Delimara Gas and Power

Combined Cycle Gas Turbine

and

Liquefied Natural Gas
receiving, storage, and re-gasification facilities

Delimara Power Station

Triq il-Power Station – Marsaxlokk

ENVIRONMENTAL IMPACT STATEMENT

Environmental Survey Reports

Appendix Two

Volume One

prepared by
ERSLI Consultants Ltd
on behalf of
Enemalta Corporation

20 December 2013

Volumes	Consultants	Fields
One	Archaeology Services Cooperative	Cultural Heritage (Terrestrial)
	Axiak, Victor	Marine Water Bodies
Two	Borg, John J	Vertebrate Fauna
	Borg, Joseph A & Evans, Julian	Marine Ecology
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	Formosa, Marvin	Social Impact Assessment
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Report on the Cultural Heritage
for the Environmental Impact Assessment
regarding the proposed Combined Cycle Gas Turbine (CCGT) and
Liquid Natural Gas (LNG) storage and regasification facility
in the 'power station site' in Delimara Site.

Kurt Balzan, Daniel Borg, Marlene Borg, Ernest Vella

July 2013

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1. INTRODUCTION

1.1 Terms of Reference

In compliance with Maltese legislation and within the framework of planning policies, the Malta Environment and Planning Authority (MEPA) requires that an Environmental Impact Assessment is carried out with respect to the planned Combined Cycle Gas Turbine (CCGT) and Liquid Natural Gas (LNG) storage and regasification facility in the 'power station site' in Delimara Site, Marsaxlokk.

Archaeology Services Co-operative Ltd has been commissioned to carry out the base line studies relative to cultural heritage by Enemalta Corporation. This report is based on the draft Terms of Reference issued by MEPA on 31st May 2013 and the final version issued in June 2013.

1.2 Location and Brief Description of the Site

This proposed development lies within the site of the present power station at Delimara. Two sites have been earmarked within the footprint of the power station. A number of alternative locations for the Combined Cycle Gas Turbine (CCGT) plant and the Liquefied Natural Gas (LNG) Plant have been pinpointed for the site. However, these cover two locations, marked Site A and Site B in **Figure 1** below. The area of influence lies within a radius of the two sites, as shown in **Figure 1** as well. Both areas are within the Delimara peninsula in what is mostly cultivated terraced fields (**Figure 2)**. The proposed development is very similar to Option B presented in the first stages of the project, covering the footprint of the present power station, with a jetty connecting an FSU to the south east of the site, and 4 stacks on the main site.

Present site of Delimara Power Station

Proposed Sites for CCGT and LNG Plants

Respective Areas of Influence

Figure 1: Proposed area of development and the area of influence for the cultural heritage study

Figure 2: Areas of Influence as seen from Marsaxlokk Bay

2. REPORT COMPILATION METHOD

2.1 Methodology of Study

An Environmental Impact Assessment is required to cover the area and its surroundings. Such an evaluation is required to provide information regarding provisions for environmental protection including, among others, the protection of archaeological and cultural (both vernacular and rural, including rubble walls, huts, wells, irrigation channels, ancient quarrying sites and farmhouses) features.

This report is based on findings from what is technically referred to as Ground Reconnaissance. This method of investigation primarily involves actual fieldwork, and incorporates the consultation of documentary sources and place-name evidence [Renfrew & Bahn 1991: 63]. The fieldwork carried out consisted of a site-surface survey, or field-walking, in order to locate and record the whereabouts of sites and features. No aerial reconnaissance or sub-surface surveys, including excavations, were carried out.

The report is the result of a site-surface survey complimented by desktop research. This work was carried out in June 2013 by qualified archaeologists from ASC Ltd. The report compilation method was developed after an initial site visit to examine the general landscape of the area.

The survey was undertaken by Kurt Balzan BA Archaeology and English, Diploma Public Administration; Daniel Borg BA (Hons) Archaeology, MA; Marlene Borg BA (Hons) Archaeology, MA; Ernest Vella BA (Hons) Archaeology, MA; of Archaeology Services Co-operative Ltd. On-site surveys were carried out on 25 June 2013, 28 June 2013 and 3 July 2013.

2.2 Desk-Top Research

The general works of Abela (1647) and Wettinger (2000) were consulted, as well as Evans (1971), Trump (1997), Sagona (2002), Spiteri (1996; 2008) and Bonanno (2005). Other publications have also been consulted and are listed in the bibliography.

The Annual Reports on the Workings of the Museums Department (MARs), published from 1904 onwards, were also examined, providing no references for the area in question. Specific works regarding the different settlements which are affected by the proposed development were also consulted in order to further our understanding of the area under consideration as well as its sites and features.

Survey sheets dating to 1898-1910 available at the Chief Draughtsman's Office of the Works Department were also consulted to study the changes in landscape and to date some of the features.

2.3 Site Survey

The area of the proposed development and its surrounding areas as described above. The survey was limited to surface investigation, leaving out any possible cultural heritage buried beneath the ground. We therefore cannot exclude the possibility that archaeological remains do exist beneath the surface of the site surveyed.

The site survey consisted in walking along all roads in the area, looking for visible cultural features such as:

- architectural structures and the remains of structures;
- evidence of rock-cutting and rock-cut chambers;
- patterns and building techniques of rubble walls and dry-stone walls;
- piles of stones or dispersed large stones;
- caves or cavities in the rock-faces;
- rock-cut features, quarry marks, and cart-ruts;
- surface scatters of artefacts such as pottery sherds;
- important public and private buildings with particular architectural features.

2.4 Recording Systems

Any feature considered to be of cultural interest was recorded on the sheets described above including all the information required as detailed in **Appendix 1**.

2.5 Statutory Protection

The importance of the conservation of the identified sites and features has been identified with reference to relevant legislation standards, guidance and practices. These include the Structure Plan for the Maltese Islands that refer to the grading of archaeological sites and buildings, Development Planning Act 1992, the Cultural Heritage Act and the Northwest Local Plan.

2.5.1 Cultural Heritage Act

This Act provides overall protection to "all movable or immovable objects of artistic, architectural, historical, archaeological, ethnographic, palaeontological and geological importance and includes information or data relative to cultural heritage pertaining to Malta or to any other country" (section 2). In section 3 it also specifies that "For the purposes of this Act, an object shall not be deemed to form part of the cultural heritage unless it has existed in Malta, including the territorial waters thereof, or in any other country, for fifty years, or unless it is an object of cultural, artistic, historical, ethnographic, scientific or industrial value, even if contemporary, that is worth preserving".

"No person shall make any interventions on such cultural property or classes thereof without first having obtained a permit therefore from the Superintendent" (Section 44.3). Applications are determined subject to the results of prior investigation: "Before determining an application under subarticle (3) hereof the Superintendent may require such information including the results of such tests, examinations or inspection by such persons accredited under this Act for the purpose as may be required by the Superintendent" (Section 44.4).

The restrictions on archaeological excavations is stated in Section 43(1) whereby "Archaeological or palaeontological excavations or explorations on land as well as in the territorial waters or in the contiguous zone of Malta can only be made by the Superintendent, or with written permission of the Superintendent". Chance discoveries of archaeological remains are also regulated by Section 43(2), "Any person who, even accidentally, discovers any object, site or building to which this Act applies in accordance with article 3, shall immediately inform the Superintendent, keep the object found in situ, and shall not for a period of six working days after informing the Superintendent proceed with any work on the site where the object of cultural property is discovered". The details about rights and obligations by all parties in the eventuality of an archaeological discovery are described in Sections 43(3), 43(4), 43(5), 43(6), 43(7).

2.5.2 Legal Notice 169 of 2004

The Rubble Walls and Rural Structures (Conservation and Maintenance) Regulations as amended by LN 169 of 2004 protects all rubble walls and non-habitable rural structures in "view of their historical and architectural importance, their exceptional beauty, their affording a habitat for flora and fauna, and their vital importance in the conservation of the soil and water". Walls may be sensitively repaired without MEPA's prior authorisation. Certain areas may also be declared to be Rubble Wall Conservation Areas in which no alterations to the location or construction of rubble walls and the traditional methods of their repair and maintenance will be permitted without the written approval of MEPA. In such Conservation Areas, the Minister for the Environment may order the owner or occupier to repair and re-erect all the rubble walls within the area, and to continue to maintain them. The dismantling of the wall requires a permit from MEPA.

2.5.3 Structure Plan Policies

The Structure Plan contains policies that refer to the grading of archaeological sites and buildings.

Policy ARC 1 states that in Local Plans within Rural Conservation Areas the Planning Authority may identify and designate Areas and Sites of Archaeological Importance. Structure Plan Policy ARC 2, indicates that if an area is considered to be of top priority conservation (Class A), no development will be allowed that would adversely affect the natural setting of these monuments or sites. A minimum buffer zone around the periphery of the site will need to be established in which no development will be allowed. Features identified as Class B are regarded as very important and should be preserved at all costs. Adequate measures to be taken to preclude any damage from immediate development. For features that are listed as Class C, every effort must be made for preservation, but may be covered up after proper investigation, documentation and cataloguing. Provision for subsequent access shall be provided. Class D features are similar to numerous others and must be properly recorded and catalogued before covering or destroying. Class E has been introduced in the Northwest Local Plan (approved in 2006). This deals with a site or area in which the Superintendence of Cultural Heritage or MEPA may have some archaeological interest. Should MEPA or the Superintendence have such an interest, the applicant proposing development in that location will be required to undertake an investigation, including excavation, if necessary. If following investigation, the Superintendence of Cultural Heritage considers the site to be of archaeological value, MEPA will normally refuse development permission if the proposed development would lead to the destruction of the site, or require the development to be modified so that the archaeological value of the site is protected.

The permissible effects of the proposed development on archaeological remains are regulated by policy ARC 3 that states that "development affecting ancient monuments and important archaeological areas and sites, including areas and sites having such potential, will normally be refused if there is an overriding case for preservation. Where there is no overriding case for preservation, development of such sites will not normally be permitted until adequate opportunities have been provided for the recording and, where desirable, the excavation of such sites".

All other archaeological features listed in the catalogue may be included in the National Protective Inventory of the Planning Authority according to policy ARC 7 for which protection is granted by means of policy ARC 6.

Rural buildings and rubble walls are protected by the Rural Conservation Areas policies and policy UCO 7. Policy UCO 7 establishes the grading of listed buildings in Urban Conservation Areas and regulates works that are acceptable in such buildings.

In the case of architectural heritage the following protection levels apply:

Grade 1 buildings are of outstanding architectural or historical interest that shall be preserved in their entirety. Demolition or alterations which impair the setting or change the external or internal appearance, including anything contained within the curtilage of the building, will not be allowed. Any interventions allowed must be directed to their scientific restoration and rehabilitation. Internal structural alterations will only be allowed in exceptional circumstances where this is paramount for reasons of keeping the building in active use.

Grade 2 protection applies to buildings of some architectural or historical interest or which contribute to the visual image of an Urban Conservation Area. Permission to demolish such buildings will not normally be given. Alterations to the interior will be allowed if proposed to be carried out sensitively and causing the least detriment to the character and architectural homogeneity of the building.

Grade 3 buildings have no historical importance and are of relatively minor architectural interest. Demolition may be permitted provided the replacement building is in harmony with its surroundings.

2.5.4 Scheduling

The area of influence for the proposed development lies within an area of High Landscape Value designated as Levels 2 and 3 by GN400/96 as shown in Figure 3. This means that this area "encompasses an array of diverse components such as geological formations, geomorphological and/or semi-natural terrain and ecosystems" (URL: http://www.mepa.org.mt/malta-scheduled-property, accessed on 30 June 2013). There are no scheduled sites in the area of influence.

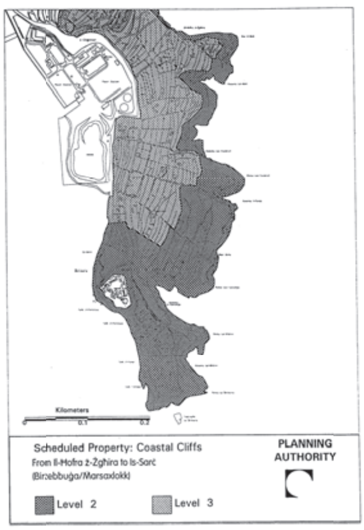


Figure 3: Boundary of AHLV of Delimara (from GN400/96)

2.5.5 The European Landscape Convention (Florence Convention)

The Florence Convention signed by all members of the Council of Europe, and therefore by Malta as well, clearly defines landscape and is aware that "sustainable development based on a balanced and harmonious relationship between social needs, economic activity and the environment" must be achieved (European Landscape Convention 2000: 1). It also maintains that "the landscape is an important part of the quality of life of people everywhere" and that it is a "key element of individual and social well-being and that its protection, management and planning entails rights and responsibilities for everyone" (European Landscape Convention 2000: 1).

According to this Convention landscape "means an area, as perceived by people, whose character is the results of the action and interaction of natural and/or human factors" and covers "natural, rural, urban and peri-urban areas" (European Landscape Convention 2000: 2).

2.5.6 The Burra Charter (The Australia ICOMOS charter for the conservation of places of cultural significance)

The Burra Charter provides guidance for the conservation and management of places of cultural significance. It states that "Places of cultural significance enrich people's lives, often providing a deep and inspirational sense of connection to community and landscape, to the past and to lived experiences… They are irreplaceable and precious". Such places must therefore be conserved for present and future generations.

The Charter promotes a vigilant approach to change: "do as much as necessary to care for the place and to make it useable, but otherwise change it as little as possible so that its cultural significance is retained". Places of cultural significance are made up of *fabric,* that is all physical materials constituting them like building interiors, excavated material, fixtures and components. Such fabric should be disturbed as little as possible, even for study and documentation purposes.

2.5.7. The Marsaxlokk Bay Local Plan (May 1995)

Policy MT03 in the Marsaxlokk Local Plan includes the area of influence of the proposed development in a proposed heritage trail with MD01 suggesting the establishment of Delimara National Park and "the effect of the Power Station…be reduced as much as possible". This park should also have "improve the access road, provide designated car parks and a recreational footpath system will be introduced" (MD02). According to the same Local Plan, Forts Tas-Silġ and Delimara, both in the vicinity of the Delimara Power Station and the area of influence covered by this study, are in a bad state of repair and should be rehabilitated (MD03). MD 04 directly deals with the Power Station in that it states that the visual impact of the structures should be mitigated by afforestation and landscaping. **Figure 4** shows the areas affected by the policies mentioned above.

Figure 4: Excerpt from the Marsaxlokk Bay Local Plan Policy Map showing Policies affecting Delimara Peninsula.

2.6 Difficulties

The proposed development lies within disturbed land in the confines of the present Delimara Power Station. Therefore, the land directly affected by this development has already been highly disturbed and there are no indications of cultural heritage on the said site. On the other hand, the area of influence is mostly cultivated land, most of which is inaccessible, locked, and covered in vegetation as shown in **Plate 1**. Another difficulty lies in a number of field rooms in the area, which, since they are still being used, modern accretions have been added on, make it difficult to date such structures.

Plate 1: Inaccessible land at Il-Wilġa (Area of Influence for Site A)

3. CULTURAL LANDSCAPE ASSESSMENT

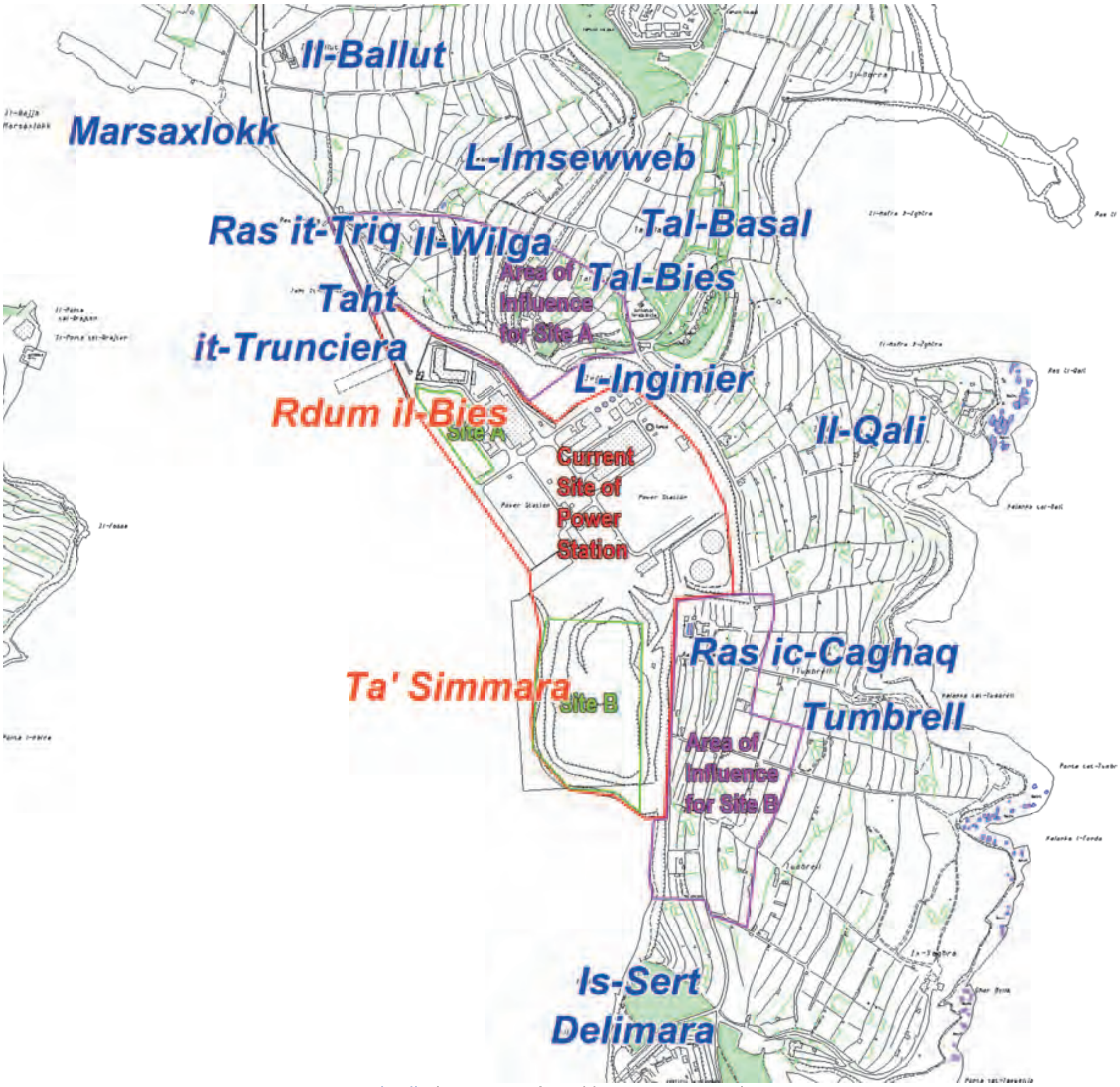
Archaeological research is increasingly concerned with historical landscapes. The whole of our landscape, rural and urban, is a vast historical document. Such approaches aim at the preservation of historically important landscapes, especially when relating to arrangements of archaeological remains within the landscape. The historical landscape considers not only the important sites, but also the '*flora, fauna, topography, geology and scenery, as well as spiritual matters such as aesthetics, artistic and literary associations, folklore and tradition*.' [Darvill et al. 1993: 571].

3.1 Toponomy

A number of place-names have been identified from the survey sheet or other literature in the proposed area of development and its immediate surroundings (refer to Figure 5). Toponomy, can be a very useful tool to reconstruct past landscapes as they give a hint of past land uses, tenure names, type of vegetation, and also topographical features that existed in the area. Below is a list of these place-names and related information according to the tunnel segment.

Marsaxlokk	A notarial deed of 1487 mentions 'Marsasloc', when it refers to the port at the south east of Malta (Wettinger 2000: 365).
Delimara	The place name of 'Dejr l-Imara' or 'Dejr Limara' may be derived from a Semitic personal name. A Basilius Limara *cives Melite* was recorded in a 1324 document (Buhagiar 2002: 263). The earliest reference to this placename dates to1486 and subsequent notarial documents when referring to the headland bounding Marsaxlokk. According to Wettinger (2000: 109), it refers to the sheepfold of commanders, and to 'Calimera', a surname which was common in Malta before the 15th century. Abela (1647: 21) refers to the area as 'Il Marbat ta' Deyr Limara' referring to the hill before entering the Harbour of Marsaxlokk. Abela explains that the word "marbat" means a place where one can tie, "Deyr" means a convent or a community living together, "Limara" could either refer to "el Aamara", that is a dwelling or "Eemara " che tanto suona quanto che fabrica".
Il-Ballut	No reference was found by Wettinger (2000) to this place name in this locality. However, it is found in other localities in Malta and refers to oak trees (Wettinger 2000: 17).
L-Imsewweb	No reference was found in Wettinger (2000).
Ras it-Triq	No reference was found in Wettinger (2000).
Taht it-Trunċiera	This place name refers an entrenchment or to tal-Wilġa Battery (**DLM13/002**) built by the Order of St John to guard Marsaxlokk Bay from corsair incursions.

Rdum il-Bies/Tal-Bies	This was a militia watching post in the Knights Period located between Xrobb l-Għaġin and Delimara. This was listed by Abela and refers to the peregrine falcon, and was a common nickname or personal name in Zejtun until recently (Wettinger 2000: 33).
Ta' Simmara	No reference was found to this place name, although it might be a corruption of 'Simar' which is a place name found in other localities and refers to rushes (Wettinger 2000: 531-532).
Is-Sert	No reference was found to this place name.
Tumbrell	Abela also mentions this location in between Xrobb l-Għaġin and Delimara (Abela 1647: 21). It refers to a kind of fish – the bonito (Wettinger 2000: 557).
Ras ic-Caghaq	No reference to this place name in this locality was found. According to Wettinger (2000: 87), the place name refers to either a pebbly beach or "less likely" to a personal name. Given the location of this place name, the former is the most plausible.
Il-Qali	Given that the area is characterised by a number of inlets, the toponym of 'cali' or qala, is obviously used. Although Wettinger (2000), does not locate any references to this place name in Delimara, the reference to the inlets is evident.
L-Inginier	No reference to this place name was found.
Tal-Basal	No reference to this place name was found.
Il-Wilġa	Wettinger (2000: 595) refers to 'Il-Wilġa ta' Delimara', found in a notarial deed of 1558, and translates it into 'the hill side-field of Delimara.



Tumbrell Place name found in 1992 survey sheet
Rdum il-Bies Place name found in 1910 survey sheet

Figure 5: Location of **P**lace Names covered by this study

3.2 Historical Importance of the Area

3.2.1 Prehistoric Period

Overlooking Marsaxlokk Bay which is the most accessible landing post of the south-eastern Maltese coast. About 1 kilometre away from the site of development, at a height of about 40m above sea level, is the multicultural site of Tas-Silġ. At this site structural remains from the Prehistoric period in the form of a temple apse have been integrated within a Phoenician temple dedicated to Astarte. Recent excavations behind this apse carried out by the Missione Archeologica Italiana A Malta, have uncovered other prehistoric structures which are presently being investigated (Recchia 2007). Human activity at Tas-Silġ dates back to the Neolithic and continues to the Bronze Age, followed by the Phoenician and Classical periods and up to the medieval period. According to David Trump (2002:253), prehistoric sherd scatters identified on the southern slopes of Tas-Silġ, are an indication of a prehistoric "open village" in this area. The Tas-Silġ temple, is one of the three prehistoric sites located in the south-eastern part of Malta, the others being Ħal-Ġinwi, and Xrobb L-Għaġin all located just 2 kilometres away from each other (refer to **Figure 6**).

Figure 6: Location of Prehistoric sites in relation to the area of proposed development

3.2.2 Classical Period

Around 700 BC the Phoenicians took over the Tas-Silġ prehistoric temple and integrated it to their own temple dedicated to Astarte (Bonanno 2005: 284-285). Similarly, the prehistoric site of Ħal- Ġinwi was also occupied by the Phoenicians as attested by the remains of pottery sherds, masonry and mosaic pavements dating to that period (Sagona 2002: 3). By the second-century Ptolemy listed Tas-Silġ sanctuary as one of the five most important locations on the Maltese Islands (Bonanno 2005: 220) while Cicero wrote that this temple possessed a number of riches and was universally respected (Verrines: II, 4,103-104).

The strategic location of Tas-Silġ, guaranteed the economic prosperity of the Marsaxlokk area and its uninterrupted settlement. This was also possible due to the sheltered quality of Marsaxlokk Harbour protected by the two promontories of Delimara and Benġħajsa in turn divided into two inlets by the Marnisi peninsula. This port was one of the most sought sheltered inlets up to the Early Modern Period when the Grand Harbour in Valletta became the main harbour on the Island (Bruno 2009: 117-118). The fact that the Tas-Silġ sanctuary was located on a rounded hill overlooking Marsaxlokk Bay "guaranteed a wide control over maritime activity, also making it clearly visible to those arriving by sea" (Bruno 2009: 121). This is also confirmed by Gambin (2005: 92) who writes that vessels entering Marsaxlokk Bay would have been able to locate the temple perched on the Tas-Silġ hill and used it as a waypoint. As it was the common practice in antiquity of offering sacred objects and sacrifices in a maritime context it is therefore assumable that the same offerings were made by the vessels entering and leaving Marsaxlokk as a means of thanksgiving or supplication for a save journey. Bruno (2009: 121 &1 64 concludes the economic potential of this area was due to the Marsaxlokk Harbour and its maritime activities as attested by the 1960's underwater discoveries that this bay has yielded.

From a field survey conducted in 1999 by the Missione Archaeologica Italiana in the area of Tas-Silġ,a number of "closely grouped sites" were identified that could have been either rural settlements linked to the sanctuary or properties pertaining to the sanctuary itself (Bruno 2009: 119). Other remains were also discovered, including a Roman building with a number of rooms complete with a bath complex discovered at Marine Street in Marsaxlokk overlooking Marsaxlokk Bay. This could have been the "villa marittima" recorded in the Musuem Annual Reports of 1930-1931 and 1931-1932 (Gambin 2005: 105, Bruno 2009: 48 & 119, MAR 1930-31: III-IV, MAR 1931-32: V). Brunella Bruno (2009: 119) believes that this structure could have been part of a more extensive settlement which could have existed on the exact location of the present fishing village. A similar structure with a bath complex was also discovered at Delimara (Caruana 1899:222, Bruno 2009: 49), but no further reference was found.

3.2.3 Medieval Period

The Medieval Period is very sparsely documented. The main urban centres were the fortified towns of Mdina and Birgu, with a number of casali or villages dotting the countryside. Information about the Medieval Period in the area of Marsaxlokk, mainly hails from the excavations carried out at Tas-Silġ by the Missione in the sixties. We know that by the fifth century a Paleochristian Basilica was built in the central area of the temple previously dedicated to Astarte. The temple by that time was almost deserted. This Basilica was built along the inner colonnade of a central courtyard and its interior was divided into three naives. Behind the central apse (pertaining to the prehistoric temple), was located the baptistery together with its baptismal basin. Nearby to this area, a medieval burial was excavated. Inside the Basilica in the central naïve, one would find the presbytery which was built by reused ancient materials recovered from the same site (Cagiano De Azavedo 1975: 89). Bruno (2009: 163,211) explains that during this period, Tas-Silġ "seems to have had an important maritime and territorial function", as confirmed by the finding of "exceptional" goods, like the small Byzantine amphorae normally related to wine imports that were coming from the Aegean-East Mediterranean Sea.

Excavations showed that the presbytery had been rebuilt several times, most probably due to the repeated sacking by the Arabs between 825 and 870AD when the site was permanently occupied by the aggressors. Throughout this period, the site must have suffered irreparable damage and destruction. (Cagiano De Azavedo 1975: 89). During this period of raid, there is evidence that at Tas-Silġ the walled structures were taken care of and also a tower was constructed on the seaward side (Bruno 2009: 129). Bruno 2009: 129) believes that during the Medieval period, Tas-Silġ must have look as a fortified structure to the Arabs who referred to it as *kasar*.

There is also the possibility that, later on a mosque was built in the baptistery, as indicated by a niche- shaped construction similar to a *mihrab* (a shallow apse typically found in Muslim mosques) that was found facing the direction of the Mecca (Cagiano De Azavedo 1975: 89). There is still no conclusive evidence whether at this time, the Christian cult at Tas-Silġ had survived or not, however, seeing the intensity by which the Arab culture took over the Maltese islands, Christianity would probably have been eradicated (Bruno 2009: 212). Of interest are the Arabic sources describing acts of plunder on a rich Byzantine marble building (probably referring to Tas-Silġ Basilica) committed by the Arabs, where precious materials and marbles were shipped to a palace in Tunis (Bruno 2009: 212).

By the twelfth century the site was mostly in ruins with just a few poor Arab dwellings (Cagiano De Azavedo 1975: 89). By that period, a church was built in the baptistery area of the old Basilica, probably to reconfirm the Christian tradition and the memories which had somewhat survived on this site (Cagiano De Azavedo 1975: 89,92 and Luttrell 1975: 35). There is no indications that the Christians tried to restore the former basilica which had been profaned by the Muslim rulers (Cagiano De Azavedo 1975: 89,92).

At the north east of the site, traces of a building of an ecclesiastical nature (probably a church) pertaining to the Norman period was uncovered. From this area, a large quantity of glazed Norman pottery was recovered. A tomb probably later than 1100 AD was also found in the vicinity. As all the structures found at Tas-Silġ, the foundations of this building were made from fragments of the ancient buildings in the area. Nearby to this building other structures were uncovered (Cagiano De Azavedo 1975: 92). Cagiano De Azavedo (1975: 93) believes that such complex could have been a monastery. However he also points out that there are no written sources to prove this hypothesis. Buhagiar (2005: 9) believes that a monastic complex could be possible, however the evidence is still inconclusive.

Given the scarce documentation about the area, the above description of activities going on at Tas-Silġ, shows that the area was inhabited. However, Delimara, was exposed to attack, and would have been scarcely populated. This is further attested by the fact that the Ottomans landed at Marsaxlokk in 1565 (Abela 1647: 21), and that a militia was established later on by the Order (see below).

3.2.4 Knights Period

With the arrival of the Knights of St John, coastal fortifications become a priority for the Order's defensive strategy for the Maltese Islands as proven throughout the seventeenth and eighteenth centuries (Spiteri 2008: 338). In the Siege of 1565, Marsaxlokk was vulnerable enough to let the Ottoman fleet land on the islands (Abela 1647: 21). By the early seventeenth-century the Turkish threat once again started to be felt, causing the Order to take into serious consideration the defence of its coastal waters (Spiteri 2008: 342-343). This led to the commissioning of the first set of large towers which were commissioned by Alof de Wignacourt between 1609 and 1620. These towers were the first step in creating a chain of coastal strong points around the Maltese shores (Spiteri 2008: 344). This strategy is witnessed with the erection of St Lucian Tower in 1610 (**Figure 7**) as the first step to defend the coast of Marsaxlokk Bay (Spiteri 2008: 344).

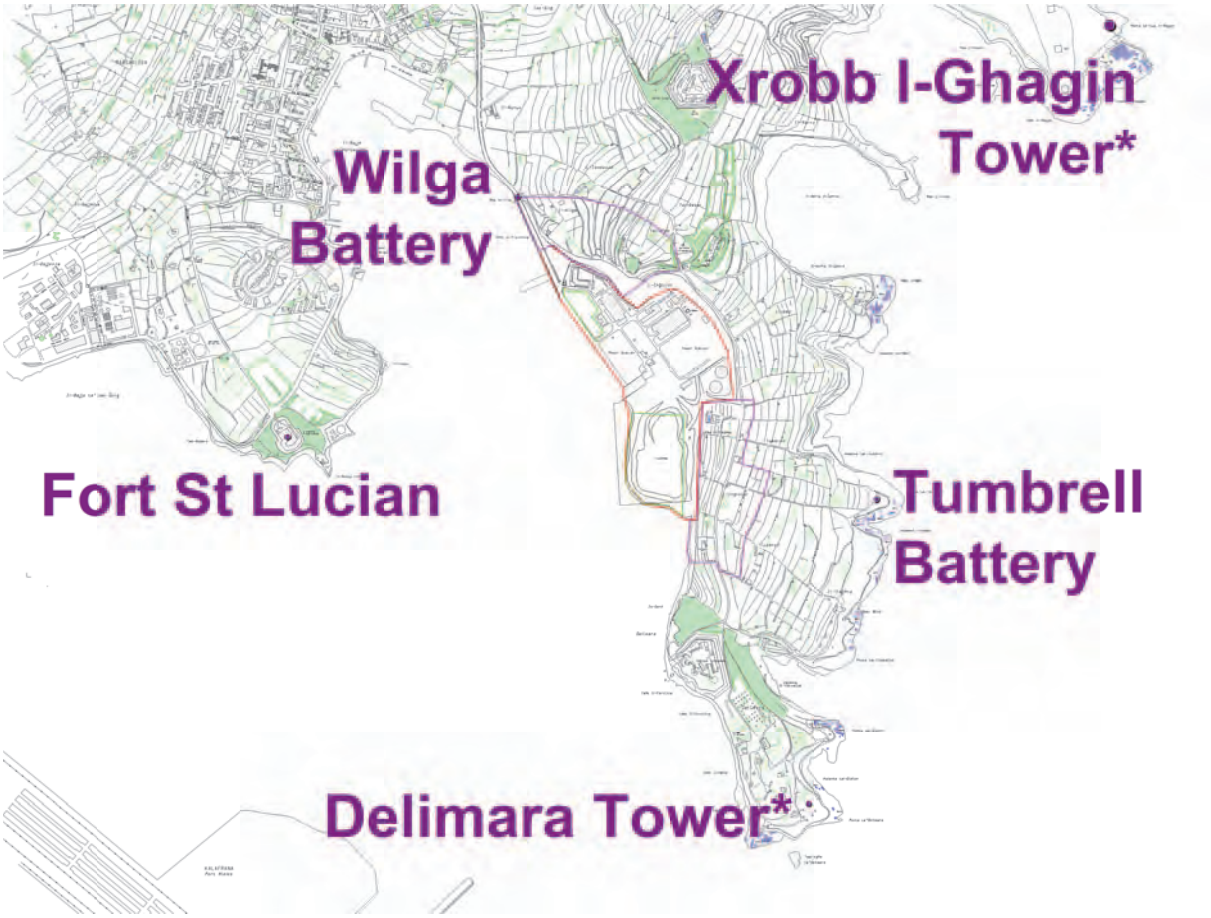


Figure 7: Fortifications built by the Order of St John in the vicinity of Delimara
(*) marks approximate location

Gian Frangisk Abela (1647: 60) gives a list of the "guardie marittime" to be found around the coast of Malta in 1647. Among the coastal watch posts serving under St. Lucian Tower we find the areas of Ras Guljana at Bengħisa and San Ġorġ, both keeping watch on Marsaxlokk Bay. Among the locations serving at St. Thomas Tower we find the watch posts for the Delimara area at Xrobb L-Għaġin (Sciuyereb el

Aagin) and Tumbrell. These coastal looking posts were later be substituted by a watch tower or coastal fortification.

By 1658, Grand Master de Redin commissioned thirteen smaller towers. These towers were to be manned by a permanent tower guard. Two of these towers were built at the strategic locations at Delimara and Xrobb L-Għaġin in Marsaxlokk (In **Figure 7**, marked with (*), their location is approximate). Both Towers were built in 1659 (Spiteri 1994:499) The now demolished Delimara Tower was the tenth tower to be built by de Redin. It was erected at the extreme end of the Delimara promontory and was designed in the same pattern of the other de Redin towers. The tower was two storeys high and its lower masonry was scarped. However it had some structural differences from the other ones, which included a box-machicoulis which projected from the tower's parapet and lateral buttresses, implying that the tower had some form of structural weakness (Spiteri 1988: 157, Spiteri 1989:170, Spiteri 1994:, Spiteri 2008: 352). Affixed to the tower was the following inscription:

FR. D. MARTIVS DE REDIN
M.MR. MELITAE ET GAULOS PRINCEPS
NE DORMI (ENTIBVS) SVBDITI IMPARATI
OFFEND...DECIMAM SPEVLAM
STATV...DAERE ANNO MDCLIX (Spiteri 1994)

The Xrobb L-Għaġin tower was the eighth tower to be erected from the thirteen De Redin towers. It was built on the Delimara headland south of St. Thomas Bay. This tower, being built of Globigerina Limestone, has been heavily damaged by the corrosive action of the sea water (Spiteri 1994:, Spiteri 2008: 460, 463-464).

Delimara Tower

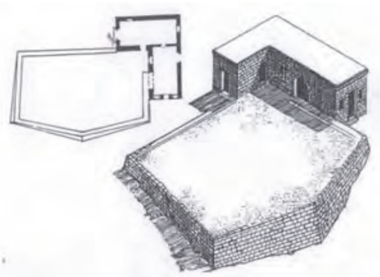
Remains of Xrop l-Għaġin Tower

Figure 8: De Redin Towers in the Delimara area (from Spiteri 2008)

The eighteenth-century was the busiest in the construction of coastal fortifications. Between 1714 and 1716, French military engineers were brought to Malta to design and built a vast network of fortifications comprising batteries, redoubts and entrenchments. These new types of defence systems, unlike the towers, were designed specifically to serve as solid barriers, resist invasion and attack (Spiteri 2008: 357). The French military engineers were particularly concerned about the vulnerability of Marsaxlokk to enemy landings and stressed the need for the construction of a number of coastal fortifications which could assist in the defence of this harbour (Spiteri 1994: 505). Hence throughout the 18th century, Marsaxlokk Bay saw a number of batteries being constructed on either side of its coast (Figure 7). On the Marsaxlokk side of the harbour three batteries were erected. These were the St. Lucian's Tower Battery, the Wilġa Battery and the Tumbrell Battery.

Of these, Wilġa Battery, also known as St. James Battery is located within the area of influence for Site A on the edge of the Delimara promontory facing the harbour (**DLM13/002**). The battery was built in 1714, and consisted of a large pentagonal platform with an adjacent L-shaped block house. Until recently the block house was partly ruined with a collapsed roof. In 1994 part of battery was demolished for the widening of the existent road (Spiteri 1994: 527, Guillaumier 2002: 414). (**Figure 9**).

Plate 2: Wilġa Battery (DLM13/002)



Plan, and aerial perspective of the Battery

Wilġa battery with collapsed roof

Demolished carp wall of the battery during road works

Figure 9: Wilġa Battery Plan and state of preservation before modern restoration (Spiteri 1994: 257)

A few years ago the block house was restored and is now being used for private functions (personal communication with Marsaxlokk residents). On the other edge of the Delimara promontory the Tombrell battery was constructed (**Figure 10**). This Battery, demolished in the 19th century, was probably located in the area called Ponta tat-Tumbrell. Built in the mid-18th-century, it consisted of a semi-circular platform with a ringed low parapet. It had a rectangular blockhouse and was flanked by entrenchment walls (Spiteri 1994: 529).

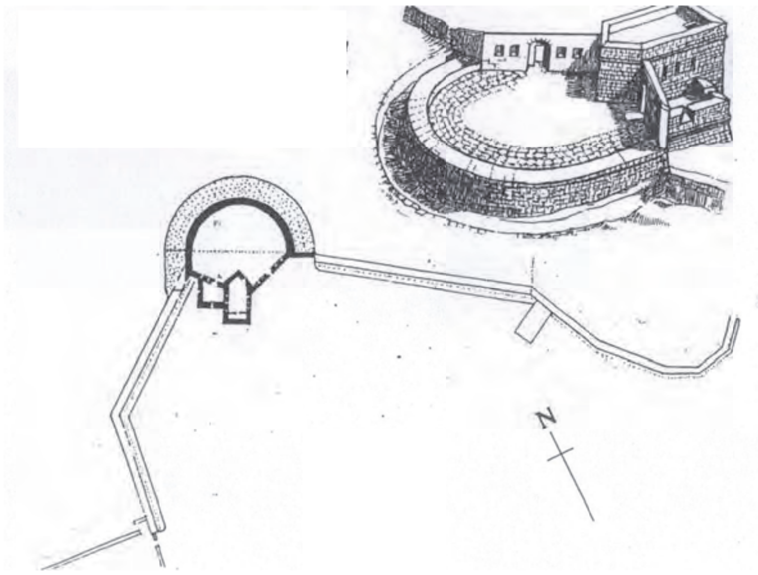


Figure 10: Tombrell Battery (from Spiteri 1994: 529)

During this period an entrenchment wall was erected around the rock scrap beneath the tower of Xrobb L-Għaġin (Spiteri 1988: 175, Spiter 1989: 190, Spiteri 1994: 564) (**Figure 11**). In 1793 in the vicinity of the Delimara tower a small mortar battery was erected (Spiteri 1994: 499).

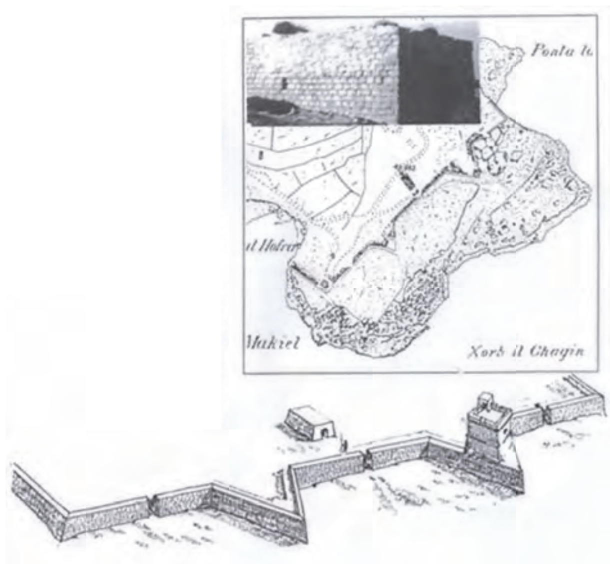


Figure 11: The Xrobb l-Għaġin Entrenchment (Spiteri 1994: 564)

3.2.5 British Period

With the arrival of the British in the nineteenth-century, Marsaxlokk Bay was still considered as a strategic port from where an attacking force could invade. For this reason most of the defence systems which were designed by the engineers of the Order of St. John were retained in use for the first decades. However by the middle of the nineteenth century most of the coastal batteries and redoubts were obsolete and the defence of the bay consisted only of the few coastal towers and the line of entrenchments that were erected around the Bay. As in previous years the St. Lucian's Tower and Battery were still considered as the core of these defences (Spiteri 1996: 333). In 1872 there was still the threat that an enemy could use the south-eastern coast to approach and invade the Great Harbour. For this reason it was decided that a number of forts be built along the south-eastern coast. For Marsaxlokk Bay the following forts and batteries were planned: Fort Delimara, Fort St. Lucian, Fort Tas-Silġ, St. Paul's Battery, Wolseley Battery (**DLM13/010**) and Fort Benghisa (Spiteri 1991: 11). Four of these fortifications (Fort Delimara, Fort Tas-Silġ, St. Paul's Battery and Wolseley Battery) are located in the Delimara peninsula and therefore relevant to this study re land use of this area (refer to **Figure 12**).

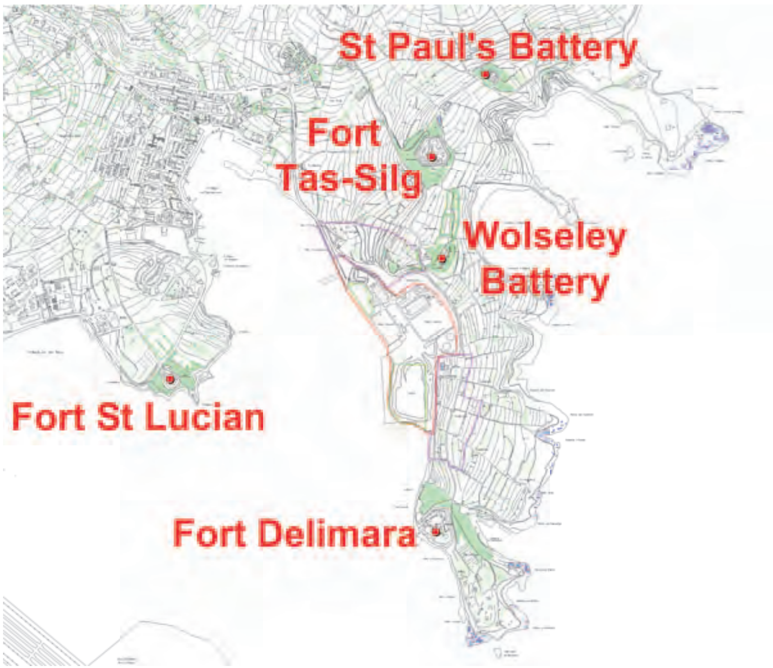


Figure 12: British Fortifications of the 19th century at Delimara and surroundings

Works on Fort Delimara commenced in January 1876. The Defence Committee believed that this fort would be strategic for the defence of the Marsaxlokk Bay as it would command the entrance. It was therefore recommended that the guns be sited in a such a way as to be able to have a great lateral range which would cover the approaches (Spiteri 1996: 340, Hughes 1993: 115). By 1878 the works at the fort had been completed. Fort Delimara follows the plan of an irregular hexagon. The seaward facade of the fort was built on the edge of the cliff. This facade had six embrasures which were cut directly into the rock face of the cliff opening from inside the vaulted masonry casemates (Spiteri 1996: 340). The other "four sides of the fort followed a polygonal trace and were protected by a vertical rock-hewn ditch and a parapet topped by a row of musketry loop holes" (Spiteri 1996: 340). Three counterscrap galleries armed with loading guns served as flanking defences of the fort while a steel palisade lined the counterscarp which helped the guards fight against any direct enemy infantry assault (Spiteri 1996: 340).

Spiteri (1991:123) and Hughes (1993: 115) write that the Fort Delimara had no keep as the interior of the fort was commanded by Fort Tas-Silġ located inland on the highest tip of the Delimara headland. From the inside the enclosure was mostly barren. It had barrack accommodation for a garrison of thirty six men and a mutation magazine that could store up to 1510 barrels of gunpowder and four hundred cartridge shells (Spiteri 1996: 340-343). In mid 1970s this fort was given to the private sector to be utilised as a farm.

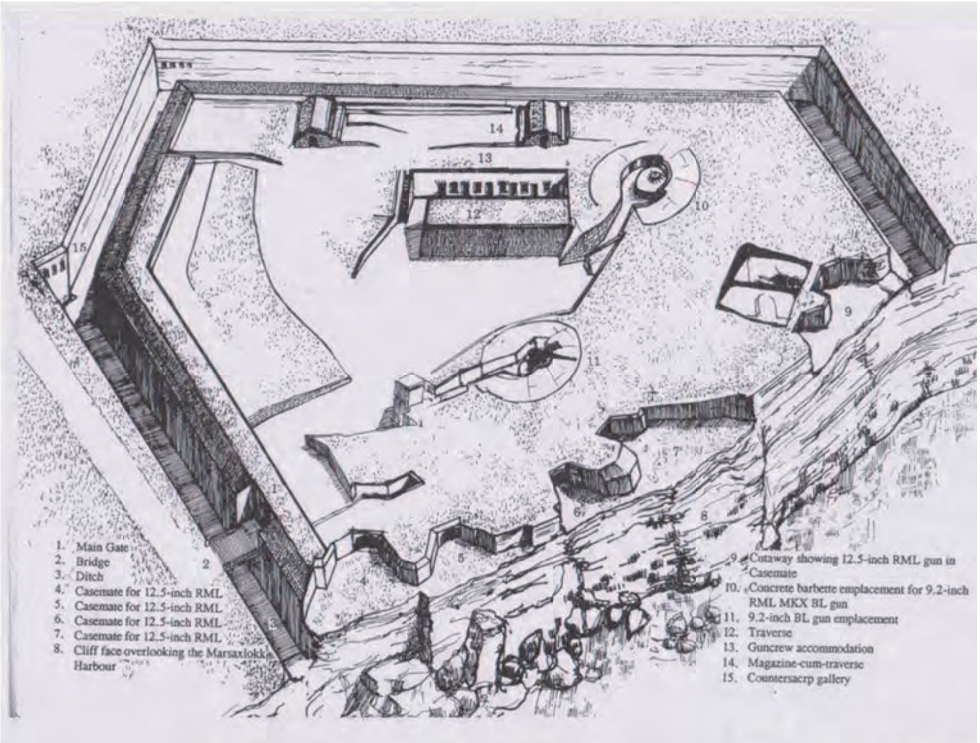


Figure 13: Fort Delimara (from Spiteri 1991: 124)

Plate 3: Fort Delimara

By the end of the nineteenth century Fort Delimara was the only fort capable to defend Marsaxlokk Bay. However its guns could only cover the south-western approaches of the bay leaving the coastline from Delimara Point to Xrobb L-Għaġin, undefended. For this reason it was decided that a new battery was to be built to defend this area. The battery was to be sited on the narrowest part of the Delimara promontory just four hundred meters south of Fort Tas-Silġ. This battery was to be called Wolseley Battery (**DLM13/010**) and works on it commenced in 1897 and were completed in 1899 (Spiteri 1996: 467). This battery is located just outside of the Area of influence of this study and has been included in the Catalogue of Cultural Features shown in **Appendix 1** (refer to **Figure 14**). The Wolseley Battery was the first battery to have low-in-profile earth works defences and heavily protected by barbed wire and machine gun fire. These were to substitute the permanent ditch and rampart defences that were common features in older batteries (Spiteri 1991: 12, Spiteri 1996: 467).

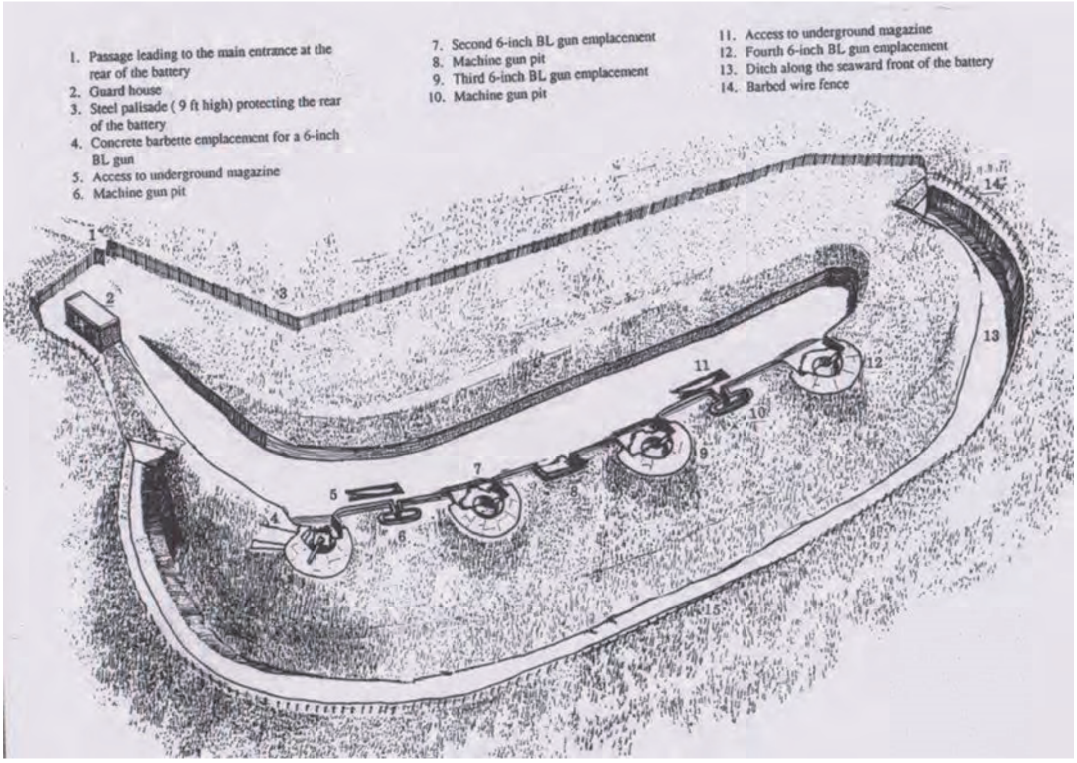


Figure 14: Wolseley Battery (from Spiteri 1991: 210)

This battery was built on the model of an experimental fortification developed at Twydall in England. The Wolseley Battery had an approximately oval plan and had four barbette emplacements (still visible) which hosted four six-inch guns (Spiteri 1996: 48, 467, Hughes 1993: 281). The glacis in front of the barbette mountings slopped outwards and downwards terminating in a shallow ditch fillled in with barbed wire entanglements. Around the battery, at its rear and along the shallow counterscrap, a nine foot iron fence was erected. The guns of this battery pointed in the directions of the Tombrell Battery which was built by the Knights in the mid-18th century. For this reason the Knights' battery had to be demolished in order to provide the Wolseley Battery a clear field of fire (Spiteri 1991: 209 and Spiteri 1996: 467).

Near the entrance of Wolseley Battery there was a building which housed the caretaker's quarters (**Plate 4**)**.** One can still see the date 1899 inscribed on the keystone of the central arch supporting the veranda (Spiteri 1996: 467). The main entrance steel palisaded gate has survived till this day (**Plate 5**). This was the sole entrance to the battery (Spiteri 1996: 469). Spiteri and Hughes state that by 1906 this type of battery was already absolute and by 1916 the Wolseley Battery was dismantled (Spiteri 1991 :209, Hughes: 281). One can also see a "circular, girna-shaped pillbox" (**DLM13/009; Plate 7)** situated to the rear of the guardhouse of Wolseley Battery (Spiteri 1996: 521).

Plate 4: Caretaker's Lodgings at the entrance of Wolseley Battery

Plate 5: Entrance to Wolseley Battery still extant

Plate 6: Loading mechanisms at Wolseley Battery

Plate 7: Stone-clad pillbox (**DLM13/009**)

Works on Fort Tas-Silġ commenced in 1879 and were completed in 1883. This fort was an "exception to the rule" for it was planned not to defend the coast and fire on enemy shipping like all other forts build during this period. Located on Tas-Silġ hill - the highest point on the Delimara promontory – it was built to protect and defend Fort Delimara and its gunners (Thake and Hughes 2005: 127). It was also to act as fallback position for the garrisons of Fort Delimara and Wolseley Battery. Fort Tas-Silġ has quite a regular hexagonal design. Spiteri (1996: 328) writes that originally the "fort was designed without flanking defences and was to be protected only by a vertical ditch". Gun platforms were designed in order to accommodate four guns on its northwest face overlooking St Thomas Bay and another four pointing onto Fort Delimara. The other sides of the hexagonal fort were to have three more platforms (Spiteri 1996: 328). The fort's internal space consisted of a large parade ground. Barracks and magazines were located below the ground level. Along the parameters of the fort there were also seven raised gun platforms with ramps placed at regular intervals (Spiteri 1991: 119).

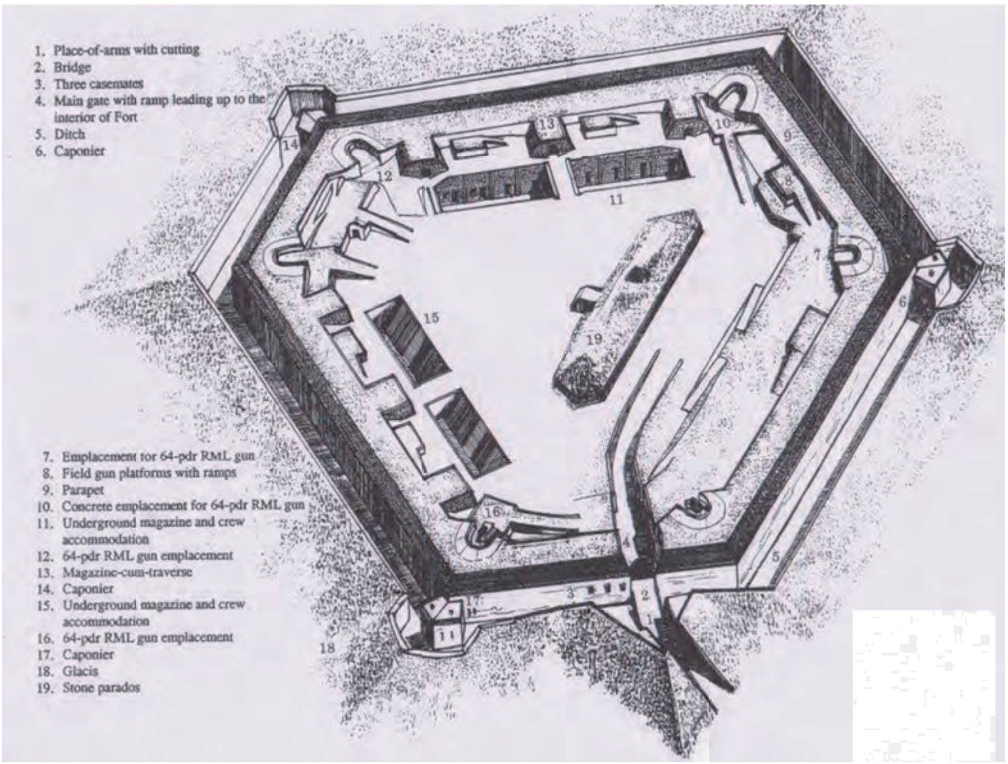


Figure 15: Fort Tas-Silġ (from Spiteri 1991: 120)

Plate 8: Entrance to Fort Tas-Silġ

It was later noticed that the location of Fort Tas-Silġ proved not to be an ideal one with regards to the defence of St. Thomas Bay. For this purpose, St. Paul's Battery was commissioned to be built just a few meters away overlooking Xrobb l-Għaġin (Spiteri 1991: 119). The building of St. Paul's Battery started in 1881 and was finalised by 1886. The battery was built above the site of Xrobb L-Għaġin in order to have a better cover in the surrounding bays and was located just four hundred meters away from Fort Tas-Silġ. St. Paul's Battery had a D shaped plan being 75 meters wide and 50 metres deep. The battery had three gun emplacements, one on the right and two on the left. Ammunition to these three guns was hoisted to a tunnel located at ground level. The battery was surrounded and protected by a dry shallow ditch devoid of any flanking defences or capioners. The battery had no facilities for the gun crew who would normally be stationed at Fort Tas-Silġ. At the turn of the century the battery had lost its importance as a defensive position and was thus disarmed and abounded (Spiter 1991: 191 and Spiteri 1996: 435-438). On the other hand, Fort Tas-Silġ became an Army depot and Wireless and Telegraphy Station until the 1960s when it was then handed over to the Civil Authorities (Spiteri 1991: 192).

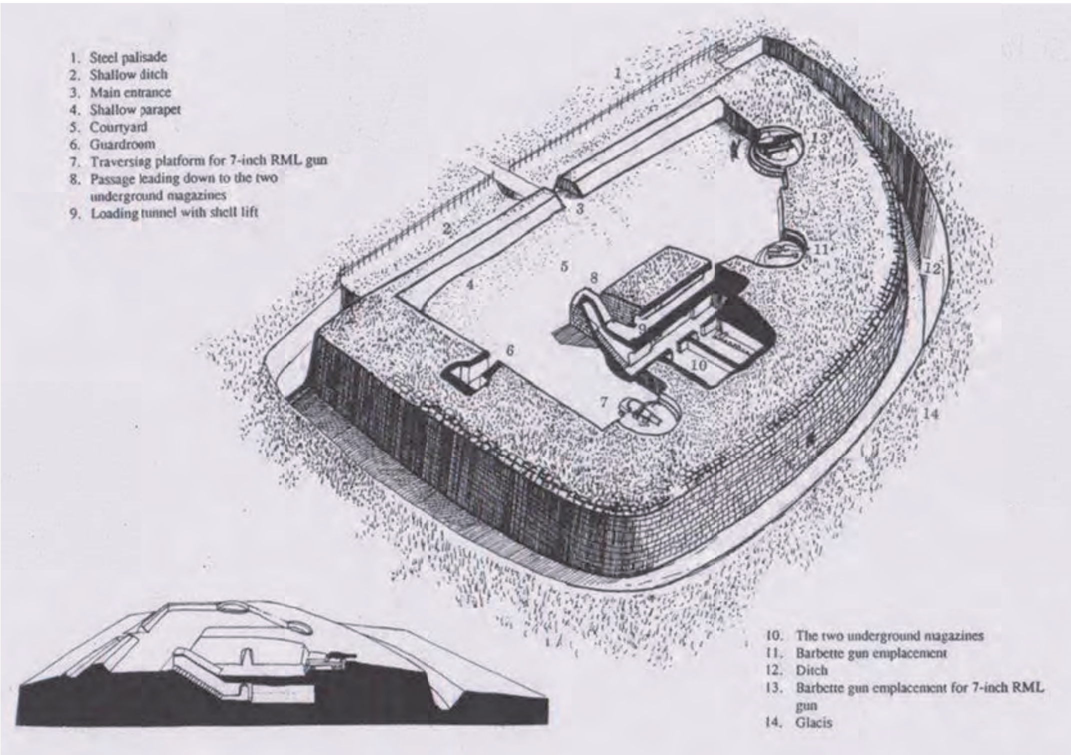


Figure 16: St Paul's Battery (Spiteri 1991: 192)

Plate 9: Remains of St Paul's Battery

A feature worth noting from the ordinance survey sheet of 1910 sheet 134, (**Figure 17**) is the Tal-Bies Position Finding Station (**DLM13/007**) located in the vicinity of the Wolsleley Battery, near the Delimara Power Station. Spiteri (1996: 485) writes that the Position Finding Stations were a very important element in the coastal defence system. These stations greatly increased the accuracy and fire control of the coastal guns when firing at distant and fast moving targets. The use of telephone also made it possible for these positions to be advantageously sited away from the gun batteries. Position Finding Stations would normally consist of a number of cells, which would be partly buried into the ground. Each cell would have a low opening in front. Inside there would normally be a large table with a PF Instrument on it. In some occasions the cells would be well concealed with their roofs even covered with earth. These instruments would be linked to another battery through an electric cable which normally was laid at about three feet deep (Spiteri 1996: 485- 486).

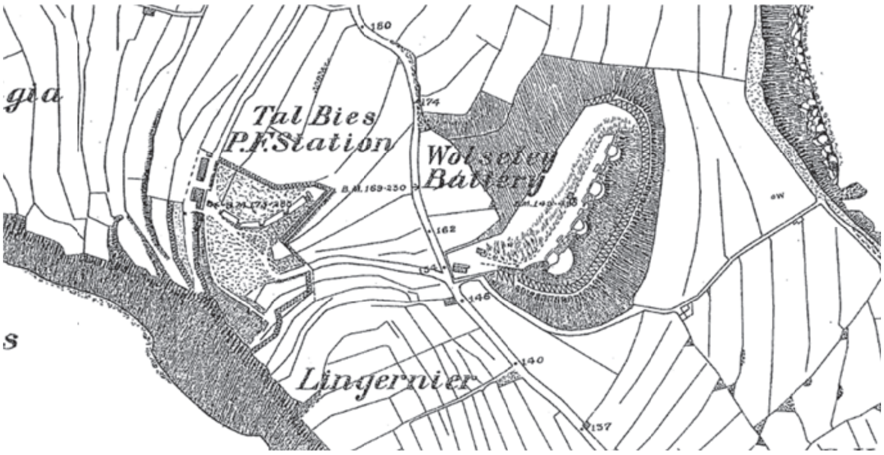


Figure 17: Excerpt from Ordnance Survey Sheet 134 of 1910 showing the Tal-Bies Position Finding Station

Apart from the fortifications in the area, a characteristic landmark of the Delimara Peninsula is the lighthouse which stands at a height of 24m (Vella 2011: 24). This was built between 1850 and 1851 and had a Fresnel lantern (now being restored). Fresnel was a French scientist who revolutionised lighthouse lanterns with a system of mirrors. Depending on weather conditions and intensity of the light source, the lighthouse could emit a beam of 24 km (15 miles) (vella 2011: 24). The lighthouse emitted such a beam every 30 seconds, alternating between red and white light. Timing was controlled by a clock mechanism and the light was provided by a pear-shaped paraffin tank supported by three lion paws (Vella 20011: 25). The lighthouse suffered a lot of damage after years of neglect, and is now being restored and transformed into a holiday vacation home (Vella 2011: 25).

Plate 10: Delimara Lighthouse

The Delimara Peninsula holds a strategic location at the entrance of Marsaxlokk. With the advent of aircraft, new military strategies were needed. This required the building of pill boxes and beach posts, as well as anti-aircraft batteries. **DLM13/009** (refer to **Plate 7** above) is one such pillbox. It is of the earliest structures, built during the Abyssinian Crisis (Spiteri 1991: 222), as witnessed by the stone-cladding characterising the earlier ones. Later pillboxes were either left uncovered, or else the cement was painted in camouflage patterns. Such pillboxes were built to defend strategic locations with machine gun fire.

At the tip of Delimara Point (**Figures 18** and **19**), a Heavy-Anti Aircraft Battery was constructed to form part of the aerial defences against Axis attacks in WW2 (Spiteri 1991: 231).

Figure 18: Delimara Heavy-Anti Aircraft Battery at Delimara Point

Figure 19: Aerial photo of Delimara Heavy Anti-Aircraft Battery
(from Spiteri 1991: 234)

3.3 Description of the Cultural Heritage in the Area

The Delimara Peninsula had basically two land uses, apart from the modern power station and leisure activities related to the landscape and the beach. These are agriculture and defence. The cultural heritage recorded in the areas of influence either consist of vernacular features related to the agricultural nature of the area or structures related to defence. The recorded features during this study and their proposed or present protection are listed in **Table 1**. Their location is shown in **Figure 20.**

Site Code	Location	Category	Site Description (Address)	Proposed or Actual Protection
DLM13/001	Ras it-Triq, Marsaxlokk	Vernacular	St Anthony Farmhouse	Grade 3
DLM13/002	Il-Wilġa, Marsaxlokk	Military	Tal-Wilġa Battery	Grade 2
DLM13/003	Ras iċ-Ċagħaq, Marsaxlokk	Vernacular	Field room and field road	Grade 3
DLM13/004	Tumbrell, Marsaxlokk	Vernacular	Field rooms and field road	Grade 3
DLM13/005	L-Inginier, Marsaxlokk	Vernacular	Small farmhouse and field road	Grade 2
DLM13/006	L-Inginier, Marsaxlokk	Vernacular	Dry Stone Complex	Grade 2
DLM13/007	Tal-Bies, Marsaxlokk	Military	Position Finding Station	Grade 2
DLM13/008	L-Inginier, Marsaxlokk	Vernacular	Field patterns and road layout	Grade 2
DLM13/009	L-Inginier, Marsaxlokk	Military	Stone-clad pillbox	Grade 2
DLM13/010	L-Inginier, Marsaxlokk	Military	Wolseley Battery	Grade 2

Table 1: List of recorded cultural features and their proposed protection

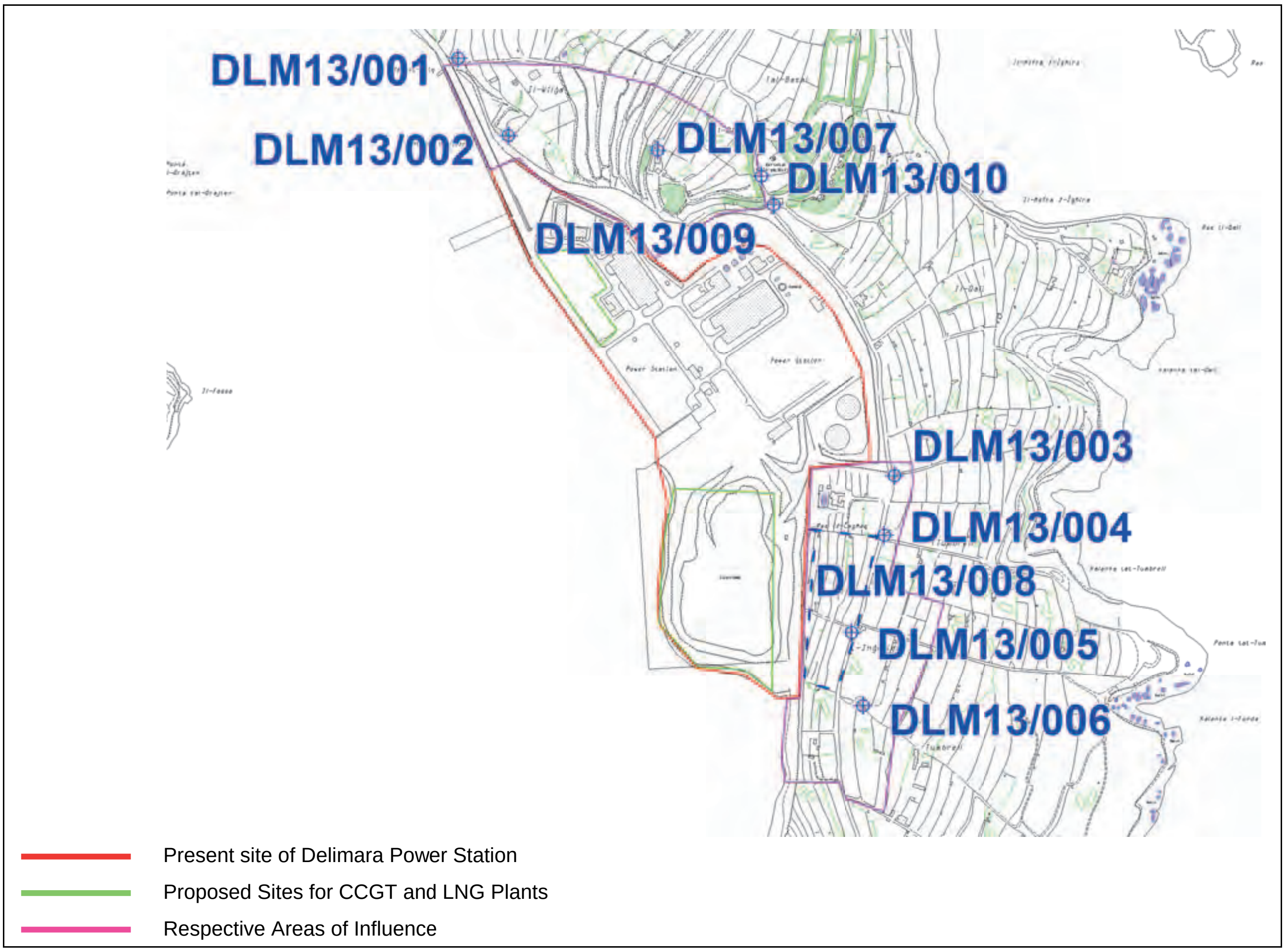


Figure 20: Cultural features recorded during the site-surface survey

3.3.1 Vernacular Features

The agricultural character of the Delimara Peninsula has led to the recording of a number of vernacular features. **DLM13/001**, **DLM13/003**, **DLM13/004** and **DLM13/005** are farmhouses and field rooms which have a number of typical characteristics of vernacular architecture, including buttressing, exterior staircases, and small apertures functioning as windows. Such structures are very common in the Maltese landscape, most of which are still being used as field rooms. One must keep in mind that any alterations made to fit modern needs must respect the vernacular character of these features. This explains why a Grade 2 or 3 Level of Protection is being proposed.

DLM13/006 is a very interesting dry-stone structure, that deserves further attention, and should not be destroyed. The circular structure might suggest that these are the remains of a corbelled hut ('girna'). If this is so, it would be a very particular structure since these huts are very rare in the southern part of Malta. That is why a Grade 2 Level of Protection has been proposed.

Rubble Walls

Rubble walls are an essential part of the Maltese landscape. They are not only boundary walls between land holdings, but also the habitat of a number of organisms, and are essential soil and water retainers (Borg 2000: 125). They are found in other areas in the Mediterranean region, but they are "the commonest dry stone expression of the Maltese archipelago, with the corbelled stone hut and the farmhouse, they are the most distinctive landmarks of its landscape" (Jaccarini 1998: 20, 22).

In the area under study, rubble walls are found in the Area of Influence for Site B. Unfortunately, the Area of Influence for Site B (Il-Wilġa) is mostly inaccessible, while some rubble walls have been even destroyed, as shown in **Figure 21**. The condition of the rubble walls recorded in the survey is summarised in **Table 2** and **Figures 21** and **22**.

	Grade	**Length (m)**	**% of total length**	**Colour Code on Figure 9**
Good Condition	A	1854	39	Red
Fair Condition	B	1776	37	Orange
Bad	C	1170	24	Green

Table 2: Condition of Rubble Walls

The rubble wall survey was based on the following criteria:

<u>Grade A Walls</u> are considered to be in a good condition, that is they are in a very good state of preservation, since they still retain a large proportion of the original stonework. They presently need little or no restoration (refer to **Plate 11**).

<u>Grade B Walls</u>, are in a fair condition but require restoration since at least half of the wall is damaged or destroyed. However, should repairs be carried out, the walls may still be preserved. (refer to **Plate 12**).

<u>Grade C Walls</u> are in a bad condition, near collapse and need to be almost completely rebuilt (refer to **Plate 13**).

(red line)	Present site of Delimara Power Station	(red line)	Grade A Rubble Walls
(green line)	Proposed Sites for CCGT and LNG Plants	(orange line)	Grade B Rubble Walls
(pink line)	Respective Areas of Influence	(green line)	Grade C Rubble Walls
		(blue line)	Destroyed Rubble Walls
		(green area)	Inaccessible Areas

Figure 21: Inaccessible parts of the Area of Influence for Site A and the conditions of the rubble walls in the area.

Present site of Delimara Power Station
Proposed Sites for CCGT and LNG Plants
Respective Areas of Influence

Grade A Rubble Walls
Grade B Rubble Walls
Grade C Rubble Walls
Destroyed Rubble Walls
Inaccessible Areas

Figure 22: Inaccessible parts of the Area of Influence for Site B and the conditions of the rubble walls in the area.

Plate 11: Example of a Grade A rubble wall

Plate 12: Example of a Grade B rubble wall

Plate 13: Example of a Grade C rubble wall

As Grove and Rackham (2003: 112) write "understanding terraces is the key to understanding the chronology and development of many Mediterranean landscapes". The rubble walls and field patterns found around the areas of Site A and Site B were already existent as evidenced by the Ordnance Survey sheets of 1910 (OSS 1910: Sheet 134), as proven by **DLM13/008**. These field patterns, including their walls, could easily date back to the Knights' Period where, as we know from Blouet (1963), it was a time where there was a lot reorganisation of the agricultural land to satisfy the needs of the Order and also of its inhabitants. According to Grove and Rackham (2003: 112) "terraces are notoriously difficult to date archaeologically" however these can be dated by careful archaeological excavation. A recent study by Harfouche (2007: vii) on various Mediterranean countries has shown the important role played by terracing in the shaping of the Mediterranean landscapes from prehistory to present times. Her study also showed that the technique of agricultural terracing was put into practice at least as far back as the Bronze Age as evidenced in both the western and eastern Mediterranean areas (Harfouche 2007: vii).

In the case of **DLM13/008**, although the area is still being exploited for agricultural purposes, minimal changes have been incurred. Such field patterns need to be recorded and preserved, therefore deeming a Grade 2 level of protection.

3.3.2. Military Features

The strategic location of Delimara has led to its use a defence point for the entrance to Marsaxlokk Bay and beyond. Four military features have been recorded within the Area of Influence, while there are other features in the vicinity.

DLM013/002 is chronologically the earliest structure related to defence, and is less preserved than the others due to various factors. Tal-Wilġa Battery, built by the Order of St John, should be further preserved, and modern accretions minimised as much as possible. The same accounts for the Tal-Bies Position Finding Station (**DLM13/007**). This structure is not accessible, but it is being used. This also accounts for the circular stone-clad pillbox (**DLM13/009**) and parts of Wolseley Battery (**DLM13/010**). While it is ideal that such structures continue to be used, other than being abandoned to the elements and vandalism, it is highly important that they are preserved in their original state as much as possible, thus protected with a Grade 2. The significance of these features, is a collective one, in that Delimara Peninsula, contains a concentration of fortifications, that call for rehabilitation, restoration and protection. In fact, although Wolseley Battery (**DLM13/010**), mostly lies outside the area of influence for this study, its entrance gate and caretaker's quarters are within the area of study. The gate, as witnessed in **Figure 23**, is of particular interest, since it still is the original pallisaded gate, and should therefore be preserved.

Figure 23: The Original Entrance Gate to Wosleley Battery, and the gate as recorded by Spiteri (1996: 469).

3.4 The Cultural Landscape

All archaeological and historical sites and features form part of the landscape which surrounds them, and any survey of the cultural heritage has to study a site's context as well as the site itself. No cultural future is isolated from the fields and geographical features which surround it, and on which it depends, to varying degrees. Every site is a piece of local history, embedded in its immediate cultural landscape and relating to the area around it [Barker 1993:254]. The phrase "cultural landscape" does not mean a special type of landscape, but rather a way of seeing landscapes that emphasizes the interaction between human beings and nature over time. The main value of the cultural heritage in the area lies in the information it can yield regarding past settlement patterns, as well as the indications regarding land-use patterns.

Easy access to the sea and the mainland, a good sheltered harbour, availability of water and good fertile land have made the Delimara peninsula an ideal site for human activity, dating from prehistoric times to the present day. This long tradition of human activity has therefore altered the cultural landscape of the Delimara peninsula with each culture, leaving an indelible imprint of its existence. Hence a person walking this area is unconsciously experiencing elements in the landscape that have been continuously used, reutilized, and modified by cultures dating from the Prehistory (Temple Period, Bronze Age) to Phoenician, to Punic, to Roman, to Byzantine, to Arab, to Norman, to the Early Modern and British periods with their coastal fortifications. Thus as Crawford (1953: 51-52) explains, landscapes can be compared to a palimpsest that is "a document which has been written on and erased over and over again". Roberts (1987: 83), for example, compared visible landscapes with icebergs where "only a small proportion of their real substance lies above the surface". One therefore must keep in mind that "everything in landscape is older than we think" (Hoskins 1988: 12).

As landscape archaeologist Stephen Rippon (2000: 119) notes, landscapes are therefore composed of stratified layers dating back from the early prehistory through to the present day. Therefore it is possible to study the processes of how the landscape changed over time retrogressively , that is starting from the most recent to the most ancient cultural material (Rippon 2003:10).

Although the Power Station at Delimara has greatly changed its surrounding landscape, many elements of the cultural landscape have survived. One example is the road network and the field pattern with its associated rural structures of the agricultural landscape at Delimara, which can be surely dated back to 1910 as recorded in the Ordnance Survey Sheets. However, these field patterns and road network could easily date back to the Knights' Period and may also be of an older date. Preserving as much as possible of the landscape at the Delimara Peninsula is therefore a must for the preservation of this part of the Maltese cultural landscape which is changing at a faster pace than ever before. Also one must keep in mind that on this peninsula there is a concentration of Military architecture that has become an integral part of the Delimara cultural landscape. These are in dire need of preservation and restoration.

Delimara CCGT – Summary of Impacts

Given that the proposed development is within the footprint of the already existing Power Station, and the areas earmarked for development are located on either already developed or reclaimed land, the possibility of uncovering new archaeological material is minimal.

On the other hand the development of the CCGT and LNG plants will continue to add on the visual Impact of the area as attested by the installation of the storage tanks (up to 125,000m^3) which will be "the largest single item within the LNG facility, the proposed jetty".

The QRA report states that one of the risks that may occur is a leakage that will produce a Gas Cloud. Although in itself this cloud is not dangerous (SGS Report 4 December 2013: Annex B Drawings 9 -13), there could also be the possibility that ignition points from the Delimara Power Plant may ignite the Gas Cloud. In such a scenario the area covering all the cultural sites from DLM13/002 to DLM13/10, Delimara Lighthouse and Fort Delimara would be affected.

The location of the loading arm as indicated in Drawing 13 (SGS Report 4 December 2013: Annex B Drawing 13), the Flammable Gas cloud could reach Fort Delimara, Delimara Lighthouse and the area covering cultural features DLM13/004, 005, 006 and 008 depending on wind direction.

It is envisaged that this project will affect:

A. The Context of Military Installations in the area:

Although the development will not directly affect any of the built culture heritage in area the developers would be encouraged to restore and the conserve t military installations that dot this landscape as also stated in Policies MD 01 and MD 03 of the Marsaxlokk Local Plan.

B. The Cultural Landscape

This project will continue to alter visually the cultural landscape of the Delimara peninsula, and the Marsaxlokk Port. For this reason, the cultural landscape should be conserved and rehabilitated as much as possible. The following mitigation strategies are being proposed:

1. The 150m stack if not functional anymore should be dismantled as it alters the skyline of the landscape.

2. Integration of the Delimara Power Station complex within the rural landscape through:

a. Restoration of rubble walls in the area of influence. This will serve to integrate more the power plant and to reduce soil erosion of the area. Any restoration of rubble walls should firstly involve the study of the landscape from Cartographic materials dating to the British and Knights period. This may help to date rubble walls and understand better their role in the modern rural landscape.

b. Soft landscaping by planting and cultivating indigenous trees and autoctonic trees such as: mulberry, fig, olive, pomengranate, carrob trees or any other trees which farmers used to grow. Where possible, alien species such as eucalyptus and acacia trees should be uprooted and indigenous/autoctonic trees are planted instead.

This can be done through an agreement with local farmers, were they are provided with the trees and water (for a number of years to sustain the growth of the saplings).

3. The creation of a heritage trail were a number of sites (refer to Table below) earmarked in the EIA are fully investigated, restored and some open to the public, while being scheduled to ensure their continuous protection. These sites are both of a vernacular and military character, and thus represent the two main uses of the Delimara peninsula prior to the development of the power station on this headland.

Site Code	Site Description (Address)	Proposed Protection	Proposed Intervention
DLM13/001	St Anthony Farmhouse	Grade 3	Restoration
DLM13/003	Field room and field road	Grade 3	Restoration
DLM13/004	Field rooms and field road	Grade 3	Restoration
DLM13/005	Small farmhouse and field road	Grade 2	Restoration
DLM13/006	Dry Stone Complex	Grade 2	Restoration
DLM13/007	Position Finding Station	Grade 2	Restoration, and possibly opened to the public
DLM13/008	Field patterns and road layout	Grade 2	Restoration
DLM13/009	Stone-clad pillbox	Grade 2	Restoration, and possibly opened to the public
DLM13/010	Wolseley Battery	Grade 2	Restoration, and possibly opened to the public
	Fort Delimara	Grade 2	Restoration, and possibly opened to the public as a visitors' centre with a permanent display describing the military history of the area

4. In the eventuality of fires caused by a Flammable Gas Cloud, in the areas of extending from DLM13/002 to DLM13/10, including Delimara lighthouse, Fort Delimara and Fort Sant Luċjan, precautions should be taken by equipping the sites with fire fighting equipment and systems.

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Appendix I:
Catalogue of Cultural Features

Data Capture Sheet

ref no
DLM13/001

Location
Ras it-Triq,
Marsaxlokk

Category
Vernacular

Site Description (Address)
St Anthony, Ras it-Triq, Marsaxlokk

Eastings
5953

Northings
6619

Period
Late 19th - Early 20th century

SS No1
5866

SS No2

SS No4

SS No3

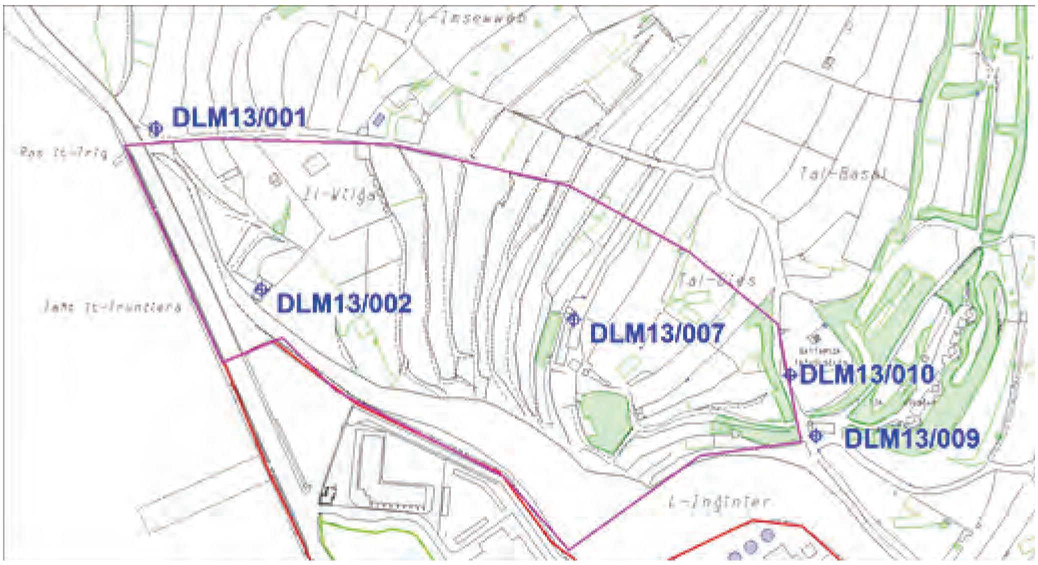
Date of survey sheet: 1992

Description
A small corner farmhouse built in the Northwestern part of a field, looking on a lane leading to Il-Wilġa. Built in globigerina limestone, the complex has typical razzett features: upper room (għorfa); stone water spout (miżieb) and a small four-petaled oculus in the għorfa wall (loġġ). The staircase turrett is decorated with four-spade shaped corner stones, which were also used in another corner of the roof.

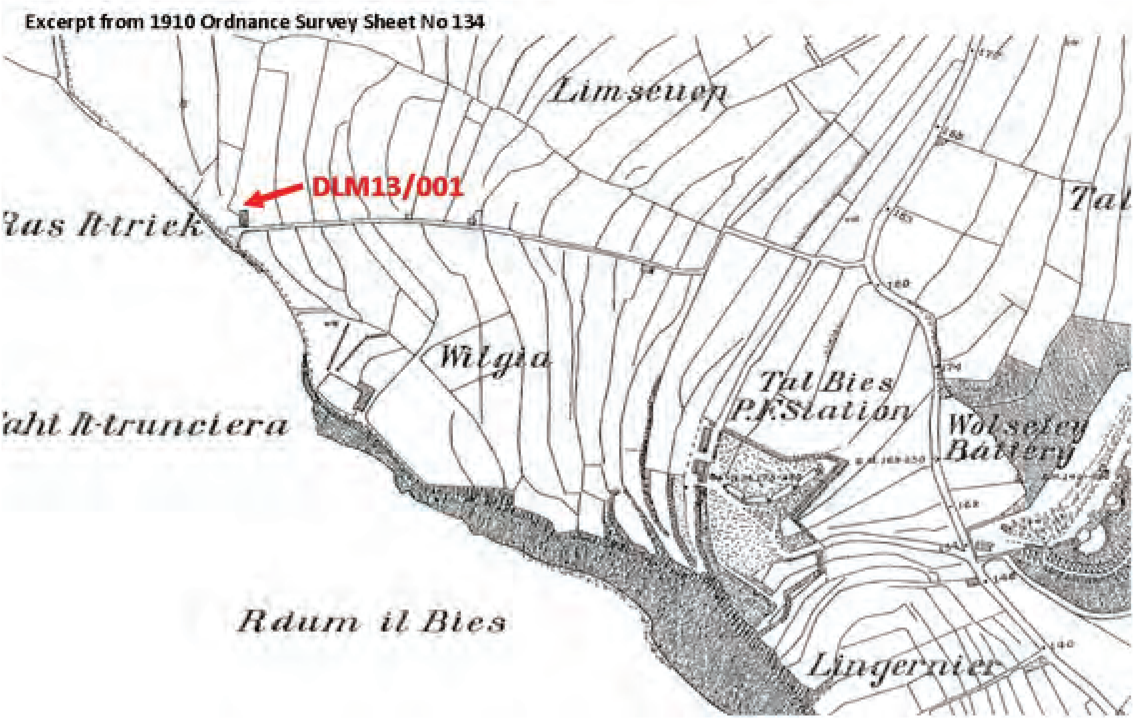
Present Utilisation
Unknown

Comments

Site



Characteristics



Condition

Very good

Degree of Protection

None

Proposed Protection

Grade 3

Basic Bibliography

Ordnance Survey Sheet 1910 No 134; Jaccarini, C.J., 1998, Ir-Razzett – The Maltese Farmhouse, P.E.G. Ltd, Malta.

Compiled by

KDB, DB, MB, EV

Date of Survey

25/6/2013

DLM13/001 (2)

DLM13/001 (6)

Data Capture Sheet

ref no
DLM13/002

Location
Il-Wilġa, Marsaxlokk

Category
Military

Site Description (Address)
Tal-Wilġa Battery, Il-Wilġa, Marsaxlokk

Eastings
5961

Northings
6606

Period
Built between 1714-1716

SS No1
5866

SS No2

SS No4

SS No3

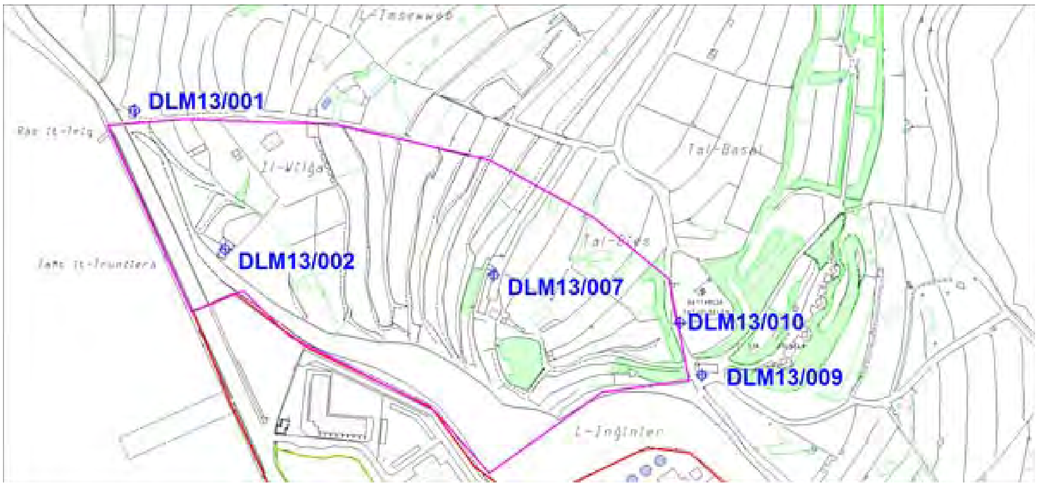
Date of survey sheet: 1992

Description
An unusual L-shaped block house, part of an 18th century battery complex, restored in recent years. The actual battery could not be made out. It is reported that originally it had a pentagon plan, but was partially destroyed to make way for the road. The present strucutre has been heavily restored.

Present Utilisation
Private Functions

Comments
In 2004 the Lands Department leased the Wilġa battery and adjacent land to private ownership.

Site



DLM13/002 (2)

Condition

Good condition on the exterior, which has been heavily restored due to its partial collapse.

Degree of Protection

None

Proposed Protection

Grade 2

Basic Bibliography

Spiteri, Stephen C., 1996, British military architecture in Malta, Valletta.

Compiled by

KDB, DB, MB, EV

Date of Survey

25/6/2013

DLM13/002 (3)

ASC Archaeology Services Co-operative Ltd	**Data Capture Sheet**	**ref no** DLM13/003

Location
Ras iċ-Ċagħaq, Marsaxlokk

Category
Vernacular

Site Description (Address)
Field room and field road at Ras ic-Caghaq, Marsaxlokk

Eastings
6021

Northings
6553

Period
19th-20th century

SS No1
6065

SS No2

SS No4

SS No3

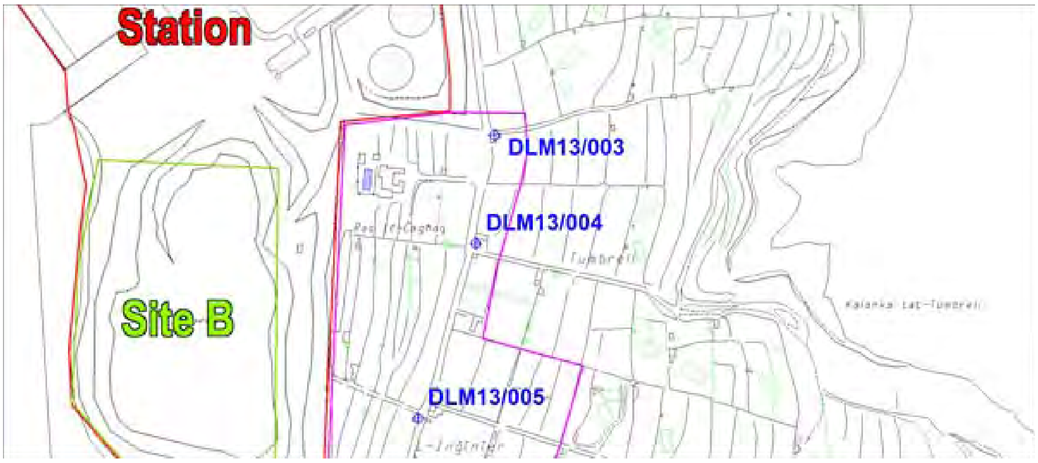
Description
Field room built of globigerina limestone. The field room is flanked by an alley between two enclosed fields. A small window looks southwards.

Date of survey sheet: 1992

Present Utilisation
Fieldroom

Comments
Good

Site



DLM13/003 (2)

Condition

Good

Degree of Protection

None

Proposed Protection

Grade 3

Basic Bibliography

Ordnance Survey Sheet 1910 No 134; Jaccarini, C.J., 1998, Ir-Razzett – The Maltese Farmhouse, P.E.G. Ltd, Malta.

Compiled by

KDB, DB, MB, EV

Date of Survey

25/6/2013

Data Capture Sheet

ref no
DLM13/004

Location	**Category**	**Site Description (Address)**
Tumbrell, Marsaxlokk	Vernacular	Field rooms and field road at Tumbrell, Marsaxlokk

Eastings	**Northings**	**Period**
6020	6543	19th-20th century

SS No1
6065

SS No2

SS No4

SS No3

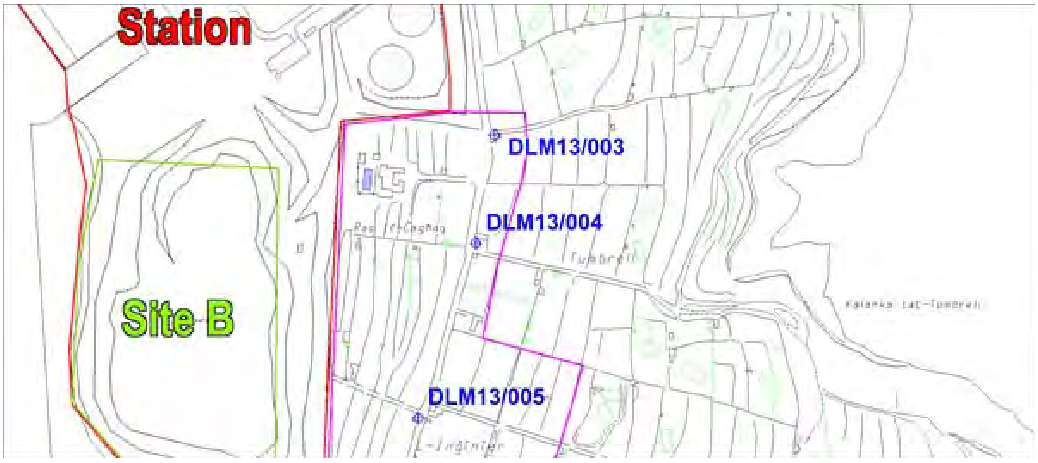
Date of survey sheet: 1992

Description
A complex of three field rooms, cornering an alley. Two field rooms are built adjacent each other. In the southeastern part, a stone staircase (setaħ) leads to the roof of the rooms. On the northern side, overlooking the road, is the upper room built of globigerina. The lower rooms bear signs of buttressing. Unlike the rest of the structure, unhewn stones were used for this buttressing. In front of the complex is a clearance, enclosed on two sides by a rubble wall. This could have served as a courtyard.

Present Utilisation
Field rooms

Comments
The lower rooms are painted in cement.

Site



DLM13/004 (5)

Condition
Fair

Degree of Protection
None

Proposed Protection
Grade 3

Basic Bibliography

Ordnance Survey Sheet 1910, No 144; Jaccarini, C.J., 1998, Ir-Razzett – The Maltese Farmhouse, P.E.G. Ltd, Malta.

Compiled by
KDB, DB, MB, EV

Date of Survey
28/6/2013

ASC Archaeology Services Co-operative Ltd

Data Capture Sheet

ref no
DLM13/005

Location
L-Inginier, Marsaxlokk

Category
Vernacular

Site Description (Address)
Small farmhouse and field road at L-Inginier, Marsaxlokk

Eastings
6015

Northings
6528

Period
19th century

SS No1
6065

SS No2

SS No4

SS No3

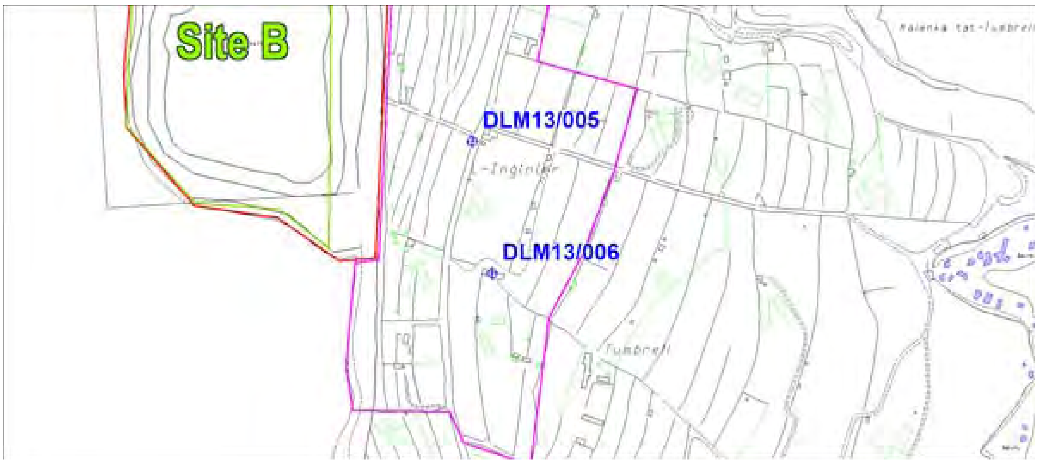
Date of survey sheet: 1992

Description
A two storey small farmhouse comprising two rooms at ground level and one on the first floor. The latter overlooks the fields and was built later. The first storey room has two windows, one to the north and the other overloooking the road. The lintel of the room at ground level bears an inscribed cross and the year 1849. About 4m east of the entrance is a one-course high well-head.

Present Utilisation
Field rooms

Comments

Site



DLM13/005 (4)

Condition

Good

Degree of Protection

None

Proposed Protection

Grade 3

Basic Bibliography

Ordnance Survey Sheet 1910 No 144; Jaccarini, C.J., 1998, Ir-Razzett – The Maltese Farmhouse, P.E.G. Ltd, Malta.

Compiled by

KDB, DB, MB, EV

Date of Survey

28/6/2013

DLM13_005 (1)

DLM13_005 (8)

DLM13_005 (14)

DLM13_005 (13)

Data Capture Sheet

ref no
DLM13/006

Location	**Category**	**Site Description (Address)**
L-Inginier, Marsaxlokk	Vernacular	Dry Stone Complex at L-Inginier, Marsaxlokk

Eastings	**Northings**	**Period**
6017	6516	Early Modern

SS No1
6065

SS No2

SS No4

SS No3

Description
A complex of dry stone structures comprising of possibly a girna, and two rectangular yards (mandra). The entrance looks towards the east.

Date of survey sheet: 1992

Present Utilisation
None

Comments
If the structure is a girna then this is the most southern girna found in Malta.

Site

Data Capture Sheet

ref no
DLM13/006

Location	**Category**	**Site Description (Address)**
L-Inginier, Marsaxlokk	Vernacular	Dry Stone Complex at L-Inginier, Marsaxlokk
Eastings	**Northings**	**Period**
6017	6516	Early Modern

SS No1
6065

SS No2

SS No4

SS No3

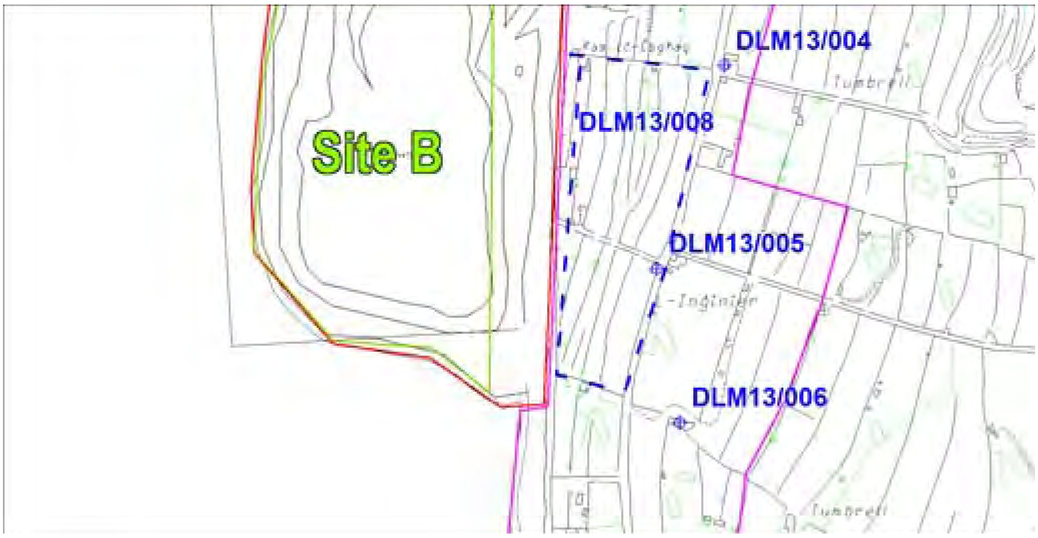
Description
A complex of dry stone structures comprising of a collapsed strucutre built in the dry-stone technqieru, possibly a girna, and two rectangular yards (mandra). The entrance looks towards the east.

Date of survey sheet: 1992

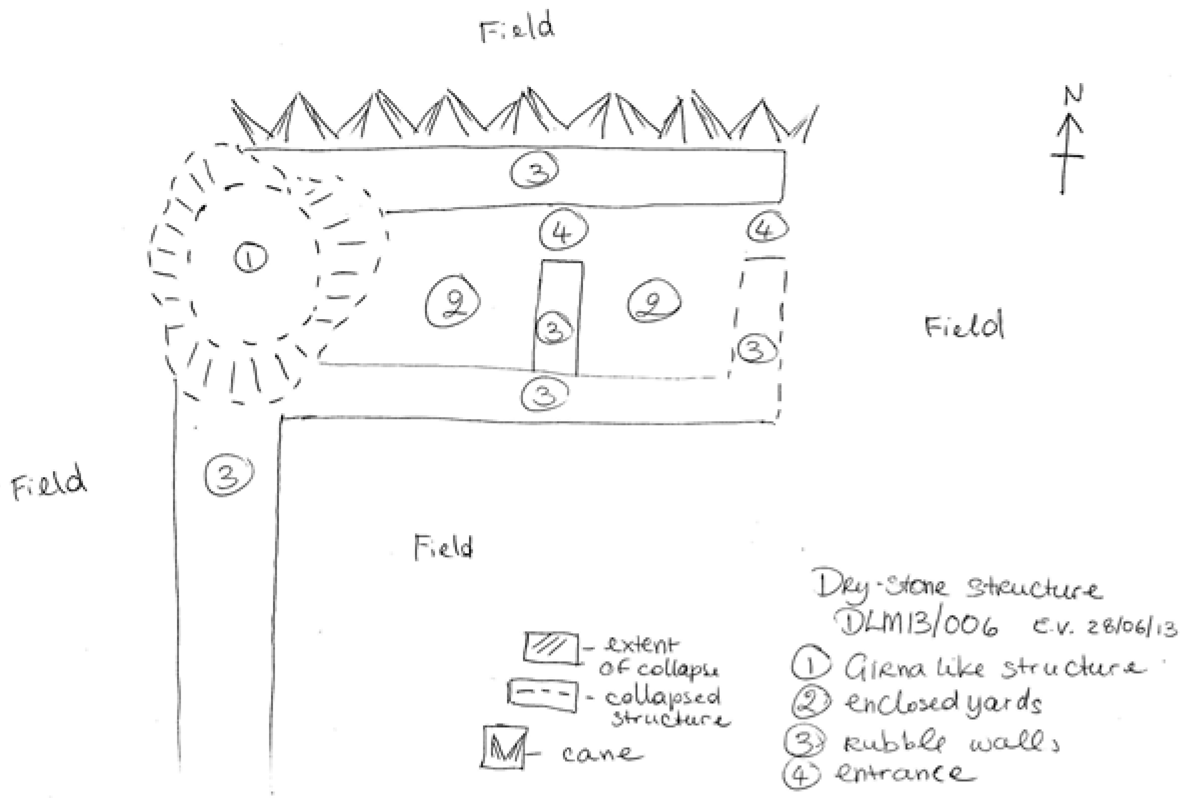
Present Utilisation
None

Comments
If the structure is a girna then this is the most southern girna found in Malta.

Site



Characteristics



Condition

Fair

Degree of Protection

None

Proposed Protection

Grade 2

Basic Bibliography

Vella, Ernest, A landscape archaeological approach of the Maltese Girna, Unpublished MA Dissertation, University of Malta.

Compiled by

KDB, DB, MB, EV

Date of Survey

28/6/2013

DLM13/006 (1)

DLM13/006 (2)

DLM13/006 (5)

Data Capture Sheet

ref no
DLM13/007

Location
Tal-Bies,
Marsaxlokk

Category
Military

Site Description (Address)
Position Finding Station at Tal-Bies, Marsaxlokk

Eastings
5985

Northings
6604

Period
late 19th - early 20th century

SS No1
5866

SS No2

SS No4

SS No3

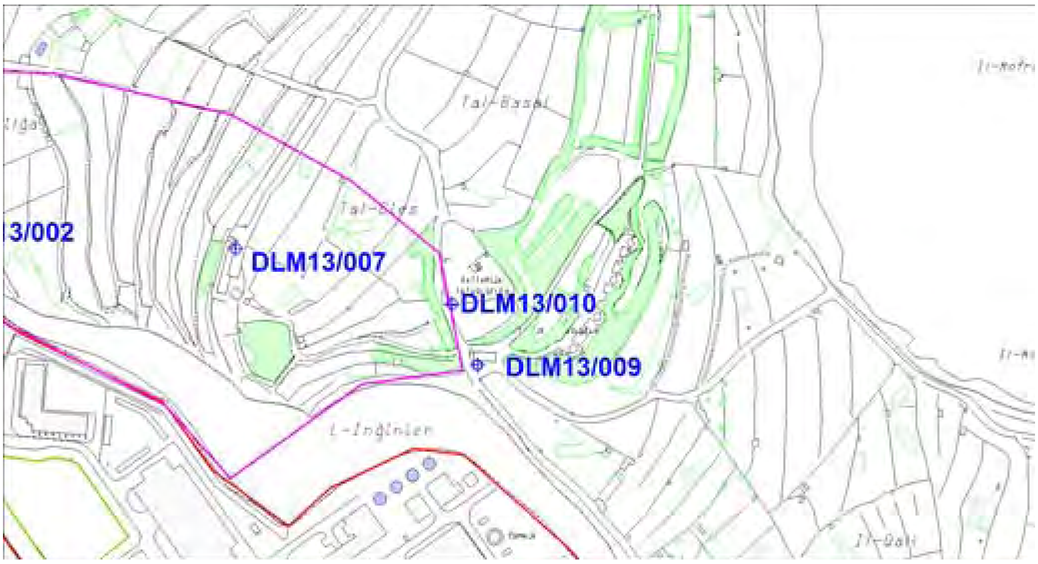
Description
Tal-Bies Position Finding Station used to communicate with Fort Tas-Silg and Fort Delimara to improve gun accuracy. The sructure is inaccessable and being used. It is also well-hidden by high eucalyptus trees.

Date of survey sheet: 1992

Present Utilisation
Field rooms

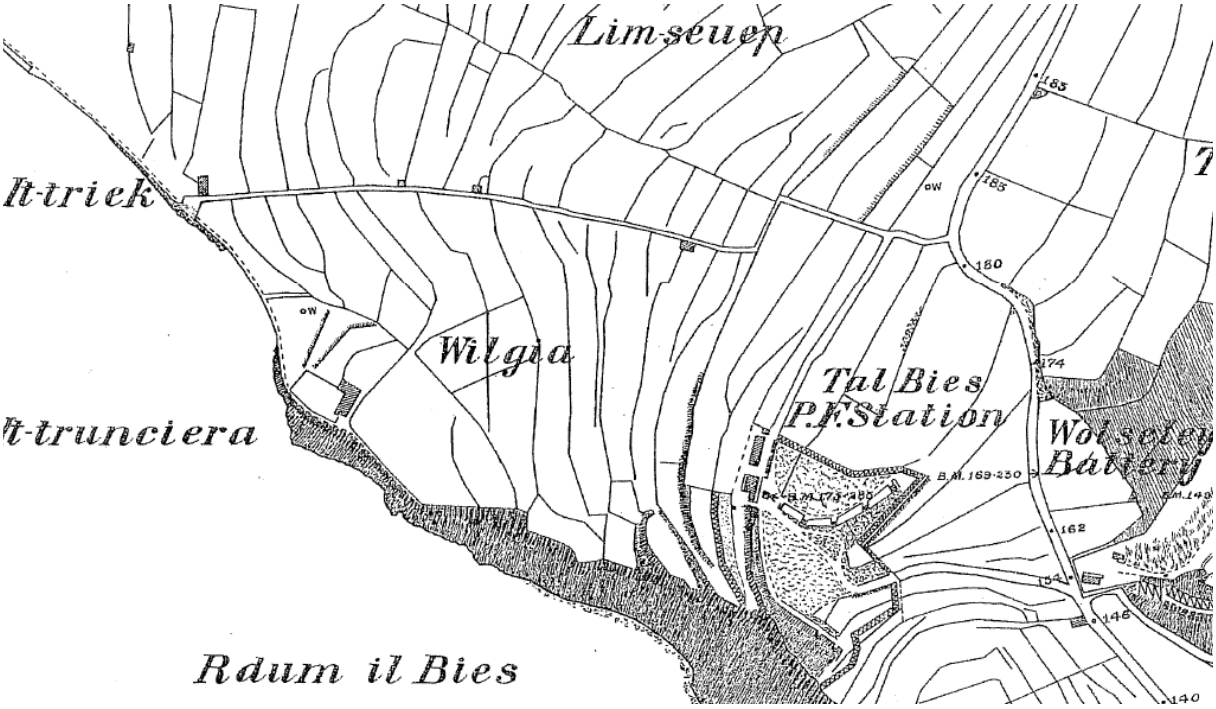
Comments

Site



Characteristics

Excerpt from 1910 Ordnance Survey



Condition
Possibly good

Degree of Protection
None

Proposed Protection
Grade 2

Basic Bibliography

Ordnance Survey Sheet 1910, No 134, Spiteri, Stephen C., 1996, British Military Architecture in Malta, Valletta, Malta.

Compiled by
KDB, DB, MB, EV

Date of Survey
28/6/2013

DLM13/007 (1)

DLM13/007

Data Capture Sheet

ref no
DLM13/008

Location	Category	Site Description (Address)
L-Inginier, Marsaxlokk	Vernacular	Field patterns and road layout at L-Inginier, Marsaxlokk

Eastings	Northings	Period
6013	6532	19th century

SS No1	SS No2
6065	
SS No4	**SS No3**

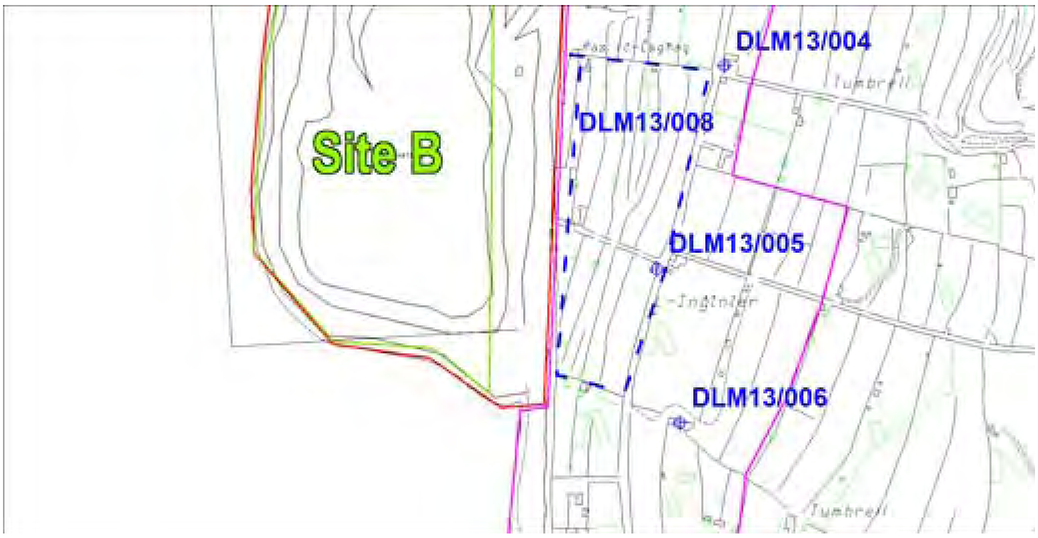
Description
Fields enclosed with rubble walls. The general landscape pattern of the fields still bears the plan recorded on the Ordance Survey Sheet No 144 of 1910. Possibly, it reflects the portioning of the landscape in the Knights period.

Date of survey sheet: 1992

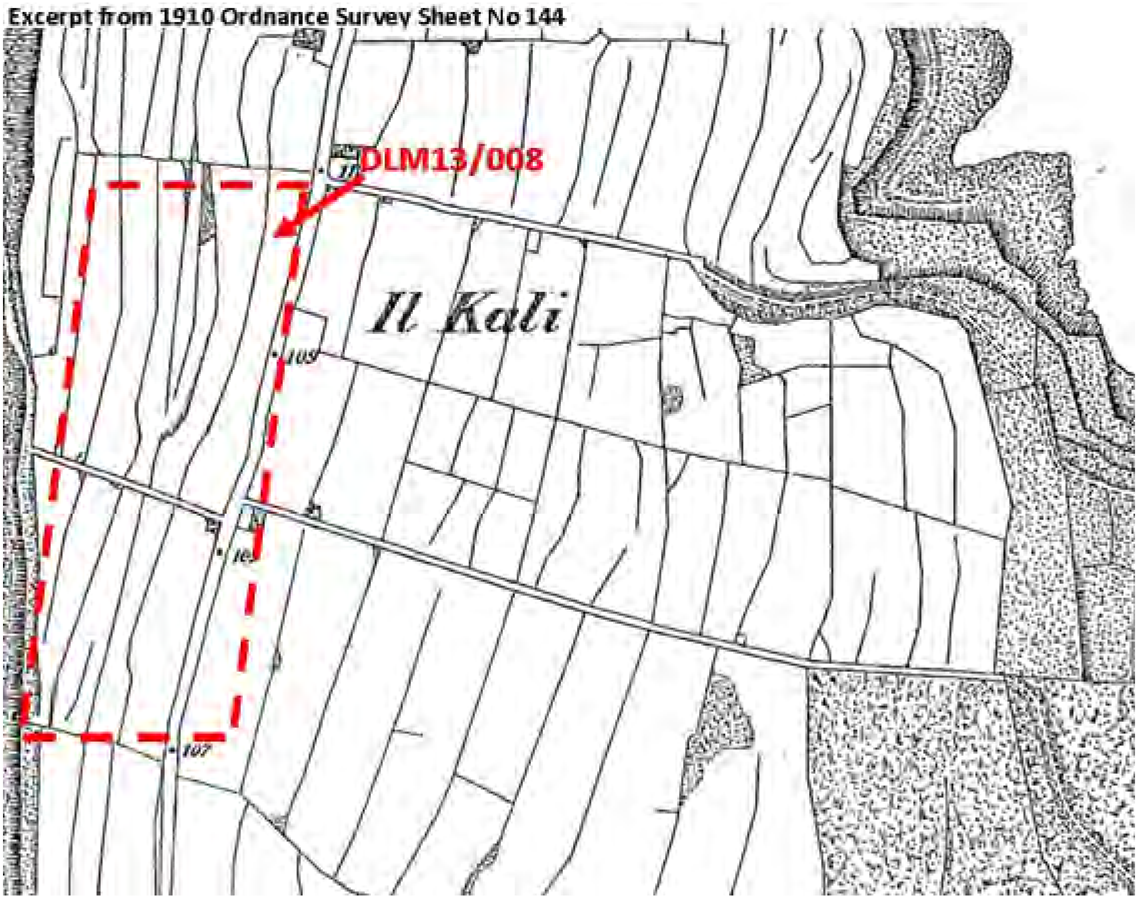
Present Utilisation
Agriculture

Comments
The fields pattern and agricultural landscape should be protected as a whole unit. Any development should integrate vernacular and rural characteristics.

Site



Characteristics



Condition

Good

Degree of Protection

None

Proposed Protection

Grade 2

Basic Bibliography

Ordnance Survey Sheet no. 144, 1910; BLOUET, B.W. 1963 The Changing Landscape of Malta during the Rule of the Order of St. John of Jerusalem 1530-1798. Dissertation submitted for the degree of Doctor of Philosophy, University of Hull; VELLA, N and SPITERI, M. 2008 Documentary Sources for a Study of the Maltese Landscape. Storja 30th Anniversary Edition, pp. 16-29.

Compiled by

KDB, DB, MB, EV

Date of Survey

25/6/2013

DLM13/008

ref no
DLM13/009

Data Capture Sheet

Location
L-Inginier, Marsaxlokk

Category
Military

Site Description (Address)
Stone-clad pillbox at L-Inginier, Marsaxlokk

Eastings
6003

Northings
6596

Period
1930s

SS No1
6065

SS No2

SS No4

SS No3

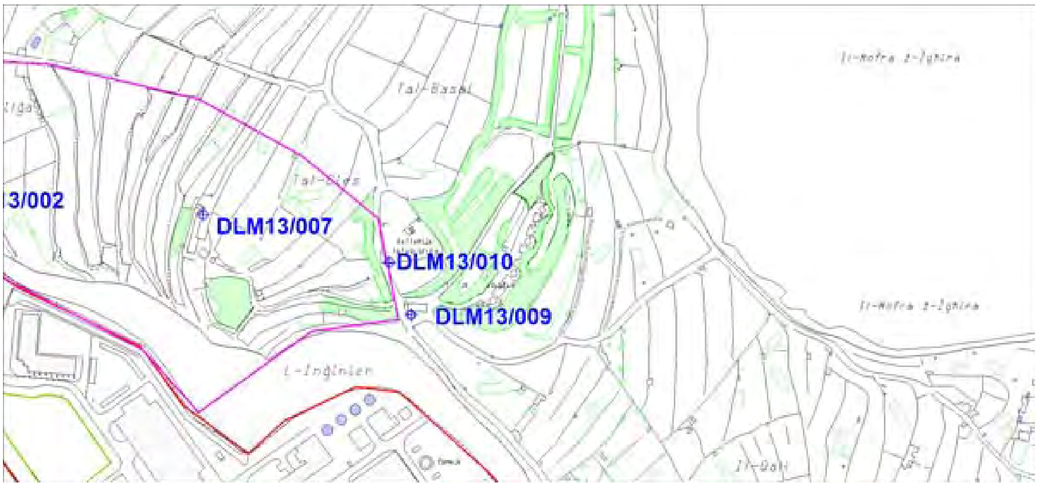
Description
Stone-clad pillbox abutting the caretaker's quarters of Wolsely Battery (DLM13/010). This pillbox has a circular shape, which does not follow standard plan. The stone cladding indicates that it is one of the early pillboxes.

Date of survey sheet: 1992

Present Utilisation
Unknown

Comments
Inacessable

Site



DLM13/009 (3)

Condition

Fair

Degree of Protection

None

Proposed Protection

Grade 2

Basic Bibliography

Spiteri, Stephen C.
1991 British Fortifications: An illustrated guide to the British fortifications in Malta

Compiled by

KDB, DB, MB, EV

Date of Survey

28/6/2013

ASC Archaeology Services Co-operative Ltd

Data Capture Sheet

ref no
DLM13/010

Location
L-Inginier, Marsaxlokk

Category
Military

Site Description (Address)
Wolseley Battery

Eastings
5984

Northings
6608

Period
1897-1899

SS No1
5866

SS No2

SS No4

SS No3

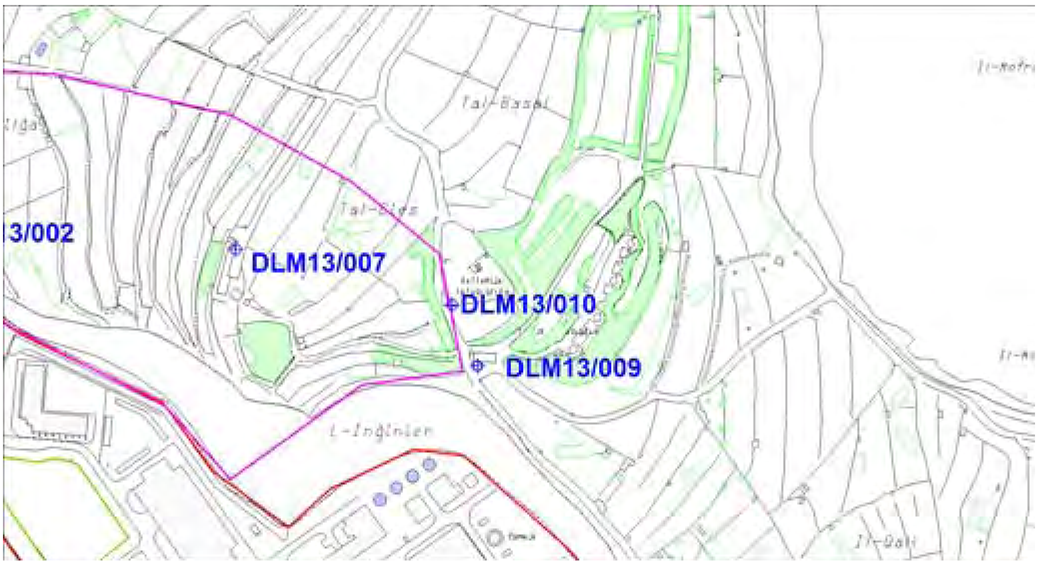
Date of survey sheet: 1992

Description
Wolseley Battery, including caretakers' quarters and entrance gate. The Battery is only partially accessable. Surviving features include the pallisaded gate, the caretaker's quarters, parts of the strucutre of the battery, as well as loading mechanisms. This was the first Battery in Malta to be built in a low profile to avoid visibility from the coast.

Present Utilisation
None

Comments

Site



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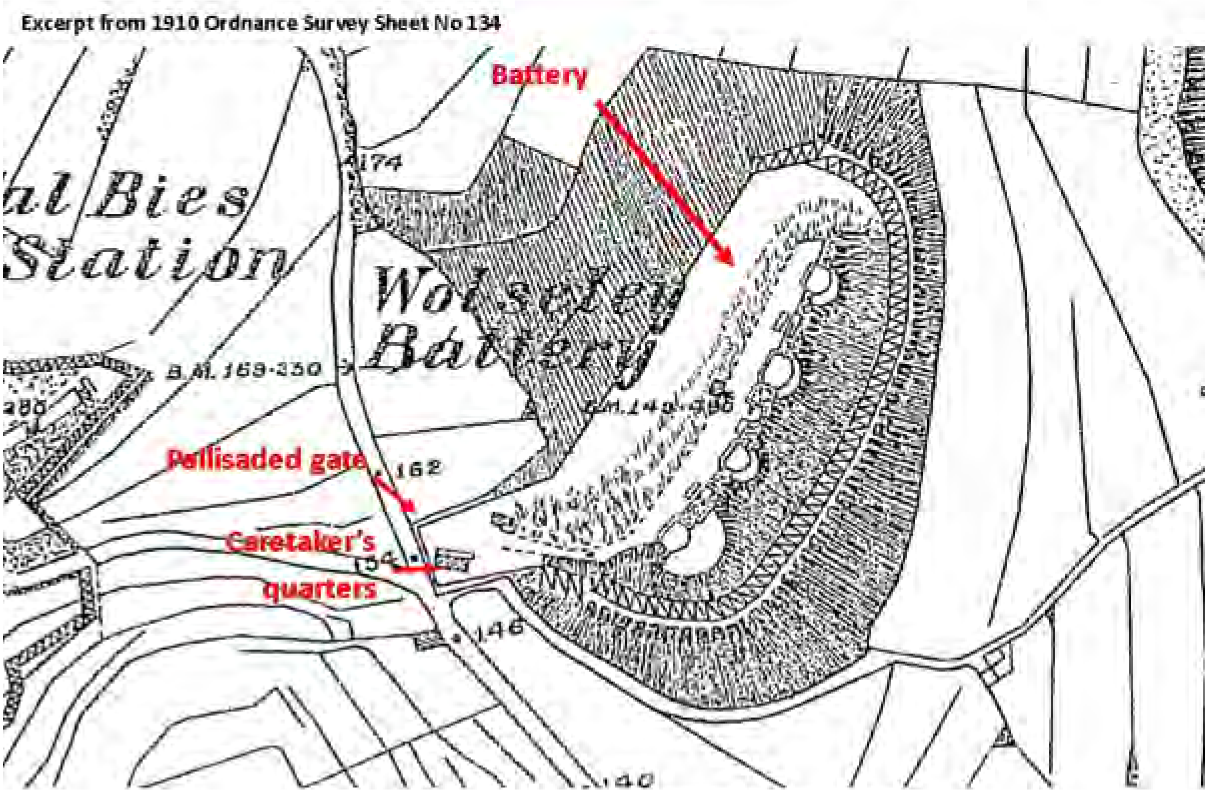

Condition

Fair to Bad

Degree of Protection

None

Proposed Protection

Grade 2

Basic Bibliography

Ordnance Survey Sheet, 1910, No 134; Spiteri, Stephen C., 1991 British Fortifications: An illustrated guide to the British fortifications in Malta.

Compiled by

KDB, DB, MB, EV

Date of Survey

25/6/2013

DLM13/010 (2)

DLM13/010 (6)

DLM13/010 (7)

DLM13/010 (17)

Delimara Gas and Power: Combined Cycle Gas Turbine and Liquefied Natural Gas receiving, storage and regasification facilities

Environmental Impact Statement

Assessment of Environmental Impacts on Water Quality of Proposed Project

REVISED VERSION 4 DECEMBER 2013
(OF REPORT DATED 14 AUGUST 2013)

Report submitted to Enemalta Corporation

by

Victor Axiak

Independent Consultant

Logistic and technical support:

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ECOSERV REPORT REFERENCE: 085-13_R

Legal Notice 114 of 2007

Regulation 28: Identification of Consultants and Contributors

Extract from Legal Notice:

28 (1) The environmental impact statement shall list the registration number and the names of the consultants and contributors responsible for the preparation of the environmental impact statement, environmental survey reports, appendices, non-technical summary and other components of the statement.

(2) The consultants who are responsible for a particular analysis, including analysis in the environmental survey reports, shall be identified.

(3) All consultants and contributors employed in the environmental impact assessment shall sign a declaration stating that the particular study (or part thereof) was solely carried out by them and that they take responsibility for any statement and conclusion contained therein. This signed declaration shall be included with each environmental survey report included with the environmental impact statement.

Signed declaration in accordance with Sub-regulation 28(3):
This declaration is to be submitted with each environmental survey report forming part of the EIA.

Attn: Director of Environment Protection (MEPA)

I, **VICTOR AXIAK**, who carried out the study (or part thereof) on **Assessment of Environmental Impacts on Water Quality of Proposed Project** for the EIA for the proposed **Delimara Gas and Power: Combined Cycle Gas Turbine and Liquefied Gas Receiving, Storage, and Regasification Facilities**, hereby declare that such study was solely carried out by me and take responsibility for any statement and conclusion contained therein.

05 December 2013

Date

Signature

CONTENTS

1. Introduction

ERSLI Consultants Ltd have commissioned Ecoserv Ltd (henceforth ‘Ecoserv’) to contribute towards the EIS for the Delimara Gas and Power: Combined Cycle Gas Turbine and Liquefied Natural Gas Receiving, Storage and Regasification facilities, and in particular, to assess the environmental impacts of the proposed development on marine water quality.

Presently, the Delimara Power Station (DPS) includes two steam turbine generators commissioned in 1992, fired on heavy fuel oil and having a gross capacity of 120 MW (Delimara 1-ST); two gas turbines fired on gasoil, commissioned in 1996 and delivering 74 MW (Delimara 2A-GT); a combined cycle gas turbine (CCGT, comprising of two gas turbines and one steam turbine, all fired on gasoil, delivering 110 MW and commissioned in 1998 (Delimara 2B) and the most recent facility of 8 internal combustion engines fired on heavy fuel oil, having a gross capacity of 149 MW and commissioned in 2012 (Delimara 3). Therefore the DPS currently has a gross supply of 452 MW which amounts to 73% of the current fossil fuel energy generation.

The proposed development at Delimara Power Station will include:

- The conversion of Delimara 3 to operate on natural gas;
- The construction of a new 180-220MW CCGT;
- The construction of a Liquid Natural Gas (LNG) terminal to supply such generators.

Such development forms part of the nation’s energy strategy whereby it is envisaged that heavy fuel oil will no longer be employed locally in energy generation, and where 200 MW of energy will be imported through an Interconnector from Sicily. The main objectives of such strategy are to reduce the costs of fossel fuel energy generation and to reduce the environmental impacts of such generation.

The present report addresses the TORs for such development as issued by MEPA with respect to impacts on marine environmental quality. It will include:

- A review of the current environmental marine water and sediment quality along the Delimara headland in particular, and within Marsaxlokk Bay in general as well as Hofra z-Zghira. This will establish the current sources of releases of marine contaminants in the area and subsequently the current risk profile to the marine environmental quality;

- Identify the main features of the proposed development at DPS which are more relevant to how the marine environmental quality risk profile may change;

- Identify and assess the subsequent significance of likely impacts on marine environmental quality;

- Propose mitigating measures;

- Propose a monitoring programme to be undertaken during the construction and operation phase of the project, as required by the TORs.

2. Present Marine Environmental Quality Status

2.1 Current Land and Sea-Uses and Potential Sources of Marine Contamination in the Area under Review.

The proposed development at the DPS will be located within the present footprint of the facilities. Cooling waters from the current turbines as well as those arising from this development will be discharged at Hofra z-Zghira. The present section will review the available data on the current risks to the marine environmental quality of this area, as well as on its present marine environmental quality status.

Located at the South-Eastern end of mainland Malta, Marsaxlokk Bay is a natural harbour covering a surface area of 3.88 km^2 and outlined by approximately 12.5km of coastline (**Figure 1**). It is surrounded by two main residential localities of Marsaxlokk and Birzebbuga, each with a coastal population of 3200 (density 690/km^2) and 9600 (density (190/km^2) respectively.

Figure 2 shows the main features/activities giving rise to marine contamination risks, as identified in the following sections.

Sewage Overflows and other Sources in Residential Areas

There are a number of potential sewage overflows from coastal pumping stations located in the area. These may release domestic wastewater especially during rainstorms, or when the sewerage system is not operating normally. Sewage pumping stations are located in Pretty Bay, St. George's Bay and Marsaxlokk Bay (Xatt is-Sajjieda).

30% of the coastline of Marsaxlokk Bay is lined by residential area and therefore exposed to intense anthropogenic activities.

Maritime and Fuel Handling Sources

Maritime activities within Marsaxlokk are intense throughout the year. The Malta Freeport Terminal is located on the south-western part of the bay. It is one of the largest cargo handling terminals in the Mediterranean, hosting numerous cargo vessels on a 24-hour basis. Birzebbuga and St. Georges' Bay are designated sites for small boat mooring, while the fishing village of Marsaxlokk hosts a number of fishing vessels.

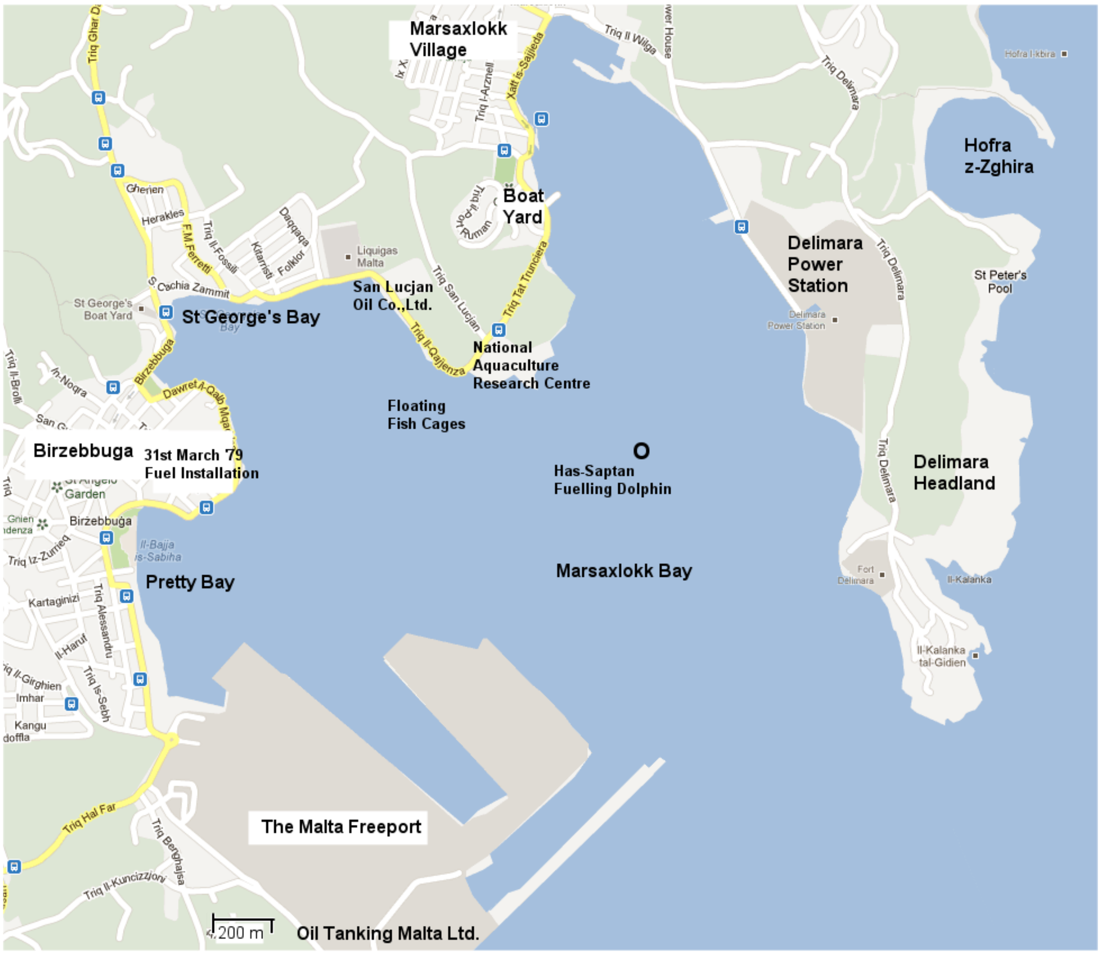


Figure 1: Various locations referred to in text within Marsaxlokk Bay.
Adapted from Google Maps.

At several sites especially along Xatt is-Sajjieda, there are various locations used for servicing of boats and other water craft, and equipped with slipways. These include an official boat yard. Hull washings, including antifouling paint residues, are expected to be discharged into the bay from these land-based sources.

There are several installations/facilities related to fuel handling and storage in Marsaxlokk Bay. Oiltanking Malta Ltd., located at the western part of the bay, has a number of storage tanks for petroleum and other hazardous chemicals. This facility is served with four jetties with a capacity to receive vessels up to 120,000 dwt. The fuels handled at this site range from gasoline to gasoil, bunker oil, heavy fuel oil and jet fuel.

Enemalta operates a coastal installation (31st March 1979 Installation) for unloading of fuel oils from ships onto land-based storage tanks at the area known at 'It-

Tankijiet'. The installation has nine storage tanks capable of handing gasoline, kerosene, aviation fuel and diesel oil. It has a 120m quay extending SSE from a low promontory (see Figure 1) . Tanker vessels calling to discharge their product do so through two pipelines. After the receipt of every fuel cargo, the product within the pipelines is normally displaced using seawater. The tanker itself, after discharging the fuel, does this flushing operation into the shore cargo tank. All the seawater that ends into the cargo tank is then drained and passed through an oil-water separator before being discharged at sea. An annual volume of 2800m^3 of pipe flushing is normally discharged into the sea at a normal discharge rate of approx. 0.7m^3/min (Axiak & Delia, 2000).

Near Qajjenza, San Lucian Oil Company Limited owns a small fuel terminal and installation, which can supply various petroleum products to vessels. The tanks of such installation hold an overall capacity of about 45,000 m^3 of different oil products, while the terminal is equipped with facilities ensuring operational flexibility, such as a boiler and electronic blending system.

The Has-Saptan Fuelling Dolphin is located mid-way between DPS and St. Lucian promontory. It allows fuels (mostly gasoil and jetA1) to be loaded from ships, to the Has- Saptan onshore storage installation (where over 150,000 tonnes of petroleum products may be stored).

The current Delimara Power Station has berthing facilities (total quay length of 370m and a depth of 9m) for oil and fuel handling ships, including an unloading arm. There are also a system of storage tanks for keeping fuel oils for the power station itself.

Fishfarming

The National Aquaculture Research Centre (NARC) at Fort Saint Lucian, includes a hatchery as well as laboratory facilities. Waste waters are normally generated from the fish tanks. These effluents are discharged directly into Marsaxlokk Bay in the vicinity of Fort San Lucian, at an approximate rate of 5m^3 per minute (Axiak, 2000). Based on consideration of the nature of operations and activities carried out in this complex, it may be assumed that the discharged waters will contain a number of pollutants/chemicals including: nutrients, organic residues and traces of antibiotics and formalin (against parasites), as well as of phenoxyethanol (anesthetic) and of bleach (sodium hypochlorite) (Axiak & Delia, 2000).

NACR also operates a near-shore coastal fish farm consisting of a number of cages (approx. 9) located at the centre of Marsaxlokk Bay, approx 230 m off Saint Lucian. Such intensive culture may give rise to releases of organic wastes (including fishfood) and to a lesser extent, to a range of other contaminants such as antifoulings, food additives, and possible therapeutic agents as administered to fish.

Delimara Power Station

The operations of the present installations at DPS also include a number of significant sources of chronic risks of marine contamination in the area. Axiak (2003) reviewed the various releases into the marine environment by operations at DPS as could be assessed in 2002-3. A number of contaminated wastestreams were then identified. The study noted that the dewatering of fuel oil during storage produces approximately 100 000 m^3 of waste water per year. This is led to settling tanks (as does all rain water runoff) and then to an oil interceptor. According to a more recent report (Enemalta, IPPC Sub-report: C3.1.3 DPS P3 08 Waste Disposal-Recovery, 2011), it was expected that the 144MW extension to the DPS would produce 30 m^3 of oily water and 3 m^3 of oil sludge (from the oil interceptor) per day. Enemalta claim that this oil treatment will reduce the levels of oil in the discharged waters to 5ppm. Furthermore, such treated waters were being discharged at sea in compliance with Council Directive 76/464/EEC on water pollution by discharges of certain dangerous substances. The oily sludge was to be retained in holding tanks.

Boiler washings produce an annual volume of discharge of approximately 400m^3. These effluents are discharged at sea after settling and pH neutralization. No detailed information regarding their chemical composition was available during the early 2000s. Suspended solids in such a stream may contain sulphur, nickel, vanadium and iron compounds. In a recent report (Enemalta IPPC Sub-report: C3.1.3 DPS P3 08 Waste Disposal- Recovery, 2011), it was expected that the 144MW extension to the DPS would produce approximately 150 m^3 of boiler wash-waters annually. Afterwards, the collected effluent is neutralized and allowed to settle. This was estimated to produce about 8m^3 of sludge annually and was planned to be disposed of at the hazardous landfill at Ghallis.

Boiler blow-down waters also generate another wastewater stream at a discharge rate of 0.7m^3/hour. These waters are led to a settling tank and a neutralization pit to reduce suspended and settable solids as well as control pH.

The most evident wastestream from any power station is that of cooling waters. For DPS, the annual volume of such cooling waters which are discharged into Hofra iz-Zghira and as assessed prior to 2004 may have amounted to 250 million m^3. The rate of discharge is 500 m^3/minute (as reported in 2002/3). Enemalta officials claimed that these effluents were discharged at approximately 4^{o}C above ambient. These effluents contain chlorine as an antifouling agent which is released at 1-2 mg/L for 3 hours daily (as reported in 2002/3).

Land Runoff

Marsaxlokk is a natural catchment area and rainwater from the surrounding lands lead into its basin. Such runoff is a significant land-based source of pollution by contaminants such as heavy metals, pesticides, agricultural chemicals as well as petroleum residues (resulting from various land-based activities such as fuel handling and storage, heavy traffic, along its shores, etc). **Figure 2** identifies the major runoff routes and major valleys leading to the bay.

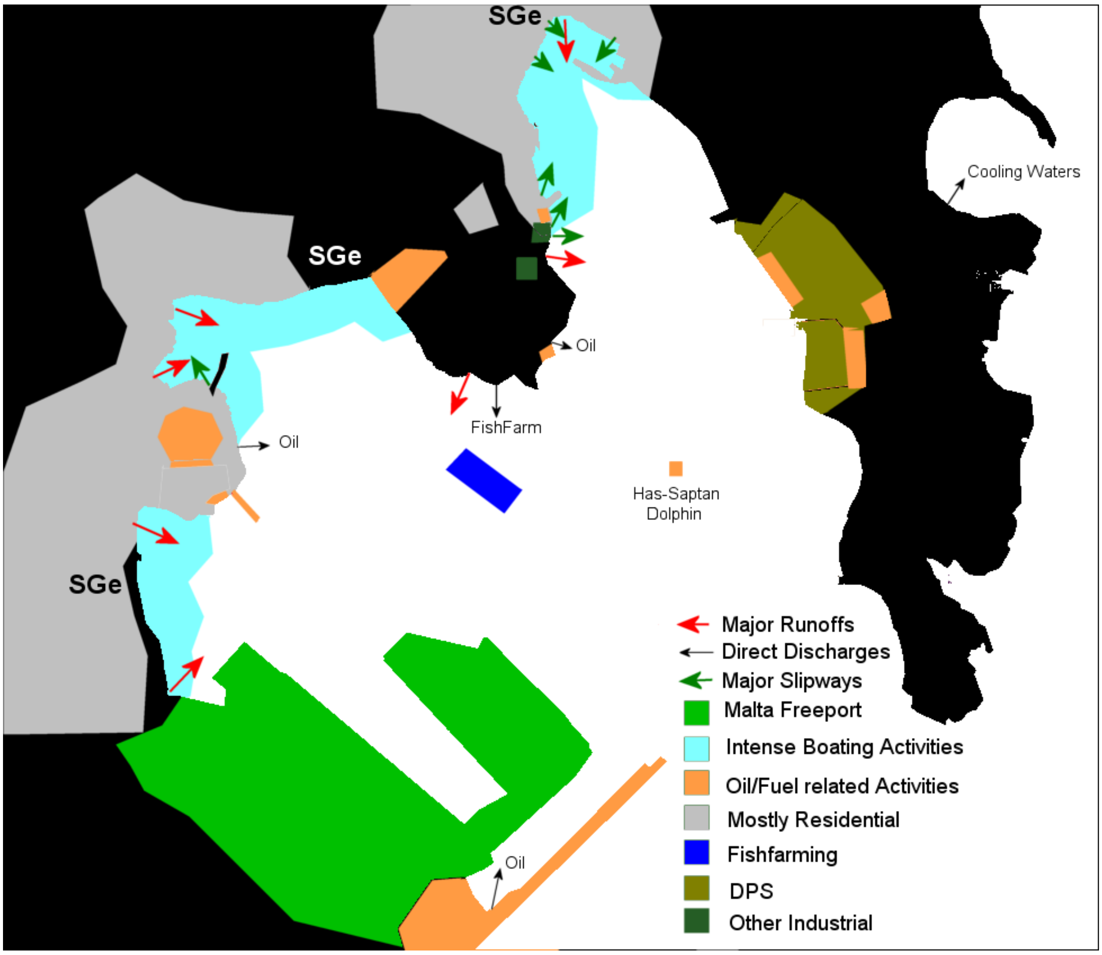


Figure 2: The main features/activities giving rise to marine contamination risks, as identified in the Marsaxlokk Bay. ***(SGe = Sewage emergency overflows from coastal pumping stations).***

2.2 Natural Features and Water Dynamics in Marsaxlokk

The assessment of impacts on water and sediment quality by the proposed development at the DPS will ideally need to take into account the natural features and hydrodynamics (especially flushing rates) of the various areas of Marsaxlokk Bay as well as of Hofra z-Zghira. This section will subsequently review our current knowledge of such features.

Marsaxlokk is the biggest bay in Malta, measuring approximately 2500 m at its widest part (Pretty Bay at Birzebbuga to DPS). St Lucian promontory (known as il-Ponta l-Kbira) divides the bay into two large enclaves, with Birzebbugia area and the Malta Freeport to the West and Marsaxlokk village and the Delimara headland (including DPS) to the East. The bay communicates with the outer sea through an 850 m-wide channel between the tip of the Freeport breakwater and Delimara Point. The deepest part of this channel is approximately 26m. The central parts of Marsaxlokk Bay are approximately 18 m deep, with the eastern and western basins of the bay being somewhat of similar depths (with an average depth of approx less than 10 m). The basin along the Freeport is generally deeper than the rest of the bay (with depths varying from 10 to 20m), mainly due to dredging.

Hofra z-Zghira located on the eastern shoreline of the Delimara headland receives the cooling waters of DPS. It is an almost circular enclave measuring approximately 440 m in diameter and communicating with the open sea via an opening which is 230 m wide. By 2009 this locality was receiving 29,500 m^3/h of cooling waters. This has been increased to 43,000 m^3/h with the new DPS extension which came into operation recently. According to a recent report (AIS Environmental and SLR Global Environment Solutions, 2011) in connection with the most recent DPS redevelopment (Delimara 3), the discharged waters are now expected to be released at 8^o C above ambient.

Surface water currents give a clear indication of the direction and the possible fate of a pollutant/s, particularly in semi-enclosed bays such as harbours. As such, data on sea currents and on the hydrodynamics of the area under review would be extremely relevant to the present impact assessment. The present consultant was unable to locate any published data on the sea currents and hydrodynamics as actually measured within Marsaxlokk Bay . The same problem has been encountered by other consultants for EIAs of other recent developments at DPS.

The only field information regarding the direction of surface currents within Marsaxlokk Bay was made available by a project undertaken by G. Pisani (2011) involving monitoring of environmental quality of local harbours. As part of such monitoring, records were kept of the direct of drift of the boat used to collect seawater samples and to undertaken in-situ measurements of a number of parameters at fixed stations. **Figure 3** shows the direction of sea currents as monitored through such a indirect method for four dates.

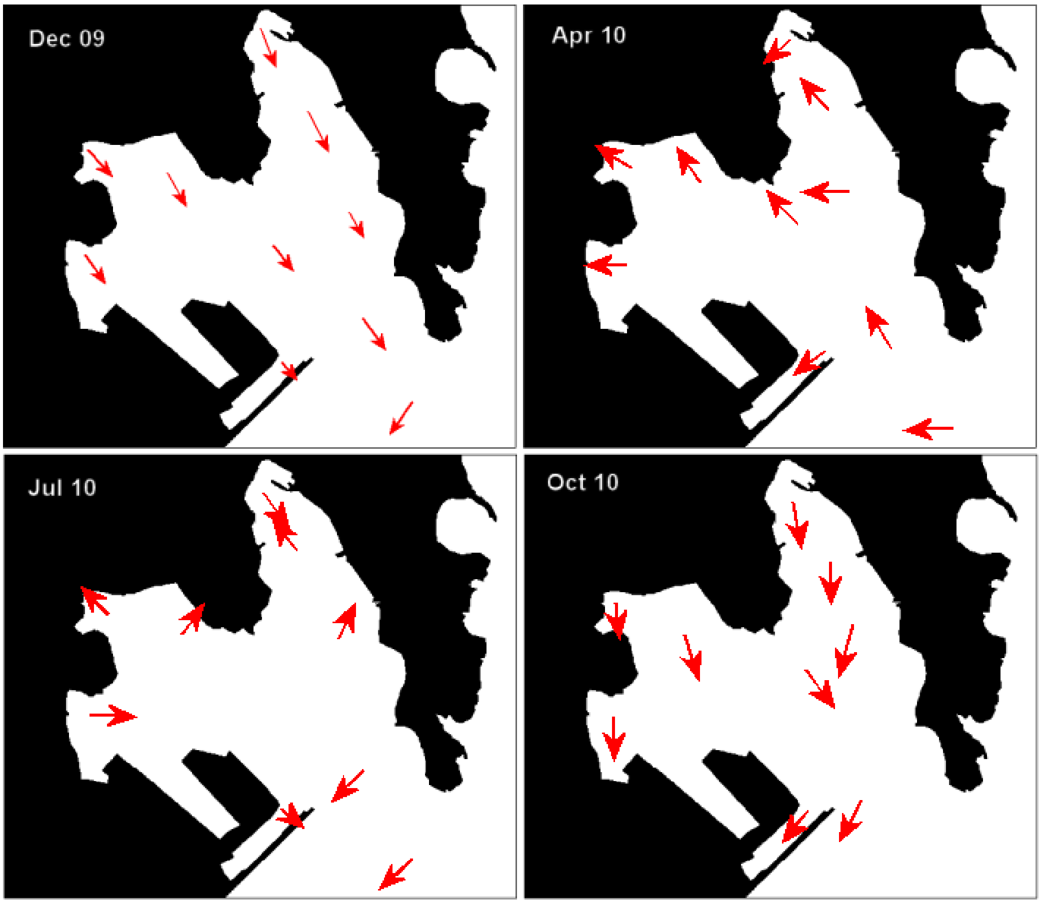


Figure 3: Direction of surface sea currents as indicated by boat drift on four different days over the period December 2009-October 2010. Observations were made in approximately the same time of day (9am-noon) (*From Pisani, 2011*).

In spite of the low level of accuracy of the method of measurement employed, we can still make a number of relevant points from such data:

The direction of surface waters in the innermost part of Marsaxlokk (off Xatt is-Sajjieda) is quite consistent, and in fact it was always pointing offshore during the four surveys spanning different seasons.

The direction of surface currents along the Delimara headland and along the DPS were found to be leading parallel to the shore, towards the outer channel in 50% of the time. However such direction could be quite variable including leading onshore (set towards the shoreline) or in the opposite direction.

The directions of the surface currents in the central part of the bay are quite variable, and in a number of cases appear to form part of large-scale gyre systems.

During 2 out of the 4 surveys, the surface currents at all stations (i.e. in all the localities of Marsaxlokk Bay) were set towards the outer opening of the bay. Presumably, during such periods, bottom waters were set towards the inside of the bay.

In 2010, Toms and Partners produced a number of predictive wave regimes and maps of sea currents as induced by wave action in Marsaxlokk, in order to assess impacts of a number of different options of breakwaters. Such models predicted that wave induced currents within Marsaxlokk may reach up to 2 m/s towards the outer part of the bay, while in most cases current speeds range from 1.4 to 1.6 m/s elsewhere. The central parts and the eastern half of the bay, at least under certain climatic conditions, are dominated by clockwise gyre patterns of surface currents. Such circulation may lead to accumulation of floating debris (and of suspended solids at surface) at a distance of 100-150 m away from the DPS shoreline.

In 2011, AIS/SLR had produced some results on the hydrodynamics within Marsaxlokk and Hofra z-Zghira on the basis of mathematical modelling and on data on tides. In this study it was noted that there are no measurements of tidal flows in coastal waters near Marsaxlokk. Nonetheless tidal currents predicted by modelling within Marsaxlokk range in the order of 1 cm/s. Higher sea currents at surface within Marsaxlokk were predicted on the basis of tides plus prevalent circulation flows nearshore.

More recently, Svasek Hydraulics (2013), produced other predictive models of sea currents within Marsaxlokk Bay, using finite element 2-D numerical flow models at different wind directions. One interesting feature of such models is the prediction that with a prevalent wind blowing from the West, significant eddy currents would be formed in the vicinity of the current Has-Saptan Dolphin. The same phenomenon was predicted but to a lesser extent when winds would be blowing from the South and North. These predicted eddy currents may lead to accumulation of any surface contaminants in this area. Evidence of such eddy currents in the central part of the bay, have been recorded in the field (**Figure 3**) with directions of the recorded surface currents apparently forming part of large-scale gyre systems.

The sea currents and water residence time within the various parts of Marsaxlokk Bay may be determined by a number of factors including: seiches (and to a lesser extent, tides); sea and swell wave-induced oscillations; local wind shear forces and density effects due to temperature and salinities.

In the summertime, some temperature stratification can occur inside the basin especially in the deeper and outer regions, when the upper layers of the water are warmed by solar radiation. In the deeper parts of the bay, the temperature difference between surface and bottom waters may generally be in the range of 2^{o} C.

Salinity vertical fluctuations are also minimal (within 0.5 ppt) in the deep parts of the bay. More significant salinity fluctuations may occur in the inner and more shallow creeks especially during the rainy season, due to significant rain runoffs.

At this stage of data availability, the estimation of water residence time and flushing rates at the various locations within Marsaxlokk, may only be carried out through rough calculations and as based on very simple assumptions. More estimations that are accurate will need to be based on mathematical modeling.

Therefore, it may be assumed that while various factors may influence the water residence time in the various creeks, tidal action and the subsequent changes in water levels may be expected to play a dominant role.

It is reasonable to assume that inside Marsaxlokk Bay there is the general Mediterranean tidal fluctuation with a period of approximately 12 hours, on which are superimposed smaller fluctuations due to swell waves, internal resonance of the particular basin and other factors. In general, we may assume a bi-diurnal tidal change in water level of 35 cm on average. By estimating the approximate surface areas of the various creeks and parts of the Marsaxlokk Bay, we may produce a rough estimate of the water residence time in the basin as a whole and in different sub-basins.

Making such assumptions and calculations, it may be estimated that the water residence time within the whole of Marsaxlokk basin be in the region of 27 days.

For the purpose of the present assessment, it may be constructive to consider as a sub-basin, the part of Marsaxlokk inner bay (off Marsaxlokk village) as being bounded on its outer limits by San Lucian promontory and DPS. The residence time for such sub-basin may be estimated to be in the region of 12 days.

Using the same estimations and assumptions, the residence time of waters within Hofra z-Zghira would be 4 days. In actual fact, due to the discharge of cooling waters from the DPS within this circular enclave, it is most likely that the actual water residence time at this locality will be much shorter and more likely to be 1 day or less.

2.3 Marine Environmental Quality in Marsaxlokk: Review of Archived Data

The following account is based on published and unpublished data and results of marine surveys by the research group of the present consultant (Marine Ecotoxicology Laboratory, Department of Biology, University of Malta) undertaken within Marsaxlokk Bay over the period from November 2008 to October 2010. Over this period, water quality parameters were measured in 11 stations distributed throughout the whole area. Results are summarized in **Table 1**.

Table 1: Levels of various water quality parameters as measured in 11 stations throughout Marsaxlokk Bay over the period November 2008 to October 2010. Statistics are for 7 surveys. ***(bdl = below detection limit)***

	at surface			at 5 m depth		
	mean	**min**	**max**	**mean**	**min**	**max**
Water transparency (BACm^{-1})	0.60	0.03	1.54	0.54	0.11	1.32
Dissolved Oxygen (% of saturation)	93.10	67.20	108.20	93.65	64.40	107.60
Chlorophyll *a* (µg/L)	0.215	0.129	0.402	0.237	0.145	0.457
Nitrates (µmol N/L)	2.076	0.145	8.574	1.255	bdl	8.010
Phosphates (µmot P/L)	0.189	bdl	4.808	0.243	bdl	4.201

2.3.1 Dissolved Oxygen Levels

The annual mean levels of dissolved oxygen (DO) in most areas within Marsaxlokk Bay are usually not far from saturation (mean levels for whole area per survey rarely being less than 90%). No anoxic conditions are ever reported in the bottom waters. The lowest recorded DO at surface was of 67% off DPS, while the lowest DO level at 5m depth was of 64.4% in the vicinity of the floating fish cages off St Lucian promontory.

2.3.2 Water Transparency

Water transparency is a good indication of water quality. It may be measured either in terms of Secchi depths (more turbid waters have reduced Secchi depths) or Beam Attenuation Coefficients (BAC, more turbid waters have higher coefficients) as measured by an in situ transmissometer. In many studies undertaken by the present consultant and being reviewed for the purpose of the present report, water transparency has also been reported in terms of beam attenuation coefficients at 660 nm. This is a more accurate and informative index than that previously used which was based on the use of a Secchi disc. However, since until recently, water transparency in local coastal waters used to be reported in Secchi depths, these are also being reported here whenever possible.

The mean Secchi depth, indicating the degree of water transparency outside the harbours is generally over 15 m and this is typical of oligotrophic coastal waters of the region. The transparency of the waters decreases significantly towards the innermost parts of most harbours where minimum levels ranging from 1.2 m to 1.8 m have been recorded in various months of the year.

For Marsaxlokk over the period November 2008 until October 2010, minimum Secchi depths of less than 2m were recorded occasionally (though not consistently) in various stations with no particular spatial trend. This may be due to incidents of runoff.

In terms of BAC, clear offshore waters usually have values below 0.18 m^{-1} while turbid waters under the influence of land-based discharges tend to have values above 1 m^{-1}. Water transparency as measured in terms of BAC, off Marsaxlokk village, was generally found to be relatively low, with values ranging from 0.6 to 0.9 m^{-1} for surface waters. In waters 100 m off DPS, the mean BAC level was estimated to be rather low at 0.958 m^{-1}, with waters at 5m depth being more transparent.

2.3.3 Nutrients, Chlorophyll *a* and Eutrophication

Table 1 also shows some statistics on the levels of a number of water quality parameters monitored in Marsaxlokk Bay over the period November 2008 to October 2010.

The overall mean levels for nitrates and phosphates in surface waters were found to be 2.076 umol N/L and 0.189 umol P/L respectively. Nutrient levels in the Grand Harbour and in Marsamxett Harbour during the same period, were generally found to be higher.

Chlorophyll *a* levels ranged from 0.1 to 0.5 ug/L confirming that apart from the innermost part of the bay at the fishing village, the levels of primary productivity of the area are not excessively high and rarely show any evidence of eutrophication.

High levels of nutrients and chlorophyll in the water may lead to **eutrophication**. Eutrophication is a phenomenon of poor water quality usually associated with sewage pollution and elevated nutrient levels. This condition may lead to uncontrolled growth of microscopic plants (some of which may be directly toxic to humans and to marine life), with the colour of water becoming abnormally green and turbid. There is usually a reduction in oxygen levels, which may lead to fish mortality and to stress on marine life.

One index of eutrophication is TRIX. Pisani (2011) has recently reviewed its use in the Mediterranean. The TRIX index is based on chlorophyll *a*, oxygen saturation, total nitrogen and total phosphorus. It assigns a numerical value to the trophic levels of coastal waters on a scale from 0 to 10 TRIX units. As can be seen in the following table, the higher the value of the TRIX index the poorer the water quality is. When the TRIX index is less than 4, the levels of eutrophication are considered to be minimal and water conditions as excellent. When the value exceeds 6 eutrophic conditions are deemed to be significantly high.

Pisani (2011) calculated the TRIX index for various stations in Maraxlokk, Grand Harbour and Marsamxett over the period December 2009, October 2010. TRIX levels in the Grand Harbour were generally higher than those in Marsamxett and more so than in Marsaxlokk, with the overall mean TRIX levels being 4.16, 3.68, and 3.36 respectively. This score clearly ranks these three harbours in order of eutrophication risks. Evidently, as a whole area, Marsaxlokk is the least exposed to eutrophic risks of the three harbours, and as per definition of TRIX in the previous paragraph, we may conclude that the levels of eutrophication in this basin as a whole are minimal.

2.3.4 Microbiological Pollution

Levels of microbiological pollution resulting from sewage contamination are reliably monitored using faecal coliforms (FC) as indicator.

Over the period November 2008 to October 2010, 60% of samples collected exceeded 500 FC CFU/100mL. This is indicative of chronic releases of sewage and possibly release of animal wastes through runoff, throughout the whole year, within the whole of Marasxlokk Bay.

It is to be noted that the stations used for monitoring were not located within the designated swimming zones at St. George’s Bay and Pretty Bay. During the bathing seasons of 2009 and 2010, the bathing waters of St George’s Bay and Pretty Bay were relatively clean with only about 6% of samples exceeding 100 CFU/100mL. Such data is available from the official bathing water monitoring programme undertaken by the Environmental Health Directorate.

Therefore the available data suggest that while the officially designated swimming areas within Marsaxlokk (St George’s Bay and Pretty Bay) are relatively free of sewage pollution, over the period 2008 to 2010, the rest of the waters within the bay, are exposed to chronic pollution by sewage. These include the waters along the DPS.

2.3.5 Other Pollutants

AIS/(2009) analysed for a wide range of potential contaminants in seawater at four stations, namely: about 30 metres off DPS; within *Kalanka l-Fonda* outside Marsaxlokk Bay; on the eastern part of Delimara headland; immediately next to the current discharge point of cooling waters at *Hofra z-Zghira*, and at the mouth of *Hofra z-Zghira*. The parameters monitored included:

- Benzene, Ethybenzene, Styrene,Toluene and Xylene;
- Chromium, Nichel, Lead, Vanadium;
- A range of poly aromatic hydrocarbons.

All pollutants were recorded to be below detection limits.

These data suggest that the water quality along both sides of Delimara headland is very good, and that the current operations of the DPS are having no impact on the marine environment. Nonetheless these results need to be treated with caution. No replicate samples were taken at each location and monitoring was carried out only once. Furthermore, water is a highly mobile phase and the levels of contaminants in surface waters, especially in areas exposed to rapid dispersions are known to be highly variable and distributed heterogeneously. For this reason, monitoring of pollutants in superficial marine sediments, would have produced a more reliable set of data on the marine environmental quality in the area, since marine sediments are known to act as integrative sinks for pollution.

2.4 Marine Environmental Quality in Hofra z-Zghira: Review of Archived Data

2.4.1 Thermal Conditions

In spite of receiving all the discharged cooling waters from DPS, very little information is available on the water and sediment quality within Hofra z-Zghira. The following section is mostly based on field data collected from two fixed stations (S26, S27) located within Hofra z-Zghira by the present consultant over the period June 2000 to March 2004. Monitoring was also undertaken at other stations including one located off Munxar Point (S25) in the limits of St Thomas Bay to the north of Hofra z-Zghira, and another located to the south of Hofra (S28). Most of the relevant data for all four stations are summarized in **Table 2**. Data from S25 and S28 are being included since these may serve to a certain extent as reference to the thermal and other conditions within Hofra. Nonetheless it must be pointed out that both S25 and S28 were located in the vicinity of fish farming cages.

During the period 2000 to 2004, DPS had a total energy production capacity of 304 MW, with a total of 3 steam turbins and 4 gas turbines being in operation. Cooling waters were being discharged at Hofra z-Zghira in the immediate vicinity of station S26.

From **Table 2**, it is evident that thermal pollution was significant at Hofra z-Zghira, with the overall mean yearly water temperature at surface being 23.5 ^{o}C compared to that at the reference stations of 21.2 ^{o}C. Maximum surface sea temperatures reached 30.5 ^{o}C. During these 4 years, the surface temperatures in the vicinity of the discharge point of cooling waters was estimated to be 12.2% above ambient, often exceeding 15% above ambient during several months of the year. The maximum thermal anomaly was recorded in March 2004, when it reached 33% above ambient.

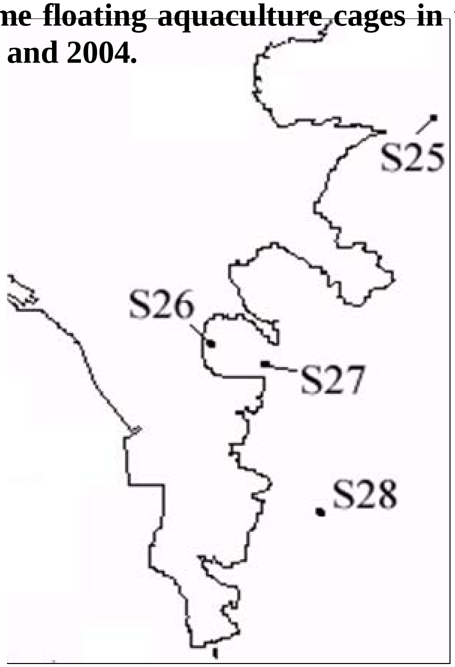
Nonetheless, this thermal anomaly rapidly declined with distance away from the discharge point so that at S27, which was located at the outer part of Hofra, the overall yearly thermal anomaly recorded for the period (2000-2004) was 4.3% above ambient. This is due to the fact that heat was being rapidly lost to the air by the buoyant surface thermal plume.

The present consultant is not aware of any further field data on thermal conditions within Hofra z-Zghira after 2004. More recently, EIS/SLR (2011) reported that prior to 2011 the discharged rate of cooling waters by DPS at Hofra z-Zghira were 29,500 m^3/h. The study predicted that the increase in energy generation which occured in 2012 (commissioning of Delimara 3) would produce an increased discharge of cooling waters of 43,000 m^3/h; both at 8^{o}C above the ambient water temperature.

The same report produced results based on mathematical models of the predicted extent of thermal plume under different climatic conditions as discharged at Hofra z-Zghira. These show that the natural water currents in the area are low and that the flow dynamics in Hofra iz Zghira are dominated by the discharge. Surface temperature in the coastal waters (i.e. outside of Hofra iz Zghira) were up to 1.5^{o}C above background, and the temperature at the mouth of the bay was +2^{o}C. Within the bay, temperatures increased to +8^{o}C at the outfall with the highest temperatures along the west and north coasts.

The same mathematical predictions suggested that the bottom temperatures outside the bay were unaffected by the discharge. Within the bay sea bed temperatures are increased along the western and northern shores. Under conditions of strong winds and wave action the vertical mixing in the area was increased resulting in warmer water being mixed to the water bottom. Water of +0.5^{o}C was predicted to occur at the sea bottom in limited areas outside the bay; the bottom temperature at the southern point of the mouth of the bay is +1^{o}C, which would give a maximum of 28^{o}C at the height of the summer.

Table 2: Various water parameters as monitored at four fixed stations, off St Thomas Bay (S25), immediately in the vicinity of the cooling waters discharge point in Hofra z-Zghira (S26); in outer part of Hofra z-Zghira (S27) , and in the vicinity of some floating aquaculture cages in the open area south off Hofra z-Zghira (S28). Monitoring was undertaken between 2000 and 2004.



Station		Temperature	Salinity	Chlorophyll a	BAC	Dissolved Oxygen	Nitrates	Phosphates	pH
		Deg C	*ppt*	*ug/l*	*m^{-1}*	*% sat*	*umol N/l*	*umol P/l*	
S25	n	8	8	7	7	1	8	8	4
	mean	**21.3**	**37.0**	**2.1**	**0.2**	**98.0**	**8.8**	**0.2**	**8.2**
	max	26.4	38.6	3.8	0.5	98.0	37.1	0.5	8.3
	min	15.5	36.6	0.1	0.2	98.0	0.0	0.0	8.1
S26	n	9	9	9	9	2	9	9	4
	mean	**23.5**	**37.2**	**2.4**	**0.7**	**89.9**	**2.9**	**0.1**	**8.2**
	max	30.5	38.6	3.6	3.2	94.9	8.1	0.4	8.3
	min	17.7	36.7	0.1	0.2	84.9	0.0	0.0	8.0
S27	n	9	9	9	9	2	9	9	4
	mean	**21.9**	**37.1**	**2.1**	**0.3**	**90.8**	**10.0**	**0.1**	**8.2**
	max	27.6	38.5	2.9	0.5	97.1	42.0	0.3	8.4
	min	15.8	36.5	0.1	0.2	84.4	0.0	0.0	8.0
S28	n	9	9	9	9	2	9	9	3
	mean	**21.1**	**37.0**	**2.1**	**0.3**	**91.5**	**6.1**	**0.1**	**8.2**
	max	27.2	38.6	3.1	0.5	95.6	12.8	0.4	8.4
	min	15.0	36.6	0.1	0.2	87.4	0.0	0.0	8.0

With the increased discharge of cooling waters due to the coming in operation of Delimara 3, it was predicted that the surface temperature in the coastal waters (i.e. outside of Hofra iz-Zghira) were up to 2^{o}C above background, and the temperature at the mouth of the bay on the northern side would be +3^{o}C. Within the bay temperatures would increase to +8^{o}C at the outfall with the highest temperatures along the west and north coasts.

In the experience of the present consultant, these mathematically based predictions are more likely to over-estimate the thermal anomalies within Hofra.

2.4.2 Other Water Quality Parameters

Table 2 shows that at least for the period 2000-2004, the discharge of cooling waters within Hofra z-Zghira, did not produce any significant salinity or pH anomalies in this locality. As expected (due to lower oxygen solubility in warmer waters), the levels of dissolved oxygen in the immediate vicinity of the outfall occasionally declined below ambient levels, so that in some cases, levels dropped below 90% of saturation. Nonetheless no hypoxic or anoxic conditions were ever recorded.

Water turbidity in terms of BAC values in surface water in the immediate vicinity of the discharge point of cooling waters was found to be 0.7 m^{-1} which dropped to 0.3 m^{-1} at the opening of the enclave.

There was no evidence of eutrophication (in terms of chlorophyll *a* levels) within Hofra z-Zghira. Nonetheless occasional high levels of nitrates were monitored over the period 2000-2004.

As already indicated in a previous section (**2.3.5**), AIS (2009) analysed for a wide range of potential contaminants in seawater within Hofra z-Zghira, and all parameters were recorded to be below detection limit. These included a range of low boiling point aromatics, polyaromatic hydrocarbons and metals.

Occasionally, there is evidence of lasting foam at the surface in the vicinity of the thermal outfall. For example, according to visual reports made on the 19th June 2013, a white surface foam was noted within Hofra z-Zghira which was streaked with a brown tinge and had a smell of amines. The nature of such foam may not be ascertained at present. For the purpose of the present assessment, it is opportune to note that the presence of such foam has been occasionally reported by casual observers. It had never been reported during any of the various monitoring programmes, the data of which, are being reviewed in the present assessment. So it is likely to be of an ‘episodic nature’. Incidentally, similar reports have been made from other inshore local areas not exposed to cooling water discharges.

2.4.3 IPPC Data for Cooling Waters

In compliance with IPPC Directive, (CD 96/61/EC concerning integrated pollution prevention and control), Enemalta has commissioned periodic chemical analysis of the cooling waters for a number of years. For the purpose of the present report, data for the period March 2012 to April 2013 have been made available to the present consultant. Such data include analysis for a wide range of water quality parameters and chemicals (over 120) of water samples (a single sample for each survey; no replicates) taken at the cooling water discharge point at Hofra z-Zghira , and at the marine intake point within Marsaxlokk. Monitoring was carried out every three months.

A number of observations may be made on such results for the period March 2012 to April 2013:

- For a number of parameters, levels of contaminants are present both at the inlet and outlet sites, which indicate that the particular contaminant has not necessarily been released by the direct operations of DPS.
- An overall average level of 10 mg/L of total suspended solids are being released at Hofra z-Zghira through the discharge of cooling waters.
- The residual chlorine levels were always found to be below 0.01 mg/L (i.e. detection limit);
- The BOD (Biochemical Oxygen Demand) were always found to be below 1mg/L (i.e. detection limit);
- No polychlorinated biphenyls (PCBs) were every detected in the discharged waters;
- No significant polyaromatic hydrocarbons or other aromatics were ever detected;
- Some traces of metals were occasionally released. Of these, zinc featured most significantly at an average level of 11 ug/L (this being the difference between levels at inlet and outlet). Copper, arsenic and cadmium were being released at much lower levels (3.2; 1.9; 1.0 ug/L respectively).

Evidently, when we take into account the huge volume of waters being discharged on a daily basis, the levels of releases of certain contaminants may assume greater significance. For example, assuming that the rate of discharge of cooling waters to Hofra z-Zghira of this period was 43,000 m^3/h, then the rate of daily releases originating from the DPS operations amount to 0.5 kg of suspended solids, 0.5 g of zinc, 0.1 g of copper and of arsenic, etc... Nonetheless, taking into consideration the high dispersive conditions at Hofra z-Zghira, the impacts on water quality of such releases are curruntly minimal.

2.5 Marine Environmental Quality: Review of Monitoring Data made available by MEPA icw WFD monitoring.

As will be discussed in detail in **Section 2.10**, Malta is required to undertake baseline (surveillance) monitoring of marine environmental quality in designated water coastal water bodies in compliance with the Water Framework Directive. As a result of this monitoring the chemical status of each water body will be determined in compliance with Environmental Quality Standards for specific chemicals or group of chemicals.

Marsaxlokk area (including Hofra z-Zghira) has been designated as a single water body with code MTC107. Surveillance monitoring data generated over the period 2012-13 has been made available by MEPA (the Competent Authority, under the WFD) to the present consultant for the purpose of the present assessment. Results will be reviewed in this section.

The stations used for this surveillance monitoring are shown in **Figure 4**. Results were made available for water monitoring at Stations CN07-1,CN07-2, CN07-3, and CP07 over the period June 2012 to March 2013, and for sediment monitoring at the same four stations for samples collected in August 2012. For the sampling of water, two replicates from each station at 5m depth were taken at each survey. It seems that the full list of water parameters were monitoried only at station CP07. pH, and nutrients (including ammonia) were monitored at the rest of the 3 stations. Superficial sediments were collected with the use of Van Veen grab sampler.

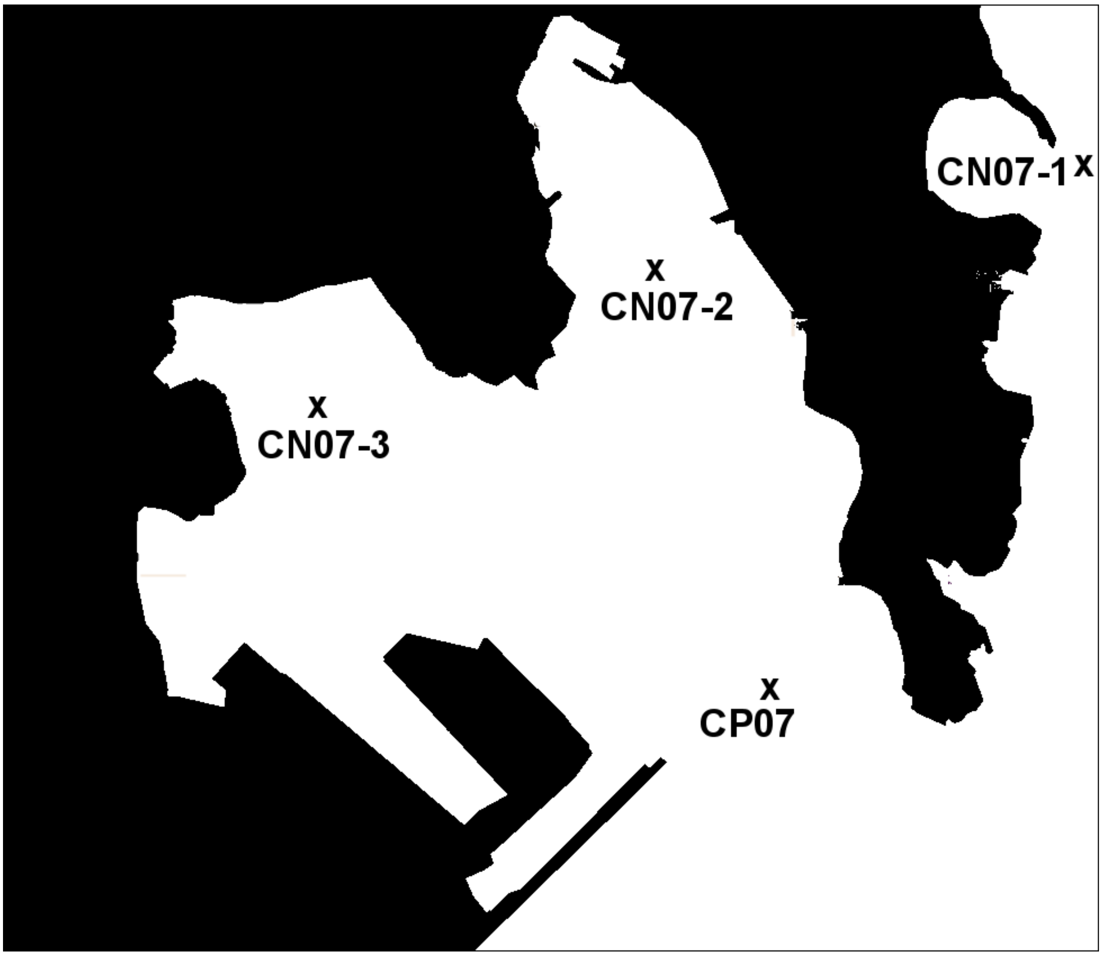


Figure 4: Location of monitoring stations used for WFD surveillance monitoring undertaken by MEPA.

Some relevant statistics for these results are shown in **Tables 3** and **4**.

Table 3: Water parameters as monitored at four fixed stations (Figure 4). Means are for 18 replicates over the period June 2012 to March 2013. ***(bdl = below detection limit)***

		Station	CN07-1			CN07-2			CN07-3			CP07		
Parameter	**Units**	**Detection limits**	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*
pH			**7.92**	*8.3*	*7.5*	**7.93**	*8.3*	*7.7*	**7.89**	*8.3*	*7.6*	**7.94**	*8.4*	*7.7*
Nitrites	mg/L	0.05	**bdl**			**bdl**			**bdl**			**bdl**		
Nitrates	mg/L	0.1	**0.70**	*3.3*	*0.05*	**0.29**	*1.4*	*0.05*	**0.28**	*1.4*	*0.05*	**0.39**	*3.7*	*bdl*
Ammonium (as NH4)	mg/L	0.1	**0.02**	*0.12*	*bdl*	**0.02**	*0.12*	*bdl*	**bdl**			**bdl**		
Total N	mg/L	0.1	**2.42**	*3.5*	*1*	**2.58**	*4.3*	*1.2*	**2.71**	*3.5*	*1.1*	**2.18**	*3.8*	*1.2*
Phosphate	mg/L	0.2	**bdl**			**bdl**			**bdl**			**bdl**		
Total P (as P)	mg/L	0.07	**0.19**	*0.75*	*0.07*	**0.27**	*1.8*	*0.074*	**0.28**	*2.2*	*0.035*	**0.18**	*0.78*	*bdl*
Alachlor	µg/L	0.01										**bdl**		
Anthracene	µg/L	0.005										**bdl**		
Atrazine	µg/L	0.005										**bdl**		
Benzene	µg/L	0.1										**bdl**		
Brominated diphenylethers	µg/L	0.05										**bdl**		
Cadmium	µg/L	0.45										**bdl**		
Carbon tetrachloride	µg/L	0.01										**bdl**		
Chloroalkanes, C10-13	µg/L	0.4										**bdl**		
Chlorfenvinphos	µg/L	0.01										**bdl**		

		Station	CN07-1			CN07-2			CN07-3			CP07		
Parameter	**Units**	**Detection limits**	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*
Chlorpyrifos	µg/L	0.01										**bdl**		
Endrin	µg/L	0.001										**bdl**		
Isodrin	µg/L	0.001										**bdl**		
Aldrin	µg/L	0.001										**bdl**		
Dieldrin	µg/L	0.001										**bdl**		
DDT Total	µg/L	0.01										**bdl**		
Para-para-DDT	µg/L											**bdl**		
1,2-Dichloroethane	µg/L	0.01										**bdl**		
Dichloromethane	mg/L	0.01										**bdl**		
Di(2-ethylhexyl) phthalate	µg/L	1										**0.56**	*1*	*bdl*
Diuron	µg/L	0.01										**bdl**		
Endosulfane	µg/L	0.001										**bdl**		
Fluoranthene (PHC)	µg/L	0.005										**bdl**		
Hexachloro-benzene	µg/L	0.001										**bdl**		
Hexachloro-butadiene	µg/L	0.01										**bdl**		
Hexachloro-cyclohexane	µg/L	0.001										**bdl**		
Isoproturon	µg/L	0.1										**bdl**		

		Station	CN07-1			CN07-2			CN07-3			CP07		
Parameter	**Units**	**Detection limits**	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*
Lead	µg/L											**1.19**	*4.1*	*0.37*
Mercury	µg/L	0.05										**0.17**	*0.48*	*bdl*
Naphthalene	µg/L	0.005										**bdl**	*0*	*0*
Nickel	µg/L											**5.73**	*19*	*bdl*
Nonylphenols	µg/L	0.3										**bdl**		
4-nonylphenol	µg/L	0.3										**bdl**		
Octylphenols	µg/L	0.01										**bdl**		
Pentachlorobenzene	µg/L	0.001										**bdl**		
Pentachlorophenol	µg/L	0.05										**bdl**		
Polyaromatic Hydrocarbons SUM	ug/l	0.1										**bdl**		
Benzo(a)pyrene	µg/L	0.001										**bdl**		
Benzo(b) fluoranthene	µg/L	0.01										**bdl**		
Benzo(g.h.i) perylene	µg/L	0.001										**bdl**		
Benzo(k) fluoranthene	µg/L	0.005										**bdl**		
Indeno(1,2,3-cd)pyrene	µg/L	0.001										**bdl**		
Simazine	µg/L	0.001										**bdl**		
Tetrachloro-ethylene	µg/L	0.01										**bdl**		

		Station	CN07-1			CN07-2			CN07-3			CP07		
Parameter	**Units**	**Detection limits**	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*	**MEAN**	*max*	*min*
Trichloro-ethylene	µg/L	0.01										**bdl**		
Tributyltin compounds	µg/L	0.05										**bdl**		
Trichloro-benzene	µg/L	0.2										**bdl**		
Trichloro-methane	µg/L	0.01										**bdl**		
Trifluralin	µg/L	0.01										**bdl**		

Table 4: Sediment quality parameters as monitored at four fixed stations (Figure 4) as monitored in a single survey undertaken in August 2012. N = number of replicates. ***(bdl = below detection limit; NA= not available)***

Parameter	Units	Detection limits	MEAN	max	min	N
Cadmium	mg/kg	0.05	**0.039**	0.073	bdl	8
Nickel	mg/kg	NA	**7.63**	10.00	4.40	8
Lead	mg/kg	NA	**7.03**	11.00	3.60	8
Mercury	mg/kg	NA	**0.035**	0.057	0.021	8
Copper	mg/kg	NA	**6.5**	15.0	1.9	8
Chromium Tot	mg/kg	NA	**8.93**	11.00	3.60	8
Cobalt	mg/kg	2	**bdl**			7
Manganese	mg/kg	NA	**29.8**	41.0	15.0	8
Zinc	mg/kg	NA	**18.2**	29.0	7.5	8
Barium	mg/kg	NA	**11.8**	16.0	6.1	8
Beryllium	mg/kg	0.2	**0.179**	0.220	bdl	7
Boron	mg/kg	NA	**28.8**	53.0	11.0	8
Fluorides	mg/kg	2.5	**2.164**	3.200	bdl	7
Total Hydrocarbons	mg/kg	NA	**52.8**	135.0	18.0	8
Indeno(1,2,3-cd)pyrene	mg/kg	0.001	**0.004**	0.015	bdl	8
Benzo(a)pyrene	mg/kg	0.001	**0.008**	0.027	bdl	8
Benzo(b)fluoranthene	mg/kg	0.001	**0.007**	0.025	bdl	8
Benzo(g.h.i)perylene	mg/kg	0.001	**0.005**	0.018	bdl	8
Benzo(k)fluoranthene	mg/kg	0.001	**0.004**	0.013	bdl	8
Anthracene	mg/kg	0.001	**bdl**			8
Fluoranthene (PHC)	mg/kg	0.001	**0.011**	0.044	bdl	8
Naphtalene	mg/kg	0.001	**bdl**			8
PAH	mg/kg	NA	**0.084**	0.280	0.001	8
PHC	mg/kg	NA	**52.8**	135.0	18.0	8
Malathion	mg/kg	0.001	**bdl**			8
DDT Total	mg/kg	0.0001	**bdl**			6
Diuron	mg/kg	0.001	**bdl**			6
Endosulfane I Alpha	mg/kg	0.0001	**bdl**			6
Endosulfane II Beta	mg/kg	0.0001	**bdl**			6
Endrin	mg/kg	0.0005	**bdl**			6
Hexachlorobenzene	mg/kg	0.005	**bdl**			6
Hexachlorobutadiene	mg/kg	0.01	**bdl**			6
Hexachlorocyclohexane alpha	mg/kg	0.0005	**bdl**			6

Parameter	Units	Detection limits	MEAN	max	min	N
Hexachlorocyclohexane beta	mg/kg	0.0005	**bdl**			6
Hexachlorocyclohexane gamma Lindane	mg/kg	0.0005	**bdl**			6
Pentachlorobenzene	mg/kg	0.0001	**bdl**			6
Brominated diphenylethers	mg/kg	0.01	**bdl**			6
Chloroalkanes, C10-13	mg/kg	0.01	**bdl**			6
Bis (2-ethyhexyl) phthalate	mg/kg	0.001	**0.033**	0.065	bdl	6
Tributyltin	mg/kg	0.01	**0.062**	0.180	bdl	6

A number of observations may be made on such data:

- The recorded pH of marine waters in Marsaxlokk as well as in the vicinity of Hofra z-Zghira, was in the normal ranges as recorded elsewhere in local waters.

- Nutrient levels were relatively low as would be expected in oligotrophic waters. In the case of phosphates, the lowest detection limit for the standard analytical method used, was evidently inappropriate for our waters.

- Valuable data may be obtained by computing the N:P ratio (in this case total nitrogen and total phosphorus levels were used for such computation) from such data. This ratio is indicative of whether nitrogen or phosphorus would be the main limiting factor for the primary productivity in the area. Lowest N:P ratios were recorded during the months of September, November and December probably due to relatively high levels of phosphorus in surface waters due to its replenishment via relatively rough sea conditions. For the rest of the year, N:P ratios at all stations were generally (but not always) above 15 to 20. This suggests that phosphorous may be the more important limiting factor.

- Overall nutrient levels near Hofra z-Zghira as well as N:P ratios in this area, were not significantly different from those reported in Marsaxlokk. This suggests that the discharge of cooling waters is not having any impact on nutrient levels, at least in the vicinity of Hofra z-Zghira.

- Most organic contaminants, including pesticides, solvents, antifouling agents, etc, were below detection limits.

- 11% of samples (2 out of a total of 18 samples analyzed, including replicates) had levels of Di(2-ethylhexyl)phthalate (DEHP), well above detection limits. The overall mean level was estimated to be 0.56 ug/L This may be taken as the annual average level of this contaminant for this water body. This is 43% of the AA-EQS (Annual Average-Environmental Quality Standard) as established by the Environmental Quality Standards Directive (EC 105/2008). In the case of this contaminant, the Directive did not establish a maximum level which could not be exceeded at any single reading. DEHP is a relatively ubiquitous chemical, which may frequently be found in the environment. Its likely source within Marsaxlokk may be more properly assessed by the consultants who are reviewing the whole data set for sediment/water quality for other coastal water bodies in Malta under the WFD. In any case, given the usual land-based sources of releases of DEHP, the proposed development at DPS will not lead to a further release of this contaminant in the area of influence of the proposed project.

- Three heavy metals were detected in these waters, above detection limits. These include lead, with an annual average level of 1.19 ug/L. The new AA-EQS set for Lead is now 1.3 ug/L while formerly it was 7.2 ug/L. Therefore, the AA level for lead in this locality does not exceed the set EQSs. Even the highest single level recorded (4.1 ug/L), did not exceed the new maximum set limit of 14ug/L. Nickel was also found well above its analytical detection limit but still did not exceed the AA-EQS, which has been formerly set at 20 ug/L but now reduced to 8.6 ug/L. The MAC-EQS for nickel, which has now been set to 34 ug/L, has also not been exceeded by any sample.

- For the case of mercury (and its compounds as found dissolved or suspended in marine waters), the annual average level for this water body was estimated to be 0.17 ug/L which well exceeded the (formerly) set AA-EQS of 0.05 ug/L. In fact, 12 out of a total of 18 samples (including replicates) were found to have mercury levels above detection limit, over a period of 9 months. The maximum level was recorded at 0.5 ug/L. Evidently, this result needs to be investigated further. It needs to be compared to other results for mercury levels in other local coastal water bodies (results available to MEPA). At this stage, it may be noted that the minimum detection limit for mercury for the standard analytical technique used in this monitoring programme (EPA 3015A2007+EPA 6020A 2007), was given as 0.05 ug/L. This may present a problem of interpretation, since the minimum detection limit should ideally be 30% of the set EQS. Furthermore, the relevant EU Directive now requires that Member States set EQS for mercury in biota rather than in waters.

With respect to sediments on the bases of data available in **Table 4**, the following conclusions may be reached:

- A range of heavy metals were found well above analytical detection limits in these sediments, as would be expected (since sediments often act as reservoirs for contaminants). However all such levels were found below guideline values as indicated in **Table 8**. Such values were also comparable to those recorded in this same locality by other sources (as will be reviewed later on in this report).

- Levels of petroleum hydrocarbons were found well above detection limits, with the highest values recorded in the eastern basin of Marsaxlokk (Station CN07-2) off DPS and in the immediate vicinity of Has-Saptan Dolphin. These values are generally higher than those recorded previously for the same area (results to be reviewed later on in this report), however this may also be due to different analytical techniques used.

- Several PAHs were recorded above detection limits. Highest levels were again recorded at Station CN07-2, and therefore these are mostly likely to be related to pollution by oil and fuels.

- Tributyltin (antifouling agent) was recorded above detection limits, only at Station CN07-2.

2.6 Marine Environmental Quality: Review of Data Made Available for the Present Study

As part of the present assessment, it was deemed proper to update the available archived data on marine quality in the area (which has been reviewed in the previous sections) with other field data as monitored in June 2013. This monitoring was undertaken by Ecoserv Ltd. on the 19th June 2013 and full details of water and sediment sample collection, analytical methodology, as well as results obtained are being reported in Annex I of this report (Ecoserv, 2013).

Water samples were collected from 7 stations as shown in **Figure 5**. Water temperature, salinity, dissolved oxygen and water turbidity (in terms of NTU units), , were measured *in situ* by Ecoserv. Chlorophyll *a* levels were analysed in the laboratory. Levels of *Eschericia coli* and of Intestinal Enterococci, were also measured by Ecoserv, using the standard membrane filtration test protocol. Chlorophyll *a* and bacteriological parameters were analysed immediately upon arrival of the samples at the lab, as is required by the respective protocols. Monitoring at each station was carried out at different water depths. Such results and indications of depths monitored, are presented in **Table 5**.

Table 6 represents the data on levels of various contaminants in surface waters at four of such stations. Values shown are means of two replicate values. For the purpose of computing such means, when one out of the two replicate values was above the minimum detection limit, the other value was taken as 50% of the detection limit. This calculation protocol was adopted from EC Guideline (2009).

Furthermore, superficial marine sediments were collected from 4 stations (**Figure 5**). Results of contaminants in such sediments are presented in **Table 7**.

Figure 5: Location of monitoring stations used for water and sediment quality monitoring in June 2013. ***Crosses indicate stations used for water quality only, while crosses within boxes indicate stations used for water and sediment quality monitoring.***

Table 5: Several Water Quality Parameters as measured in June 2013 (for further details see text). (*Values shown are means of 4 replicates, except for TSS, Nitrates, Phosphates, BOD, COD, and bacteriological parameters were means shown are for 2 replicates)*

Station	Depth	Temp	Salinity	ODO%	Chlorophyll a	Turbidity+	Tot.Susp. Solids	Nitrates	Phosphates	BOD	COD	*E.coli*	*Intestinal Enterococci*
	m	°C	ppt	%	ug/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
1	0	23.47	36.15	107.8	0.679	0.7	1.7	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	17.5	0.5
	5	22.66	36.75	116.6	0.679	0.8	2.9	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	6.5	0.5
	Bottom	22.87	36.70	114.2		0.7							
2	0	22.94	33.98	108.6	0.441	0.4	2.9	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	5.5	0
	5	21.71	36.67	109.2	0.213	0.8	1.7	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	3	7.5
	20 (bottom)	20.97	36.71	105.6		0.7							
3	0	22.80	36.78	108.1	0.339	0.4	1	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	19	9.5
	5	21.64	36.74	106.6	0.280	1.0	2.3	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	8.5	14
	20 (bottom)	21.36	36.74	107.3		1.3							
4	0	23.36	36.79	109.9	0.339	0.5	1.3	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	29.5	6.5
	5	21.68	36.76	106.9	0.280	0.8	3.3	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	3	75
	20-25 (bottom)	21.27	36.74	106.1		1.0							
5	0	22.61	36.78	107.7	0.221	0.5	0.7	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	10	1
	5	21.71	36.76	106.1	0.221	0.3	3.1	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	1.5	0.5
	Approx. 40 (bottom)	20.03	36.70	103.5		0.1							
6	0	26.14	36.80	123.2	0.562	0.3	1.2	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	3.5	2.5
	5	22.44	36.75	115.7	0.826	0.2	1.9	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	2.5	0
	Approx. 10 (bottom)	21.70	36.74	108.2		68.2							
7	0	24.76	36.80	116.7	0.715	0.3	1.3	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	5.5	2.5
	5	22.42	36.78	110.5	0.460	0.1	0.6	ND < 0.01	ND < 0.01	ND < 5.0	ND < 5.0	1.5	3
	10 bottom)	20.84	36.70	110.2		0.2							

Table 6: Levels of contaminants in surface waters as monitored in June 2013 at four stations (see Figure 5 for location). (*Values shown are means of two replicates)*

Chemical Parameters	Units	Minimum Detection Limit	STATION : 1	3	5	6
Arsenic	µg/l	1	BDT	BDT	BDT	BDT
Cadmium	µg/l	0.1	BDT	BDT	BDT	BDT
Chromium	µg/l	1	BDT	BDT	BDT	BDT
Copper	µg/l	1	**1.3**	BDT	BDT	BDT
Lead	µg/l	1	BDT	BDT	BDT	BDT
Mercury	µg/l	0.05	BDT	**0.5**	BDT	BDT
Nickel	µg/l	1	BDT	BDT	BDT	BDT
Zinc	µg/l	1	BDT	BDT	BDT	BDT
Chloroalkanes (C10-13)	mg/l	0.01	BDT	BDT	BDT	BDT
Pentabromodiphenylether	µg/l	0.0001	BDT	BDT	BDT	BDT
Di(2-ethylhexyl)phthalate	µg/l		**8.7**	**1.5**	**2.1**	**2.6**
Hexachlorobenzene	µg/l	0.001	BDT	BDT	BDT	BDT
Hexachlorobutadiene	µg/l	0.01	BDT	BDT	BDT	BDT
Hexachlorocyclohexane	µg/l	0.001	BDT	BDT	BDT	BDT
Pentachlorobenzene	µg/l	0.01	BDT	BDT	BDT	BDT
Benzo (a) pyrene PAH	µg/l	0.001	BDT	BDT	BDT	BDT
Benzo (b) fluoroanthene PAH	µg/l	0.001	BDT	BDT	BDT	BDT
Benzo (k) fluoroanthene PAH	µg/l	0.001	BDT	BDT	BDT	BDT
Benzo (g,h,i) perylene PAH	µg/l	0.001	BDT	BDT	BDT	BDT
Indeno (1,2,3-c,d) pyrene PAH	µg/l	0.001	BDT	BDT	BDT	BDT
TBT	mg/l	0.001	BDT	BDT	BDT	BDT
DBT	mg/l	0.001	BDT	BDT	BDT	BDT
MBT	mg/l	0.001	BDT	BDT	BDT	BDT
Chloroform	µg/l	0.1	BDT	BDT	**4.6**	BDT

BDT = Below detection limit.

Table 7: Levels of contaminants in superficial marine sediments as monitored by Ecoserv, in June 2013 at four stations (see Figure 5 for location). (*Values shown are means of two replicates)*

		STATION:	**1**	**3**	**5**	**6**
Chemical Parameters	**Units**	**Minimum Detection Limit**				
Organic Carbon	%		**0.5**	**9.05**	**3.05**	**1.5**
Sulfates	mg/Kg		**759.5**	**3689.5**	**1403**	**807**
Arsenic	mg/Kg		**2**	**9.5**	**3.5**	**5.5**
Cadmium	mg/Kg		**0.35**	**1**	**0.45**	**0.5**
Chromium	mg/Kg		**2.5**	**21**	**6.5**	**9**
Copper	mg/Kg		**1.5**	**27.5**	**2**	**2.5**
Lead	mg/Kg		**9.5**	**21**	**4.5**	**6**
Mercury	mg/Kg	0.1	BDL	BDL	BDL	BDL
Nickel	mg/Kg		**1**	**10**	**2.5**	**3.5**
Zinc	mg/Kg		**5**	**43**	**9**	**13**
Chloroalkanes (C10-13)	mg/Kg	0.1	BDL	BDL	BDL	BDL
Pentabromodiphenylether	mg/Kg	0.001	BDL	BDL	BDL	BDL
Di(2-ethylhexyl)phthalate	mg/Kg	0.01	BDL	BDL	BDL	BDL
Hexachlorobenzene	mg/Kg	0.001	BDL	BDL	BDL	BDL
Hexachlorobutadiene	mg/Kg	0.01	BDL	BDL	BDL	BDL
Hexachlorocyclohexane	mg/Kg	0.001	BDL	BDL	BDL	BDL
Pentachlorobenzene	mg/Kg	0.001	BDL	BDL	BDL	BDL
Benzo (a) pyrene	mg/Kg	0.01	BDL	0.03	BDL	**0.0075**
Benzo (b) fluoroanthene	mg/Kg	0.01	BDL	**0.04**	BDL	**0.0075**
Benzo (k) fluoroanthene	mg/Kg	0.01	BDL	**0.01**	BDL	BDL
Benzo (g,h,i) perylene	mg/Kg	0.01	BDL	**0.02**	BDL	BDL
Indeno (1,2,3-c,d) pyrene	mg/Kg	0.01	BDL	BDL	BDL	BDL
TBT	mg/Kg	0.1	BDL	BDL	BDL	BDL
DBT	mg/Kg	0.1	BDL	BDL	BDL	BDL
MBT	mg/Kg	0.1	BDL	BDL	BDL	BDL
Chloroform	mg/Kg	0.01	BDL	BDL	BDL	BDL

BDT = Below detection limit.

With respect to water quality, a number of observations may be made on such results:

- Within Marsaxlokk Bay, some **water stratification** is evident in June with a temperature difference of approximately 2 ^{o}C between surface and bottom waters.

- Levels of **water transparency** (in terms of NTU) were generally good throughout the water column and comparable to conditions in other local harbours . However, with respect to water turbidity as recorded at Station 5 (which may be considered as a reference station), NTU values as recorded in the central part of Marsaxlokk (Stations 2, 3 and 4) increased significantly with depth. At 5 m depth, water turbidity in the central area was 3 times higher than at the same level in the open sea, while at bottom, water turbidity was 10 times higher than at reference.

- Levels of **dissolved oxygen** were high throughout the water column showing no evidence of hypoxic or eutrophic conditions, even in the innermost part of Marsaxlokk.

- Likewise, levels of **chlorophyll *a*** did not show any eutrophic conditions.

- Levels of **nutrients** were recorded to be below detection limits. However one is to note that this was due to the standard analytical methods which have been used for such study (which are those recommended by the EU's Water Framework Directive) not being sufficiently sensitive to the generally low levels of nutrients in local waters. In fact, the nutrient levels reported in **Table 2**, were monitored using more sensitive analytical methods, with minimum detection limits being 16 (for nitrates) to 20 (for phosphates) times lower than those used for **Table 3**.

- Levels of **total suspended solids** in individual replicate samples varied from 5 to 0.8 mg/L. Limited data is available for this parameter in local marine waters. Data collected from coastal waters off Qalet Marku to St George's Bay in June and December 2005, produced a mean value of 7.2 mg/L (8 samples: maximum 16, minimum 4 mg/L). This suggests that the TSS as monitored in Marsaxlokk and Hofra z-Zghira were comparable if not lower than those found in other local coastal waters which are not exposed to intense anthropogenic pressures. Furthermore surface waters generally carried less suspended solids than waters at 5m depth (also as evidenced by levels of NTU (see above).

- As expected in these oligotrophic waters, water at all stations was found to have **BOD** and **COD** below detection limit. These two indices are indicative of levels of organic pollution.

- **Bacteriological** levels were low indicating that there was practically no pollution by sewage at the sites monitored.

- Levels of **heavy metals** in surface waters were generally below detection limits, except for one replicate sample in the innermost part of Marsaxlokk (Station 1), where copper was detected, and another replicate sample off DPS (Station 3), where mercury was detected. In both cases, levels were exceedingly low, and just above detection limits. The ecotoxicological significance of these results may not be ascertained at this stage.

- Levels of **polyaromatic hydrocarbons** in surface waters were all below detection limit.

- With two exceptions, levels of **all other contaminants** were found to be below detection limit.

- Surface waters from all stations had significant levels of **Di(2-ethylhexyl)phthalate (DEHP),** with an overall mean of 3.7 ug/L. This exceeds the Annual Average Environmental Quality Standard for this chemical, which is set at 1.3 ug/L (Environmental Quality Standards Directive, EC 105/2008). No maximum allowable environmental quality standard has been set for such parameter. In data reviewed in Section 2.5, over a period of 10 months, only 2 out of 18 water samples collected from the same locality were found to contain this chemical above detection limit. However in a recent study for local inland waters (Axiak, Borg and Debono, 2012), this was found to be the most ubiquitous contaminant found in all samples at all water bodies. Levels were moderately correlated with degree of urbanization of the respective water catchment basin.

  Almost all the DEHP present in the environment arises from anthropogenic sources rather than from natural ones. It represents the most widely used plasticizer (comprising 50% of all phthalate ester plasticizers) that softens resins. It may account for 40% (w/w) or more of the plastic. The water solubility of DEHP is low though its high adsorption to organic matter may render its introduction in inland WBs, especially in their sediments, as quite likely. According to most published sources as reviewed by Axiak, Borg and Debono (2102), DEHP exists widely in the environment and is often found in most samples, including air, precipitation, water, sediments, soil and biota. Levels are generally highest in industrialized regions.

- **Chloroform** was detected in one station (in one of the replicate samples only) at Station 5. The overall mean for all stations was computed at 1.2 ug/L. This was below the set annual average environmental quality objective for this parameter (This being 2.5 ug/L, on an annual average basis). As for heavy metals (see above) the ecotoxicological significance of this single datum may not be ascertained at this stage. This is because we do not have any other reports of levels of chloroform in these waters.

- Within **Hofra z-Zghira**, in the immediate vicinity of the discharge point for cooling waters, the **temperature anomaly** was found to be +3.2^{o}C at surface. This temperature anomaly rapidly declined to +1.8 ^{o}C at a distance of 315m away from discharge point (i.e. anomaly was reduced to 56% at surface). No significant temperature anomalies were present at 5m depth or at bottom at Hofra z-Zghira. This shows that as expected, the thermal plume is buoyant and only surface waters are being effected.

- These thermal conditions at Hofra z-Zghira are not having any effects on the **dissolved oxygen levels**.

- The **levels of water transparency** are likely not being effected within Hofra z-Zghira (in terms of NTU values). The extremely high NTU level reported at bottom at the discharge point (see **Table 5**) seems to be an artifact.

Results for sediment quality will be commented upon in next section.

2.7 Sediment Quality

Sediments are known to play a key role both as reservoirs of pollution as well as sources of re-pollution into the water columns especially during dredging works, and events of sediment perturbation such as during intense rain storms and resultant runoff.

The author of the present assessment has available some unpublished data on the quality of superficial marine sediments within Marsaxlokk as monitored by T. Paris (2009) over the period November 2008 up to May 2009. Over this period, 7 fixed stations were monitored for total petreoleum hydrocarbons, zinc, lead, cadmium and copper. Stations were located throughout the whole of Marsaxlokk Bay, including along the western part of Delimara headland.

Subsequently, the following assessment of current environmental quality of superficial sediments will be based on:

- Archived data monitored over 2008 to 2009 (Paris, 2009).
- Data available for this report and presented in **Table 5** (above)
- Data available in AIS (2009). In this case marine sediment samples were collected from Hofra z-Zghira.

Data on levels of contaminants in sediments for Marsaxlokk and Hofra z-Zghira are presented in **Table 8**. Such table also includes various reference and guideline levels for sediments.

Table 8: Levels of contaminants in superficial marine sediments in Marsaxlokk and Hofra z-Zghira as well as in other localities in Malta (given for comparision). In addition: Target Values, EQS and Guideline Values from various sources.

	units	Marsaxlokk 2008/09 [1]	Marsaxlokk June 2013 [2]	Hofra z-Zghira June 2013 [2]	Hofra z-Zghira 2009 [3]	Cirkewwa 2012 [4]	Grand Harbour 2008/09 [1]	Marsamxett 2008-09 [1]	Target Values [5]	Intervention Values [5]	EQS [6]	Reference Values in Sweden [7]	UK Cefas Guidelines [8]	Dutch Guidelines [9]	OSPAR Background Conc. BC [10]	OSPAR Background Conc. ABC [10]
Cadmium	mg/kg	0.43 (1.3-0)	0.6 (1-0.3)	0.5		0.09 (0.2-0)	0.7 (2-0)	1.1 (7.4-2.4)	0.8	12	2 (UK) 0.7 Pr EAC	0.2	0.4	0.8	0.2	0.31
Copper	mg/kg	15 (176-0)	10.3 (28-1)	2.5		1.5 (3-1)	106 (340-0)	138 (338-101)	36	190	40 (UK) 19 Pr EAC	15	40	35	20	27
Lead	mg/kg	15.7 (44-1.8)	11.7 (22-4)	6	11.2	3.5 (6-2)	330 (778-82)	267.5 (974-373)	85	530	40 (UK) 30 Pr EAC	31	50	30.2	25	38
Zinc	mg/kg	48.9 (166-0)	19 (43-4)	13		14.8 (29-8)	262 (868-37)	188 (1384-464)	140	720	200 (UK) 12 Pr EAC	85	130	140	90	122
Arsenic	mg/kg		5 (10-2)	5.5		1.5 (2-0)					8 (UK) 16 Pr EAC	10	20	29	15	25
Chromium	mg/kg		10 (24-2)	9	12.6	5.5 (6-5)			100	380	100 (UK) 52 Pr EAC	80	40	100	60	81
Mercury	mg/kg		BDL	bdl		bdl			0.3	10	0.4 (UK) 0.13 Pr EAC	0.04	0.3	0.3	0.05	0.07
Nickel	mg/kg		4.5 (11-1)	3.5	6.7	2 (2-2)			35	210	100 (UK) 16 Pr EAC	33	20	35	30	36

	units	Marsaxlokk 2008/09 [1]	Marsaxlokk June 2013 [2]	Hofra z-Zghira June 2013 [2]	Hofra z-Zghira 2009 [3]	Cirkewwa 2012 [4]	Grand Harbour 2008/09 [1]	Marsamxett 2008-09 [1]	Target Values [5]	Intervention Values [5]	EQS [6]	Reference Values in Sweden [7]	UK Cefas Guidelines [8]	Dutch Guidelines [9]	OSPAR Background Conc. BC [10]	OSPAR Background Conc. ABC [10]
Organic Carbon	%		4.2 (9.7-0.3)													
Sulphates	mg/kg		1950 (4110-739)													
Petroleum Hydrocarbons	ug CE/g	7.9 (34-1.4)					39 (106-1)									
Benzo (a) pyrene (PAH)	mg/kg		0.01 (0.03-0)	0.005 (0.01-0)	bdl	bdl				0.02						
Benzo (b) fluoroanthene (PAH)	mg/kg		0.01 (0.04-0)	0.005 (0.01-0)	bdl	bdl				0.05					15	30
Benzo (k) fluoroanthene (PAH)	mg/kg		0.003 (0.01-0)	bdl	bdl	bdl				0.02					45	80
Benzo (g,h,i) perylene (PAH)	mg/kg		0.007 (0.02-0)	bdl	bdl	bdl				0.03					50	103

	units	Marsaxlokk 2008/09 [1]	Marsaxlokk June 2013 [2]	Hofra z-Zghira June 2013 [2]	Hofra z-Zghira 2009 [3]		Cirkewwa 2012 [4]	Grand Harbour 2008/09 [1]	Marsamxett 2008-09 [1]	Target Values [5]	Intervention Values [5]	EQS [6]	Reference Values in Sweden [7]	UK Cefas Guidelines [8]	Dutch Guidelines [9]	OSPAR Background Conc. BC [10]	OSPAR Background Conc. ABC [10]
other PAH	mg/kg		bdl	bdl	bdl												
Organotins	ug/kg		bdl	bdl			bdl							0.1			

Column Notes for Table, given on next page.

Column Notes for Table 6.

[1] Archived data monitored from 2008 to 2009 (Paris, 2009). Whenever possible, data shown include overall mean value followed by maximum and minimum levels recorded in brackets.

[2] Data made available for this report (Ecoserv, 2013) and presented in **Table 5** (above). Whenever possible, data shown include overall mean value followed by maximum and minimum levels recorded in brackets.

[3] Data from AIS (2009). Samples were collected from Hofra z-Zghira. Whenever possible, data shown include overall mean value followed by maximum and minimum levels recorded in brackets.

[4] Data from ADI, 2012, for Cirkewwa. Whenever possible, data shown include overall mean value followed by maximum and minimum levels recorded in brackets.

[5] Target and Intervension Values for sediment management options. Parameters in sediments given by Netherlands Ministry of Housing Spatial Planning and the Environment (VROM,2000).

[6] Environmental Quality Standards given for UK, and EQS Provisional values for EAC, OSPAR. as quoted by HELCOM HOLAS, 2009.

[7] Reference values for contaminants in sediments set by Sweden as quoted by HELCOM HOLAS, 2009.

[8] UK Cefas Guidelines: These guidelines are non-statutory contaminant concentrations for dredged material that serve as a tool for decision-making with regard to dredge spoil disposal. Contaminant levels in dredged material below the lower threshold levels are of no concern or are unlikely to influence a dredge licensing decision. CEFAS: Centre for Environment, Fisheries and Aquaculture Science.

[9] Dutch quality standards (IADC/CEDA, 1997) – These standards are reference values used in environmental remediation work. Contaminant levels in dredged material below these standards are considered safe for sea disposal and do not pose a significant environmental risk.

[10] OSPAR guideline background levels as quoted by HELCOM HOLAS, 2009.

Petroleum Hydrocarbons

Petroleum Hydrocarbons (PHC) have been analysed using UV spectrofluorimetry . In general, sediments having levels of PHC which are above 10 ug/g dry weight Chrysene Equivalents, may be considered as polluted. Hydrocarbons of biological (natural) origin which may not be distinguished from PHC, usually do not exceed 1ug Chrysene Eq./g DW.

Within Marsaxlokk, the levels of PHC as monitored and analyzed using the same metodology referred to in the previous paragraph, varried from 1.4 to 34.2 ug/g dry weight Chrysene Equivalents, with an overall mean level of 7.9 ug/g dry weight Chrysene Equivalents. Over the same time period, the mean level of PHC as monitored within the Grand Harbour was found to be 39.4 ug/g dry weight Chrysene Equivalents. This means that the overall levels of PHC within Marsaxlokk are less and approximately 20% those levels as found in Grand Harbour.

As regards the levels of PHC in marine sediments off DPS, these were found to range from 1.7 to 10.5 ug/g dry weight Chrysene Equivalents. Therefore the presently available data suggest that the levels of pollution by oil and fuels within Marsaxlokk are moderate to low (as compared to those recrded within Grand harbour). Furthermore, there is no indication that the levels of pollution by fuels off DPS are any higher or different from those found elsewhere within the rest of Marsaxlokk Bay.

Levels of polyaromatic hydrocarbons such as those indicated in Table 6, are also indicative of oil pollution. These were also found to be low in sediments of Marsaxlokk and of Hofra z-Zghira. Nonetheless replicate samples collected off DPS (**Station 3, Figure 4**) did show some PAH levels above detection limits.

Other Organic Compounds

Other organic compounds including organotins (antifouling agents) were found to be below detection limit.

Heavy Metals

The mean levels of heavy metals in superficial marine sediments off DPS over the period November 2008 to May 2009, for cadmium, copper, lead and copper were: 0.24, 12.7, 20.6 and 54 ug/gDW respectively. These levels were of the same order of magnitude, or lower than those monitored for other parts within Marsaxlokk Bay. These data suggest that the current operations of DPS did not lead to increased releases of heavy metals wthin Marsaxlokk.

As indicated in **Table 6**, except for the case of cadmium, the reported levels of heavy metals in superficial marine sediments in both Marsaxlokk and Hofra z-Zghira were generally below the various guideline levels and EQS indicated in the same table. In the case of copper, the highest level reported in June 2013 was in one replicate sample off DPS.

In the case of cadmium, the overall mean level for all samples collected from Marsaxlokk in June 2013, was 0.6 mg/kg, with the maximum levels being recorded off DPS at 1mg/kg. Such values are quite close to the various reference levels and the given EQS (see **Table 8**). Unfortunately the validity and significance of such result may not be fully ascertained at this stage. However it seems that operations of the DPS may at least partly be responsable for the releases of such cadmium. Nonetheless the data presented so far also suggests that there are other important sources of cadmium releases locally. For example these levels in Marsaxlokk are comparable to those found in the sediments of Grand Harbour, while much higher levels were found in Marsamxett. Further data will help to clarify such issues.

2.8 Conclusion regarding current environmental quality within Marsaxlokk

Within Marsaxlokk Bay, some water stratification is evident during the summer months. Nonetheless, no anoxic conditions were ever reported in the bottom waters, though occasionally low levels of DO were recorded at surface waters off DPS, and at 5m The lowest recorded DO at surface was of 67% off DPS, while the lowest DO level at 5m depth was of 64.4% in the vicinity of the floating fish cages off St Lucian.

Water transparency in general is very good except occasionally due to runoff events, and in certain parts such as along Marsaxlokk village, Malta Freeport and off DPS. Water transparency decrease rapidly with depth. Total suspended solids as monitored in Marsaxlokk and Hofra z-Zghira were comparable if not lower than those found in other local coastal waters not exposed to intense anthropogenic pressures.

Nutrient and chlorophylll levels indicate that, as a whole area, Marsaxlokk is the least exposed to eutrophic risks when compared to other local harbours. In the recent past (2008-2010, chronic sewage pollution was evident in many parts of Marsaxlokk. More recently, in June 2013, there was practically no pollution by sewage at the sites monitored.

The available data on N:P ratios indicate that for most of the year, suggesting that phosphorous may be the more important limiting factor for primary productivity.

In general, levels of heavy metals in surface waters were found to be lower than the set AA-EQS. Lead and nickel were often detected but never exceeded the AA-EQS or the MAC-EQS. Mercury featured often prominently in surface waters with an annual average being estimated at above the set AA-EQS which was formerly set by the relevant Directive. The ecotoxicological significance of these findings still need to be verified by comparing such values with other mercury levels which may have been recorded in other coastal water bodies over the same period (June 2012 to March 2013) as well as by monitoring mercury in suitable biota from this locality. As was already pointed out, the relevant EU Directive now requires that member states set EQS for mercury in biota rather than in waters. Furthermore, it is quite likely that multiple sources may be releasing such mercury: including natural and anthropogenic.

Levels of petroleum hydrocarbons and most other organic contaminants, including pesticides, solvents, antifouling agents, etc., were below detection limits. On the other hand, in June 2013, Di(2-ethylhexyl)phthalate which was present in all stations. The significance of these results have been discussed above.

With respect to sediment quality, petroleum hydrocarbons were found in various locations. However the present data suggest that the levels of pollution by oil and fuels within Marsaxlokk are moderate to low (as compared to those recorded within Grand harbour). Various potential sources of releases of petroleum hydrocarbons (as well as of PAH) in Marsaxlokk had been reviewed in Section 2.1.

Other organic compounds were found to be below detection limit. Organotins were seldom detected.

Except for the case of cadmium, the reported levels of heavy metals in superficial marine sediments in both Marsaxlokk and Hofra z-Zghira were generally below the various guideline levels and EQS. In the case of copper, the highest level reported in June 2013 was in one replicate sample off DPS. In the case of cadmium, the overall mean level for all samples collected from Marsaxlokk in June 2013 (though not as measured in this locality for June 2012, when the mean level was lower by a factor of 15), was quite close to the various reference levels and the given EQS as reviewed above. It seems that operations of the DPS may be responsable for the releases of such cadmium. Nonetheless the data presented so far also suggests that there are other important sources of cadmium releases locally. For example these levels in Marsaxlokk are comparable to those found in the sediments of Grand Harbour, while much higher levels were found in Marsamxett. Further data will help to clarify such issues. For example, clarification of this point may be possible when the whole data set on levels of marine contaminants generated through the WFD surveillance monitoring programme (which has been recently undertaken by MEPA over the period 2012-13) is assessed.

2.9 Conclusion regarding Current Environmental Quality within Hofra z-Zghira

Currently, Hofra z-Zghira may be receiving as much as 43,000 m^3/h of cooling waters at temperatures up to +8^{o}C above ambient. Therefore in a single day, as much as 1.03 million m^3 of waters are being discharged into this enclave. This means that the whole basin of Hofra is being renewed every 16 hours due to the discharge of cooling waters. Evidently the water quality of the area is under the direct control of such massive discharge. Furthermore, one would expect that such waters will include significant levels of biocides, including chlorine.

Nonetheless it seems that apart from the expected thermal anomalies as found through field studies reported in the previous section and predicted by mathematical modelling, no major and evident impact on the normal marine water quality parameters are evident in the area. This is most likely due to the rapid diffusion of any released contaminants (including chlorine and biocides) out into the open sea and away from the enclave, due to the presence of the rapid and voluminous discharge.

Furthermore, the overall nutrient levels near Hofra z-Zghira as well as N:P ratios in this area, were not significantly different from those reported in Marsaxlokk. This suggests that the discharge of cooling waters is not having any impact on nutrient levels, at least in the vicinity of Hofra z-Zghira.

2.10 Considerations regarding the Water Framework Directive

The terms of reference issued by MEPA for the current EIS, require that a specific reference will be made to the current environmental quality of the area with respect to Malta’s obligations related to the Water Framework Directive (2000/60/EC) and the Priority Substances Directive (2008/105/EC).

The Water Framework Directive, aims to protect different types of water bodies (including coastal waters) from further deterioration; to enhance the status of aquatic ecosystems and to promote sustainable use of water resources. Its objectives include:

- expanding the scope of water protection to all waters, surface waters and groundwater;
- achieving "good status" for all waters by a certain deadline;
- water management based on river basins;
- "combined approach" of emission limit values and quality standards;
- getting the prices right: charges for water and waste water reflecting the true costs;
- getting the citizen involved more closely; and streamlining legislation.

Good chemical status will be determined by compliance with European Environmental Quality Standards (EQS) for specific contaminants (Annex X substances). This Directive sets up EQS for pollutants classified as priority substances at Community level and leaves it to member states to lay down, where necessary, rules for remaining pollutants at national level, subject to the application of relevant Community rules. As far as it is known, there is no legally-binding Maltese text which sets EQS for pollutants of national concern.

Annual average EQS (AA-EQS) is estimated over a one-year period and should not be exceeded in order to ensure long-term quality of the marine environment. The Maximum Allowable Concentration (MAC-EQS) of a contaminant should not be exceeded at any time, in order to protect the marine environment from short-term pollution events. Member states must ensure compliance with these standards. They must also verify that the concentration of substances concerned does not increase significantly in sediments and/or relevant biota.

More recently the new Priority Substances Proposal (COM 2011/876 final) sets stricter EQS for four existing priority substances, including that for lead and nickel in seawater whose AA-EQS have been set at 1.3 ug/L from 7.2 ug/L; and at 8.6 ug/L from 20 for lead and nickel respectively. These changes are likely to be highly relevant for Malta.

In Malta, the WFD has been transposed as LN194/2004 and entered into force on the 23rd April 2004. Malta has been designated as one Water Catchment District (equivalent to a River Basin District) through Legal Notice 194 of 2004. Furthermore, a Water Catchment Management Plan (WCMP) for the Maltese Islands has been published in 2011 (MEPA and MRA, 2011). With respect to coastal waters, it has identified a number of coastal water bodies. Both Marsaxlokk Bay and Hofra z-Zghira have been included the coastal water body with code MTC107, entitled Il-Port ta' Marsaxlokk. This has been classified as an area with waters of intermediate depth which are exposed.

Such a plan also includes a Natura 2000, protected area within Marsaxlokk area, which is l-Ballut ta' Marsaxlokk.

In addition, the Urban Waste Water Treatment Directive protects the environment from impacts of wastewater discharges from urban and industrial conglomerates. MTC107 has been designated as an Urban Waste Water Sensitive Zone, which means that any discharges must comply with specific emission standards.

The WCMP has concluded that Marsaxlokk area (MTC107) is at risk from points sources of pollution as well as diffuse sources and from hydromorphological pressures. Such pressures have already been identified in the present Section of this report. Furthermore, Marsaxlokk was designated as a heavily modified water body. This means that by WFD standards, this is a water body which is substantially changed (being a harbor) in character and cannot therefore meet 'good ecological status. Accordingly, the WFD allows Malta to set a less stringent environmental quality standard which is referred to as 'Good Ecological Potential'. Such standard makes allowances for ecological impacts resulting from alterations to the physical environment that are necessary to either support a specific use (i.e. harbor), or must be maintained in order to avoid effects on the wider environment. This means that appropriate objectives can be set for the management of pressures on condition that the adverse ecological impacts caused by any physical alteration can be appropriately mitigated without undermining the benefits they serve.

The WFD requires monitoring programmes for all water bodies. Surveillance monitoring (i.e. background monitoring) has been already undertaken locally, though no results have been published as yet. On the basis of such data, the chemical status of the various water bodies will be determined.

According to a first qualitative assessment of chemical status carried out by the WCMP report, Marsaxlokk (MTC107) had a BAD chemical status, mainly due to the presence of direct marine discharges into the area from industrial complexes. The chemical status of this water body (as well as of others) should be reviewed on the basis of monitoring data which will hopefully be published soon.

The WFD allows for a number of exemptions to the quality objectives that may be set for specific water bodies (which should be achieved by 2015). Such an exemption has been request for MTC107, since in this case, the scale of improvements required can only be achieved in phases exceeding the timescale, for reasons of technical feasibility and Article 4-4(a)(iii) – natural conditions do not allow for timely improvement in the status of the body of water. The technical feasibility refers to (i) the delay in the implementation of monitoring programs that are required to define ecological potential and (ii) management measures to improve status will be implemented primarily through the issuing of environmental permits for all industrial installations that will require significant investments from industry and whose full implementation will extend beyond 2015. Consequently, the response of the water body to the measures is expected to be very gradual and good status/potential can only be realistically achieved beyond 2015.

On the basis of the data as has been presented in the present report, a preliminary conclusion may be reached as regards the chemical status of Marsaxlokk area. Since for most priority substances, the levels of such contaminants are very low and below EQS as established for marine waters by the Directive 2008/105/EC, the final chemical status for this water body may be provisionally revised from a **BAD status, to a GOOD POTENTIAL status.** Evidently, such conclusion will need to be confirmed and validated by further data from the surveillance monitoring programme which has been recently undertaken by MEPA in compliance with the WFD. For example, levels of contaminants in the water column as well as in sediments as have been recorded for Marsaxlokk will need to be compared with levels as monitored in other coastal water bodies such as harbours, as well as in areas, which are less exposed to anthropogenic pressures.

Furthermore the WFD requires that the operational activities within Marsaxlokk will not lead to any significant increase in contaminants in sediments (or biota).

3. Proposed Development at DPS: Relevant Details.

The following account is based on the following documents as supplied by Enemalta / iAS Ltd., :

a) the PDS for the development dated 31st May 2013,
b) A report entitled: New CCGT Plant at Delimara: intended activity and environmental emissions and impact, produced by Kema DNV and dated 11 June 2013;
c) A report entitled: CCGT Plant - Minimum Functional Specifications, produced by Enemalta and dated 7th June 2013;
d) A report entitled: LNG Storage and Re-gasification Plant - Minimum Functional specifications produced by Enemalta and DNV Kema and dated 23rd May 2013.
e) Various correspondences through email received from iAS Ltd,. through Ecoserv Ltd., with updated details of the project, in October 2013.

Furthermore, a meeting was held by the present consultant with Enemalta officials and Mr. Thomas Leonard from DNV KEMA, (who is a consultant agency commissioned by Enemalta) on the 21st June 2013.

As already indicated in the **Section 1**, the proposed development at Delimara Power Station will include:

- The conversion of Delimara 3 to operate on natural gas;
- The construction of a new 180-220MW CCGT;
- The construction of a Liquid Natural Gas (LNG) terminal and re-gasification plant to supply such generators with natural gas.

Such development forms part of the nation's energy strategy whereby it is envisaged that heavy fuel oil will no longer be employed locally in energy generation, and where up to 200 MW of energy may be imported through an Interconnector from Sicily. The main objectives of such strategy are to reduce the costs of fossil fuel energy generation and to reduce the environmental impacts of such generation.

While at the initial stage of planning, a number of components of the development were still to be finalized, the final project layout has now been confirmed and is shown in **Figure 6**. The main features of this final project layout are listed below:

- The CCGT will be located on Site A (as indicated in Figure 6);
- The regasification plant and the storage facility will be located on land;

- The LPG storage facility will have a volume capacity of less than 130,000 m3 and it is projected that refuelling operations will occur at approximately 10-12 times a year;
- A jetty for refuelling has now been planned to be much smaller than originally envisaged. It will have 6 mooring points, 3 to the north and 3 to the south of the loading arm jetty. The mooring points will be founded on piles which will be inserted vertically into the seabed.
- The regasification plant will be larger than originally envisaged and now will include a part which is intended as a welfare area for the FSU personnel;
- The coastal engineering works required for the redevelopment will include no dredging and no land reclamation;
- The road connecting the jetty to site B has been shifted to the south;
- The minimum functional specifications which have been included in the tender document have been respected in the final layout.
- The rates of wastewater discharges that have been originally estimated in the first draft of this assessment report will remain unchanged.

Sections 3.1 to 3.4 will elaborate on the above list, especially with the most relevant construction and operational features relevant to the present assessment of impacts on the marine quality of the proposed development.

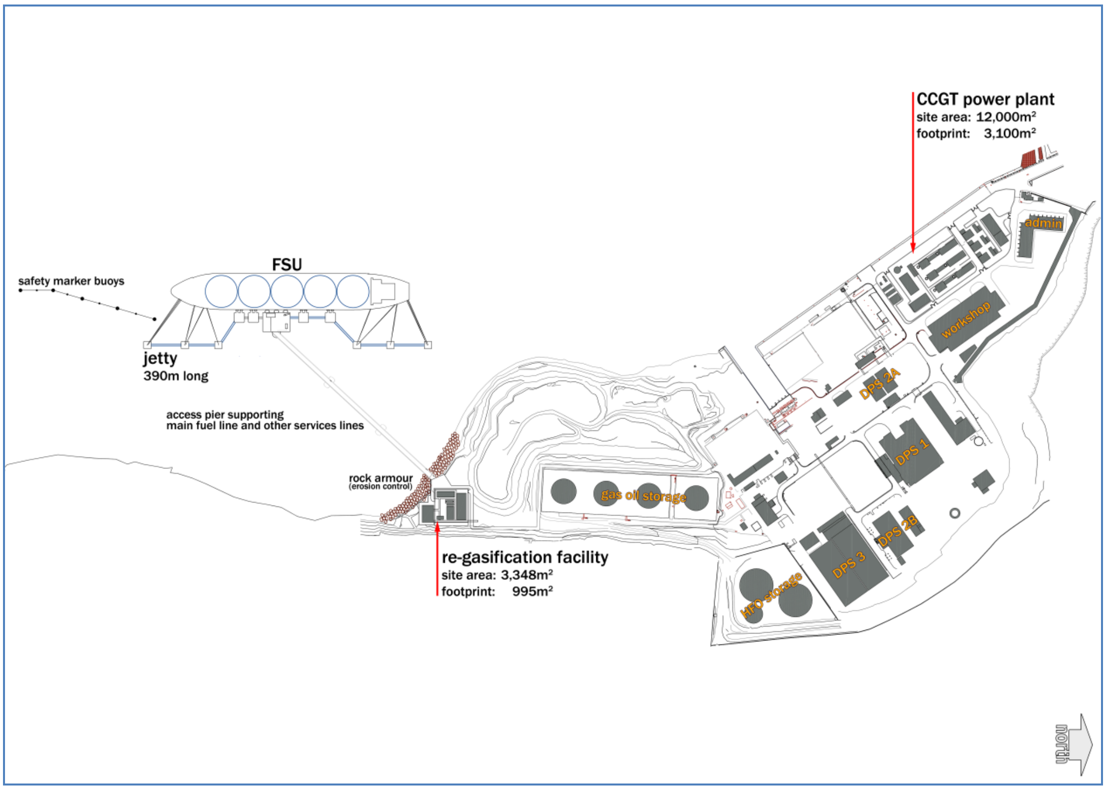


Figure 6: Final project layout being proposed for the new development at the DPS.

3.1 Decommissioning of Delimara 1 and Changes in Delimara 3.

The decommissioning of Delimara 1 Steam Turbine Generators should not be included in the present EIS. Nonetheless the resultant changes in the performance of the DPS as a result of such decommissioning, will need to be taken into consideration, in order to be able to have a holistic perspective of the expected impacts of such changes on water quality.

Delimara 1 – ST presently utilises 21,000 m^3/h of cooling water which are being discharged at Hofra z-Zghira. Its decommissioning will lead to a cessation of such discharges.

Likewise, the conversion of Delimara 3, now to be fired on natural gas, instead of heavy fuel oil, will not be included in the present EIS. Again however, the expected changes in the overall operations of DPS, will need to be taken into consideration. Delimara 3, presently includes 8 internal combustion engines fired on heavy fuel oil, will not entail relocation of such facilities. Such conversion will not lead to any change in the amount of discharge rate of cooling water from such facility (presently at 13,600 m^3/h). Furthermore, the nature and rate of input of the biocides used in such wastewater stream will remain unchanged (i.e. input of chlorine dioxide to achieve a residual level of chlorine of 0.1 ppm at the level of the inlet of the condenser.

Furthermore, the conversion of Delimara 3, will lead to significant changes in the present atmospheric emissions abatement technology. These changes will include a reduction in the rate of urea used, and probably the cessation of use of sodium bicarbonate. Evidently, the use of natural gas instead of heavy fuel oil for this facility, will lead to significant environmental improvements in its operation.

3.2 CCGT (Delimara 4)

The new CCGT plant will be fired on natural gas and will have a gross design capacity from 180 to 220 MW. It will employ the cooling effect of re-gasification for the cooling of its power generators. It will consume approximately 2,440 m^3 of LNG per day. The PDS states that it is expected that such CCGT will operate normally at very low rates of emissions and additional abatement facilities may not be required. The expected NOx released would be 291 tonnes per year. Nonetheless, some abatement technology may be required to reduce emissions of nitrogen oxides. Such technology is already in use at DPS and employs the use of urea or ammonia. The rate of use of such reagents will however be much less for Delimara 4, than the current Delimara 3.

The CCGT will cover a footprint of 3,100m^2.

A number of wastewater streams may be expected to be generated during the operation of the CCGT. A summary of such wastewater streams are graphically depicted in **Figure 7**. These include:

- **Water used for cleaning/cooling air intake** leading to the air compressor of the gas turbine. It is still unclear whether the CCGT technology to be adopted will generate such wastewater stream. Nonetheless, such stream will be expected to be quite clean and devoid of any significant marine contaminants.

- **Cooling waters** used for the steam condenser. Chlorine dioxide will be injected upstream of the coarse screen at the inlet of the cooling waters. This will lead to a residual concentration of 0.1 ppm at the condenser inlet. Such cooling waters will be discharged along the same culvert leading to Hofra z-Zghira. The expected rate of discharge of cooling waters from the new CCGT has been estimated to be 16,000 m^3/h.

Therefore the current discharge of cooling waters at Hofra z-Zghira, as result of the various changes in the DPS energy production facilities, may be summarized in **Table 9.**

Table 9: Expected Changes in the Discharge Rates of Cooling Waters at Hofra z-Zghira.

	Current Situation				Expected Changes		
	capacity MW	fuel	cooling waters m^3/h		capacity MW	fuel	cooling waters m^3/h
Delimara 1 - ST	120	HFO	21000				
Delimara 2A-GT	74	Gasoil	*a*		74	Gasoil	*a*
Delimara 2B	110	Gasoil	8500		110[b]	Gasoil[b]	8500[b]
Delimara 3	149	HFO	13600		149	NG	13600
DELIMARA 4 (NEW CCGT)					220	NG	16000
Total	**453**		**43100**		**443**		**29600**

Note a = included in other discharges
Note b= This will be a reserve plant and will only be operational if either Delimara3 or Delimara 4 are not in service. Therefore, its cooling waters will not be discharged simultaneously with the other streams of cooling waters originating from Delimara 3 and Delimara 4.

Therefore:

- The overall discharge rate will be reduced from the current estimated 43,100m^3/h to 29,600 m^3/h;
- The temperature of discharge will probably remain unaltered;
- The rate of input and nature of biocides will remain unaltered.

- The Heat Recovery Steam Generator (HRSG) will be fed with water from a Demineralization Plant (DP). Such water will be produced from seawater which will be processed through an evaporator. **Excess brine** from the evaporator, which may contain traces of scale control reagents, will be discharged at sea.

- The DP will purify the feed-water to the HRSG through the application of ion exchangers using sulphuric acid and sodium hydroxide reagents for recharging. **Discharges from the DP** which may include acids or alkali, will be released into the sea.

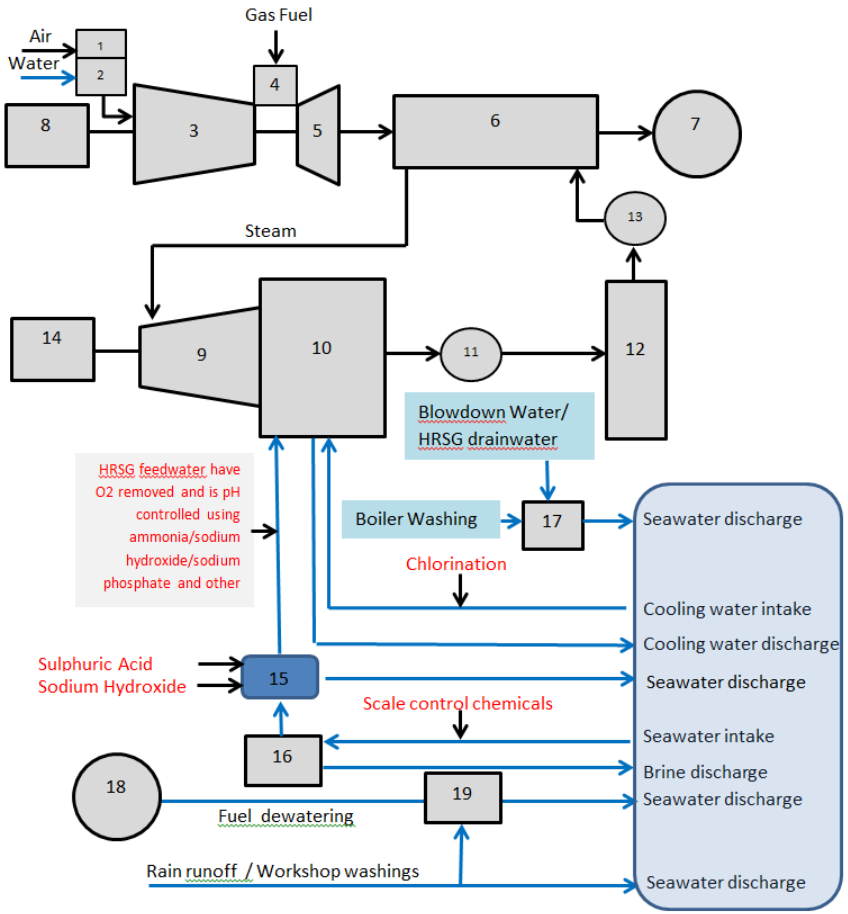
- HRSG feed-water will be deoxygenated and its pH will be controlled, using reagents such as ammonia, sodium hydroxide and sodium phosphate . **HRSG will be periodically drained** to prevent increase in salt concentration in boiler. The composition of drain water, will include sodium phosphate and ammonia. Approximately 65m^3 of such waste-stream will be produced annually and will be discharged at Hofra z-Zghira at a max rate of 2m^3/h. Such wastewater stream may be treated by passing through Settling Tank, to reduce the level of suspended solids, and after its pH is controlled.

- **Boiler washings** will also be periodically produced containing substantial quantities of suspended solids, as well as acids and/or alkali. Such washings will be led to settling tanks where their pH will be controlled prior to discharge at sea.

- Any **fuel tanks may need to be dewatered**. Such water will be discharged at sea after passing through an oil interceptor/separator. It is to be noted that the fuel tanks referred to in **Figure 7** refer to tanks which are already in operation, and not necessarily only to tanks which would be specifically required for the new CCGT.

- **Floor washings** generated within the floorshops/workshops, will most likely be contaminated with varying amounts and types of oils, and reagents such as industrial degreasers (organic industrial solvents, etc.,). Such washings and runoff will be discharged at sea, after being treated through the oil interceptor. It is difficult to estimate the amount of such waste-stream generated, but may not exceed 400 m^3 per year.

Figure 7: Outline of wastewater streams produced by the operation of the new CCGT facility at DPS.



1	Air Inlet Filter
2	Evaporative cooler and cleaner
3	Air compressor
4	Combustion chamber
5	Gas turbine
6	Heat recovery steam generator
7	Exhaust stack
8	Generator
9	Steam turbine
10	Steam condenser
11	Condensate extraction pump
12	Feed water storage tank
13	Feed water pump
14	Generator
15	Demineralization water tank
16	Evaporator
17	Settling Tank/pH control
18	Fuel tanks
19	Oil interceptor
20	Marine Environment

- **Rain runoff** generated within the footprint (especially from the roof of the various sheds) of the proposed new CCGT facility will need to be managed separately than that currently generated by the existing facilities The new CCGT facility will include a reservoir to collect the rain water collected from its building roof-tops for irrigation purposes and with all other rain runoff treated before being discharged into Marsaxlokk Bay. The estimated amount of such waste-stream may amount to 2500 m^3/year (estimated from the expected annual precipitation rate and the footprint of the CCGT facility).

The chemical profiles of these various wastewater streams will be expected to vary both with time and with nature of waste-stream. However it is to be noted that according to Enemalta, all marine discharges as identified above, will need to comply with the current legislation controlling such releases. These include:

- LN213/2001 - Pollution caused by certain dangerous substances discharged into the aquatic environment regulations, 2001
- LN218/2001 - Limit values and quality objectives for hexachlorocyclohexane discharges regulation, 2001
- LN219/2001 - Limit values and quality objectives for mercury discharges by sectors other than the chlor-alkali electrolysis industry regulations, 2001
- LN221/2001 - Limit values and quality objectives for cadmium discharges regulations, 2001
- LN227/2001 - Limit values and quality objectives for discharges of certain dangerous substances into the aquatic environment regulations, 2001
- LN194/2004 - Water policy framework regulations, 2004
- Directive 2008/105/EC on environmental quality standards in the field of water policy, as has been transposed through LN 24 of 2011, as an amendment to LN 194 of 2004.
- Directive 2006/11/EC - Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the community.
- Directive 2000/60/EC - establishing a framework for Community action in the field of water policy,
- L.N. 161 of 2002 - Waste Management (Waste Oils) Regulations 2002

Any effluent from the plant into the aquatic environment must be treated to comply with these regulations. Such waste treatment would have to take place within the station's boundary. Long term storage of waste substances within DPS would not be permitted.

According to Enemalta (2013b), the oil-contaminated process waters shall be collected in oil interceptor. The oily water shall than be collected into central collecting tanks/pits and treated. If necessary, the necessary equipment to separate the oil from the water shall be supplied so that the water can be re-used or discharged into the sea. It is important that the emission regulations, to which the plant has to abide to, are always respected. The quality of the water to be discharged has to be continuously monitored as stipulated in permit conditions. At the current stage of planning, it is unclear how this continuous monitoring, will be carried out. It may be pointed out, that the water quality parameters, which are currently more frequently monitored, are pH and temperature.

3.3 The LNG Plant

This LNG Plant will provide the natural gas for the new CCGT as well as for the converted Delimara 3, which is currently fired on HFO.

The chemical composition of natural gas is a function of its source of origin and type of processing. Nonetheless it is always a mixture of methane (>85% by volume) , ethane (from <1% up to 10% by volume), propane (1% to 5% by volume) and butane with small amounts of heavier hydrocarbons and some impurities, notably nitrogen and complex sulphur compounds, water, carbon dioxide and hydrogen sulphide which may exist in the feed gas but are removed before liquefaction.

LNG is natural gas which has been converted to liquid by very cold temperatures (approx.. -162^{o}C) form for ease of storage or transport. It is transported in special LNG carriers. At the LNG Plant, the carrier will unload the LNG, which will subsequently be stored and then regasified prior to being pumped for combustion.

The unloading is usually carried out through an unloading arm, with the LNG being kept at -160 ^{o}C. There will be a vapour return arm leading back to the carrier. The LNG is then stored in special cryogenic tanks which are equipped with facilities to minimize boil-off, and to capture such evaporated gas to possibly re-condense it and return it to storage.

Regasification involves the step-wise warming of the LNG through the use of seawater. The ambient thermal conditions of seawater will be sufficient to cause re-gasification. The seawater to be used for the re-gasification process will also be used to control the temperature of glycol, which in turn will be used to regulate the gas temperature for re-gasification purposes. Such seawater will not come in contact with the LNG, nor with any other contaminants during this process. The volume of seawater to be used for such a purpose amounts to 29,600 m^3/h, part of this volume will be used for the glycol at certain times of the year. Such waters will eventually be used as cooling waters for the CCGT plant and subsequently be discharged at Hofra z-Zghira. This volume will form part (and not be in addition to) of the estimated volume of cooling waters to be discharged at Hofra z-Zghira.

The NG will then be pumped for combustion and subsequent energy generation.

As already indicated above, the storage and regasification facilities will be located on land.

The LNG Plant will generate the following wastewater streams:

- The main wastewater stream will be that of **seawater to warm up the LNG** for regasification. In fact, seawater is likely to be used in combination with Open Rack Vaporizers for regasifying LNG.
- The FSU will probably need to discharge **some ballast water** during unloading of LNG to the land storage tanks. This ballast water will be discharged in Marsaxlokk Bay. The discharge of this ballast water will need to be compliant with regional and EU regulations controlling maritime activities in harbours.

- **Bilge water** will occasionally need to be removed from the FSU. It is unlikely that such waters will be discharged at sea. One option is to pump them onshore for treatment in an oil interceptor. No further details on the expected volumes and on rates of generation of such waste-stream are available at this stage.

- The re-gasification Plant will need to employ some small boilers. These will probably employ a closed-loop system requiring no blowdown water. However they they will need to be periodically drained producing some **boiler washings.**

- The LNG Plant will need to be equipped with a **firefighting water system**. Such a facility will occasionally need to be recharged and this may entail some discharged of water into the sea.

- As for the CCGT facility, some **floor washings** will be generated within the floorshops/workshops of the various plants. This wastewater will most likely be contaminated with varying amounts and types of oils, and reagents such as industrial degreasers (organic industrial solvents, etc).

- Some **sanitary wastewaters** will be produced in the various plants which most probably be discharged in sewers, but definitely not discharged at sea.

As for the CCGT Plant, any discharges into the marine environment will need to comply with the current legislation controlling such releases. These regulations have already been listed above.

Enemalta (2013c) stipulates that the operator of the LNG Plant will need to have to implement an Environmental Management System (e.g. ISO 14001 or equivalent) with respect to any discharges into the marine environment. Furthermore, the use of sea water and heat load discharge should be minimised. The operator shall submit details of the nature and the proposed quantities including ballast water, cooling water, regasification water. He shall minimally measure the free chlorine and heat load discharge to the sea. (ISO 7393 or equivalent may be used for measuring free chlorine; ISO 6416 or equivalent may be used for the continuous measurement of heat load discharge).

The LNG Plant will necessarily limit the atmospheric emissions of methane (since this will present a waste of fuel). In order to ensure this, the plant will be equipped with facilities for continuous monitoring of methane.

The PDS indicates that the operation of the LNG Plant will include: gasoil transport and storage; the use of oil/water separator; chemical storage and lubricating and hydraulic oil storage.

3.4 Construction Phase

The construction phase for both the LNG Plant and the CCGT will be completed in a maximum period of 18 months but most probably will extend from (January 2014 until March 2015.

As already indicated above, the coastal engineering works required for the proposed redevelopment of DPS will include no dredging and no land reclamation.

The operation of the new CCGT and of the LNG Plant will require a number of refueling operations and it is envisaged that LNG carriers will visit the site 10-12 times a year.

The jetty to receive LNG carriers will be probably be constructed from a combination of pre-cast elements and cast in-situ concrete

The construction of the proposed facilities will entail the transport to the area of petroleum products (including fuel oils and lubricating oils) as well as other reagents; building equipment, etc.. The PDS confirms that all storage on the construction site will be equipped with secondary containment and fire prevention systems. This will evidently be required to control risks of accidents and therefore of jeopardizing the ongoing energy production of the current DPS during such construction phase.

According to iAS Ltd., the storage of any materials on site will be located in the holding down area which would be located along the DPS shoreline next to the present inlet for cooling waters.

Solid wastes expected to be generated during construction will include: **combustible organic waste** (such as wood, cardboard, paper, trees, bushes, etc.); **bulky construction waste** such as concrete, clean fill material, scrap metal, glass and plastics; special/hazardous waste such as lead acid storage batteries, etc..

Liquid wastes will include: concrete wash-downs from construction vehicles, used industrial solvents and other chemical wastes, grease trap pumpings, used oils, sanitary and shipboard wastes.

The CMP for this project was not available for the present consultant by the time of finalizing this report.

4. Potential Impacts on the Marine Environment.

The present consultant was specifically asked to limit his assessment on the potential impacts of the construction and operation phases of the proposed project, on the marine water quality only, as resulting from chronic releases into the marine environment. Another part of the present EIS will deal with accidental and major spill incidents.

4.1 Significance of Impacts

In the following section all significant impacts of and risks posed by the proposed project, during construction, and operation on the marine environmental quality will be assessed. This assessment will be carried out on the basis of the current environmental status of the area as has been identified in Section 2.

In determining the significance of the various impacts identified, the following criteria will be applied:

An **impact** is being considered as an effect resulting directly or indirectly from any stage of the proposed project, on the relevant environmental targets in question.

For the purpose of the present assessment report, **the environmental targets** being considered are the quality of the water column, and that of marine sediments in the area of influence exposed to the proposed development.

By **environmental quality** (of water or of marine sediments), it is meant the sum total of all physic-chemical and biotic characteristics of the environment which allows it to support life, and to safeguard the integrity of its resources.

An impact (effect) arising from the proposed project on the relevant environmental targets, may be **beneficial** or **adverse**, depending on whether the environmental quality (as defined above) will be improved or not. If the impact is neutral, that is, if it will lead to no effect, then by definition it does not exist. However for the purpose of the present report, a **neutral impact** is being considered as one in which an particular element of the project will produce no effect on environmental quality.

An impact may have various levels of **severity** (high, moderate, low, neutral or none). For the purpose of the present report, the level of severity means the magnitude of change (whether for the better or otherwise) that the impact being considered can potentially have on one or more environmental target. The magnitude of change will need to take into account both spatial (geographical extent of change) and temporal (duration of change, including whether may be considered as reversible or not) dimensions.

The likelihood or **probability** of an impact from happening may vary from most likely to most unlikely. Such level of probability is considered to be more qualitative than quantitative in nature. Therefore when a reference is made to probability in the following assessment, this does not refer to probability in a statistical (mathematical and quantitative) sense.

The **level of significance** of an impact will then need to take into account, its level of severity as well as the probability of such impact happening. For example, an impact which may potentially cause disastrous changes (the highest possible level of severity), but is highly unlikely to occur (or practically impossible to occur) will be judged to be of low or no significance.

The impact will first be identified and described, together with its nature (adverse or beneficial) and likely magnitude and extent (both in temporal and spatial terms). The significance of the impact will further take into account the type of targets and resources it may affect, their sensitivity to such impact, whether it will likely to be reversible or irreversible effects, and its probability of occurrence. In each case, the scope for mitigation and residual impacts will be assessed.

Any predicted change in the current marine environmental status (impacts) will furthermore have an effect on at least four target levels: public health (including food safety, swimming, etc.); coastal and marine resources; the health of ecosystems; and socio-economic sectors and activities.

Subsequently, the impact significance criteria adopted in the present study (including Tables 11 and 12) are being defined as:

Neutral: when no known impact or material change will be predicted on all target levels;

Low: Low level of occurrence of pollution/pressure, and low level of severity of impact over a localized geographical extent, on at least one target level, which may be mitigated.

Moderate: Moderate level of severity of impact or pressure with a moderate probability of it occurring over the whole zone (area of influence) and beyond, on at least one target level.

High: High level of severity of impact or pressure with a moderate to high probability of it occurring over the whole zone (area of influence)and beyond, on at least one target level.

The above considerations may be recapitulated as follows:

Assessment criteria – Beneficial/Adverse

Beneficial	Impact (change) as resulting directly or indirectly from a component of the project, which will lead to an improvement in the environmental quality of the water column or sediments.
Neutral	One in which a particular element of the project will produce no effect on environmental quality.
Adverse	Impact (change) as resulting directly or indirectly from a component of the project, which will lead to a deterioration in the environmental quality of the water column or sediments.

Assessment criteria – Severity

High	A high magnitude of change that an impact may have on one or more environmental targets being considered. Change will occur over a large spatial extent (more than 50% of area of influence) and/or for a long period of time. It may also be irreversible.
Moderate	A moderate magnitude of change that an impact may have on one or more environmental targets being considered. Change will occur over a moderate spatial extent (less than 50% of area of influence) and/or for a medium period of time. It will be reversible.
Low	A low magnitude of change that an impact may have on one or more environmental targets being considered. Change will occur over a spatial extent which is less than 10% of area of influence (in both horizontal and vertical dimensions, such as when one considers the water column) and/or for a brief period of time. It will be reversible.
Insignificant	A magnitude of change that an impact may have on one or more environmental targets being considered, that is so low as to be ignored in the assessment.

Assessment criteria – Significance

High	High level of severity of impact or pressure with a moderate to high probability of it occurring over the whole zone (area of influence) and beyond, on at least one target level.
Moderate	Moderate level of severity of impact or pressure with a moderate probability of it occurring over the whole zone (area of influence) and beyond, on at least one target level.
Low	Low level of occurrence of pollution/pressure, and low level of severity of impact over a localized geographical extent, on at least one target level, which may be mitigated.
Insignificant or Neutral	When no known impact or material change will be predicted on all target levels;

Whenever relevant, **worst case scenarios** will be assessed. For example, in assessing impacts of wastewater discharges, in case of periodic discrete events (such as boiler washings), it was assumed that the maximum possible number of such events would occur per year, and the maximum amount of water would be used in such operations.

4.2 Impacts During the Construction Phase of the Development

4.2.1 Release of Particulate Matter

The main risk to water quality during the construction phase of this development is likely to result from the release of un-dissolved and suspended particulate matter, which may be released into the water from the various engineering works, including:

- o Excavation works along within Area B, which may involve up to 45,000 m^3 of earth moving.
- o Other coastal works involved with the construction of a jetty and other features for the LNG Plant. Such works will also include the mixing of concrete mixes or mortars on site. If such particulate matter reaches the marine environment, it will inevitably lead to a reducing in water transparency.

The degree of impact on water quality (reduced water transparency) will depend on a number of factors, including:

- the amounts and rates of discharge of suspended particulates at sea;
- the type of coastal engineering works to be undertaken as well as the level of workmanship and supervision of such engineering works;
- the size distribution of such particulates which in turn will determine their rates and pattern of sedimentation through the water column;
- the hydrodynamics of the area which will determine the advection and subsequent transport of such particulate matter;
- the duration and time of year during which this phenomenon occurs;
- the existing water transparency of the locality;

Particulates originating from these activities may reach the marine environment both through direct releases as well as through atmospheric fallout of air-borne dust.

It will be of paramount importance that the release of particulate matter in the water column along the DPS arising from such engineering works will be minimal. Otherwise, there will be interference with the energy production of the DPS due to silt intake with the cooling water stream, and subsequent deposition in the condenser tubes, leading to serious maintenance problems. As indicated in **Section 3**, the storage of construction materials on site will be located in the holding down area, that would be located along the DPS shoreline next to the present inlet for cooling waters. Silt curtains (geo-textile curtains) may be set up to protect such inlet as well as to prevent excessive spread of silt during arising from various coastal engineering works.

As measured in June 2013, the levels of water turbidity in terms of NTU, in the central areas of Marsaxlokk Bay (as well as off DPS) were found to be comparable to those recorded in other harbours (e.g. Grand Harbour). Furthermore, water turbidity increased significantly with depth so that at bottom layers, NTU values were approximately 10 times higher than at bottom in the reference station (**Section 2.6**).

No increase in water turbidity as a result of the coastal engineering works will be expected to occur within Hofra z-Zghira.

When taking into consideration all the above information, the overall level of significance of this impact may therefore be considered to be of **MODERATE (Worst Case Scenario)** to **LOW** magnitude and significance**.** Nonetheless, this impact will not last for long, and no residual effects are likely to be evident.

4.2.2 Release of Dissolved Substances from the Coastal Engineering Works.

Along with particulate matter, dissolved substances may also be released into the water column from the various coastal engineering works. These substances may include dissolved nitrates and phosphates, as well as a range of other potential contaminants. The risk of this happening is mostly related to dredging works. However since no dredging is envisaged in the present proposed development, then the likelihood of such releases would be greatly reduced.

Taking into account all the above considerations, the level of significance of impact of this re-suspension of pollutants including nutrients is expected to be **MODERATE to LOW**. Nonetheless, such impacts will not last for long, and no residual effects are likely to occur.

4.2.3 Other Impacts Arising During the Construction Phase.

Various aspects of the construction phase of the proposed development may lead to increased risks of marine contamination by fuels, lubricating oils, etc. Such risks may be properly controlled and managed by a well-executed and professional project management programme. For example, all forms of deliberate marine discharges should be strictly prohibited. This applies in particular, to the considerable excavation wastes, which would be generated; to solid waste and litter; to diesels as well as other fuels and oils for the engineering vehicles and equipment; as well as to the wash down of concrete residues from concrete mixers and transport vehicles. Accidental spills (rather than deliberate discharges) of hazardous materials used during the construction phase, including cement additives, lubricating oil and fuels, also give rise to marine environmental risks of contamination.

As already indicated in **Section 3.4**, the construction of the proposed facilities will entail the transport to the area of petroleum products, reagents, building equipment, etc.. The PDS confirms that all storage on the construction site will be equipped with secondary containment and fire prevention systems. This will control risks of accidents and therefore of jeopardizing the ongoing energy production of the current DPS during such construction phase.

The solid and liquid wastes which may be expected to be generated during the construction phase have already been reviewed in **Section 3.4**.

If good engineering site management is properly enforced, and if spill contingency plans (including appropriate containment equipment such as floating booms) are properly in place, then the significance of such risks may be considered to be **LOW**.

During the construction phase, the increased use of land transport vehicles themselves will lead to the release of atmospheric pollutants such as dust, sulphur and nitrogen oxides as well as of lead and of various forms of hydrocarbons. These will be produced in an aerosol format and may reach the marine environment through atmospheric fall out. However taking into account that the area is already exposed to considerable land-traffic, it may be assumed that the overall significance of such releases will be only **LOW**.

Likewise, it is likely that during the construction phase, there will be increased maritime activity to and away from the DPS construction sites. It is yet unclear the extent to which excavation and demolition materials will be transported away from the site via sea transport. The employment of barges for this purpose will further increase maritime activities in the area. Such increased maritime activities may lead to increased risks of marine contamination due to the operational or accidental releases of contaminants such as fuels, lubricating oils, etc. Proper supervision of such maritime transport as part of good practice of major coastal engineering works, should control such risks to an acceptable level. The level of significance of this impact on water quality may vary from **MODERATE to LOW** depending on the level of competence and workmanship of the staff involved, as well as on the supervision of such operations.

4.3 Impacts Arising During the Operation Phase of the Development

4.3.1 Discharge of Cooling Waters.

As based on the information provided by Enemalta and reviewed in **Section 3.2**, there will be an overall reduction in the rates of discharge of cooling waters in Hofra z-Zghira as a direct result of the development at DPS. In fact, the current rate of discharge of 43,100 m^3/h will be reduced by over 30% to 29,600 m^3/h. The rate of release and nature of biocide being currently dosed into this waste-stream of cooling waters will remain unaltered. Furthermore, the water temperatures within the flow and possibly prior to discharge will remain unaltered (i.e. +8^{o}C). There is also no reason to suggest that the present chemical profile of this discharge will be significantly altered (for example with respect to total suspended solids, or pH).

According to mathematical model predictions (EIS/SLR, 2011), the current dishcarge is presently dominating the hydrodynamics of Hofra z-Zghira. The buoyant surface thermal plume would cause the surface temperature in the coastal waters (i.e. outside of Hofra iz Zghira) to increase up to 1.5^{o}C above background, and the temperature at the mouth of the bay would be +2^{o}C. Within the bay temperatures would increase to +8^{o}C at the outfall with the highest temperatures along the west and north coasts. The same mathematical models predicted that the sea bed temperatures outside the bay would be unaffected by the discharge.

A review of the limited field data available (**Sections 2.4** and **2.5**) suggest that these mathematically based predictions were more likely to over-estimate the thermal anomalies within Hofra. In any case, the thermal anomalies expected to result from the changes in discharge rates of cooling waters, are bound to be less.

When taking all the above issues in consideration, it may be included that the considerable reduction in the discharge rate of the cooling waters at Hofra z-Zghira, and may be viewed as a **POSITIVE MODERATE** impact on water quality at this locality. As a worst case scenario, that is in the case that the expected reduction in the rates of discharge of cooling waters at Hofra z-Zghira will not materialize, the impact will be **NEUTRAL**.

4.3.2 Generation of Wastewaters used for Regasification.

The main wastewater stream that will be produced by the LNG Plant will be that of seawater to warm up the LNG for regasification. It is likely that the same biocides and at the same rate of input as that for cooling waters (chlorine dioxide, so as to maintain a residual level of chlorine of 0.1mg/L within the regasification system).

These waters will be cooled through the re-gasification process, at a temperature below ambient. Furthermore, this wastewater stream will be introduced into the cooling wastewater stream, and the combined streams will be discharged at Hofra z-Zghira. The total volume and rates of discharge at Hofra z-Zghira will be as quoted in Table 9 (above), that is 29,600 m^3/h.
According to the available information, this generated wastewater streamwill not be contaminated with methane or any of the constituents of the LNG, since seawater will never come in direct with the LNG, during the operation of re-gasification. In any case, methane has a low solubility in seawater.

<u>The spatial extent of any impact of such discharge may be estimated to be limited to the immediate vicinity of the cooling waters inlet, since the rate of release of such waters is relatively small, being only 5% of those released at Hofra z-Zghira).</u>

Therefore taking into consideration all the above points, it may be assumed that the impact of the generation of such wastewater stream and its eventual discharge at Hofra z-Zghira on water quality in the area will be **LOW**.

4.3.3 Discharge of other Wastewater Streams.

Section 3.2 had identified other waste-water process streams that are expected to be generated from the operation of the CCGT Plant. Most of such streams may be finally discharged at sea (possibly after preliminary treatment). In order to be able to assess the likely impact of such discharges on the water quality, a number of factors will need to be taken into consideration, including:

- the annual volumes expected to be discharged at sea, as well as the hourly rates of discharge. It is to be noted that none of such discharges would be continuous, but they will be periodic or intermittent as the need arises (according to the particular phase of operation of the plant). However in some cases it was difficult to be able to make even rough estimates of the volumes/rates of discharge to be expected to such streams. In some cases, estimations had to be extrapolated from data from 2000 (Axiak and Delia, 2000 and Axiak, 2004). Whenever possible and where applicable, worst-case scenarios were adopted in such estimations. Therefore, whenever possible, and when sufficient data was available, it was assumed that in case of periodic discrete events (such as boiler washings0, it was assumed that the maximum possible number of such events would occur per year, and the maximum amount of water would be used in such operations.

- the chemical profile of the waste-water stream. In most cases, only the expected main chemical constituents may be predicted.

- the level of treatment, if any, that such waste-water stream will be exposed to prior to discharge.

- the site of discharge of such waste-water stream. In many cases such waste streams will be expected to be discharged into the main cooling waters stream.

Table 10 outlines the data on such waste-water streams (apart from the cooling waters which have already been discussed above) as expected to be generated as a result of this development at DPS. This includes the coming in operation of the CCGT Plant as well as of the LNG Plant .

No published information is available on the chemical profiles of such waste-water streams, though the types of chemicals which may be expected to be present may be known from the processes involved. However in 2002 (Axiak 2003b) a limited monitoring programme was undertaken for waste-water discharges from DPS and for the Marsa Power Station. This was based only on a limited number of samples (5 from each station). The results indicate that the mean BOD levels ranged from 15 to 44 mg/l, mean nitrate levels ranged from 0.35 to 0.88 mg/l, mean level for total phosphorus levels was 1.7 mg/l and for total suspended solids was 15 mg/l.

Except for the waste-stream of rain-runoff from the bunded spaces for storage tanks for ammonia and urea, all the other waste-streams have been generated and discharged at sea since the DPS came in operation. Furthermore, from the review of the marine environmental quality near DPS and well as within Hofra z-Zghira, both in the recent past as well as at present (**Section 2**), no significant impact on water quality has been evident.

Furthermore, according to the information available from Enemalta, all marine discharges as identified above, will need to comply with the current legislation controlling such releases. Such legislation have been listed in a previous section. Any effluents from the CCGT and LNG plants, to be discharged into the aquatic environment must be treated to comply with these regulations. Such waste treatment would have to take place within the station's boundary. Long term storage of waste substances within DPS would not be permitted.

Table 10. Information on other waste-water streams expected to be generated by the new CCGT and the LNG Plants, (apart from cooling and regasification waters).

			Discharge Rate/Amount and Location		
New CCGT Plant	**chemicals**	**treatment**	**m^3/h**	**m^3/y**	**location**
excess brine from evaporator	salts, scale control and foam control reagents	NI		190,000[a]	at sea
discharges from Demineralization Plant	alkali, acids	settling tank, pH control		150 [a]	at sea
HRSG drain	sodium phosphate, ammonia, suspended solids, acid, alkali	settling tank, pH control	2	65	at sea
boiler washings	suspended solids, others	settling tank, pH control	6	200 [a]	at sea
floor washings	oils, industrial solvents, etc	oil interceptor	0.2	100 [a]	at sea
rain runoff	probably traces of oil	NI		2500	at sea
fuel tanks dewatering (not only for CCGT)	Oils (a range of different hydrocarbons depending on the nature of the fuel stored)	oil interceptor		200 [a]	at sea

NLG Plant	**chemicals**	**treatment**	**m^3/h**	**m^3/y**	**at**
ballast water	possibly traces of oil	none		NI	to special contractor
bilge oil/water	mostly oil	oil interceptor		NI	to special contractor
firefighting water recharge	probably none, except for some fire retardant reagents	none		NI	at sea
floor washing	oils, industrial solvents, etc.	oil interceptor	0.2	100 [a]	at sea
rain runoff	probably traces of oil	NI		15,000	at sea
sanitary wastewaters	as domestic wastewater	none		NI	sewers
boiler washings	suspended solids, others	oil interceptor		NI	to special contractor
rain runoff from bunded spaces for storage tanks for ammonia and urea for abatement	probably traces of oil and of ammonium salts and urea.	none		NI	at sea

Note a = estimations based on extrapolations from data in Axiak and Delia 2000, and Axiak 2004.
NI = No information is currently available.

When taking into consideration all the above information, the level of impact on water quality of the generation and discharge of effluents into the marine environment from the new plants, may be expected to be of **MODERATE (**as a worst case scenario**)** to **LOW** levels of significance.

The actual level of significance will depend on the levels of workmanship and of supervision of the operations involved. It is important that the emission regulations, to which the plants have to abide to, be always respected. The quality of the water to be discharged has to be continuously monitored as stipulated in permit conditions. Furthermore, periodic and frequent monitoring needs to be carried out on such waste-streams. The water parameters which are currently more frequently monitored are pH and temperature. Other water quality parameters need to be monitored including: levels of oil and hydrocarbons, a range of low boiling aromatic hydrocarbons, polyaromatics hydrocarbons, etc. Currently, it seems that only the cooling water waste-stream is being monitored in a comprehensive manner for IPPC environmental permitting. It is hereby being suggested that such monitoring will be carried out for all other waste-streams prior to the point of their discharge into the cooling water waste-stream, or to the point of their discharge at sea (if they are not discharged into the cooling water stream).

Furthermore, in order to minimize risks of marine contamination from rain runoff from bunded spaces for storage tanks, it is proposed that drainage from bunded areas will be controlled by providing valved outlets which will normally be in the closed position. The contents of bunds to bulk chemical tanks will be chemically monitored prior to their release.

Delivery of bulk chemicals should be permitted only in a designated area, drainage from which will be directed to the neutralization system of a water treatment plant.

4.3.4 Atmospheric Fallout of Methane and Other Gases.

In principle, water quality may also be impacted upon by atmospheric fallouts of gases emitted by the operations at DPS.

Methane is known to occur naturally in the marine environment due to a number of factors. In Malta, the most relevant process would be that of microbial production of methane in anoxic marine sediments rich in organic matter. Methane production is accompanied by sulphur reduction into hydrogen sulphide. These processes may occur in the innermost parts of Marsaxlokk Bay where moderate to low eutrophic conditions may occur. However, the resultant levels of methane production as produced by these conditions are expected to be insignificant. Methane itself is quite insoluble in seawater, attaining a saturated concentration of only 20 to 23 mg/L in pure water at 20 to 25 ^{o}C.

The occasional and operational releases of methane from the LNG Plant are expected to be low and generally not sufficient to increase the level of methane in the water column, except possibly in the immediate vicinity of the plant. The only instances when levels of methane in the water column would be expected to be significantly high, will be in the case of major LNG spill accidents. In such cases, methane levels in the surface seawater may be expected to exceed background levels by a factor of 10 to 100 times. Little is known about the marine ecotoxicological properties of such LNG spills. Acute toxicity and sub-lethal physiological changes in fish are known to occur at relatively high levels of free methane in water, as would be expected in spill incidents (Glabrybvod, 1983, Azniirkh, 1986, Metelev, 1971; Patin, 1979; Lukyanenko, 1983). In the present study, the most likely biological target to this risk impact would be the floating aquaculture fish cages off St Lucian promontory, in the case a moderate to major spill incident from the LNG Plant. In any case, these spill risks will be dealt with in another section of the present EIS.

With respect to the release of chronic low-level atmospheric releases of methane from the LNG Plant, the subsequent levels of this gas as would be found in the water surface and water column through atmospheric fallout, would be expected to be very low. Subsequently the level of significance of this impact on water quality within the area, and especially with respect to the fish floating cages, may be expected to be **LOW**.

Unlike methane, ammonia is much more soluble in water. Under standard conditions at 20°C, 500g of ammonia will dissolve in 1 litre of fresh water. Ammonia along with urea, may be used in the abatement of NOx emissions. However since the CCGT plant will have much less emission loads of NOx than the current Delimara 3 (working on heavy fuel oil), the use of ammonia as an abatement reagent is expected to be much less than at present.

As regards other flue gases emitted by the CCGT plant itself, their potential atmospheric fallout to effect the water quality within Marsaxlokk bay would be expected to be low. Therefore, the level of significance of the impact of atmospheric fallouts from gases produced by the development at DPS, on water quality in the area is expected to be **LOW**.

4.3.5 Changes in Maritime Traffic in the Area

A regular service of LNG carriers will need to be established with the LNG plant so as to supply the required cargo. According to the latest information available from the developers, refueling will be required at 10 to 12 times per year. In addition, gasoil as well as other reagents will need to be carried to the site probably also by ships. Currently, DPS is supplied by regular shipments of gasoil and heavy fuel oil. The LNG re-supply ships are likely to be considerably larger than the oil tankers which currently serve the site. Therefore larger tankers will need to visit DPS less frequently. In general LNG shipping is viewed as a lower risk vs. crude oil and HFO shipping, all things being equal (such as operator experience, vessel size, etc.)

This maritime traffic will necessarily give rise to risks to water quality in the area, through operational losses of fuels and oils. Such operational risks can be mitigated through controls, monitoring and correction actions. Furthermore accidental spills and accidents will need to be properly addressed through contingency planning (to be considered in another part of the present EIS) and possibly through the establishment of LNG vessel safety zones in the area.

It is assumed that no marine discharges from such traffic will be allowed within Marsaxlokk, in compliance with IMO and national regulations. Proper reception facilities for solid and liquid wastes generated by such carriers will need to be established (if not already available within Marsaxlokk and DPS in particular).

Furthermore, it seems that the current water quality within Marsaxlokk Bay as reviewed in a previous section, has not been significantly compromised by the current high level of maritime operations of the Malta Freeport.

Also, the water residence time on the eastern half of Marsaxlokk Bay and along the DPS is sufficiently high (see Section 2.2) so as to ensure a reasonable level of diffusivity within this sub-basin. This will ensure that any (if any) water contaminants released by the ships making use of this area, will be rapidly diffused to the open sea.

Under these circumstances, the level of significance of any impact on water quality as arising from maritime traffic related to the DPS development may be considered to be **LOW**. This relates only to potential chronic and operational releases of pollutants, and not to any accidental spillages or any other maritime accidents, which will be dealt with by another section of this EIS.

4.3.6 Permanent Changes in the Hydrodynamics of the Area due to the Construction of Jetty

The coastal engineering works may potentially lead to changes in the surface currents and possibly in the hydrodynamics of the immediate vicinity. Any decrease in the dispersive properties of the altered hydrodynamic regime may subsequently lead to reduced water quality. The significance of such an impact will be directly determined by the quantitative and spatial extent of such changes.

SVASEK (2013), had been commissioned by Enemalta to specifically investigate the possibility of such changes in the hydrodynamics of the area which may be caused by the construction of the jetty and the various options of location of the various LPG components. Subsequently they produced a series of surface circulation patterns under different wind directions using a finite element 2-D numerical flow model. Such model assumed that the main driver was very mild winds (1.5 m/s) that are exceeded roughly 95% of the time from various directions. The models also took into account the effect of cooling water intake of the power plant at the current rate of intake.

As expected, the model predicted that under all conditions, any modifications of the surface currents by the construction of the jetty as well as the presence of the floating LPG plant were limited to within 1 km (maximum) of the jetty and coastal engineering works. Such changes did not extend neither to the innermost half of Masraxlokk (off Marsaxlokk village) nor to the western basin of Marsaxlokk Bay. This effectively means that any change in hydrodynamics resulting from any of the options of this development at DPS will not aggravate any current problems of water contamination in such areas (due to already existing anthropogenic factors). For example, the occasionally weak eutrophic conditions in the innermost parts of eastern half of the bay (off Marsaxlokk village) will not be aggravated by predicted changes in the hydrodynamics due to the construction of the jetty.

On the other hand, the same model predicted hydrodynamic changes (both increase, as well as decrease in surface currents and flushing rates) within a range of approximately 1km from the jetty. Assuming a worst case scenario (Option A, as indicated by SVASEK, 2013), a significant reduction in sea current speeds will be evident between the shore connection of the jetty and the current intake for cooling water. Therefore the dispersive powers of the surface waters in immediate contact with the DPS shoreline and extending approximately 85,000 m^2 in area will be reduced. This reduction is being mostly predicted in the vicinity of the current intake of cooling water.

This change in the surface hydrodynamics of this limited area may lead to accumulation of any spilt oil (or fuel) which may occur. Nonetheless, it is quite unlikely that such minor oil spills will be allowed to occur (without any prompt mitigating measures) by the management of the DPS, since if the cooling waters become contaminated with oil, they could lead to operational problems to the functioning of the power station itself.

Taking all the above points in consideration, the likely significance of this impact on the level of water quality in the area as a result of changes in hydrodynamics, may be considered to be **LOW**.

4.3.7 A Holistic View of the Individually Identified Risks.

For the purpose of this report, environmental impacts have been identified and discussed separately. However, it is evident that when the same living or non-living resource is exposed simultaneously to more than one risk, then the combined risks may interact in a highly complex manner. In fact, such risks may interact in an additive, or more than additive manner.

With respect to impacts on water quality at Hofra z-Zghira, the present report has suggested that the discharge of cooling waters will be reduced, and that the levels of residual chlorine used as a biocide, will remain unaltered as at present. Furthermore, the water temperatures at the inlet of cooling waters at Marsaxlokk, will be at least 5^0C below ambient, due to seawater used for degasification being discharged here. Therefore, it is possible that at least in certain parts of the year, the thermal plume currently being discharged at Hofra z-Zghira, will be less in volume as well as in thermal anomaly. This will lead to an overall reduction of current impact on water quality in the area, which will constitute an overall **positive impact** on water quality as a direct result of the development at DPS on Hofra z-Zghira.

With respect to the chemical quality status for Marsaxlokk body of water as has been provisionally determined in the present report (Section 2.10), the reviewed impacts as identified above and as arising from the proposed development as DPS (including the construction and operation phases), will as far as may be ascertained (on the basis of available data presented in this report) not lead to any deterioration from GOOD POTENTIAL STATUS.

Finally, none of the impacts on water quality in the area, as identified and assessed in the above sections, will lead to any direct impact on climate change. One end-result of climate change on marine waters, is the slight acidification of surface marine waters as a result of increased levels in atmospheric carbon dioxide. While some of the discharges of waste-water streams as identified above, may lead to an occasional reduction in pH at surface waters, this impact will be restricted in spatial extent as well as in magnitude. Therefore, this cannot be considered as a significant factor contributing to deterioration in water quality in combination with impacts of climate change.

4.3.8 Summary of Impacts on Water Quality.

The various impacts on the current marine environmental quality arising from the proposed development as have been identified above, are summarized in **Table 11**.

This table includes brief references to mitigating measures and monitoring. Details of such measures (most of which would be standard measures of good practice) will be included in the Construction Management Plan for the project.

Table 11: Matrix showing summary of Impacts on Water Quality arising from the Proposed Development at DPS: Combined Cycle Gas Turbine and Liquefied Natural Gas receiving, storage and regasification facilities.

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	Specific intervention leading to impact	Project phase *(construction operation)*	Receptor type	Sensitivity and resilience toward impact	Direct Indirect Cumulative	Beneficial Adverse	Severity	Physical geographic extent of impact	Short medium long	Temporary Permanent	Reversible Irreversible			
Release of particulate matter: increased turbidity	coastal engineering works	construction	water quality	low to medium	cumulative	adverse	high	central area of M'Xlokk Bay and along DPS shoreline	medium	temporary for duration of construction phase	reversible	Likely (if good work practices are enforced) otherwise inevitable	**Moderate to Low**	None
Proposed mitigation measures	Good practices of coastal engineering works. Proper application of silt/geo textile curtains if these are to be employed.													
Other requirements	Monitoring of water turbidity as indicated in text													
Increased nutrients	coastal engineering works	construction	water quality	low to medium	cumulative	adverse	medium	central area of M'Xlokk Bay and along DPS shoreline	medium	temporary for duration of construction phase	reversible	inevitable	**Moderate to Low**	None
Proposed mitigation measures	Good practices of coastal engineering works. Full control over discharges at sea.													
Other requirements	Monitoring of nutrient levels as indicated in text													

Table 11: Continued / 2

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	**Specific intervention leading to impact**	**Project phase** *(construction operation)*	**Receptor type**	**Sensitivity and resilience toward impact**	**Direct Indirect Cumulative**	**Beneficial Adverse**	**Severity**	**Physical geographic extent of impact**	**Short medium long**	**Temporary Permanent**	**Reversible Irreversible**			
Releases of oil/fuels and other contaminants	Land-based activities and Increased maritime activities related to coastal engineering works	construction	water and sediment quality	medium	cumulative	adverse	high	central area of M'Xlokk Bay but mostly in vicinity of coastal works	medium	temporary for duration of construction phase	reversible	likely to remote (if good work practices are enforced)	**Moderate to Low**	None
Proposed mitigation measures	Good practices of coastal engineering works. Proper supervision especially of barge operations (if any) and of any loading/unloading of construction material onto marine vehicles (if any).													
Other requirements	Monitoring as indicated in text													
Reduction in discharge of Cooling Waters	from turbines (including the CCGT)	operation	water and sediment quality	high	direct/ cumulative	beneficial	high	Hofra z-Zghira	long	for whole operation period	reversible	likely	**Moderate (Beneficial to neutral)**	High if impact is beneficial
Proposed mitigation measures	Proposed and planned designs are adhered to, in order to reduce rates of discharges of cooling waters.													

Table 11: Continued / 3

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	Specific intervention leading to impact	Project phase *(construction operation)*	Receptor type	Sensitivity and resilience toward impact	Direct Indirect Cumulative	Beneficial Adverse	Severity	Physical geographic extent of impact	Short medium long	Temporary Permanent	Reversible Irreversible			
Generation of re-gasification waters and their eventual discharge at Hofra z-ZGhira.	re-gasification of LNG	operation	water and sediment quality	medium	direct	adverse	high	Immediate vicinity of discharge point at Hofra z-ZGhira.	long	temporary	reversible	likely	**Low**	low
Discharge of other wastewater streams	from CCGT and LNG facilities	operation	water and sediment quality	medium	direct and cumulative	adverse	medium to low depending on nature of contaminants	Hofra z-Zghira or near vicinity of discharge points	long	temprary	reversible	likely	**Moderate to Low**	Low
Proposed mitigating measures	Strict compliance with all discharge regulations. Good workmanship and strict supervision of all operations including water treatment.													
Other requirements	More comprehensive monitoring of the chemical profiles of the various waste-streams.													

Table 11: Continued / 4

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	Specific intervention leading to impact	Project phase *(construction operation)*	Receptor type	Sensitivity and resilience toward impact	Direct Indirect Cumulative	Beneficial Adverse	Severity	Physical geographic extent of impact	Short medium long	Temporary Permanent	Reversible Irreversible			
Atmospheric fallout into the water column of gases emitted by the developments at DPS	re-gasification plant, storage facilities	operation	water and sediment quality	high	direct	adverse	high	central part of M'Xlokk Bay and near jetty	long	temporary	reversible	uncertain	**Low**	Low
Proposed mitigating measures	Minimization of all gaseous emissions													

Increased maritime traffic and increased potential operational releases of pollutants such as fuels and lubricating oils.	LNG and other carriers	operation	water and sediment quality	high	direct	adverse	medium	central part of M'Xlokk Bay and near jetty	long	temporary	reversible	likely	**Low**	Low
mitigating measures	Proper supervision of harbour and maritime activities. Full compliance by maritime operators to regulations controlling solid and liquid wastes by ships in harbours.													

Table 11: Continued / 5

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	Specific intervention leading to impact	Project phase *(construction operation)*	Receptor type	Sensitivity and resilience toward impact	Direct Indirect Cumulative	Beneficial Adverse	Severity	Physical geographic extent of impact	Short medium long	Temporary Permanent	Reversible Irreversible			
Atmospheric fallout into the water column of gases emitted by the developments at DPS	re-gasification plant, storage facilities	operation	water and sediment quality	high	direct	adverse	high	central part of M'Xlokk Bay and near jetty	long	temporary	reversible	uncertain	**Low**	Low
Proposed mitigating measures	Minimization of all gaseous emissions													

Increased maritime traffic and increased potential operational releases of pollutants such as fuels and lubricating oils.	LNG and other carriers	operation	water and sediment quality	high	direct	adverse	medium	central part of M'Xlokk Bay and near jetty	long	temporary	reversible	likely	**Low**	Low
mitigating measures	Proper supervision of harbour and maritime activities. Full compliance by maritime operators to regulations controlling solid and liquid wastes by ships in harbours.													

Table 11: Continued / 6

Impact type and source			Impact receptor		Effect and Scale							Probability of impact occurring *inevitable likely unlikely remote uncertain*	Overall impact significance	Residual impact significance
Impact type	Specific intervention leading to impact	Project phase *(construction operation)*	Receptor type	Sensitivity and resilience toward impact	Direct Indirect Cumulative	Beneficial Adverse	Severity	Physical geographic extent of impact	Short medium long	Temporary Permanent	Reversible Irreversible			
Changes in hydrodynamics of the area	construction of jetty leading to reduced diffusivity of marine contaminants.	operation	water and sediment quality	high	indirect	adverse	medium	Eastern Half of Marsaxlokk and along DPS shoreline	long	permanent	irreversible	medium	**Low**	low
Proposed mitigating measures	Proper supervision of DPS operations to avoid any oil spills in immediate vicinity of cooling water intake. Prompt contingency planning to control such minor spills, if they occur.													

5. Mitigation and Monitoring

In the present section, various mitigating measures will be proposed to control the environmental risks as identified above. A number of recommendations have already been made in the previous sections, but they will be reviewed hereunder in a comprehensive manner.

5.1 Recommendations to be Adopted during Construction Phase

a) The management team responsible for the various components of the development at DPS, including the demolition of Delimara 1, the conversation of Delimara 3 to fire on natural gas, the construction of the new CCGT plant as well as of the LNG Plantc should include a high-level official (Project Environmental Officer, PEO) who would be responsible for the monitoring of the environmental performance of the various sub-contractors involved.

b) The deployment of strategically placed geo-textile curtains may be considered, in relation to some coastal engineering works. Such deployment should not only aim at reducing impacts on water quality but also to prevent any operational difficulties with the remaining turbines (which will remain in operation during the construction phase), which may arise from intake of cooling waters laden with suspended solids.

c) The coastal engineering works should follow accepted norms of practice so as to minimize operational losses of oils and other contaminants into the water. All marine discharges of any waste waters should be prohibited, or at least should require the prior permission of the Environment Protection Directorate. Such discharges will include the concrete wash-down waters. Alternatively a dedicated facility for such concrete wash-down wastewaters should be available on the site, complete with gravity separation tanks to treat the wastewaters. The PEO should keep a record of the performance of sub-contractors.

d) There should be good supervision of any loading/unloading operations of materials required for construction, or of solid wastes produced during construction, onto barges or onto marine crafts.

5.2 Recommendations to be Adopted during Operation Phase

a) One major positive impact of the proposed development on water quality as identified above, will be the reduction of discharge of cooling waters at Hofra z-Zghira.

b) There is a need to monitor the spatial extent of the expected plume of cool waters which will be discharged by the re-gasification facility.

c) There is a need for improved (in terms of parameters monitored) and more frequent monitoring of chemical profiles of all separate waste-water streams (as identified above) to be discharged into the marine environment.

d) There should be proper supervision to ensure strict compliance with all discharge regulations for such wastes-streams.

e) All efforts should be made to minimize any gaseous emissions, not only from the LNG Plant but also from all storage facilities.

f) There should be an adequate liquid waste management programme integrated within the whole project once, this becomes operational. This liquid waste management should include proper management of ballast waters, of any bilge oils, of sanitary liquid wastes, and of other effluents which may be generated by LNG Plant.

g) Any bunded storage sites should be properly supervised to minimize contamination of any rain runoff which may be generated within them. Drainage from such bunded areas will be controlled by providing valved outlets which will normally be in the closed position. The contents of bunds to bulk chemical tanks will be chemically monitored prior to their release.

h) Delivery of bulk chemicals should be permitted only in a designated area, drainage from which will be directed to the neutralisation system of a water treatment plant.

5.2 Environmental Monitoring Programme

The various environmental risks identified above, may be controlled through a comprehensive strategy of environmental risk management to be formulated jointly by the developers and the competent planning and environment authorities. Such a strategy must be based on detailed information about the quality of the existing marine environment and how it changes with time in response to development itself as well as other factors. Therefore, the following marine monitoring programme is being proposed:

5.2.1 Baseline Monitoring

Initially, the aim of the programme would be to confirm the baseline information that has already been presented in the present report. This baseline monitoring will start as soon as possible, and preferably cover a period of two seasons, prior to the start of the coastal engineering works, especially earth moving. The parameters to be monitored are shown in **Table 13**. The water and sediment parameters will be monitored at 4 to 7 fixed stations (similar to those shown in **Figure 4**, above).

Table 13 Proposed Marine Environmental Monitoring Programme

Baseline Monitoring	Duration: 2 to 4 seasons	
Parameter	***Depth (m)***	***Frequency***
Water		
Temperature	Profile	seasonally
Salinity	Profile	seasonally
Chlorophyll a	0,5,bottom	seasonally
Nitrates	0,5,bottom	seasonally
Phosphates	0,5,bottom	seasonally
Water turbidity	Profile	seasonally
Total suspended solids	Profile	seasonally
pH	profile	seasonally
Microbiology	0,5	seasonally
Sediments		
Granulometry		seasonally
Relevant organic contaminants, including butyltins		seasonally
Petroleum hydrocarbons		seasonally
Heavy metals		seasonally
Hydrodynamic survey		seasonally

A detailed hydrodynamic survey should be undertaken with the aim of identifying the current regime and as it changes with different seasons in the area of influence. It will also identify water stratification and surface and sub-surface currents in the area.

On the basis of such baseline information, and on the basis of environmental quality objectives to be formulated by the environmental and planning authorities, a set of environmental quality standards and threshold limits will be identified for most water and sediment parameters. These will serve as bench marks (thresholds) for the surveillance monitoring to follow.

5.2.2 Surveillance Monitoring

The purpose of this monitoring is to detect at the earliest possible stage, any environmental damage both during the construction and operation phase of the project. Compliance with the set environmental standards as applied under specific conditions will ensure a satisfactory control of environmental risks as identified in the present report.

The same parameters will be monitored at the same stations, with at least a seasonal frequency.

Marine monitoring will also continue when the marina becomes operational. The parameters to be monitored as well as other modalities will have to be reformulated on the basis of experience gained during the baseline and construction phase monitoring. The main aim of such monitoring will then be to ensure that the marina management is attaining the desired objectives of environmental quality.

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Annex I

Ecoserv's Report of analysis of water and sediment samples

Annex I

Ecoserv's Report of analysis of water and sediment samples

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Report Reference: 085-13

Date of sampling session: **19 June 2013**
Reporting date: **24 July 2013**

LABORATORY REPORT

Collection and analysis of marine water and sediment samples in relation to marine environmental studies, undertaken as part of the environment impact statement for the Delimara Gas and Power: Combined Cycle Gas Turbine and Liquefied Natural Gas receiving, storage and regasification facilities

Client: Enemalta Corporation

PREAMBLE

1. Client (Enemalta Corporation), through Dr Paul Gauci of ERSLI consultants, commissioned Ecoserv Ltd to carry out chemical analysis of a number of water samples, obtained from seven stations from three different depths, and of eight sediment samples, obtained from four stations. All samples were collected by Ecoserv Ltd.

METHODOLOGY

2. Fieldwork was carried out in June 2013.

3. The locations of the seven stations (**1 – 7**) used in the survey are indicated in Figure 1, while the respective station coordinates are given in Table 1. Stations **1** to **5** are located within Marsaxlokk Harbour, while stations **6** and **7** are located in il-Hofra z-Zghira. Station **3** is located in front of the proposed new extension of the power plant and gas storage tanks.

Water Quality Analysis

4. The parameters considered for water analysis are listed in Table 2. The standard analytical methods used in the analysis of the various physico-chemical parameters are listed in Appendix I of this report.

5. During fieldwork, scientific personnel were transported to the seven sampling stations using a 5 m boat equipped with a GPS set and depth sounder. The locations of each sampling station were determined in the field using the boat's Global Positioning System (GPS)[1] set.

Table 1
Latitude/longitude coordinates of the seven sampling stations 1 - 7 (shown in Figure 1).

Sampling Station	Latitude	Longitude
1	35°50'16.92"N	14°32'50.49"E
2	35°49'45.51"N	14°32'59.85"E
3	35°49'51.87"N	14°33'12.11"E
4	35°49'33.59"N	14°32'46.47"E
5	35°49'5.93"N	14°33'15.56"E
6	35°50'10.38"N	14°33'36.59"E
7	35°50'10.44"N	14°33'53.44"E

Figure 1. Map showing the locations of sampling stations for: water within Marsaxlokk Bay (Stations 1, 2, 3, 4, and 5) and il-Hofra z-Zghira (Stations 6 and 7); and sediments within Marsaxlokk Bay (Stations 1, 3, and 5) and il-Hofra z-Zghira (Station 6). Image source: Google Earth.

6. Measurements of temperature, salinity, turbidity and dissolved oxygen were carried out *in situ* at each of the seven stations **1 – 7** (see Figure 1) using a YSI 650 MDS meter connected to a 6820 multi-parameter probe. Measurements using the *in situ* meter were carried out at three depths – surface (0.5 m below the surface), 5 m below the surface and bottom (0.5 m above the seabed). Two replicate measurements were taken at each depth. The unit was calibrated according to the manufacturer's instructions prior to the sampling session.

[1] Chart datum set to WGS 84; accuracy degeneration = *ca* 5 - 10m.

7. For the determination of chemical parameters, water samples were collected from stations **1 – 7** from the surface (0.5 m below the surface) and at a depth of 5 m below the surface. Water samples were also collected from stations **1, 3, 5 & 6** from the surface (0.5 m below the surface) only. Samples were collected using a pre-cleaned and pre-treated Van Dohrn water sampler.Two replicate water samples were collected from each water depth and these were stored in polycarbonate bottles for the determination of levels of inorganic ions, total suspended solids and heavy metals, while for the determination of organic compounds, two replicate samples were collected from the two water depths at each station and stored in glass bottles. The sample bottled, which had been already thoroughly washed with distilled water in the lab before use, were also rinsed with seawater at each respective station prior to sample collection.

8. All samples were transported to the laboratory in cooler boxes and maintained at a temperature of approximately 4° - 8°C until analysis.

9. The analysis of samples collected from the respective station and depth was carried out for the parameters as indicated in Table 2. Analysis for chlorophyll *a* and bacteriological parameters were undertaken immediately upon arrival to the laboratory as these parameters can be affected by prolonged storage, according to standard methodology. The remaining detailed chemical analyses of water samples were carried out according to standard methodology at CADA Laboratories s.n.c. (Italy), which are accredited according to ACCREDIA[2] CEN/ISO 17025 certification (Accreditation number 0439).

Table 2

Parameters analysed in water collected from the various sampling stations

Stations	Depths	Parameters
Stations 1 – 7	Surface and 5m	Temperature Salinity Turbidity Dissolved oxygen
Stations 1 – 7	Surface and 5m	Intestinal enterococci *E. coli* Chlorophyll *a* Nitrates Phosphates Biological Oxygen Demand Chemical Oxygen Demand Total Suspended Solids
Stations 1, 3, 5, 6	Surface	Sulfates Metals: - Arsenic - Cadmium - Chromium - Copper - Lead - Mercury - Nickel - Zinc C10-13-chloroalkanes Brominated diphenylethers (Pentabromodiphenylether (indicator)) Di(2-ethylhexyl)phthalate (DEHP) Hexachlorobenzene Hexachlorobutadiene Hexachlorocyclohexane Pentachlorobenzene Total Polyaromatic hydrocarbons:

[2] ACCREDIA Italian Accreditation System is the National Accreditation Body in Italy

		- Benzo(a)pyrene - Benzo(b)fluoranthene - Benzo(k)fluoranthene - Benzo(g,h,i,)perylene - Indeno(1,2,3-cd)pyrene Total Organotins (TBT, MBT, DBT) Chloroform

Sediment Analysis

10. The parameters considered for the sediment characterisation studies are listed in Table 4. The standard analytical methods used in the analysis of the various physico-chemical parameters are listed in Appendix I.

11. To determine chemical parameters in sediments, samples were collected from Stations **1, 3, 5** and **6**, as indicated in Figure 1. Station **6** was located as close as possible to the cooling water discharge point.

12. During fieldwork, scientific personnel were transported to the four sampling stations using a 5 m boat equipped with a GPS set and depth sounder. The locations of each sampling station were determined in the field using the boat's Global Positioning System (GPS)[3] set.

13. To assess the chemical quality of sediments in the areas of study, two replicate samples were collected from each of the four stations using a pre-cleaned and pre-treated stainless steel handheld grab. Pre-treatment of the grab was carried out to eliminate traces of contamination. The procedure included washing with phosphate-free soap, degreasing and washing with distilled water. The grab was lowered to the bottom and released. The grab was then pulled back and the sediment content were emptied into a pre-treated stainless steel tray. Between each station and replicates from the same stations, the grab was rinsed thoroughly with tap water and distilled water. Sediment samples for analysis of organic compounds were placed in polycarbonate container while the sediment samples for analysis of metals and metal compounds were placed in glass containers.

14. To assess the physical characteristics of the sediments at each of the 4 stations, sediment samples for granulometric analysis were also collected. For this purpose, two replicate samples were collected were collected from the 4 sampling stations using a clean stainless steel handheld grab. In the laboratory, the samples were analysed by sieving through nested Endecott test-sieves on a mechanical sieve-shaker, according to the method given in Buchanan (1984)[4]. The sediment will hence be separated into the different grain size fractions and the percentage contribution of each size fraction, the mean sediment grain size and the sediment's overall classification, calculated. All references to grain sizes are based on the Wentworth Scale

15. Analyses for the chemical parameters used for sediment characterisation listed in Table 4 were carried out according to standard accredited methods at CADA Laboratories s.n.c. (Italy), which are accredited according to ACCREDIA[5] CEN/ISO 17025 certification.

[3] Chart datum set to WGS 84; accuracy degeneration = *ca* 5 - 10m.
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[5] ACCREDIA Italian Accreditation System is the National Accreditation Body in Italy.

Table 4

Parameters analysed in sediment samples collected from stations 1, 3, 5 and6.

Physical parameter	Granulometry
Chemical parameters	Chemical Oxygen Demand Sulphates Metals: - Arsenic - Cadmium - Chromium - Copper - Lead - Mercury - Nickel - Zinc C10-13-chloroalkanes Brominated diphenylethers (Pentabromodiphenylether (indicator)) Di(2-ethylhexyl)phthalate (DEHP) Hexachlorobenzene Hexachlorobutadiene Hexachlorocyclohexane Pentachlorobenzene Total Polyaromatic hydrocarbons: - Benzo(a)pyrene - Benzo(b)fluoranthene - Benzo(k)fluoranthene - Benzo(g,h,i,)perylene - Indeno(1,2,3-cd)pyrene Total Organotins (TBT, MBT, DBT) Chloroform

RESULTS

16. The sample reference codes for analysis reported herein are as follows:
    - Bacteriology and chemical analyses of water samples: **W-244-13 to W-271-13**
    - *In situ* physicochemical parameters of water: **W-272-13**
    - Sediment samples for chemical and physical analysis: **S-165-13 to S-172-13**

17. The raw data for the individual samples (and replicates) is presented in Appendix II.

Water Quality Analysis

18. The results of bacteriological test are given below in Table 5. The results of chlorophyll *a* determinations and of the *in situ* parameters are given in Tables 6 and 7 respectively. The results of the detailed chemical analysis are given in Tables 8 and 9.

Table 5

Results of bacteriological studies (cfu = colony forming units).

Station	Depth (m)	E.coli (cfu/100mL)		Intestinal Enterococci (cfu/100mL)	
		Mean	SD	Mean	SD
1	0	17.50	0.71	0.50	0.71
	5	6.50	2.12	0.50	0.71
2	0	5.50	0.71	0.00	0.00
	5	3.00	1.41	7.50	3.54
3	0	19.00	2.83	9.50	9.19
	5	8.50	3.54	14.00	15.56
4	0	29.50	6.36	6.50	6.36
	5	3.00	0.00	75.00	66.47
5	0	10.00	2.83	1.00	0.00
	5	1.50	0.71	0.50	0.71
6	0	3.50	2.12	2.50	0.71
	5	2.50	0.71	0.00	0.00
7	0	5.50	2.12	2.50	2.12
	5	1.50	0.71	3.00	1.41

Table 6

Values of chlorophyll *a* recorded from Stations 1 - 7.

Station	Depth (m)	Chlorophyll a (mg/m^3)	
		Mean	SD
1	0	0.68	0.00
	5	0.68	0.17
2	0	0.44	0.00
	5	0.21	0.01
3	0	0.34	0.00
	5	0.28	0.08
4	0	0.34	0.00
	5	0.28	0.08
5	0	0.22	0.00
	5	0.22	0.00
6	0	0.56	0.07
	5	0.83	0.01
7	0	0.72	0.00
	5	0.46	0.07

Table 7

Mean values (± SD) of temperature, salinity, turbidity and dissolved oxygen recorded at the surface (0m), at 5m and 0.5 m above the bottom from Stations 1 – 7.

Station	Depth (m)	Temperature (°C)		Salinity (ppt)		Turbidity (NTU)		DO%	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0	23.47	0.21	36.15	0.83	0.68	0.05	107.83	4.83
	5	22.66	0.08	36.75	0.01	0.80	0.18	116.63	1.24
	<5	22.87	0.05	36.70	0.03	0.65	0.10	114.15	2.24
2	0	22.94	0.00	33.98	0.15	0.38	0.05	108.63	0.05
	5	21.71	0.00	36.67	0.01	0.83	0.05	109.18	0.05
	~20	20.97	0.00	36.71	0.00	0.70	0.00	105.55	0.06
3	0	22.80	0.01	36.78	0.00	0.40	0.00	108.13	0.05
	5	21.64	0.02	36.74	0.01	1.00	0.00	106.60	0.00
	~20	21.36	0.00	36.74	0.00	1.25	0.06	107.25	0.06
4	0	23.36	0.01	36.79	0.00	0.50	0.00	109.88	0.05
	5	21.68	0.00	36.76	0.00	0.80	0.00	106.93	0.05
	20-25	21.27	0.01	36.74	0.00	1.00	0.00	106.10	0.00
5	0	22.61	0.00	36.78	0.00	0.48	0.05	107.73	0.10
	5	21.71	0.14	36.76	0.03	0.30	0.00	106.10	0.27
	~40	20.03	0.01	36.70	0.00	0.10	0.00	103.53	0.13
6	0	26.14	0.07	36.80	0.01	0.30	0.00	123.15	0.17
	5	22.44	0.44	36.75	0.02	0.18	0.05	115.68	0.29
	5-10	21.70	0.01	36.74	0.01	68.20	42.77	108.20	4.60
7	0	24.76	0.11	36.80	0.01	0.25	0.06	116.68	0.15
	5	22.42	0.11	36.78	0.00	0.13	0.05	110.45	2.04
	10	20.84	0.15	36.70	0.02	0.20	0.00	110.18	1.12

Table 8

Mean levels (± 1SD) of chemical parameters recorded in water samples collected from Stations 1– 7. ND = not detected.

Parameters	Units	Station							
		1 (0m)	1 (5m)	2 (0m)	2 (5m)	3 (0m)	3 (5m)	4 (0m)	4 (5m)
Total Suspended Solids	mg/L	1.7 ± 0.71	2.9 ± 0.42	2.9 ± 2.12	1.7 ± 1.27	1.0 ± 0.57	2.3 ± 0.42	1.3 ± 0.71	3.3 ± 2.12
Nitrates	mg/L	ND < 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phosphates	mg/L	ND < 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BOD	mg/L	ND < 5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
COD	mg/L	ND < 5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Parameters	Units	Station					
		5 (0m)	5 (5m)	6 (0m)	6 (5m)	7 (0m)	7 (5m)
Total Suspended Solids	mg/L	0.7 ± 0.14	3.1 ± 2.69	1.2 ± 0.57	1.9 ± 0.71	1.3 ± 0.42	0.6 ± 0.00
Nitrates	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phosphates	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BOD	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
COD	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Table 9

Mean levels (± 1SD) of sulfates, heavy metals and PAHs recorded in water samples collected from the surface at Stations 1, 3, 5 and 6. ND = not detected.

Parameter	Units	Station			
		1	3	5	6
Sulfates	mg/L	2775.5 ± 54.45	2832.5 ± 61.52	2836.5 ± 54.45	2892.5 ± 113.84
Arsenic	µg/l	ND < 1	ND < 1	ND < 1	ND < 1
Cadmium	µg/l	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Chromium	µg/l	ND < 1	ND < 1	ND < 1	ND < 1
Copper	µg/l	2.0*	ND < 1	ND < 1	ND < 1
Lead	µg/l	ND < 1	ND < 1	ND < 1	ND < 1
Mercury	µg/l	ND < 0.05	ND < 0.05	ND < 0.05	ND < 0.05
Nickel	µg/l	ND < 1	ND < 1	ND < 1	ND < 1
Zinc	µg/l	ND < 1	ND < 1	ND < 1	ND < 1

Parameter	Units	Station			
		1	3	5	6
Chloroalkanes (C10-13)	mg/l	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Pentabromodiphenylether	µg/l	ND < 0.0000001	ND < 0.0000001	ND < 0.0000001	ND < 0.0000001
Di(2-ethylhexyl)phtalate	µg/l	8.7 ± 7.28	1.5 ± 0.00	2.1 ± 1.34	2.6 ± 1.56
Hexachlorobenzene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Hexachlorobutadiene	µg/l	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Hexachlorocyclohexane	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Pentachlorobenzene	µg/l	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Benzo (a) pyrene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Benzo (b) fluoroanthene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Benzo (k) fluoranthene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Benzo (g,h,i) perylene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Indeno (1,2,3-c,d) pyrene	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
TBT	mg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
DBT	mg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
MBT	mg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Chloroform	µg/l	ND < 0.1	ND < 0.1	9.1*	ND < 0.1

** = detectable value available for one replicate; the other replicate recorded as ND.*

Sediment Analysis

19. The results for chemical analysis in sediments collected from Stations **1, 3, 5** and **6** are given in Table 10.

20. The results of granulometric analysis of sediment samples collected from Stations **1, 3, 5** and **6** are given in Table 11.

Table 10

Mean values (± 1SD) for the various chemical parameters in sediment samples collected from Stations 1, 3, 5 and **6. ND = not detected.**

Parameter	Units	Station			
		1	3	5	6
COD	mg/Kg	0.5 ± 0.3	9.1 ± 0.9	3.1 ± 0.6	1.5 ± 0.3
Sulfates	mg/Kg	759.5 ± 29.0	3689.5 ± 594.7	1403.0 ± 9.9	807.0 ± 21.2
Arsenic	mg/Kg	2.0 ± 0.0	9.5 ± 0.7	3.5 ± 0.7	5.5 ± 0.7
Cadmium	mg/Kg	0.4 ± 0.1	1.0 ± 0.0	0.5 ± 0.1	0.5 ± 0.0
Chromium	mg/Kg	2.5 ± 0.7	21.0 ± 4.2	6.5 ± 0.7	9.0 ± 1.4
Copper	mg/Kg	1.5 ± 0.7	27.5 ± 0.7	2.0 ± 0.0	2.5 ± 0.7
Lead	mg/Kg	9.5 ± 2.1	21.0 ± 1.4	4.5 ± 0.7	6.0 ± 0.0
Mercury	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Nickel	mg/Kg	1.0 ± 0.0	10.0 ± 1.4	2.5 ± 0.7	3.5 ± 0.7
Zinc	mg/Kg	5.0 ± 1.4	43.0 ± 0.0	9.0 ± 1.4	71.5 ± 82.7
Chloroalkanes (C10-13)	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Pentabromodiphenylether	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Di(2-ethylhexyl)phtalate	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Hexachlorobenzene	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Hexachlorobutadiene	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Hexachlorocyclohexane	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Pentachlorobenzene	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Benzo (a) pyrene	mg/Kg	ND < 0.01	0.03 ± 0.0	ND < 0.01	0.01*
Benzo (b) fluoroanthene	mg/Kg	ND < 0.01	0.04 ± 0.0	ND < 0.01	0.01*
Benzo (k) fluoranthene	mg/Kg	ND < 0.01	0.01 ± 0.0	ND < 0.01	ND < 0.01
Benzo (g,h,i) perylene	mg/Kg	ND < 0.01	0.02 ± 0.0	ND < 0.01	ND < 0.01
Indeno (1,2,3-c,d) pyrene	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
TBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
DBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1

Parameter	Units	Station			
		1	3	5	6
MBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Chloroform	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01

** = detectable value available for one replicate; the other replicate recorded as ND*

Table 11

Mean values of sediment grain size (± SD), sorting and degree of sorting for the sediment samples collected from Stations 1, 3, 5 and 6.

Station	Mean sediment grain size (µm)	Classification	Mean Sorting (Ø)	Degree of sorting
1	243.42 ± 64.96	Muddy sandy gravel / gravelly muddy sand	13.05 ± 3.22	Very poorly sorted
3	11.60 ± 0.45	Slightly gravelly sandy mud	2.73 ± 0.11	Poorly sorted
5	136.75 ± 16.40	(Slightly) gravelly muddy sand	5.62 ± 2.04	(Very) poorly sorted
6	507.56 ± 129.21	(Slightly) gravelly sand	4.31 ± 0.19	Poorly sorted

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Appendix I

Standard methods used for the analysis of seawater and sediment.

Table I-1. Details of the method of analysis for parameters in seawater.

Analytical test	Units of measurement	Reference to standard method
Temperature	^oC	Thermistor sensor probe Portable meter
Salinity	ppt	Electrometry Portable meter
Turbidity	NTU	Electrometry Portable meter
Dissolved oxygen	%	ISO 7888:1985 Portable meter
Intestinal enterococci	cfu/100mL	ISO 7899-2:2000 Membrane filtration
E. coli	cfu/100mL	ISO 9308-1:2000 Membrane filtration
Chlorophyll *a*	mg/m^3	Strickland & Parsons (1972) [6]
Total suspended solids	µg/L	APAT CNR IRSA 2090 B Man 29 2003 Gravimetry
Nitrate	mg/L	EPA 300.1 1999 Ion Chromatography
Phosphate	mg/L	APAT CNR IRSA 4110 Man 29 2003 Spectrophotometry
Sulfates	mg/L	EPA 300.1 1999 Ion Chromatography
Biological Oxygen Demand	mg/L	APHA Standard Methods, ed 21 th 2005, 5210 D Respirometry
Chemical Oxygen Demand	mg/L	APAT CNR IRSA 5130 Man 29 2003 Volumetric
Arsenic	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Cadmium	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Chromium	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Copper	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Lead	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Mercury	µg/L	UNI EN ISO 17294-02:2005 ICP-MS

[6] Strickland J. D. H. & Parsons T. R., (1972). A Practical Handbook of Seawater Analysis (2nd Ed.) Ottawa: Fisheries Research Board of Canada.

Analytical test	Units of measurement	Reference to standard method
Nickel	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Zinc	µg/L	APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Chloroalkanes (C10-13)	mg/l	EPA 3510C 1996 + EPA 8270D 2007 GC-MS
Pentabromodiphenylether	µg/l	EPA 3545:2007 + EPA 1614:2007 GC-HRMS
Di(2-ethylhexyl)phtalate	µg/l	EPA 3510C 1996 + EPA 8270D 2007 GC-MS
Hexachlorobenzene	µg/l	EPA 3510C 1996 + EPA 8270D 2007 GC-MS
Hexachlorobutadiene	µg/l	EPA 5030C 2003 + EPA 8260C 2006 GC-MS
Hexachlorocyclohexane	µg/l	EPA 3510C 1996 + EPA 8270D 2007 GC-MS
Pentachlorobenzene	µg/l	EPA 3510C 1996 + EPA 8270D 2007 GC-MS
Benzo (a) pyrene	µg/l	APAT CNR IRSA 5080 Man 29 2003 GC-MS
Benzo (b) fluoroanthene	µg/l	APAT CNR IRSA 5080 Man 29 2003 GC-MS
Benzo (k) fluoranthene	µg/l	APAT CNR IRSA 5080 Man 29 2003 GC-MS
Benzo (g,h,i) perylene	µg/l	APAT CNR IRSA 5080 Man 29 2003 GC-MS
Indeno (1,2,3-c,d) pyrene	µg/l	APAT CNR IRSA 5080 Man 29 2003 GC-MS
TBT	mg/l	UNI EN ISO 17353:2006 GC-MS
DBT	mg/l	UNI EN ISO 17353:2006 GC-MS
MBT	mg/l	UNI EN ISO 17353:2006 GC-MS
Chloroform	µg/l	EPA 5030C 2003 + EPA 8260C 2006 GC-MS

Table I-2. Details of the method of analysis for parameters in sediment.

Analytical test	Units of measurement	Method of analysis
Sulfates	mg/Kg	DM 13/09/1999 GU n°248 21/10/1999 Met. IV.2 Ion Chromatography
Arsenic	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Cadmium	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Chromium	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Copper	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Lead	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Mercury	mg/Kg	EPA 3051A 2007 + EPA 6010C 2007ICP-OES
Nickel	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Zinc	mg/Kg	UNI EN ISO 13657: 2004 + APAT CNR IRSA 3020 Man 29 2003 ICP-OES
Chloroalkanes (C10-13)	mg/Kg	EPA 3541 1994 + EPA 3620C 2007 + EPA 8270D 2007 GC-MS
Pentabromodiphenylether	µg/l	EPA 3545:2007 + EPA 1614:2007 GC-HRMS
Di(2-ethylhexyl)phtalate	mg/Kg	EPA 3541 1994 + EPA 3620C 2007 + EPA 8270D 2007 GC-MS
Hexachlorobenzene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996+ EPA 8081B 2007 GC-ECD
Hexachlorobutadiene	mg/Kg	EPA 5021A 2003 + EPA 8260C 2006 GC-MS
Hexachlorocyclohexane	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8081B 2007 GC-ECD
Pentachlorobenzene	mg/Kg	EPA 3541 1994 + EPA 3620C 2007 + EPA 8270D 2007 GC-MS
Benzo (a) pyrene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8270D 2007 GC-MS
Benzo (b) fluoroanthene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8270D 2007 GC-MS
Benzo (k) fluoranthene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8270D 2007 GC-MS

Analytical test	Units of measurement	Method of analysis
Benzo (g,h,i) perylene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8270D 2007 GC-MS
Indeno (1,2,3-c,d) pyrene	mg/Kg	EPA 3541 1994 + EPA 3630C 1996 + EPA 8270D 2007 GC-MS
TBT	mg/Kg	ICRAM App. 1 2001 – 2003 GC-MS
DBT	mg/Kg	ICRAM App. 1 2001 – 2003 GC-MS
MBT	mg/Kg	ICRAM App. 1 2001 – 2003 GC-MS
Chloroform	mg/Kg	EPA 5021A 2003 + EPA 8260C 2006 GC-MS

Table I-3. Details of the method of analysis for granulometric analysis of sediments.

Analytical test	Units of measurement	Method of analysis
Mean sediment grain size	mm	Buchanan (1984)
Classification of sediment	N/A	Buchanan (1984)
Kurtosis	N/A	Buchanan (1984)
Sorting	N/A	Buchanan (1984)

Key to abbreviated methodology used in Tables I-1 – I-2

ICP-OES	Inductively coupled plasma - Optical emission spectrometry
GC-MS	Gas chromatography - Mass spectrometry
GC-HRMS	Gas Chromatography - High Resolution Mass Spectrometry
GC-ECD	Gas chromatography - Electron Capture Detector

Appendix II

Raw Data Tables

Table II-1. Values for the parameters in list A recorded in sediment samples collected from Stations 1 – 7. ND = not detected.

Parameter		Station 1				Station 2				Station 3			
		1 (Surface)		1 (5 m)		2 (Surface)		2 (5 m)		3 (Surface)		3 (5 m)	
		W-244-13	W-245-13	W-246-13	W-247-13	W-248-13	W-249-13	W-250-13	W-251-13	W-252-13	W-253-13	W-254-13	W-255-13
Total Suspended Solids	mg/L	2.2	1.2	2.6	3.2	4.4	1.4	0.8	2.6	0.6	1.4	2	2.6
Nitrates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
Phosphates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
BOD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0
COD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0
Sulfates	mg/L	2814.0	2737.0							2876.0	2789.0		
Arsenic	µg/l	ND < 1	ND < 1							ND < 1	ND < 1		
Cadmium	µg/l	ND < 0.1	ND < 0.1							ND < 0.1	ND < 0.1		
Chromium	µg/l	ND < 1	ND < 1							ND < 1	ND < 1		
Copper	µg/l	2.0	ND < 1							ND < 1	ND < 1		
Lead	µg/l	ND < 1	ND < 1							ND < 1	ND < 1		
Mercury	µg/l	ND < 0.05	ND < 0.05							ND < 0.05	1.0		
Nickel	µg/l	ND < 1	ND < 1							ND < 1	ND < 1		
Zinc	µg/l	ND < 1	ND < 1							ND < 1	ND < 1		
Chloroalkanes (C10-13)	mg/l	ND < 0.01	ND < 0.01							ND < 0.01	ND < 0.01		
Pentabromodiphenylether	µg/l	ND < 0.0000001	ND < 0.0000001							ND < 0.0000001	ND < 0.0000001		
Di(2-ethylhexyl)phtalate	µg/l	3.5	13.8							1.5	1.5		
Hexachlorobenzene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Hexachlorobutadiene	µg/l	ND < 0.01	ND < 0.01							ND < 0.01	ND < 0.01		
Hexachlorocyclohexane	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Pentachlorobenzene	µg/l	ND < 0.01	ND < 0.01							ND < 0.01	ND < 0.01		

Parameter		Station 1				Station 2				Station 3			
		1 (Surface)		1 (5 m)		2 (Surface)		2 (5 m)		3 (Surface)		3 (5 m)	
		W-244-13	W-245-13	W-246-13	W-247-13	W-248-13	W-249-13	W-250-13	W-251-13	W-252-13	W-253-13	W-254-13	W-255-13
Benzo (a) pyrene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Benzo (b) fluoroanthene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Benzo (k) fluoranthene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Benzo (g,h,i) perylene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Indeno (1,2,3-c,d) pyrene	µg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
TBT	mg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
DBT	mg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
MBT	mg/l	ND < 0.001	ND < 0.001							ND < 0.001	ND < 0.001		
Chloroform	µg/l	ND < 0.1	ND < 0.1							ND < 0.1	ND < 0.1		

		Station 4				Station 5			
		4 (Surface)		4 (5 m)		5 (Surface)		5 (5 m)	
		W-256-13	W-257-13	W-258-13	W-259-13	W-260-13	W-261-13	W-262-13	W-263-13
Total Suspended Solids	mg/L	0.8	1.8	4.8	1.8	0.8	0.6	1.2	5
Nitrates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
Phosphates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
BOD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0
COD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0
Sulfates	mg/L					2798.0	2875.0		
Arsenic	µg/l					ND < 1	ND < 1		
Cadmium	µg/l					ND < 0.1	ND < 0.1		
Chromium	µg/l					ND < 1	ND < 1		
Copper	µg/l					ND < 1	ND < 1		
Lead	µg/l					ND < 1	ND < 1		
Mercury	µg/l					ND < 0.05	ND < 0.05		
Nickel	µg/l					ND < 1	ND < 1		

		Station 4				Station 5			
		4 (Surface)		4 (5 m)		5 (Surface)		5 (5 m)	
		W-256-13	W-257-13	W-258-13	W-259-13	W-260-13	W-261-13	W-262-13	W-263-13
Zinc	µg/l					ND < 1	ND < 1		
Chloroalkanes (C10-13)	mg/l					ND < 0.01	ND < 0.01		
Pentabromodiphenylether	µg/l					ND < 0.0000001	ND < 0.0000001		
Di(2-ethylhexyl)phtalate	µg/l					3.0	1.1		
Hexachlorobenzene	µg/l					ND < 0.001	ND < 0.001		
Hexachlorobutadiene	µg/l					ND < 0.01	ND < 0.01		
Hexachlorocyclohexane	µg/l					ND < 0.001	ND < 0.001		
Pentachlorobenzene	µg/l					ND < 0.01	ND < 0.01		
Benzo (a) pyrene	µg/l					ND < 0.001	ND < 0.001		
Benzo (b) fluoroanthene	µg/l					ND < 0.001	ND < 0.001		
Benzo (k) fluoranthene	µg/l					ND < 0.001	ND < 0.001		
Benzo (g,h,i) perylene	µg/l					ND < 0.001	ND < 0.001		
Indeno (1,2,3-c,d) pyrene	µg/l					ND < 0.001	ND < 0.001		
TBT	mg/l					ND < 0.001	ND < 0.001		
DBT	mg/l					ND < 0.001	ND < 0.001		
MBT	mg/l					ND < 0.001	ND < 0.001		
Chloroform	µg/l					ND < 0.1	9.1		

		Station 6				Station 7			
		6 (Surface)		6 (5 m)		7 (Surface)		7 (5 m)	
		W-264-13	W-265-13	W-266-13	W-267-13	W-268-13	W-269-13	W-270-13	W-271-13
Total Suspended Solids	mg/L	1.6	0.8	2.4	1.4	1.6	1	0.6	0.6
Nitrates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
Phosphates	mg/L	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01	ND <0.01
BOD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0
COD	mg/L	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0	ND <5.0

		Station 6				Station 7			
		6 (Surface)		6 (5 m)		7 (Surface)		7 (5 m)	
		W-264-13	W-265-13	W-266-13	W-267-13	W-268-13	W-269-13	W-270-13	W-271-13
Sulfates	mg/L	2812.0	2973.0						
Arsenic	µg/l	ND < 1	ND < 1						
Cadmium	µg/l	ND < 0.1	ND < 0.1						
Chromium	µg/l	ND < 1	ND < 1						
Copper	µg/l	ND < 1	ND < 1						
Lead	µg/l	ND < 1	ND < 1						
Mercury	µg/l	ND < 0.05	ND < 0.05						
Nickel	µg/l	ND < 1	ND < 1						
Zinc	µg/l	ND < 1	ND < 1						
Chloroalkanes (C10-13)	mg/l	ND < 0.01	ND < 0.01						
Pentabromodiphenylether	µg/l	ND < 0.0000001	ND < 0.0000001						
Di(2-ethylhexyl)phtalate	µg/l	1.5	3.7						
Hexachlorobenzene	µg/l	ND < 0.001	ND < 0.001						
Hexachlorobutadiene	µg/l	ND < 0.01	ND < 0.01						
Hexachlorocyclohexane	µg/l	ND < 0.001	ND < 0.001						
Pentachlorobenzene	µg/l	ND < 0.01	ND < 0.01						
Benzo (a) pyrene	µg/l	ND < 0.001	ND < 0.001						
Benzo (b) fluoroanthene	µg/l	ND < 0.001	ND < 0.001						
Benzo (k) fluoranthene	µg/l	ND < 0.001	ND < 0.001						
Benzo (g,h,i) perylene	µg/l	ND < 0.001	ND < 0.001						
Indeno (1,2,3-c,d) pyrene	µg/l	ND < 0.001	ND < 0.001						
TBT	mg/l	ND < 0.001	ND < 0.001						
DBT	mg/l	ND < 0.001	ND < 0.001						
MBT	mg/l	ND < 0.001	ND < 0.001						
Chloroform	µg/l	ND < 0.1	ND < 0.1						

Table II-2. Values for parameters recorded in sediment samples collected from Stations 1, 3, 5 & 6. ND = not detected.

Parameter	Units	Sample Reference Code							
		S-165-13	S-166-13	S-167-13	S-168-13	S-169-13	S-170-13	S-171-13	S-172-13
		1 A	1 B	3 A	3 B	4 A	4 B	5 A	5 B
COD	mg/Kg	0.3	0.7	9.7	8.4	3.5	2.6	1.3	1.7
Sulfates	mg/Kg	739.0	780.0	3269.0	4110.0	1410.0	1396.0	792.0	822.0
Arsenic	mg/Kg	2.0	2.0	10.0	9.0	4.0	3.0	6.0	5.0
Cadmium	mg/Kg	0.3	0.4	1.0	1.0	0.5	0.4	0.5	0.5
Chromium	mg/Kg	2.0	3.0	24.0	18.0	6.0	7.0	10.0	8.0
Copper	mg/Kg	1.0	2.0	27.0	28.0	2.0	2.0	3.0	2.0
Lead	mg/Kg	8.0	11.0	22.0	20.0	5.0	4.0	6.0	6.0
Mercury	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Nickel	mg/Kg	1.0	1.0	11.0	9.0	2.0	3.0	4.0	3.0
Zinc	mg/Kg	4.0	6.0	43.0	43.0	10.0	8.0	130.0	13.0
Chloroalkanes (C10-13)	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Pentabromodiphenylether	µg/l	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Di(2-ethylhexyl)phtalate	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Hexachlorobenzene	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Hexachlorobutadiene	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Hexachlorocyclohexane	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Pentachlorobenzene	mg/Kg	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001	ND < 0.001
Benzo (a) pyrene	mg/Kg	ND < 0.01	ND < 0.01	0.03	0.03	ND < 0.01	ND < 0.01	0.01	ND < 0.01
Benzo (b) fluoroanthene	mg/Kg	ND < 0.01	ND < 0.01	0.04	0.04	ND < 0.01	ND < 0.01	0.01	ND < 0.01
Benzo (k) fluoranthene	mg/Kg	ND < 0.01	ND < 0.01	0.01	0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Benzo (g,h,i) perylene	mg/Kg	ND < 0.01	ND < 0.01	0.02	0.02	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
Indeno (1,2,3-c,d) pyrene	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01
TBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
DBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
MBT	mg/Kg	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1	ND < 0.1
Chloroform	mg/Kg	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01	ND < 0.01