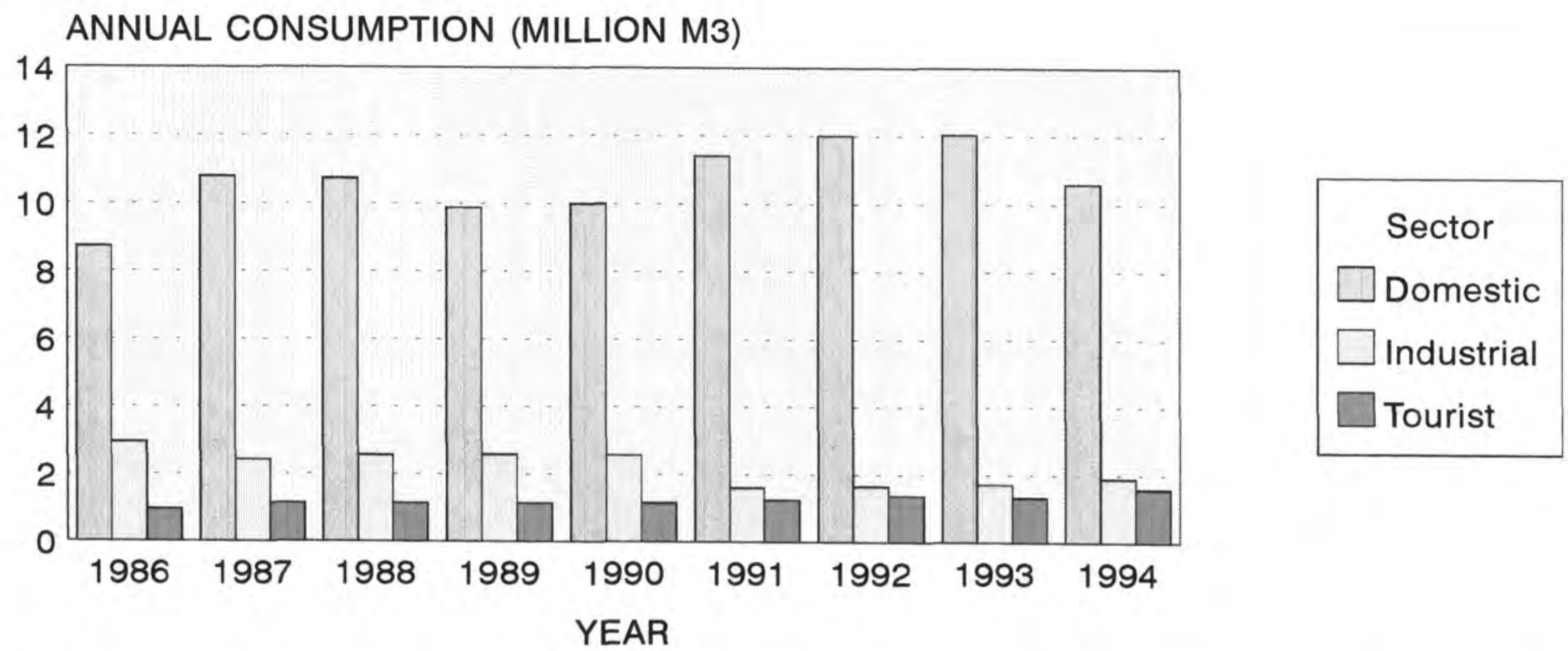
Note: `Others' includes consumption by the commercial sector, boat-houses, gardens, fields, and the the legitimate use of first class water in the agricultural sector



Percentages of water consumption for each sector of the economy.

Note: It is estimated that farmers extract (through vested rights) approximately 5.5. million m3/annum from the aquifers (not incluing illegally extracted groundwater). This is not included above as it constitutes second class water. Source: Jaccarini and Degaetano, 1993.

Figure 4.3. Annual first class water consumption for the domestic, industrial and tourist sectors
for the period 1986 to 1994



Note: Consumption includes only that which has been billed; i.e. not including unaccounted for water (pp.432-443).
Source: WSC unpublished data.

to tourist arrivals (pp.286-291).

From Table 4.2. it can be seen that the domestic sector has always been the largest consumer of water, presently accounting for 66% of first class water consumption, followed by the industrial and tourist sectors. Figure 4.2. shows the percentage share of consumption by each sector. Again, agricultural consumption is insignificant because it relies mainly on second class water, while tourism's share is not as large as might be imagined, but is of course much larger during the summer months only (pp.286-292). It can be seen from Table 4.2. and Figure 4.3. that the growth in consumption has been mostly in the domestic sector. The Table shows consumption which is not always determined by meter readings alone, but can include various methods of deduction, including a certain amount of estimation by guesswork (the implications of which are discussed on pp.439-440). Approximately 53% to 54% of water production is unaccounted for (Table 4.2., last column) due to leakages, theft, billing mistakes and meter under-registeration (pp.432-443) (Ministry for the Environment, 1992; WSC 1993a).

Although the WSC has increased water production, this has still been outstripped by demand, as already stated, mostly in the domestic sector. This pattern is also reflected in the increasing demand and consumption of electricity. This is in part due to the close relationship between water consumption and electricity consumption since 18% (Debono, 1994) of the nation's electricity is used to produce water.

Table 4.2. and Figure 4.3. show that industrial consumption increased until 1986 when it began to decrease, mainly due to the changing structure of the industrial sector and production methods for new products. Consumption in the tourist sector has been steadily increasing. The decrease in domestic consumption

in 1994, is most likely due to the impact of a national campaign to curb consumption in that year (pp.682-698).

During peak demand periods the WSC cannot cope and water suspensions occur (WSC source, 1993), during which the WSC bowser service is under pressure and often consumers are willing to pay for private bowsers (Briguglio, 1994).

One University source (1993) stated that, "No matter how much water you supply to a household, in essence that water is going to be consumed, it seems. That is not just the case in Malta but recognised all over the world. If you give people one hundred and fifty litres of water per day they won't think of installing a washing machine. If you give three hundred then people will."

Another University source (1993) stated that, "The Government has been caught in a classic consumption-production spiral: the more water is produced, the more is consumed." The WSC Chief Executive is aware of this:

> "Experience in other countries has shown that unless wastage and demand are kept well under control, a vicious circle of demand-production will occur with obvious results. This can be confirmed by experience in Malta, where water demand appeared to expand to absorb additional supplies made available by new production." (Riolo *et al*, 1993, p.10).

It is as a result of this "vicious circle" that the consumption of water in Malta is almost always equal to the amount of water that is produced (except for water lost through leakage) (WSC source, 1993).

However, consumption is not an effective measure of demand. People may consume all the water that is supplied but this does not mean that they are satisfied. Furthermore, consumption per capita varies from place to place, which may give the impression that demands vary geographically, when in fact it is the amount of water supplied that varies (pp.333-334).

4.3. INCREASES IN DOMESTIC WATER DEMANDS

The domestic population of the Maltese Islands is approximately 363,000 persons (Lockhart, undated unpublished draft) giving rise to one of the highest national population densities in the World: approximately 1,150 persons/km^2 (Busuttil, 1995). Consequently, the pressure on resources, especially land and water, in an island environment such as Malta's is intense.

Gozo is less densely populated than Malta, with a population of approximately 23,000 persons and has relatively fewer demands.

As already stated, growth in domestic demands for water has been the main cause of an overall increase in demand. The reasons for this growth are:

1. A gradual, but significant increase in population. However, this is the least significant factor in determining the increase in water demand;

2. The standard of living has been steadily increasing;

3. A construction boom, most recently in the south, has increased the number of homes, relative to population growth, as extended families and the number of people in a dwelling have decreased (Mallia, 1994; WSC source, 1993).

4. Increased water production has meant that demand and consumption has continually increased to absorb increases in supplies.

"Moreover, unlike previous times, every household is obliged to have its own water meter and gone are the days when people, especially in villages went to the pump to procure water. This greater availability of water has resulted in more consumption." (Brincat, 1979, p.34).

5. Old values of water conservation and perceptions of water scarcity have disintegrated as modernisation and RO technology have, unfortunately, propagated a myth of water abundance in the minds of many people who have access to water.

Average daily domestic consumption is approximately $0.150m^3$ per capita (Ministry for the Environment, 1992). A more recent estimate by Briguglio (1994) puts this figure at $63m^3$ per annum or $0.178m^3$ per capita, per day, a reasonable quantity by World Bank definitions ($40-80m^3$ per annum). However as stated previously, the amount of water supplied varies geographically (generally less in the south) and also seasonally (less in summer due to water cuts and shortages (pp.328-341)) and so consumption will reflect this variation.

4.3.1. Increasing standards of living and the rise of consumerism

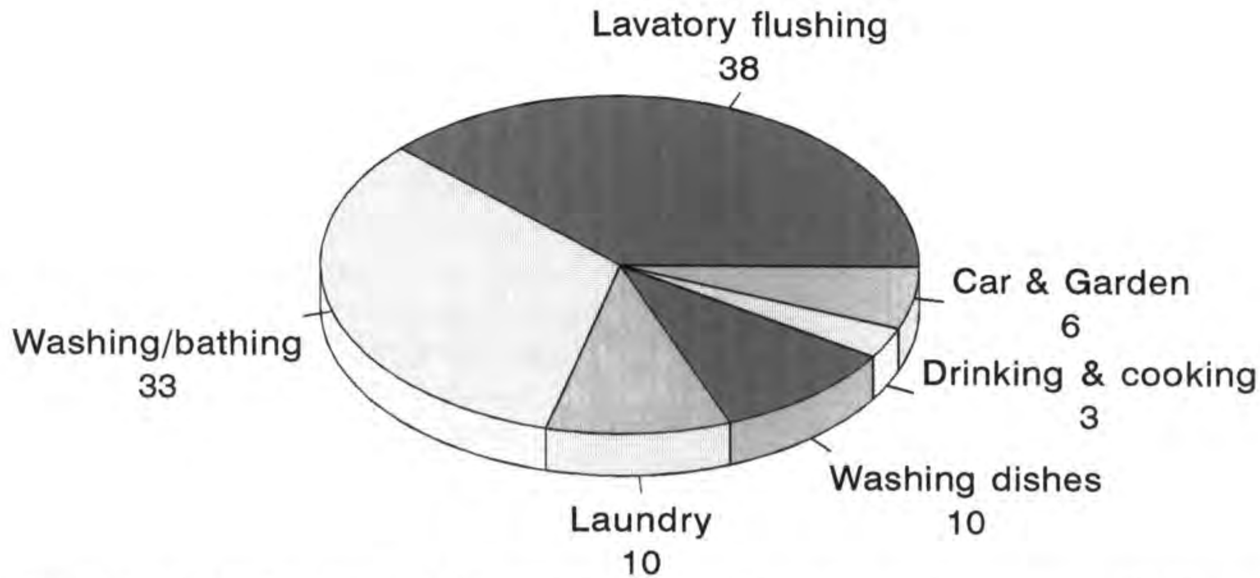
"Most Maltese, upon being asked to identify a key characteristic feature of the social formation they inhabit, would probably mention the relatively recent emphasis on the consumption of durable and non-durable goods." (Sultana, 1994b, p.163).

The increase in consumer needs were driven initially by the creation of the welfare state by the previous Labour Government which led to higher incomes. Overseas role models made people want to aspire to the same wants as those abroad. The average Maltese wage has increased giving greater spending power. The per capita income in 1976 was Lm712 and had risen to Lm2,219 in 1990. Consumer spending was up from Lm160.7 million (at constant prices) in 1983 to Lm229.7 million in 1991 (Ministry of Finance, 1992). Once this was established,

"The economic policies of the Nationalist government, elected into office in 1987, have clearly fanned the flames of a consumeristic culture.... there was now to be 'unlimited choice' through the freeing of imports. There has, indeed, been a proliferation of sites of consumption where imported - hitherto exotic - goods have been displayed to titillate every taste. The department store phenomenon, for instance, has now hit Malta and Gozo.... Trade Fairs, with their dual roles as markets and sites of pleasure, and customarily held once every year for the past 36 years, have proliferated in number." (Sultana, 1994b, pp.165-166).

High water consuming appliances designed for temperate climates where water is more freely available and not as precious, have played a strong part in this proliferation. These include modern toilet flush sytems (the largest single component of domestic water

Figure 4.4. Domestic water uses in the Maltese Islands



Percentage breakdown of the main domestic water consuming activities.

Source: Debono, 1994.

consumption (Figure 4.4.)), washing machines, dishwashers and car washes. Imports of consumer goods have increased from Lm82.2 million in 1986 (1991 prices) to Lm147.6 million in 1991 (Ministry of Finance, 1992). Figure 4.4. shows the percentage breakdown of the main domestic water consuming activities. It shows that lavatory flushing is the most water consuming activity in the home followed by washing of different types. Many of these water consuming appliances (toilet cisterns, shower heads, washing machines, dishwashers, etc.) are inappropriate in the Maltese Islands given water's scarcity. Ironically, drinking and cooking constitute the smallest percentage of water consumption (3%).

The proliferation of slick and highly tempting advertising has accompanied the availability of such goods, attatching,

".... images of romance, exotica, desire, beauty, fulfilment, communality, scientific progress and the good life to mundane consumer goods such as soap, washing machines...." (Featherstone, 1990, p.7).

4.3.2. Increased development

The long standing complaints from domestic consumers about the lack of water in the south (pp.531-540) are indicative of the high level of water demand in this part of Malta (NTOM source, 1993). The domestic demand for water has risen here recently more than in any other part of Malta. The reason for this was a sudden construction boom in the south, particularly during the 1980's, fuelled in part by the breakdown of the extended family and partly the attractiveness of employment at the port development around Birzebbuga and Marsaxlokk. The lack of planning control and poor enforcement of what little legislation existed, encouraged this growth.

Southern settlements grew in a very short space of time. However, at the same time there was a relative decline in water supply in the south due to the rapid closure of many boreholes there, in order to try and reduce rising salinity levels of the MSLA (pp.362-369). At one time there were 210 operational boreholes in Malta. In 1994 there were only 94 (Debono, 1994; WSC source, 1993).

In the north demands increased prior to this in the 1970's due to the growth of tourism (pp.280-285) and the purchase of new homes, but have since been mostly met, whereas the south is still waiting (pp.331-336).

Between 1957 and 1985 the number of households in Malta,

".... increased by 40% for a 10% increase in population, reflecting a distinct break from the extended family situations prevalent in the 1930's." (Mallia, 1994, p.690).

During this period, although the population growth rate was small, the problem of water supply was exacerbated by this increase in the number of households and, consequently, the number of dwellings and the area under settlement (WSC source, 1993).

Figure 5.1. and the discussion on pp.319-325 illustrate these points further. Figures 5.2. and 5.3., when compared with each other, show, although for a longer time lapse (settlement patterns for 1910 and the period 1968-1984, respectively), the growth in settlements for the whole of the Maltese Islands. The difference illustrates that there was an extremely rapid expansion in the settlement area.

Settlement populations and areas continued to grow in the south after 1985 (mainly due to internal migration) (Delia, 1995). However, population growth was, essentially, in line with national growth rates, with population density in the south increasing from 1,073 persons/km^2 in 1985 to 1,191 persons/km^2 in 1993 (ibid). Figure 4.5. shows that the percentage population increase between 1980 and 1995 in all regions is similar to the national increase, except for in the inner harbour region, where overcrowding and employment opportunities elsewhere led to depopulation between 1980 and 1985. More crucial was the large area of land taken up by this growth, which continued to occur as it had been, such that several settlements have, or almost have, merged.

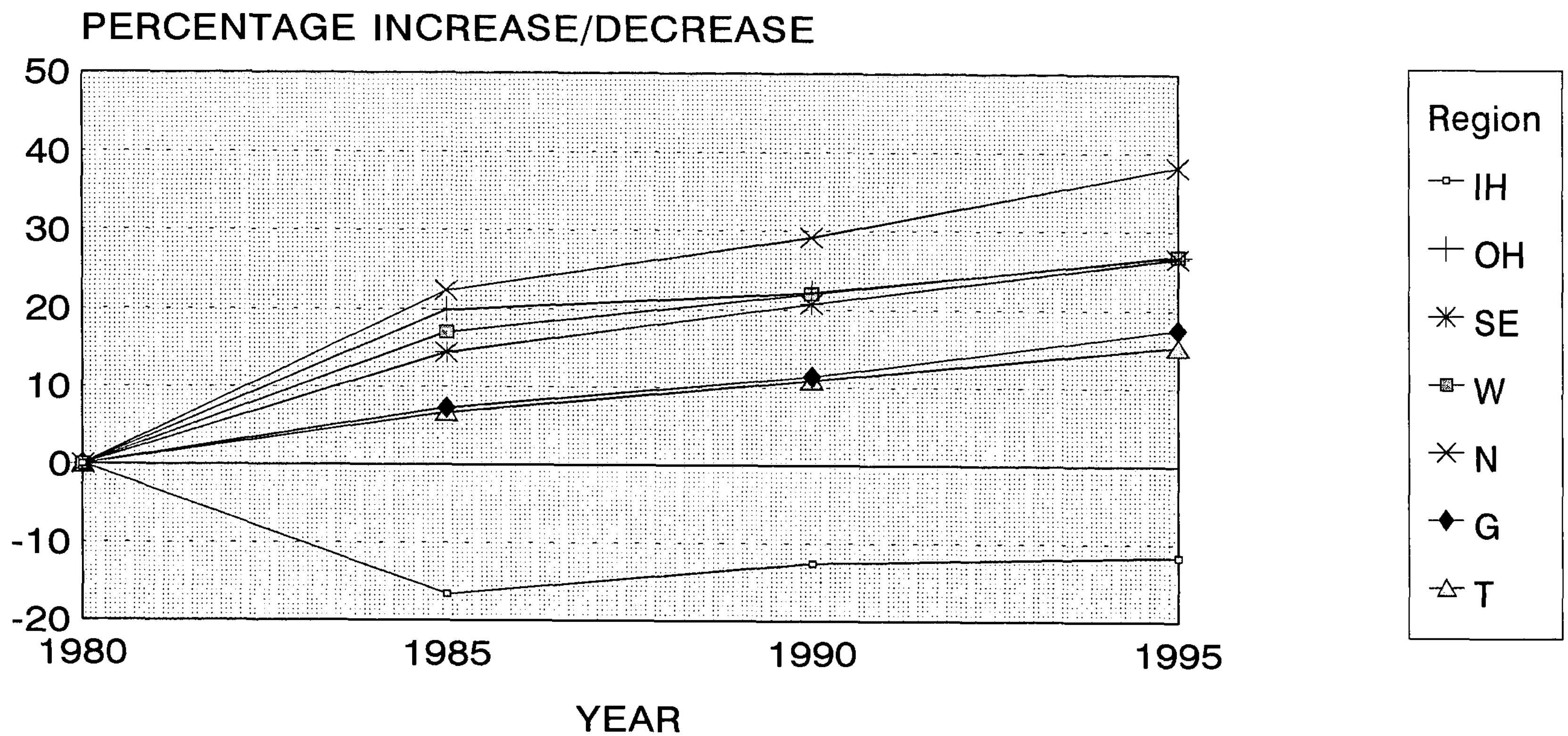
Increasing levels of affluence meant that many households were second holiday homes or became homes that were left unoccupied when people moved out of undesirable locations, particularly the Inner Harbour region (Figure 4.5.) (Borg, 1973).

The lack of planning control had led to the drafting of a proper planning law as early as 1952. However, this new scheme was worked out in such a hurry a few days before a general election by people without any training in town and country planning (ibid).

"Perhaps all this may account for the serious deficiencies of the new scheme. The Police Laws that had previously given the Courts power to punish the offenders by ordering all work done in contravention to be removed or destroyed at the expense of the owner, were now deleted, and no new measure was put forward giving power to impose penalties on developers who contravened the code." (ibid, section 3.2)

Water supply could not keep pace with the growing demand. More importantly, it was the distribution system that did not keep pace. New houses were built without the infrastructure necessary for water supply (pp.331-336).

Figure 4.5. Percentage increase/decrease in total and regional populations in the Maltese Islands since 1980



IH = Inner Harbour region; OH = Outer Harbour region; SE = South-Eastern region; W = Western region; N = Northern region; G = Gozo; T = Total for the Maltese Islands.
Derived from data on the official website of the Maltese Government, 1997.

4.3.3. Changing perceptions towards conservation

There has been a change in the attitudes towards water consumption amongst the Maltese people. Many seem to assume that ever since RO technology was introduced the water scarcity problem has been solved. The erosion of water conserving attitudes and the breaching and poor enforcement of water conserving laws (pp.446-456) has increased demand.

4.4. THE INCREASE IN THE WATER DEMANDS OF THE TOURIST SECTOR

At the time of Malta's independence, tourism and industrialisation were seen as the two viable options to uphold the economy. The tourist industry grew rapidly, as it did in the rest of the Mediterranean (Oglethorpe, 1982; Grenon and Batisse, 1989).

"Their [tourists'] annual number started being counted in hundreds of thousands instead of tens of thousands and it appeared that tourism was a source of undreamt-of wealth" (Pace, 1995, p.2).

Today tourism is the biggest service industry in Malta. It employs 7% of the workforce (9,500 persons) and in 1994 netted Lm242 million, 27.5% of Malta's total foreign exchange earnings (ibid).

Demand for water from the tourist sector has been increasing as the sector has grown. In 1993, the total number of tourists was equal to almost three times the resident population with an average length of stay of 11 days per tourist (Briguglio, 1995). This demand is not just for water but for good quality water, because tourists expect a certain standard: the same which they would find back home, since the majority are from developed, temperate, European countries. Figure 4.6. shows that there has been a large increase in annual tourist arrivals since 1960. Figure 4.7. (and a comparison of tourist arrivals and tourist water consumption in Table 4.2.) shows that the increase in tourist consumption closely corresponds to the increase in arrivals. However, the increase in the latter is greater than the increase in the former, implying that while tourist numbers have been increasing, tourist consumption per capita has been decreasing.

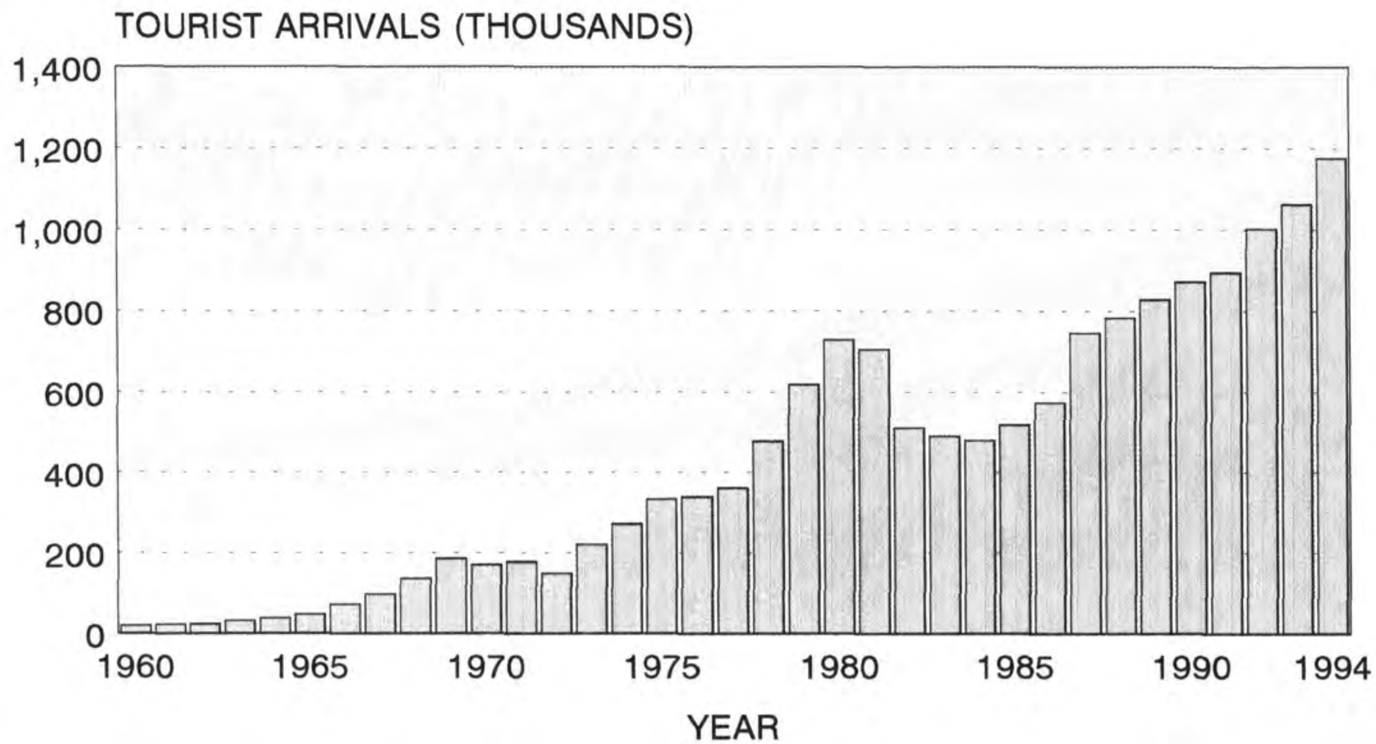
An NTOM source (1993) spuriously informed me that tourists use approximately $0.3m^3$ of water/capita/day compared to the $0.15m^3$/capita/day consumed by locals. Contradicting this understatement, the *Malta Structure Plan* (Ministry for the Environment, 1992) states that the average tourist consumption is $0.235m^3$/capita/day which is still much higher than domestic per capita consumption. The figure includes water consumption by catering establishments. The tourist sector has to pay the commercial water tariff because its large demands for water are seen as a burden (NTOM source, 1993).

In 1994, 1,176,223 tourists visited Malta and Gozo. If the average length of stay is 11 days, this amounts to an additional 35,448 residents over the span of a year (1,176,223 x 11/365), approximately 10.5% of the Maltese population, who use on average nearly twice as much water as the local population (NTOM, 1995).

".... as expected such high densities exert heavy pressure on the environment and infrastructure of the Maltese Islands, where population density is extremely high, with about 1150 persons per square kilometre" (Briguglio, 1995, p.6).

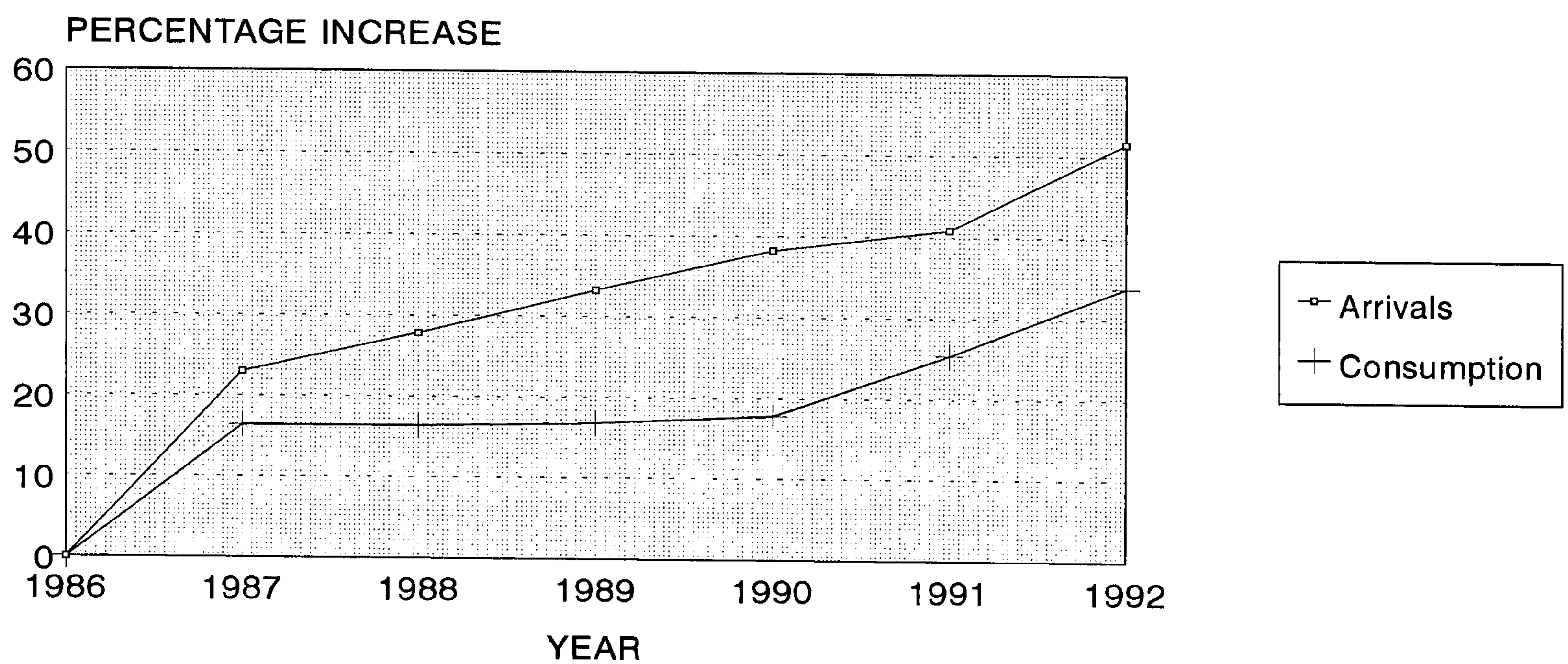
It is important to understand that tourist demand for water is concentrated in particular areas and at

Figure 4.6. Tourist arrivals per annum in the Maltese Islands for the period 1960 to 1994



Source: Zammit Satariano, 1993; NTOM, 1995.

Figure 4.7. Annual percentage increases in tourist arrivals and tourist water consumption
for the period 1986 to 1992



Note: Billed consumption does not include unaccounted for water (see Table 5.12., p.435).
Source: WSC unpublished data.

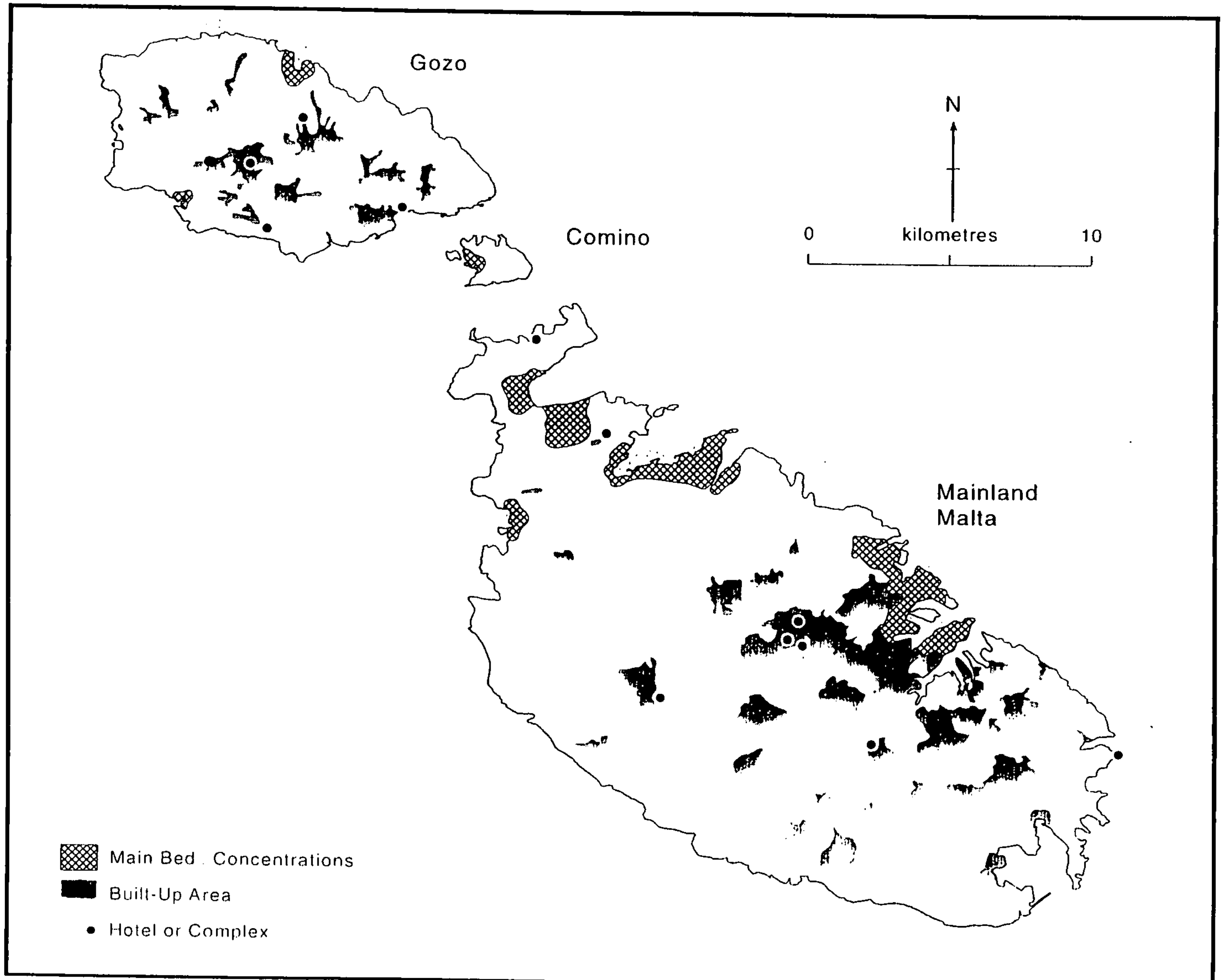


Figure 4.8. Location of major tourist accommodation in Malta and Gozo.
Source: Ministry for the Development of Infrastructure, 1990; 1991.

particular times of the year.

4.4.1. The geography of tourism and water demand

Figure 4.8. shows the location of major tourist accommodation in Malta and Gozo. This is represented by the main concentrations of hotel beds, and large hotels or complexes outside of these main concentrations. Development has almost exclusively been restricted to these areas since tourism first began. Water demands rapidly increased in the north in the late 1970's, especially in the Sliema and St. Paul's Bay area, while water supply could not keep pace with the uncontrolled tourist development.

"Complexes, villas, hotels, bars and restaurants sprang up.... By the late seventies we had reached a stage where blocks of flats were being built in months and they were being leased to tour operators while still under construction with the expectation that they would be ready by the time the first guests arrived. In fact buildings were being completed even before the Works Department had had time to process the applications for Building Permits which were not infrequently received after guests had been coming and going for some time" (Pace, 1995, p.3).

One of the reasons why Gozo ceased to supply Malta with water is that its own demands for water were increasing. This was mostly because of the growth of Xlendi and Marsalforn as tourist centres and the increasing number of visitors from abroad and Malta (FIS source, 1993). The construction of new housing has also increased and many Maltese own or rent holiday homes in Gozo.

4.4.2. Seasonality of tourism and water demand

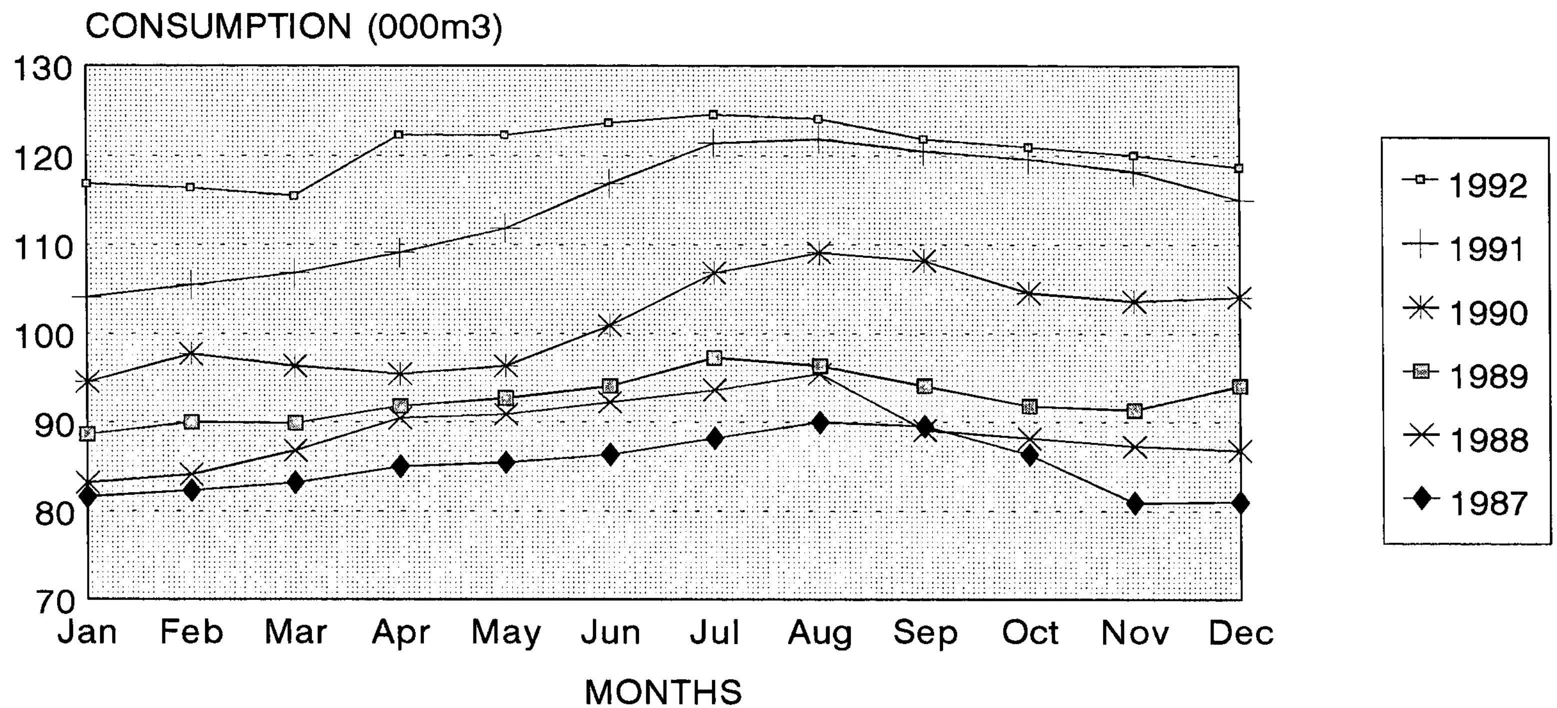
The demand for water inevitably increases during the summer months in Malta, as is the case in most countries. Tourism is partly to blame for the seasonality of demand.

During 1986 the Regional Activity Centre for the priority Actions Programme of the United Nations Environment Programme (UNEP) Mediterranean Action Plan was undertaking work under the title "Water Resource Management in Mediterranean Islands and Coastal Areas." (Scicluna, 1986). One of the problems this project addressed was the seasonal fluctuations in water consumptions due to the changing population size on islands like Malta and Gozo, because of mass tourism (ibid). Table 4.2. and Figure 4.1. have already shown that water consumption is significantly higher in summer than the rest of the year. Figure 4.9. also illustrates this for 1987 to 1992. It shows that as annual consumption has increased, the disparity between consumption in the summer (July to September) and during the rest of the year, for this period, has stayed relatively constant, a problem which demand managers need to try and overcome (pp.702-717).

Scicluna (1986) used econometric analysis in order to estimate growth trends and seasonal indices for water consumption in Malta and Gozo. His analysis concludes that the seasonality of water use in Malta and Gozo is significantly attributed to tourism.

Given that 40% of Malta's tourists visit from July to September, while during the last two and first two months of the year only 19% visit, it is clear that tourism is a seasonal problem (NTOM, 1995). Table 4.3. and Figures 4.10. and 4.11. illustrate the seasonality of tourist arrivals. It can be seen that the summer (July to September) is the peak season and arrivals in the shoulder months (March, April, May, June and October), and especially in the winter months (November to

Figure 4.9. Mean monthly billed first class water consumption for the period 1987 to 1992



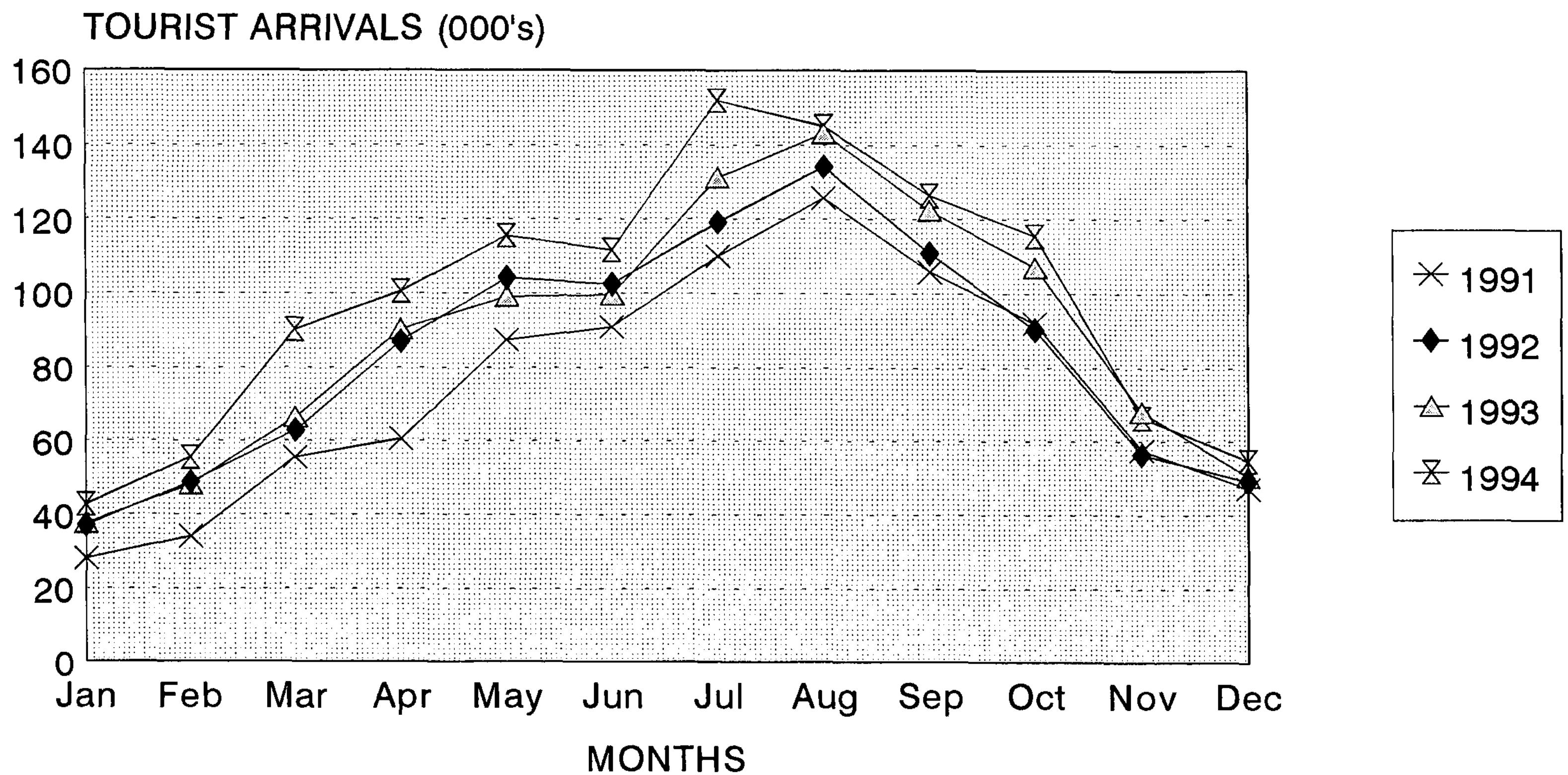
Note: Billed consumption does not include unaccounted for water (see Table 5.12., p.435).
Derived from data obtained from the PN library, Pieta.

Table 4.3. Tourist arrivals per month in the Maltese Islands for the period 1987 to 1994

Month	1987	1988	1989	1990	1991	1992	1993	1994
January	20419	23988	28580	29209	28052	37053	37573	42726
February	25432	31502	35504	38361	34051	48812	48135	55504
March	36581	47618	57388	54044	55557	62836	66409	90203
April	52915	52441	58836	76786	60582	86991	90286	100541
May	75014	76484	83933	82270	87329	104200	99134	115576
June	82042	84411	87202	91543	90914	102513	99572	111667
July	99757	105207	104353	105997	110116	119205	131238	151926
August	110441	106405	110210	116082	125752	134150	143063	145011
September	90752	94600	94703	101309	105825	110812	122389	126406
October	76109	78585	80674	83613	91988	90209	107000	115496
November	39421	45627	50261	52087	57589	56462	67944	66392
December	37060	36978	36667	40475	47281	49138	50470	54775
Total	745943	783846	828311	871776	895036	1002381	1063213	1176223

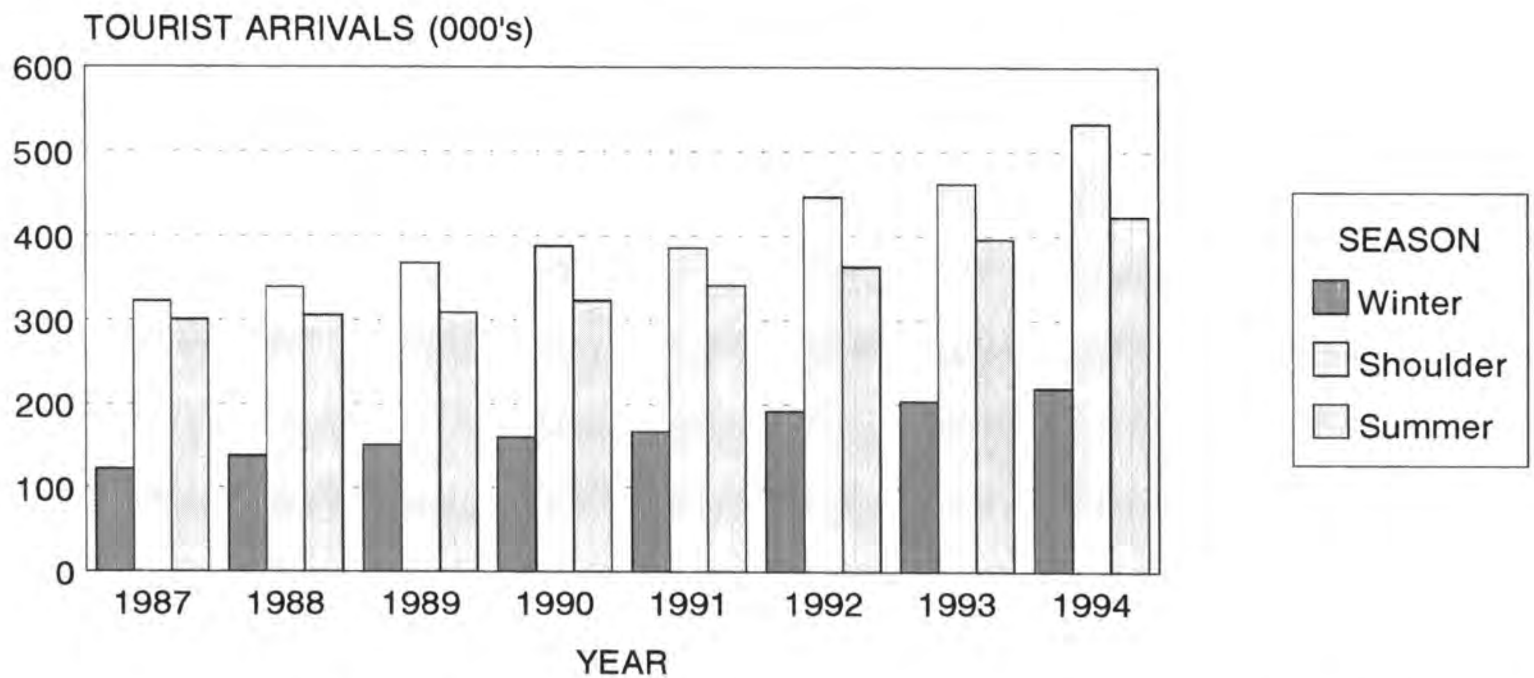
Source: NTOM, 1995.

Figure 4.10. Tourist arrivals per month in the Maltese Islands for the period 1991 to 1994



Source: NTOM, 1995.

Figure 4.11. Seasonal (winter, shoulder and summer months) patterns in annual tourist arrivals
for the period 1987 to 1994



Winter = Jan, Feb, Nov & Dec; Shoulder = Mar, Apr, May, Jun & Oct; Summer = Jul, Aug & Sep.
Source: NTOM, 1995.

February) are significantly lower. During the summer peak the influx of tourists pushes up the population density by 17% to 1,337 persons/km^2 (Busuttil, 1995).

August is the peak month with around 134,000 total arrivals on average. During the peak season there are on average the equivalent of approximately 50,000 extra people per day in Malta because of tourism. This figure is 25,000 tourists per day in the shoulder months and 17,000 in the winter months (ibid).

As far as tourists are concerned, the carrying capacity for Malta (mostly in terms of infrastructure and resource limits) is 1,200,000 per year. In 1994, tourist arrivals were very close to this limit (1,176,223) (ibid).

However, the carrying capacity for the peak three months is a maximum allowable limit of 130,000 tourist arrivals per month. This has been exceeded in the July of 1993 and 1994 and the August of 1992, 1993 and 1994 (Table 4.3.) (ibid; NTOM source, 1993; NTOM source, 1995).

The number of tourists arriving during these months is expected to increase even though the only sustainable potential for increasing tourism is during the shoulder and winter months. Without precautions the pressure during the summmer months on water resources will increase.

The NTOM is fully aware of the problem:

"When you add to the 340,000 inhabitants the more than 140,000 tourists who arrive during each of these months, you can just imagine the demands on the water supply." (Pace, 1995, p.9).

4.4.3. Tourism related water consuming activities

As already stated, the average tourist water consumption is $0.235m^3$, relatively high when compared to the domestic equivalent of $0.15m^3$ (Ministry for the Environment, 1992). Tourists like to enjoy their holiday as fully as possible, including the use of basic resources like water (Sivignon, 1989). As well as being accustomed to water availability in their home countries (the majority of tourists are British and German), there are a number of activities specifically related to the type of 'sun, sea and sand' tourism which Malta offers, that encourage water consumption:

In addition to their normal daily washing, their extra personal demands for water are for showers and baths, often several times a day (usually to wash off seawater, chlorine, sun lotion and to cool down).

Extravagant demands that are provided for include swimming pools and some hotels can have up to 5 or 6 open air pools, with water constantly evaporating from them. Many are freshwater pools using second class water and in many cases, illegally using tap water (pp.440-443). In a joint study of tourism and water resources in Malta by Beel (1995) and Wood (1995), they found that:

"The New Dolmen [hotel] had a staggering 6 pools - although 5 of these were salt water. The Floriana [hotel] had 4 and was constructing 2 more and the Mellieha Bay hotel had 4 fresh and 3 salt and claimed to change the water twice daily!" (Wood, 1995, p.11).

Planning applications for further tourist development have been submitted. Some of the projects proposed are highly water consumptive. For example, in 1995 there was an application for a golf course awaiting planning permission. The water demands of this project would be immense (*Independent on Sunday*, 30/4/95, p.18), not just for watering greens but for the associated development, such as hotels and a clubhouse (PA source, 1995).

4.5. AGRICULTURAL WATER DEMANDS

As previously stated, approximately, 5.5 million m^3/annum of groundwater is extracted by farmers through vested rights (not including illegal extraction) (Jaccarini and Degaetano, 1993), while approximately 1.7 million m^3/annum of recycled sewage effluent is supplied and used in the south-east. Again, however, consumption is not the best measure of demand since most farmers would like more water (p.294), but demands are not met due to production and extraction limits (pp.325-326 and pp.346-356).

It is not envisaged that the general demand for crop water will increase on a large (national) scale (University source, 1994), especially since,

"The number of farmers and the total cultivated area are decreasing. The irrigated area represents only 4% of the total cultivated area of some 13,000ha. The share of agriculture in the national economy is much reduced." (Ministry for Development of Infractructure, 1990b, p.3).

For cultivated (particularly irrigated) land that remains,

"The major problem is lack of irrigation water." (ibid, p.49).

Since without water crops cannot be grown, or growth is poor and limited, demand for it is high. For example, in the central region and much of the west, water is essential for certain crops which are needed for the Maltese market. In late August and September farmers will put up their onion seed beds. Without water they cannot do this. The presence of water and its abundance will dictate the market price and availability of a crop. For example, during August 1993, Malta had to import onions, reflecting the bad rainfall and subsequent lack of water for that year (DA source, 1993).

Many farmers at some time want to introduce new crops. The availability of water is the most important prerequisite to make this possible. For example, if a farmer wants to start fruit tree growing or a small vineyard, water is essential for fruit production (ibid).

The value, and security from urban development, of agricultural land increases if it is irrigated, a further incentive to want water (ibid).

To say that agricultural demand for water is not expected to grow significantly is not exactly true. Demand will not increase if water is not available, but if it is made available then demand for that water becomes apparent, at least on a regional level, as was and still is the case in the south-east region, irrigated by the SASTP.

Many farmers have taken to stealing water from the Government supply (tap water) and illegally drilling boreholes to water their fields (pp.440-445) (WSC source, 1993). It reflects the fact that demands are high in relation to supply and are not being met.

According to DA sources (1993) the demand for agricultural water will increase because of the need for more and better products and the possibility of exports. Fortunately, the DA is trying to encourage the use of drip irrigation in order to make more efficient use of existing water supplies and ease any demand for more water. The second reason for increasing water use efficiency is that agricultural plots are getting smaller year by year due to the handing down of land from father to sons. Agricultural resources and equipment can be used more efficiently in large consolidated plots than in small disaggregated plots. So, farmers need to be more efficient in a smaller area. However, the adoption of drip irrigation has disadvantages which are discussed in Chapter 8 (pp.721-723).

There are important regional differences in water demand across Malta, most notably between the north-west and west regions, and the south-east region.

4.5.1. Agricultural demands in the north-west and west

It is not known exactly how much water farmers are extracting from the perched aquifer in the west. There is no effective way of restricting or regulating the demand on its water, which is presently detrimental to its sustainability.

According to DA sources (1993), when a pump is renewed its capacity for pumping groundwater is limited to a maximum of 1000 gallons ($4.5m^3$) per hour. But there are no effective means of enforcing restrictions on the length of time of pumping and it is relatively easy to obtain a diesel pump or be connected to the electricity grid. As a result overextraction has occurred. The maximum demand occurs from July to August (DA source, 1993).

In the north-west, where semi-confined aquifers and springs are used for irrigation, demands are generally satisfied due to the unrestricted extraction of groundwater in contact with seawater (DA source, 1993).

4.5.2. <u>Agricultural demands in the south-east</u>

As previously discussed the,

"SASTP was designed primarily to reclaim water for the unrestricted irrigation of crops in the south east of Malta, an area that was traditionally under dry farming conditions and producing one crop per year. Double cropping or even three crops are being cultivated per year, and 25% of all locally grown vegetables are produced in this area." (Micallef, 1994, p.31).

The main crops cultivated now are vegetables, including, potatoes, tomatoes, broad and runner beans, vegetable marrows, green peppers, turnips, cabbages, cauliflowers, lettuces, clover and strawberries (Gauci, 1993).

Up until the introduction of the SASTP, farming in the south-east depended solely on rainfall for any water that was required. With the introduction of the SASTP, once farmers had been convinced that it was safe to use and had been made aware of the potential benefits of using the recycled water for irrigation, demand for the water rapidly increased. Micallef notes that before the SASTP's introduction, since,

"Only one crop per year could be yielded due to a consistent lack of water supply for irrigation.... the introduction of the sewage treatment plant has changed the situation quite radically with demand for such water exceeding the production." (Micallef, 1994, pp.29-30).

Irrigation occurs from March to November but since this area is south facing, the majority of production occurs early in the year. However, crops are still grown during the summer, when high temperatures frequently limit productivity, especially during July to August, with some farmers abandoning their fields until the spring due to the lack of water. During this time water demands are at their greatest and there is the need to irrigate very frequently (DA source, 1993; SASTP source, 1993; Farmer interviewees, 1993).

Even during the main growing season from March to April, when air temperature is lower and rainfall higher than in the summer, demand far exceeds supply. Often all the water that is supplied on a morning has been used up by 10 to 11 am. As previously stated, the SASTP is only able to produce enough water to irrigate 240ha of land (Ministry for the Environment, 1992). However, there is approximately 400ha of agricultural land relying on this water (Short and Tricker, 1994).

According to SASTP sources (1993) the problem is compounded by the unnecessary demands of many farmers. It is its low cost that makes it desirable for most farmers (ibid).

"During the first years the farmers were reluctant to use the effluent on full scale but now the supply is not meeting demand." (Gauci, 1993, p.86).

"However, owing to deficiencies in the distribution system not all 240 hectares receive water." (Ministry for the Environment, 1992, p.3.3).

Peak demands remain dissatisfied and when demand falls in winter, the SASTP reduces production accordingly (DA source, 1994).

4.6. INDUSTRIAL/COMMERCIAL WATER DEMANDS

Since industrialisation occurred in the Maltese Islands in the 1960's, water consumption by the industrial sector increased significantly up until the mid-1980's (Table 4.2.). Although consumption has decreased since 1986 (Figure 4.3.) it still remains significantly higher today than in the early stages of industrialisation in 1970 (Table 4.2.) This has been due to the overall growth of the industrial sector which expanded rapidly and also due to the type of industry that has located in Malta, some of which has been highly water consuming.

With the withdrawal of British troops in Malta, industrial development (and tourism) was targeted as a source of national income (Spiteri, 1975) with the announcement in 1957,

".... of drastic cuts in British military spending. It culminated in the first five year development plan (1959-1964) [Office of the Prime Minister, 1959] and the enhancement of the Aids to Industries Ordinance, both in 1959. The plan stressed the primacy of industry and specifically of export industry:

'Industry must be built up, and by, the very smallness of the home market, any significant industrial development must look largely to the highly competitive export markets in the United Kingdom and elsewhere, particularly in the Mediterranean and African markets.... Even so the task of winning export markets is formidable and will demand a high level of efficiency and productivity in relation to wage levels (quoted from Spiteri, 1969, p.14).'" (Vella, 1994, p.64).

The plan also stated,

"The lack of natural resources, other than industrial skill makes it imperative to offer substantial inducements for overseas industrialists to invest in Malta." (quoted from Spiteri, 1975, p.16; Office of the Prime Minister, 1959).

Furthermore,

"The need of water for directly productive activities necessitates that Government provides it below cost...." (Zahra, 1979, p.119).

So, providing highly subsidised water rates became one way of winning markets.

It was stressed that the emphasis was to be upon developing manufacturing industry (Spiteri, 1969). Agnew and Anderson (1992) emphasise that industrial activity, particularly manufacturing processes, presents a significant factor in the increasing demand for water in arid countries. For example, to manufacture just one can of vegetables requires $0.18m^3$ (40 litres) of water (Agnew and Anderson, 1992).

The Aids to Industries Ordinance established a Board that processed applications to assist export manufacturers in many ways, including exemption from customs duties for plants, equipments and raw materials (including water supply). Industrial projects submitted for consideration, included, textiles, plastic, building materials, paints, synthetic fabrics and steel rolling, all large water consumers (Vella, 1994).

The Malta Development Corporation (MDC), set up in 1968, continued to encourage the manufacturing sector and its gross output increased from Lm38.8 million to Lm248.5 million from 1968 to 1980. By 1980 it comprised textile, clothing and leather industries, all with relatively high water demands especially for the washing of garments (ibid).

Today the industrial sector includes the following: shipyards, breweries, dairies, slaughter houses and meat processing factories, vegetable processing factories, power stations, PVC processing factories, textiles manufacturers, glass manufacturers, electronics factories, soft drinks manufacturers, and bottled water producers (Riolo *et al*, 1993, p.46). All, with the exception of the electronics industry (which has grown since the mid-1980's and eased the overall industrial demand on water) are large water consumers. Figure 4.12. shows that the main industrial areas are located in the north-east of Malta and consist mostly of industrial estates.

Table 4.4. lists the ten industries with the highest water consumption in the Maltese Islands. It can be seen that manufacturing industries and dock and ship works are the most water consuming industries.

Industrial demand varies spatially, where consumption inside estates, is significantly lower than outside them (Figure 4.12.). Total billed consumption per annum over 1000m^3 inside estates is 188 million m^3/annum while it is 300 million m^3/annum outside them (Ministry for the Environment, 1992).

This seems unusal since the industrial estates constitute the main industrial areas (Figure 4.12.). One reason for this may be that, as with the agricultural and domestic sectors, demand in some areas is not being satisfied. The demands of the industrial estates have grown significantly as they have expanded. Unfortunately, supply has not kept pace because the infrastructure has not been upgraded, particularly at the Bulebel industrial estate (MDC source, 1993). Its water requirements are so great that 10% of the SASTP water has been designated to it (DA source, 1993).

Industrial demand for water falls during August because some industries close down for holidays (University source, 1993).

Commercial water demands are spatially confined to the Floriana/Valletta region, with the exception of the several hospitals across the island. Total commercial

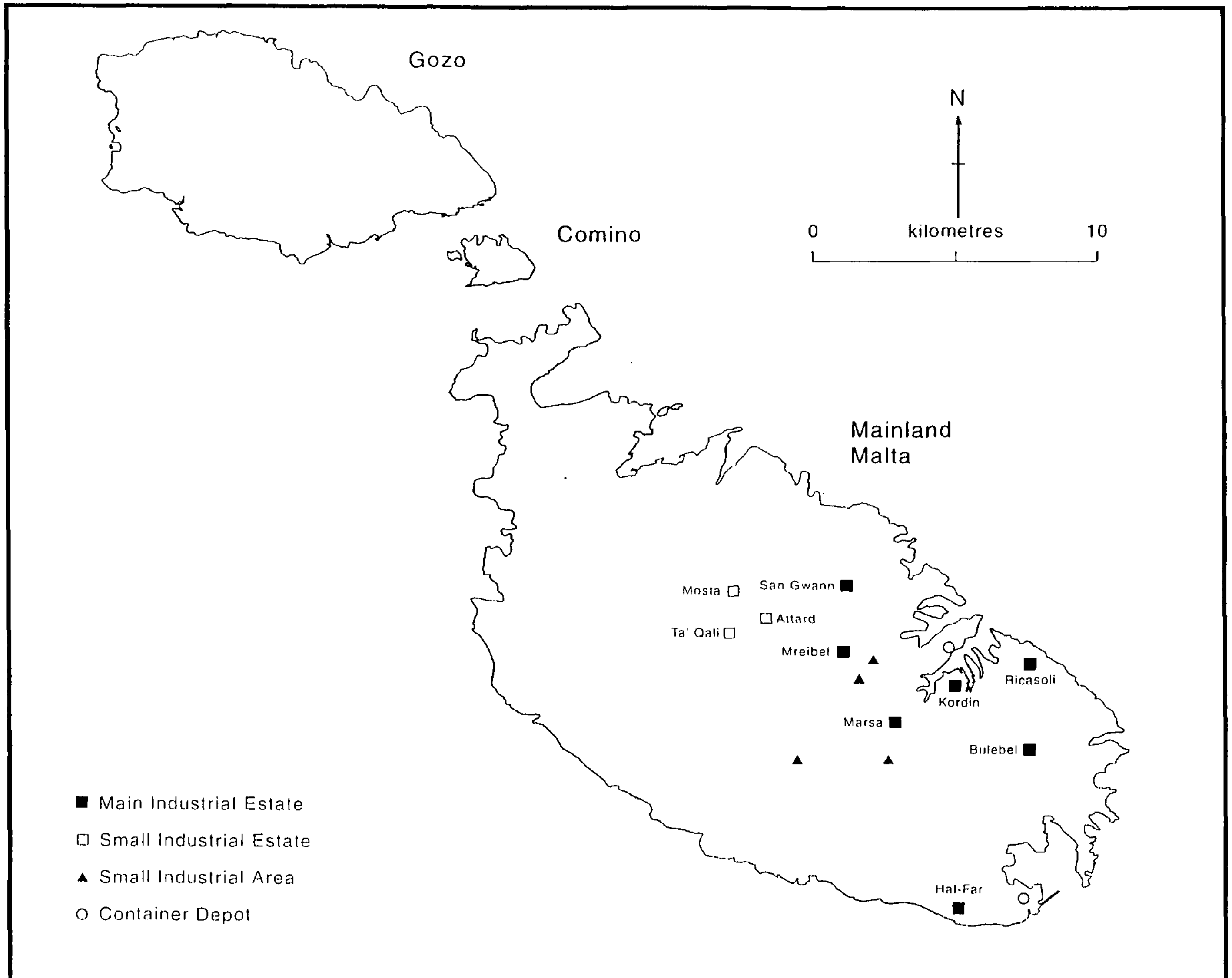


Figure 4.12. Main industrial areas in Malta.
Source: Ministry for the Development of Infrastructure, 1990; 1991.

Table 4.4. The ten most water consuming industrial establishments

Industry	Consumption 1000m3/year for 1990/1991
1. Farsons Breweries, Mriehel	249
2. Malta Drydocks, Cospicua	236
3. SGS Thompson, Kirkop	219
4. Civil Abattoir, Marsa	188
5. Portanier, Hamrun	105
6. Malta Dairy Products	50
7. Marsovin, Marsa	41
8. Royal Products, Mriehel	35
9. Malta Shipbuilding, Marsa	34
10. China Dock, Corradino	28
Total	1185 m3

Table 4.5. Selected large water consuming institutions

Institution	Consumption 1000m3/year for 1990/1991
St. Luke's Hospital, Gwardamangia	210
Mount Carmel Hospital, Attard	52
Sir Paul Boffa Hospital, Floriana	11
Haz-Zmien Hospital, Mtarfa	23
Ghammieri Farm, Marsa	31
University of Malta, Msida	10

Source: Ministry for the Environment, 1992.

consumption is approximately equal to that of the permanent residents in that region (Ministry for the Environment, 1992).

The largest water consuming institutions are listed in Table 4.5. It can be seen that most of these are hospitals. As discussed previously, given their large demands and the importance of water to hospital operation, it is understandable that to meet their demand is of the utmost importance.

4.7. THE DEMAND FOR BOTTLED WATER

Water cuts, shortages and poor tap water quality has meant that the demand for bottled water has steadily increased over the last fifteen years, especially in the domestic sector (WSC source, 1995).

"Consumption of bottled water in Malta stands at between 25 and 30 million litres a year when only two decades ago bottled water was virtually unheard of." (*The Times*, 29/9/93, p.21).

Some industries, such as bakeries and goldsmiths demand high grade bottled water because of the qualitative nature of their products and service.

The tourist industry is a large consumer since many tourists do not drink tap water, understandable given that most perceive Maltese tap water to be of low quality (NTOM source, 1993).

4.9. FUTURE DEMANDS

Demand for water in the Maltese Islands is expected to continue increasing largely due to the continued increase in standards of living and tourist numbers. Urban demand is increasing at a rate of 4%/annum (Food and Agricultural Organization of the United Nations, 1992).

Agricultural demands are expected to be completely satisfied by 2010 when all sewage will, hopefully, be recycled, providing ample second class water (pp.612-626). Industrial demands on both first and second class water supplies are unlikely to decrease unless industries are encouraged to save water.

The population in Malta and Gozo has been projected to increase to about 394,000 in 2010 (Ministry for the Environment, 1992). If current levels of demand per capita for locals and tourists are maintained, then only population growth and increases in annual tourist arrivals will cause an increase in water demand.

This will only happen, of course, if mitigating factors to curb increases in domestic and tourist per capita demand are successful. Such measures (for all sectors) are discussed in Chapter 8 (pp.681-726). However, from Table 4.2. and Figure 4.7. it can be seen that tourist per capita consumption has decreased since the increase in total tourist consumption has been significantly less than the increase in tourist arrivals. This may well be due to the growing awareness of environmental and conservation issues in tourists' home countries, especially Germany and to a certain extent, Britain (Malta's two main tourism markets). A reduction in total per capita demand and consumption will occur if conservation measures are successful.

Conservation measures aside, the WSC estimates that, assuming a 30% increase in consumption, a total consumption of 38.5 million m^3 is arrived at for the year

Table 4.6. Annual first class water consumption/sector (million m3) for 1990 and predicted for 2010

Note: `Other sectors' includes consumption by the commercial sector, boat-houses, gardens, fields and the legitimate use of first class water in the agricultural sector.

Sector	Percentage	Consumptions for 1990	Consumptions for 2010
Domestic	67	19.8	25.8
Tourism	8	2.4	3.1
Industry	10	3.0	3.9
Other sectors	15	4.4	5.7
Total	100	29.6	38.5

Note: Figures for 1990 and 2010 are estimated true consumptions; i.e. including all components of estimated unaccounted for water, not including water lost via leakages (see Table 5.12., p.435).
Source: Ministry for the Environment, 1992.

2010, which is distributed amongst the sectors as in Table 4.6. (the figures will need to be revised given the continuing pipe leakage detection work (pp.658-665)) (Ministry for the Environment, 1992). This estimate is based upon an annual percentage increase of 2.4% (ibid) in the average daily consumption per capita:

"The upward trend in per capita consumption to the years 2000 and 2010 is likely to level out at about 320 litres [$0.32m^3$] because of the saturation of demand and economies in the use of water." (Ministry for Development of Infrastructure, 1990b, p.20)

4.9. CONCLUSION

Water demand and consumption has increased rapidly in the Maltese Islands since the late 1960's. The result has been an increase in pressure on already scarce water resources and water production has not been able to keep pace: a case of bad demand management. The water problem is not simply a question of bad water supply management but a lack of control of water demands. Successive governments should have managed demand better than they did. This increase in demand has been attributed to: the increased standard of living, increased development, the erosion of conservation values in the domestic sector and, to a smaller extent: domestic population increases, increasing tourist arrivals and industrialisation.

Tackling demand is a much more difficult task than trying to improve water supply because it is almost impossible to reverse the growth that has occurred (people do not want to give up the 'good life' once they have tasted it). At best, the growing demand can be halted without depriving consumers of their higher standard of living (pp.681-726).

Presently, in many cases, demands are not being met (because supply cannot keep pace), particularly in the domestic and agricultural sectors, and at some industrial estates. This is despite the fact that the Government has increased production significantly. Groundwater restrictions and production limitations at the SASTP mean that many farmers are not getting as much water as they would like, a common source of complaint (pp.480-497).

Although an increase in standards of living is a natural desire, the environmental consequences of such increases have to be taken into account. Beyond a certain (unspecified) point consumer culture takes hold and wasteful consumption of resources, which is harmful to the environment and the resource base, becomes the norm. This 'throwaway' mentality should have been prevented or at least kept in check. The erosion of conservation promoting values has partly been caused by this relatively new consumer mentality and education should have been used as a means to prevent it.

The aggressive nature of many advertising methods used to sell modern goods (including highly water consumptive appliances and utilities like cars (which are frequently washed) and swimming pools) and the appeal of capitalist notions of success, that turn such goods into symbols of status, are very much to blame for the water problem as they are for many of the Islands' other physical problems (most notably, pollution and land use conflicts). A more environmentally aware education would have gone against the vested interests of companies selling such goods and most probably, those who have their own personal interests in the success of these companies. Given the information available, for the authorities to claim ignorance of these impacts is unacceptable.

The rapid and uncontrolled development of Malta should have been kept in check or at the very least the required infrastructural and water storage facilities (such as drains, culverts, cisterns and reservoirs) been provided to collect the vast amounts of water lost to the sea. Again, ignorance, a lack of planning and relaxed notions about the law has led consumers and politicians to disregard what is best (and legal) for communities, in the long run as well as now. It has been taken over by notions of immediate gratification, individualism, and badly planned cost cutting: the wrong course for sustainable and equitable development and, to a large extent, the reason for Malta's water problems.

Both tourism and industry are vital sources of revenue and nothing should be done that could damage the Islands' economy. However, tourism carrying capacities during the summer (which perhaps should have been lower in the first place) should never have been allowed to have been breached. One need only observe that many years before summer carrying capacities were exceeded, water extraction in the summer had already exceeded sustainable limits (pp.362-369), something that had been warned against several times by water experts who advised on the nation's water resources development.

Industrial demands should also have been contained by encouraging or enforcing industries to incorporate water efficient processes and appliances such as recycling and water re-use (pp.718-720). It certainly is not too late to do so and steps should be taken immediately to begin this process. The same goes for agricultural consumption of second class water (pp.720-726), which places huge demands on groundwater resources.

The demand for high quality water has seen a proliferation of Maltese bottled waters, consumed mostly by the domestic and tourist sectors (either out of a misguided fear or suspicion of tap water, because tap water tastes salty and is discoloured in some places, a genuine knowledge of the poor quality of tap water in certain areas, or because to be seen drinking bottled water is considered trendy and a status symbol). This is not necessarily a good thing because those consumers who can afford to do so will happily buy bottled water, thereby weakening the lobby and the onus on the Government, and the WSC, to supply good quality tap water, to the detriment of those consumers who cannot afford to buy bottled water.

Demand for water will continue to grow, unless some form of demand management is introduced. This management is essential for the sustainable development and well being of the country's resource base. Measures to do this are discussed in Chapter 8 (pp.681-726).

CHAPTER 5

WATER PROBLEMS

5.1. INTRODUCTION

The Maltese Islands have frequently experienced severe water resource problems. The last time this happened was in 1993, when a combination of factors caused water problems in terms of quantity, quality and access, and many of these problems still persist. Their causes and consequences which are discussed here (some causes have been introduced in Chapters 3 and 4 but are discussed here in the context of the water problem) have not all been recent in origin. Some are related to water policies and planning methods from more than half a century ago.

This Chapter considers the need for water security, which is presently inadequate. Comprehensive water security is related to efficient and competent water management, and the security of water production and the protection of supplies from pollution.

Water scarcity issues in terms of quantity, because of shortages and rationing, and access (distribution inequity), and its effects on sectors of the economy and certain regions, are analysed. Scarcity issues in terms of water quality and their potential impacts on health are also examined.

In addition to distribution inequity, smaller scale distribution problems, such as corroding pipes, faulty water meters and water theft, are also discussed.

Finally, this Chapter presents the inapproporiate societal mentality that prevents water conservation and promotes lavish and wasteful water use.

The Maltese Islands are unique in that they present a microcosm of a wide range of water resource problems that can be found in many other semi-arid and arid environments. Although the Islands may be geologically and geographically different from other countries, the causes of the problems are mainly social, economic and to a certain extent, political (water politics are discussed separately in Chapter 7).

As a result of this similarity with other places, other developing countries can learn from the mistakes made in Malta and hopefully avoid the same course of water mismanagement.

5.2. THE SECURITY OF WATER SUPPLIES: PRODUCTION AND MANAGEMENT PROBLEMS

Given the importance of water as a basic human need it is incredulous that in an isolated semi-arid environment such as that of Malta, where water is naturally scarce and desalination expensive, that supplies have not been sufficiently secured, protected and managed.

This section discusses the vulnerability of RO plants to accidental and intentional damage; the lack of emergency water reserves for times of catastrophe or unforseen widespread shortages; the lack of conservation and management of surface run-off supplies; the production problems at Malta's main sewage recycling plant, which has implications for future plants; and the low level of professional water management and finance.

Regrettably, a lack of foresight and planning has been the main cause of these shortcomings, a characteristic common to many aspects of Malta's development (WSC source, 1993). Many of the other problems discussed in this Chapter are also a result of this lack of planning.

5.2.1. RO plant security and vulnerability

Oils spills pose one of the greatest threats to the security and operations of RO plants. Plate 5.1. shows how close sea traffic, including oil tankers, come to the coast where RO plants are located. The threat depends on the size of the slick, its location and sea and weather conditions. For example, an oil spill in Grand Harbour in August 1993 had to be contained with the use of dispersants. Dispersants are not always able to deal with an oil spill, depending on the size of the slick, and they are damaging to marine life. In this case the operation was said to have been successful. Given that the Government received a gift of one million dollars (US) worth of oil dispersants from the Netherlands in 1992, means that their use is likely to continue for sometime (*The Times*, 16/8/93, p.2). An ECO source (1995) informed me that given that Medserv, the company commissioned to clear up oil slicks around Malta, is a significant financial contributor to the Government, their use will continue.

In another incident the Tigne RO plant had to be shutdown as a precautionary measure when oil from a "huge slick" (10x3km) on the east coast of Malta reached the shore in several places in April 1994 (*The Times*, 28/4/94, p.48). The slick only broke up thanks to strong winds and rough seas. *The Times* reported that:

> .... there had been a danger of the slick reaching the coast between Delimara and Mellieha, affecting the Pembroke and Tigne reverse osmosis plants.... Its [Tigne RO plant] shutting down caused water cuts or low pressure in San Gwann, Kappara, St. Julian's, Paceville, Swieqi, St. Andrew's, Sliema, Gzira, Msida, Ta' Xbiex, Valetta, Floriana, Guardamangia and Pieta (*The Times*, 27/4/94, p.1).

Plate 5.1. Sea traffic passing close to the Ghar Lapsi RO plant.

Plate 5.2. WSC bowsers providing water in Msida during the 1993 drought.

If a similar incident happens on the north side of the island then the loss of production from the Pembroke (which provides 22.5% of water supply alone), Tigne and Cirkewwa plants would drastically reduce water supply. For example, just one day's loss of production due to technical failure at Cirkewwa, Pembroke and Tigne on September 29th 1993 caused water suspensions in approximately half of Malta's settlements. Damage to RO membranes from an oil slick would result in prolonged water suspensions and possibly a decline in health and hygiene, together with social unrest. Seaborne sewage pollution, a common problem, poses a similar threat (*Moviment ghall-Ambjent* source, 1995). For the Government to take such chances is irresponsible.

The oil spill in 1994 prompted the call by Mr Lawrence Micallef, head of the Oil Pollution Co-ordination Unit, for more money to buy new apparatus in the form of booms, skimmers and vacuums for the dispersal and gathering of spills and also training (also to his company's financial advantage) (*The Times*, 2/5/94, p.3). This is progressive but he also admitted that:

".... in the case of full-scale oil disaster no country could respond on its own and Malta would undoubtedly have to get help from her Mediterranean neighbours." (ibid, p.3).

Long term loss of water production could also occur from sabotage. Given the value of the RO plants and the water they produce, the lack of security around them is astounding. I was able to walk unquestioned into the Pembroke RO plant without a visitors pass.

The vulnerability of water supply from sabotage became an important issue on February 9th 1994 when an explosion, caused by a bomb, blew up two sections of the pipeline connecting the Ghar Lapsi RO plant and the Qrendi reservoir. The Department of Information identified the incident as sabotage. Maltese bird hunters and trappers were suspected to have caused the explosion in protest against new hunting prohibitions. The explosion caused widespread cuts in the south of Malta, although the pipes were repaired 11 hours after the explosion (*The Times*, 10/2/94, p.1; 11/2/94, p.2). Were such an explosion to occur at an RO plant, repairs could take as long as it takes to rebuild it.

5.2.2. The lack of emergency reserves

The absence of emergency water reserves is a worrying problem given the short term disruptions to water production (pp.329-330) and the risk of long term disruption from an oil spill or sabotage (University source, 1993), especially since 60% of water comes from RO plants.

The fact that Malta is far from the nearest mainland has serious implications for water supply in times of crisis. The water shortage in 1986 is an example of when water had to be imported from Sicily in oil tankers at a very high cost (*The Times*, 17/5/86, p.4; 20/5/86, p.3; 23/5/86, p.3). This practice occurred several times and was stopped as soon as one of the tankers was found to be contaminated (ibid).

There is little more than one day's reserve in Malta's reservoirs (University source, 1993). If long term emergency reserves are not possible then security measures need to be undertaken to protect against such incidents.

5.2.3. The loss of rainwater and run-off water

Rainwater, which is a free, good quality and seasonally reliable source of water, is undervalued and consequently unused or lost to the sea as run-off. Historically, the main source of water in the Maltese

Islands was rainwater collected in cisterns. As modernity occurred people became more dependent on the Government water supply which is often poorer in quality, subject to shortages and cuts and expensive to produce.

Secondly, urban sprawl has rendered the surface of the Islands increasingly impermeable, excacerbating run-off losses. These two problems are discussed here.

5.2.3.1. <u>The decline in the use of cisterns</u>

The cistern law in Malta and Gozo, that states that each household must have a cistern to store rainfall from the roof, is not enforced and consequently rarely obeyed. An ECO source (1995) informed me that the, "Cistern law was abandoned in about 1965 until about three years ago...." when the Planning Authority (PA) was established in 1992. A lamentable situation which means that so much perfectly good water is allowed to run to waste.

A source at the WSC (1995) stated that although many old buildings have cisterns, they are often not used and are unclean: "Up until fifty years ago wells [cisterns] were used by almost everyone since most people did not receive the Government water supply or received it at a very low pressure. So most people used their well [cistern] all year round. They did not have bathrooms and toilets and flush systems. The water was at the very least used for cooking, washing and irrigating gardens."

A source from *Moviment ghall-Ambjent* (1995) told me that when cisterns were used widely, the Maltese were very conscious about water conservation in order to survive. Now people depend on RO water and are more complacent since they have a technological fix (pp.445-456).

Many new buildings do not have cisterns. People are less likely to invest the capital and labour into having a cistern if the law that requires them to is not enforced. The rapid increase in new homes during the construction boom of the 1960's and 1970's occurred mostly without the construction of cisterns. A WSC source (1993) stated that, "The law has always been there [since the times of the Knights of St.John] but has not been enforced with the result that whenever we get heavy rains we end up like Venice." Up to a foot of floodwater is a common occurrence, after heavy rainfall, in the roads of some built up areas. The rainwater goes into the sewer drainage system which cannot cope and overflows a mixture of rainwater and sewage effluent into the streets: "I have seen water throw up a manhole lid causing a fountain of four feet above the ground." (ibid).

According to another WSC source (1993), if the law were enforced then it is quite possible that water scarcity would be nowhere near the problem it is: "People would use well water for other uses and it would have reduced demand [on tap water] greatly." (ibid).

"Among the general public, a prevalent view is that law and regulation are a good thing and should be observed, most particularly by others. Those who are called to higher things, should not really be bound by such restrictions. A great amount of time and energy is devoted to finding ways and means of evading them. The large number of court cases on infringement of building regulations is one manifestation of such attitudes.... Where building regulations are concerned, the relatively small number of building inspectors, coupled with a limited sense of duty leads to very patchy monitoring." (Mallia, 1994, pp.698-699).

This characteristic of law enforcement described by Mallia will be discussed again several times later in this study in relation to different water issues.

One of the advantages of cistern water is that it is soft. This makes it ideal for washing clothes. A standard washing machine uses about 14 gallons (0.064m^3) of water per wash and during the summer, the average Maltese household can have approximately two washes per day (University source, 1993). The use of cistern water for this and many other household purposes would significantly reduce the burden on tap water supplies, which are relatively hard in terms of water softness. Approximately 35 to 40 years ago, Government subsidies were available to help build cisterns. This incentive is no longer available and many people are not aware of the benefits of having a cistern (WSC source, 1993).

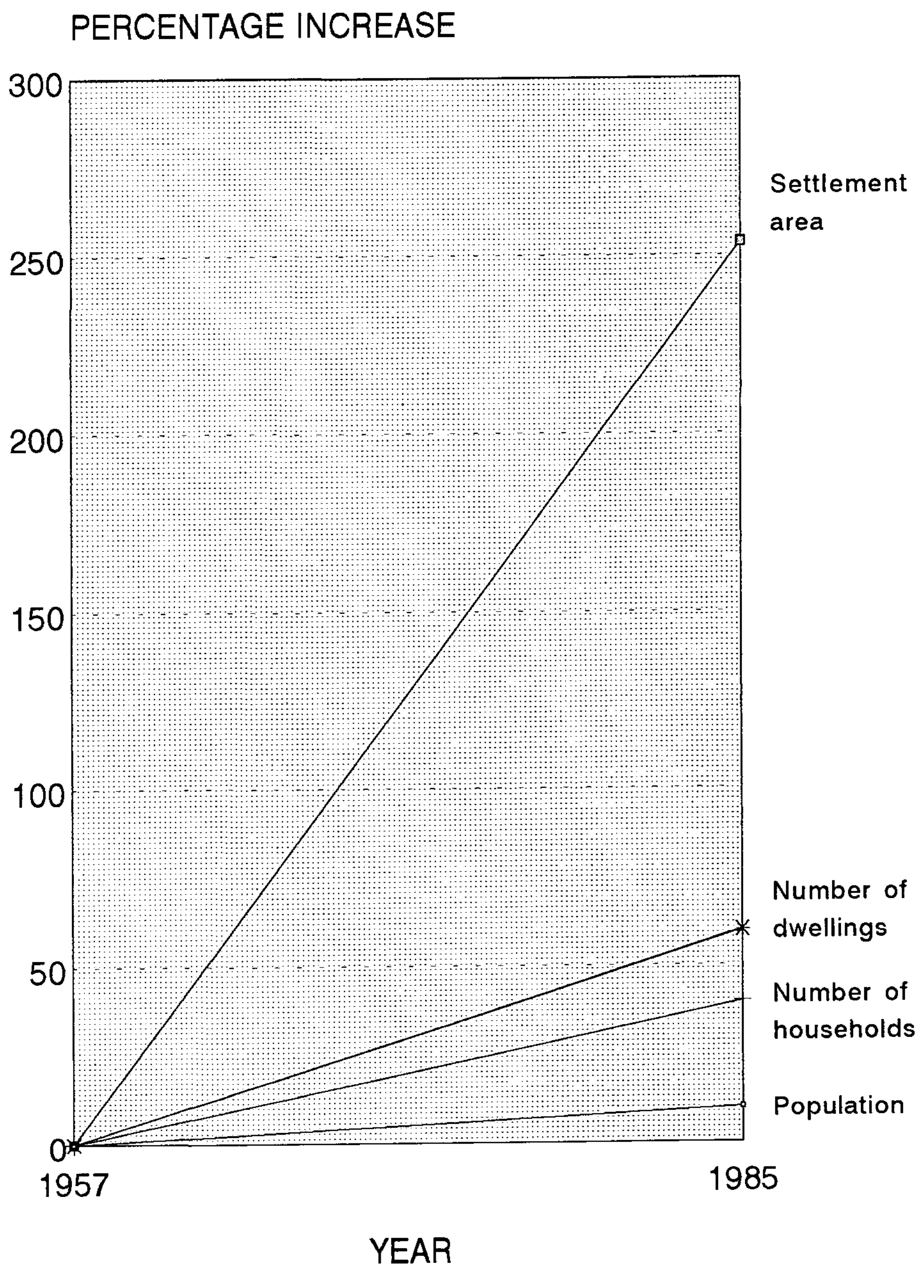
"But the bitterest pill of all is that Government is itself a major law breaker. One of the best known instances relates to the regulation that every house must have a well [cistern], which has been completely ignored in the construction of public and private housing." (Mallia, 1994, p.699).

5.2.3.2. <u>Urbanisation as a cause of rainwater loss</u>

It has already been discussed in Chapter 4 (pp.276-278) that a break from the extended family, the growth of industry (and the associated attraction of employment) and a lack of planning and development control caused an increase in the number of households and the growth of settlements, most recently in the south of Malta. This has led to a decrease in infiltration and aquifer recharge, and has increased levels of urban run-off.

Figure 5.1. shows that in addition to the 40% increase in the number of households between 1957 and 1985, the number of dwellings increased by 60% for only a 10% increase in population. More alarmingly, the settlement area dramatically increased by 254%. This strongly suggests that the surface area of a dwelling has

Figure 5.1. A comparison of settlement growth parameters in Malta
between 1957 and 1985



Derived from Mallia, 1994.

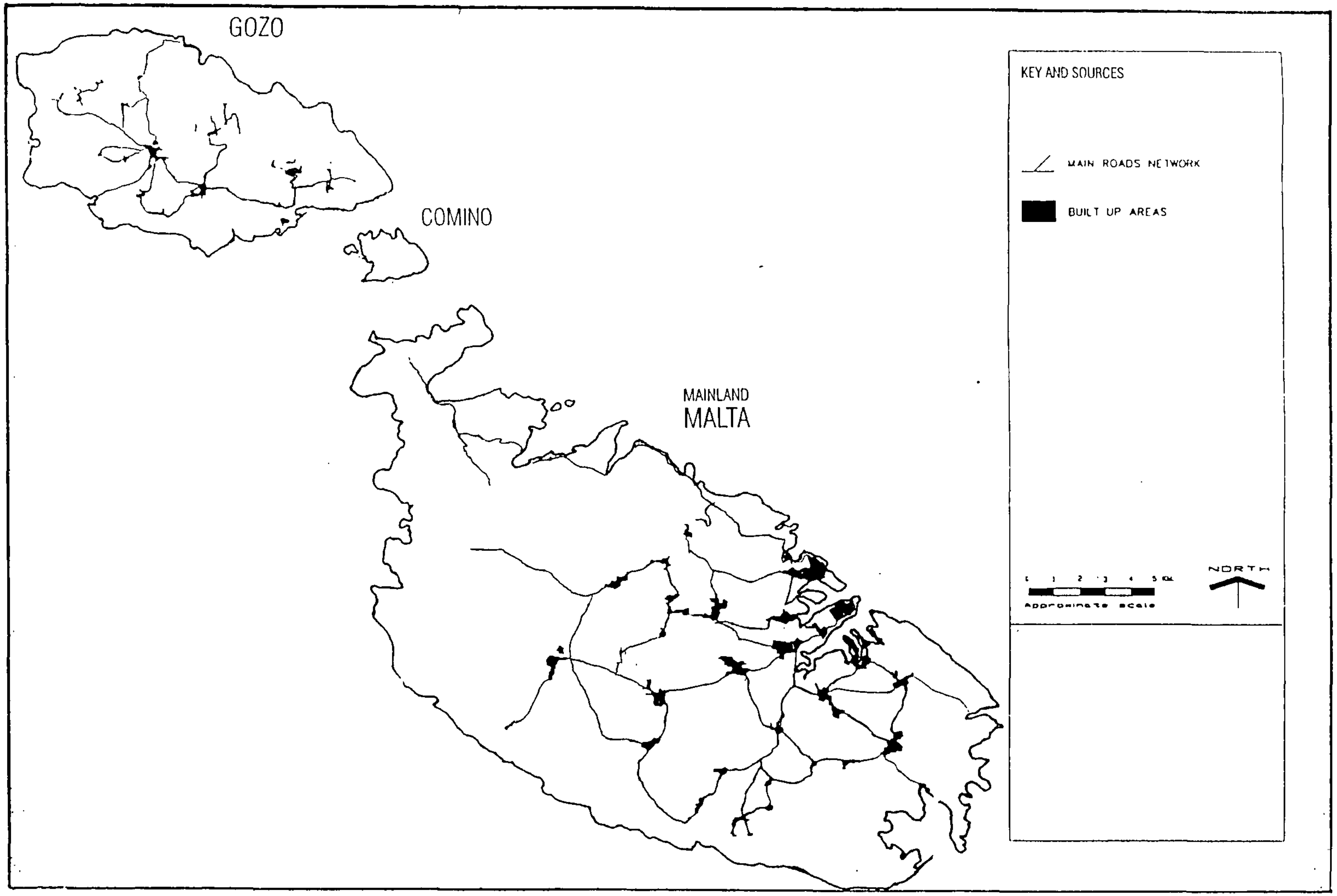


Figure 5.2. The settlement pattern and the main road network in 1910.
Source: Spiteri, 1992a.

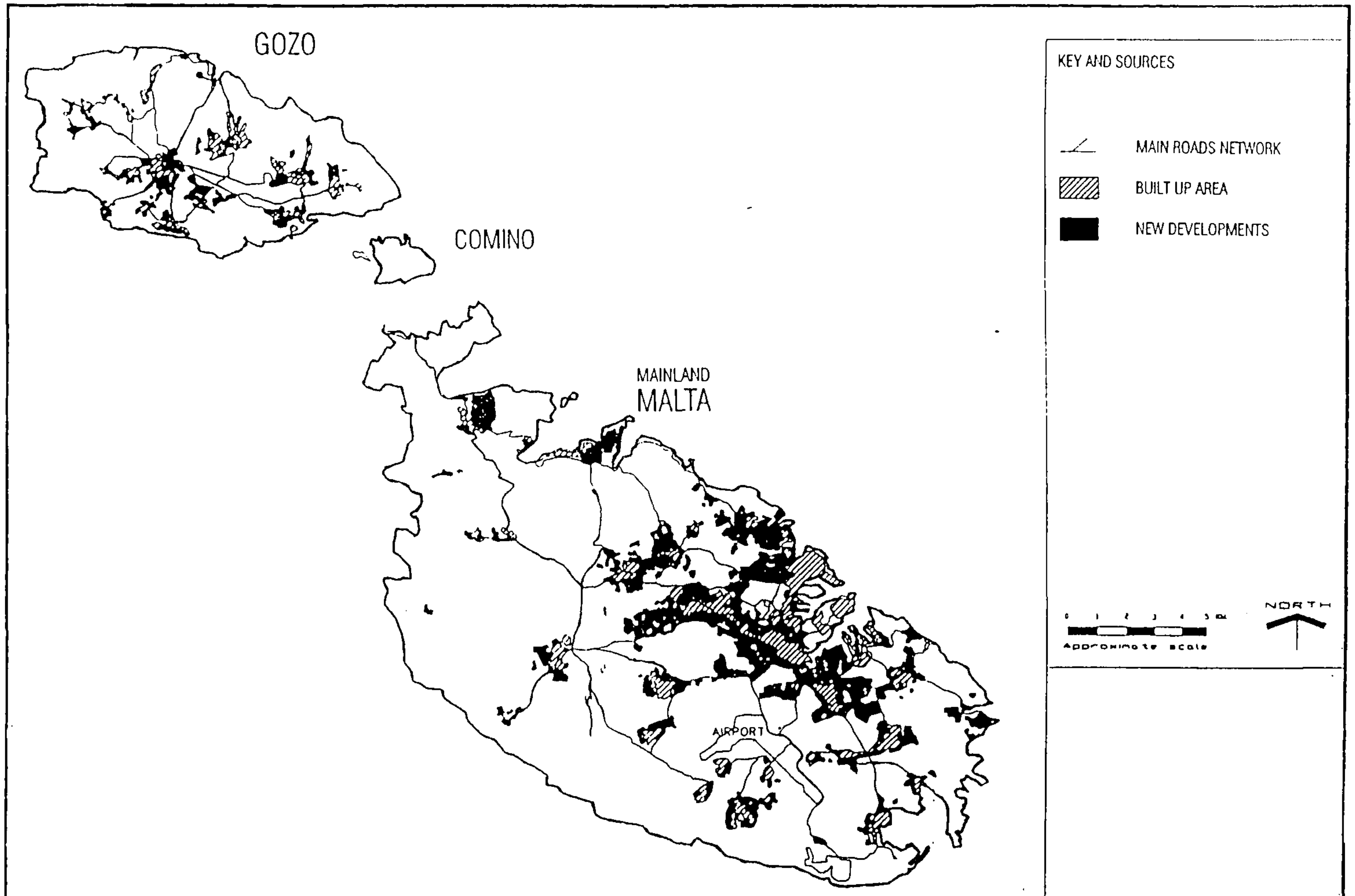


Figure 5.3. The settlement pattern and the main road network for 1968-1984.
Source: Spiteri, 1992a.

significantly increased (Mallia, 1994). Certainly, Figures 5.2. and 5.3., which show the settlement pattern and main road network for Malta and Gozo in 1910 and for 1968 to 1984, respectively, confirm that since 1910 the built up area in Malta and Gozo has increased to a very large extent. Mallia states,

"The built up area on Malta has gone from 11 square kilometre in 1957 (4.5% of the total land area) to 44 square kilometre (18%) in 1990, with another 5 square kilometre (2%) covered by roads, which have expanded from 900 kilometre to 1,500 kilometre in length over the same period. On Gozo, some 3.4 square kilometre (5%) in 1957 have expanded to 5.4 square kilometre (8%), and this against a backdrop of a declining population." (ibid, p.690).

Mallia describes how the expansion of settlement area has caused a displacement of agricultural land, an ideal surface for the infiltration of rainfall. The decline in land under agriculture from 185 km^2 (55%) in 1960 to under 110 km^2 (35%) in 1990, has occurred due to ribbon development and increasing tourist accommodation (as well as urban and road development) (ibid).

"The latter has led to the wholesale development of the Qawra-Bugibba peninsula, Xemxija, Marsascala and Marsalforn and Xlendi on Gozo. Major infrastructural works like the extension of the airport runway and the provision of a new terminal building have consumed their fair share of arable land, as have the industrial estates at Marsa, Bulebel (Zabbar), Corradino, Ricasoli, Hal Far, San Gwann and Xewkija (Gozo)." (ibid, pp.690-691).

There are plans for a new landing strip and terminal in Gozo (the construction of which was under debate in 1995), and further tourist development, particularly in the south of Malta (NTOM source, 1995). Already, over one-third of Malta's coastal zone is covered with tourist development and a further quarter by industrial land and maritime activities. The figures for Gozo and Comino are 20% and 10% respectively (ibid). The *Malta Structure Plan* (Ministry for Development of Infrastructure, 1990a) acknowledges the damage that has been done:

"The environmental cost of this unplanned development was and will continue to be extremely high. Most of the tourism developments located on the coast or concentrated within existing settlements have greatly modified the original environment..." (Ministry for Development of Infrastructure, 1990a, p.3).

In addition Mallia warns of the knock-on effects of urban development:

"But the effects of development are by no means confined to the land area actually taken up. There is always a strong multiplier effect. For instance, the extension of roads to previously inaccessible areas encourages settlement development away from the old nuclei." (Mallia, 1994, p.692).

Flooding occurs almost every year in a number of urbanised places. One area notorious for flooding is the lower part of Gzira and Msida by Msida quay. This area is always flooded after heavy rains and makes driving on the main road hazardous, even though the sea is only a few metres away in some parts (*The Times*, 7/12/93, p.4).

Another problem area is the intersection between Kokka and Hida streets in Kappara. The roads are without culverts and repeated flooding makes it difficult for drivers and pedestrians to use them (*The Malta Independent*, 30/1/94, p.6).

Water loss due to the impermeable nature of the urban fabric needs further study to assess the amount that actually runs into the sea. If effectively harvested, the water could be used in all sectors, particularly agriculture, where there is a shortage of good quality water (pp.422-425).

5.2.4. Production problems at the SASTP

The SASTP frequently experiences technical problems which can reduce production and the quality of the recycled effluent. The plant rarely fulfills its daily production target of 6000m^3/day. When such problems occur the plant manages to only produce approximately 3,500m^3/day (SASTP source, 1993).

A DA source (1994) informed me that, "Sometimes we have no water for a week especially because of biological problems." Vincent Gauci, the plant manager states:

"Biological plants, like the one at Sant Antnin, are easily upset by wrong biomass management operations, waste-water feed flow fluctuations and insufficient aeration capacities." (Gauci, 1993, p.85).

The main reason for these problems is that maintenance is carried out only when there is a breakdown. No preventative work is ever done (SASTP source, 1993).

In addition the *Sewerage Master Plan for Malta and Gozo* (1992) states that:

"The main problems experienced in operating the plant has so far been:

- Shortage of qualified staff to run the plant
- Lack of monitoring and control facilities

- Shortcomings related to logistics and materials." (Ministry for the Environment, 1992, p.6.28).

Given these shortcomings it is no surprise that the plant frequently experiences production and quality problems.

5.2.5. Inadequate water management and funding

Inadequate water management has been a longstanding problem and one of the fundamental causes of the water problem. When the WSC was the WWD, Abela (1992) wrote:

"The Water Authority has benefitted from a monopolistic situation for many years, hence instilling a great reluctance to change which has led to poor investments and efficiency." (Abela, 1992, p.1).

The *Malta Structure Plan* (1990b) stated:

"A lack of qualified personnel exists in all public utility services. This is partly a product of the labour market conditions in which qualified and skilled personnel are absorbed by private industries which offer better salaries. This in turn causes delays in most of the programmes for improving this sector." (Ministry for Development of Infrastructure, 1990b, p.33).

Also,

".... the structure and organisation of that Department [WWD] was not the flexible framework required to run enterprises that are essentially commercial in nature. The Government set-up of the time did not provide sufficient motivation, discipline and scope for the specialisations required." (WSC unpublished paper).

To a large extent this was also true of the WSC while it was in a transitional phase in 1993/1994 (WSC sources 1993; 1994):

"Environment Minister Michael Falzon called the present time a period of transition from the former Water Works Department to the Water Services Corporation, whose board was appointed just before the 1992 elections." (*The Times*, 28/5/93, p.4).

The low level of professionalism and training, together with the lack of funds for the large number of urgently needed projects, is a significant part of the water problem, most notably during and prior to 1993 (Ministry for Development of Infrastructure, 1991b).

When asked in what way the WWD has changed since it became the WSC, one WSC source (1993) stated that the transformation had only occurred on paper. However, the transformation of the WWD to the WSC on a professional level has begun and by 1995 considerable change had occurred (pp.640-651) which was more difficult than was expected.

It was felt by several WSC sources (1993) that the WSC needs to recruit more staff. They need people to take responsibilities and be properly trained in the relevant fields. It is also time consuming for those with professional responsibilities to do all their own administration. For example, the Engineering Services Branch of the WSC is only a two man team. Many of their better technical people are involved in training courses (ibid). Other WSC sources (1993) also felt that there is not enough staff and they only have enough time to deal with present and past problems rather than deal with the future. In contradiction, the WSC Chief Executive, Antoine Riolo, has stated that,

"We have more people than we really need, and with the wrong skills. We tried to get rid of unnecessary positions by getting workers to do all jobs.... However, that just drove some workers to ask to rejoin government service. Personally, I encouraged them. We have around 1,400 people at the moment when we need around 1,000." (*The Times*, 15/12/94, p.8).

With regards to management policies, they only exist on a branch level in the WSC with each branch making its own policies (WSC source, 1995). One WSC source (1995) informed me that there is little or no reference to policies or activities of a branch in the WSC by the other branches. This is indicated by how little workers in a branch, such as the Production Branch, for example, knew about the policies, activities or goals of, say, the Distribution Branch, when questioned about them.

Finally, finance is a problem. The WSC requests higher budgets but they do not receive enough according to one source (1993) there. For example, they only own three bowsers because of financial constraints (ibid), a grave shortcoming in times of severe water scarcity.

5.3. WATER SCARCITY

Development and associated rising demands for water have caused a relative decline in water resources. The 1964 Development Plan (Office of the Prime Minister, 1964) for Malta stated that,

"One of the serious drawbacks for expansion on a large scale of the industrial and agricultural sectors is the limited water supply." (Office of the Prime Minister, 1964, p.27).

The demands of the tourist and domestic sectors could not be met either and up until 1987, Malta experienced extreme cases of water scarcity.

Since 1987 water production has increased dramatically at the expense of large investments in RO technology and high production costs. Yet problems still exist and the summer of 1993 was the most problematic since 1986, with prolonged water shortages in several settlements.

This water scarcity is generally due to a combination of demand almost always being greater than supply, and the distribution system being unable to cater for everyone's demands, even if water is available: quantity scarcity and access scarcity, respectively (Pearce, 1994).

With the latter, water access is determined by the location of a settlement in relation to the distribution system. Some settlements, industrial areas, and tourist areas have access to enough water (in some cases more than enough, which is often nevertheless consumed), while other places receive less, some with just a trickle or nothing for several weeks. This problem was particularly pronounced in summer 1993 (WSC source, 1993).

Quantity scarcity arises due to a shortage of water (despite large amounts of water produced by RO plants). Hence the WSC deliberately suspends the water supply in settlements to try and conserve what little (groundwater) reserves there are to make them last up to and throughout the summer. The exceptionally low winter rainfall in 1993 (Figure 3.12.) meant that these water cuts were frequent and in some cases lengthy. Suspensions also occur during RO plant maintenance operations and expansions (*The Times*, 8/11/93, p.1).

Water cuts can also occur due to power failures, given that water production and distribution are mostly electrically powered. Most adversely affected are the RO plants. For example, in August 1993 a power failure (*The*

Times, 29/8/93, p.4) caused production at the Ghar Lapsi RO plant to suffer by 9,100m³ (two million gallons). The main reservoir supplying the south (Qrendi reservoir) almost dried up, causing water cuts in thirteen southern settlements (*The Times*, 26/8/93, p.1). Again, on the 28th September 1993, a fault at the Marsa power station caused the loss of 13,650m³ (three million gallons) of water at the Tigne, Pembroke and Marsa RO plants (*The Times*, 29/9/93, p.1).

Technical faults at the RO plants frequently occur and the next day these three plants were experiencing problems, which may have been caused by the power failure. The loss of production caused water supply suspensions in nineteen northern settlements. (*The Times*, 30/9/93, p.1).

Extreme weather can disrupt water production. For example, in April 1994, after heavy rains, run-off carried soil and other material into the sea, polluting RO plant feedwater. The storm also caused a fault in the electricity cable feeding the Ghar Lapsi RO plant and rendered the Tal-Hlas pumping station inoperable (*The Times*, 7/4/94, p.48).

Whereas warnings can be given before water cuts occur, failures at RO plants have an unpredictable and widespread effect on water supply.

5.3.1. Water scarcity and the domestic sector

Given the different levels of priority given to each sector (in terms of water supply) water cuts and water shortages affect residential areas the most, although some tourist and industrial areas are affected due to the shortcomings of the distribution system. The agricultural sector is least affected since it relies on second class water sources. During water suspensions, the WSC bowser service (Plate 5.2.) is under great pressure from domestic water demands.

5.3.1.1. The distribution system as a cause of water shortages in the domestic sector

The distribution system has become undersized (pp.428-429) as many settlements have rapidly grown in terms of area, population and water demands. The distribution system is not capable of transporting water at the volume, rate and pressure necessary to satisfactorily supply them, causing access scarcity.

Access is most difficult for settlements at the end of distribution lines and/or on high ground, since low water pressures mean that they are poorly served. For example, up until 1987 Sliema was last along one branch of the distribution system and experienced low water pressures and prolonged shortages.

Today, there is a distinct difference in water access between the north and south of Malta, although water rationing can affect all parts of Malta and Gozo.

5.3.1.1.1. Access scarcity and water cuts in the south of Malta

Today the main water shortage problem is in the south because settlements there, particularly on the coast, are poorly supplied by an undersized distribution system in the south. The WSC Chief Executive, Antoine Riolo (*et al*, 1993), explains:

"The zone distribution system is based upon a village based system that have since sprawled as the villages have merged together. They tend to be small diameter pipes that have been extended and then extended again such that often there is little supporting mains to supply them. Similarly the major distribution is very much a linear system with a principal main supplying a string of villages. This has created situations where villages at the end are very susceptible to supply problems, e.g. Valetta and Zabbar/Marsascala.... very little major distribution works have been undertaken in the last two decades.... Together with the loss in hydraulic capacity due to the effect of corrosion [p.430] the distribution system is grossly undersized to cope not only with future demands but in a number of localities with existing demands.... the distribution system is [mostly] dependent on unlined 300mm or smaller diameter pipes. They are physically not able to cope with consumer demands, particularly now that production resources are no longer the constraint they once were. In a number of areas, the only reason consumer supplies are maintained is because of direct input of [groundwater] production sources to the distribution system." (Riolo *et al*, 1993, pp.19-20).

The drought in 1993 exacerbated these problems, especially in the summer, due to a shortage of groundwater, which the south heavily relies upon. The direct input of groundwater adds insult to injury since it is very saline, becoming more saline as more is extracted.

Cottonera, Xghajra (*The Sunday Times*, 8/8/93, p.5), Zabbar and parts of Marsascala were without water for several weeks. Marsaxlokk and Birzebbuga were also badly affected. Being closer to the Qrendi reservoir (Figure 3.24, p.245), settlements like Zejtun and Ghaxaq also suffered but to a lesser extent.

Demands on the distribution system are greatest during the day so that at night consumers may hear their tanks filling up once demand falls.

There are differences in water supply within settlements. For example, parts of Marsascala are without water for several weeks because they are on high ground.

Given that southern settlements can be subject to water cuts (mainly due to production shortages at the Ta' Kandja pumping station and the Ghar Lapsi RO plant), they are dealt a double blow (WSC source, 1993).

The following are testimonies of some of the residents in the south experiencing the problem:

"Once or twice a week.... if you're not prepared, you'll be short of water." (Cospicua)

"I've been in Marsascala for over two and a half years. Since about four to five months, six months most - not even one drop of water."

"[We] have water cuts in winter.... there is a tank on the roof but for washing it's not enough.... the rest of the roads may not get enough because of pressure.... then people may argue." (Vittoriosa).

A joint study of water scarcity in Marsascala by Dodd (1994) and O'Hara (1994) concluded that,

"It appeared that water supply in Marsascala was at best below average and at worst, non existent." (Dodd, 1994, p.11).

The inequity of water supply between the north and south of Malta is illustrated by Table 5.1. It can be seen that settlements in the south with populations larger than settlements in the north, for example Zejtun and St. Julians, respectively, have a much lower consumption of water. The overall daily consumption per capita is much higher in the north than in the south (Riolo *et al*, 1993). As stated in Chapter 4, this is not necessarily because there is a lower level of demand in

Table 5.1. Mean daily consumption (m3) in 1989 for some settlements in the north and south of Malta

Mean daily consumption per capita (m3) in each settlement has been adjusted to allow for leakages.

Settlement	Daily billed consumption	Population (1989)	Daily consumption per capita
NORTHERN REGION			
Mellieha	181366	4571	108
Sliema	526238	13541	106
St. Julians	704065	10136	190
Mosta	378409	12633	82
Naxxar	277061	6685	113
Gzira	329695	10405	86
SOUTHERN REGION			
Marsaxlokk	70972	2510	77
Zabbar	315372	13565	63
Zejtun	227355	11816	52
Tarxien	107350	7087	41
Luqa	116246	5611	56
Fgura	188402	8847	56

Source: Riolo et al, 1993.

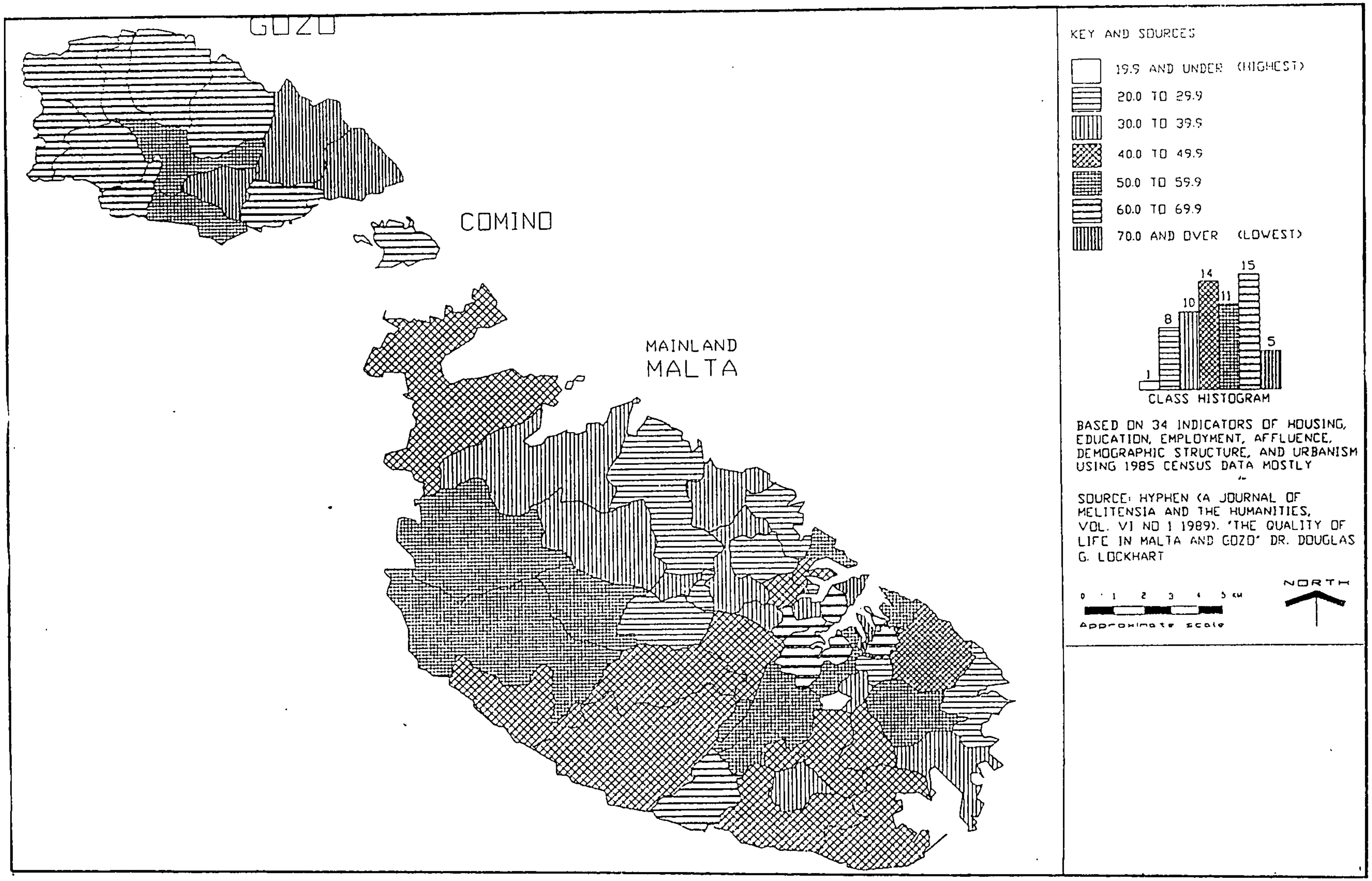


Figure 5.4. Standards of living in Malta and Gozo by census localities.
Source: Ministry for the Development of Infrastructure, 1991b.

the south (although the shortage necessitates conservation), but more to do with the limited water supply there (WSC source, 1993).

The consequences for standards of living, hygiene and consequently, health can be appalling. Dysentry is just one problem that can occur due to a lack of water. The article in Figure App.3.5.1. describes the hardship of many people and the following is a response to the article by a reader:

"I am sure that nobody in Malta can fail to empathise with the unenviable scenario she decribed. During my rounds as a family doctor I have frequently encountered the setting of somebody with the runs and no water available. I have frequently been offered bottled water to wash my hands after visiting a patient...." (*The Sunday Times*, 22/8/93, p.15).

The south is generally of lower income, relative to the north. Figure 5.4. shows that standards of living are lowest in the southern half of the Island, while they are much higher in the north. Standards of living are closely related to income. Many people living in the south cannot afford to buy large tanks to cope with the prolonged waterless periods. People in the north are more affluent and more likely to cope with water suspensions (which are shorter anyway) by purchasing larger roof tanks, private bowsers and bottled water.

5.3.1.1.2 Production shortages and water cuts in the north and central settlements

The north, with its better sized distribution system, has a relatively plentiful supply of water, particularly those settlements supplied directly by the

RO plants (Table 5.1.). With the exception of a few, northern settlements rarely experience distributive shortages, since after the growth of residential and tourist areas in the north during the 1970's and 1980's, the distribution system was upgraded and extended and RO plants introduced there.

However, residential areas in the same settlement as tourist areas, like Paceville and Bugibba may experience shortages for short periods in the summer when demand peaks (pp.341-344) because the distribution system is unable to satisfy the demand.

Since the northern and central settlements suffer relatively little from water shortages, they are often subject to deliberate water suspensions to ration groundwater. The WSC try and give prior public notice, through the media, of the location and duration of the water cuts (WSC source, 1993).

Supply is suspended on a rota system, mostly in areas where it can be resumed again quickly. These tend to be low lying areas closest to reservoirs (as opposed to areas on higher ground and/or at the end of distribution lines) (ibid).

Ironically, settlements supplied solely with RO water, mostly those in the north, are generally least affected since it is groundwater that is being rationed (ibid). From my survey it appeared that Birkirkara was one of the few areas that suffered the least from water cuts. The fact that the Prime Minister lives there may have some bearing on this. Central settlements (with the exception of Birkirkara) fed by reservoirs that include a relatively large amount of groundwater experience more cuts than the north (ibid). The following testimonies from residents in northern and central areas reflects this pattern to a certain extent.

"[Water is cut].... only once a week .... not too bad." (Mellieha).

"We have the water turned off once a week, I can survive that.... having a big tank." (Mellieha).

"[Water is cut].... sometimes twice a week, but only for a couple of hours." (Birkirkara).

"Because a lot of other areas are being cut off.... this area, we don't have so many problems around here." (Swieqi).

"Every Tuesday we are without water.... I use my well when I don't have water." (St. Lucia).

"Over here we have water everyday. Once in a while we have water cut." (Fgura).

"Over here once or twice a week they suffer from water cuts." (Marsa).

"Water is cut off at least once a week." (Dingli).

".... it gets cut off a lot." (Mosta).

The suspensions are normally not more than 24 hours (WSC source, 1993). However, from newspaper reports and my own experience of living in an elevated part of Msida, called Tal-Qroqq, water cuts could last as long as up to a week in the summer. Although Tal-Qroqq is relatively close to a reservoir, it is on high ground and water pressure can take longer to build up than elsewhere, once supply is resumed.

Residential areas with hospitals or with industrial and tourist areas, are least likely to have their water supply cut (for reasons previously outlined).

5.3.1.1.3. Water cuts and shortages in Gozo

There were a number of water cuts during the summer of 1993 in Gozo, for the first time in a long time (University source, 1993). A WSC source (1993) explained that this was, ".... probably because there's a lower reserve in the reservoirs [due to the low rainfall that winter] and.... Consumption has risen overall in Gozo as well."

"Unfortunately, demand for water last summer outstripped supply, which had therefore to be better managed and controlled. This substantial increase in demand for water which is the result of a flourishing tourist industry and of a big leap in the quality of life of the local people necessitates tapping new sources of supply," (Tabone, 1994, pp.4-5).

Tourism in Gozo is relatively young (about two decades old) (Macelli, 1990). Between 1965 and 1976 the number of daytrippers and hotel or apartment tourists increased by 500 percent, to approximately 220,000 per annum (Macelli, 1980).

A WSC source (1993) stated that domestic tourism in the form of holiday-makers from Malta increases the water consumption significantly, especially in July and August.

He also told me that, "They cut the water at night to stop the stealing of water by farmers [pp.440-443].... In summer they tend to have heavy consumption around these two popular bays, Marsalforn and Xlendi, where the majority of Maltese [as opposed to Gozitans] have flats."

However, Macelli (1990) states that:

"On an island with a native population of 23,000, such an invasion, especially in the summer, means more pressure on the already scarce water resources....

Changes have therefore occurred in hydrological and ecological structures." (Macelli, 1990, p.176).

The following are the perceptions and opinions of residents on the problem in Gozo:

"It just started from a month ago, the whole of Gozo is being cut nearly every day...." (Zebbug).

".... this summer [1993], nearly everyday during the night from about six in the afternoon.... it's just started.... the boreholes are empty." (Victoria).

"One of the reasons they are shutting off the water supply at night is that most of these abuses that are going on - the farmers stealing water - are done during night, because during the day, someone might see them and report the authorities." (Munxar).

"They are cutting the supply.... rumours are.... there isn't enough water in Gozo.... the supplies that are coming from underground are finished. Just rumours. But most probably they are true. Secondly, also they are saying that it may be one way to force the Government to instal an RO plant here in Gozo...." (Victoria).

High places.... like Nadur [suffer the most because water pressure may not be sufficient]. The pressure is higher at night and this is when the tanks fill." (Nadur).

"After five or six it gets cut." (Xghajra)

Water cuts in Gozo in 1993 occurred mostly at night. An FIS source (1993) also said that these were to prevent irrigation of crops and gardens with tap water.

However, the low rainfall in 1993 was the main reason for water rationing in Gozo since then it relied completely on groundwater. Even as early in the year as April, water consumption in Gozo exceeded production by 9,100m^3 (two million gallons) and water stored in reservoirs in Gozo was 9,100m^3 lower than normal (*The Times*, 5/5/93, p.11). Any other reason is purely a rumor or a subsidiary strategy. Between 1987 and 1993 water production in Gozo rose from 2,084,400m^3 (457 million gallons) to 3,119,700m^3 (684 million gallons), however consumption in the same period dramatically increased from 510,800m^3 (112 million gallons) to 3,119,700m^3 (684 million gallons). Water had to be brought over from Malta in 1994 (*The Times*, 8/11/94, p.16).

5.3.2. Water shortages and the tourist sector

The water problem had a negative effect on Malta's tourist industry during the early to mid 1980's. The rapid rise in water demand meant that supply could not keep pace:

"Then suddenly the infrastructure gave out. The unbelievable had happened. There simply wasn't enough water to go around and energy likewise. The water and power cuts became more frequent and got longer and longer while the number of visitors nosedived." (Pace, 1995, p.3).

Hotels, severely hit by the water shortages, at this time, had to ask tourists to use water sparingly. Although the drop in tourist arrivals was most probably due to the world recession and the rising popularity of Spain as a holiday destination, it was also possibly due to the 1981 Maltese general election which was accompanied by anti-British, pro-Libyan fervour. Any adverse world press coverage of Malta's water problem would not have helped to make the situation any better

(Peplow, 1989; NTOM source, 1993). As reported in *The Times* (13/8/81, p.11), visible shortages of water, even at the airport, had an adverse psychological impact on tourists as soon as they arrived, thus creating a negative initial image of Mata. Gozo's newly developing tourist industry was also hit with water cuts (Ministry for Development of Infrastructure, 1990a).

These problems largely remained until the change in Government in 1987. Lockhart and Ashton (1987) wrote then:

".... the areas which suffer most are the main tourist centres such as Sliema, St. Julian's and Bugibba...." (Lockhart and Ashton, 1987, p.257).

The *Malta Structure Plan* (1991b; 1990a) acknowledges the fact that,

"Hotels and other tourism establishments are already affected by water supply [problems]," (Ministry for Development of Infrastructure, 1991b, p.40)

And,

"To enable the effective development of tourism, a number of problems must be solved. These include availability of water and electricity...." (Ministry for Development of Infrastructure, 1990a, p.20).

Tourism's water demands, however, are a part of the problem. The reason why tourism has been allowed to become so unplanned, uncontrolled and heavily concentrated in just a few areas is due to the fact that 80% to 90% of tourist establishments were developed when planning was either non-existent, or not applied or enforced, or when it was a relatively new tool (NTOM source, 1993).

A source at the PA (1995) informed me that, "Infrastructure was lacking then [1970's and early to mid-1980's] because development grew faster than the increase in infrastructure." It was a period of development when it was expected that the Government would spontaneously provide the necessary infrastructure. "There was no consideration as to the impact hotels were going to have on water resources." (ibid).

Water shortages and cuts still affect tourism in specific areas. A source at the NTOM (1993) stated that the main problems during summer 1993 were in Bugibba and some other parts of the St. Paul's Bay area. Domestic tourist demands, as well as foreign demand, is to blame, since many Maltese have their summer residences in this area. The population increases by more than 50% (ibid).

At a 3 star hotel in Bugibba I was told that the area is without water for three days in the week but they still manage to cope with their large tanks, a reservoir and by calling on private bowsers to bring water. At another hotel, also in Bugibba, I was told that they usually experience water cuts twice a week but cope by means of their 6.82m^3 (1,500 gallon) storage capacity and by buying four bowsers of water per week.

In Gozo, the water problems in summer 1993 affected the two tourist areas of Xlendi and Marsalforn. At a 4 star hotel in Marsalforn I was told, "We get water cuts quite regularly here in Gozo but we have a storage supply system so we're usually covered." In Xlendi I was told by an owner of a block of apartments (2 star), "We haven't had this problem for a number of years and all of a sudden it started this year.... we can cope with big tanks."

Most tourist establishments are able to cope one way or another by storing large amounts of water or by buying it from bowsers. However, since many hotels in the north of Malta are supplied by the RO plants, occasionally power cuts may interrupt supply (NTOM source, 1993).

Generally though, since tourist areas are of priority when it comes to water supply, they do not experience water cuts in the same way as they did during the 1980's, since the cuts usually last two to three days at the most, allowing coping measures to last (ibid).

Unfortunately, the need to satisfy tourists means that domestic demands are not treated in the same way and even unnecessary tourist demands are using precious water while many Maltese homes have none. This is a source of conflict between the two sectors (pp.502-510). For example, landscaping is increasingly being used to create a good impression on visitors. The large area the airport occupies is landscaped and well watered. Landscaped hotels include the Coastline Hotel on the Coastal road near Salina and the Danish Village in Mellieha. The water required for landscaping could be put to more important uses.

Tourist pressure on water resources will increase given that tourist arrivals per annum are still increasing and that in response, new hotels are under, or pending, construction, while the number of seats on incoming flights is increasing (PA source, 1995).

By April 1995 (latest available data) there were approximately 40 applications for new hotels. If they are all approved this will create an additional 5000-7000 new beds and 2,700 of these will be in the Mellieha, Bugibba and Sliema area. Furthermore, current tourism policy (1995) is to encourage tourist development in the south of Malta, since 1994 saw a new Minister for Tourism (from the south) who is expected to favour this. This could exacerbate the current water problems there (ibid).

5.3.3. Water shortages in the industrial sector

Although the industrial sector is a priority for the WSC, some industries are affected by water problems. The water problem for the industrial sector was much worse before the introduction of the RO plants and before industry became a priority (MDC source, 1993).

A source (1993) at Malta Dairy Products stated that disruptions to production occur only when water supply is cut, and then a large number of private bowsers have to be relied upon. At the new *Lowenbrau* brewery the brewmaster told me that the water cuts have little impact as long as advance warning is given. If no warning is given then production is badly affected. During 1993, the industrial area of Qormi regularly had its water cut on a Friday and a source (1993) at the Marsovin company stated that industries there can generally work around that since they know when it will happen.

A large beverage manufacturer, which requested confidentiality, stated (1993) that their water supply is insufficient when water pressure is low and that, "Cuts affect us badly. Bad quality raw water (when there is a drop in tap water quality) results in very high costs of treatment and reduced capacity. At times, we do not cope and are forced to reduce production.... We are not always affected to the same degree because we do not depend on one source." This, they said, consisted of 75% tap water and 25% from boreholes and collected rainfall.

Like tourist establishments, many industries have invested in large reservoirs that can last the duration of most water cuts (MDC source, 1993). Portaneur's production manager stated (1993) that, "The longest cut we had was 48 hours but we can cope because of our reservoirs. It [a water cut of this duration] happens only about once a year.... It's not a big problem."

Electricity cuts cause disruptions in water supply for those industries, like The General Soft Drinks Co. Ltd, that draw water from boreholes with an electrically driven pump.

Water shortages usually occur where an industrial estate will develop so that its demands can no longer be met by the pipeline supplying it. Up until 1993, the

Bulebel industrial estate had been suffering from water shortages for this reason (MDC source, 1993).

Another problem area in terms of supply is the industrial estate at San Gwann because it is located on high ground (WSC source, 1993). The freeport at Birzebbuga and the industrial estates at Hal Far and Ricasoli are also deprived, being at the end of major distribution pipelines (ibid).

5.3.4. Supply shortages in the agricultural sector

Water availability is the most important factor in agriculture after soil type. Unfortunately, a lack of sufficient water is a major constraint (Busuttil, 1993). Although agriculture's contribution to the economy has been declining, its importance to food self-sufficiency is obvious. The *Malta Structure Plan* (Ministry for Development of Infrastructure, 1990a) acknowledges that:

"The main constraints to better food self sufficiency are the scarcity of water and the lack of easily cultivable land." (ibid, p.20).

Short and Tricker (1994) also state that:

"Agriculture having declined in relative importance faces all the recognized 'pressures of modern life' enhanced by island constraints on basic resources such as space and water." (ibid, p.212).

As stated previously, water scarcity is exacerbated by the sub-division of pumping rights to shared boreholes as fathers hand down and divide their land and water amongst their sons. In this way more and more farmers come to rely on the same source and plots become inefficiently smaller. The holdings are often scattered and very often, as a result, farmers are not irrigating all their land but only part of it (DA source, 1993).

"The operation of tiny farms consisting of or assembled from miniscule plots clearly raises intrinsic issues of viability and efficiency in resource management." (Short and Tricker, 1994, p.218).

5.3.4.1. <u>Water supply problems in the SASTP irrigation project</u>

The south-east has a water shortage problem that far exceeds that of irrigated agriculture anywhere else in the Maltese Islands. In their survey of farming in the area, Short and Tricker (1994) found that water shortages were ranked by the farmers as their greatest problem.

"Summer demand periodically exceeds the capacity of the plant leading to inequitable distribution and a sceptical attitude from the farming community." (Short and Tricker, 1994, p.215).

In addition to the production problems at the SASTP, the inefficient distribution system, the low water charge, and the farming structure are to blame, particularly for the "inequitable distribution."

"An area of 240 hectares is equipped with distribution facilities for irrigation. However, owing to deficiencies in the hydraulic distribution system, only 120 hectares can be regularly irrigated. Apparently the main problem of the irrigation scheme is deficiencies in the distribution system, which mainly is attributed to the institutional set-up." (Ministry for the Environment, 1992, p.10.2).

Short and Tricker (1994) state that the distribution systems' primitive and inefficient design was due to the need to,

".... maximise local labour and material inputs in a period of relatively high urban unemployment. Water distribution by cast-concrete open troughs which wind tortuous paths across the intensely subdivided farmland, often resting on top of stone boundary and terrace walls. This 'appropriate technology' - based on a centuries-old prototype hewn from local stone - sits uncomfortably alongside the modern plant and permits high losses from evaporation [and from the satellite reservoirs], spillage [mainly due to sudden changes in channel direction] and uncontrolled interception [and no metering]. Farmers in 'core' locations are therefore tempted towards excessive use while those at the system's periphery complain of drought. In aspects such as these the disciplined equilibrium in access to water at the heart of successful management of small-farm irrigation has been undermined from the outset. Certainly the project seems never to have attained its planned extent or reliability." (Short and Tricker, 1994, p.215).

Vincent Gauci, the manager of the SASTP, is aware of these problems and states that:

"The open channel system was adopted because of its lower cost and because it is the traditional distribution system for irrigation in these Islands.... The system however is prone to losses, is very labour intensive, both for its operation and maintenance, and often results in the farmers next to the reservoirs getting most of the water [Plate 5.3.]." (Gauci, 1993, p.86).

The people working at SASTP have had problems where all kinds of material, such as stones, occasionally block

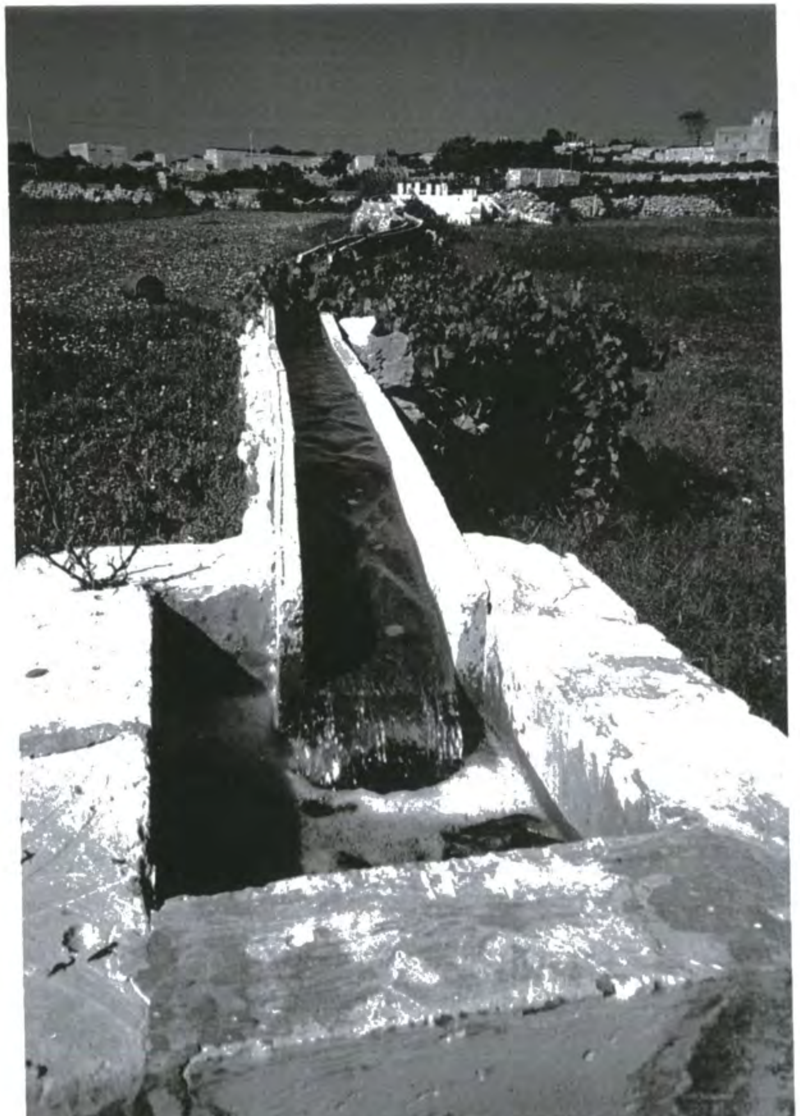


Plate 5.3. Near the Habel Abjad reservoir. The channel water level is high and gives farmers there an advantage over others.

Plate 5.4. Near the Habel Abjad supply area periphery. The channel water level is lower and less water is available for farmers there

Plate 5.5.
Water leaking
from a crack
in the water
channel.

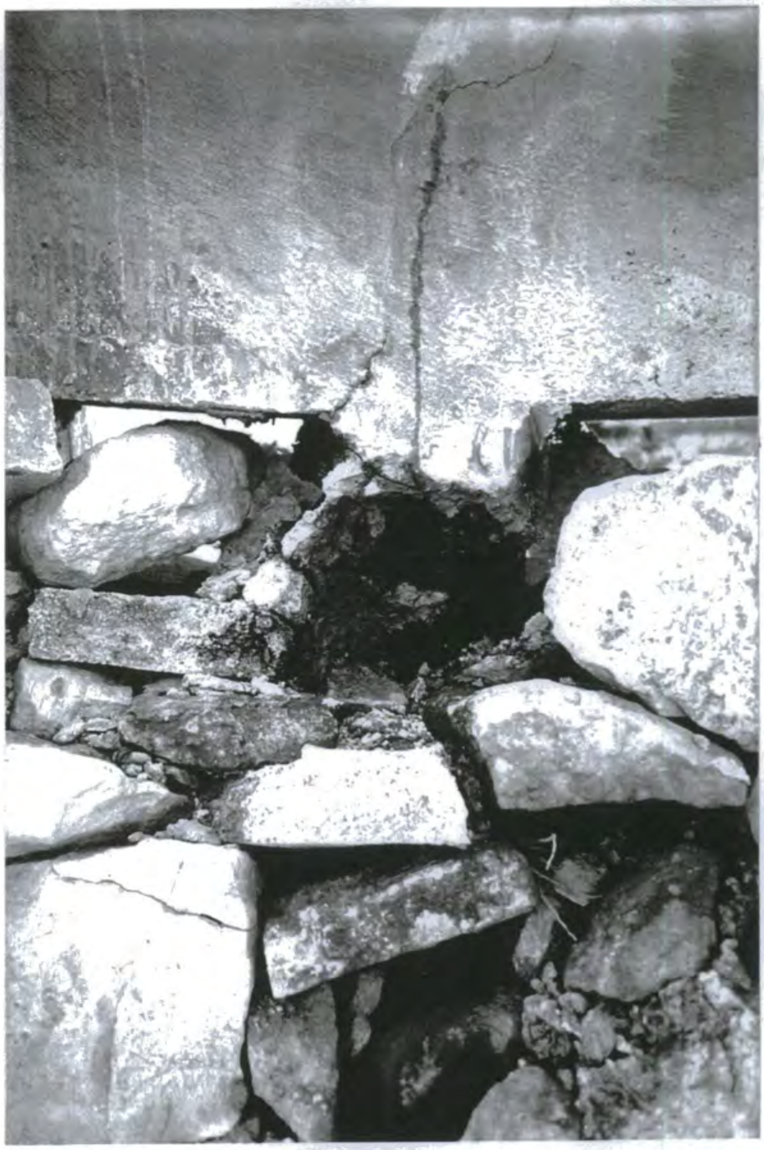


Plate 5.6.
Large volumes
of water leaking
from a water
channel. It
can take
several days
before it
is reported
and repaired.

Plate 5.7.
A low level
leak in a
water channel.

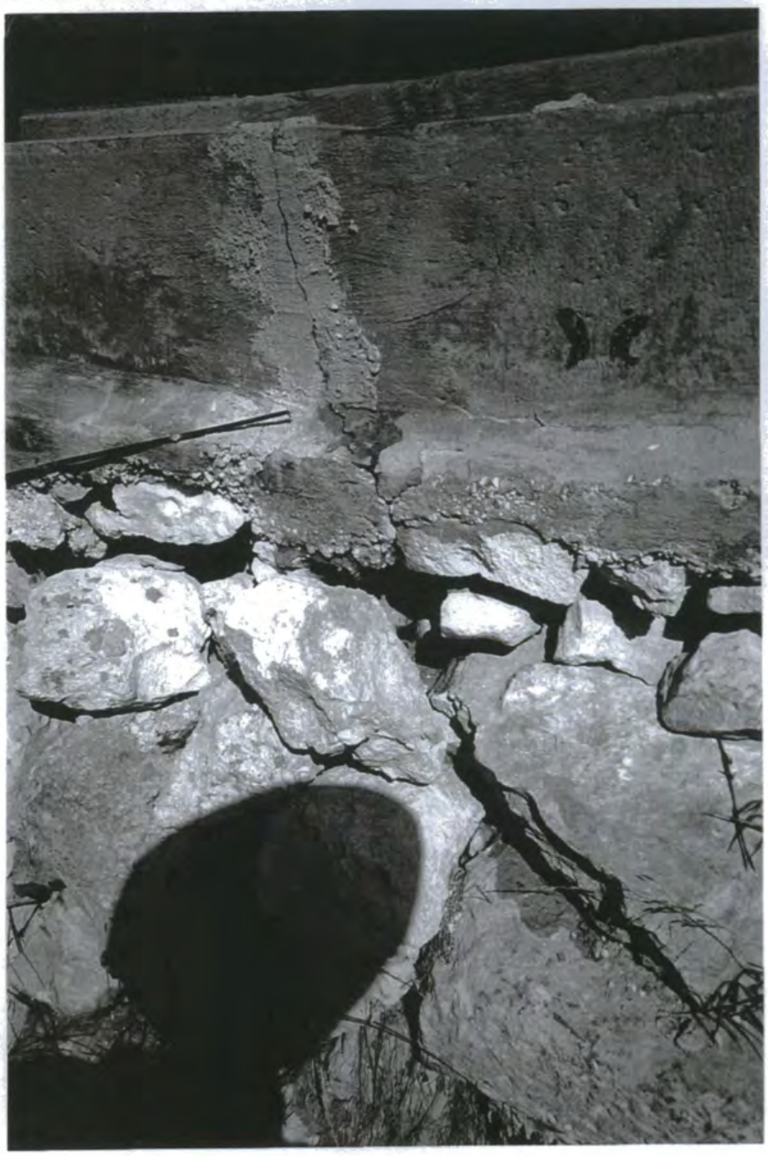


Plate 5.8.
A small
leak which
is difficult
to detect and
represents a
large water
loss.

Plate 5.9. Workmen repairing a collapsed channel.

Plate 5.10. Water is still flowing in this collapsed channel, making repairs difficult.

the stone channels (SASTP source, 1993).

Turbulence in the flow of the water and the very nature of the channel material, cement, causes a certain amount of resistance to water flow (University source, 1993). This and the fact that atmospheric pressure and channel gradients are insufficient (and excessive offtakes by farmers in core positions near reservoirs), means that water often does not reach farmers at the end of the network (Plate 5.4.) (ibid).

Leaking channels (Plates 5.5. to 5.8.) are a common problem. A leaking channel frequently destroys the material in the wall it rests on. Eventually the wall will collapse and destroy the channel (Plate 5.9.), causing the loss of large volumes of water (ibid).

The farmers do little to help repair or remedy the situation. The least they could do is to report the problem but they rarely do this (Plate 5.6.), mostly due to the poor relations between them and the authorities (pp.493-498) (ibid).

Furthermore, it is difficult to repair a broken wall/channel if water is still flowing in the channel and can take up to two weeks (Plate 5.10.). The system's remoteness and complexity makes trouble spots difficult to find. The workers ideally need transport to bring the right equipment and materials with them. Often this is not available and work is undertaken on foot (ibid).

Furthermore, as one SASTP source (1993) stated, "The whole system is as completely disorganised as you can get," and access to different parts of it can be a navigational and terrain tackling problem (Ministry for the Environment, 1992), especially since there are crops in the plots all year round.

The Structure Plan acknowledges the system's deficiencies, yet little has been done.

"The efficiency of the lateral irrigation channels largely depends on the users and the mode of usage. However, as the farmers are not responsible for the lateral system a kind of anarchy has developed, and even illegal tapping from the reservoir feeder mains takes place. The overall efficiency is assessed, by the Haiste Report of 1990, to be as low as 30%. The said Haiste report recommends piping with individual water meters... and relatively advanced application in the form of drip irrigation." (Ministry for the Environment, 1992, p.10.6).

Yet the authorities state that such a system would be too expensive to introduce (SASTP source, 1993). The principle of charging a flat rate to the farmers is counter-productive to water equity. As one DA source (1993) stated: "It's a ridiculously low rate for the amount of water they get. It's not used efficiently. They are trying to grow fruit and vegetables rather than legumes [as was originally intended and which are less water consuming]."

".... a fair pricing and distribution system should be put into immediate effect: the present Sant' Antnin rate of Lm36 per annum without limit on quantity is a joke." (*The Sunday Times*, 12/9/94, p.16).

Part-time farmers are also blamed for the shortages. Short and Tricker explain that:

"Responsibility for many problems, particularly those associated with unreliable/inadequate water-supply, is routinely apportioned variably between design-faults in the distribution system and the role of 'part-time farmers'. These are characterised as less committed to farming in principle, and more careless when using the water supply in practice. Implicit in this view is the belief that if non-specialists were persuaded to withdraw from the land, farms could be enlarged and water management simplified. In the absence of powerful inducements or coercive legislation, however, the pattern of farm structure described at Sant'Antnin seems likely to persist. If anything, it has been reinforced by the new technological environment. Part-time operators of tiny holdings (up to 1 ha) currently form a substantial majority of occupiers." (Short and Tricker, 1994, p.220).

Closed piping, realistic prices and metering would: reduce evaporation and turbidity; prevent excessive offtakes; encourage conservation and efficiency; and eliminate the problem of large areas not being served because of insufficient (atmospheric) pressure and slope gradients.

The authorities concerned (Department of Agriculture, Works Department, Drainage Department and WSC) will not adopt these measures due to the expense involved, the unsolved conflicts and issues relating to operation, distribution and maintenance responsibilities (pp.500-502), undecided policies on water charges (ibid) and because farmers would react strongly to having to pay realistic prices (DA source, 1993).

5.3.4.2. <u>Groundwater shortages in agriculture in the west</u>

In contrast to the north-west, where water supply is saline but unlimited, overpumping by farmers over the perched aquifer has caused a significant lowering of the water table (DA source, 1993).

One farmer in the Bahrija Valley, in the west, told me that due to the low rainfall in winter 1992/1993, he didn't have enough water available from the underground spring that he uses. He shares pumping times with other farmers but did not think he was geting enough water.

Another case is the shortage in the Girghenti Valley where farmers are in conflict over water (pp.511-524).

5.3.4.3. Government water supply cuts and agriculture

Water shortages and water cuts are not a problem for most farmers, unless they are stealing tap water. However, dairy farmers have to rely on tap water to feed and wash their cows. A dairy farmer in the south-east told me that, "This week there were four days without no mains water at all.... We have a reservoir and we catch rainwater and we use it when there is a cut.... We need about 6000 to 8000 gallons [$27.3m^3$ to $36.4m^3$] per day.... If we run out of water we have to buy water and it's not easy. It costs about Lm6.00 to Lm10.00 per 1,000 gallons [$4.5m^3$]." He said that he receives little support from the DA, even though dairy farmers are supposedly a priority.

Another dairy farmer in Gozo told me that he had similar problems the same summer (1993). Without water his cows eat much more than usual and when water supply is resumed, rapid drinking due to thirst causes the food to expand in their stomachs. This sometimes leads to death.

5.4. THE WATER QUALITY PROBLEM

Water quality has been a problem that has run parallel to the problem of water shortages and one that is related to it. As the Islands have developed, the over-extraction of the natural resource base and increasing amounts of pollution has caused a deterioration in water quality.

What is worrying is that there has never been a satisfactory means of monitoring the quality of the water supplied to the population. This poses possible short term and long term health risks. The WWD laboratory, as well as having staff lacking in the necessary qualifications and training, did not have the means to monitor all aspects of water quality for health and safety means (WSC source, 1995; *Moviment ghall-Ambjent* source, 1995). The same is true of the WSC today (WSC source, 1995).

There are quality problems with both first class and second class water. Substandard first class water supply has health implications for the public, while poor quality second class water can lead to production problems in agriculture and industry, with the result that the product may be of an inferior quality.

5.4.1. First class water quality problems

The Maltese Government is currently trying to gain the Maltese Islands membership of the European Union (EU). All of Malta and Gozo's tap water supply will have to meet European quality standards if the Islands are to join the EU. Currently it does not and in some areas falls below WHO standards. Some of the water quality directives demanded by the EU are difficult to meet, not just for the Maltese Islands but also for most of the Mediterranean region where groundwater has become saline. There are different hydrogeological conditions in the Mediterranean and the climate does not allow for an abundance of water resources (University source, 1993).

In Malta the two main problems with groundwater is its high concentration of chlorides and nitrates due to over-extraction, causing seawater intrusion, and pollution from farming activities, respectively:

"At present, water chemical composition has a salt content of about 730 parts per million for boreholes and about 1,500 ppm for pumping stations. Average content of nitrates is about 70 mg/l [ppm] and water of this quality cannot be considered potable. Water quality in Gozo is better than mainland Malta, especially from pumping stations." (Ministry for the Development of Infrastructure, 1991b, p.15).

There are a number of water sources in Malta that should not be used because they are a health hazard. No matter how much groundwater quality deteriorates in any part of Malta (mainly the south), as long as it poses no bacteriological risk to the public, the WSC will not withhold from distributing it. As one WSC source (1993) stated, "It's better to give salty water than nothing."

As discussed previously, a number of industries, hotels and farms, dissatisfied with water cuts and the quality of tap water, have invested in RO plants and other water treatment facilities. The fact that many people drink bottled water says something about the quality of tap water.

The perched aquifer is polluted with nitrate compounds leached from fertilisers but with regard to salinity, it is relatively good because it is isolated from seawater intrusion. The MSLA is saline but although high in nitrate compounds, nitrate levels are lower than in the perched aquifer, although they are increasing (University source, 1993). This section analyses: sodium chloride levels in RO water, in the MSLA and in tap water; nitrate levels in both aquifers and tap water; and the associated health risks.

The conclusions are mostly determined from interviews with WSC and University sources, secondary sources and analyses of maps and data which were obtained from the WSC.

5.4.1.1. Sodium chloride levels in the water supply

The quality of tap water in terms of salinity depends on the ratio of RO water to groundwater in the blend supplied, which can vary widely. The worst of these waters in terms of chloride levels is that which is purely borehole water derived from the MSLA, while the best is RO water only. Chlorides in RO water range from about 250ppm to about just under 400ppm, while in groundwater, from certain boreholes, levels can be up to 3,800ppm (Debono, 1994).

"The worst water [of total supply] is from the Mean Sea Level pumping stations which supply the bulk of groundwater." (Riolo *et al*, 1993, p.8).

There is a spatial variation in the salinity of the MSLA. Boreholes and pumping stations in the south are the worst due to the greater concentration of operating boreholes there. Of these, those nearest to the coast are most saline since the freshwater lens is thickest at the centre of Malta and thinnest at the coast, where seawater intrusion has occurred. Figure 5.5. illustrates this.

The older the operational life of a borehole the more saline the water it produces due to the creation of a hydraulic gradient towards the borehole, which attracts increasingly saline water (WSC source, 1993). Figure 5.6. illustrates this phenomenon.

In summary, the most saline sources are those boreholes along the southern coast which have been in operation the longest (ibid).

The MSLA in Gozo is also subject to seawater intrusion along the coast and excessive pumping from boreholes near the coast has resulted in the drawing in of saline water (Figure 5.6.) (WSC source, 1993).

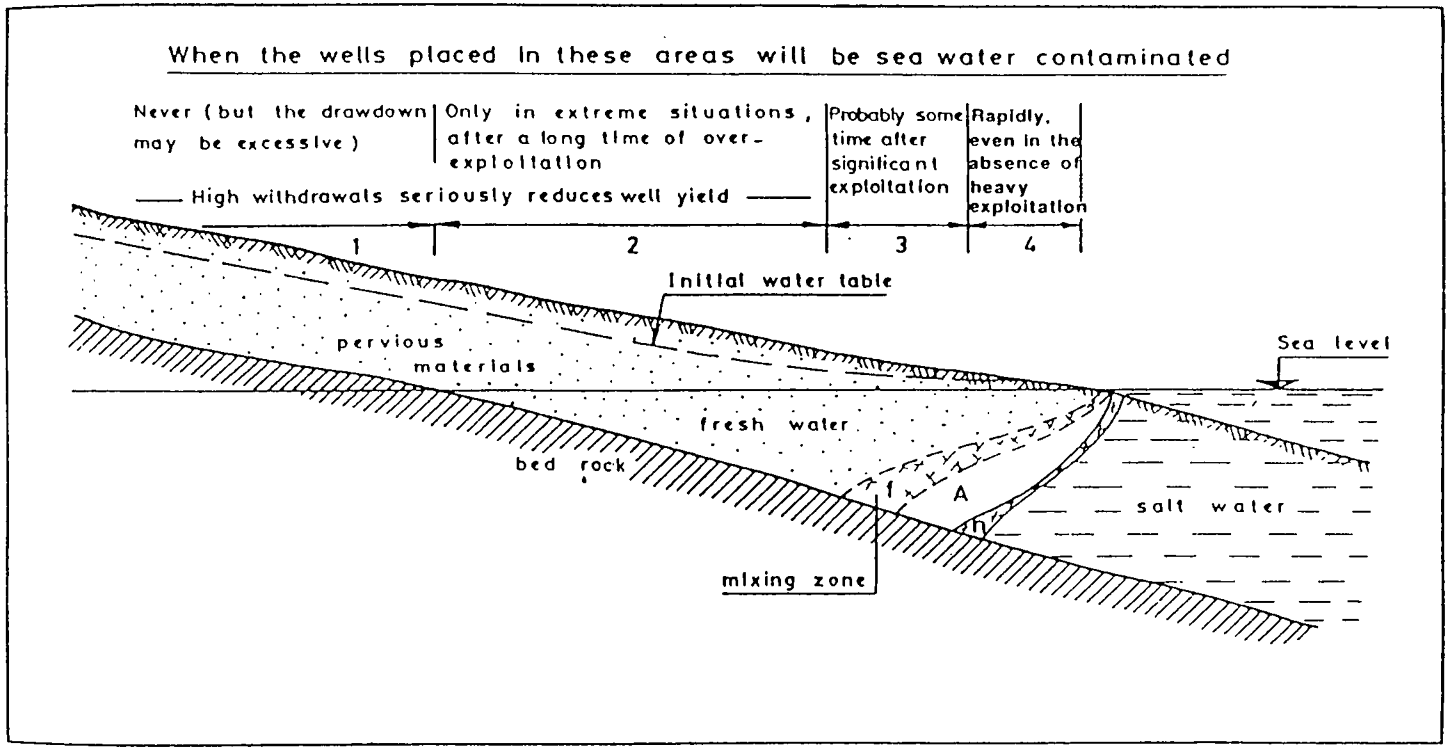


Figure 5.5. Degree of saltwater contamination to be expected in a coastal aquifer. Wells or boreholes placed in areas 3 and 4 can easily draw in sea or mixed water. 'A' represents the one-time reserve of freshwater, most of it removed during the movement of the transition zone from its natural position to the new equilibrium position 'f', in order to maintain the necessary freshwater flow to the sea over the saltwater body.
Source: Falkland and Custodio, 1991.

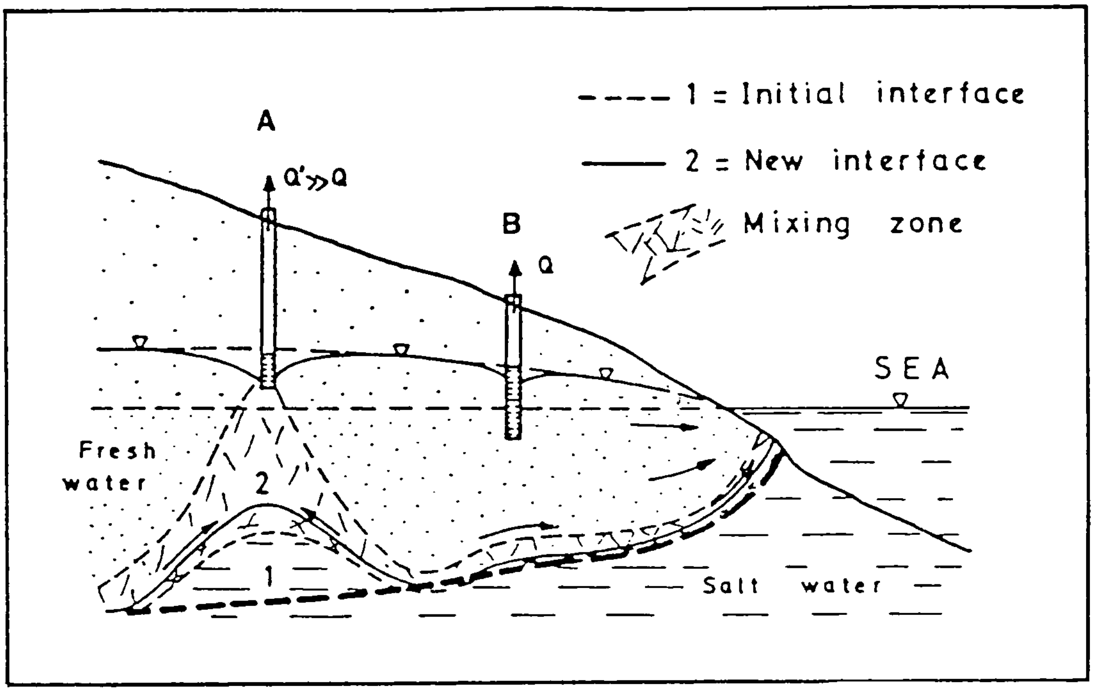


Figure 5.6. Upconing under groundwater extraction works. Well or borehole 'A' is not directly affected by saltwater since it does not reach sea level, but around it there is no net freshwater flow towards the coast; then, the transition zone expands and after some time some brackish water, less dense than seawater, can reach the well bottom. Well or borehole 'B', in spite of its penetration below sea level, is operated with a small water level drawdown and no long term impairment of the water quality appears when freshwater flow towards the sea is maintained below it. If 'A' and 'B' are on the same flow path, the expansion of the transition zone created by 'A' will propagate downstream and can affect 'B', especially when extraction is intermittent. Source: Falkland and Custodio, 1991.

5.4.1.1.1. Chloride levels in RO water

RO water salinity levels are relatively average when compared to WHO recommendations and relatively poor when compared to European requirements. This is because given that seawater is used, to obtain a product with a salinity of 50ppm would consume enormous amounts of energy. So the end product is approximately 180ppm to 300ppm which is under the WHO maximum permissable limit of 400ppm but above the Council for Europe Directive of 15/7/80, of 25ppm (Vella, 1993). For example, the Ghar Lapsi RO plant's product water has 380 chlorides ppm, Tigne, 280 chlorides ppm, and Marsa, 340 chlorides ppm (WSC unpublished data).

5.4.1.1.2. Chloride levels in groundwater (MSLA)

The size and shape of Malta has meant that seawater intrusion has become a serious problem. It is small and with a relatively long coastal perimeter (Riolo *et al*, 1993). However, of greater concern is the fact that over-extraction has rendered the MSLA saline for many years to come.

Morris warned as long ago as 1952, as a conclusion to his report on the water supply of Malta, that:

"As a result of grossly exaggerated misconceptions of its potentialities, the Mean Sea Level Table has been mistakenly allowed to become the Island's main source of public water supplies, and the problem of providing adequate storage facilities has been evaded. This water table is being strongly over-pumped by Government water supply stations, and by numerous works for private extraction. The salinity of supplies drawn from it has risen practically continuously since 1910, and if the present rate of deterioration is permitted to continue, the limit of potability will be reached in a few years time." (Morris, 1952, p.121).

His warning was not heeded, particularly during the 1970's when groundwater extraction suddenly increased in all sectors. The water table has reached the stage of being 40 per cent over-exploited (Food and Agriculture Organisation of the United Nations, 1992; *The Malta Independent*, 8/5/94, p.3).

"Moreover the apparent slight increase in quantity pumped between 1986 and 1992 must hide a more serious situation as it does not include the amounts extracted by industry from private (illegal?) boreholes." (*The Sunday Times*, 12/9/94, p.16).

The same applies for agricultural and other private boreholes, many of which are illegal (pp.443-445).

Over-extraction has resulted in an average chloride concentration (from 6 of the major pumping stations) for the MSLA of 1,318 chlorides ppm, more than twice the WHO recommended threshold of 600 ppm. Some pumping stations have produced water of a salinity up to six times over this recommended level (Briguglio, 1994).

Table 5.2. and Figure 5.7. show that the average annual salinity of groundwater from the six major pumping stations in Malta has increased from 803 chlorides ppm in 1974 (which was already higher than the WHO threshold) to 1318 chlorides ppm in 1993 (ibid).

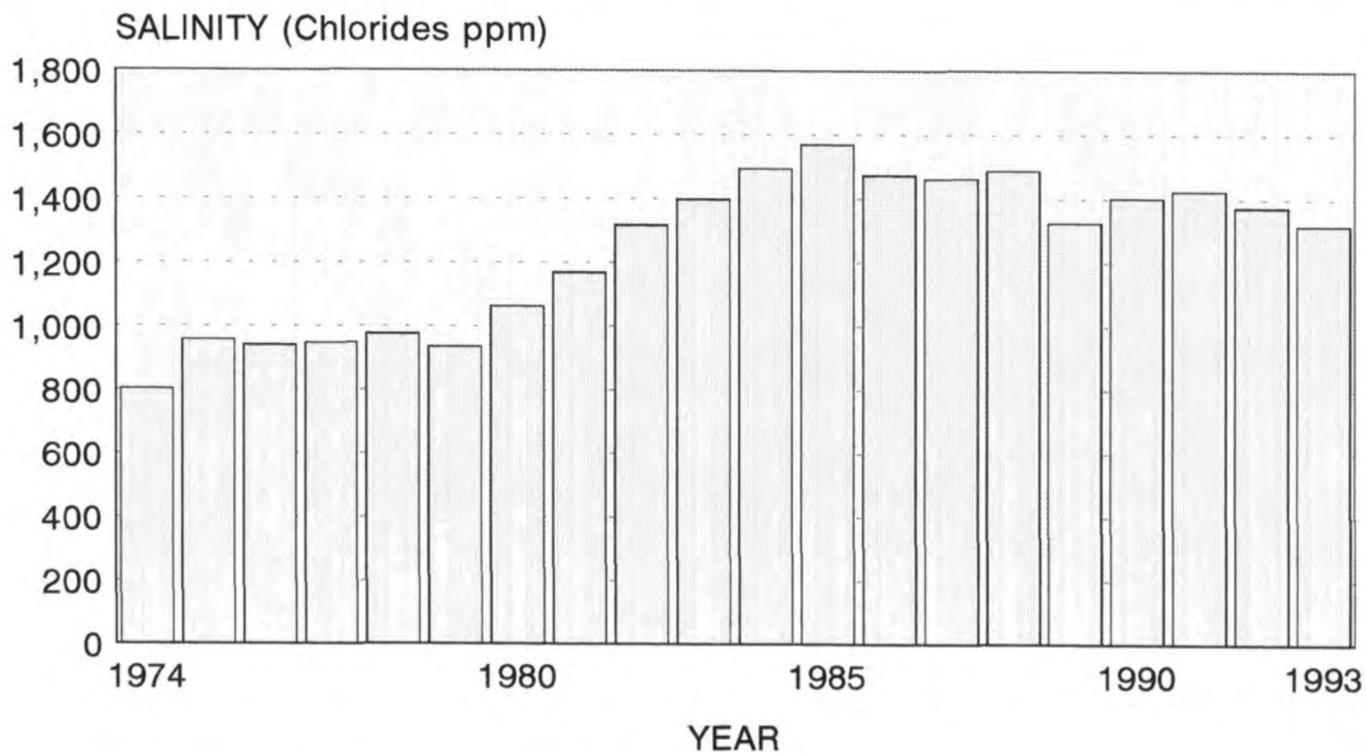
Salinity of the MSLA varies geographically. As already stated, groundwater is more saline in the south. However, salinity also varies seasonally. Water extracted from the MSLA tends to be more saline during the summer months due to greater extraction rates to meet increased demands and also due to very little aquifer recharge. Table 5.3. and Figure 5.8. illustrate the variation which is particularly notable for two of the largest pumping

Table 5.2. Average annual salinity of groundwater from six major pumping stations in Malta

Year	Salinity (Chlorides ppm)
1974	803
1975	958
1976	941
1977	948
1978	977
1979	936
1980	1063
1981	1169
1982	1317
1983	1399
1984	1495
1985	1570
1986	1474
1987	1463
1988	1489
1989	1326
1990	1403
1991	1425
1992	1375
1993	1318

Source: Briguglio, 1994.

Figure 5.7. Average annual salinity of groundwater from six major pumping stations in Malta



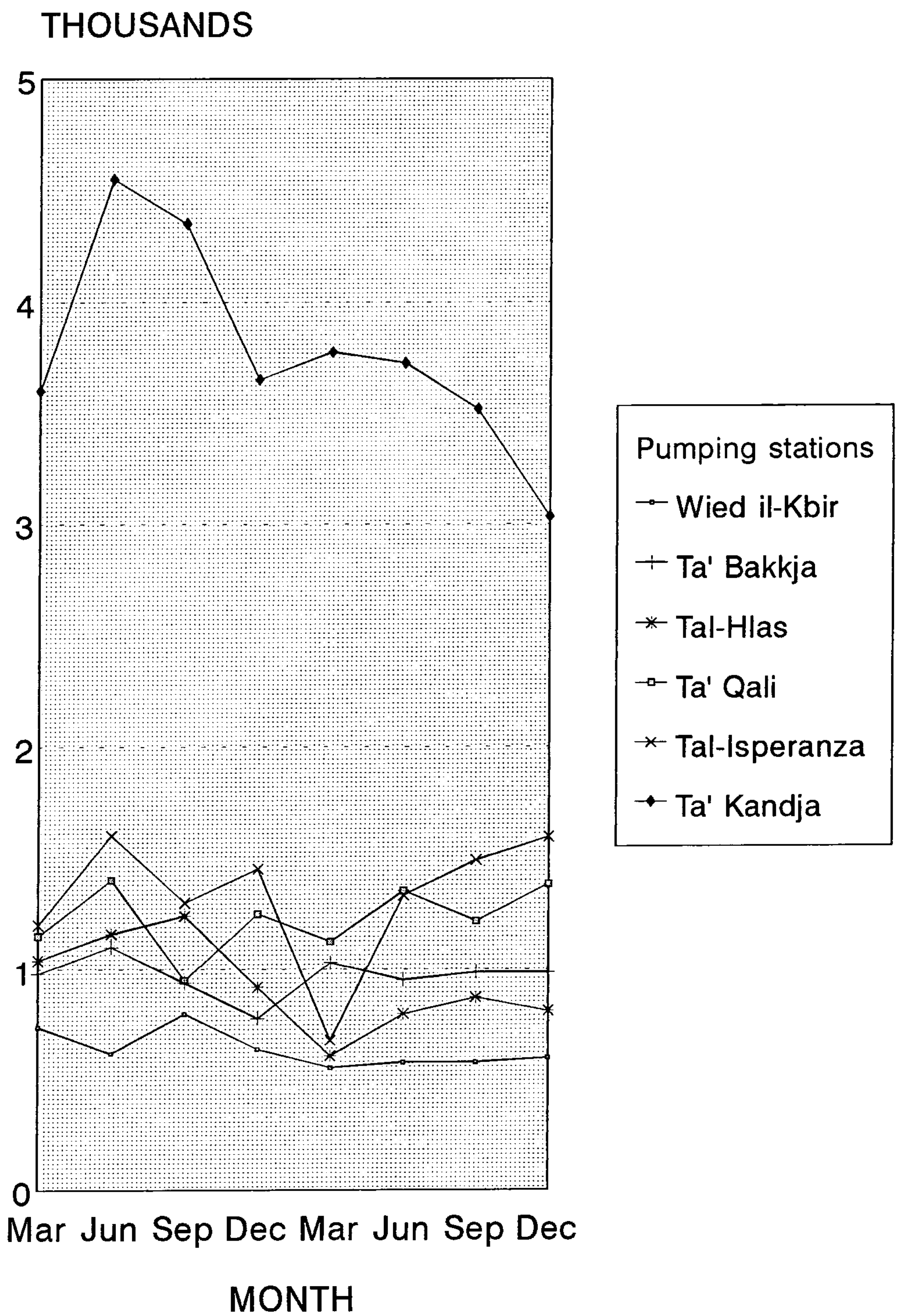
Source: Briguglio, 1994.

Table 5.3. Seasonal variation in groundwater salinity (Chlorides ppm) at six major pumping stations
in Malta from March 1991 to December 1992

MONTH	Wied il-Kbir	Ta' Bakkja	Tal-Hlas	Ta' Qali	Tal-Isperanza	Ta' Kandja
Mar	740	980	1040	1150	1200	3600
Jun	620	1100	1160	1400	1600	4550
Sep	800	940	1240	950	1300	4350
Dec	640	780	920	1250	1450	3650
Mar	555	1030	610	1125	680	3775
Jun	580	953	800	1353	1333	3725
Sep	580	987	873	1217	1490	3517
Dec	600	987	813	1383	1593	3033

Source: Central Office of Statistics - Malta, 1993; Durham University Department of Geography, 1995.

Figure 5.8. Seasonal variation in groundwater salinity (Chlorides ppm)
at six major pumping stations in Malta from March 1991 to December 1992



Source: Central Office of Statistics - Malta, 1993; Durham University Department of Geography, 1995.

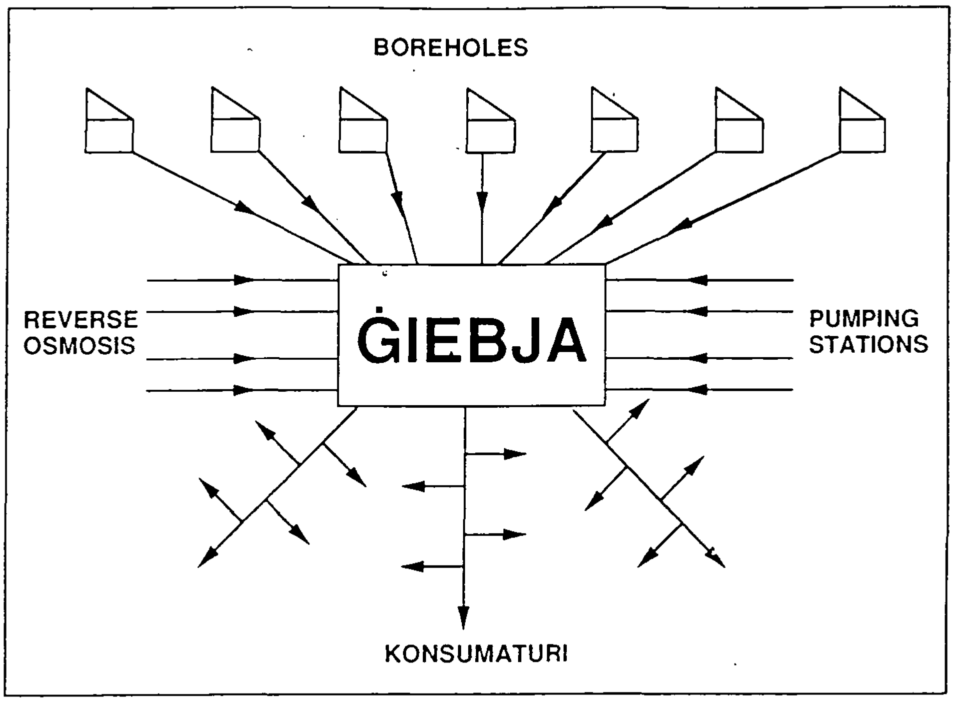


Figure 5.9. The ideal principle of water distribution from sources to consumers in Malta: via reservoirs (Ġiebja) for blending.
Source: Vella, 1993.

stations, Ta' Kandja and Ta' Qali, which also have high overall salinity levels due to the large amount of water they extract.

A safe extraction level has been estimated to be 11.5 million m^3 per annum. Since present extraction rates of almost 20 million m^3 per annum are unsustainable, the aquifer has been temporarily exhausted in terms of quantity and quality. Further extraction will greatly hinder the aquifer's ability to recover (Briguglio, 1994).

In addition, there has been some evidence that the perched aquifer, generally considered to be generally isolated from saline intrusions because of the Blue Clay layer, is also becoming increasingly saline. Zammit stated as long ago as 1979 that:

"There has been an increase in the Perched Aquifer from 170 to 230 mg/l,cl [ppm] due to irrigation with saline water." (Zammit, 1979, p.47).

5.4.1.1.3. <u>The distribution of water quality and inequity</u>

Figure 5.9. illustrates the ideal principles of the public water distribution system. All the water produced, from RO plants and boreholes, should be collected in reservoirs and blended before being distributed.

In practice this is not the case since settlements in the north receive most of the RO water, while southern settlements receive most of the groundwater that is extracted.

The WSC are aware that this is a problem. Its Chief Executive, Antoine Riolo (*et al*, 1993) states:

"This combination of production sources has led to water quality varying from aggressive to passive from locality to locality." (Riolo *et al*, 1993, p.22).

The distribution map (Figure 3.24. (p.245)) and flow diagram (Figure 3.27. (p.249)) help to illustrate the following:

Generally, the north has, on average, chloride levels of approximately, 500 ppm. There are settlements in the north which may have some groundwater blended in their supply and hence can receive water with salinity levels of approximately 800 ppm (University source, 1993). For example, for some areas supplied by the Tigne RO plant, the RO water is first blended with groundwater at the Misrah Lewza reservoir near San Gwann. Usually the mix is relatively good, however it is up to the management at the reservoir to determine what blending ratios they use, which mostly depends on the amount of RO water and/or groundwater available. On one day an area may receive purely RO water and on another purely groundwater (University source, 1993). This example demonstrates how RO water/groundwater ratios in tap water can vary considerably from place to place and day to day.

Tap water quality in the south of Malta is generally poor relative to the north. A source at the University (1993) explained his personal experience of tap water quality: "The worst quality water is where I live around the Cottonera area. It tends to be very poor quality. I cope by using tap water for cooking and ironing and use bottled water to drink." This is because most of the south is supplied mostly or solely with very saline groundwater. In the worst cases:

"There are individual boreholes with very poor quality which in turn produce localised problems because of direct connections of the distribution system." (Riolo *et al*, 1993, p.22).

In particular, the southern coastal towns of Xghajra, Marsascala, Marsaxlokk and Birzebbuġa are, in practice, supposed to be supplied with a mixture of water from the RO plant at Ghar Lapsi (380ppm Cl) and the highly saline water from Ta' Kandja pumping station (from which chloride levels can reach 4,550ppm (Central Office of Statistics - Malta, 1993)). But since all four settlements are at the end of distribution lines, very little, if anything, of this poor blend reaches them and local boreholes are used to augment their supply (WSC source, 1993). Up until November 1993, even Kirkop, which is very near to the Qrendi reservoir, was supplied directly from the Kirkop borehole (*The Times*, 23/11/93, p.3).

"Some feed into the distribution storages, but by far most boreholes feed directly into the distribution system." (Riolo *et al*, 1993, p.19).

The salinity of tap water in the south makes it unpleasant to drink in many settlements. A WSC source (1993) described his experience: ".... [It] depends where you live. Where I live it used to be one of the better boreholes [supplying his settlement] in terms of taste and salt content. As time passes, it's becoming more saline but since I'm used to it, I've not noticed the change. But were I to go to Zurrieq I would not drink it because it's more saline even though it's mixed with Ghar Lapsi RO water." (ibid).

Consumption of saline water poses a health risk, especially for babies and people with high blood pressure (University source, 1993). Since the south consists mostly of lower income households, many cannot afford to buy bottled water. To quantify the problem and bring it to the attention of the authorities Dr. Alfred Vella, Senior Lecturer in chemistry at the University, conducted a study of tap water quality in the south of Malta (Vella, 1993).

In Table 5.4. are Dr. Vella's results for the chemical analyses on tap water for a number of urban

Table 5.4. Tap water quality parameters in five southern settlements in Malta

Parameter	Birzebbuga	Marsascala	Marsaxlokk	Zabbar	Zejtun
Conductivity	2.73	5.13	3.06	2.62	2.44
(mS/cm)	2.66	5.12	3.22	2.69	2.53
Chloride	1168	2374	1384	1179	1139
(ppm Cl)	1157	2432	1409	1232	1136
Sodium	610	1280	740	630	590
(ppm Na)	6107	1300	740	670	610
Potassium	30	50	30	30	23
(ppm K)	25	55	30	30	25
Iron	0.2	0.1	0.1	0.2	0.1
(ppm Fe)	0.3	0.2	0.3	2.0	0.1
Calcium	90	143	80	80	65
(ppm Ca)	105	135	85	85	85
Magnesium	88	147	96	80	65
(ppm Mg)	85	149	94	81	76
Nitrates	51	41	96	19	18
(ppm NO3)	51	56	94	23	18

Source: Vella, 1993.

Table 5.5. Guidelines and maximum permissable levels of tap water quality levels

Recommended in the European Community (European Union) directive 80/778 of 15th July 1980

Parameter	Guideline level	Maximum permissable concentration.
Conductivity (mS/cm)	0.400	*
Chloride (ppm Cl)	25	*
Sodium (ppm Na)	20	150
Potassium (ppm K)	10	12
Iron (ppm Fe)	0.05	0.2
Calcium (ppm Ca)	100	*
Magnesium (ppm Mg)	30	50
Nitrates (ppm NO3)	25	50

* No figure has been determined for these parameters.
Source: Vella, 1993.

areas in the south. The study quantified the salinity problem. A comparison of the results with the water quality parameters stipulated by the Council of Europe Directive 80/778 of 15/7/80, in Table 5.5., shows that tap water in the south of Malta should not be deemed potable given the level of chlorides and sodium present. Levels for both salts exceed the WHO and European permissable levels of 400ppm and 150ppm (University source, 1993), respectively. The exceptionally high levels for Wied il-Ghan (Marsascala) are attributed to the exceptionally high salinity levels of local boreholes used to supply the settlement (ibid).

In addition, certain samples contained brown sediment, suggesting the presence of rust (iron oxide) which on analysis placed the total iron (Fe) content of the samples towards maximum acceptable limits (ibid). This discolours the water, a major source of complaint (pp.528-540).

A University source (1993) told me, "Everyone can taste the salinity but people prefer not to quantify the problem.... I was hoping that someone in authority would take notice of.... [Dr. Vella's] report of the water condition in the south and do something about it.... [and] remove the inequity which is at the moment rampant."

5.4.1.2. Nitrogenous pollution from fertilisers

The leaching of agricultural fertilisers into the water table has caused the build up nitrate compounds in groundwater (University source, 1993):

"Fertilizer use in agriculture is in fact the greatest contributer of nitrates to the mean sea level aquifer [and the perched aquifer]. This is so because many farmers apply nitrogen containing fertilizers at higher rates than those recommended since they think that additional amounts of fertilizer, which may add little to the total costs of crop production, may be justified either in terms of extra yield or as an insurance policy against unfavourable growing conditions. In fact experiments show that although a relationship exists between the nitrogenous application to the soil and crop value, the curve passes through a maxima beyond which increasing the nitrogen application rate does not lead to an increase in crop value. Also.... fertilizer application should be related to the soil type, previous cropping and seasonal weathering conditions." (Zahra, 1991, p.71).

Being soluble in water, nitrates are easily leached into groundwater after winter rains. From Figure 5.10. it can be seen that the amount of nitrogenous fertilisers imported to Malta was on the increase since the late 1960's until the 1980's (even though agricultural land area was decreasing) (ibid), while,

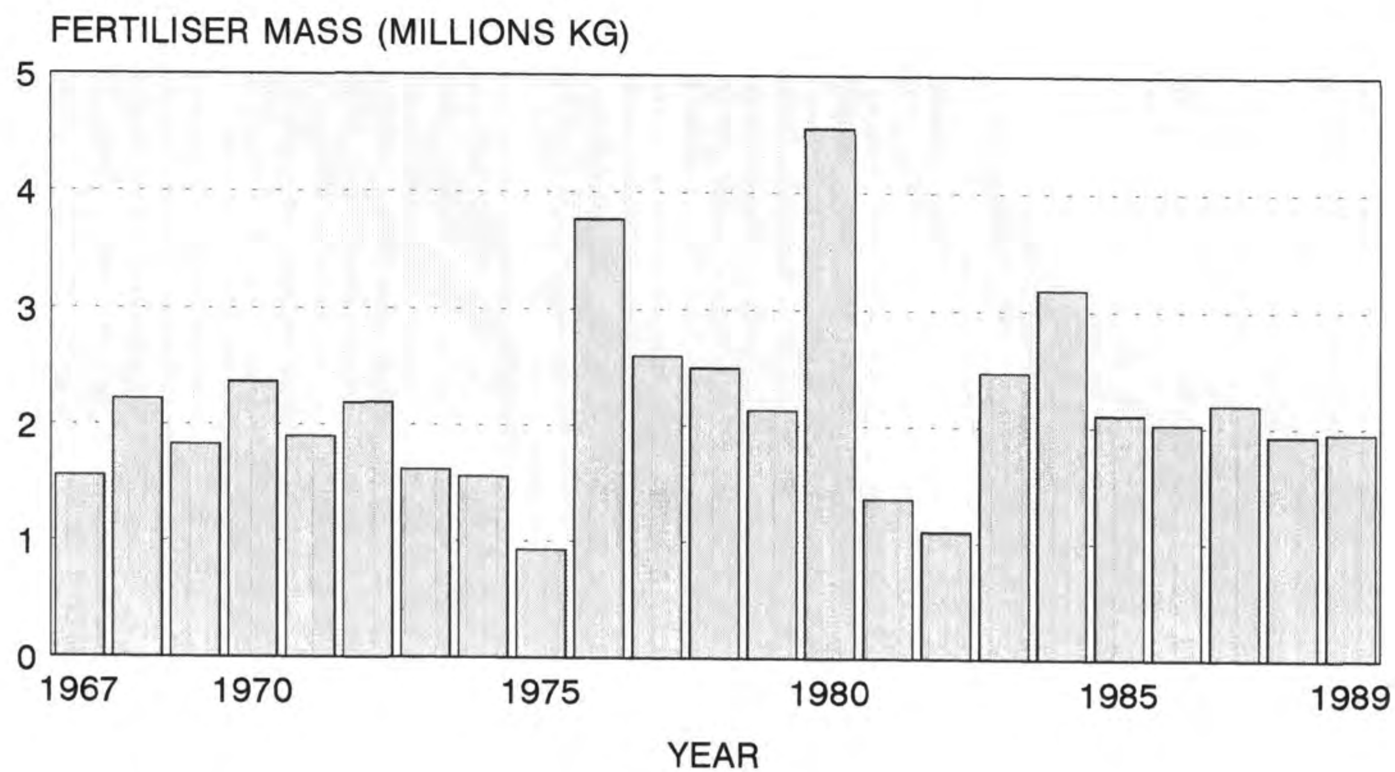
"Large amounts of fertilizer, i.e. superphosphates, ammonium sulphate etc. are each year imported to Malta, so far without any specific law concerning control and usage." (Ministry for the Environment, 1992, pp.9.18-9.19).

The only measure taken, to date, to protect groundwater is legislation preventing the construction of new farms and other polluting developments in the protected water catchment areas (Zahra, 1991). This has been considered ineffective (pp.412-414).

5.4.1.2.1. <u>Nitrate pollution of the perched aquifer</u>

Zahra (1991) has shown that approximately 45% of nitrate fertilisers, including manure, are not utilised

Figure 5.10. Amount of fertiliser imported, per annum, into Malta between 1967 and 1989



Source: Zahra, 1991.

by crops but leached into the groundwater table. He states,

"Water analysis of water coming from the perched aquifer reveals the presence of high contents of nitrates and this again is explained by the excessive use of fertilizers (ibid, p.65).

Nitrate levels of tap water derived from the perched aquifer can exceed 400ppm (University source, 1993). Given that the maximum allowable nitrate concentration for drinking water is 50ppm (Mallia and Vella, 1991), the use of perched aquifer water for potable supplies (WSC source, 1993) is worrying, given that there is evidence of a link (although tenuous) with methaemoglobinaemia (blue baby syndrome) and stomach cancer (ibid; Headworth, 1989; Zahra, 1991; Mallia and Vella, 1991).

Unlike the salinity problem, people are not aware of the nitrate levels in tap water. They can taste the level of chlorides but not the level of nitrates (WHO, 1992). A University source (1993) informed me that, "There is a need for educating the people. The responsibility lies with the authorities. The recipient needs to be aware of what he or she is exactly drinking - that's what equity is all about."

It is a problem that the WSC is fully aware of:

"The Perched aquifer is largely loaded with nitrate due to intensive irrigation, so that its water cannot be used for drinking." (Riolo *et al*, 1993, p.48)

Unfortunately it is used for drinking water, and nitrate levels in groundwater and tap water are geographically related (pp.382-392) so that only certain settlements are significantly affected (WSC sources, 1993; 1994; 1995; University source, 1993; WSC unpublished data).

5.4.1.2.2. Nitrate pollution of the MSLA

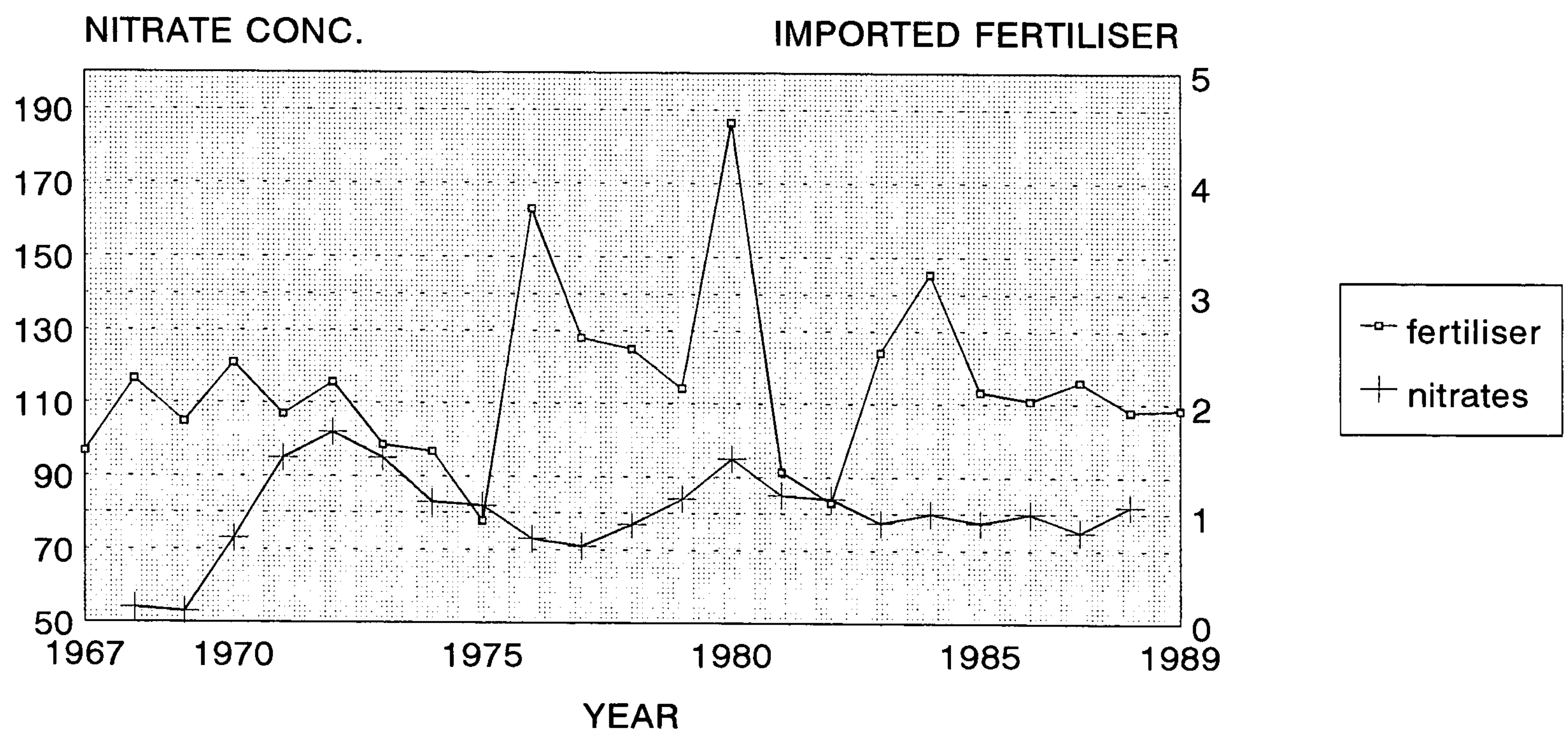
Recently, there has been an increase in the nitrate pollution of the MSLA. Correspondingly, the nitrate content of public water supplies derived from the MSLA has also increased, posing an ever greater health risk given that Malta (especially the south) relies heavily on this source for its tap water.

One University source (1993) stated that, "Since fertilisers have been used for a long time here, there is no reason why [nitrate] levels in the perched aquifer should be different to the MSLA. The response [infiltration] time is only quicker [for the perched aquifer]."

For example, during the early 1980's Malta received a free shipment of fertiliser from North Korea. It was given free to farmers who used it very liberally and two to three years later the MSLA's nitrate levels showed a large increase. Figure 5.11. illustrates this relationship and the two to three year lag time between fertiliser importation/application, and MSLA pollution is evident (Zahra, 1991; Magro, unpublished essay).

University sources (1993) informed me that, as a result of their studies, they had found that, "The southern areas had an interesting situation in that the boreholes in the vicinity of the SASTP were reporting 180 ppm. But its not been reported publicly.... this is because of 10 years of SASTP irrigation water, high in nitrates and phosphates, seeping into the MSLA," as well as the excessive use of fertilisers in the area. Most farmers do not realise that the pollutants, nitrogen, phosphorus, potassium and organic matter in the irrigation effluent serve as nutrients (Pescod, 1992).

Figure 5.11. Correlation between imported fertiliser (million kg) and nitrate concentrations (ppm)
in groundwater (MSLA) for the period 1967 to 1989



Derived from Zahra, 1991.

"The fertilizing value of sewage effluent and consequently the required amount of additional fertilizer is difficult to establish.... The amount of nitrogen and potassium will probably be sufficient for most irrigated plants." (Zammit, 1979, p.59).

The Food and Agricultural Organisation (FAO) states:

"Wastewater irrigation potentially may supply all of the N and most of the P and K required by many crops, as well as important micronutrients." (Food and Agricultural Organization Regional Office for the Near East, 1991).

Zahra (1991) also states that the nutrients in the effluent are most probably sufficient for crop growth. Given the nitrate content of the SASTP irrigation effluent (28ppm (Table 5.11.)) and that it is used liberally and lavishly by those farmers that have access to it, they do not need to use as much fertiliser as they presently do. Sources at the SASTP (1995) confirmed that, "Farmers do in some cases apply too much fertiliser as well as pesticides and other agro-chemicals."

A University source (1993) informed me that the SASTP irrigation project was located over a coastal aquifer that is, apparently, independent of the MSLA (knowledge of this aquifer's existence is apparently uncommon and reflects the degree to which the Islands' hydrogeology is still not fully understood). It was not used for potable supplies and it was intended that it never would be since the recycled irrigation effluent would render it polluted. Zammit (1979) confirms this:

"The coastal area near Zabbar, Marsaskala [*sic*] and Zejtun was selected as being most suitable for irrigation with reclaimed effluent since there are no extraction facilities there." (Zammit, 1979, p.56).

However, a few years after the plant became operational water shortages in nearby Marsascala, Xghajra, Zabbar and Cottonera were being relieved with water from this aquifer (University source, 1993).

A WSC source (1994) denied the existence of this aquifer, when queried why water from it had been used. However, its existence has been confirmed by Paul Micallef, Head of the WSC's Water Re-use Section:

"This is the aquifer in the vicinity of SASTP and lies outside the Groundwater Protected Zone." (Micallef, 1994, p.40)

Furthermore, the analyses of nitrates and chlorides in tap water, above and below, confirms that nearby towns supplied from boreholes (registering nitrate levels of 130 to 250ppm according to a University source (1993) and Zahra) show high levels of nitrates, as well as chlorides.

This problem has been highlighted by Zahra:

"Boreholes in the vicinity of the Sant Antnin treatment Plant... reveal high levels of nitrates which exceed 100mg/l [ppm]. The nitrate content of groundwater is not only high under this irrigated area but also over most parts of the island where it usually exceeds 50mg/l [ppm], the norm established for drinking water" (Zahra, 1991, p.43).

Micallef found that:

"Agricultural wastes associated with nitrates, phosphates and pesticides affect to a certain amount the [SASTP irrigation] effluent.... excessive spreading of these may be associated to pollution." (Micallef, 1994, p.28).

The irony is that the presence of nitrates and other compounds in the irrigation effluent is a result of agricultural activities originally. In turn, this pollutes the groundwater, which is extracted for potable supplies and enters the sewers to be recycled for agricultural use. Once more, it enters the water table, with additional leachate from fertilisers, which is again extracted for tap water, etc. A vicious cycle of ever-increasing pollution that should never have been allowed to occur.

5.4.1.2.3. The geography of nitrates in groundwater in Malta

In Table 5.6. is Zahra's list of nitrate levels in groundwater extracted from borehole and pumping stations in Malta. Figure 5.12. shows the location of some of these boreholes and pumping stations (the numbers on the map correspond to the borehole or pumping station name in Table 5.6.). It can be seen that many of the boreholes in the central region and the south have nitrate concentrations above 50ppm. The Dingli road pumping station has the highest value of 203.3ppm.

From this information, Figure 5.13. has been derived (by Zahra) to show areas of high nitrate concentrations in groundwater. Areas 'A' and 'B', in the central-west and south-east, respectively, are the most significant with nitrate concentrations of up to 140ppm. Zahra eliminated leaks from the sewage network (pp.400-401) as a major cause since the location of sewage networks only coincides partly with area 'B' and only slightly with 'A', and the three small areas of concentration to the south are mostly rural (ibid).

Areas 'A' and 'B' have a high level of agricultural activity. Area 'A' is close to major *widien* used by farmers and area 'B' corresponds strongly with the agricultural activity around the SASTP.

Table 5.6. Production and nitrate levels in groundwater sources in Malta for the period May 1988-April 1989 (Zahra, 1991).

Borehole name	Prod/annum m^3	Mean NO_3 ppm
1. Balal	246280.2	51.8
2. Barrada	31861.7	40.3
3. Bettina	121194.0	67.8
4. Bir ix-Xaghra	67130.6	61.6
5. Bomb Dump I	111632.7	40.3
6. Bomb Dump II	18457.2	28.8
7. Brija I	64417.0	47.4
8. Brija II	33905.6	32.3
9. Burset	45115.0	126.3
10. Campra	61710.1	63.4
11. Cawla	52040.2	74.0
12. Chadwick Lakes	27813.3	41.2
13. Dawl	64801.8	43.9
14. Dolf	93351.6	62.5
15. Farzina	130545.2	79.3
16. Fawwara	33961.7	21.7
17. Fiddien	45317.1	31.5
18. Fieres	32143.5	108.5
19. Froxx	102975.9	66.0
20. Fulija	64946.5	81.1
21. Garibaldi	41275.8	66.0
22. Gebel Xijn	50676.6	58.0
23. Germun	38163.9	29.7
24. Ghagusa	81492.5	91.7
25. Ghaqba	129249.2	65.1
26. Ghar Hanzir	40842.6	66.0
27. Gharghur I	61883.4	90.8
28. Gharghur II	-------	90.8
29. Ghaxaq reservoir	183618.3	113.0
30. Giebja	41522.7	49.2
31. Girghenti	34422.9	23.5
32. Gnien	35893.0	30.6
33. Habel Bello	10949.4	65.1
34. Hal-Far reservoir	14257.6	50.1
35. Hal-Far Road	30320.5	40.3
36. Hal-Mann	48880.3	69.6
37. Hal-Tmiem	78294.8	139.5
38. Handaq I	53595.9	54.5
39. Handaq II	40751.8	86.4
40. Harruba	55235.8	75.8
41. Has-Saptar	50635.3	37.7
42. Hemsija	-------	----
43. Hlantum	42880.4	48.3
44. Hofor	115405.6	69.6
45. Hofra I	-------	----
46. Hofra II	22524.0	62.5
47. Iklin I	10723.5	81.1
48. Iklin II	123185.8	91.7
49. Kapella	30822.3	28.8
50. Kirkop I	42722.5	40.3
51. Kirkop III	63421.1	70.4
52. Lewza	98416.1	55.4
53. Loretu	22173.0	55.4

Borehole/pumping st. name	Prod/annum m^3	Mean NO_3 ppm
54. Luqa dump	53168.5	55.4
55. Luqa II (Tamla)	116817.7	43.0
56. Luqa reservoir	86910.8	15.5
57. Macedonia	9365.1	22.6
58. Madliena	--------	21.9
59. Mdina Road	58724.6	92.6
60. Mejdia	14782.2	51.8
61. Mentna	137034.6	108.5
62. Mgieret	44502.2	44.7
63. Misrah Lewza	151224.8	83.7
64. Naxxar reservoir	206086.8	76.6
65. Paci	69653.5	28.8
66. Propostu	42409.6	49.2
67. Qali II	69472.9	53.6
68. Qattara	47257.2	36.8
69. Qattus	80298.6	66.9
70. Raddiena	42554.2	82.0
71. Saltar	89243.9	85.5
72. Salib	30451.8	90.8
73. Salvun	66973.9	35.9
74. San Blas	96749.5	36.8
75. San Gakbu	137243.4	50.9
76. San Klement	97364.8	113.9
77. San Niklaw	108097.2	51.8
78. Shinas	109201.7	52.7
79. Srina	109112.9	101.5
80. Sta. Agatha	64408.3	70.4
81. Tech. Institute	67492.0	54.5
82. Tellerit	65166.9	44.7
83. Torba	58146.4	57.1
84. Vnezja	45487.3	45.6
85. Wied Betti	49123.9	60.7
86. Wied Bordi	53703.5	38.5
87. Wied il-Qliegha I	6993.1	50.9
88. Wied Qirda	48947.3	72.2
89. Wied Qoton	99655.0	36.8
90. Wied Xkora	91920.7	109.4
91. Wied Zikku	47238.6	35.0
92. Xatba l-Hamra	-------	----
93. Xlejli	99326.6	149.3
94. Xwieki	66995.8	50.9
95. Zabbar road	35097.4	137.8
96. Zaruna	42220.7	118.3
97. Zurrieq road	45145.1	46.5
98. Bakkja pumping st.	2235956.9	66.9
99. Bingemma pumping st.	314946.9	70.4
100. Dingli Road pumping st.	36254.4	203.3
101. Falka puming st.	37363.6	57.1
102. Hlas pumping st.	1368659.0	134.2
103. Kandja pumping st.	2069311.9	43.9
104. Mgarr pumping st.	156436.4	36.8
105. Mizieb pumping st.	306181.0	158.2
106. Qali pumping st.	1354084.1	78.4
107. Speranza pumping st.	1639669.1	69.6
108. Wied il-Ghasel pumping st.	514043.5	87.3
109. Wied il-Kbir pumping st.	774461.1	54.5

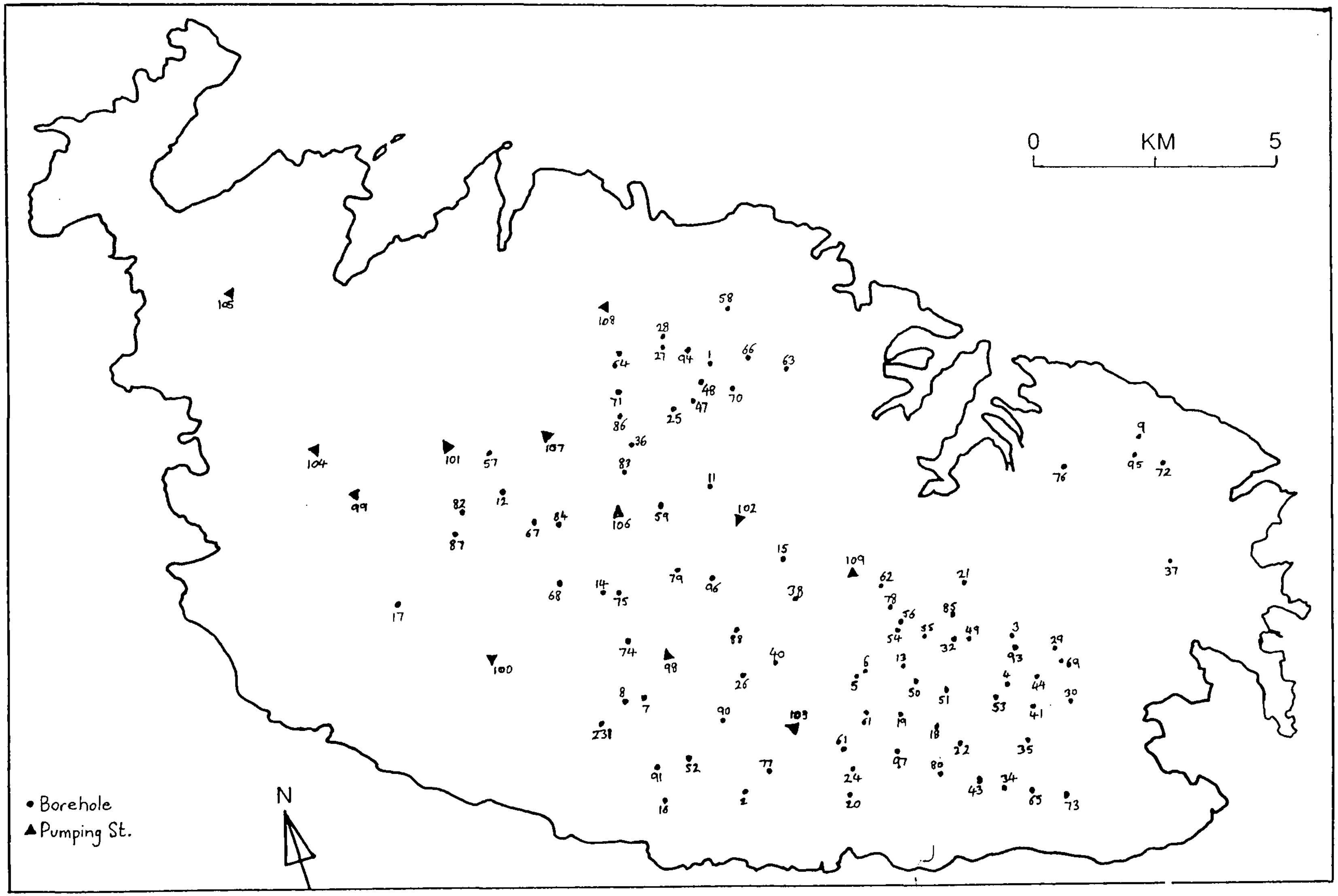


Figure 5.11. Nitrate concentrations (ppm) from some active boreholes and pumping stations in Malta. Numbers refer to boreholes/pumping sts. listed in Table 5.6. Derived from Zahra, 1991.

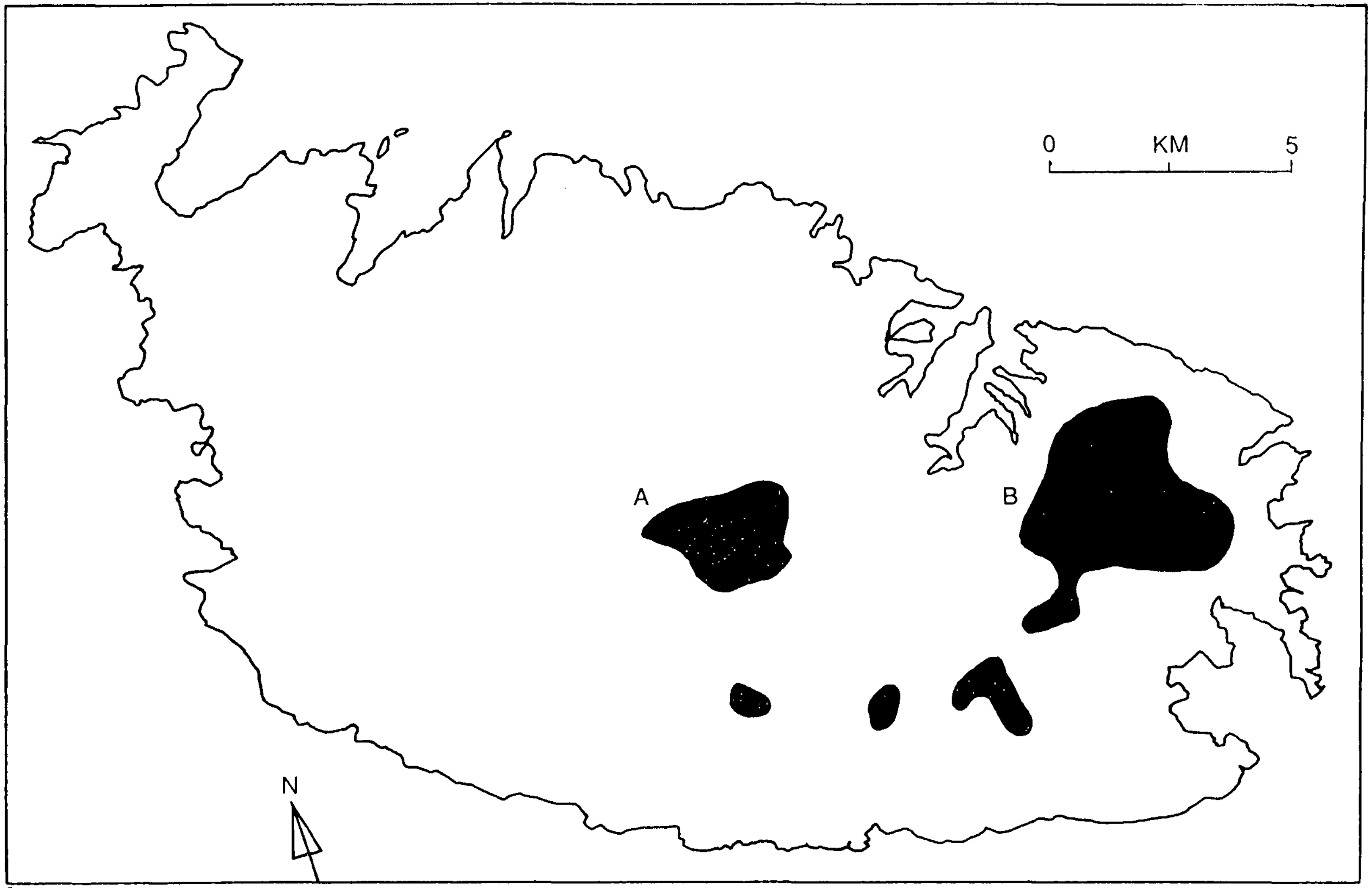


Figure 5.12. Areas (shaded) of high nitrate concentrations in groundwater.
Source: Zahra, 1991.

"This southerly irrigated area consists of an area of about 30km2 and boreholes in the vicinity of Zabbar and Zejtun show very high nitrate concentrations.... and this is surely being caused by fertilizer and manure application in the area [in addition to the nitrates in the irrigation effluent]." (Zahra, 1991, pp.64-65).

This spatial variation has a close relationship with the spatial variation of nitrates in tap water.

5.4.1.2.4. The geography and variation of nitrates in tap water

A study conducted by Mallia and Vella (1991) to determine nitrate concentrations in tap water found that quality varied for consumers across the Islands. Tables 5.7. and 5.8. show their results for Malta and Gozo, respectively. Central settlements like Attard and Rabat have very high nitrate levels in tap water, as do some southern settlements, like Marsascala and Zabbar.

Nitrates are almost non-existent in RO water, hence the concentration of nitrates in tap water can be attributed to two factors:

1. The nitrate content of groundwater from particular MSLA boreholes and pumping stations. As discussed above, this can vary from 20ppm to 200ppm (Zahra, 1991), while values over 400ppm have been recorded for the perched aquifer (University source, 1993).

2. The mixing ratio of RO water to groundwater in the blend supplied to consumers (Mallia and Vella, 1991).

Mallia and Vella compiled their results to group settlements into four colour coded categories, which they call 'zones', depending on the nitrate levels in their

Table 5.7. Nitrate concentration (ppm) in tap water for Malta during 1991

Locality/Sampling session*	1	2	3	4	5
Attard (centre)	75	60	67		
Attard (St. Catherine)		127			
Balzan	65		55		
Cospicua					38
St. Lucia	27		22		
Valletta	2				
G'Mangia	0.5			nd#	
Sliema	0.4		nd#		
Misrah Kola		72			
Zabbar	54	95			42
Zurrieq	20		24		
Tarxien	38			28	
Xemxija	39		65		
Rabat	110	106	135		
Msida		69			10
Siggiewi		100	99		
Lija		121	118		
Kappara			4		5
Zejtun			33		39
Mellieha					65
Marsascala					64
St. Paul's Bay					0.5

* Sampling session dates: 1: 12/7/91; 2: 24/7/91; 3: 27/8/91; 4: 26/9/91; 5: 4/10/91.
# nd = not detected.
Source: Mallia and Vella, 1991.

Table 5.8. Nitrate concentration (ppm) in tap water for Gozo during 1991

Locality/Sampling session*	3	4
Victoria	72	
Qala		88
Mgarr ix-Xini		103
Dwejra		55
Dahlet Qorrot		46
Sannat		60

* Sampling session dates: 3: 27/8/91; 4: 26/9/91.
Source: Mallia and Vella, 1991.

Table 5.9. Nitrate concentration (ppm) in tap water by zone
in Malta and Gozo during 1991

Nitrate range (ppm)	Descripter	Locality
> 65	Red zone	Attard, Rabat, Siggiewi, Lija, Misrah Kola, Siggiewi, Victoria, Qala, Mgarr ix-Xini.
46 - 65	Orange zone	Balzan, Xemxija, Mellieha, Zabbar, Marsascala, Dwejra, Dahlet Qorrot, Sannat,
11 - 45	Green zone	Cospicua, Zurrieq, Zejtun, Tarxien, St. Lucia.
0 - 10	Blue zone	Sliema, Valletta, Kappara, Guardamangia, St. Paul's Bay.

Source: Mallia and Vella, 1991.

tap waters. Table 5.9. shows their classification of settlements into different coloured zones.

It can be seen that some areas in Malta and Gozo are being supplied solely or predominantly from groundwater sources high in nitrates (red zone). These include Attard, Rabat, Siggiewi and Lija in Malta, and Rabat (Victoria) and Qala in Gozo. Previous discussion, WSC, University and *Moviment ghall-Ambjent* sources (1993; 1994; 1995) and Figures 3.24. (p.245) and 3.27. (p.249) confirm that this is because local, nitrate rich water from perched aquifer boreholes, pumping stations and springs is used to supply these settlements (especially since RO water from Cirkewwa and Pembroke only reaches the central reservoirs in insignificant amounts, if ever, once northern settlements have been supplied). Siggiewi is supplied solely by springs (Figure 3.27.).

The Orange zone areas like Balzan, Zabbar, Xemxija, Marsascala and Sannat are either receiving a poor mix of RO/groundwater water or have a groundwater content very high in nitrates, or both. From previous discussion and Zahra's analysis, it can be concluded that it is both, since some southern settlements receive groundwater only.

A comparison with Zahra's map of nitrate concentrations in groundwater (Figure 5.12.) shows that red and orange zone settlements correspond significantly with the two main ('A' and 'B') areas of high nitrate concentrations in groundwater. The very high nitrate levels in some of the outlying boreholes and pumping stations in Figure 5.11. are reflected in the tap water of nearby settlements that they supply. For example, Dingli road pumping station (203.3ppm) and Siggiewi (100ppm), and Mizieb pumping station (158.2ppm) and Mellieha (65ppm).

The green zone areas like Zurrieq, Zejtun and Tarxien appear to receive a,

".... properly adjusted RO-ground water blend"

(Mallia and Vella, 1991, p.6).

This is confirmed by previous discussion (pp.246-252).

At the other end of the scale, the low nitrate Blue zone areas of Sliema, Valletta and Guardamangia can be accounted for by the RO water they mostly receive.

In Gozo, since tap water is almost completely derived from groundwater, the high level of nitrates in tap water of Rabat, Qala and Mgarr ix-Xini is due to the intensive agricultural activity around these settlements. In comparison, Dwejra and Dahlet Qorrot have relatively less agricultural activity which explains the lower nitrate levels in their tap water.

Although Mellieha may appear to be anomolous, Figure 3.27. shows that it is supplied by perched aquifer springs and pumping stations (very nitrate rich) and RO water (nitrate free) from Cirkewwa, which would account for the compromise in Mellieha's tap water quality (a nitrate concentration of 65ppm) between these two extremes. Naudi (1979) notes that,

"The most striking case of nitrate concentration was found near Mellieha in the water of the Tal-Madonna Gallery." (Naudi, 1979, p.47).

5.4.1.2.5. Nitrogenous pollution: outlook

This analysis has illustrated the inequity in water quality supplied across the Islands.

The future problem is that by 2010 all sewage will be treated and the recycled water will be used mostly for agricultural irrigation (pp.612-626). If precautions are not taken, nitrate concentrations in groundwater and tap water will increase. Increases in crop yield and variety, that the effluent will allow, are likely to be accompanied by increased fertiliser use.

Furthermore, no quantifiable analysis has ever been made of the effect of the SASTP water on groundwater, yet it has been operating for more than ten years (University source, 1995).

The WSC had yet to perform this task and Micallef maintains that,

"One of the drawbacks to using sewage in agriculture is that it may raise the nitrate level of the groundwater and the geology of the Maltese islands being of karst nature and therefore rich in secondary permeability, allows easy leaching of contaminant into the aquifer." (Micallef, 1994, p.35).

Fertiliser use is likely to increase in the short term, particularly with the provision of recycled compost from the composting plant, which was introduced as a pilot project at the SASTP site in 1992. The plant is now providing compost for farmers served by the SASTP. Short and Tricker state that,

"It is worth noting that official advice, given at the time of the interview survey, was that recycled compost would become available free or at a nominal cost." (Short and Tricker, 1994, p.215).

They found that all farmers were keen to implement the use of the recycled compost, which, unfortunately, is likely to increase pollution levels in groundwater.

5.4.1.3. Other sources of groundwater pollution

Other potential threats to water quality include sources of bacteria, heavy metals, hydrocarbons and other harmful substances, both from agricultural and non-agricultural sources, and sources of nitrates other than those from fertilisers and recycled irrigation effluent (Packham, 1990; Zahra, 1991).

They represent a serious health hazard when in the vicinity of pumping stations and boreholes, as they often are, since so called groundwater protection zones (pp.412-414) are not policed.

After heavy rainfall, such as those during the storm of spring 1994, the WSC often issues tap water quality warnings, via the media, instructing people in certain areas to boil their tap water before consumption, due to the leaching of pollution, usually agricultural and domestic waste near or at boreholes and pumping stations (*The Times*, 7/4/94, p.48; WSC source, 1994).

5.4.1.3.1. Agro-chemicals

Pesticides have been proved to have a polluting effect on groundwater (Malcolm, 1989). They are complex organic compounds and their contents includes heavy metals (arsenic, cadmium, mercury, copper and lead) (Zahra, 1991). The *Sewerage Master Plan for Malta and Gozo* (Ministry for the Environment, 1992) states that,

"Import data show that the amount of fungicides and pesticides have increased by 62% since 1983, an increase which may indicate incorrect usage of the compounds." (Ministry for the Environment, 1992, p.9.18).

Again, the main problems are a lack of awareness on the part of farmers and a lack of legislation controlling use:

"As most agricultural pesticides contain organophosphorus and pesticides, organotin compounds [*sic*], excessive spreading of these may be a pronounced source of pollution. Import of the most toxic substances is controlled by the pesticide importation criteria. However, the lack of testing facilities prevents serious control." (ibid, p.9.18).

Many farmers wrongly believe that the more pesticides are used, the better the crop. Some will go as far as to applying pesticides to the crop once it has been picked and put on to market trucks (DA source, 1993; SASTP source, 1993). One University source (1993) stated that there should be greater concern about the ingestion of such chemicals, be it through the water supply or crops, since they will have an adverse effect on the health of people. He said, "In Malta there is a total lack of information. People [the authorities] are more interested in hiding it [the truth about environmental pollution risks to health]. Breast cancer in Malta almost certainly has some environmental link. It's probably the highest in Europe." The quantities of these pollutants in groundwater are worrying:

"Pesticides such as DDT, Dieldrin, Malathion, Lindane, etc, are found to be present in surface water in concentrations between 10-80 mg/l [ppm]" (Zahra, 1991, p.37).

Without the education of farmers and control and testing faciltiies, this pollution will continue (Plate 5.11.). The problem is acknowledged by the WSC:

"Pesticides and herbicides have not been shown to be problems so far but are considered to be 'time-bombs'." (Riolo *et al*, 1993, p.7).

What is worrying is that,

"Little is known about the long-term toxicity of many of these chemicals." (Headworth, 1989, p.518).

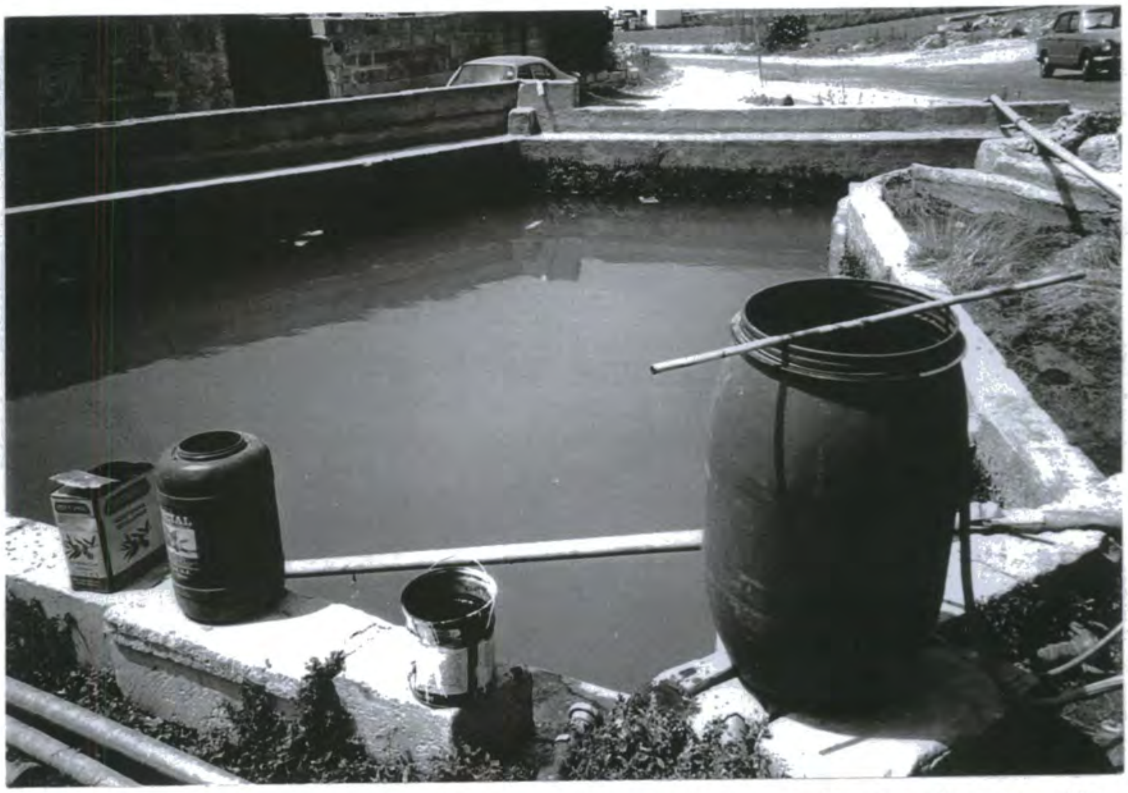


Plate 5.11. Agro-chemicals. These are often mixed with irrigation water with little or no measurement.

Plate 5.12. A disused quarry used as an illegal dump.

Further research needs to be undertaken into the threat these agro-chemicals pose to groundwater, particularly:

"Properties such as persistence, mobility, biodegradation, bioacummulation and toxicity need intensive investigation. The organochlorine group are exceptionally persistent in the environment, and the mobile organophosphorous are also a potential threat to groundwater systems.... Socio-economic disasters can occur as a result of the adverse effects of poor water management of the agro-hydrological systems caused by agricultural pollutants." (*The Times*, 14/10/94, p.17).

5.4.1.3.2. <u>Agricultural manure and sewage</u>

"Also needing regular monitoring are manure stockpiles which often cause leakages that are the source of bio-organic pollution of the groundwater system." (ibid, p.17).

A large pit is often dug to collect this waste. According to a source (1993) at the University, to save time and money on cleaning equipment, farmers will place explosives at the bottom of the pit and detonate them until the underlying ground cracks and the effluent seeps into the ground (and the water table). Other illegal practices include the filling of bowsers at night with effluent to be dumped into the public sewer system (ibid).

After domestic sources, the single most significant contributor of organic waste are piggeries, and there are several in Malta. Strong sewage is also discharged from dairies, abbatoirs, breweries, tanneries and dairy and poultry farms (Ministry for the Environment, 1992). According to sources from the environmental pressure group, *Moviment ghall-Ambjent* (1993), this waste is often illegaly dumped.

Furthermore, the illegal use of bacteria laden sewage water for irrigation is a common practice, especially in Gozo. Not only is this bad for the crop but also a typhoid hazard (pp.425-426).

On a wider scale, there have been concerns about the bacteriological pollution of groundwater from the use of treated sewage effluent in agriculture. To date no study has been undertaken in the SASTP area as to whether this is occurring. Zammit states that,

"The soil cover is not deep averaging around 1m and lies on fissured limestone. Malta lies on its own aquifer, so that irrigation with reclaimed water poses a danger of ground-water contamination, since this scanty cover cannot be relied upon for purification." (Zammit, 1979, pp.55-56).

Again, this problem will be of greater concern once all of Malta and Gozo's sewage is recycled.

5.4.1.3.3. <u>Domestic cesspits</u>

The sewerage system in Malta does not serve every household:

"The existing sewerage system on mainland Malta is broadly divided into two networks with a few villages and outlying areas not connected to the network: Bahrija, Bahar Ic-Caghaq, Madliena, San Pawl tat-Targa, Zebbiegh, and Ramla Taz-Zejtun (summer resort in St. Thomas Bay)." (Ministry for Development of Infrastructure, 1990b, p.3).

Households in areas which are not serviced by the system are usually located in remote rural areas, new built up areas or illegal settlements. These households discharge their sewage into septic tanks or cesspits. Septic tanks contain primary effluent (heavy particles have been removed) which is digested in the tank (Zahra, 1991). Cesspits, however, are buried chambers with porous walls, which may be connected to septic tanks, from which the effluent seeps into the ground. Zahra states that,

"Although there is no available data about the number of houses in Malta which use septic tank systems, in view of the huge housing development which took place during the last twenty years, it is assumed that this is a significant source of pollution (Zahra, 1991, pp.32-33).

These problems are created when new housing and settlements are built before the necessary infrastructure has been provided, especially when there is a delay in this provision. For example, in 1994 homes built on Government land in Ghargur were without a drainage system, water and electricity (*The Malta Independent*, 13/2/94, p.6).

In addition, a number of illegal settlements, mostly along the coast and consisting of small makeshift huts called 'boathouses' (used mainly as summer houses), are disposing their waste on to self-created dumps and into the sea. Examples of these boathouse settlements can be found at Gnejna Bay and Paradise Bay in Malta.

The pollution includes pathogen contamination, organic matter in suspended or dissolved form and nutrients from decaying organic compounds, such as phosphorus and nitrogen compounds, fats and detergents (Zahra, 1991).

"Some of the bacteria present in sewage that can cause disease include Salmonella (typhoid), Shigella (bacillary dysentry), Mycobacterium (tuberculosis), and

Vibrio (cholera). Pathogenic viruses include enteroviruses, reoviruses, adenoviruses, rotaviruses and hepatitis viruses" (ibid, p.33).

In addition, the leaching of sewage into the ground contributes to the nitrate and phosphate pollution of groundwater (ibid).

Although there has been no significant reporting of illnesses, the problem may be a hidden one where it is not possible to identify a link between the illness and its source or it is simply not reported (*The Malta Independent* 5/12/93, p.36; ibid).

As previously stated, the WSC from time to time has to cut water due to contamination of groundwater. Cesspits are often the cause of this. The following is a report of such an incident:

"Water cuts of a 'short' duration in several areas are being put into effect due to water sources having been contaminated by overflows of animal remains from cesspits, Water Corporation said yesterday. The overflows went into a valley which has galleries leading to Tal-Hlas pumping station and water production there had to be suspended" (*The Times*, 13/1/94, p.1)

Unfortunately, it is not possible to monitor for and detect every example of this type.

5.4.1.3.4. Unintentional sewage exfiltration from sewers

The *Malta Structure Plan* (Ministry for Development of Infrastructure, 1990b) states that one of the major problems with the drainage system in Malta is the,

"Exfiltration of sewage...." (ibid p.30).

This pollutes groundwater and poses health risks from the same bacteria and diseases associated with cesspits. The problem has also been acknowledged by Zahra (1991) and to date little has been done to remedy it.

Zammit cites a WHO study into this source of pollution:

"An intensive inspection of the sewers was carried out during the WHO study by television and conventional means. It was found that during periods of rain, the level of sewage rises in the unlined sewer manholes and galleries and diluted sewage seeps into the sub-strata through rock fissures and pervious walls, although the effect on the ground water table could not be ascertained." (Zammit, 1979, p.53).

Bugibba is an example where the problem is so acute that sewage spills over into the streets (*The Times*, 21/4/94, p.4; 24/5/94, p.22). While at Marsa, animal blood has been seen overspilling with the sewage (*The Malta Independent* 18/12/94, p.10). Again, the WSC has to often issue warnings through the media, for people to boil their tap water for fear of this contamination of local groundwater supplies.

"Ever-expanding urban construction and a far from perfect infrastructure, particularly in sewage disposal has had an effect on groundwater quality." (Riolo *et al*, 1993, p.7).

5.4.1.3.5. Pollution from reclaimed land

According to a source at the University (1993) the area called Mtahleb, in the west, is a problem area as far as groundwater quality is concerned. He stated that during the 1980's there was a land reclamation project conducted there and now the quality of springs is suspect. They are brown in colour with a noxious odour. The farmers in that area assume that some substance or waste that should not have been used for land reclamation is leaching out and affecting the whole water supply there. This source stated that they are not wrong:

Bare rock was reclaimed to make it fertile. First rocks and gravel were laid down and then fine sands to ensure drainage. Unfortunately, short cut measures were taken and refuse was simply dumped on top of this and then covered with soil (ibid).

At that time, land reclamation was under the jurisdiction of the military and the work was done by a group of agricultural corps, known as the *Izra' u Rabbi* (Sow and Rear) (Mizzi, 1993), formed in the late 1970's to help the economy. The help that was given by Italian technical experts provided good methods and the experience of previous land reclamation successes, but political technicalities caused these mixed results which are now having their toll on the water table (University source, 1993). Given that spring water is used to supply nearby settlements like Siggiewi, this may be a significant health hazard to consumers.

Even today the DA is undertaking land reclamation in an area very close to the Bahrija Valley, "But the people involved with this are not versed in soil technology and can't even distinguish between upper and lower soil. In the long run they do more harm than good." (ibid).

5.4.1.3.6. Illegal dumping

Illegal dumping is a widespread and common problem in Malta and although legislation exists to guard against such pratices, it is barely policed or enforced.

"At present there are two main legal tipping sites on mainland Malta, at Wied Fulija (Zurrieq) and Maghtab. In Gozo there is only one main tip in Ghajn Barrani. There are several illegal tipping sites." (Ministry for Development of Infrastructure, 1990b, p.9).

Even these legal tipping sites are polluting since they are not lined or covered and tipping at them is uncontrolled (*The Times*, 6/4/93, p.3). Figure 5.14. shows the location of waste dumps in Malta. It can be seen from the map that while official dumps are all located near the coast, outside groundwater protection zones (Figure 5.15.), many of the unofficial dumps are located within these zones and inside major water catchment areas.

With regard to illegal dumping:

"Unauthorised tipping sites, which together with quarries have become a peculiar characteristic of the islands, are a serious problems, causing pollution to the water table through infiltration...." (ibid, p.30).

The sites include:

In the northern region: Ic-Cumnija Ta' Pennellu (Mellieha); near the neolithic tomb at Xemxija.

In the central region: Between San Gwann and St. Julians.

In the southern region: Between Zabbar and Cospicua; betweeen Zejtun and Marsaxlokk; between Marsascala and Sant' Antnin; between Mosta and Naxxar. (Ministry for Development of Infrastructure, 1991b, p.73).

Illegal dumps have also been sited at Marfa Ridge, St. Thomas's Bay, the historic site of Verdala (*The Malta Independent*, 30/10/94, p.10) and at Pembroke between the RO plant and the Pembroke settlement, which may be

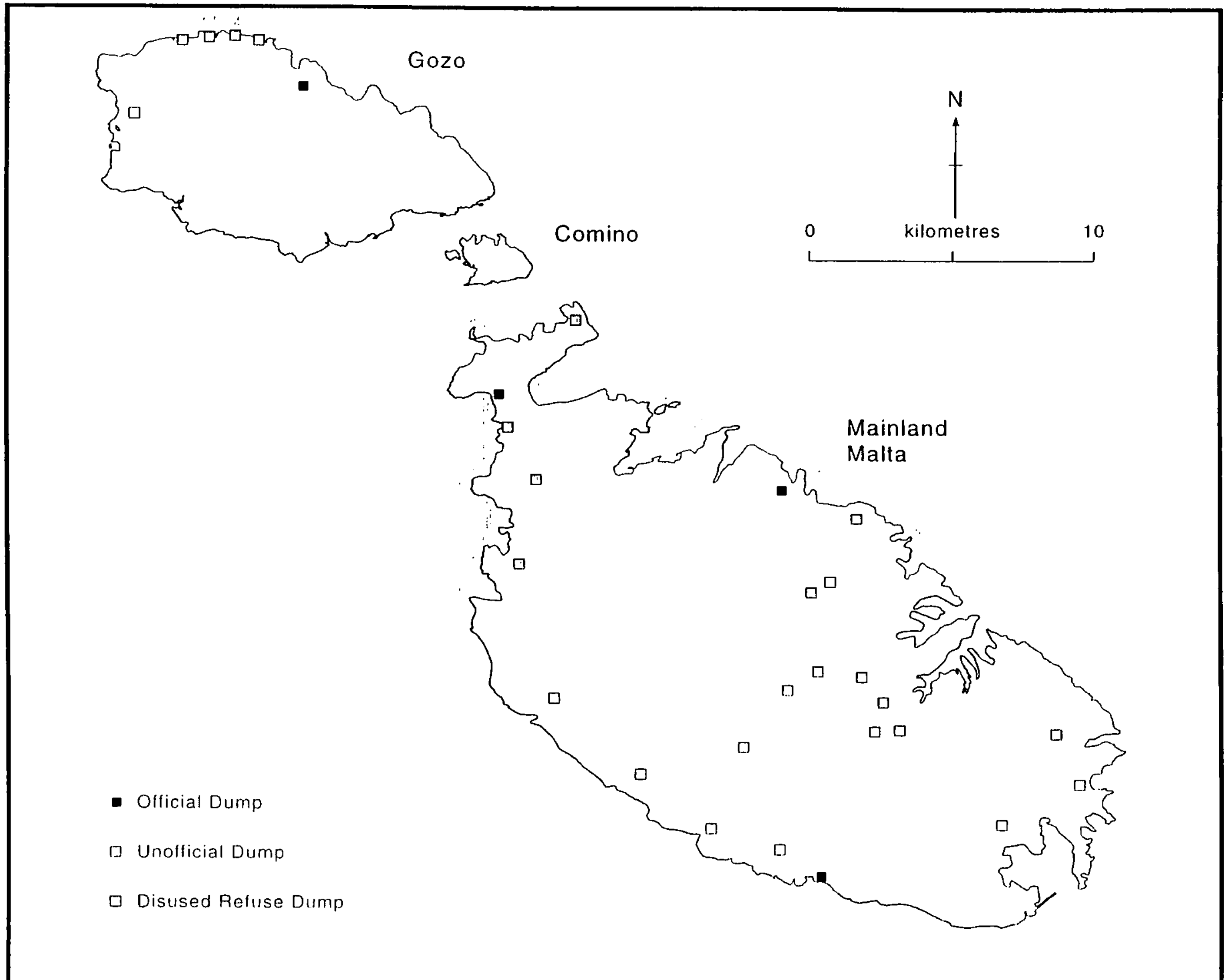


Figure 5.13. The location of waste dumps in Malta and Gozo.
Source: Ministry for the Development of Infrastructure, 1990a.

polluting the feedwater for the plant after heavy rains as well as groundwater. Certainly exhausted quarries (Plate 5.12.) and *widien* that are used as rubbish tips, such as Wied il-Ghasel (the Chadwick Lakes in the Ta' l-Isperanza and Qleigha Valleys), a popular picnic and dumping site (ibid, 18/12/94, p.10), and Wied Qirda (ibid, 2/4/93, p.52), are allowing polluted rainwater to infiltrate into the ground below. In 1993, Wied Mexju in St. Andrew's was being turned into a rubbish tip:

"Cookers, beds etc. find their way onto the valley floor." (*The Times*, 5/10/93, p.4).

Recently at Fomm Ir-Rih, the picturesque bay has been accummulating a mound of rusting scrap metal (ibid, 13/3/95, p.27). Abandoned vehicles, including old public transport buses, are left to corrode in the countryside (*The Malta Independent*, 13/2/94, p.6). Meanwhile new dumps are being created all over the island (ibid, 30/10/94, p.10).

To date, no one has been prosecuted for the contamination of groundwater resources by illegal dumping, which largely reflects the inadequate policing and enforcement (University source, 1993).

"The lack of strong legislation has led to the low efficiency and slowness of current control measures." (*The Malta Independent*, 13/2/94, p.78).

Some industries are also guilty of discharging their waste products into the environment. A WSC source (1993) informed me that the SGS-THOMSON factory at Kirkop was disposing waste products into an adjacent abandoned quarry. A visit to the site confirmed this and Plate 5.13. shows the visual level of the pollution.

Plate 5.13. Waste from the SGS-THOMSON factory is disposed of in a disused quarry.

Plate 5.14. Accumulated rubbish (background) in a disused open reservoir.

Plate 5.15. Building rubble dumped at a borehole.

Plate 5.16. Rubbish discarded at a borehole.

Plate 5.17.
Rubbish discarded near the Fiddien reservoir (in a groundwater protection zone)

Plate 5.18.
Rubbish discarded near a borehole.

"These illegal tipping sites can cause water table pollution depending on the type of material disposed there" (*The Malta Independent*, 13/2/94, p.73).

Even within five metres of some boreholes and reservoirs, piles of manure, rusting cars and domestic waste can be found dumped and left indefinitely to leach toxic materials into the water table (Plates 5.14. to 5.18). Although boreholes are meant to be fenced in, they rarely are. One borehole in Gozo is situated in a traffic island and it is likely that car exhaust emmissions are leached into the immediate area, contaminating the extracted water with harmful toxins such as lead (*Moviment ghall-Ambjent* source, 1995). A WSC source (1995) informed me that the WSC gets the blame, yet there are no national policies or national sentiment to combat what is described as a 'national pastime'.

Again, after heavy rains, sources of pollution such as this can seriously affect tap water quality by contaminating extracted groundwater and RO plant feedwater. The following example illustrates this:

"The Water Services Corporation has advised people living in Rabat, Mdina, Dingli, Kuncizzjoni, Mthaleb, Bahrija, Girghenti and Fawwara to boil their tap water before drinking. The warning is a precaution against possible underground water contamination following heavy rains earlier this week.... The Tal-Hlas pumping station has been stopped due to water contamination. The reverse osmosis plants in Cirkewwa and Marsa are not operating because the quality of the feedwater has deteriorated (*The Times*, 7/4/94, p.48).

Finally, illegal discharges of toxic waste enter the sewage system directly. This waste can enter groundwater supplies either via sewage exflitration or via recycled irrigation effluent. The culprits are mainly industrial, agrarian and catering establishments, but domestic waste is also to blame. In the case of garages, burnt oil is often dumped directly into the sewers (*The Times*, 5/7/93, p.48).

5.4.1.3.7. Hydrocarbons

Petrol stations/garages are also a potential source of hydrocarbon pollution in Malta. Many store oil and petrol underground and are susceptible to leaks. Furthermore, the WSC has no means for testing for hydrocarbons in water (*Moviment ghall-Ambjent* source, 1995). Strict regulations are needed for the protection of groundwater from hydrocarbons (ibid).

With regards to oil from tank washing:

"The main source of pollution in this establishment is oil originating from tank washing at the Ricasoli Tank Cleaning Station (RTCS) as well as received sea ballast and slop oil." (Ministry for the Environment, 1992, p.9.18).

From Ricasoli,

"The oilbased sludge is dumped at [unlined] domestic dumping sites..." (ibid).

In addition to this, sewage leaking from the drainage system will include hydrocarbons, amongst other contaminants, that will eventually end up in groundwater.

5.4.1.3.8. Heavy metals

As with hydrocarbons, the WSC has no means of testing for the presence of heavy metal pollutants like lead, cadmium and copper. Only the University laboratory is capable of this (*Moviment ghall-Ambjent* source, 1995). This raises concern that industrial pollution may be passing into the water table undetected. The WSC claim that industrial pollution is not a problem, yet a source from *Moviment ghall-Ambjent* (1995) posed the question of how they can reach this conclusion without having the means to monitor or detect certain types of industrial pollution. Furthermore:

"Importation of toxic substances is controlled but lack of testing facilities at times hinders serious control." (Micallef, 1994, p.328).

An MDC source (1993) informed me that many industries abuse the drainage system and illegally dump toxic waste which leaches into the ground to pollute the aquifers. This occurs particularly in the subsidiary sewer systems of industries posing the threat of toxic as well as bacterial contamination (*Moviment ghall-Ambjent* source, 1995).

The metals used by the electroplating industry in Malta are the most toxic substances used in industry on the island. (Ministry for the Environment, 1992). Further light is thrown on this problem by Micallef who states that,

"Plating sludge is dumped at domestic dumping sites." (Micallef, 1994, p.27).

Presently, industries are not paying the environmental cost of their production and disposal methods. This is occurring at different scales from Enemalta and the disposal of their pulverised coal ash, to small mechanical workshops. The drydocks is also a big polluter with the disposal of its slop oil, while fly ash from the power station at Marsa is being dumped in the

Benjhisa area (WSC source, 1995).

Heavy metals are also contained in pesticides, fertilisers and in domestic wastes, mainly, copper, lead, mercury, arsenic and cadmium. Small amounts are toxic and accumulate in the body (Zahra, 1991).

Arsenic accumulation can lead to skin cancer (*The Malta Independent*, 5/12/93, p.37), while just 1g to 2g of mercury can cause digestive, nervous and excretory problems and eventually death. Lead is stored in the bones and can lead to their disintegration (Zahra, 1991) and is toxic to the central and peripheral nervous systems (*The Malta Independent*, 5/12/93, p.37). Zahra states that,

"Serious studies have shown that the Maltese people have the highest lead content in the blood amongst Europeans," (Zahra, 1991, pp.36-37)

5.4.1.4. Groundwater protection zones

The only means of protecting groundwater from pollution has been the designation of groundwater protection zones (WSC source, 1993; *Moviment ghall-Ambjent* source, 1995). Figure 5.15. shows the location of these zones.

Certain types of land use are not allowed within the zones by the PA to prevent pollution. However, illegal activities such as the dumping of waste inside the zone are not policed (ibid).

This aside, many sources of pollution have been wrongly permitted outside the protection zones, on the assumption that groundwater simply flows outwards from the centre of the island (ibid). Hence, boreholes and pumping stations that rely on these 'protected' catchment areas are considered safeguarded from pollution.

However, the movement of groundwater is not as

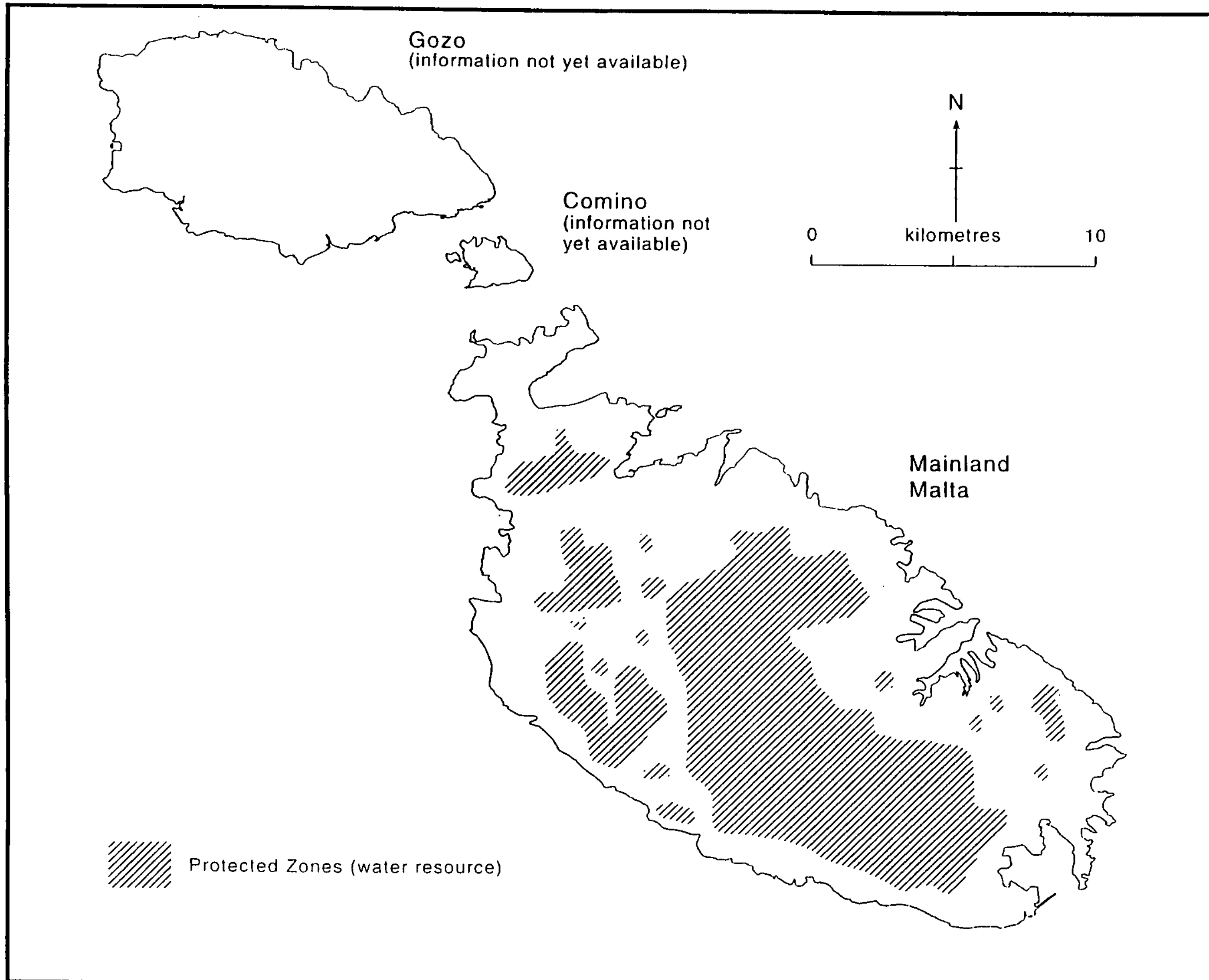


Figure 5.14. Groundwater protection zones in Malta.
Source: Ministry for the Development of Infrastructure, 1990a.

simple as this since the limestone is very fissured and has many sinkholes and conduits. As a result, flow inwards from coastal areas is possible, particularly since Maltese geology has never been surveyed in fine detail. Many sources, including those from *Moviment ghall-Ambjent* (1995), agreed that the groundwater protection zone provides a false sense of security which may be doing more harm to the MSLA by allowing polluting land use at its periphery (ibid).

"The criteria governing the delineation of the protected areas are based on a hypothetical radius of influence of 300m from any source of groundwater. It is thus assumed that outside the area of influence polluting solutes will not be transported towards pumped wells or galleries. This assumption, however, does not take into account the heterogeneous geological characteristics of the Lower Coralline Limestone and the varying physical parameters which effect groundwater flow in a karstic aquifer." (Institute for Water Technology, unpublished report).

Examples already discussed of groundwater contamination warnings given by the WSC illustrate that boreholes and pumping stations are not completely protected.

5.4.1.5. Discolouration of tap water

A widespread problem caused by the ageing infrastructure of the distribution system is that consumers frequently receive brown coloured water.

In most cases this occurs because when water supply is suspended the salinity in groundwater and/or the acidity in RO water that remains in the old iron pipes, causes rust to build up. When supply is resumed the rust is dislodged. It can take a long time for the water to become clear again. This problem occurs particularly in the south since as well as experiencing water suspensions, it receives the most saline water.

5.4.1.6. Chlorination of tap water

Tap water in Malta is heavily chlorinated to avoid the possibility of bacterial contamination. The chlorine leaves an unpleasant taste and odour in the water which can be noticed especially in areas where the salinity is low or has improved so that the salty taste no longer hides the chlorine (University source, 1995).

A source at the University (1995) stated that the presence of high levels of chlorine in the tap water in the US has had hazardous consequences. The levels are so high that toxic chloroform has been released in some cases as the chlorine reacts with the carbon in the type of organic matter found in the tap water. Fawell *et al* (1987) state:

"Although the benefits of chlorination are beyond doubt, the fact that chlorine reacts with many of the organic substances in raw waters forming some substances of potential risk to health has led to concern and has stimulated a series of investigations." (Fawell *et al*, 1987, p.61).

These have shown that,

".... hundreds of organics are present in water, including many that are a product of reactions with chlorine." (ibid, p.65).

No investigation has been undertaken in Malta to detect for this hazard (ibid). The effects of such a hazard may not be noticed for several years since the harm done to health is long term (*Moviment ghall-Ambjent* source, 1995).

Presently, however, evidence of a health risk is not sufficient to justify a change in water treatment (Fawell *et al*, 1987).

5.4.1.7. <u>Bottled water</u>

After his work on tap water salinity in the south of Malta, Dr. Alfred Vella, of the University of Malta, analysed the quality of Maltese bottled waters. From the results in Table 5.10. it can be seen that *Flavia*, bottled by Aquatess Ltd, and *Kristal*, bottled by The General Soft Drinks Co. Ltd, were found to have higher levels of nitrates in the water than stated on the bottle label, which also happened to be slightly higher than the EU recommended level of 50ppm (*The Malta Independent*, 18/4/93, p.3).

The results were published in *The Malta Independent* newspaper and it caused what Dr. Vella called an, ".... uproar.... people began to fear all brands of bottled water and turned to foreign water, including [one brand] which has notoriously high levels of nitrates." (1993). In comparison the levels of nitrates in *Kristal* and *Flavia* were not something to be seriously feared, especially since the latter only had one sample slightly over the EU level, the rest well below. However, the media gave the perception that the public was being defrauded and in danger, only because of the mismatch between the label and reality. The irony is that no public inquiry has been made into the level of nitrates in tap water which are much higher in many parts of the Islands:

"Regrettably the public cannot rely on the

Table 5.10. Results of the study of nitrate concentrations (ppm) in Maltese bottled waters

Brand	TESTS 1	2	3	4	5	Nitrate level claimed
Tivoli	1.1					Nil
Aquadot	1.5					Nil
Fontana	1.8					Traces
Flavia	51	15	22	14	14	Traces
Kristal	44	62	62	62	66	8.0
San Michel	13	15	15	13	13	0.6

Source: The Malta Independent, 18/4/93, p.3.

Department of Health's 'vigilant eye' in these matters. The DOH's 'periodic analyses' are never published. In this case it would do Flavia a power of good if the nitrate values found by the DOH from a month before your first report [the test results] were to be published. But then, the same DOH has never raised a whisper about nitrates in the public water supply, which in some central and western parts of Malta and in all of Gozo are way above the WHO maximum acceptable limit. Neither has the DOH ever said that the WHO convern is quite unjustified." (*The Malta Independent* 23/5/93, p.26).

In its defence and to try and recover lost sales, The General Soft Drinks Co. invited Professor David Kay to,

".... inspect procedures and facilities at the Kristal plant...." (*The Malta Independent*, 23/5/93, p.26).

and reassure the public that they,

".... had nothing to fear." (ibid, p.26).

Professor Kay is the director of the Centre for Research into Environment and Health of the Universities of Leeds and Wales and adviser on recreational water quality to the WHO/UNEP, the EU and the British Department of the Environment (ibid, p.26). Yet the company promised the public that it was going to reduce the nitrate content of *Kristal*, hence, in a way, admitting that they had a problem that needed addressing.

According to one source at the University (1993), the company seriously mismanaged their RO technology. They did not replace their membrane filters and also if your raw water is high in nitrates then so will be your product. The process of RO only manages to eliminate approximately 50% of nitrates in the raw source. The company's raw water (from its private borehole) was high in nitrates and because their membranes deteriorated then so did the quality of water to the point where the level of nitrates in the product became higher than that stated on the bottle label (University source, 1993).

Aquatess obtain their water from an underground spring in the Girghenti Valley over the perched aquifer. It is the nitrates that have leached into this water from agricultural fertilisers that have caused the quality problems for them (*The Malta Independent*, 16/5/93, p.22). They have since managed to reduce the nitrate level of *Flavia* to 12ppm (ibid).

Marsovin's bottled waters, *Fontana* and *Tivoli*, are also obtained from underground springs at Wied Rini in Bahrija. In contrast to Aquatess, Marsovin has the advantage that most of the catchment area for Wied Rini is uncultivated. Consequently, there is little if no leaching of nitrates into this water source (ibid).

This study led to a great deal of conflict between certain bottled water companies (pp.474-477).

5.4.1.8. <u>RO water</u>

The quality of RO water in terms of chloride levels has already been discussed.

In 1991 Dr. Alfred Vella conducted a survey on the fluoride levels in Maltese tap water. He concluded that because Malta has a large RO component in its tap water and because RO water is devoid of fluoride, then the intake of fluoride will be reduced and so dental hygiene may suffer as a result.

Again, the press did not help to accurately convey Dr. Vella's research findings. His results were written into an article and published in a medical journal. A newspaper carried the main conclusions of the article and stated that tap water is poisonous because it has no fluoride. Dr. Vella told me, "The middle and upper classes would know how to interpret the problem. The majority of others are not educated enough to understand.... but they worry for a couple of weeks and then forget about it." (1993).

Media reports often sensationalise and cause panic. This is of course something that is not exclusive to Malta but occurs in all places where the media has a strong influence on public perception.

"The customers still only have their primary senses to judge water quality, and rarely will taste, odour and appearance give any indication of the 'problems' posed by nitrate, pesticides, aluminium, trihalomethanes and lead, the front runners in media campaigns. It is not surprising, therefore, that the customer tends to believe the story writers and has developed a worrying distrust of the water supply industry and scientists in general. During recent years reference to 'poison' in drinking water has become common-place." (Fawell and Miller, 1992, p.726).

5.4.1.9. WSC bowser water

Water supplied via bowsers by the WSC is usually drawn from the Luqa reservoir near the WSC headquarters. However, at times, bowsers can become accidently contaminated with bacteria while being emptied. This is especially so during the summer months. In the case of such incidents the WSC will advise households to boil tap water before drinking it (*The Times*, 28/7/93, p.23). Undetected cases of contamination are a cause of concern and a public health risk.

5.4.2. Second class water

There are problems associated with the quality of different sources of second class water, which may vary across the Islands with consequences for domestic, industrial and agricultural consumers which rely, or should rely, on this water.

5.4.2.1. Cistern water

In some parts of Malta the quality of cistern water has been degraded by airborne pollution. One University source (1993) said: "I would not have any use for water from my roof in Senglea - it gets soot from Marsa power station and the ships in the drydocks. It is acid rain."

Another source at the University (1993) stated that, "The quality of rainwater off roofs will not be all that high especially in Marsa, Hamrun, Marsaxlokk, because of the power stations. Marsa's roofs are very sooty and some of it is radioactive.... It's very dependent on the wind direction.... within three kilometres of Marsa power station are some very high concentrations of sulphur dioxide in the air. However, outside that sort of dust range, cistern water ought to be reasonable."

Bacteriologically it is often contaminated (*The Malta Independent*, 15/1/95, p.27) but it can be boiled. Proper maintenance of the cistern and the roof catchment area is essential to prevent bacterial contamination. Despite this, in most wells the water is clean in appearance and virtually free of nitrates and chlorides and other materials found in tap water, hence boiling this water provides a relatively healthy and palatable source of drinking water (*The Times*, 1/5/93, p.22). Quality Analysis Ltd. of Valletta has concluded that,

"Generally, well water was of an excellent quality."

(ibid, p.22).

The problem is that large amounts of good quality water are not available because many cisterns were never built.

5.4.2.2. Agricultural water

Some sources of irrigation water may have adverse effects on crop health, growth and quality. Of most concern have been the use of groundwater from the semi-confined aquifers in the north-west, the SASTP irrigation effluent and the illegal use of sewage.

5.4.2.2.1. Irrigation water from semi-confined aquifers

In the north-west, where farmers rely on the semi-confined aquifers, groundwater has an electrical conductivity of around 7000 microsiemens/cm. This is very saline and considered unsuitable for irrigation (DA source, 1993). It can be toxic for the crop and leaves a salt residue on the soil and may block pores, disabling infiltration (ibid; Agnew and Anderson, 1992). Overpumping of some semi-confined aquifers has meant that many farmers are having to blend groundwater with collected rainwater to try and reduce the salinity of their irrigation water (ibid).

5.4.2.2.2. SASTP recycled water for irrigation

Faith in the quality of the second class water provided by the SASTP for agriculture was not strong initially and even now it is viewed as second rate irrigation water by some farmers. Table 5.11. shows the

Table 5.11. SASTP recycled wastewater characteristics (quality parameters) for 1991

BOD mg/l	Turbidity N.T.U.	Conductivity microsiemens/cm	Ammonia-N mg/l	Nitrate-N mg/l	Free Cc mg/l	pH
3.0	7.2	3565	0.5	28	0.8	7.0

Note: Values are annual averages for the year; 1mg/l = 1ppm.
Source: Ministry for the Environment, 1992.

water quality characteristics for the SASTP water. The raw wastewater is strong with a Biological Oxygen Demand (BOD) of 3.0.mg/l (ppm), but this is much lower after treatment (Table 5.11.). BOD is a measure for organic matter biodegradation in mg/l (equivalent to one ppm) and is determined after 5 days at 20°C. The lower it is, the better the quality of the effluent (Ministry for the Environment, 1992).

SASTP water is relatively high in chlorides, with an electrical conductivity of almost 4,000 micro-siemens/cm (Table 5.11.), which, according to a DA source, (1993), is not considered fit for agriculture by text book definitions and above WHO recommendations. This value is an average and increases during the summer (ibid). Yet farmers in the area still grow salt sensitive crops like strawberries. Crop growth has been surprisingly successful. The SASTP's manager states:

"Strictly speaking, it [the irrigation effluent] must be considered as a water of marginal quality, needing special agricultural management techniques. However, no special techniques have been adopted and still no salinity problems have as yet emerged. Salts accumulate in the soil during the dry season, to be washed down again by heavy rain during winter. Also, some of the crops cultivated are generally considered as intolerant to salinity, e.g. strawberries and runner beans; nevertheless, they have been cultivated with success. This is related to the permeable nature of the calcareous soil in the area." (Gauci, 1993, p.86).

Nevertheless, another source at the SASTP (1995) stated, "You have no control on what the farmers do. They do the most stupid things.... Before the plant, this area was one whole desert except for those with private boreholes." Unlike irrigators in the north, the farmers in the south do not have generations of experience of irrigated farming.

Given their inexperience, it is not surprising that most farmers in the south-east do not know that,

".... generally speaking, sewage [recycled sewage effluent] should not be used on or near vegetables that are to be eaten raw. The risk is reduced with proper management determining when and when not to spread sewage and the drying of the crop. Arborial, cereals [*sic*], beets [*sic*] and oleaginous crops are the types of cultivation most suited. Surface irrigation is preferred to spray irrigation." (Micallef, 1994, p.34).

Zammit (1979) also gives this warning:

".... pathogenic organisms may survive treatment or start to regrow after pasteurization so that it is advisable that sewage sludges should not be used with crops that are to be eaten raw or at least, the application should be stopped well before harvesting." (Zammit, 1993, pp.16-17).

Yet many farmers continue to grow fruit and vegetables for raw consumption, strawberries, melons, onions and tomatoes being some of the most favoured. Spray/sprinkler irrigation is also popular, which is also a risk to farmers who may inadvertantly consume the spray, especially in such a windy regime (ibid).

5.4.2.2.3. <u>Irrigation with sewage</u>

Some farmers, mostly in Gozo, use sewage water for irrigation (FIS source, 1993; University source, 1993). They,

".... were doing untold damage to the drainage system in Gozo, because they were breaking it up to deroute the flow to the fields." (*The Times*, 11/11/93, p.6).

This is illegal and a health risk. For example, a source at the FIS (1993) informed me that, "Farmers on Gozo frequently use gelignite to blow up the main pipe to drainage outfalls.... these farmers use the sewage water to irrigate with, thinking that it serves as well as manure. It's bad for the product and a typhoid hazard."

"Raw sewage sludges contain many pathogenic organisms and should never be disposed of on land without further treatment for health reasons...." (Zammit, 1979, p.16).

The problem has been acknowledged by the Government as a serious health threat:

"A second problem is the utilisation of the sewage water directly for irrigation without treatment from the main sewerage network. This water, generally used to irrigate vegetables, represents a serious health hazard for Gozo and mainland Malta inhabitants and for tourists." (Ministry for Development of Infrastructure, 1991b, p.72).

5.4.2.3. <u>SASTP water for industrial use</u>

Presently, only the industrial estate at Bulebel is being supplied with recycled water from the SASTP. The water quality of recycled water has caused problems for some industries on the estate (WSC source, 1994).

The Swan Laundry, on the Bulebel estate, is having the greatest trouble with water quality. The laundry has a reservoir which receives water from the SASTP. This is then pumped to a pre-treatment tank before it goes to the laundry for use. Here, two water quality problems have arisen (ibid).

The first of these problems concerns the growth of bacteria in the feedwater to the laundry. This was attributed to the water from the SASTP by the laundry. However, further investigations found that the water from the SASTP to the laundry was free of bacteria with a residual chlorine content. So it seemed that the bacterial growth was in their pre-treatment tank (ibid):

"Biological growth at the inlet to the dry cleaning process of one of the Laundries. This problem can be attributed to two reasons:

i) Ion exchange resin bed is the ideal environment for the growth and multiplication of bacteria. No chlorination is carried out to eliminate any micro-organisms which might be present. The laundry in fact needs to chlorinate and dechlorinate for process reasons prior to Ion Exchange [*sic*].

Other laundries do not exhibit the same problems because they utilise the water solely for washing of denim and leather and so do not pre-treat this water.

ii) The Bulebel reservoir needs thorough cleaning. Lack of periodic cleaning can result in an accumulated growth of micro-organisms which are not representative of the effluent existing at SASTP." (Debono, 1994, pp. 36-37).

The second problem concerns the effluent's salinity which is causing corrosion in the laundry's boiler tubes. The laundry asked the WSC for an alternative supply and were given a borehole with a relatively lower level of conductivity which has helped, but by 1994 they were still having problems with water quality and wanted to do away with the SASTP water completely (WSC source, 1994).

5.5. THE DISTRIBUTION SYSTEM

The water distribution system in Malta has come under much criticism from the public, politicians and the media. This section discusses the shortcomings of the system, the result of a lack of planning and poor construction practices such that today it is undersized and deteriorating.

Discussed here are problems arising from the system's undersizing and deterioration. These include the inequity in water distribution and water that is unaccountably lost, unbilled, unregistered/unpaid and stolen (known as 'unaccounted for water'). Obstacles to remedial distribution projects are also discussed.

5.5.1. An unplanned and undersized distribution system

One source at the WSC (1993) described the condition of the distribution system: "It could be better. It's not planned as such. It just evolves with the demands of the people. It just improvises, it's not perfect." Another source at the University (1993) said, "I think the situation in the south is that the distribution system is falling to pieces."

When it was constructed there was no anticipation for the growth of settlements and the satisfactory infrastructure was not provided to accommodate it.

"The distribution system has become outdated and lacks flexibility. Expansion of the system was carried out in recent years in a haphazard manner. Major leakages occur in the distribution network, and a high proportion of water is unaccounted for. In some cases water supply is direct from boreholes without the ability to be supplemented from the main network." (Ministry for Development of Infrastructure, 1990b, p.3)

WSC sources (1993) stated that the lack of planning was characteristic of the previous Labour administration's policies. Such opinions may well not be apolitical and are probably biased in favour of the present Nationalist Government. However, infrastructural provisions for water supply were constructed haphazardly during the building boom of the 1960's and 1970's, particularly in the south (which caused the problems discussed earlier). This period overlaps with Government by both main political parties.

A WSC source (1993) stated that, "The development of the water system doesn't keep pace with the development of the whole country. It's a problem with the entire infrastructure too: electricity, roads and telephones." This has serious implications for the country's economy:

"If Malta's industrial and tourism potentials are to be effectively exploited the problem of improvement of infrastructure requires high priority...." (Ministry for Development of Infrastructure, 1990a, p.19).

Up until 1993, the Government had increased water production as the main solution to the Islands' water problems (and this practice continued after 1993). However, providing water via an undersized and corroding distribution system is not the sole solution to the water problem. Those denied access to water by the undersized sections do not benefit, while those who already had access receive even more water, and more water is lost through leaks.

5.5.2. <u>Distribution pipes: corrosion and rehabilitation</u>

A lot of the old distribution system, especially around the harbour area, is very old and in very bad condition (PA source, 1993). Riolo *et al* (1993) state that,

"Approximately two thirds of the existing system is unlined iron pipes. Together with the aggressive nature of the water and the practice of using the water supply for electricity earthing.... significant internal corrosion of the unlined pipes is a major problem. This creates structural problems with the pipe, water quality problems, leakage and a significant loss in hydraulic capacity." (ibid, p.20).

The pipes also become encrusted with rust and other material (University source, 1993), which causes poor hydraulic performance (low water pressure). Hazen Williams roughness coefficients for the unlined pipes are typically about 60 to 70, which is extremely rough (Riolo *et al*, 1993).

In 1993 the WSC were studying the feasibility of rehabilitating the distribution system as a whole. Attempts at rehabilitating specific parts and individual pipes were already in progress. 'Pigs', foam based cleaning instruments that are pushed through pipes at high pressure to remove encrustations, were used. However, the encrustations were difficult to remove and the 'pigs' were easily destroyed (WSC source, 1993).

Further attempts to remove encrustations involved a method called 'pressure jetting', which sends a jet of water at high pressure through the pipe. This cleaning process was successful but it also blocked household connections with the dislodged encrustation. Following this, in 1993 the WSC were conducting a pilot project to try and attempt the same cleaning process on trunk mains, where blockage is less likely (ibid).

5.5.2.1. Obstacles to solutions: The case of Qrendi Phase 1

A number of technical, administrative, financial and legislative obstacles can arise in almost any large scale development project. This has been the case in the construction of new trunk mains to redistribute and increase water supply to the south. The first, Phase 1 of the new Qrendi pipeline in the south (p.671), was delayed. Had it been completed, when it was due to be, before the summer of 1993, it could have prevented the problems that arose in many southern settlements. It was not completed until the end of August and began operation in September due to a number of reasons:

Initially the funds to start work on the pipeline were unavailable. After that, the arrival of materials was delayed (WSC source, 1994).

Next, the Public Works Department demanded improved construction specifications, which in turn led to a delay in making contracts (ibid).

After that there were legislative delays because of problems with trenching regulations (ibid).

The laying of the pipes was delayed for four months because new regulations were established which required that the WSC undertook insurance for the project, which took a long time to obtain (ibid).

Next, it was found that the trench for the pipeline was much larger than the pipeline. The Public Works Department applied pressure on the WSC to backfill the trench. Neither department would do this until funds were available. Hence, further delay was inevitable (ibid).

Finally, delays arose because of problems arising during work, such as drainage overflows seeping into the trench, unidentified cables and the discovery of archaeological remains (ibid). The *Malta Structure Plan* (Ministry for Development of Infrastructure, 1990b) states that the,

"Lack of co-ordination with other public utility services," (Ministry for Development of Infrastructure, 1990b, p.30)

is one of the existing problems with the Drainage Department. This is true of most of the public utilities, including the WSC (WSC source, 1994).

"From an analysis of the whole public utilities sector, the main constraints to problem solving are legislative and economic in character. The lack of strong legislation has led to low efficiency and inadequate control measures. The other major obstacle has been the lack of funding for improvement of the services and their organisation." (Ministry for Development of Infrastructure, 1990b, p.33).

Phase 1 of the Qrendi pipeline took over three years to complete. There was a three month delay which although short, was a period (summer 1993) when it was desperately needed to relieve shortages (WSC sources, 1994).

5.5.3. Unaccounted for water

There is a discrepancy between the amount of water produced and that consumed, and also between the amount consumed and the amount that is registered consumed. There are the following three stages to consider:

1. The amount produced.
2. The amount consumed.
3. The amount that should be billable.

The amount of water produced is that which can be most accurately measured. Stage 2 cannot be accurately measured since:

a. Water is lost via leaks in the system between stages 1 and 2.

b. Consumption by the theft of water at stage 2 cannot be known.

c. Stopped or slowed down meters will not allow true consumption to be measured. There are many faulty meters in the Maltese Islands.

The accuracy of measuring stage 2 has a direct bearing on stage 3. The amount that should be paid for is therefore not known so bills are often inaccurate in the respect that they do not reflect the real charges for water consumption. The WSC loses revenue and there is an inequity where some households may be receiving water for less money than others.

The WSC also frequently makes billing mistakes, either undercharging or overcharging customers since bills are frequently based on estimates.

The WSC cannot tell accurately how much water is lost via leaks. If they knew the true figure for consumption, they could arrive at the figure for leakages by subtracting the former from the figure for production.

Figures for estimated unaccounted for water in Malta vary between 53% to 54% of water production (Ministry for the Environment, 1992; WSC, 1993a). In Gozo the figure is lower: 50%, despite the fact that meters are much older than those in Malta and are more likely to be faulty. A WSC source (1993) put the difference down to what in his opinion is a greater level of water theft in Malta than in Gozo.

While the production of water (for 1990) is approximately 37 million m^3/year, the total metered quantity of water is only approximately 17 million m^3/year. The remaining approximately 20 million m^3/year of unaccounted for water is assumed to be distributed as in Table 5.12. (Ministry for the Environment, 1992).

This represents a substantial amount of water that is not accounted for. But it is not all lost, as it is commonly perceived to be. Most of this figure is consumed but not paid for. Leakages are the most serious problem since they represent a loss to the consumer as well as the WSC. However, the water is not completely lost because most of it seeps back into the aquifer, but the cost of producing that water is lost and since 60% of water supply is from RO plants, this is an expensive loss. Billing mistakes, faulty meters and water theft mean that the WSC is not recovering the cost of the water consumed under these circumstances.

5.5.3.1. Leakages

Approximately 20% (Ministry for the Environment, 1992) of water is being lost via leaks. This is largely due to corroded pipes, pumping surges causing bursts, repeated manual valve closures, and poor mains laying practices, where pipes were normally laid in uneven trenches without sufficient support and cover (ibid).

More recent estimations from WSC pilot projects state that leakage is in the order of 17-20% (Rizzo and Muscat, 1992).

Leakage detection is a difficult task:

"Leaks are potentially difficult to find in Malta for two reasons. The geology lends itself to quick passage of water back to the aquifer and secondly the past practice of placing excavated material back into the trench provide an excellent drain to take water away from the leak site. Thus unless it is a major leak, there is often no surface indication.... Maintenance of the

Table 5.12. Unaccounted for components in total water production for 1991

Present assessment by WSC	Percentage	million m3
BILLED CONSUMPTION:		
Actual readings	37	13.6
Estimations	9	3.4
UNACCOUNTED FOR:		
Meter under registeration	16	5.8
Estimation errors	9	3.4
Theft (illegal tappings)	9	3.4
Leakage	20	7.4
TOTAL PRODUCTION	100	37.0

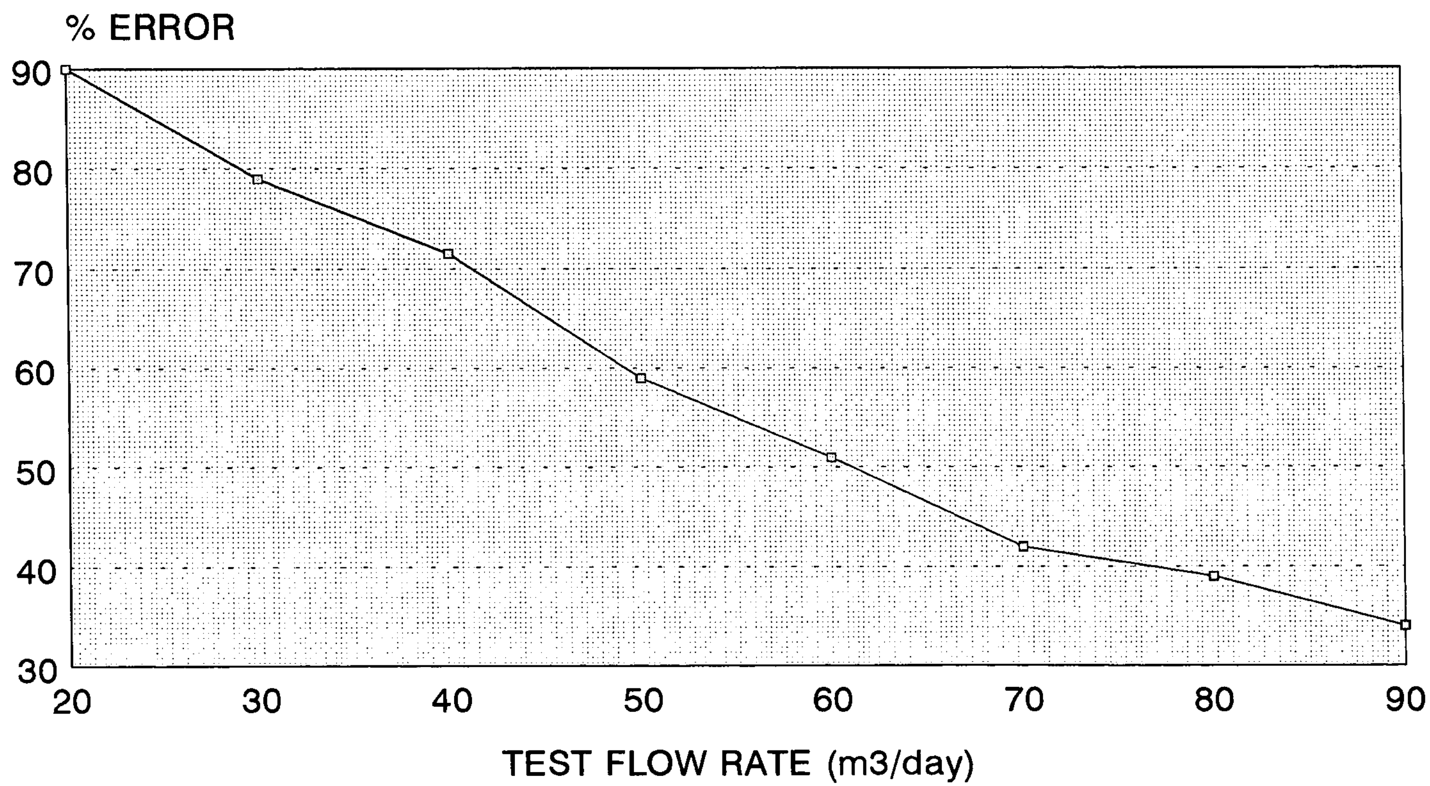
Source: Ministry for the Environment, 1992.

Table 5.13. Water consumption for certain flow ranges and mean error in class `C' meter registration

Flow ranges m3/day	Percentage consumption	Mean error of class `C' meters
0-48	20%	70%
48-86	10%	50%
86-144	20%	35%
>144	50%	25%
Mean weighted		38.5%

Source: WSC, 1993a.

Figure 5.16. Error testing on 100 randomly chosen class `C' meters withdrawn from domestic service



Derived from WSC, 1993a.

distribution system has not been adequate. Because of this a large number of valves have been 'lost' and/or are inoperable.... Also lacking has been the external maintenance of exposed pipes and internal maintenance of all pipes. The effect this has had for example, is that 'step tests' cannot be readily undertaken to locate areas of unacceptably high leakage." (Riolo *et al*, 1993, p.21).

The WSC had completed their first study into leakages in Marsaxlokk in 1993. They had expected leakages to account for 40% of production there but unexpectedly, they arrived at a figure of approximately 12% (WSC, 1993a).

Visible leaks are frequently reported to the WSC by the public however it can take several days before the WSC will see to the reported leak, a source of consumer frustration (pp.539-540).

5.5.3.2. Faulty meters

Up until the end of the summer in 1993, most of the meters in Malta and Gozo were of the old class 'C' type. Many have either slowed down in their rate of water registration or completely stopped registering. Also, Table 5.13. shows that these class 'C' meters do not register low flows and approximately 18% of water is supplied via low flows because of low water pressure in many areas (WSC, 1994a).

Out of 100 randomnly chosen class 'C' meters withdrawn from domestic services, only 54 were in working order. Figure 5.16. shows that the accuracy of these 54, at various flow rates, decreased with decreasing flow rate (WSC, 1994a).

Estimates have placed the figure for unaccounted water due to faulty meters at 16% to 18% of production (Ministry for the Environment, 1992; WSC, 1993a). The WSC states that,

"It is suspected that around 18% of production is not recorded due to meter underregistration (including stoppage)." (WSC, 1994a, p.3).

Faulty meters have also been found to log airflow as water consumption when the mains supply has been suspended. Meters only stop registering once the stop-cock is closed, but in many cases consumers may not be aware of this false consumption causing further inequity (*The Malta Independent*, 5/6/94, p.3).

Where meters are faulty and the owner is aware of the fault, he or she is legally obliged to report the fault. Often this is not done because of the obvious benefits to the consumer and constitutes theft. However, even when it is reported, it can take several weeks for the WSC to repair or replace the meter. One source at the University (1995) stated that after he had reported that his meter had stopped, it took over six months for the WSC to arrive to repair it.

5.5.3.3. <u>Billing estimation errors</u>

It is a policy of the WSC to undertake assessments of consumption in cases where meters are either stopped or inaccesible. Approximately 9-13% of water is unaccounted for due to errors at the billing stage such as low estimates. For example a pilot study in Mdina showed that estimates were low by 70% (Ministry for the Environment, 1992; WSC, 1993a).

The WSC's Chief Executive has explained that,

".... errors in the billing system could arise when consumption was estimated, such as when premises were found closed, or due to errors in data entry or adjustments.... the situation was not being helped by the existing computer system." (*The Times*, 30/3/95, p.56).

5.5.3.4. Water Theft

Approximately 9% (Ministry for the Environment, 1992) of water produced is stolen. It is consumed but not paid for due to deliberate avoidance of meter registration. The largest percentage of unaccounted for water is in water services provided to farms and agricultural dwellings. Approximately 60% of water supplied is unaccounted for (*The Malta Independent*, 26/6/94, p.7) in these dwellings, largely due to the fact that,

"Theft is specially prevalent in agricultural areas, and large consumers." (WSC, 1993a, p.6)

In Gozo, there are rumours that farmers are stealing water from the mains supply to irrigate fields. Some of the farmers I tried to interview there were secretive, suspicious, unwilling to talk or hostile. A Gozitan friend told me that they were either stealing water at the time or thought that I was someone from the WSC carrying out inspections.

A University source (1993) informed me that, "The Minister for Gozo will never stop the farmers from stealing. Gozo is a Mafia, mainly constructed on criminal activities. The authorities on Gozo know all about everything. They know farmers are stealing water. They don't stop them.... There are plenty of other examples [of such corruption]. All plants of 'Readymix', the cementers, are illegal. Bird-trapping, quarrying - much of it done without a permit.... the stealing of water is pinching the tax payer's money directly."

Although the problem appears to be worse in Gozo, a

WSC source (1993) assured me that it is more widespread in Malta. People are simply more aware of it occurring in Gozo because it is a much smaller island and so it is harder to keep secrets there (ibid).

Many farmers remove the meter from the plumbing at night and fill their reservoirs with tap water or, in some cases, it is possible to turn the meter around so that it runs backwards (University source, 1993).

One of the key problems of the distribution network is the poor security (in the casing) surrounding meters and also the fact that many are broken or faulty. Theft is hence relatively easy (ibid).

In addition, many people will adjust their stopcock to induce a low flow which would then trick the old class 'C' meters, since they do not register any consumption at low flows. The stopcock can be left like this overnight to slowly fill the roof tanks to use the next day (*Moviment ghall-Ambjent* source, 1995).

Stealing water allows consumers to use water in amounts and for purposes that they might not have done had they paid for it. For example, farmers will irrigate excessively and businesses and industries can avoid large water bills. A University source (1993) stated: "Stealing water is not too serious because it's being used. But the problem is that it's then used lavishly and wastefully."

Of further concern is that any benefits of increased revenue and equity caused by the new domestic water tariff will not be realised as long as people are still stealing water, particularly since these are the people who will be using water in such large amounts that would otherwise be paid for at the higher tariff rate (p.684) (University source, 1993).

The fact that some WSC employees have been found, and are suspected, to be involved in water theft makes the situation more difficult (*The Sunday Times*, 19/9/93, p.68).

In 1993 the WSC had few resources to curb water theft. A WSC source (1993) stated that, "Lately there's an attempt to curb the illegal use of water, mostly by farmers. I believe there are only four or five inspections over the whole of Malta. I don't think they do any inspections in Gozo. It's not enough. Gozo is a bigger problem. There, people know each other quite well all over the island and so it's more difficult to get such control. Even when the WSC discover water theft, they report it to the police who are, unfortunately, left to deal with the matter." (ibid). As previously stated, very few of the rules and regulations regarding water supply and protection are policed and enforced:

"The police have an overwhelming share in enforcement, partly a reflection of the fact that one needs some type of police permit for nearly every imaginable activity. In situations where 'crime' is not of the obvious type, effective enforcement depends on a concerned citizenry reporting potential infringements. Such a concerned citizenry has hardly existed, and in any case the police are all too often lax in following up certain types of reports. In the smaller towns and villages, the police may be locals themselves with an extensive network of friends and relations. This is most obviously the case in Gozo. Enforcement would not come easy in such situations or in others where politicans are leaning on the police on behalf of clients." (Mallia, 1994, p.699).

The lack of a deterrent is what also makes the breaching of the cistern law, the transport of water by private bowsers, illegal dumping, illegal settlements and the illegal extraction of groundwater, relatively easy and common practices.

If enforcement occurs, it is difficult to catch thieves in the act. Even if prosecution is possible, the accused is often only found to be guilty if he or she admits to the theft. Even then the accused is given a very light punishment which is hardly a deterrent for others (WSC source, 1995).

Another problem is that it is very difficult to calculate how much has been stolen. The WSC usually find that they may only be able to prove that a very small amount was stolen, Lm10.00, for example. For this reason a magistrate is unlikely to go through the procedure of a case, let alone fix a heavy fine for such a nominal amount (ibid). Appendix 4 shows some examples of water theft cases.

It cannot be determined if stolen water has been stored or transported away or even sold by bowser. There is no way of determining for how long a person or organisation has been stealing water. Generally, if found guilty, they will admit to approximately a fortnight (ibid).

5.5.3.5. Illegal groundwater extraction

The theft of groundwater is estimated to be widespread across the Islands, mostly by farmers, industries and private suppliers of water, who are operating without pumping permits. WSC sources (1993) informed me that it is relatively easy to drill boreholes within a few hours. As with tap water theft, since the water is not paid for, it is extracted with no respect for sustainability or conservation and used lavishly. To date little has been done to try and stop this activity (ibid). There is no knowing how much is taken and hence, it constitutes unaccounted for second class water.

The WSC has discovered a number of cases but is faced with a problem with regard to prosecution and issuing penalties because although the WSC Act of 1991 made it illegal to drill for water, it did not establish a penalty (Section 45, paragraph Q). It took the WSC a long time to establish penalties that did not exist until March 1993. Then there was a problem because cases that occurred before March 1993 could not be penalised. In April 1995 there were 20 to 30 cases in court and approximately half of these occurred before 1993. There are usually more than two cases a week discovered by the WSC. Not all are taken to court (WSC source, 1995).

One farmer in Buskett (relying on the perched aquifer) told me that the WSC rarely enforce laws against illegal borehole drilling amongst farmers, particularly in the north. He said, "....everybody is drilling.... everywhere.... they [the WSC] know about them but they don't [stop them].... in our area they don't drill.... because they arrest them." I asked why only in his area: "Because it's difficult [scarce] there for water...." I asked where they drill illegaly: "Burmarrad.... the authorities don't bother because it's seawater [pumping from the MSLA near the coast].... it's illegal everywhere but they [farmers] don't stop. They [WSC] close their eyes.... one drill here, the other drill there, they share the same water.... if you take more and more, it will be more salty...."

Again, enforcement is lacking and prosecution is often futile especially if the prosecuted has contacts in Parliament. From the following example by Mallia (1994), one can see that this is a problem associated with almost every activity that requires a permit (and many outdoor activities do):

"When enforcement does take place there remains the further hurdle of long-winded legal proceedings, at the end of which even a conviction rarely results in a punishment to fit the crime. Fines are generally derisory, compared to the wages of sin or to the damage done to the res publica. A fine of Lm20 for operating a Dwejra quarry without a permit for over a year does not square with the likely minimum of Lm20,000 profit and major damage to the landscape and to the ecology. To grant a permit after conviction is then to add insult to injury." (Mallia, 1994, p.699).

5.6. A LACK OF WATER RESOURCE AWARENESS

Although scarce, since it is has been very cheap, water has generally been taken for granted and used lavishly. Consumption continually outstrips production, not just in the domestic sector but as water production increases, tourist establishments begin to invest in swimming pools as more water is made available, and the incentive to conserve and re-use water in the industrial sector decreases (WSC source, 1993).

"The failure to treat water as an economic (i.e. scarce) commodity has perverse dynamic effects, through its encouragement of a high rate of growth of water-dependent sectors." (Winpenny, 1994, p.17)

Demand is generally fuelled by a desire for improved living and luxury, while any restraint in consumption has been taken away by the erosion of notions of conservation and efficiency.

A WSC source (1993) stated: "The main problem.... in my opinion is the lack of conservation techniques - whatever supply is given is not managed. Areas with plenty of water will guzzle it with low tariffs and faulty metering.... Both factors coupled cause the problem. So up to date no matter what you supply its swallowed."

"Malta, being a Mediterranean country and having a very dry climate, needs every drop of water. But few of the Maltese population recognize what an important commodity water is. It is easily observable how lightly the great majority of the population value water and how freely they waste it." (West, 1975, p.3).

5.6.1. <u>The waste of water in the domestic sector</u>

Water conservation and a like minded approach in all households is something that the WSC realises does not exist. The WSC Chief Executive, Antoine Riolo, states:

"An unfortunate aspect for this problem is that public attitudes are not favourable to water conservation. At consumer level, desalination has become to be regarded as the panacea for providing practically unlimited amounts of water. This is an understandable reaction to the times when water was not available for weeks on end in some localities and started appearing back in people's taps only when much publicised R.O. plants were built." (Riolo *et al*, 1993, p.10).

Because law enforcement on water issues is lacking, consumers are not even discrete in illegal activities, such as the watering of gardens and hosing of cars with tap water (Plates 5.19. and 5.20.). The extremely low price of water prior to 1994 was also to blame. As one MDC source (1993) put it, "The price of water was ridiculous....it's gone up now, but it's still cheap. The Government was running at a loss of Lm4 to Lm5 million per year on water." There was no price disincentive for consumers not to water gardens or hose down cars. The new domestic tariff will not be a disincentive where water theft is concerned and there is concern that they may encourage even more theft (p.684).

The sight of a man in the street using his hosepipe to wash his car in summer, while his neighbour has to fill his empty and smaller capacity rooftanks by bowser,

Plate 5.19.
A car being
washed with
a hose.

Plate 5.20.
Water (and
detergent)
runs from
a house.

Plate 5.21.
A restaurant
owner washes
the pavement.

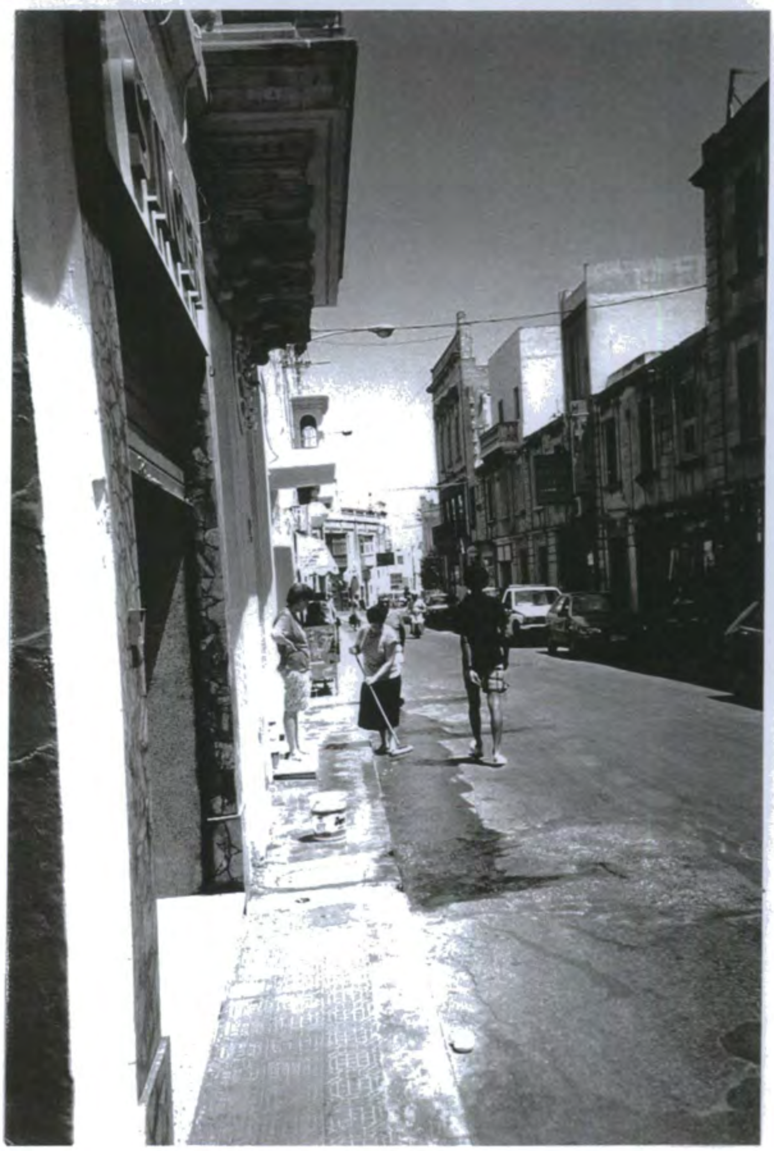


Plate 5.22.
Housewives
washing the
pavement
and gutter.

would be described as appalling and an insult in many arid and semi-arid countries. Such a sight is not rare in Malta.

The washing of doorsteps is an everyday sight (Plates 5.21. and 5.22.), motivated by the need to uphold a sense of cleanliness for others to notice or else be the subject of gossip and shame. Mizzi (1994) explains this obsession:

"....maintaining the front of the house, including not only the sidewalk, but also the gutter '*nadif tazza*' (as clean and shiny as a drinking glass) are subject matters for comment by local women. Thus if you leave your home looking anything but well turned out, neat and clean, or if debris accumulates in the gutter in front of your house, you are in danger of being talked about in a negative way." (Mizzi, 1994, p.380).

Waste also occurs because of the discolouration of water by rust which prompts consumers to run taps, sometimes for more than an hour and until the colour has gone. In some cases this may be necessary, for example, for the washing of clothes or for drinking.

Sources at the WSC (1993) informed me that there was a publicity campaign to make people aware of the need to conserve water but it was not very successful. Further attempts are discussed in Chapter 8 (pp.682-702).

An interviewee from Msida told me: "The water problem in Malta, it's not being taken seriously.... Go in Valletta. Every house has a well. During the Knights it was built.... go wherever you want in the new areas, out of ten houses you find only three having a well. And where you see a block of apartments like these, not a well [cistern]. My mother.... in the sink.... after they finished washing the clothes, [imitates his mother calling him] 'Come Tony, come'.... and she used to wash me in the same water. We talking, I am 35, talking er, at least 35 years ago, when there was no water problem...."

He told me how people are relaxed about breaking the law and often view bribes as the easy way out. Of those who have no cisterns he said, "It's the work of the building inspector.... even if they came round - don't say this [asks for anonymity] - they bribe them, put five pounds in their pocket, ten pounds, and he goes on. For him just a hole is a well [cistern].... in England at least you are afraid of the law. In Malta: 'Oh it's alright. When the police come then we'll see'."

Maltese friends told me to interview a friend of theirs involved in Maltese social and psychological issues at a professional level. The following interview gives an interesting insight into the Maltese psyche, even if it is a generalisation:

"People do not have a water saving mentality and so they tend to use it far too lavishly.... mentality is towards wasting water.... If they have a shower they're going to let it run while they are soaping themselves, if they have a bath they are going to fill it to the brim.... a lot of efforts have been made into saving water.... but educating the public is the most dificult thing.... I mean I'm a social worker, if anyone in Malta should know how difficult it is to change peoples' mentality, I do. Because half the time I'm trying to show people that there is a solution out of the problem.... they still go on believing that their way is right, even though they come to me for help.... If they are this hard headed about things which are going to affect their own life, immediately, you can imagine how difficult it is for them to accept that their actions are going to help put something right for the whole island.

Let me illustrate this. This perfectly shows the Maltese mentality: I would say that 99.9% of Maltese households were spotlessly clean, from the door in. But it's no big deal for the people to throw the rubbish out.

A lot of women in Malta seem to be convinced that they have to wash the house down from top to bottom everyday, washing floors. I mean although we're going to talk about wastage of water in households I think this is the main one....

I mean there are laws against this kind of thing but nobody seems to enforce them.... You see people washing their cars down with a hosepipe, of course it's illegal. I've never seen a policeman stop and tell these people that they've done anything wrong. Most probably a policeman himself does the same thing at home.... Most probably his wife cleans the floor in the same way.... I mean the stupidity of wetting the street down and washing and scrubbing it, especially in this village [near a dusty quarry], has to be seen to be believed.

.... I get angry about water wastage, my wife gets angry. We also get angry when we see someone dumping rubbish all over the island.... If there's a conflict it's people like me getting angry.... Most people will think I'm crazy.

[Discusses the new domestic water tariff] The worst people who are going to be hit would be the low wage earners. On the other hand, very frequently they're not the ones who waste too much water. The ones who waste too much water are the middle sector. Enough money to have a nice house, but not enough bloody brains to be socially aware.... most people in Malta are, I believe, are incapable of understanding that water has to be turned off periodically to save it.... example... people having a festa and letting off ear splitting fireworks within a couple of hundred yards of our main hospital where people are dying.... But this is the mentality which wastes water. [Quotes examples of typical attitudes] 'I want to have fun, to hell with you.'.... 'I'm not taking your water.' You say, 'But you are.' [They say] 'Where? this isn't your water, this is Government water. I'm stealing it from the Government....

[Asked if there are many people who are more conscientious?] There just aren't enough to make a real difference.... I mean I have to say this. It's stupid. I'm (sighs) not exactly proud of having to say, but I have to say it: You get a shanty near the sea which has been built up totally against the law.... they're all over the place on the seashore and the Government lays on water and electricity to these places. Well, water and electricity are wasted left, right and centre. Well I mean if the place is bloody illegal, why supply it with water and electricity. I mean I've seen kids at these places being hosed down as they come out of the sea, and the hose just put back on a hook and the water allowed to run rather than walk the length of the hose, maybe fifty feet, to turn the tap off. You know, [in waiting] for the next kid to come out.... the only way you stop these places from wasting water is to turn it off. But if they [the Government] turn it off, the Opposition is going to go up in arms and say, 'You're depriving these people. You're making these children suffer!' You know what I mean?....

[Asked if it is a matter of education?] In this matter I'm afraid I'm a little fascist. The only way you can get these people to obey is to hit them into obeying.... In defence of our politicans, if they try for any other form of Government.... most people wouldn't understand it. Suppose our politicans started working to the rule, working by the book, for one thing most of them wouldn't get re-elected and for another thing the people they are trying to help wouldn't understand that they are trying to help them by going by the book. And their attitude is: 'Sure apply the rule for him, [shouts] me! me! I went out with your sister for three years.... me! you're going to apply the law to me?'...."

This source's anger and frustration illustrates the conflict between the few who believe in conservation and the many who waste.

Dodd (1994) and O'Hara (1994), in their study of water availability and water consumption patterns in Ghaxaq and Marsascala, found contrasting attitudes to water conservation between the two settlements. The study was conducted in April 1994 and by this time water distribution for some southern settlements had improved with Phase 1 of the new Qrendi pipeline (p.671). Ghaxaq was one of these settlements, while Marsascala was not, awaiting Phase 2 (pp.674-675).

They found that in Ghaxaq,

"Concern for saving water and being economical in its usage.... was not so evident here.... Questions regarding weekly domestic household consumption generally resulted in a lack of concern for the economical use of their water, which indicated that water shortage was rarely a problem" (Dodd, 1994, pp.6-7)

Although,

"Throughout the summer months the village had water cuts, around 2-3 times a week.... people stated that their cars were washed once a week and an average of 9-11 buckets of water were used to wash their houses." (ibid, p.8).

The availability of water seems to have made people complacent about water use, although it was found that,

"An interesting comparison arose between the young and old women, as the younger ones appeared to be more aware of Malta's water problems." (ibid, p.9).

In Marsascala, Dodd and O'Hara found that,

"The village had been without water for 3-4 days, and in the summer this could be up to 3-4 weeks." (ibid, p.14).

The shortage here meant that,

".... water had to be used as economically as possible, for example clothes could not be washed regularly and when they were, the water was saved to use for flushing toilets.... the value of rainwater could be seen in private houses which generally had tanks on the roof and wells in the gardens." (ibid, p.14)

It appears that,

"People only realise how precious water is when they have no water in their pipes...." (*The Times*, 28/5/93, p.4).

One way to make people more conservation minded towards their use of water may be to restrict their water supply. This is neither socially or politically acceptable, but then one is caught in a Catch 22 situation where, as stated previously, the more water that is made available, the less it is valued and the more it will be used and wasted.

The irony is that in Marsascala, the reality of severe water scarcity necessitates its conservation. Dodd and O'Hara give an example of one Marsascala household:

"On arrival the water supply had been cut, and the man said that the family would now have to rely on the 1,500 litres [6.8m^3] of water that he had stored in tanks on his roof until it came back on. Although it would have been possible to send for Government water tankers, he said that these can take up to a week to arrive, and he couldn't afford the private ones. Generally, he said that to use the washing machine, would use 750 litres [3.4m^3]

of water, therefore until the water supply resumed, the family could not wash any clothes by that method. The family always had baths rather than showers, therefore saving water, which was then used to flush the toilet.... their view to whether the general situation would improve to any great extent, was one of discontentment with regard to the traditional Maltese culture. They felt that many people in Malta were more interested in football, politics and money, rather than water conservation and improvement of supply." (ibid, p.17).

Another interviewee,

".... summed up the attitude of many Maltese.... doing things without consideration for the effects of their actions." (ibid, p.16).

Riolo *et al* (1993) add that:

"It is an uphill, difficult task to convince people that though it may be technically possible - within limitations - it is not economically sustainable to proceed along a path of satisfying unlimited demand. It would be wise for this country's citizens to tailor their water consumption habits to circumstances. Some form of demand management is clearly called for, with the aim of using our expensive supplies in a more cost effective manner...." (Riolo *et al*, 1993, p.10).

Previous education campaigns have been either too short lived or not effectively communicated. As long ago as 1975, West proposed that:

"In the first place the Maltese population should be made more water-conscious. It should be taught how to take care of the few water resources with which the Maltese Islands are endowed. It must be taught how it should not waste water needlessly without any specific reason. It must be shown how it could preserve a little amount of water from the little rain that falls on their property and by this I mean that it must be made to have a well [cistern] or a small storage place where it could preserve water for the use of watering gardens, washing cars, floors, and clothing....

.... Secondly, laws should be legislated in Parliament by which water resources are protected. This has been done sporadically since the time of the Knights of St. John.... only by legislation of laws and their enforcement could our water supplies be protected against useless waste." (West, 1975, p.40).

5.6.2. Water wastage in the tourist sector

The types of water consuming activities of tourists and tourist establishments have been already discussed in Chapter 4 (pp.292-293). These are not ideally suited to dry environments like Malta and are contrary to notions of sustainable tourism (pp.713-716).

"Tourism has affected the consumption of water in resorts worldwide: swimming pools in luxury hotels, running showers and taps and constant lawn sprinklers, aggravate water shortages." (Eber, 1992, p.5).

In Beel (1995) and Wood's (1995) joint study of tourist water use, their main conclusions were that,

".... most visitors to Malta are from the wetter parts of Europe; namely Britain and Germany especially. These people are unlikely to be accustomed to worrying about conserving water, as it is virtually always in plentiful supply in their home regions." (Wood, 1995, pp.12-13).

"Most tourists do not seem to be fully aware of the true costs of water and unless they come from an arid region themselves, water has no real value.... The only mention of water shortages in the Suncrest [hotel] Holidays brochure is in passing and suggests that they may add to the adventure of holidaying in a foreign country! Hoteliers and tourists alike can do much more to reduce the burden on the domestic population...." (Beel, 1995, p.11).

The need for restraint in water usage is hardly appreciated by tourists who aren't aware of the Mediterranean way of life and the fact that the local population is often subject to water rationing (Sivignon, 1989). Furthermore,

"Small privately owned hotels do not seem to place any emphasis on water conservation although they also suffer high water rates" (Beel, 1995, p.7)

While it has been proved that big hotels with large amounts of greenery for landscaping, use more water than small guesthouses equipped with showers (Sivignon, 1989).

5.6.3. Industrial water wastage

Very few industries in Malta practice any methods of water conservation, such as efficient consumption and recycling or re-using the water that they use. As previously stated, where tap water is stolen or boreholes drilled illegaly, the water is often wasted and used in copious amounts. The WSC has found that,

".... certain investigations show that the quantity of unaccounted water in industry is up to 70%. There are no relevant data available which can account for the state of water consumption in industry. A great number of industrial plants use the water without control, so that it is difficult to establish the actual state." (Riolo *et al*, 1993, p.45).

Given the amount of profits generated by industries, they can afford to invest in water saving measures, but the low industrial water tariff (Table 3.1.) offers little incentive to do so (WSC source, 1994). In a dry island like Malta, it should be compulsory for industry to adopt water saving measures.

5.6.4. Agricultural water wastage

It has already been stated that the theft of tap water and groundwater, for irrigation, is often accompanied by unrestricted and lavish consumption. The same applies to the SASTP irrigation area, where the cheap flat rate of Lm36/ha/annum and the inequity of the distribution network encourages lavish and inefficient use by some farmers. The real cost of the water is 12c/m^3 and hence,

"The revenue collected is a mere 4% of the effluent cost." (Gauci, 1993, p.85).

There is little incentive to adopt efficient methods of water application, like drip irrigation. Instead, direct application in furrows along fields and the use of sprinklers in a windy regime, lead to a high loss through evaporation. This is a problem in other agricultural areas too.

The situation is made worse by the fact that water distribution to the uncovered satellite reservoirs, distribution in the open channels to farmers' plots, and irrigation applications, all take place in the morning, allowing maximum evaporation during the day. Ideally, it should be distributed and applied during the evening.

As previously stated, the division of land into small plots, most less than 1ha, owned mostly by part-time farmers excacerbates the inefficiency of water use in this farming area. Lockhart (1994) states that,

".... there are too many part-time farmers and too many small farming plots exploiting too few water resources with little care or concern." (Lockhart, 1994).

The principle of the economics of water use has been applied recently, in some parts of the world, to agricultural products to determine if the production or environmental cost of the water component for certain crops is economical (Bailey and Minhinick, 1989; Pearce, 1994). A University source (1994) informed me that no work has been done on crop profitability in terms of water cost in the Maltese Islands (ibid).

However, water consuming crops such as melons, lettuces and tomatoes are commonly grown, not only in the SASTP area but all across Malta. A farmer in the SASTP supply area, who had no water because he was at the periphery of the distribution system, told me that he was growing tomatoes because they do not use very much water, a misperception, typical of the farming community there. Another farmer, in a traditionally dry farming area between Siggiewi and Zebbug, was trying to grow melons by buying water by bowser and applying it via drip irrigation. Clearly, farmers need to be advised in crop selection.

SASTP sources (1994) informed me that the profit margins of some of the crops grown in the south-east, with SASTP water, would not even cover the cost of the water, even if realistic prices were charged. Were the water charges realistic, to discourage excessive use, then it is likely that crops that are less water consuming will be adopted. Lockhart (1994) notes that in the SASTP area, "The most common edible foods grown here comprise of green vegetables such as green peppers, broad beans and lettuce and often high water content fruits such as melons." (Lockhart, 1994, p.10).

5.7. CONCLUSION

Water problems in the Maltese Islands have arisen due to a combination of several physical, socio-economic, political and psychological factors. Hence, although the water problems need to be addressed urgently, the task will be complex and will need to be treated by addressing the factors one by one (and in relation to one another), as well as implementing remedial measures. These are presented in Chapter 8.

There are serious shortcomings in the management, funding and security of water supplies, which should be a huge cause of concern but seem to have received little attention from government and water managers, until recently. These have led to water production problems, a lack of water reserves, losses in run-off water, a lack of professional human resources and equipment and the vulnerability of RO plants. All problems which require urgent attention. First and foremost, without professional training and management, which has been lacking, none of these problems can be properly solved.

The loss of water (due to run-off and the lack of water storage facilities) is tragic, given that large amounts could otherwise have been used to alleviate a significant part of the water shortage. Of course water production would be more reliable and resourceful if management skills and training opportunities were adequate. The extreme vulnerability of the RO plants, both to seaborne pollution and sabotage, should also be of great concern. The complacency and inaction that exists at present cannot be allowed to continue, not just because of the huge amounts of capital invested, but because without the RO plants Malta would be helpless. It is unbelievable that the Maltese Government has been playing Russian roulette with the nation's water supply. It is only a matter of time before a major incident deprives the country of a key source of water. Again, with better management skills, training opportunities and decision making based on reason and goodwill, rather than politics and vested economic interests, such ignorance would probably be eradicated. The Islands' existing and potential water sources need to be evaluated and appreciated for them to be properly harvested, protected and developed.

Some of these problems have, tragically (and for those responsible, shamefully), in turn led to the problems of water scarcity in terms of quantity, quality and access. These have been caused by a lack of planning, the over-pumping of the aquifers, increased levels of groundwater pollution and an old and undersized distribution system, prone to leakages, theft and meter under-registration (which is not just limited to Malta but is common place in many countries). The water situation could not be worse (unless a catastrophe that entirely undermines water supply occurs) and is a reflection of politicians' short term goals, where environmental and resource sustainability and the need to protect and provide future generations with what is rightfully theirs, is overlooked in order to satisfy voters now and even then it is only one half of the country that is provided for. Planning for the future should be a prime consideration. The problems have been compounded by escalating water demands (a big problem in itself), which as stated previously, should have been controlled. Again, if voters demand it, it's a case of, "They shall have it," whatever the cost.

The result, depressingly, has been prolonged water shortages and regular water cuts, rising health risks due to the high level of nitrates and chlorides in tap water and an inequity in supply, with the south generally worst off; a prime trigger for social unrest which has been and is, a very real and large problem itself, absurdly, within such a small country (pp.528-531).

Problems like these should not be occurring in a country that considers itself to be developed and in a society that considers itself to be as affluent and as socially and technically developed as it is. Yet, of course, it is precisely because it is so developed that the problems are so considerable. In a country as small as Malta it is astounding that water of varying sources (RO plants, boreholes, etc.) cannot be distributed from one part of the state to the other so as to provide a mean level of potable and healthy water to all consumers wherever they are. This shortcoming raises important questions as to why this has been allowed to happen. Political obstacles have a large part to play in answering this question. Surely decision makers must realise that in such a small land, the potential for groundwater pollution, from whatever source, is extremely high. Yet it is allowed to happen and without the slightest bit of concern. Again, short term priorities based on political and economic interests take precedence over the good of the environment, its resources and the need to provide for the future and even a large proportion of the population today. The politicisation of water is dealt with in Chapter 7.

The domestic sector is most affected by water scarcity because the tourist, industrial and commercial sectors are given a high priority in water supply and can themselves afford to cope if they experience problems. Although these sectors are important to the economy, given the severity of the water problem in the domestic sector, they have an unfair advantage. Priorities need to change so that the domestic sector receives more attention and water. Social and health issues should come before economic ones, or at least before profits. The domestic sector is also important to the economy and its water problems can only serve to create an unhealthy and alienated work-force.

The agricultural sector has seen a deterioration in the quality of groundwater everywhere and, in the case of the perched aquifer, a decline in the level of the water table, particularly since the theft of groundwater is widespread. These issues must be addressed if farmers' water requirements are to be equitably satisfied amongst themselves and if conflict between those that have water (other famrers and sectors of the economy), and those that do not have water, is to be prevented. For this to happen agriculture can no longer be relegated to the lowest level in the WSC's priorities. This is not just to help improve the role of agriculture, but also to help prevent the many conflicts that have arisen and which could arise, in between farmers (pp.480-493), with other sectors (pp.590-527) and with the various water supplying authorities (pp.493-499 and pp.548-549).

Mass water wastage is a wide scale problem due to the lack of a conservation promoting mentality and the rampant inefficiency in water use, within all sectors. Conservation and efficiency promoting measures are long overdue. The benefit to consumers, if they were to curb consumption, could be rapidly realised through lower bills, a fine election offer, even though bills rarely ever go down.

Again it must be stressed that the common issue that links all these problems is the lack of foresight and planning that is so typical in Malta's recent history. There is also a mentality that takes water for granted and relies too readily on the Government for water (and many other day-to-day needs). This mentality needs to change to one that is more self-sufficient, resourceful and plans for a sustainable future.