SETTING UP OF AN EXPERIMENTAL AREA IN MALTA FOR HYDRAULIC MANAGEMENT AND ENVIRONMENTAL RESTORATION OF "CHADWICK LAKES"

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ABSTRACT

The area of "Chadwick Lakes" is one of the best landscapes and environments in Malta. This paper describes the general characteristics of the project of the hydraulic management and environmental restoration of Wied il-Qlejgha, a watercourse that includes the "Chadwick Lakes". Also, a description is given of the setting up of an experimental area within the same watershed where the effects of the proposed actions and their impact on the river habitat are tested.

RÉSUMÉ

L'aire des "Chadwick Lakes" est parmi les paysages et les milieux les plus beaux de Malte. Ce travail décrit les caractéristiques générales du projet d'aménagement hydraulique et de restauration environnementale du cours d'eau Wied il-Qlejgha qui comprend les "Chadwick Lakes". Il donne aussi une description de la mise en place d'un périmètre experimental à l'intérieur de ce bassin versant où l'on a testé les effets des mesures proposées et leur impact sur l'habitat fluvial.

In this paper, a preliminary study is presented of the hydraulic management and environmental restoration of Wied il-Qlejgha, the middle portion of Burmarrad watershed which is one of the major valleys of Malta, subject to the actions scheduled in the intergovernmental agreement between Italy and Malta[1].

The Maltese government addressed to CIHEAM-Mediterranean Agronomic Institute of Bari (IAM-B) to carry out the master project.

The IAM-B, in turn, asked for the technical-scientific collaboration of the "Istituto di Sistemazioni idraulico-forestali" of the University of Bari (agreement dated 18 November 1997).

The nature and value of the project, as well as the numerous environmental constraints to comply with, led the Italian and Maltese governments and the two Institutes, to start with the setting up of an experimental area where a pilot project of hydraulic management and environmental restoration could be implemented.

A reach of river upstream of "Chadwick Lakes" was chosen. This is a part of Wied il-Qlejgha named after the English colonel who, in the last century, built some weirs varying in height between five and seven meters for water supply and groundwater regulation.

The "Istituto di Sistemazioni idraulico-forestali" was particularly interested in this study, due to its long-time involvement in this line of research about the effects of watershed management on the river habitat and, thus, on the measures to be adopted to combine hydraulic works and environmental restoration.

These themes have always been a major part of the theory and practice of watershed management.

But, in these last years, the growing environmental awareness, also of larger social classes, has increasingly focused attention on environmentally sound soil defence and land maintenance measures (Puglisi, 1998a; Puglisi, 1998b).

Without prejudice to the importance of regulating the processes occurring along the watercourse and of defending land against their uncontrolled evolution, there seems to be a better understanding on how such purpose may not come into conflict with environmental protection. In other words, hydraulic and hydrological needs may meet ecology and landscape ones. The river is a habitat for numerous plant and animal species, and also a notable landscape resource and these are aspects

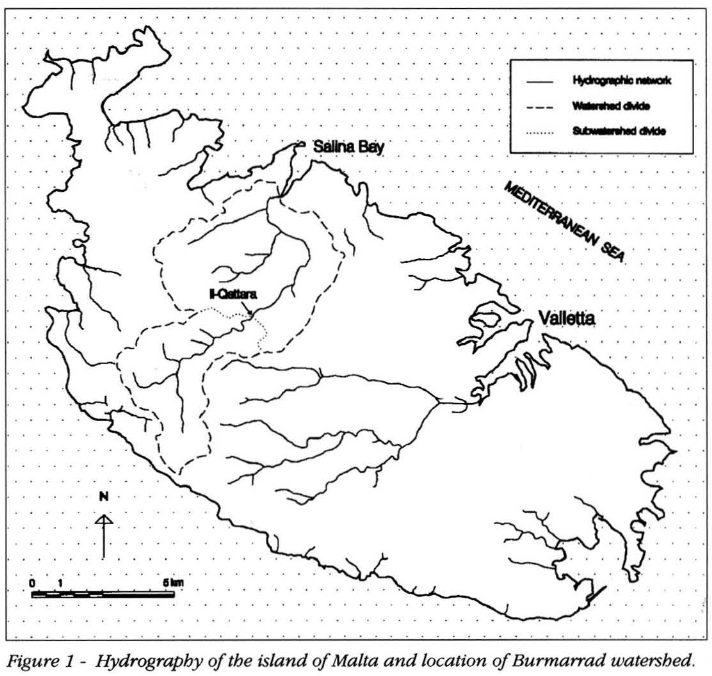

Figure 1 - Hydrography of the island of Malta and location of Burmarrad watershed.

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(1) IVth Protocol of Italian-Maltese economic assistance, signed in Valletta on 28 May 1994.

Figures 2, 3, 4, 5 - View from above of the dams in the "Chadwick Lakes" area (photo by Puglisi).

to be preserved; disturbances caused may not be localized and circumscribed since a reach of a watercourse is ecologically related to the remaining hydrographic network and consequently to the neighbouring land. As Benfratello (1998) states, "in highly man-affected countries, the amount and quality of waters are a unique aspect of the same natural resource that, even flowing through complex hydrographic networks of the watershed, crosses the land – subject or object of geo-mechanical activities – and joins, let's say, its own bio-environmental habitat (...). The scarcely evident relationship between these numerous natural phenomena is further complicated by the meteorological event hazard and the erratic behaviour of the natural hydrographic network. Such network, not only in the juvenile upstream torrential reaches, but also in the old downstream ones, exhibits its own characteristics and needs the technician has to study laboriously and understand well even through historical research, to comply with, regulate or even train them. They should not be forcedly hampered by dangerous indiscriminate coercion to avoid the risk of unleashing violent reactions and revenges of nature; as it happens to adult persons who may turn compulsive juvenile psychic repression into neurosis." The increased interest in environmental aspects of soil defence focuses attention on the types of measures that often belonged to watershed management tradition (for instance the line of the so-called "soil bio-engineering") and also contributes to propose new research themes, especially to give scientific and quantitative foundation to sometimes predominantly qualitative observations and results. It is in such a perspective that one should set the methodological approaches, analyses of the concerned land and the specific purposes of this work.

Presentation of the area

The Maltese archipelago consists of the three major islands of Malta, Gozo and Comino and a number of smaller uninhabited islands. The archipelago has a total surface area of 316 km^2 (246 km^2 of which mainly occupied by the major island of Malta); it is situated in the middle of the Mediterranean, separated from Sicily (at a distance of 96 km) by the Channel of Sicily and from North Africa (at a distance of 290 km) by the Channel of Malta. The hydrographic system of the island, depending on the geology and climatic characteristics, consists of two major watersheds and others of smaller size.

One of the two watersheds is Burmarrad watershed that stretches over the western part of the island of Malta along the north-east south-west axis, starting from an altitude of 251 m above the sea level at Dingli and flow-

ing at the sea level into Salina Bay (**figure 1**). The watercourse from the source to the mouth in the Salina Bay takes different names: Wied Liemu, Fiddien Valley, Wied il-Qlejgha, Speranza Valley, Wied Ghasel: the area and perimeter of the corresponding watershed are respectively equal to 38.9 km² and 34.1 km.

The reach called Wied il-Qlejgha is dammed at several cross-sections by low masonry dams from five to seven meters high and originates the so-called "Chadwick Lakes" (**figures 2, 3, 4, 5**), named after the English colonel who constructed them in the last century.

These are small water reservoirs for irrigation purposes; the watercourse flows in a slightly sloping watershed terraced both on the right and the left side and predominantly suitable for agriculture.

The various problems occurred in the course of the years have jeopardized the conservation of natural resources and the carrying out of anthropic activities and have thus suggested to take actions along the watercourse, that is one of the few habitats of fresh water in the archipelago.

In particular, it was decided to implement hydraulic and landscape management in the area of "Chadwick Lakes". The corresponding sub-basin is determined by the closing cross-section at il-Qattara (**figure 1**), where the watercourse changes its name from Wied il-Qlejgha into Speranza Valley. It extends over 14.7 km² and has a perimeter of 19.8 km with a relative length of the watercourse of 6.57 km; the outlet is at a height h = 73.2 m.

CLIMATIC AND MORPHOLOGICAL CHARACTERS

The Maltese climate is typically Mediterranean with mild and humid winter and hot and dry summer.

The mean yearly rainfall measured from 1960 to 1997 was equal to 505.6 mm; in the same period, the minimum yearly value was 256.4 mm and the maximum one was 806.8 mm (**table 1**).

Based on the seasonal distribution of rainfall, the period October-March with 85% of the yearly total can be classified as rainy, the period April-September as dry; 50% of yearly rainfall occurs between November and January, while 1.5% between June and August.

A peculiarity of precipitation is time variability, both from one year to another and between different periods of the same year; long dry periods are often alternated with very intense meteoric events.

Air temperature is rather moderate; the yearly mean in the period 1951-1990 was equal to 18.6 °C, the monthly means vary between 12.3 °C and 26.3 °C. Based on Bagnouls and Gaussen diagram (**figure 6**), it is observed that the dry period is between April and September. Relative humidity is generally between 65% and 80%. The Maltese islands are windy, since only 8% of the days of a year can be classified as calm. The pre-

vailing wind is in the north-west direction and, on average, it blows in 19% of windy days; the frequency of the remaining winds is more or less uniformly distributed.
Morphologically speaking, the island of Malta has low height relief (maximum altitude, at Ta'Zuta, equal to 253 m a.s.l.) with large and slightly sloping valleys, generally terraced and intensely cultivated. They are modelled into the rock of Malta (see next §) in the central-eastern part of the island; whereas at west, the upper coralline limestone forms a plateau eroded by runoff waters. Typical morphological characters of the island are the *rdum* and the *widien* (singular *wied*). The *rdum* are almost vertical rocky walls formed both by erosion and tectonic movements. The *widien* are elements of the hydrographic network formed by channel erosion, by tectonic action and a combination of both. Most of *widien*, as the one under study, convey water only during the humid season and only some of them that drain perennial springs convey flowing water all the year around. Due to their microclimatic characteristics and to the presence of water, the widien are one of the richest habitats of the island. The limestone nature of outcrops in most of the island is such that the hydrographic system as a whole is poorly developed and the few existing watercourses are torrential, depending on the seasonal pattern of precipitation. Water resources of the island mostly depend on rainfall that infiltrates in the limestone fissures and accumulates in the aquifers from where it flows through springs and is withdrawn by wells. Also karst morphologies like dolina and stone fields are present, as well as large cavities in the subsoil that favour extended infiltration processes.

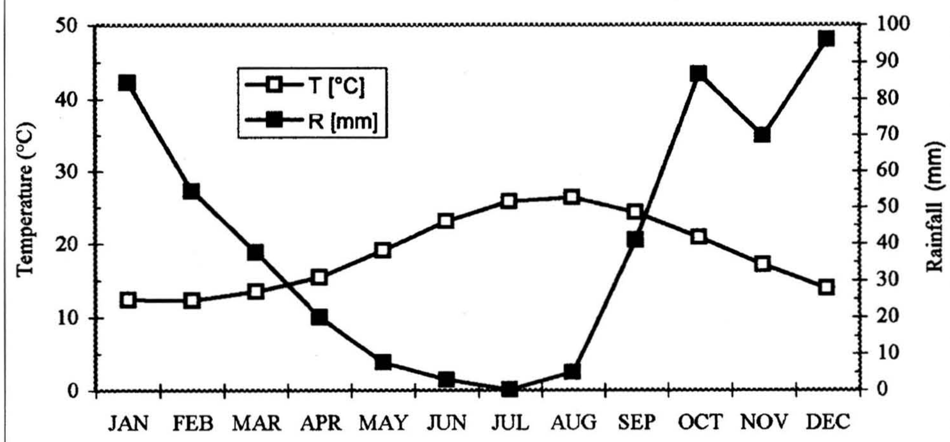

Figure 6 - Bagnouls and Gaussen diagram.

Geological and hydrogeological features

Outcropping formations in the study area mainly consist of sediments of the tertiary age (Miocene) and, subordinately, by localized quaternary deposits (**figure 7**). The tertiary succession is represented (in decreasing order of age) by the Formations of Lower Coralline Limestone, of Globigerina Limestone, of Blue Clays, of Greensands and, finally, of the Upper Coralline Limestone. The Lower Coralline Limestone is represented by bioclastic and micritic limestones, with fracturing planes and karst cavities and, to a lower extent, by calcarenites, granular in texture; the former is white and pink in colour, the latter is white-light yellow. The Globigerine Limestone (or Maltese stone) consists of a light yellow calcarenite, in some cases porous and friable, in other cases compact and fissured. The Maltese stone is generally subdivided into three members, the upper one containing marl-clays intercalations; the transition to the underlying coralline limestone is sharp and marked by a phosphate level. At the roof, the formation changes to Blue Clays, consisting of clays, marly clays, clayey marls and marls, variable in colour from blue to grey and light yellow. They outcrop in the middle portion of the survey area and constitute a large portion of the watershed of the watercourse; locally and over extremely small thicknesses, they are below Greensands, consisting of sands and calcarenite with thin limestone and marly layers that border the basis of the limestone plateau stretching along the western coast of Malta. The succession ends with the Upper Coralline Limestone, association of limestone, calcarenite and breccia, with fracturing planes and karst voids. Tectonically speaking, the island of Malta is characterized by disjunctive phenomena and inclined blocky structure. The faults have a prevailing E-NE to W-SW ([2]) direction and major differential movements have developed along these directions. In particular, the block faulting to the north of the Great Fault ([3]) gives rise to a sequence of horst (ridges) and graben (valleys). In the western area of the island, characterized by this structural complex, the river valleys follow the fault lines or sink areas. The plateau consisting of the upper coralline limestone outcrop is at several points eroded by runoff waters that subsequently reach the blue clays and cause erosion and bed load processes. The link with the tectonic structure and the different lithological types is particularly evident in the northern-western area of the island; whereas in the south-eastern portion, the stone of Malta is completely

([2]) The two major families of faults are towards NE-SW, predominantly, and towards NW-SE.
([3]) Major fault of the NE-SW system, developed from Fomm ir-Rih on the SW coast up to Madliena on the NE coast.

Tab. 1 ***Average, minimum and maximum monthly and yearly rainfall values (in mm) recorded at 13 stations at Malta in the period 1960-1997.***

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**TOT**
Pave	84.4	54.6	37.5	20.1	7.7	2.9	0.1	5.0	40.9	86.6	69.8	96.0	**505.6**
Pmin	11.0	4.2	0.4	0.3	0.0	0.0	0.0	0.0	0.4	11.0	1.9	19.1	**256.4**
Pmax	208.8	176.9	90.3	67.8	48.3	31.2	0.7	106.4	211.0	212.0	309.8	234.2	**806.8**

outcropped and creates a wide undulated morphology, with planes and shallow depressions separated by low hills. The hydrogeological structure is determined by the presence of predominantly limestone lithofacies (permeable) that constitute the tertiary lithological succession, with intercalated marly-clay horizon (practically impermeable). The stone of Malta is permeable by fissuring and porosity (or practically impermeable when the formation contains marly interbeds, as it predominantly occurs in its middle upper part). The blue clays can be considered to be practically impermeable, whereas the greensands, interposed between the upper coralline limestone and the blue clays, are permeable by porosity. Finally, the lower and upper coralline limestone formations are permeable by fissuring and karst phenomena. Consequently, the hydrogeological structure can be schematized as follows:

- A mean-sea-level aquifer, lying on intruded sea water, present in the stone of Malta and in the highly fissured lower coralline limestone;
- Perched aquifers, present both on the formations overlying the impermeable Blue Clays, and in the stone of Malta, where low permeable horizons are inserted.

In proximity of the study area, in the zone of Rabat-Mgarr, a perched aquifer is present, historically important for the water supply to local population, that lies in the upper coralline limestone, highly fissured, and in the greensands, lying on a blue clay bed.

VEGETATIONAL CHARACTERISTICS

The historical events of the island (from Roman domination to English colonization, and later under the influence of Arabs and the Knights of the Order) and the inevitable impact due to man activities have strongly affected the development of flora of the Maltese archipelago where population density, and consequently land use, is very high (1,140 inhabitants/km^2).

At present, spontaneous vegetation is present in some strips especially between cultivated fields and areas contiguous to the coast. Inland, some plant species have survived goat grazing and intense tillage over wide areas once covered with woods typical of the areas of evergreen sclerophylles with an arboreal layer characterized by the presence of species of *Quercion ilicis* like Aleppo pine (*Pinus halepensis* Miller) and holm oak (*Quercus ilex* L.). Remnants of these forests are still present at four locations and consist only of some adult species, some of which are 500 and 900 of age. Sparse elements of Aleppo pine and holm oak are spread everywhere, since they have subsequently been reintroduced by man. Also tree species are present, especially olive (*Olea europea* L.), carob (*Ceratonia siliqua* L.) and almond (*Prunus amygdalis* spp. *com.* = *P. dulcis* (Miller) P.A. Webb) sometimes associated with vine (*Vitis vinifera* L.) or fruit trees like fig-tree (*Ficus carica* L.), mulberry (*Morus alba* L.) and pomegranate (*Punica granatum* L.). Natural inland plant eco-systems can be generally considered as regressive stages of *Oleo-Ceratonion* where anthropic and edaphic determinism causes the substitution of the species of climax associations. The maquis is one of the most evolved plant formations of such regression. Sometimes, when it is preserved in areas of difficult access like steep valleys and the foot of the cliffs, it can be considered a primary formation. Spontaneous species that characterize the bushy maquis of Malta are mainly lentisk (*Pistacia lentiscus* L.), the carob tree (*Ceratonia siliqua* L.), olive tree (*Olea europaea* L.), buckthorn (*Rhamnus oleoides* (L.) Jahandiez and Maire), wall germander (*Teucrium fruticans* L.) and Sicilian tea (*Prasium majus* L.).

In more man-affected areas or areas lying in unfavourable ecological conditions (soil dryness conditions and more exposed to sun), garrigue or grassland develop, both as natural communities and as regressive stages of the maquis. The species that characterize such formations are, in the first case, the thyme (*Thymus capitatus* (L.) Hofmgg et Lk.), the wall germander, heath (*Erica multiflora* L.) the endemic Maltese euphorbias (*Euphorbia melitensis* Parl.), marine asparagus (*Asparagus aphyllus* L.), dusty miller (*Senecio cineraria* D.C.), in addition to numerous geophyte and therophyte species that are frequent also in steppe formations. Here, in particular, also esparto grass (*Lygeum spartum* L.), on clay hills, and white bryony (*Andropogon distachyus* L.) on dry and presumably coarse soils are present. In more degraded situations, steppe communities are rich in carline thistles (*Carlina involucrata* Poiret, *Notobasis syriaca* (L.) Lass and *Galactites tomentosa* Moench). Steppe communities sometimes develop also on abandoned fields. As for vegetation of coastal areas, it sometimes survives within extremely degraded eco-systems. This is the case of sandy dunes where some grasses like *Elymus farctus* L., *Sporolobus arenarius* (Gouan) Duv.-Jouve and *Ammophila aus-*

tralis (Mabille) Tutin predominate. More stable coastal formations are those of temporary swamps. They are sometimes present along the interface between marine environment, the saline one, and the terrestrial one of fresh water. These are surfaces where brackish water accumulates only during the wet season and thus capable of sustaining unique flora and fauna. Coastal formations are completed with halophytes that develop in natural vegetation pockets that can retain the soil within the winding ravines of rocks in proximity of the sea. This vegetation is attributable to natural groups resulting from edaphic factors and from the plant association of *Crithmo-limonietum*. Of special ecological importance are the rupestral formations that, especially in the area of "Dingli Cliffs", are present on the vertical walls of the cliffs. Their importance is due to the presence of many endemic species two of which belonging to two monoecious genera are pointed out: the first is one of the national plants in Malta, *Palaeocyanus crassifolius* Bertoloni, the second is *Cremnophyton lanfrancoi* Brullo and Pavone, that is a remnant species of the flora present in the region during the Tertiary period. Finally, there are plant formations of fresh water communities that also grow in the area of Chadwick lakes (see appendix). They are present both along the watercourse and in temporary swamps.

The latter get formed during the wet season in small land depressions that, by favouring water ponding and waterlogging, generate ecological condition favourable to the development of herbaceous vegetation rich in therophytic species and attributable to the alliance of *Isoetion*, though taxa of higher rank are present. As for the flora composition of the area crossed by watercourses, and in particular of the area of Chadwick lakes, numerous native species are present including some arboreal and brush species

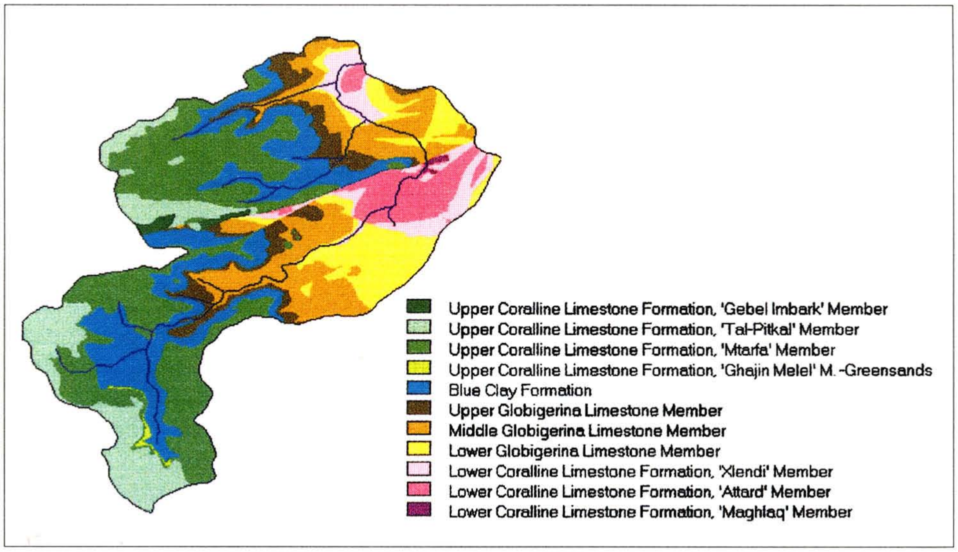

Figure 7 - Geological map of Burmarrad watershed.

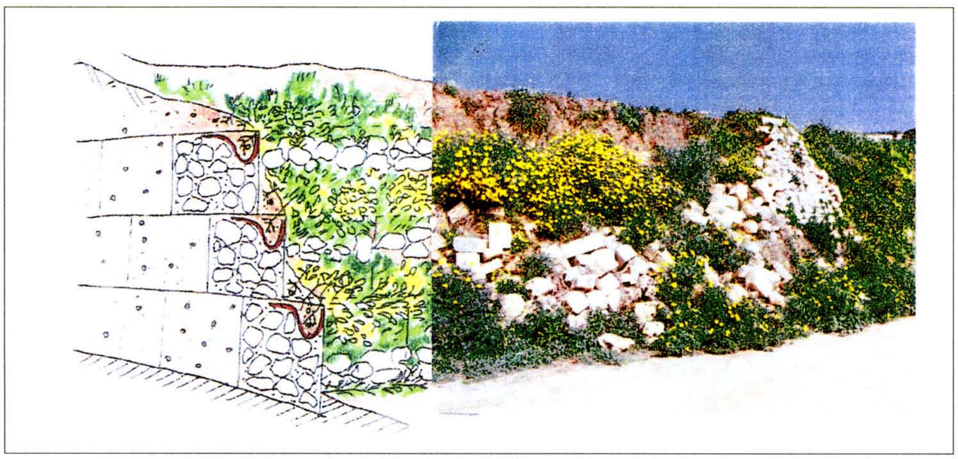

Figure 8 - Replacement of a collapsed bank defence wall by gabions and their renaturisation through vegetative pockets.

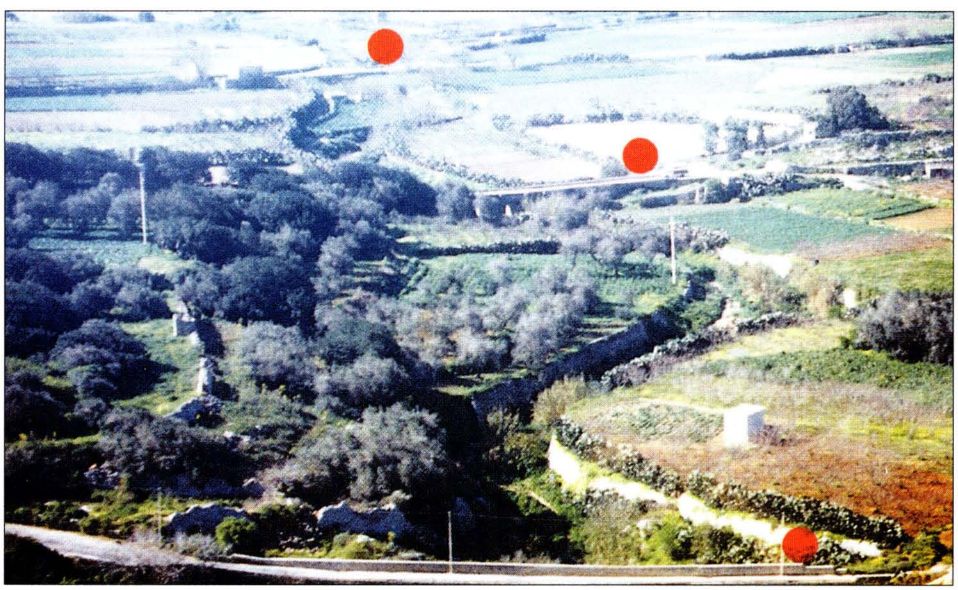

Figure 9 - View from above of the "experimental laboratory" area (photo by Puglisi). Fiddien bridge, Ghemmieri bridge and Tas-Salib bridge (from up to down) are marked with a red dot.

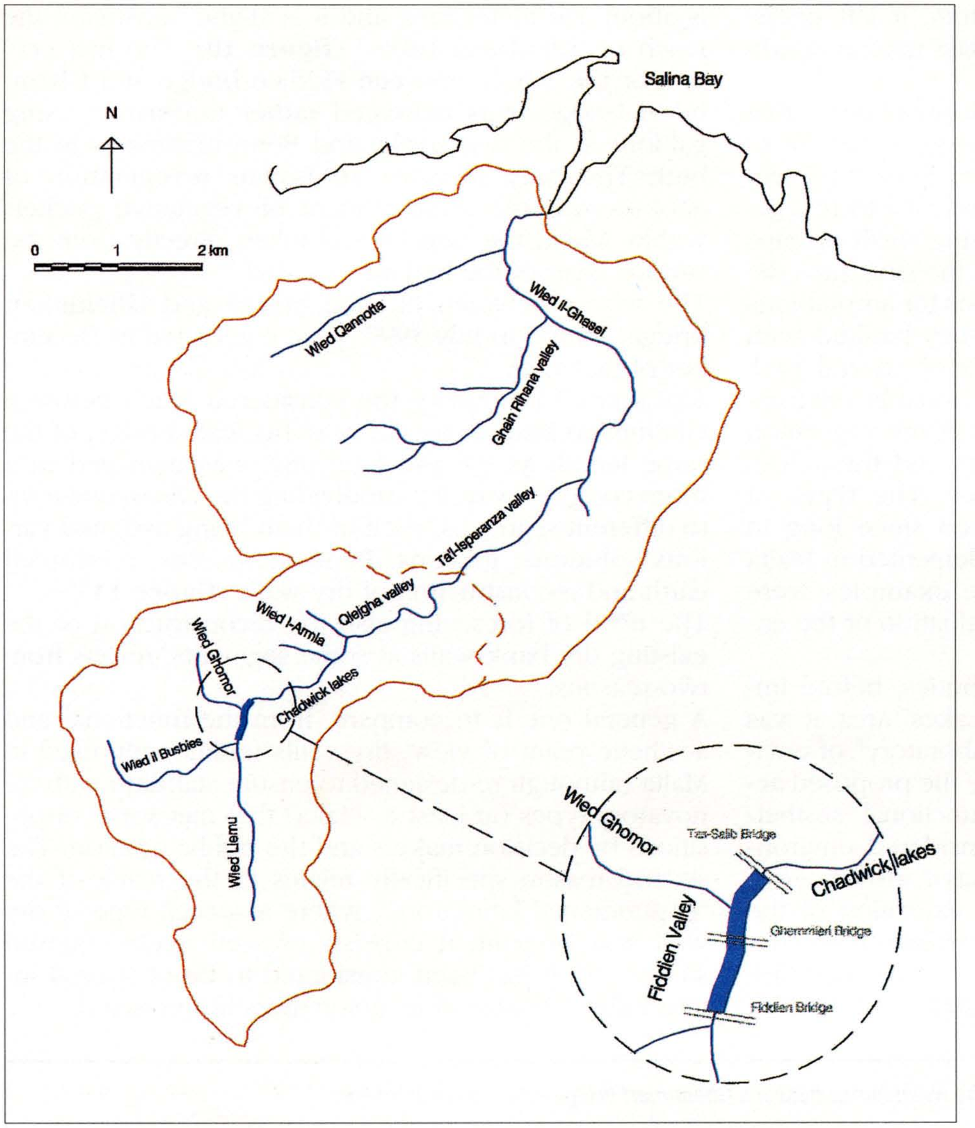

Figure 10 - Location of the "experimental laboratory".

subsequently introduced. In this type of ecosystem, vegetation that can develop can be subdivided into three major groups: the one associated with the watercourse, the riparian vegetation and the hygrophile vegetation that can grow at a greater distance from the watercourse and resembles a flood plane type vegetation. The first type consists mainly of algae (*Cladophora* spp., *Clara* spp.) and aquatic vascular plants related to the presence of water and that thus disappear when the water course bed is dry. Along the banks or at shallow water depth, riparian vegetation mainly formed by annual or perennial weeds, small brushes, reeds, rushes and different *Cyperaceae* develops. The vegetation that grows in the close proximity of the bed, starting from the upper portion of the banks, is a riparian formation dominated by poplars and rich in brushes, some of them typical of garrigue environment. There are also deciduous trees like elms, willows and ash trees.

Objectives and types of actions. The "experimental laboratory"

Hydraulic management and environmental restoration projects for the area of "Chadwick Lakes" are multiple purpose.

It is necessary to re-establish the storage capacity of the dams partially silted at present and improve their efficiency through maintenance. Bank defence works are also needed for preserving the agricultural land in the proximity of the watercourse, through the control of erosion also caused by the instability of existing dry walls; the valley system should be ecologically preserved and even improved by upgrading landscape also for suitable recreational purposes. To reach our objectives, it was decided to choose structurally reliable and time resistant works that may equally be compatible with ecosystem conservation. Therefore, gabions and Reno mattresses were chosen (in some cases reinforced earth with external gabion was adopted) already widely tested in hydraulic management and landscape restoration. These works meet various purposes: they keep flow conditions quite close to those of natural banks; support differential strains and settlements without breaking; adapt to variable morphological conditions preventing deep changes of pre-existing situations. They favour natural growth of spontaneous herbaceous, shrubby and arboreal vegetation, thus allowing to re-establish destroyed or compromised biocenosis, as well to establish natural ecological niches. Research works performed in some Italian watercourses (Martino *et al.*, 1995) have shown that the greatest impacts occur during the initial stage of works and in the period immediately after.

They are related to the inevitable involvement of areas larger than those where works are located, to earthmoving, works in the bed with the destruction of microhabitat, as well as to the relatively long visual impact of bare areas with the presence of artificial elements. At subsequent stages, the works are easily colonized with vegetation at different levels (herbaceous, shrubby, arboreal), especially where bed load fine materials deposit. Subsequent stages are those where more or less specific ecological successions get established and it

has been verified that the river system, if left undisturbed in its evolution, can reach quasi natural conditions (Martino *et al.*, 1995).
The types proposed also allow to adopt solutions that can accelerate the revegetation process, as the establishment of vegetation pockets (**figure 8**) or the introduction of cuttings. Moreover, the tendency to revegetation can be further facilitated by using small rip-raps settled by hand, to be integrated with the structures described so far to create better conditions for amphibious and fish fauna, and alternating reaches banked with gabions and mattresses with reaches of natural bed. This may occur especially in more valuable environmental areas, defined by the analysis of the vegetation present along the bed and the banks and the subsequent mapping of existing ecotypes. The types of works proposed, though being tested since long in many countries, had never been implemented in Malta in the past; therefore, no reference examples were available on the spot for a correct evaluation of the environmental impact of works.
In agreement with the Maltese authorities, before implementing the works in "Chadwick Lakes" area, it was thought to set up an "experimental laboratory" of environmental restoration, i.e. a site where the proposed actions could be tested to assess their functional, aesthetical and ecological fitting in the considered environment. Its implementation would have also been a chance for training operators in the execution of the planned design works. The area of intervention was defined along the watercourse, in the reach between Fiddien bridge and Tas-Salib bridge (**figure 9**); this reach is about 500 meter long and it is slightly upstream the reach of "Chadwick Lakes" (**figure 10**). The first portion of this reach, between Fiddien bridge and Ghemmieri bridge, was managed rather uniformly, using gabions at the two banks and Reno mattresses in the bed. The only measure to favour revegetation of gabions was the establishment of vegetative pockets within which the vegetal soil taken directly from the surface layer of the bed was located.
The works between Fiddien bridge and Ghemmieri bridge, started in July 1997, were completed in December of that year.
The second portion of the considered reach between Ghemmieri bridge and the next Tas-Salib bridge, of the same length as the previous one, was managed in a more complex way, by subdividing the watercourse into different segments, each of them being assigned various solutions: gabions, Reno mattresses, reinforced earth and reconstruction of dry walls (**figure 11**).
The need of foreseeing also the reconstruction of the existing dry bank walls at some segments, results from two reasons.
A general one is to compare, from the functional and aesthetic point of view, dry walls traditionally used in Malta (although re-designed to ensure stability) with innovatory types (at least in Malta) that met some oppositions by decision makers and the public opinion. The second reason specifically relates to the reach of the "experimental laboratory", where a special type of dry wall was present; it consists of well made squared stones and it has been considered to be of special interest also because of its uniqueness in the island.

Table 2 ***Species used for the revegetation of the watercourse between Ghemmieri bridge and Tas-Salib bridge.***

SPECIES	BIOLOGICAL FORM AND GROWTH	CHOROLOGICAL GROUP	ALTITUDE (m a.s.l.)
Species to be propagated by sowing			
Acanthus mollis L.	HC scap	Western Stenomedit.	0 - 700
Arum italicum Miller	G rhiz	Stenomediterranean	0 - 800
Asparagus aphyllus L.	Ch frut	S - Mediterranean	0 - 900
Bolboschoenus maritimus (L.)	G rhiz	Cosmopolite	0 - 600
Capparis spinosa L.	NP	Eurasiatic	0 - 400
Ecballium elaterium (L) A. Rich.	G bulb	Eurymediterranean	0 - 800
Prasium maius L.	Ch frut (NP)	Stenomediterranean	0 - 600
Rhamnus oleoides L.	Ph tuft	Stenomediterranean	0 - 300
Teucrium fruticans L.	NP	Western Stenomedit.	0 - 600
Thymus capitatus L.	Ch frut	Stenomediterranean	0 - 600
Vitex agnus-castus L.	Ph tuft (Ph scap)	Stenomediterranean	0 - 500
Species to be propagated through establishment of nursery seedings			
SPECIES	BIOLOGICAL FORM AND GROWTH	CHOROLOGICAL GROUP	ALTITUDE (m a.s.l.)
Mirtus communis L.			
Pistacia lentiscus L.	Ph tuft - Ph scap	Stenomediterranean	0 - 700
Pistacia terebintus L.	Ph tuft - Ph scap	Eurymediterranean	0 - 900
Rosmarinus officinalis L.	NP	Stenomediterranean	0 - 800
Spartium junceum L.	Ph tuft	Eurymediterranean	0 - 1200
Thymus capitatus L.	Ch frut	Stenomediterranean	0 - 600
Vitex agnus-castus L.	Ph tuft (Ph scap)	Stenomediterranean	0 - 500

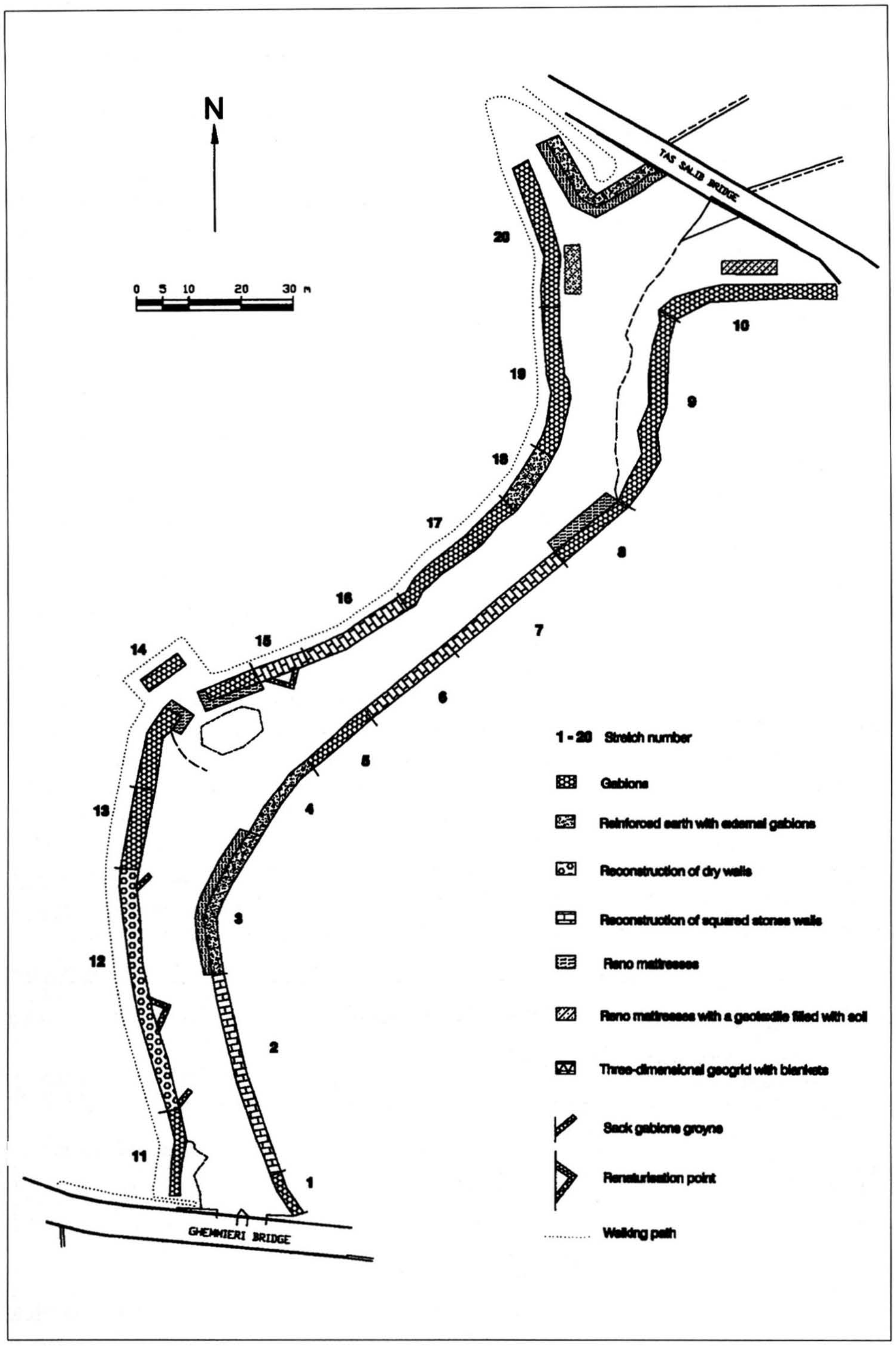

Figure 11 - Plan of the reach between Ghemmieri and Tas-Salib bridge with the indication of the type of works scheduled.

It was thus established to recover these walls, after reinforcing them to ensure stability with an adequate degree of security (4).

In the reach between Ghemmieri bridge and Tas-Salib bridge, for the revegetation of the watercourse, herbaceous and shrub species adequately chosen among those compatible with the considered environment (**table 2**), were planted into the vegetation pockets. Also, some willow cuttings were introduced at the basis of the gabions and local tree species were planted into the bed.

The works between Ghemmieri bridge and Tas-Salib bridge, started in June 1998, are still being executed.

Conclusions

This work describes the characteristics of hydraulic management and environmental restoration of Wied il-Qlejgha, the major watercourse in the island of Malta, as well as the reasons for establishing an experimental area where the effects of planned actions could be tested, especially for introducing them in the environment.

At the subsequent stages of the research, an assessment of erosion in the sub-basin subtended by the dams is scheduled, to have an estimate of their average yearly silting and then a definition of adequate water resource management and land maintenance.

Monitoring of the actions accomplished in the reach of the "experimental laboratory", with special reference to the revegetation of the watercourse, is also scheduled.

This will be possible by comparing, through adequate indicators (5), the results obtained in the reach of the "experimental site" with the "natural" situation, as the one observed in reaches upstream and downstream can be considered.

In this way, interesting results should be obtained for the applications of hydraulic management to a typical area of the Mediterranean environment.

Other aspects will concern the introduction of these works in the landscape; notice that, during the execution of works in the reach between Ghemmieri bridge and Tas-Salib bridge, a part of a previous water-

(4) To respect as much as possible the typology of the existing wall, it was thought to reconstruct it by numbering each single square stone for them to be correctly repositioned later on.

(5) Among others, refer to the E.B.I. (Ghetti, 1986) based on the use of bentonic macroinvertebrates.

course management probably of the last century has come out. The initial project was then slightly modified to adapt the introduction of these works to the present context, so that the accomplished intervention may also preserve evidence of the "history" of management over the considered reach. The methodology proposed, i.e. the accomplishment of a "pilot project" in a limited area before the execution of the global intervention, can be, in general, hardly proposed due to constraints of different types, as well as to the characteristics of "urgency" of some measures. It is worthy noticing, however, that it may be extended to other special cases: for instance, due to the relative environmental "uniqueness" of the intervention area that recommends caution in carrying out the works; for a preliminarily assessment of the efficacy of the proposed solutions or their introduction in the landscape (in the considered case all the previously mentioned motivations contributed); for other various situations that however recommend the implementation of a preliminary "test", with subsequent monitoring, before moving to the final regulation of the watercourse. Finally, there is another aspect of the present work that can be generalized starting from the specific case.
The implementation of the "Chadwick Lakes" project at its various stages and the multidisciplinary approach applied to it since the beginning has promoted numerous and quite interesting studies and research works.
It has thus given rise both to studies directly related to its purposes, as those concerning the geological-hydrological (Mangion, 1998) and ecological (Lanfranco and Schembri, 1997; Schembri, Micallef and Lanfranco, 1997a; Schembri, Micallef and Lanfranco, 1997b) aspects of the watershed, and to wider studies, as the one about the system of valleys of Malta (Haslam and Borg, 1998), about land use in the Wied il-Qlejgha watershed (Borg and Haslam, 1998) and about the analysis of the environmental impact, and of visual aspects in particular, in the area of "Chadwick Lakes" (Borg *et al.*, 1997).
The elaboration stage of the project, has thus focused the attention of the Maltese public administration and of local researchers on these themes and on the shortage of exhaustive information sometimes available on specific aspects. Thanks to the multidisciplinary approach adopted, the project has played a catalyst role for a number of studies and research works that, going even beyond the purposes strictly related to its implementation, have given a better knowledge of the Maltese territory and, consequently, we think also a greater awareness of environmental characteristics of the island and its resources and peculiarities that could be a sound basis both for further insight and for correct land management policies. ●

(6) W = watercourse, 1b = lower banks, ub = upper banks, lb + ub = b (banks).

References

Benfratello G. (1998) - Il fiume. Un sistema complesso. Terr.A in brief, year 1, n. 0.

Borg J. and Haslam S.M. (1998) - A study of the land use of Wied il-Qlejgha (from Tas-Salib bridge, l/o Rabat to il-Minkba, l/o Mosta). Unpublished report, Malta.

Borg. M., Briffa C., Darmanin S., Borg J. and Spiteri, J. (1997) - Chadwick Lakes. Visual Analysis. Unpublished report, Malta.

Debono G. and Xerri S. (1993) - Geological map of the Maltese Islands. Oil Exploration Directorate. Office of the Prime Minister, Valletta, Malta.

Ghetti P.F. (1986) - I macroinvertebrati nell'analisi di qualità dei corsi d'acqua. Provincia Autonoma di Trento.

Haslam S.M. and Borg J. (1998) - The river valleys of the maltese islands. Environment and human impact. Islands and Small States Institute, Malta and CIHEAM, Bari.

Lanfranco E. and Schembri P.J. (1997) - The "Chadwick Lakes" Project: a report on plants suitable for use in the revegetation of Wied il-Qlejgha. Malta University services Ltd.

Mangion J. (1998) - An Environmental Impact Assessment (Geology and Hydrology) of the Rehabilitation Works at the Burmarrad Surface-Water Catchment Area. Unpublished report, Malta.

Martino V.N. *et al.* (1995) - Ricerca sulle implicazioni ambientali di opere in gabbioni e materassi Reno in ambito fluviale. Officine Maccaferri - Ministero dell'Ambiente, Bologna.

Pignatti S. (1982) - La flora d'Italia. 3 voll., Edagricole, Bologna.

Puglisi S. (1998a) - Le sistemazioni idraulico-forestali tra revisione e sviluppo. Quaderni di Idronomia Montana, n.17. Ed. Bios, Cosenza.

Puglisi S. (1998b) - Per ambiente e difesa del suolo c'è bisogno di nuove risposte. Terr.A in brief, year 1, n. 1.

Schembri P.J. (1993) - Physical geography and ecology of the Maltese Islands: a brief overview. Options Méditerranéennes, Sér. B/n°7, Malta.

Schembri P.J., Micallef S. and Lanfranco E. (1997a) - Baseline ecological study of Wied il-Qlejgha (Chadwick Lakes) carried out on behalf of the Department of Agriculture. Fiddien to Ghemmieri bridge. Malta University services Ltd.

Schembri P.J., Micallef S. and Lanfranco E. (1997b) - Baseline ecological study of Wied il-Qlejgha (Chadwick Lakes) carried out on behalf of the Department of Agriculture. Ghemmieri bridge to Tas-Salib bridge. Malta University services Ltd.

Schembri P.J. and Sultana J. (1989) - Red data book for the Maltese Island. Environment Division - Ministry of Education. Department of Information.

Zezza F. (1971) - Aspetti idrogeologici delle formazioni terziarie di Malta. Geologia Applicata e Idrogeologia, vol. VI, pp. 113-134.

Appendix

The major species present in the area of "Chadwick Lakes" grouped by families are reported. For each species it was indicated the biological and growth form followed by the corresponding chorological group and by a distinctive note on their water requirements. In making the flora list, a net distinction was not made between the species of the three areas identified (6), since the corresponding plant groups often integrate with each other. The inclusion of bank species along the river bed, when it is dry, and vice versa, the rise of aquatic species on the banks when the saturation degree is high are frequently observed.

Fam. *Cupressaceae*			
Cupressus sempervirens L.	Ph scap	Eurymediterranean	ub
Fam. *Salicaceae*			
Populus alba L.	Ph scap	Paleotemperate	lb
Salix alba L.	Ph scap	Paleotemperate	lb
Fam. *Moraceae*			
Ficus carica L.	Ph scap	Medit.-Turanian	ub
Morus alba L.	Ph scap	Asiatic	ub
Fam. *Urticaceae*			
Parietaria diffusa M. et K.	HC scap	Eurymediterranean	b
Fam. *Cactaceae*			
Opuntia ficus-indica (L.) Miller	Ph succ	Neotropical	ub
Fam. *Polygonaceae*			
Rumex conglomeratus Murray	HC scap	Eurasiat.-Centre west.	w, lb
Fam. *Chenopodiaceae*			
Atriplex spp.			
Beta vulgaris L.	HC scap / Th scap	Eurymediterranean	ub
Chenopodium album L.	Th scap	Subcosmopolite	ub
Chenopodium ambrosioides L.	Th scap (HC scap)	Cosmopolite	ub
Chenopodium murale L.	Th scap	Subcosmopolite	ub
Fam. *Amaranthaceae*			
Amaranthus graecizans L.	Th scap	Paleosubtropical	ub
Fam. *Caryophyllaceae*			
Spergularia bocconii (Scheele) Asch., Gr.	Th scap (HC bienn)	Subcosmopolite	b
Fam. *Guttiferae*			
Hypericum triquetrifolium Turra	HC scap	Stenomediterranean	b
Fam. *Papaveraceae*			
Papaver rhoeas L.	Th scap	E-Mediterranean	b
Fam. *Capparidaceae*			
Capparis spinosa L.	NP	Eurasiatic (Subtropical)	ub
Fam. *Cruciferae*			
Diplotaxis tenuifolia (L.) D.C.	HC scap	Submediterranean	b
Fam. *Rosaceae*			
Potentilla reptans L.	HC ros	Subcosmopolite	w, lb
Fam. *Oxalidaceae*			
Oxalis pes-caprae L.	G bulb		ub
Fam. *Euphorbiaceae*			
Ricinus communis L.	Th scap - Ph scap	Paleotropical	lb
Fam. *Vitaceae*			
Vitis vinifera L.	Ph lian		ub
Fam. *Malvaceae*			
Lavatera cretica L.	Th scap	Stenomediterranean	b
Malva sylvestris L.	HC scap (Th scap)	Subcosmopolite	b
Fam. *Cucurbitaceae*			
Ecballium elaterium (L.) A. Rich.	G bulb	Eurymediterranean	b
Fam. *Lythraceae*			
Lythrum hyssopifolia L.	Th scap	Subcosmopolite	w
Lythrum junceum Banks et Sol.	HC scap (Th scap)	Stenomedit.-Macarones	w
Fam. *Onagraceae*			
Epilobium tetragonum L.	HC scap	Paleotemperate	w, lb
Fam. *Araliaceae*			
Hedera helix L.	Ph lian	Medit.-Atlantic	ub
Fam. *Umbelliferae*			
Apium nodiflorum (L.) Lag.	HC scap / Hy root	Eurymediterranean	w
Ferula communis L.	HC scap	S-Mediterranean	ub
Foeniculum vulgare Miller	HC scap	S-Mediterranean	ub
Kundmannia sicula (L.) D.C. (K.)	HC scap	Stenomediterranean	ub
Fam. *Primulaceae*			
Anagallis arvensis L.	Th rep	Subcosmopolite	b
Fam. *Oleaceae*			
Olea europaea L.	Ph tuft / Ph scap	Stenomediterranean	ub
Fam. *Rubiaceae*			
Galium aparinae L.	Th scap	Eurasiatic	ub
Fam. *Convolvulaceae*			
Convolvulus arvensis L.	G rhiz	Cosmopolite	lb
Convolvulus cantabrica L.	HC scap	Eurymediterranean	b
Fam. *Verbenaceae*			
Verbena officinalis L.	HC scap	Cosmopolite	ub
Fam. *Scrophulariaceae*			
Antirrhinum tortuosum Bosc	Ch frut	Steno-W-Mediterranean	ub
Veronica anagallis-aquatica L.	HC scap (Th scap)	Cosmopolite	w
Fam. *Acanthaceae*			
Acanthus mollis L.	HC scap	W-Stenomediterranean	b
Fam. *Plantaginaceae*			
Plantago major L.	HC ros	Subcosmopolite	w, lb
Fam. *Caprifoliaceae*			
Sambucus ebulus L.	G rhiz	Submediterranean	w, lb
Fam. *Compositae*			
Aster squamatus (Sprengel) Hieron.	Th scap	Cosmopolite	ub
Atractylis gummifera L.	HC ros	S-Mediterranean	ub
Chrysanthemum coronarium L.	Th scap	Stenomediterranean	ub
Galactites tomentosa Moench	HC bienn	Stenomediterranean	ub
Notobasis syriaca (L.) Lass	Th scap	Stenomediterranean	ub
Sonchus oleraceus L.	Th scap (HC bienn)	Subcosmopolite	b
Xanthium strumarium L.	Th scap / HC scap	Neotropical	ub
Fam. *Alismataceae*			
Alisma plantago-aquatica L.	Hy root	Subcosmopolite	w
Fam. *Liliaceae*			
Allium commutatum Guss.	G bulb	E-Stenomediterranean	b
Asparagus aphyllus L.	Ch frut	S-Mediterranean	ub
Fam. *Graminaceae*			
Andropogon distachyus L.	HC tuft	Paleotropical	b
Arundo donax L.	G rhiz	Subcosmopolite	w, lb
Avena barbata Potter	Th scap	Eurymedit.-Turanian	b
Avena sterilis L.	Th scap	Eurymedit.-Turanian	b
Bromus hordeaceus L.	Th scap	Subcosmopolite	b
Bromus madritensis L.	Th scap	Eurymediterranean	b
Cynodon dactylon (L.) Pers	G rhiz / HC rep	Termocosmopolite	b
Echinochloa crus-galli (L.) Beauv.	Th scap	Subcosmopolite	ub
Festuca arundinacea Schreber	HC tuft	Paleotemperate	w, lb
Hordeum leporinum Link	Th scap	Eurymediterranean	b
Phalaris coerulescens Desf	HC tuft	Stenomedit.-Macarones	ub
Phalaris minor Retz.	Th scap	Paleosubtropical	ub
Phalaris tuberosa L. (=P. Bulbosa L.)	HC tuft	Stenomedit.-Macarones	ub
Polypogon monspeliensis (L.) Desf.	Th scap	Paleosubtropical	w, lb
Polypogon viridis (Gouan) Breistr.	HC tuft	Paleosubtropical	w, lb
Fam. *Araceae*			
Arum italicum Miller	G rhiz	Stenomediterranean	ub
Fam. *Cyperaceae*			
Bolboschoenus maritimus (L.)(*)	G rhiz	Cosmopolite	w
Cyperus longus L.	G rhiz / He	Paleotemperate	w
Carex distans L.	HC tuft	Eurymediterranean	w, lb
Carex divisa Hudson	G rhiz	Eurymedit.-Atlantic	w, lb
Carex otrubae Podp	HC tuft	Eurymedit.-Atlantic	w
Eleocharis palustris (L.) R. et S.	G rhiz	Subcosmopolite	w
Holoschoenus vulgaris Link(**)	G rhiz	Mediterranean-Atlantic	w, lb

(*) = *Scirpus maritimus* L.
(**) = *Scirpus holoschoenus*.