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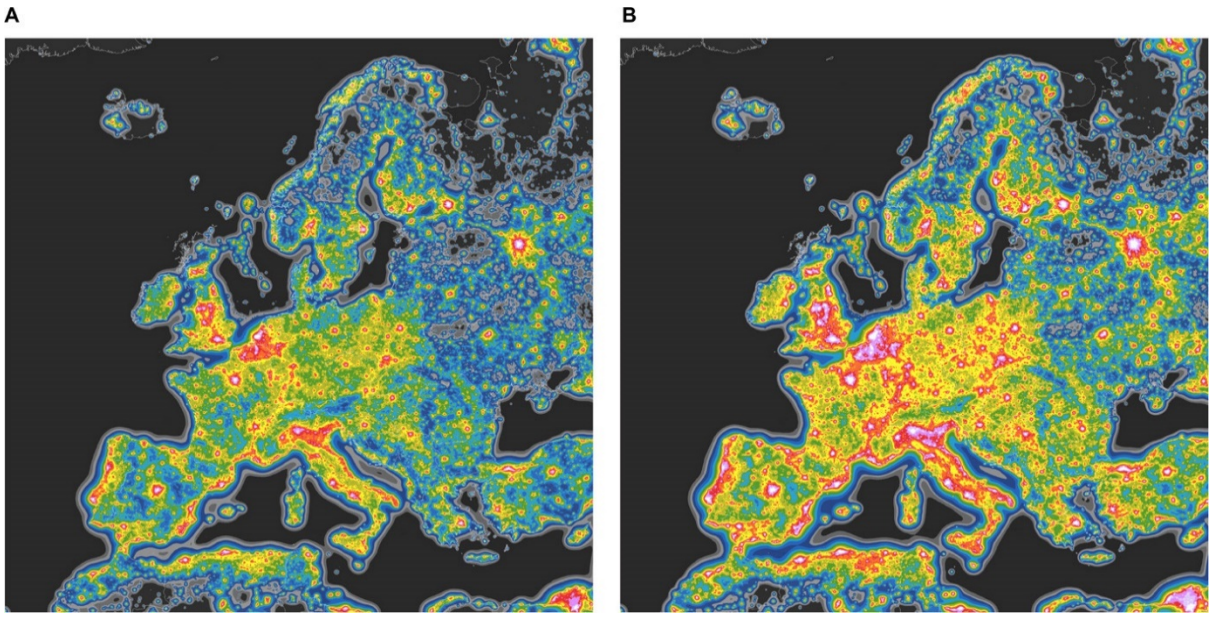
BIRDLIFE MALTA

MEASUREMENTS OF NIGHT SKY BRIGHTNESS AND IDENTIFICATION OF SOURCES OF LIGHT POLLUTION

AUTHORS: BRINCAT STEPHEN – PACE ALEXEI



LIFE Arċipelagu Garnija (LIFE14 NAT/MT/991)

Securing the Maltese Islands for the Yelkouan Shearwater *Puffinus yelkouan.*

Action A2: Threat assessment at Yelkouan shearwater colony sites.

LIFE14 NAT/MT/991 LIFE Arcipelagu Garnija
Securing the Maltese islands for the Yelkouan Shearwater *Puffinus yelkouan*

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Report written by:	Brincat Stephen, Pace Alexei
Contact:	alexei.pace@gmail.com
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Data Beneficiary

Name Beneficiary:	BirdLife Malta
Contact person:	Paulo Lago Barreiro
Postal address:	Triq Abate Rigord, 57/28, XBX 1120, Ta' Xbiex, Malta
Telephone:	+356 2134 7646
E-mail:	paulo.lagobarreiro@birdlifemalta.org
Project Website:	http://birdlifemalta.org/arcipelagugarnija/

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Front cover illustration: ***Maps of Europe's artificial sky brightness, in twofold increasing steps, as a ratio to the natural sky brightness (assumed to be 174 µcd/m^2).***

*(**A**) The map shows the artificial sky brightness in V-band, as in the other maps. (**B**) The map shows the forecast of the perceived sky brightness for a dark-adapted eye after a transition toward 4000K CCT LED technology, without increasing the photopic flux of currently installed lamps (Falchi, Cinzano et al. 2016).*

CONTENTS

This report is part of the requirements of Action A2: Threat assessment at Yelkouan shearwater colony sites as part of the EU-Life funded Arċipelagu Garnija project LIFE14 NAT/MT/991.

EXECUTIVE SUMMARY

Ever-increasing amounts of light pollution have caused the disruption of the natural day-night cycles to which all species have evolved over millions of years. The vast majority of conservation studies are concentrated on the daytime aspects. It is only now that scientists are appreciating the ecological consequences of artificial night-time illumination.

This report presents the findings of studies carried out during 2017 and 2018 which aims to characterise the brightness of the night sky in twenty locations in which colonies of the Yelkouan Shearwater (*Puffinus yelkouan)* are found to be present.

Various studies have indicated a direct link between the presence of artificial lighting and loss of pelagic avifauna species such as Yelkouan Shearwater colonies through factors such as disorientation/stranding and nest desertion amongst other factors.

For each site a panoramic description of bright sources of artificial lighting as well as a 360° plot of the night sky brightness is presented.

INTRODUCTION

LIGHT POLLUTION AND ITS EFFECTS ON THE NATURAL ENVIRONMENT

Over the past hundred years, and especially during the last three decades, we have witnessed an exponential growth in outdoor lighting brought about by the advance of urbanisation and an increase in the standard of living. The extension of our working hours into the night provides significant and substantial benefits (Gaston, Gaston et al. 2014) but has brought with it a similarly exponential increase in light pollution – the alteration of natural lighting levels[A] at night as a direct cause of anthropogenic sources of light (Cinzano, Falchi et al. 2000).

Artificial light at night (ALAN) is having a major impact on human society at large as well as biological impact on ecological communities through the disruption of the natural patterns of light and dark (Gaston, Visser et al. 2015), through which life on Earth has stabilised itself throughout evolutionary history i.e. the daily cycle of night and day, the monthly phases of the Moon and the yearly cycle of the seasons – periodic patterns of light and darkness modulated by meteorological phenomena.

Studies are still being carried out to understand better the response to ALAN (which varies amongst different species) including the effects on avifauna (Spoelstra, Visser 2013). It is widely recognised that light pollution may well be impacting whole ecosystems and biodiversity and several studies have been carried out on this aspect (Hölker, Wolter et al. 2010).

ALAN propagates into the night-time environment and hence it is recognised as environmental stressor i.e. light pollution from a range of sources such as road lighting, security lighting, advertising, architectural lighting etc. Natural habitats are not only impacted by direct light (glare) but in many cases also by reflections (skyglow) of light from far-away sources, this being the cause for disruption of ecosystems through ecological light pollution (Longcore, Rich 2004). The consequences of light pollution can be detected at places located tens (or even hundreds) of kilometres away from the source so it is essential that light pollution in urban areas is controlled to cut down on light pollution in rural sites (Bará 2016).

The most common response of birds to ALAN is the well-documented impact of attraction and orientation disruption, a phenomenon known as positive phototaxis. In dark environments, such as the twenty sites investigated through this study, any brightly-lit spots can disrupt night-migrating/diurnal and nocturnal birds, especially in situations where the sky is overcast (Poot, Ens et al. 2008) and studies have also shown how seabirds such as fledglings of short-tailed shearwaters (*Ardenna tenuirostris*) or Cory's Shearwater (*Calonectris diomedea*) were found grounded (Rodríguez, Burgan et al. 2014), (Rodríguez, Rodríguez et al. 2012). The characterisation and monitoring of light pollution in coastal areas is an important aspect which is getting more attention only recently in order to adequately protect these areas (Ges, Bará et al. 2017).

[A] *Natural lighting levels are regulated by sources such as the Moon, the stars (including the Milky Way), the zodiacal light and atmospheric emissions (airglow).*

SKY BRIGHTNESS

The brightness of the night sky is made up from natural and artificial sources of light. Light travels to an observer directly from objects in outer space (such as the stars) or it can scatter through the Earth's atmosphere off molecules and aerosols and form the characteristic yellowish diffuse glow of light pollution (artificial skyglow) in the night sky, which is observed mostly over densely populated areas.

Typical values for night sky brightness are presented in Table 1 below. Sky brightness is measured in units of magnitude per square arcsecond (mag/arcsec^2) in the Johnson-Cousins V-band (Garstang 1989).

Table 1

Typical night sky brightness values meant to be representative of luminance values estimated for the sky at the zenith based on SQM observations. Zenithal measurements are a very useful indicator of the severity of night sky brightness disruptions through comparison of the increment in relation with the expected natural levels.

Condition	Zenith radiance ($mag_{SQM}/arcsec^2$).	Reference
Overcast natural night sky	>21.8	Hölker, Kolláth et al (2016)
Bulge of the Milky Way	20.5-21.0	
Rural night sky (clear, no moon)	20.3-21.6	Kyba, Tong et al (2015)
Rural night sky (overcast)	19.0-21.6	
Suburban night sky (clear)	17.2-20.4	
Suburban night sky (overcast)	16-19.3	
Urban night sky (clear)	16.8-19.2	
Urban night sky (overcast)	14.5-17.7	
Overcast day	5.6-8.8	

In the values given above, **larger values in mag/arcsec^2 indicate darker skies** ie. lower levels of light pollution. The darkest places on Earth, during moonless nights, have a luminance of the natural night sky background brightness (away from the Milky Way and zodiacal light) approaching 22mag/arcsec^2 [B] whilst as can be seen from above in bright urban locations the values go down to around 16-17mag/arcsec^2.

THE FIELD SITES

A total of twenty coastal nesting sites were requested to be investigated in terms of their night sky characteristics. The locations are as indicated in Table 2 below. Google Maps was used to identify each field site upon inputting of the relevant geographic coordinates. All measurements took place at the latitudes and longitudes indicated below, to a tolerance of

[B] *The brightness of a natural dark sky is equivalent to 174 µcd/m^2.*

±25m in cases where access was not possible, for example where the requested measurement site happened to be inside private land or elsewhere reaching the exact site proved dangerous, for instance where it was highly risky to approach cliff edges. In all cases the authors assessed the measurement locations to be representative of the conditions present at the requested sites therefore the effects on the imagery and on the sky plot measurements is insignificant.

Table 2

Geographic details of the nesting site locations taken into consideration.

Site number	Name of site	Location	Geographic latitude	Geographic longitude
01	L-Irdum tal-Madonna	Malta	35.9904°N	14.3735°E
02	Majjistral Park	Malta	35.9554°N	14.3392°E
03	Ras il-Qammieħ	Malta	35.9762°N	14.3264°E
04	St. Paul's Islands - salt pans	Malta	35.9637°N	14.3970°E
05	Fomm ir-Riħ	Malta	35.9057°N	14.3392°E
06	Miġra Ferħa	Malta	35.8746°N	14.3420°E
07	Il-Fawwara	Malta	35.8421°N	14.3989°E
08	Għar Lapsi	Malta	35.8319°N	14.4152°E
09	Wied Babu	Malta	35.8213°N	14.4561°E
10	Ħal Far	Malta	35.8107°N	14.5042°E
11	Santa Marija	Comino	36.0181°N	14.3401°E
12	Blue Lagoon	Comino	36.0126°N	14.3247°E
13	Ta' Ċenċ (2)	Gozo	36.0149°N	14.2655°E
14	Ta' Ċenċ (1)	Gozo	36.0175°N	14.2539°E
15	Sanap Cliffs	Gozo	36.0219°N	14.2268°E
16	Ta' Sarraflu	Gozo	36.0346°N	14.2005°E
17	San Lawrenz	Gozo	36.0655°N	14.1858°E
18	Wied ir-Raħeb	Gozo	36.0743°N	14.1943°E
19	Għajn Barrani - Qortin Landfill	Gozo	36.0668°N	14.2705°E
20	Qortin ta' Isopu	Gozo	36.0551°N	14.3041°E

METHODOLOGY

INSTRUMENTATION

Sets of 360° panoramic images were shot at each site using a tripod-mounted Canon 6D camera coupled to a 24mm wide angle lens. The panoramas were stitched together in equirectangular projection.

Another instrument used was a Unihedron Sky Quality Meter (SQM-L) with a field of view of 20° (full width at half maximum, FWHM). This photometer is equipped with a SQM detector having a solid state light-to-frequency converter (TSL237S) and its use constitutes a standard method for performing night sky brightness measurements. It reports luminance readings directly in units of magnitude per square arcsecond (mag/arcsec^2), which is a logarithmic scale that, as mentioned previously, decreases with increasing brightness[C]. A second SQM was used to verify and confirm the accuracy of the first SQM. Normally single measurements are taken by pointing the instrument at the zenith. In this case however it was mounted on a tiltable table which enables the instrument to point at the entire range of altitudes and azimuths required to cover the entire celestial hemisphere by means of an all-sky mosaic. Multiple readings were taken at each point which were then averaged.

All measurements were carried out during a restricted time window i.e. under conditions of:

(a) no contribution to the night sky brightness from moonlight i.e. during the moonless period on or around new Moon,
(b) clear weather conditions i.e. no cloud cover, and
(c) after the end of astronomical twilight i.e. with the Sun situated more than 18° below the horizon i.e. in conditions of complete natural darkness.

NIGHT SKY BRIGHTNESS PLOTS

At each location the authors carried out 360° surveys of the entire celestial hemisphere by means of 49 measurements spread equally in altitude and azimuth (plus zenith) to build all-sky polar plots. A plot for each site is presented in the following reports. Multiple measurements are taken which were then averaged to reduce any errors.

The resulting maps are plotted after interpolation of the measurement points and provide a scientifically accurate representation of the brightness of the night sky in magnitude per square arcsecond from which the identification of the bright light sources contributing to an increase in light pollution at each site can be made (Zamorano, de Miguel et al. 2012).

MAP INTERPRETATION

Interpretation of the night sky brightness plots is straightforward since each circular plot shows the entire night sky from horizon to horizon as it appeared on the date of the measurement. The centre of the map is the part of the sky directly overhead from that

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[C] *A decrease of 5 mag/arcsec^2 equals to an increase in luminance by a factor of 100.*

particular location (the zenith) whilst the outer circle is the measurement horizon at 20° altitude (zenith angle 70°).

Compass directions move clockwise around the horizon circle with North at the top of the page, East at 90° azimuth, South at 180° azimuth and West at 270° azimuth. The colour scale on the right-hand side of the plot indicates the brightness of the sky, with dark blue areas being the darkest (highest mag/arcsec^2 readings) whereas the red areas constitute bright hotspots which often indicate nearby direct sources of glare and other forms of light pollution.

A series of isolines across the entire plot connect points having the same luminance (mag/arcsec^2) values. The closer the isolines are the greater is the change in night sky brightness (luminance gradient) at that point in the sky. In the example plot below, it can be seen that the night sky is at its darkest towards the south (170°-180° azimuth) in the area of sky rising up from the horizon up to around 60° altitude. On the other hand, there is a bright area towards the west (270° azimuth) as well as a much brighter area, centred exactly in a northerly direction but which however extends from the north west all the way to the north east. These two features are indicative of direct bright sources of light towards those directions which can then be confirmed via cross-referencing with the panoramic photos.

The brightness of the night sky in the rest of the plot lies somewhere between these two extreme values of light and dark.

It is recommended that the observations be repeated after a period of time so as to be able to measure the evolution of the state of light pollution of these sites and therefore it can be understood whether the conditions have worsened with additional lights installed or whether improvements can be quantitively measured if any corrective measures are taken.

NIGHT SKY BRIGHTNESS TABLES

Two tables are being presented with the results from the measurements undertaken at each site. The mean night sky brightness is the most important factor to bear into consideration for each site. However, high standard deviations indicate that a site is affected by bright sources of light. Standard deviation quantifies the amount of variation or dispersion for each set of brightness measurements. Such deviation is usually low as shown for the best sites.

The second table presents the data measured as an average value of all data points at a maximum of 20° elevation. This is where the impact from direct light sources is greatest and therefore the ranking of the sites will differ from that of the first table since in Table 3 the whole hemisphere of the sky is considered. A colour scale is also being provided to enable a quick visual comparison between different sites. **All Table 4 red locations require immediate attention and have their night sky compromised until urgent action is taken to eliminate sources of light pollution from these and nearby locations.**

	SD	**Night sky brightness measurements**
Best	<0.399	>20.19
Moderate	0.400 – 0.449	20.19 - 20.00
Worst	0.450 – 0.800	<20.00

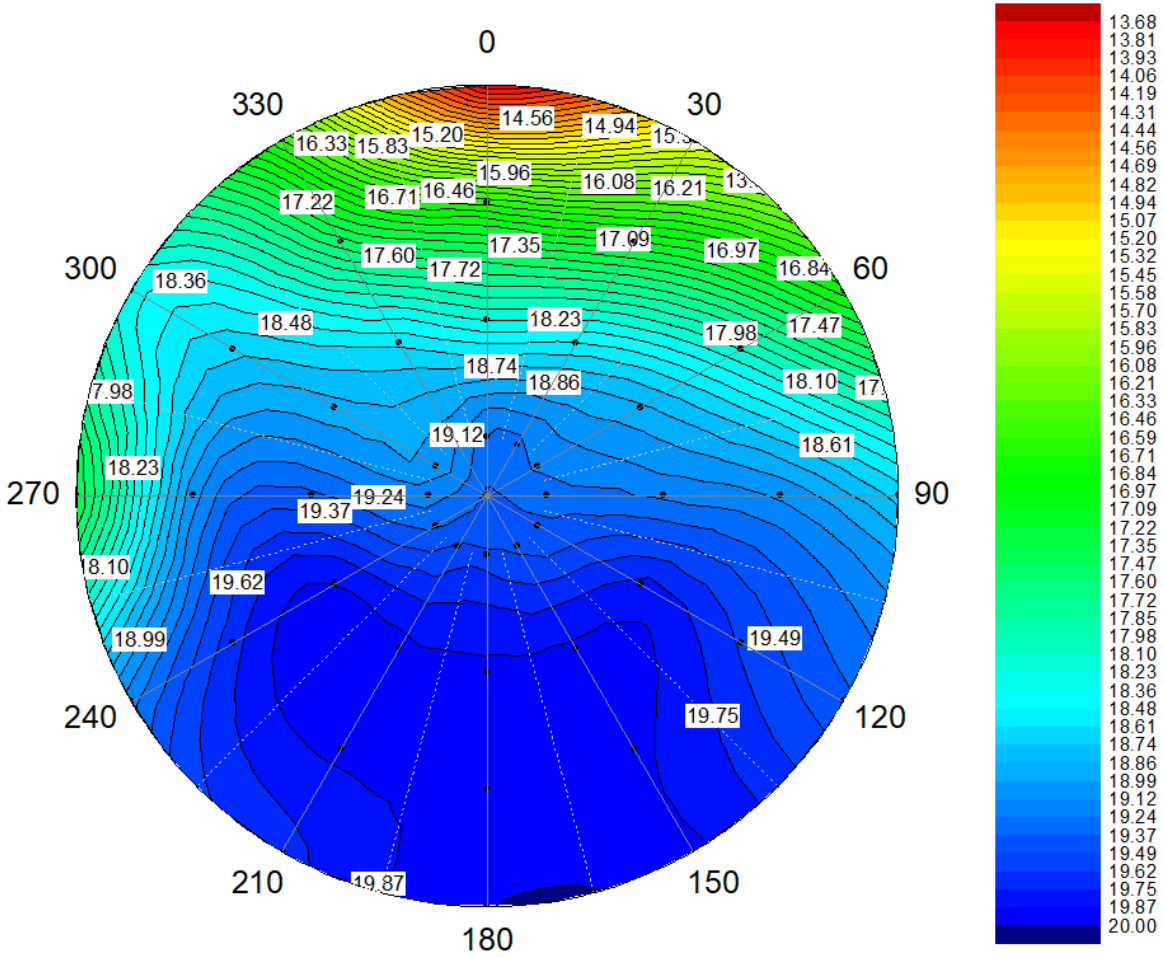


Figure 1 - A typical night sky brightness plot shows the brightness of the night sky in a false-colour representation plotted onto a 360° base to provide an all-sky image. The above example also indicates the values measured at typical representative locations as well as interpolated values. In the accompanying plots this labelling is removed for the purposes of clarity and values may be easily read via reference to the colour scale on the right-hand side.

SITE SKY QUALITY INDEX

Table 3 A sky quality index table has been calculated from the values measured at all the sites.

Site No.	Location	Brightest reading*	Faintest reading*	Mag. range	Standard deviation	Mean Intensity (MI)**	Rank [AII/SD = RNK]
1	L-Irdum tal-Madonna	19.1	20.9	1.8	0.405	20.51	50.64
2	Majjistral Park	19.2	20.9	1.7	0.421	20.49	48.66
3	Ras Il-Qammieħ	19.2	20.9	1.7	0.458	20.41	44.56
4	St. Paul's Islands - salt pans	18.5	20.5	2.0	0.450	20.07	44.60
5	Fomm Ir-Riħ	19.6	20.9	1.3	0.369	20.60	55.82
6	Miġra Ferħa	19.4	20.8	1.4	0.353	20.51	55.58
7	Il-Fawwara	19.1	20.6	1.5	0.403	20.34	50.47
8	Għar Lapsi	18.3	20.3	2.0	0.529	19.68	37.20
9	Wied Babu	13.6	20.0	6.4	1.271	18.81	14.81
10	Ħal Far	17.9	19.6	1.7	0.470	19.21	40.87
11	Santa Marija	18.7	20.7	2.0	0.515	20.23	39.28
12	Blue Lagoon	18.9	20.7	1.8	0.441	20.32	46.07
13	Ta' Ċenċ (2)	19.6	20.9	1.3	0.332	20.43	61.53
14	Ta' Ċenċ (1)	19.2	20.8	1.6	0.411	20.30	49.39
15	Sanap Cliffs	19.3	20.8	1.5	0.390	20.22	51.84
16	Ta' Sarraflu	19.2	21.1	1.9	0.433	20.44	47.20
17	San Lawrenz	19.0	21.2	2.2	0.487	20.58	42.25
18	Wied ir-Raħeb	18.9	21.0	2.1	0.472	20.51	43.45
19	Għajn Barrani – Qortin Landfill	19.3	20.8	1.5	0.423	20.33	48.06
20	Qortin ta' Isopu	17.6	20.8	3.2	0.740	20.15	27.22
	Visual scale:	Best	Moderate	Worst			

* Brightness in mag/arcsec^2

** Mean Intensity (MI) stands for the mean value of the 49 data points within each map. The higher the MI value is in mag/arcsec^2, the lesser is the light intrusion (colours for guidance).

SITE SKY QUALITY – LOW ELEVATION MEAN INTENSITY

Table 4 A low elevation mean intensity table has been calculated from the values up to 20° elevation measured at all the sites.

Site No.	SITES RANKED BY LOW ELEVATION MEAN INTENSITY	Brightest reading* mag/arcsec^2	Faintest reading* mag/arcsec^2	Mag. Range mag/arcsec^2	Standard deviation	Low elevation mean intensity *** mag/arcsec^2
1	San Lawrenz	19.0	21.2	2.2	0.737	20.43
2	Wied ir-Raħeb	18.9	21.0	2.1	0.720	20.33
3	Ta' Sarraflu	19.2	21.1	1.9	0.699	20.29
5	Fomm Ir-Riħ	19.4	20.8	1.4	0.476	20.22
4	Miġra Ferħa	19.4	20.7	1.3	0.500	20.20
6	Ta' Ċenċ (2)	19.6	20.9	1.3	0.432	20.10
7	Majjistral Park	19.2	20.9	1.7	0.561	20.08
8	L-Irdum tal-Madonna	19.1	20.8	1.7	0.504	20.08
9	Sanap Cliffs	19.3	20.8	1.5	0.605	20.04
10	Għajn Barrani – Qortin Landfill	19.2	20.8	1.6	0.601	20.02
11	Il-Fawwara	19.1	20.6	1.5	0.546	19.93
12	Ta' Ċenċ (1)	19.2	20.8	1.6	0.570	19.92
13	Blue Lagoon	18.9	20.5	1.6	0.542	19.83
14	Ras Il-Qammieħ	19.4	20.7	1.5	0.415	19.75
15	Santa Marija	18.7	20.6	1.9	0.602	19.63
16	St. Paul's Islands - salt pans	18.5	20.4	1.9	0.590	19.63
17	Qortin ta' Isopu	17.6	20.8	3.2	1.053	19.53
18	Għar Lapsi	18.3	20.3	2.0	0.788	19.31
19	Ħal Far	17.9	19.7	1.8	0.682	18.81
20	Wied Babu	15.4	20.0	6.4	1.909	17.93
	Visual scale:	Best	Moderate	Worst		

* Brightness in mag/arcsec^2. The higher the value is in mag/arcsec^2, the lesser is the light intrusion (colours for guidance).

*** Low elevation mean intensity refers to the average value of all data points at a maximum of 20° elevation where the impact from direct light sources is greatest.

SITE NR. 1
LOCATION: RDUM TAL-MADONNA – L-AĦRAX, l/o MELLIEĦA, MALTA.
Geographic coordinates: Lat 35.9904°N Lon 14.3735°E

SITE LOCATION

Figure 1.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

L-Irdum tal-Madonna is the main Yelkouan Shearwater colony in the Maltese Islands with an estimation of 500 pairs (Sultana et al. 2011) and there is also a colony of Scopoli's Shearwaters of 10 to 20 pairs (Barbara et al. 2015). Furthermore, since 2014 European Storm-petrels have started to nest in small numbers (Barbara et al. 2015).

SOURCES OF LIGHT POLLUTION

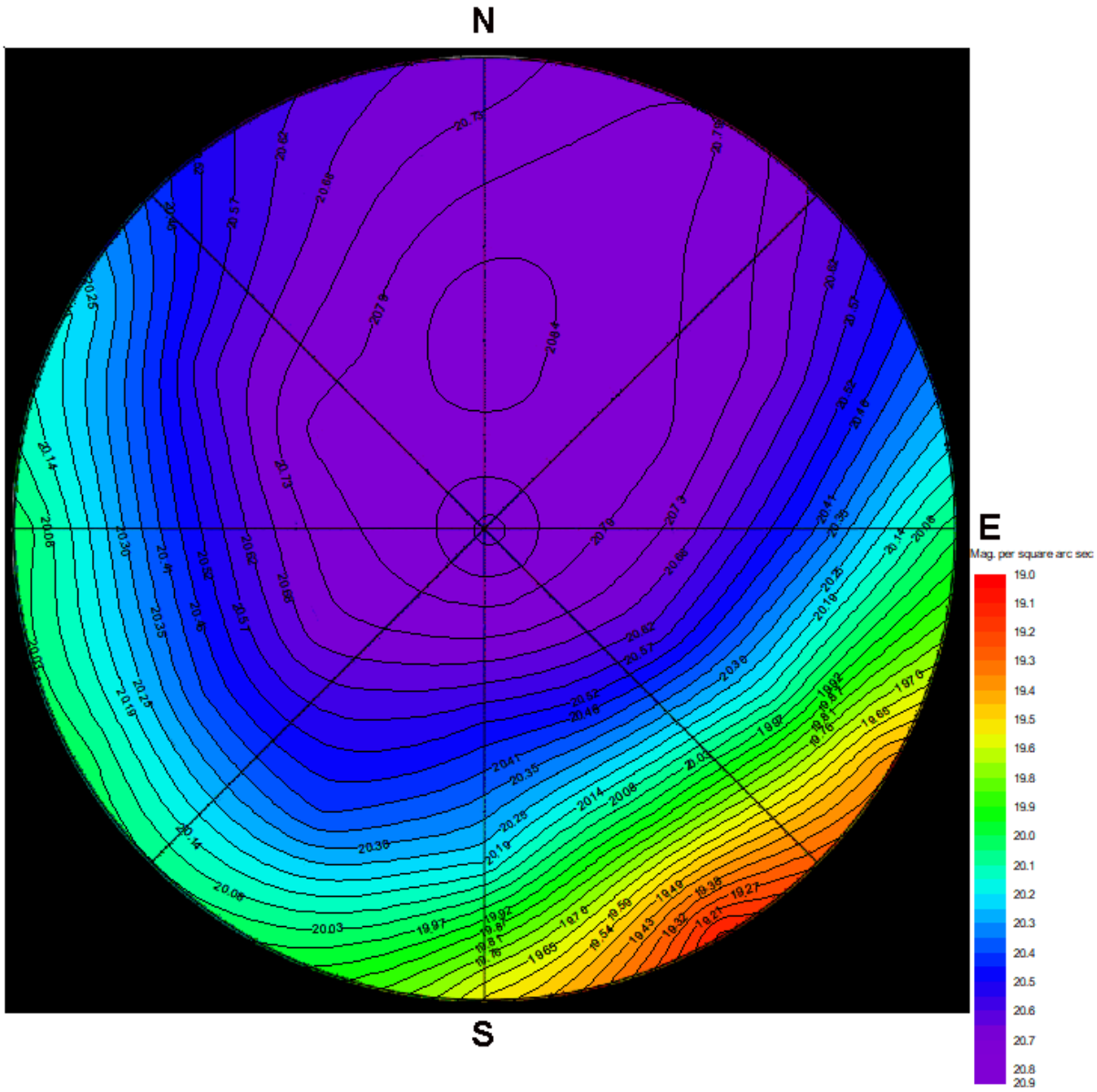


Figure 1.2 All-sky brightness contour plot.

The site at l-Irdum tal-Madonna, limits of l-Aħrax tal-Mellieħa is located at the extreme north eastern coast of Malta. The site overlooks open sea with Comino and Gozo towards the north-west and the rest of mainland Malta spanning from the west down to the south and up to the south-east.

The night sky brightness plot for this location indicates a dark area which starts overhead at the zenith and extends towards the north towards azimuth 20° (north-north-east). The greatest contribution to the sky brightness however is evident towards the south-east in the direction of Buġibba. In this area the brightness goes up to 19 mag/arcsec^2.

SUGGESTED MITIGATION MEASURES

Direct light sources from commercial activities along Buġibba promenade (ie. beyond Mellieħa bay) were identified on the mainland. Maritime bunkering activities from a number of ships noted out at sea towards the north-east (in the direction of Sikka l-Bajda) also created direct line-of-sight sources. These are visible in the panoramic images. Shipping vessels are to follow the regulations issued by Transport Malta with respect to their illumination.

Efforts should be made with Government, local councils and responsible entities for a policy on exterior lighting to be implemented at Għadira Bay and onwards to Buġibba promenade. Such policy, whilst not hampering any business activities will ensure that only proper lighting is designed and installed so as to mitigate any adverse effects and avoid direct sources of light from being visible at Irdum tal-Madonna.

Figure 1.3

SITE NR. 2
LOCATION: MAJJISTRAL PARK
Geographic coordinates: Lat 35.9554°N Lon 14.3392°E

SITE LOCATION

Figure 2.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

At Majjistral Park, south of Anchor Bay to Rdum il-Majjiesa, there is a large colony of Yelkouan Shearwaters with an estimation of 150 to 250 pairs (Barbara et al. 2015), while a smaller colony is situated in iċ-Ċumnija with at least 30 pairs estimated in 2017. No Scopoli's Shearwaters or European Storm-petrels are known to nest in this area.

SOURCES OF LIGHT POLLUTION

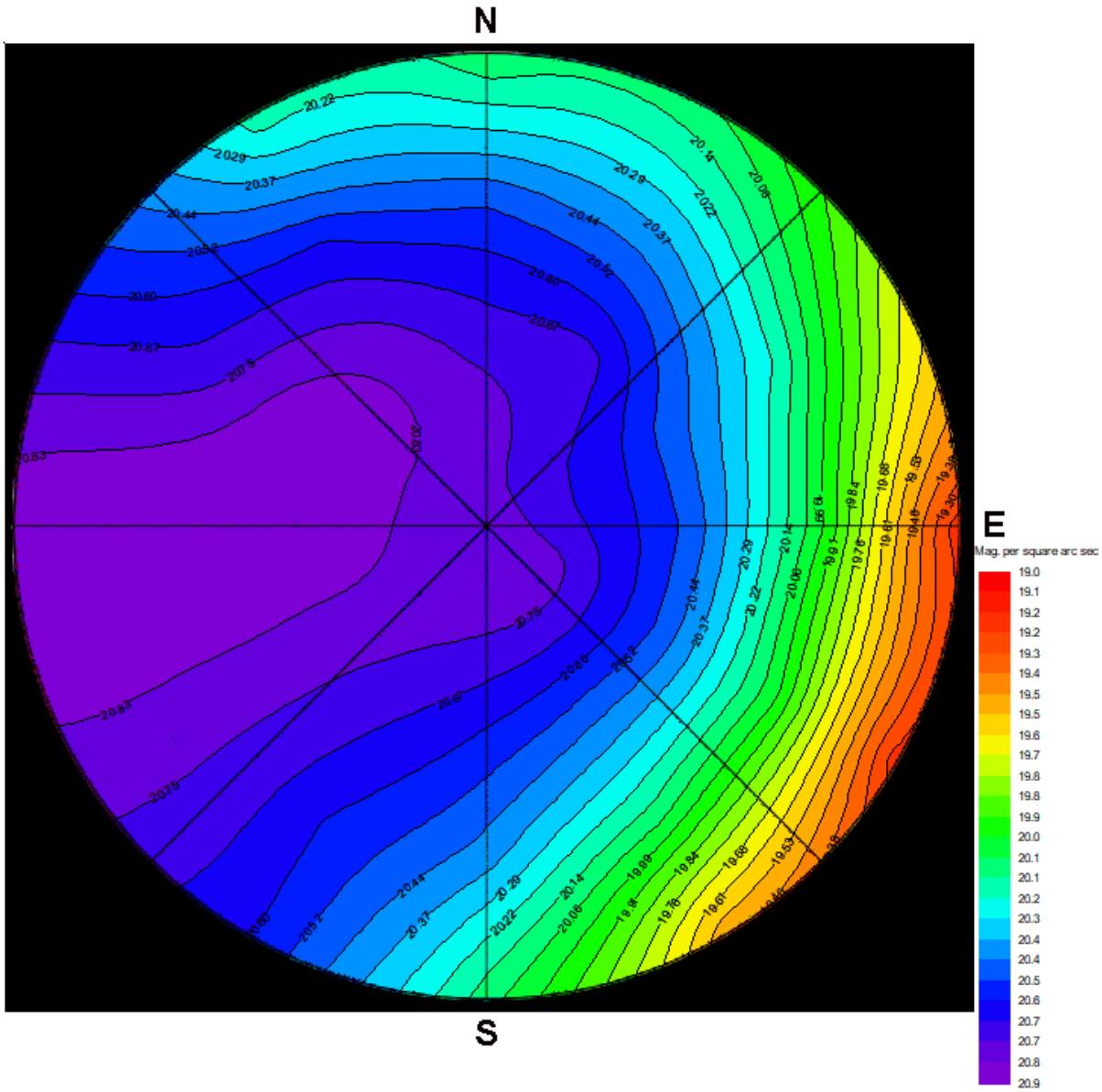


Figure 2.2 All-sky brightness contour plot.

The site at Majjistral Park (close to Anchor Bay) is characterised by a large expanse of garigue land forming part of the said park. The closest development is Popeye Village a few hundred metres away from the site being considered.

The night sky is affected by skyglow emanating from mainland Malta towards the east and east-south-east at azimuths 90° to 135°. Moreover towards the north west the site receives direct glare from a military installation at Ras il-Qammieħ. This lighting has increased the brightness of the night sky as shown on the accompanying plot when considering the measurements towards this direction.

The area out at sea towards the westerly side is mostly dark. No ships/bunkering activities were observed during the measurement periods.

SUGGESTED MITIGATION MEASURES

The photographic images show the impact of the exterior illumination to the buildings at Ras il-Qammieħ towards the north. This is a prime example of badly-designed illumination which is creating glare and skyglow visible from several kilometres away. This should be rectified immediately with all non-essential lighting switched off completely and any essential lighting reduced to the bare minimum levels required for safe operations – as determined by international illumination engineering standards.

All direct sources of light should be addressed for either:

a) Complete decommissioning and switching off if it consists of non-essential illumination in such environmentally-sensitive areas or,
b) Conversion or replacement of the fittings to full cut-off and replacement of the light fittings where necessary with others having a correlated colour temperature (CCT) of not more than 3000K.

The remaining skyglow is caused by badly-designed exterior lighting in mainland Malta therefore it would require a holistic exterior illumination policy to be able to leave a tangible effect if any action is to be undertaken.

Figure 2.3

SITE NR. 3
LOCATION: RAS IL-QAMMIEĦ (MALTA)
Geographic coordinates: Lat 35.9762°N Lon 14.3264°E

SITE LOCATION

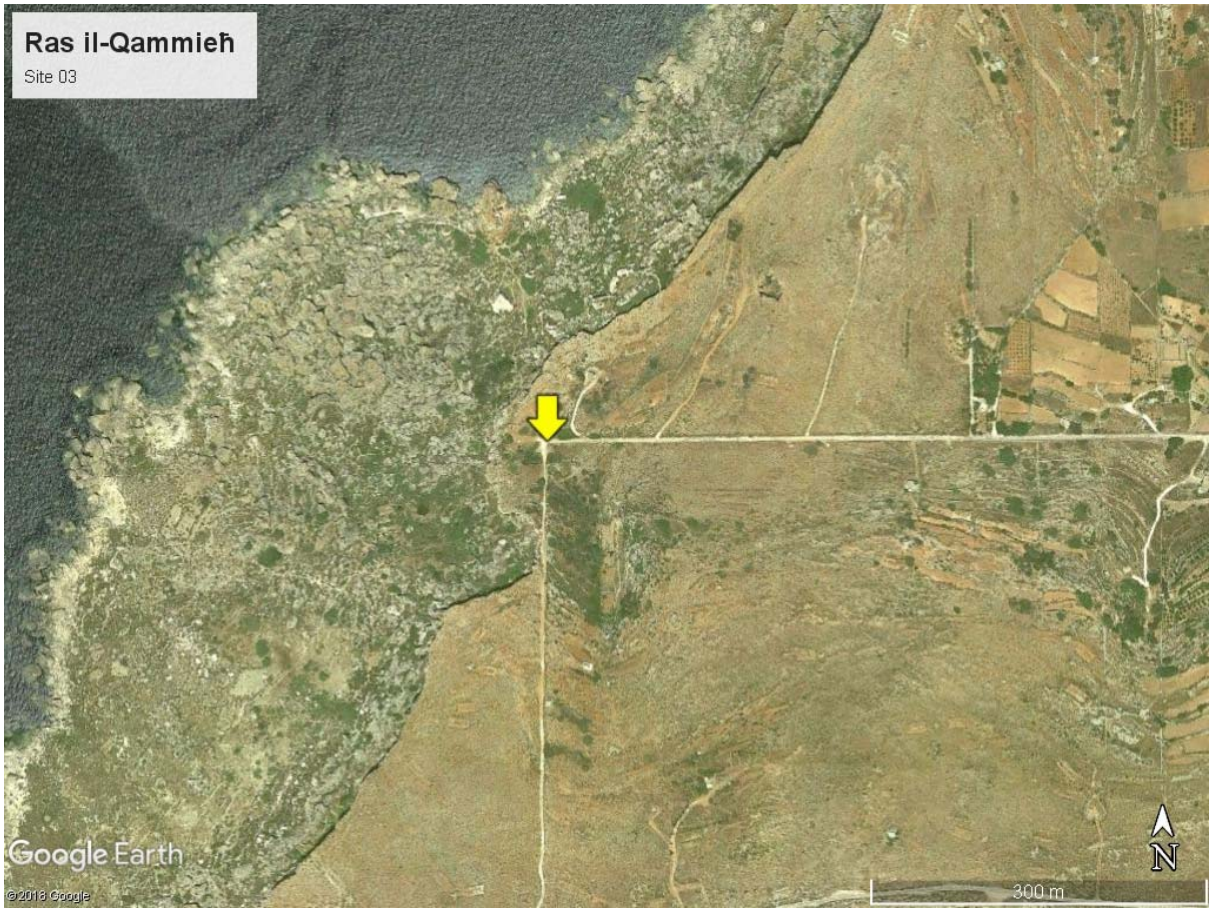


Figure 3.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

While no current nesting of seabirds is known at Ras il-Qammieħ, light pollution from the nearby Ċirkewwa ferry terminal affects several Yelkouan Shearwater colonies around the Gozo channel. These include: Rdum tal-Madonna (500 pairs); Cominotto (30 – 60 pairs); Comino (50 – 80 pairs); and Ta' Ċenċ (150 – 300 pairs) (Barbara et al. 2015).

SOURCES OF LIGHT POLLUTION

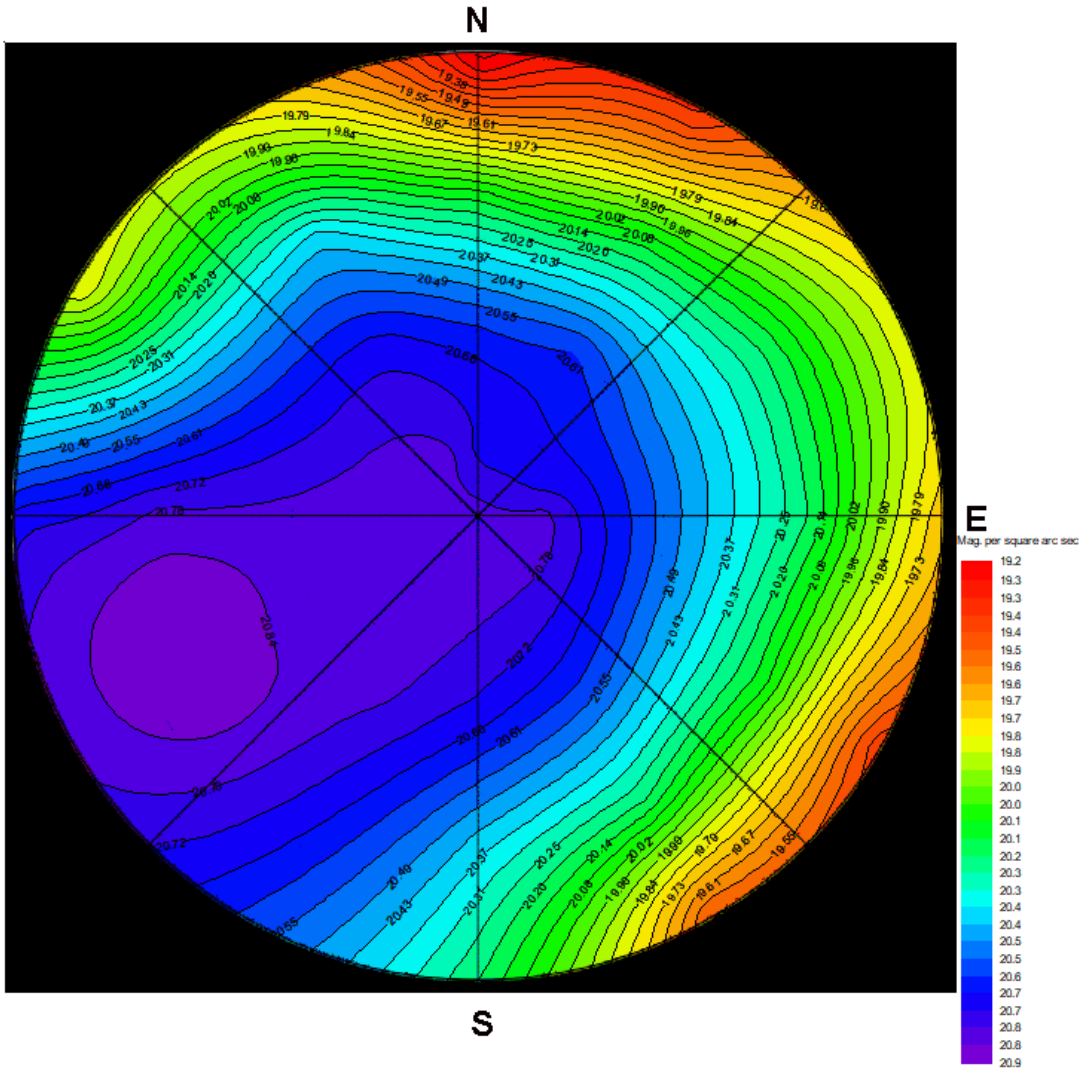


Figure 3.2 All-sky brightness contour plot.

The light pollution map of this area clearly identifies the main sources of light pollution. The main source of pollution to the north of this location is the intense light coming from the Ċirkewwa Sea Terminal. The area here is floodlit using a combination of metal halide and LED floodlights. The night sky brightness of the northern part of the sky amounts to 19.2 mag/arcsec^2 (000° az - 20° alt) and is equivalent to ten times the intensity of natural night sky from an unpolluted location.

The map also shows that the skyglow extends from the north-east direction westwards to azimuth 300° (approx WNW). This is mainly attributed to the skyglow coming from the Ċirkewwa Terminal along with other light pollution sources in Gozo. The sky glow cut-off at 300° azimuth coincides with the outermost coastal areas of Gozo visible from Ras il-Qammieħ.

The light pollution intensity diminishes when moving eastwards along the horizon in azimuth (at 65°) as this area coincides with the direction of Irdum tal-Madonna where light pollution

sources are not so intense. Once this azimuth bearing is exceeded, light pollution intensity increases again, this time coming from the developed areas of Mellieħa and Buġibba, towards the direction of the south east.

Light pollution is the least prevalent at 245° degrees azimuth (WSW) as this area does not have any inland light sources on the short stretch of land before reaching the coast. At the time sky measurements were taken, there were no sources of light pollution from ships (no bunkering activity). The highest (i.e. darkest) reading from this site has been recorded as 20.8 mag/arcsec^2. This is equivalent to twice the natural background brightness as seen from an unpolluted site.

SUGGESTED MITIGATION MEASURES

In order to mitigate the current situation it is necessary to control the sources of light causing most light pollution. Currently these would be those towards the north of the site i.e. the Gozo Terminal exterior lighting installation. Discussions should be entered into with the ferry terminal operators so as to be able to measure and propose tailored solutions to eliminate the problem at source.

Figure 3.3

SITE NR. 4
LOCATION: ST. PAUL'S ISLANDS SALT PANS (MISTRA)
Geographic coordinates: Lat 35.9637°N Lon 14.3970°E

SITE LOCATION

Figure 4.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

St. Paul's Islands hold a Yelkouan Shearwater colony of 30 to 60 pairs (Barbara et al. 2015), while no other seabird species have been confirmed to nest on these islets.

SOURCES OF LIGHT POLLUTION

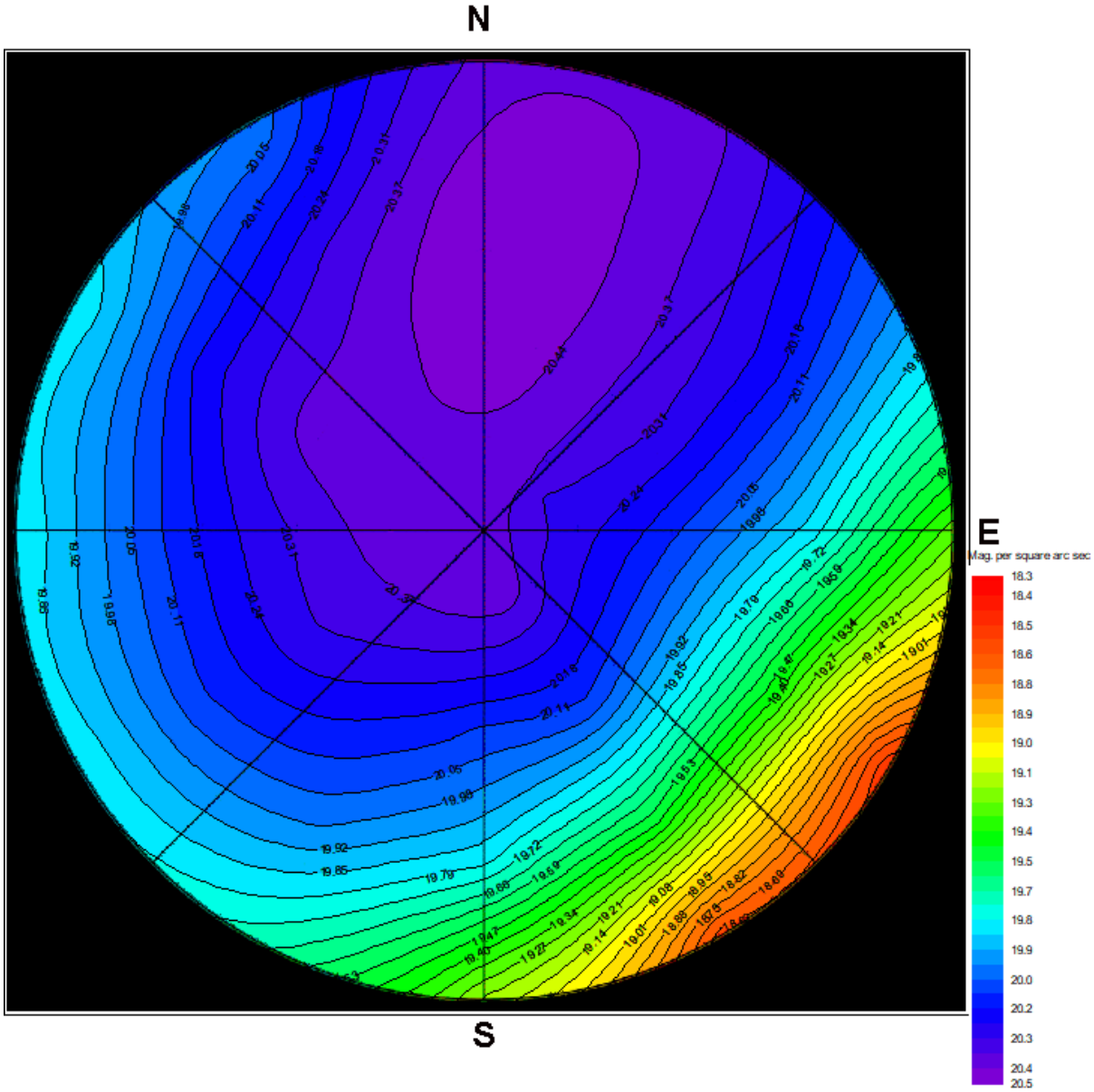


Figure 4.2 All-sky brightness contour plot

These salt pans are in the vicinity of the densely-populated area of Buġibba. The numerous commercial outlets in the area are a strong source of light pollution. Buġibba is situated to the south-east of these salt pans and from the light pollution map one can notice that the darkness of the night sky went down to as much as 18.5 mag/arcsec^2. This means that the sky at altitude 20° degrees and azimuth 120° degrees is twenty times brighter than the sky brightness at natural levels.

As the Mistra location is situated on a peninsula, landward directions up to azimuth 310° degrees exhibit additional far away light pollution sources that are spread across the area.

Due to the low development intensity towards the l-Aħrax tal-Mellieħa area, light pollution levels diminish northwards from azimuth 310° degrees. The direction towards the sea range eastwards from azimuth 338° up to azimuth 100°. As expected, the light pollution intensity over this region is the darkest, with levels of 20.5 mag/arcsec^2 which is equivalent to three times brighter than natural dark-sky levels. The surrounding landward sources of light pollution have offset the darkest area of the night sky northwards towards the sea.

SUGGESTED MITIGATION MEASURES

Sources of light pollution affecting this site are numerous and far away. Suppression of just a few sources may have a measureable effect, but the net effect will be nil since there are so many sources.

In this case a holistic approach needs to be taken with Government for a complete redesign of the exterior lighting along the Buġibba promenade and the enactment of a proper shopfront design policy with stricter controls than those provided through the Planning Authority's DC 2015.

Figure 4.3

SITE NR. 5
LOCATION: FOMM IR-RIĦ
Geographic coordinates: Lat 35.9057°N Lon 14.3392°E

SITE LOCATION

Figure 5.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

Yelkouan Shearwaters have not been confirmed to nest around Fomm ir-Riħ but around 250 pairs of Scopoli's Shearwater breed south of the headland (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

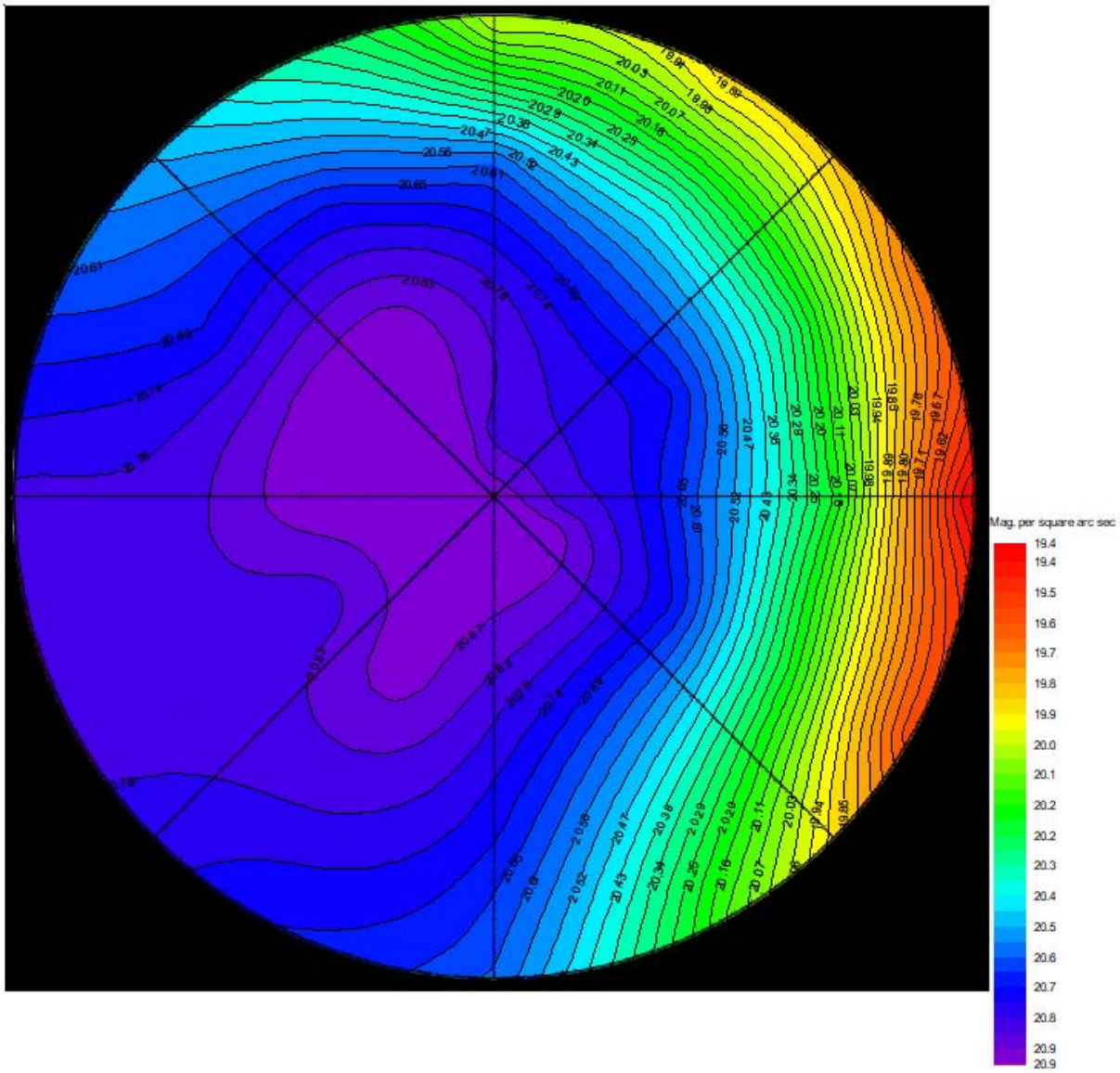


Figure 5.2 All-sky brightness contour plot.

Despite the fact that this light pollution map shows the site as being a moderately light-polluted site, it is in fact the least polluted site on the Maltese mainland. One can immediately notice the large percentage of high-value measurements, signifying darker skies.

The brightest area of the sky, eastwards from the site, measured at 19.4 mag/arcsec^2, which makes it seven times as bright as the natural sky. The source of this brightness is the skyglow emanating from the central mainland of Malta that corresponds to high-density areas such as Mosta, and in the same direction, the St. Julian's and Sliema areas.

In the north-east direction, across from the cliffs are some nearby streetlights which have added to the light pollution.

This site is the darkest recorded by this study over the Maltese mainland as over this area the sky could get as dark as 20.9 mag/arcsec^2 equivalent to just two times brighter than the natural dark sky.

This area should be kept as free from light pollution as possible because few sites have such good characteristics and are so close to the natural night sky background.

SUGGESTED MITIGATION MEASURES

Given the remoteness of the site and considering the fact that during night-time there would be practically zero traffic, the authors strongly recommend that in order to safeguard the pristine nature of the night skies in this location all streetlighting along the roads leading up to this site be decommissioned and removed. Use of steel road barriers and retro-reflective road signs should be made so as to delineate the edge of the road.

The lesser-preferred alternative would be that the existing road lighting within the direct line-of-sight of the site in question be totally replaced with shielded, full cut-off fittings, installed horizontally-level and using lamp fixtures with a CCT <3000K. This would cut down significantly on the glare and ill-effects of light pollution which currently affects the site.

05 - FOMM IR-RIH

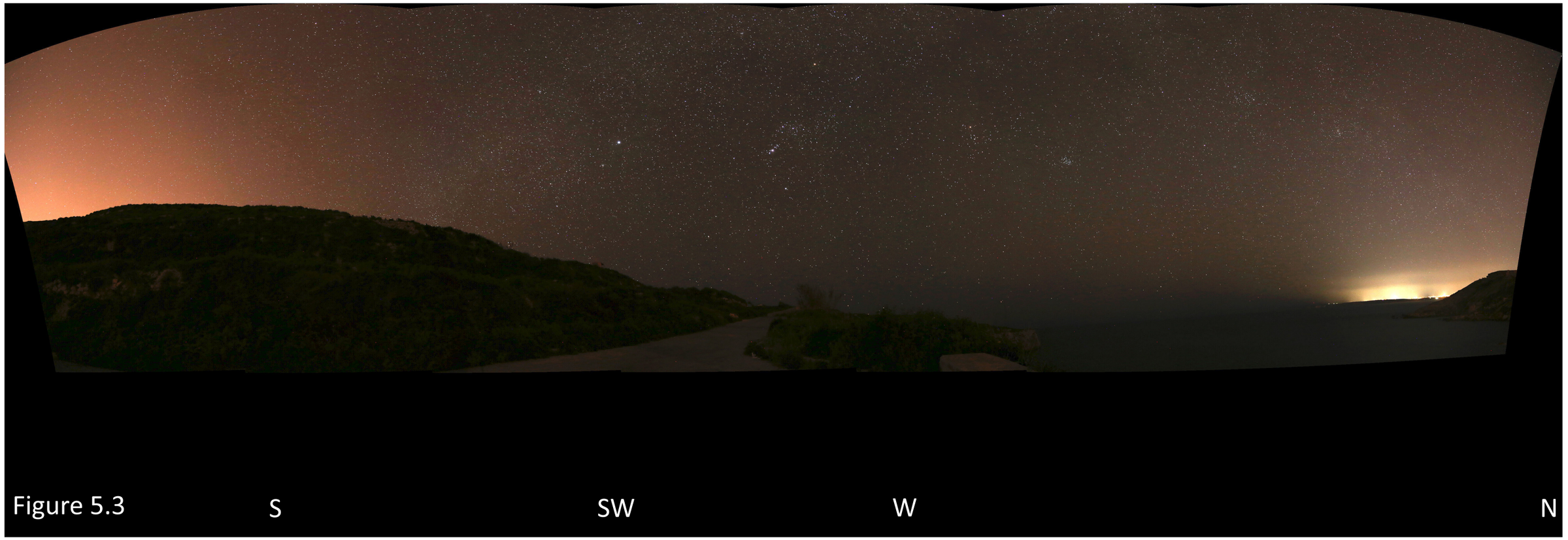


Figure 5.3

SITE NR. 6
LOCATION: MIĠRA FERĦA
Geographic coordinates: Lat 35.8746°N Lon 14.3420°E

SITE LOCATION

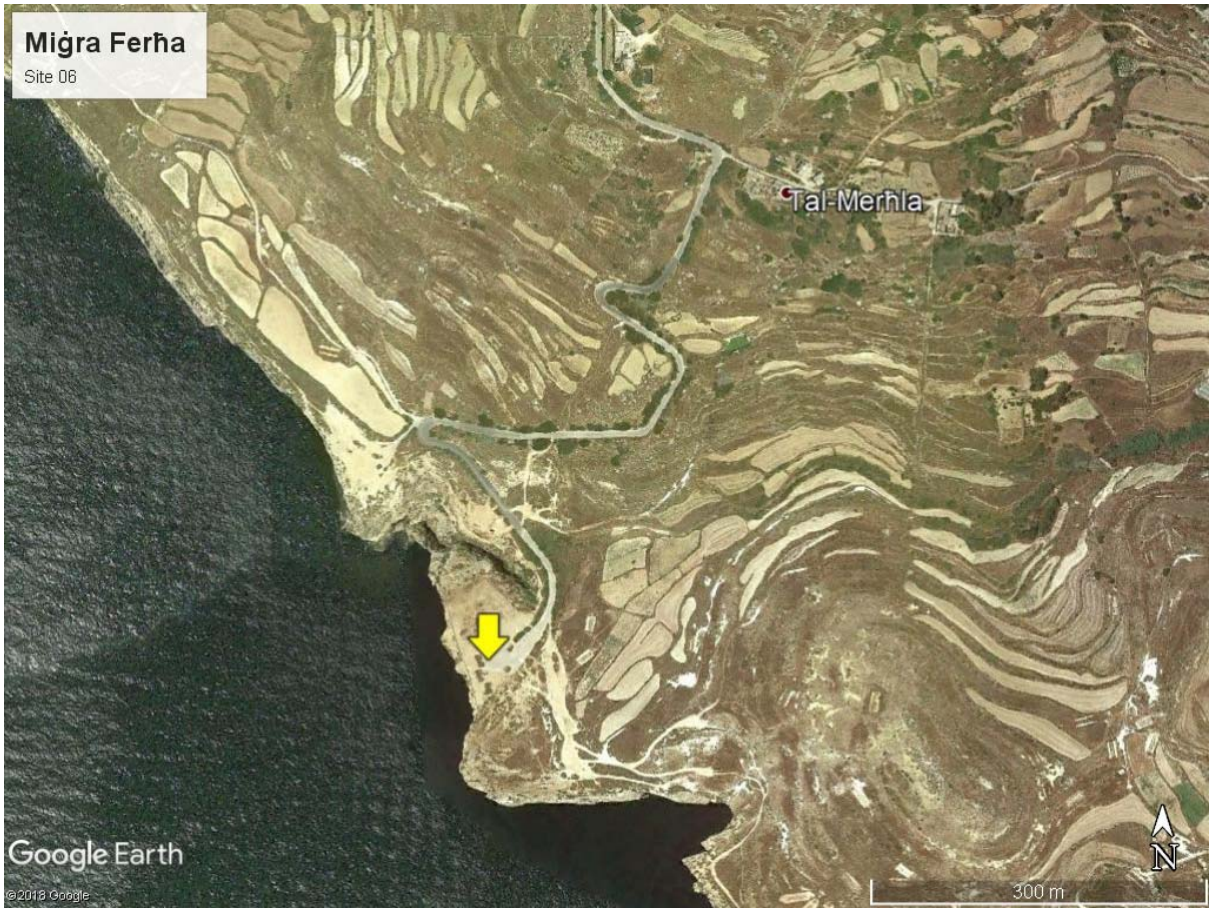


Figure 6.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

Yelkouan Shearwaters were confirmed to nest in small numbers at Miġra Ferħa in 2017, while an estimated 250 Scopoli's Shearwaters breed in the area (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

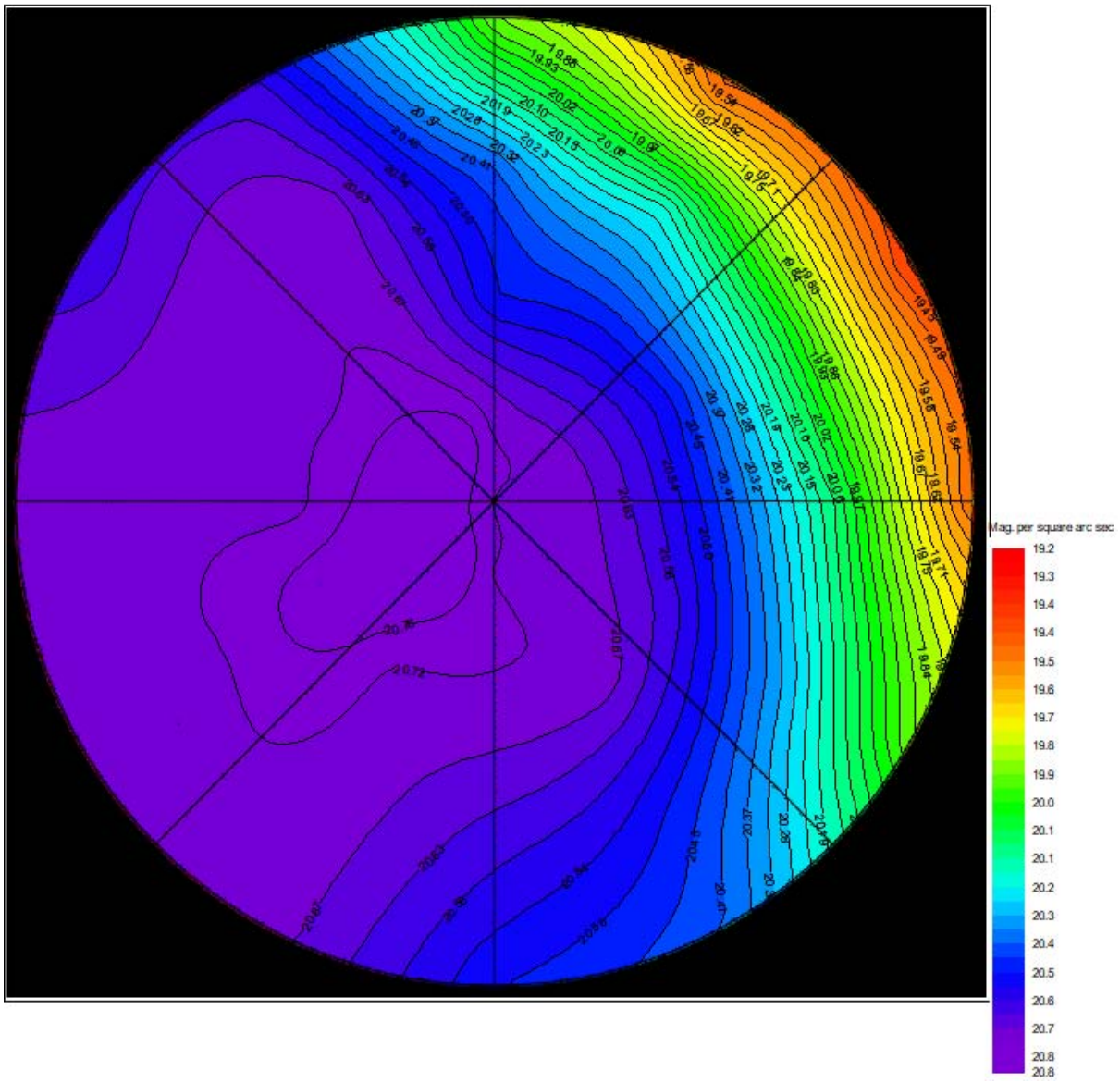


Figure 6.2 All-sky brightness contour plot.

Miġra Ferħa is one of the darkest sites on the Maltese Islands. This is due to its location away from densely-developed cities in the rest of mainland Malta.

The nearest site that is a source of light pollution is the Young Persons Offenders Unit, (YOURS), situated about 1.6km away towards the north-east. This building is not directly visible from the site however due a large number of floodlights that are aimed skywards their effect can be observed on the site as a whole. The amount of skyglow would diminish substantially if the current fixtures are substituted with full cut-off ones that utilise the right intensity to do the job adequately. As a matter of fact, the light fixtures installed as of the date of the measurements in this location (February 2017) are extremely bright and installed

incorrectly such that they emit most of their light output outwards and onto the surrounding land (light trespass) and it is highly likely that as a result the wildlife in the vicinity is adversely affected.

According to the reading from this sky quality plot, the brightness of the night sky towards the direction of the correctional facility was measured at 19.4 mag/arcsec^2 at azimuth 60°. This brightness corresponds to eight times brighter than the natural dark sky.

Another minor source of brightness can be observed towards the direction of Baħrija at 19.5 mag/arcsec^2. The light pollution due to the skyglow to the east corresponds to the light sources mainly situated at Mosta and to some degree Rabat i.e. large, densely-populated towns.

Despite the fact that the above mentioned sources are of concern, this site still remains one of the darkest on the Maltese mainland. In fact the darkest area (at mag/arcsec^2) is just nearly two times brighter than the natural night sky brightness at 20.8 mag/arcsec^2.

SUGGESTED MITIGATION MEASURES

In order to improve the overall situation over this location it is recommended that the light sources at the Young Persons Offenders Unit be replaced with full cut-off fittings, designed to illuminate at the minimum recommended lux levels and having a CCT<3000K. Similar requirements are also found in the development planning application which concerns this detention centre as approved by the Planning Authority under PA 2326/14.

Figure 6.3

SITE NR. 7
LOCATION: IL-FAWWARA
Geographic coordinates: Lat 35.8421°N Lon 14.3989°E

SITE LOCATION

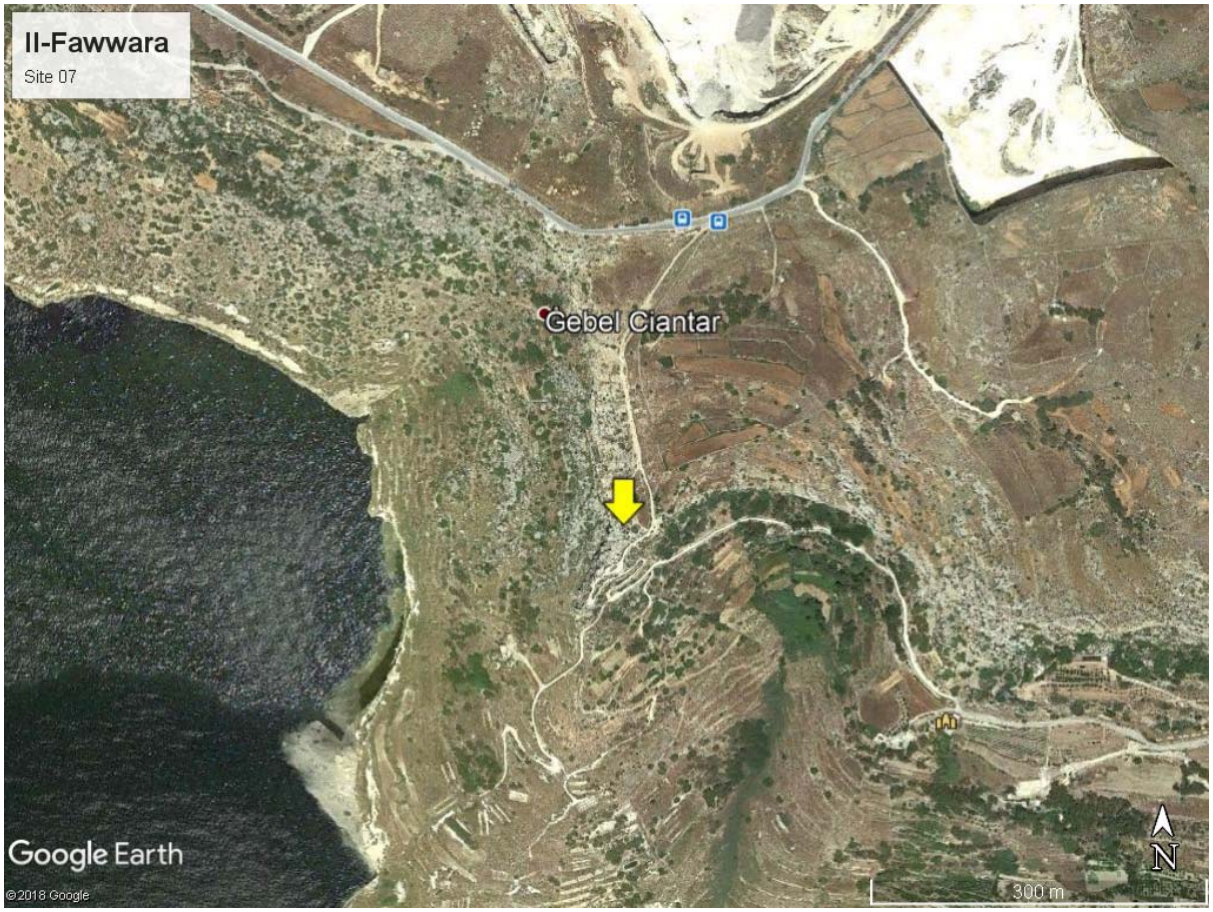


Figure 7.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

An estimated 100 to 200 pairs of Yelkouan Shearwaters breed in the cliffs at Dingli to Fawwara, as well as around 300 pairs of Scopoli's Shearwaters (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

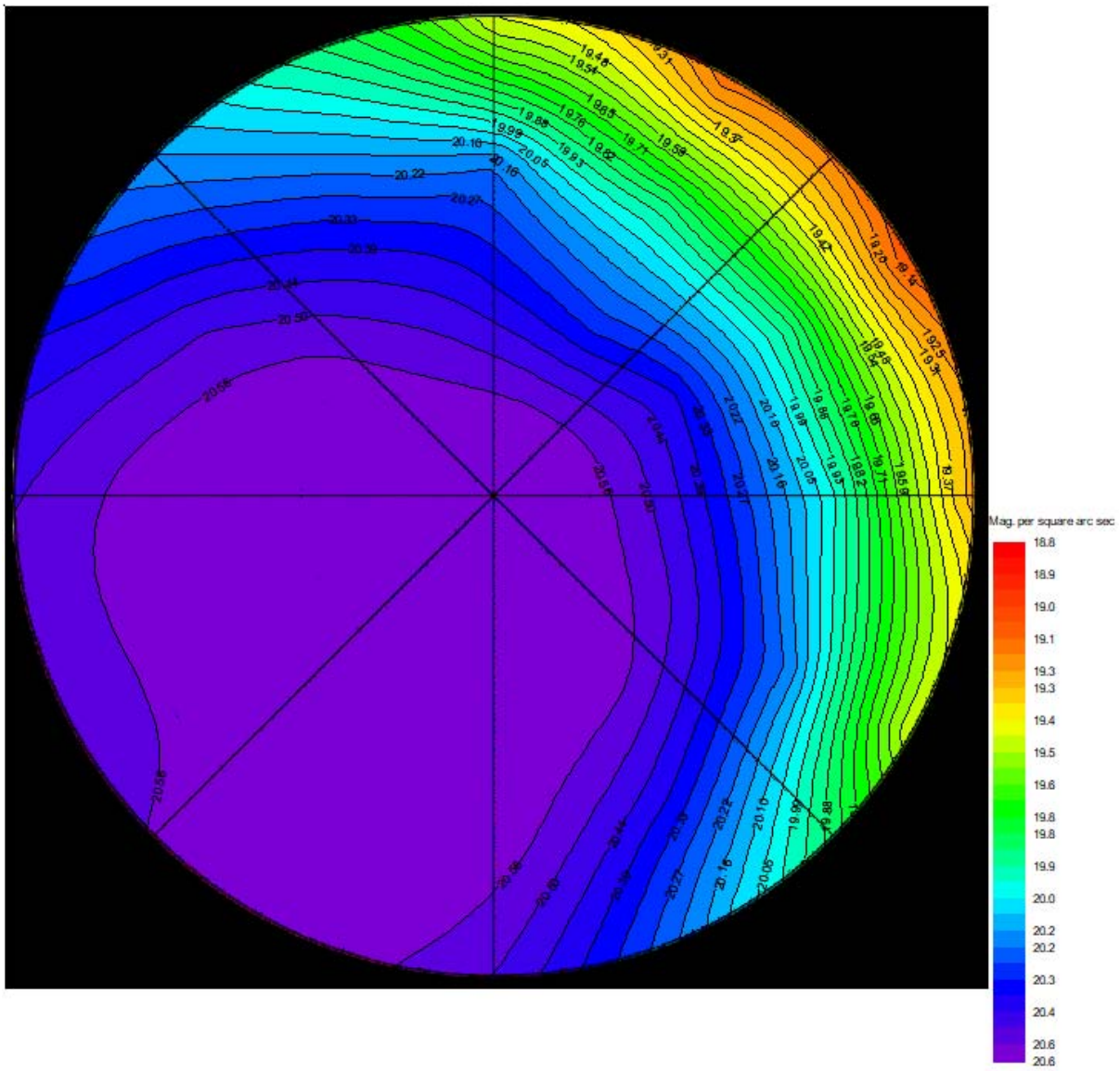


Figure 7.2 All-sky brightness contour plot.

Light pollution is not so severe at this site as the nearest source of light pollution is the Għar Lapsi Reverse Osmosis Plant. This is located about 2km away and is hidden from a direct line of sight due to the topography of the land in between both sites. However the light which we can observe is directed towards the sky with the consequence that the night sky brightness is higher in this direction. The Reverse Osmosis plant lies at azimuth 120° (east-south-east). Skyglow in this site extends from the north towards the south-east.

This light pollution map also reveals that the brightest source from this site is at azimuth 60° (east-north-east) and this coincides with the town of Siġġiewi. In this direction the sky is eleven times brighter than the natural night sky background.

Another source of light pollution is situated at around 30° azimuth (north-north-east) and coincides with the areas of Mosta and Attard with an additional possible contamination from the National Stadium at Ta' Qali whenever the floodlighting installation is in operation.

Seawards, the sky is relatively dark at a night sky brightness of 20.6 mag/arcsec^2 which is equivalent to being only three times brighter than the natural brightness of the night sky.

SUGGESTED MITIGATION MEASURES

It is recommended that the lighting on the Radome installation at Dingli Cliffs (towards the west-north-west) be reduced to the minimum requirements following ICAO standards. The bright white uplighting of the dome should be removed completely.

Another installation to tackle would be the Għar Lapsi reverse osmosis plant. All exterior lights should be replaced with full cut-off fittings installed horizontally-level and having a CCT<3000K.

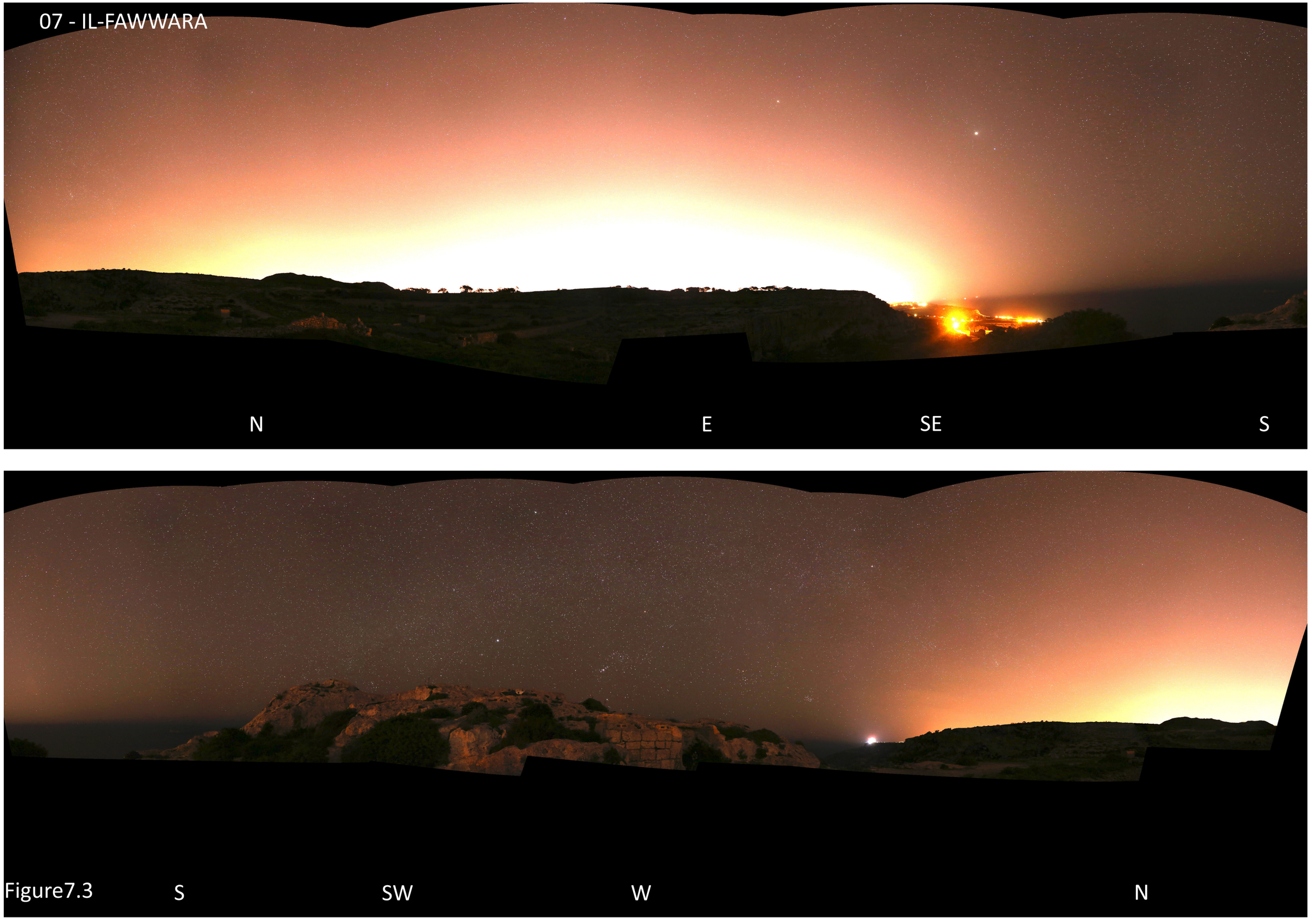


Figure7.3

SITE NR. 8
LOCATION: GĦAR LAPSI
Geographic coordinates: Lat 35.8319°N Lon 14.4152°E

SITE LOCATION

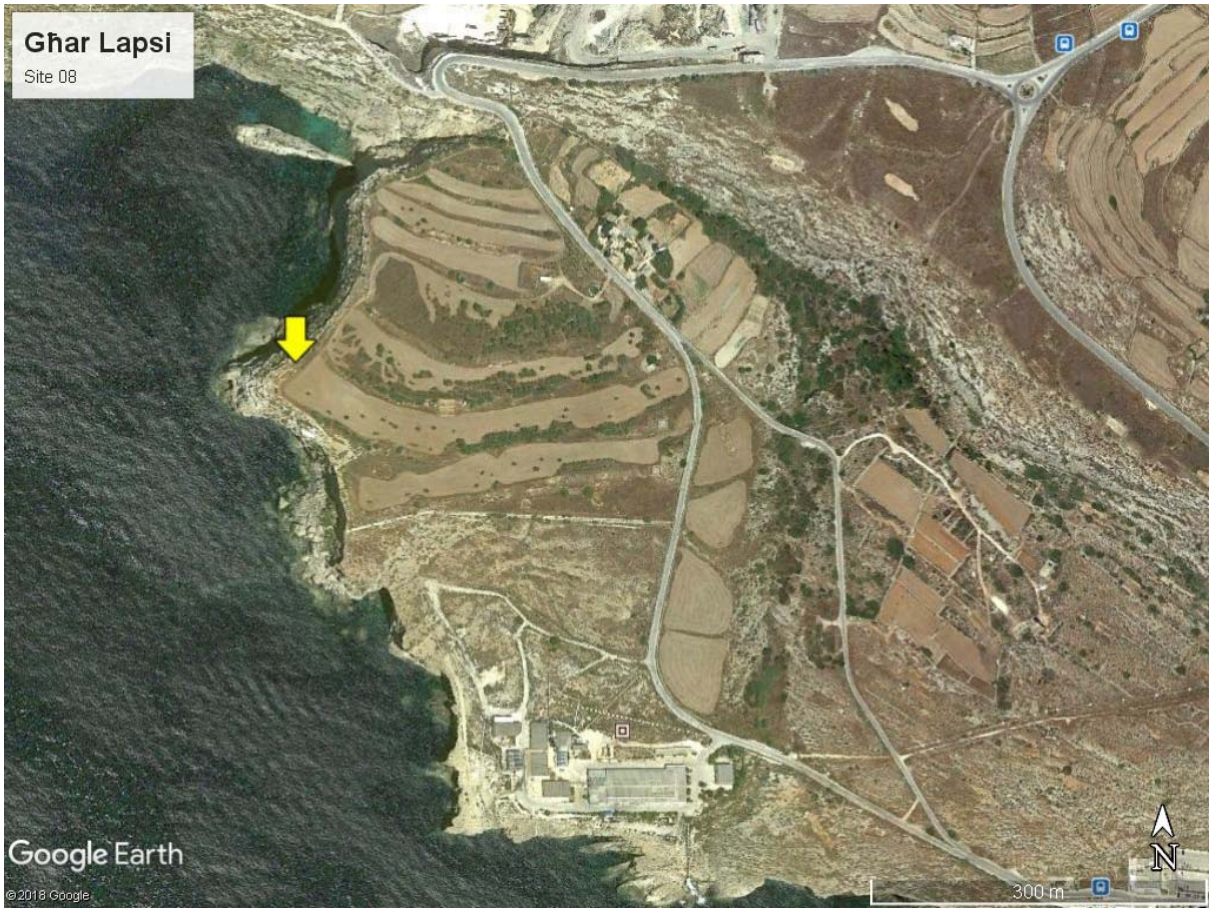


Figure 8.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

The cliffs around Għar Lapsi (ix-Xaqqa) used to hold breeding Yelkouan Shearwaters, estimated at 80 to 100 pairs (Sultana et al. 2011), but nesting has not been documented in recent years. Two hundred pairs of Scopoli's Shearwater are estimated to breed, while European Storm-Petrel seem to prospect the area due to the proximity to Filfla (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

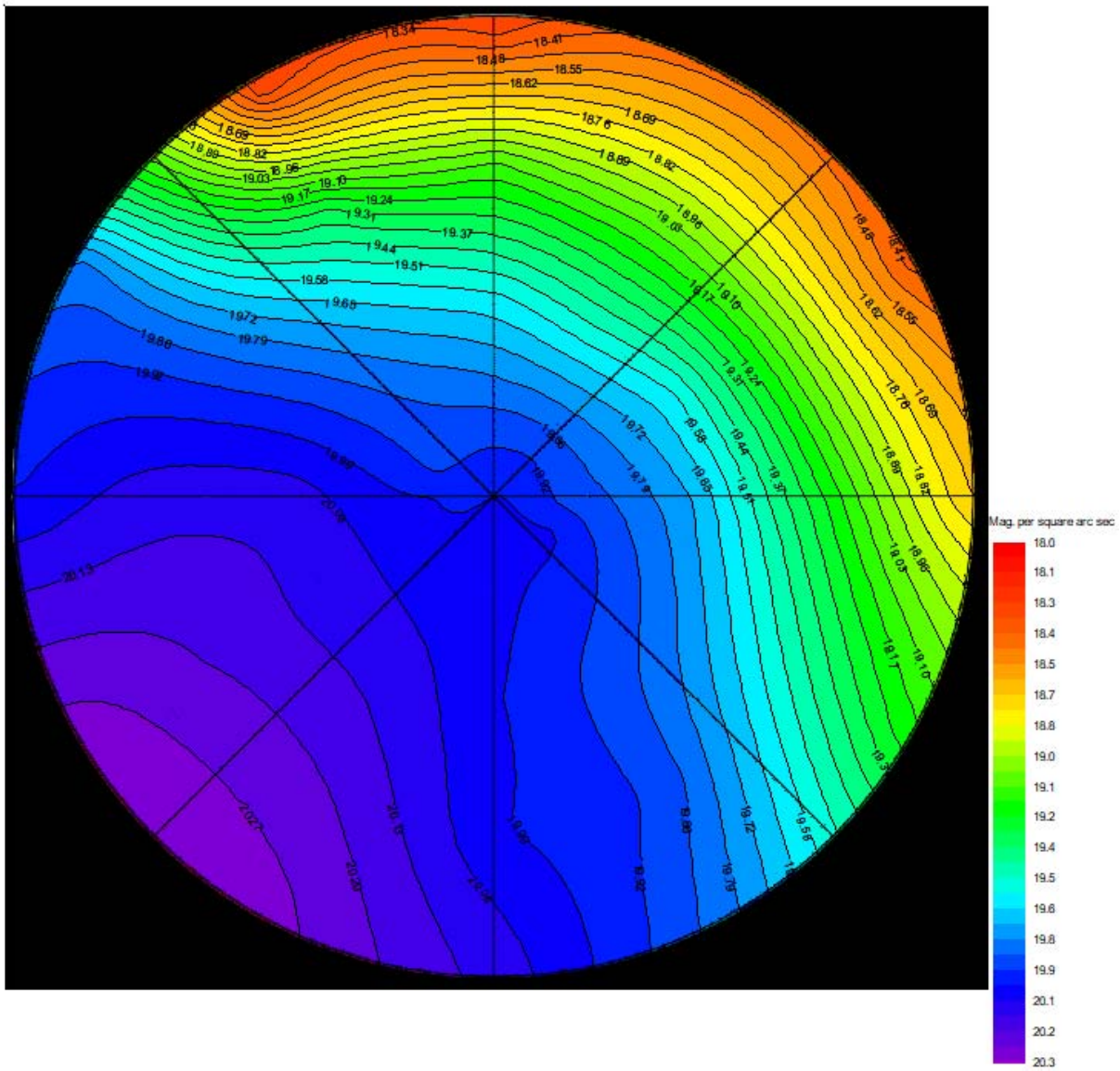


Figure 8.1 All-sky brightness contour plot.

The light pollution map clearly indicates that this site is affected to some degree by light pollution despite it being situated some distance away from the built-up areas of Siġġiewi and Qrendi. The sky darkness at the site beyond 20.0 mag/arcsec^2 barely exceeds one third of the sky. This is mainly due to the skyglow emanating from Rabat at azimuth 330° (north-north-west) and Siġġiewi at azimuth 60° (east-north-east). The brightest part of the night sky lies in the direction of Rabat at 18.32 mag/arcsec^2 that is equivalent to twenty times brighter than that of the natural dark sky. The reverse osmosis plant is an eyesore in this area and creates a lot of light pollution.

The sources mentioned have skewed the appearance of the night sky above this site by shifting the natural darkest part of the sky towards the sea to azimuth 225° (south-west). The

darkest area of the night sky was recorded as 20.3 mag/arcsec^2 at azimuth 240° (west-south-west).

SUGGESTED MITIGATION MEASURES

There is not much one can do when skyglow is concerned as this is the result of light pollution from distant towns and cities. Unless there is a holistic exterior lighting policy to regulate future development there is not much improvement which can be expected.

On the other hand the reverse osmosis installation has much room for improvement and as already suggested all exterior lighting should be replaced with full cut-off fittings having a CCT<3000K.

08 - GHAR LAPSI

Figure 8.3

SITE NR. 9
LOCATION: WIED BABU NEAR BLUE GROTTO l/o ŻURRIEQ, MALTA.
Geographic coordinates: Lat 35.8213°N Lon 14.4561°E

SITE LOCATION

Figure 9.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

One hundred to one hundred-fifty pairs of Yelkouan Shearwater are estimated to nest in the cliffs north of Wied iż-Żurrieq to Bengħisa (Sultana, Borg et al. 2011) and in 2017 a cave with over ten pairs of nesting Yelkouan Shearwaters was discovered in Wied Babu. Scopoli's Shearwaters also breed in the area (<100 pairs) (Sultana, Borg et al. 2011).

SOURCES OF LIGHT POLLUTION

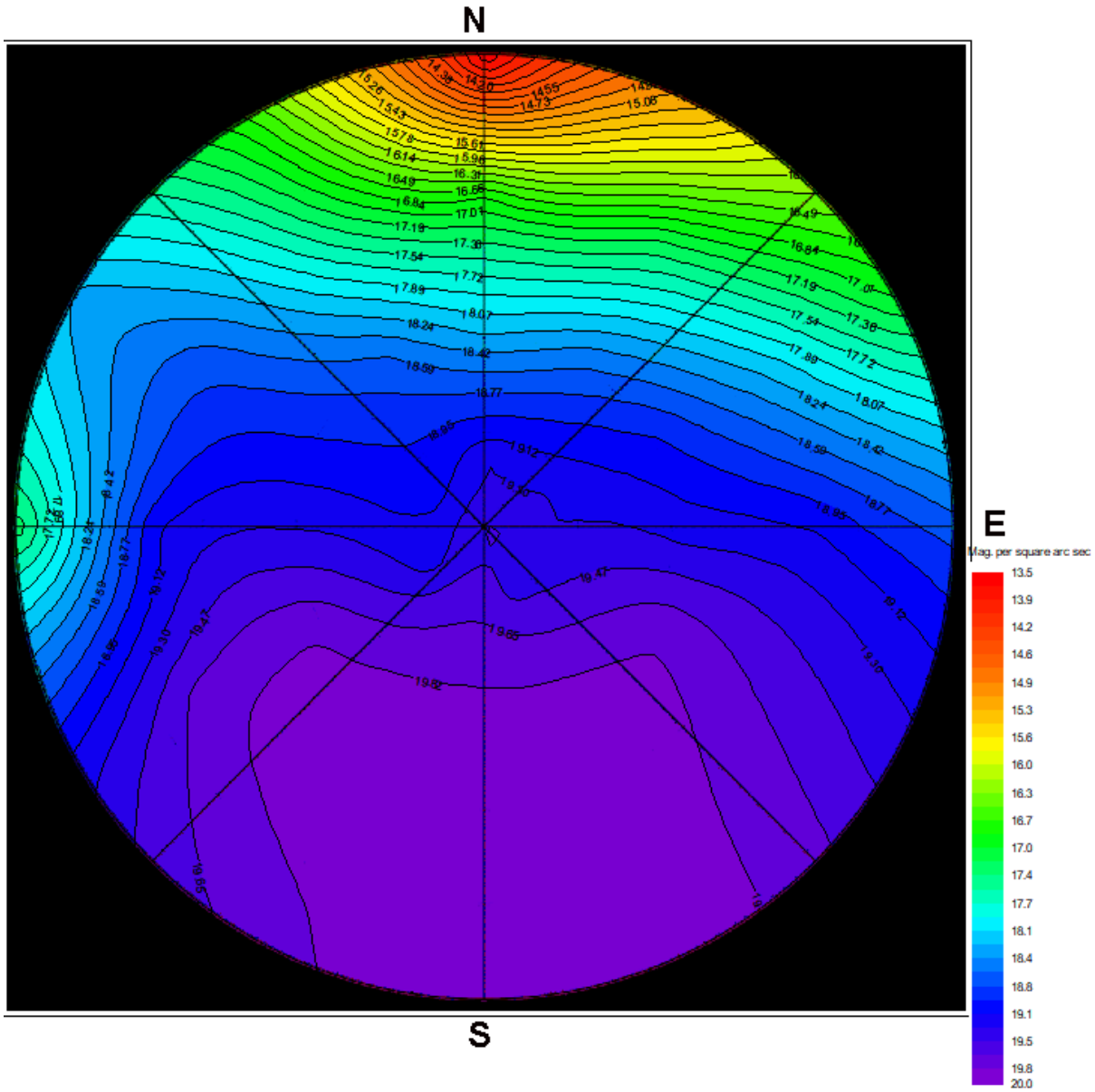


Figure 9.2 All-sky brightness contour plot.

The site at Wied Babu is located just before the road leading down into the sea inlet. It is flanked by a panoramic asphalted road (Triq Wied iż-Żurrieq) which runs from Żurrieq towards Siġġiewi. As such the road itself is a major source of light pollution due to the road lighting and the fact that the site being analysed is located below the level of the lighting – thus the lights have a major impact. Survey location is close to the edge of the cliff on a steep incline.

The polar plot above indicates the brightness of the night sky at the Blue Grotto location in Wied iż-Żurrieq at different altitudes and azimuth angles (north 0° through east 90°, south 180° and west 270°). The higher the reading, the darker is the night sky ie. lower readings are indicative of bright skies. The centre of the map indicates the zenith ie. the point directly above the measurement site.

The main sources consist of very bright high-pressure sodium road lamps which are situated at close proximity to the study site. These are clearly visible on the panoramic images and are so bright as to illuminate the rock outcrop (il-Munqar) situated on the opposite (eastern) side of the valley. The false colour image shows the stark effect of the very bright illumination onto the night sky.

The polar plot diagram indicates the impact of bright light sources on the overall night sky above the measurement site. It is clearly visible that a bright source is located at azimuth 0° (ie. towards the northern part of the site), corresponding to the bright light emitted by the streetlights mentioned above. A source of light has also been detected at azimuth 270°, corresponding to the westerly direction. This is the effect of lighting from the commercial areas at Wied iż-Żurrieq (restaurants etc.).

SUGGESTED MITIGATION MEASURES

In such a sensitive site one must pay particular attention to the way any bright exterior lighting is designed and installed. In order to try and minimise the effects of the existing installations the following measures are being suggested:

a. Investigation with relevant authority (Transport Malta/Enemalta) with respect to whether the existing stretch of road lighting can be eliminated and instead replaced with retro-reflective road markers (cat's eyes). The low vehicular traffic activity on this road at night should be taken into account.

b. Reinstalling the light poles on the valley side of the road to face the opposite direction and replacement of the fixtures to full cutoff fixtures. High pressure sodium lamps should be used or LEDs with a CCT < 3000K.

09 - WIED BABU

Figure 9.3

SITE NR. 10
LOCATION: ĦAL FAR
Geographic coordinates: Lat 35.8107°N Lon 14.5042°E

SITE LOCATION

Figure 10.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

100 to 150 pairs of Yelkouan Shearwater are estimated to nest in the cliffs north of Wied iż-Żurrieq to Bengħisa, including Ħal Far (Sultana, Borg et al. 2011). Moreover the area holds the second largest colony of Scopoli's Shearwaters with an estimated 800 pairs (Sultana, Borg et al. 2011).

SOURCES OF LIGHT POLLUTION

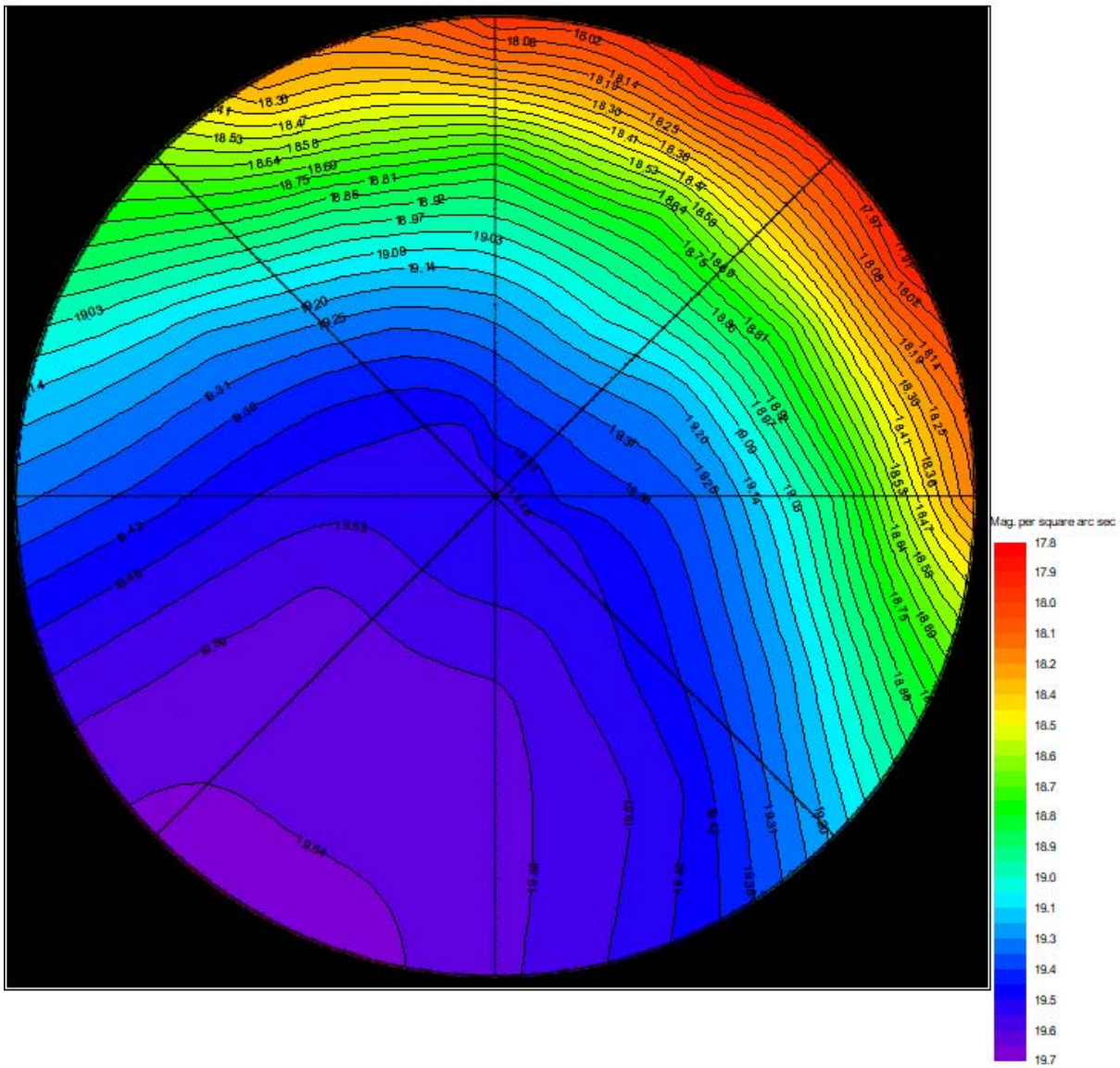


Figure 10.2 All-sky brightness contour plot

This site suffers from light pollution emanating from the nearby factories that have unshielded floodlights installed around their perimeter. The light emitted is substantial as its two brightest points, at 17.9 mag/arcsec^2, can be observed at azimuth 030° (north-north-east) and 060° (east-north-east) respectively. This means that the sky in this direction is equivalent to being thirty-three times brighter than that of a site with natural night sky brightness.

Another source of light pollution was registered due north of the site at azimuth 0° (north) with a brightness reading of 18.0 mag/arcsec^2, meaning that it is thirty times brighter than the natural night sky.

As most of the light pollution sources are within a directional range of 120°, the brightness of the skyglow emanating from these sources gradually decrease away from this direction. The natural darkest point in the sky at the zenith (overhead) has been displaced towards the direction of the sea due to the absence of light pollution sources in this direction. The zenith reading recorded for this site was of 19.5 mag/arcsec^2 and showed a marked improvement towards a natural setting. The darkest reading was recorded towards azimuth 210° at 19.7 mag/arcsec^2 which at twenty-one times brighter than natural background levels still remains somewhat bright.

SUGGESTED MITIGATION MEASURES

Light pollution arising from industrial development is always problematic because of the high number of fittings (mostly floodlights) which are set up by the individual entities/companies operating from each premises.

The best solution is an integrated approach by having Malta Industrial Parks request all its business partners in the industrial zone to gradually replace all non-conforming exterior lighting with full-cutoff fittings having zero upward light output, installed at low height and having a colour temperature not exceeding 3000K.

Figure 10.3

SITE NR. 11
LOCATION: COMINO SANTA MARIJA CAVES
Geographic coordinates: Lat 36.0181°N Lon 14.3401°E

SITE LOCATION

Figure 11.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

50 to 80 pairs of Yelkouan Shearwaters breed in Santa Marija caves on the north east part of Comino, while Scopoli's Shearwaters also breed in the area (5 to 20 pairs) (Barbara et al 2015).

SOURCES OF LIGHT POLLUTION

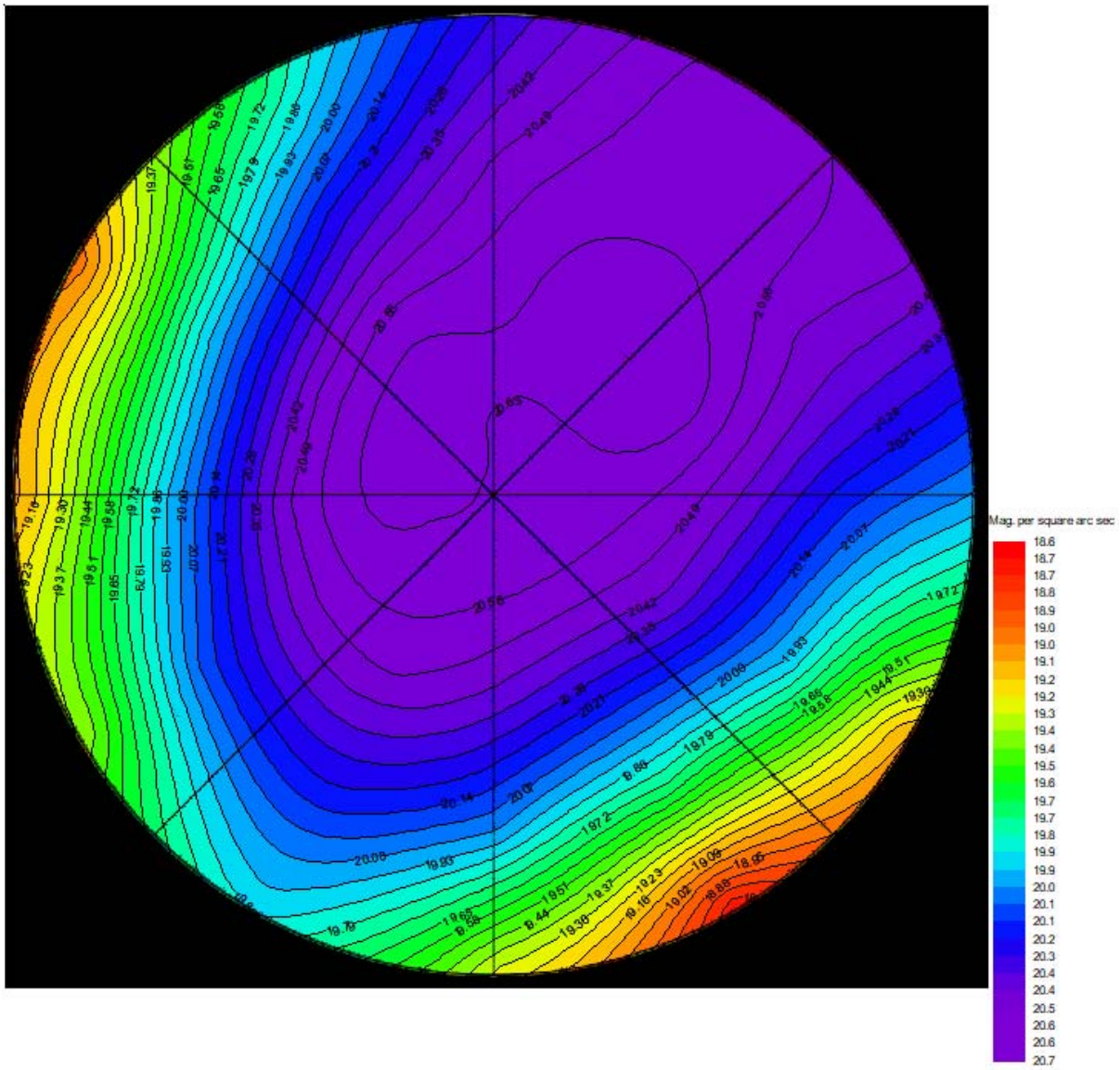


Figure 11.2 All-sky brightness contour plot.

This site is situated at the north-eastern part of Comino. The SQM readings at this site show that despite the notion that Comino is a dark place the readings gathered show otherwise. This is mainly due to the light emitted from the Maltese mainland which is also supplimented by the light from Ċirkewwa and light from Gozo. Some light pollution coming from neaby medium to low intensity lighting on Comino itself was recorded.

The brightest part of the night sky was recorded at 18.7 mag/arcsec^2 at azimuth 150° (south-south-east). This coincides with the area of Buġibba where there is high intensity lighting. Light pollution from this area brightens the sky sixteen times more than the natural brightness of the night sky. Sources of such brightness affect Comino in a way much higher than

expected. This implies that any light pollution mitigation measures at Buġibba will be beneficial to the night sky over Comino.

Another notable source of light pollution was recorded at azimuth 300°. The sky over this area was recorded as bright as 19.0 mag/arcsec^2 which is equivalent to eleven times brighter than at a natural setting.

The darkest area of the sky recored over this site was measured at 20.7 mag/arcsec^2. Such brightness implies that the sky over the darkest areas are still over twice the brightness of that of an unpolluted site.

This maps show that light pollution cannot be attributed as coming solely from two dinstinct sources, the Malta mainland and Gozo, but that skyglow can be observed extending over a large part of the sky in the south-westerly direction. This is due to light pollution sources over the island of Comino.

SUGGESTED MITIGATION MEASURES

Comino is in the situation where the light pollution present is not due to local installations but mainly due to light sources located in Malta and Gozo. In such cases the local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

Although not located in the immediate vicinity of the site, the recent (June 2018) illumination project at Comino St.Mary tower may have increased the sky brightness towards the south-west due to installation of brighter light fittings.

11 - SANTA MARIJA

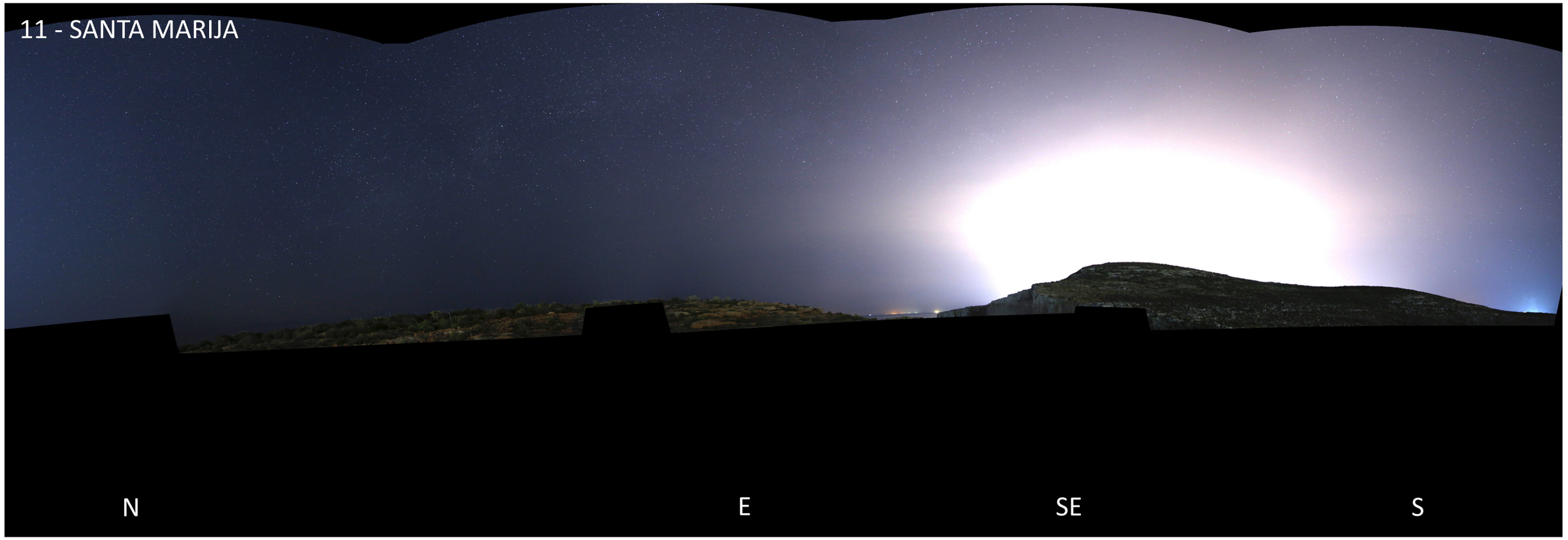


Figure 11.3

SITE NR. 12
LOCATION: COMINO – BLUE LAGOON
Geographic coordinates: Lat 36.0126°N Lon 14.3247°E

SITE LOCATION

Figure 12.1 Daytime aerial view of the site in question

PRESENCE OF SEABIRD COLONIES

30 to 60 pairs of Yelkouan Shearwaters nest on Cominotto (Barbara et al. 2015), while no other seabird species have been recorded nesting.

SOURCES OF LIGHT POLLUTION

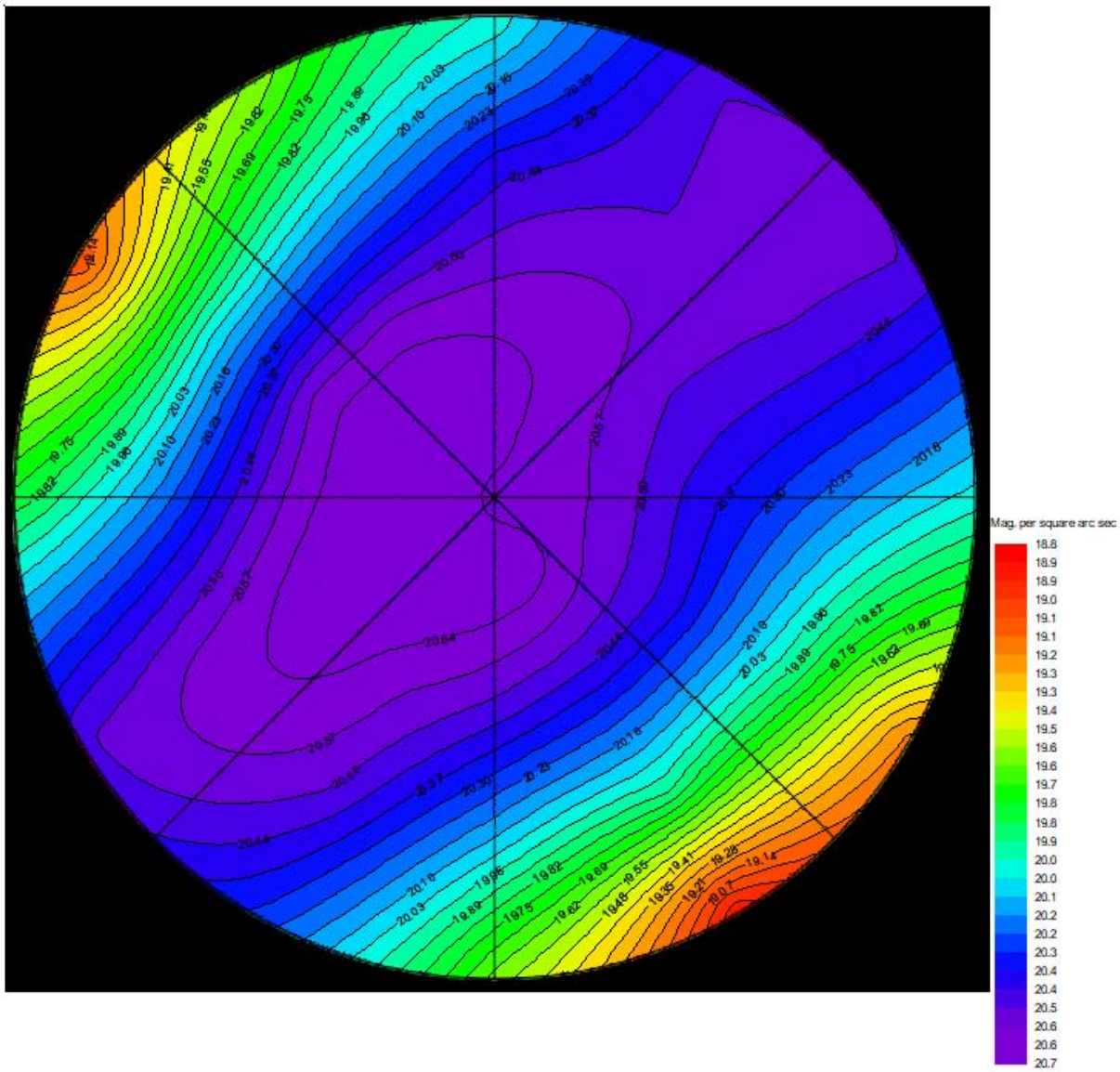


Figure 12.2 All-sky brightness contour plot

The light pollution map clearly shows two light pollution sources at azimuth 150° (south south-east) with a reading of 18.9 mag/arcsec^2 and at azimuth 300° (west-north-west) with a reading of 19.1 mag/arcsec^2. The first reading refers to the light pollution emitted from the Maltese mainland from the direction of Ċirkewwa as well as Mellieħa and Buġibba. The second source is due to light sources situated in Gozo in the direction of Mġarr harbour.

The sky at the zenith was registered as being of good quality but in the direction of the land the situation worsens considerably. The above chart shows that the overall quality in terms of light pollution is not as good as one would expect from a relatively uninhabited island which is also some distance away from the mainland because bright light sources of light pollution can be observed from the surrounding locations. This chart also shows that both terminals are having an impact on the darkness of the sky. In fact the factor of night time sky brightness

in these directions was registered as being brighter by a factor of twelve and ten times (Malta terminal and Gozo terminal respectively) the brightness of the natural background brightness of an unpolluted site.

The night sky brightness at the zenith was registered as 20.6 mag/arcsec^2 that is comparable to a sky that is three times brighter than the natural sky at night.

SUGGESTED MITIGATION MEASURES

The situation is similar to that encountered at Santa Marija – with Comino being in the situation where the light pollution present is not due to local installations but mainly due to light sources located in Malta and Gozo. In such cases the local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

Although not located in the immediate vicinity of the site, the recent (June 2018) illumination project at Comino St.Mary tower may have increased the sky brightness towards the south-east due to installation of brighter light fittings.

12 - COMINO BLUE LAGOON

Figure 12.3

SITE NR. 13
LOCATION: TA' ĊENĊ (2) - GOZO
Geographic coordinates: Lat 36.0149°N Lon 14.2655°E

SITE LOCATION

Figure 13.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

At Ta' Ċenċ 150 to 300 pairs of Yelkouan Shearwater are estimated to breed and it is the largest colony of Scopoli's Shearwaters with an estimated 1000 pairs (Sultana et al. 2011). Furthermore a sea cave holds between 25 and 50 pairs of European Storm-petrels (Barbara et al. 2015).

SOURCES OF LIGHT POLLUTION

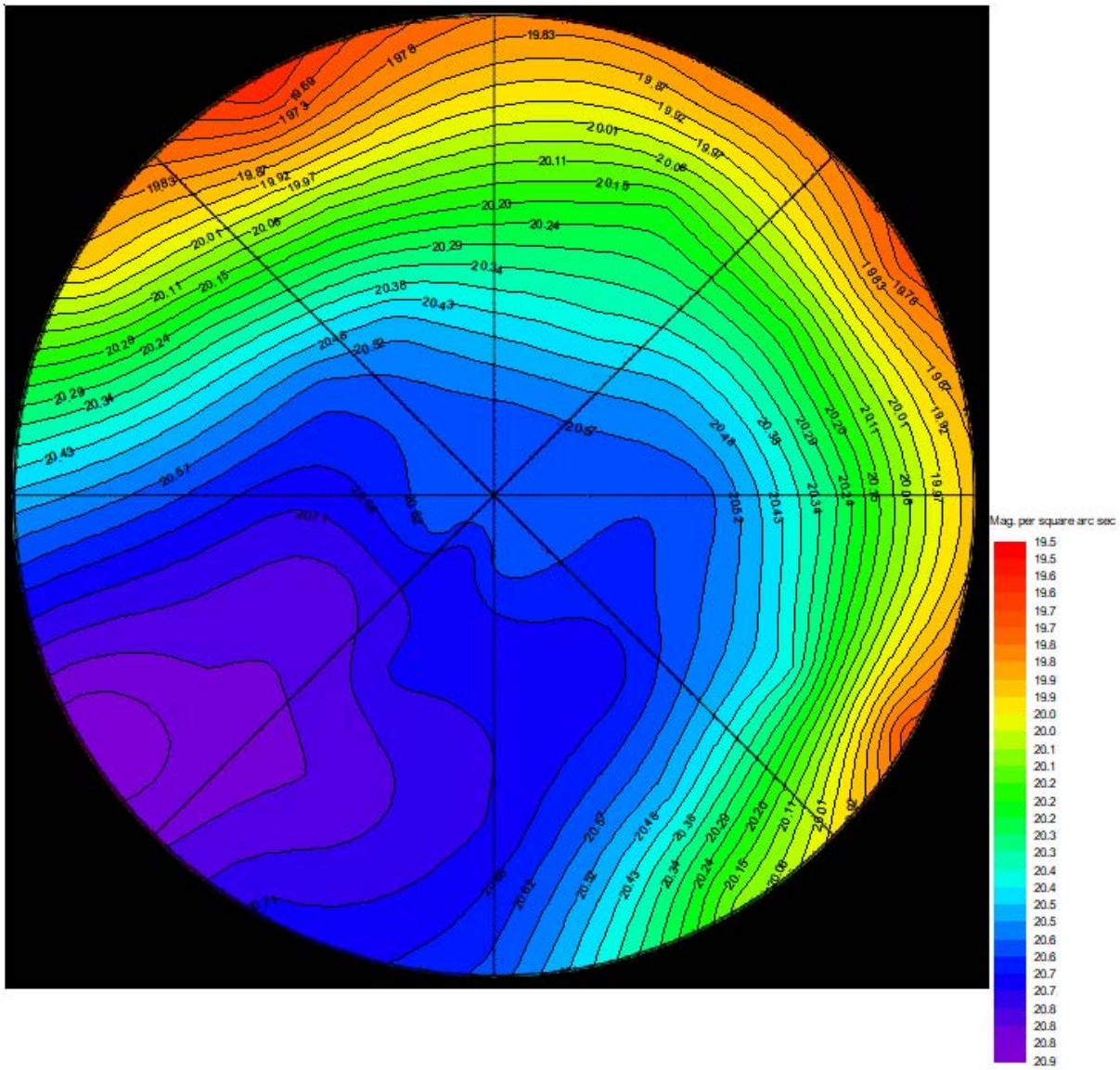


Figure 13.2 All-sky brightness contour plot

The light pollution map shows how this site is surrounded by light pollution sources except to the south-west. The location is above the south-facing cliffs overlooking the Malta/Gozo channel. It must be noted that the brightest light pollution source for this site is not as bright as in many other sites around the Maltese mainland as this source was registered as bright as 19.6 mag/arcsec2. This is around seven times brighter than the darkest background under a natural setting. This source is located at an azimuth angle of 330° that corresponds to the area of Rabat - Gozo.

The second brightest source lies towards azimuth of 60° (east-north-east) at 19.7 mag/arcsec^2, that coincides with the town of Għajnsielem. Another significant source of light pollution lies towards the direction of azimuth 120° (east-south-east) at a brightness of 19.7 mag/arcsec^2. The Ċirkewwa terminal can be found in this direction. Despite the distance, the sources of lighting in the location are bright enough to affect illumination levels of the cliff side.

Although the light pollution sources around this site are not extremely bright, either due to the distance from the sources or due to the low intensity of the nearby ones, their combined affect has offset the darkest area of the night sky from the zenith towards the south-west over the sea. Here the darkest point was measured at 20.9 mag/arcsec^2 which is just around two times brighter than for a site free of light pollution.

SUGGESTED MITIGATION MEASURES

The light sources affecting this site are those situated within the hotel complex towards the north east as well as distant ones which contribute to skyglow over Gozo. The changeover from low-pressure sodium fittings (orange light) to the much brighter/whiter LED lamps (said changeover which took place during the replacement project a few years ago) is clearly evident in the colour of the skyglow itself.

With regards to the lighting from the hotel, discussions should be entered into with the hotel owners such that a gradual replacement of all non-conforming exterior lighting be made over a defined period of time towards full cutoff fittings having a CCT <3000K.

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented. Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

13 - TA’ ĊENĊ 2

Figure 13.3

SITE NR. 14
LOCATION: TA ĊENĊ (1) - GOZO
Geographic coordinates: Lat 36.0175°N Lon 14.2539°E

SITE LOCATION

Figure 14.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

At Ta' Ċenċ 150 to 300 pairs of Yelkouan Shearwater are estimated to breed and it is the largest colony of Scopoli's Shearwaters with an estimated 1000 pairs (Sultana et al. 2011). Furthermore a sea cave holds between 25 and 50 pairs of European Storm-petrels (Barbara et al. 2015).

SOURCES OF LIGHT POLLUTION

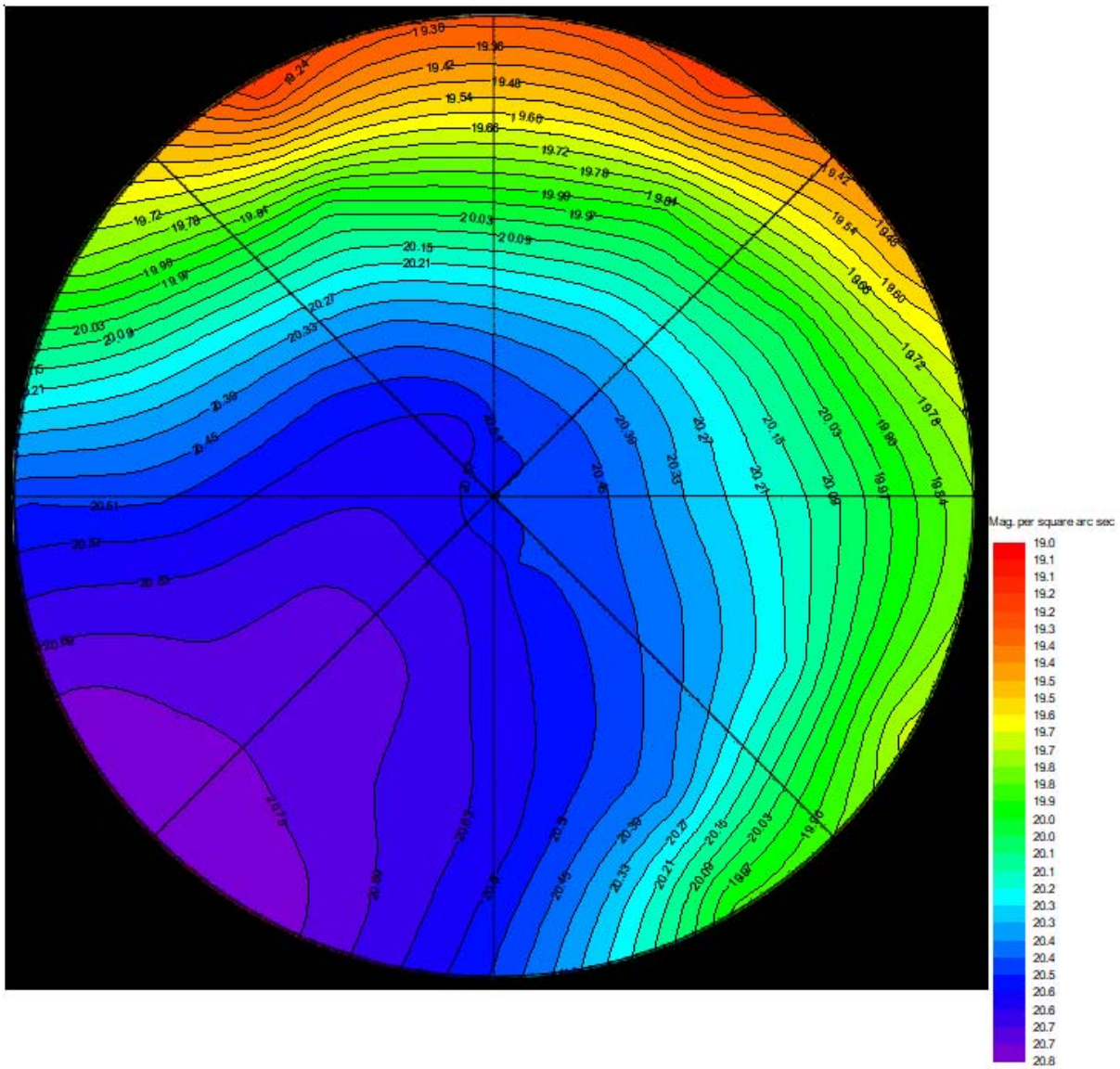


Figure 14.2 All-sky brightness contour plot

The two brightest sources at this site can be observed at azimuth 030° (north-east) and 300° (west-north-west) that coincide with the direction of Xewkija and Rabat respectively. Both sources were measured at magnitude 19.2 mag/arcsec^2 that is equivalent to a sky that is ten times brighter than that of a sky free of light pollution.

Another source of light pollution was measured at azimuth 120° (east-south-east) with a registered skyglow brightness of 19.7 mag/arcsec^2. Despite its low intensity, the sensor used was sensitive enough to pick the skyglow of the Ċirkewwa terminal. A 19.7 mag/arcsec^2 is considered as being six times brighter than a light pollution free site.

The wide angle distribution of light sources has shifted the darkest point in the night sky which is normally situated at the zenith (overhead at 90°altitude) to an altitude of 20° above the horizon at an azimuth 240° (west-south-west). The SQM reading at this point was registered at 20.8 mag/arcsec^2, equivalent to two times brighter than at a natural dark sky setting.

Even though the site shows moderate light pollution levels, the overall brightness of the night sky is quite dark when compared to other areas within the Maltese mainland.

SUGGESTED MITIGATION MEASURES

The light sources affecting this site are mainly those situated within the hotel complex towards the north east. Similarly to the previous site at Ta' Ċenċ distant sources also affect as they contribute to skyglow over Gozo. However in the case of the current site the hotel complex has a greater impact since it is situated much closer (less than one kilometre away).

The changeover from low-pressure sodium fittings (orange light) to the much brighter/whiter LED lamps (said changeover which took place during the replacement project a few years ago) is clearly evident in the colour of the skyglow itself.

With regards to the lighting from the hotel, discussions should be entered into with the hotel owners such that a gradual replacement of all non-conforming exterior lighting be made over a defined period of time towards full cutoff fittings having a CCT <3000K.

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented. Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

14 - TA’ ĊENĊ 1

Figure 14.3

SITE NR. 15
LOCATION: SANAP CLIFFS - GOZO
Geographic coordinates: Lat 36.0219°N Lon 14.2268°E

SITE LOCATION

Figure 15.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

The cliffs between Sannap and iċ-Ċnus are estimated to hold 30 to 40 pairs of Yelkouan Shearwater as well as around 300 pairs of Scopoli's Shearwater (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

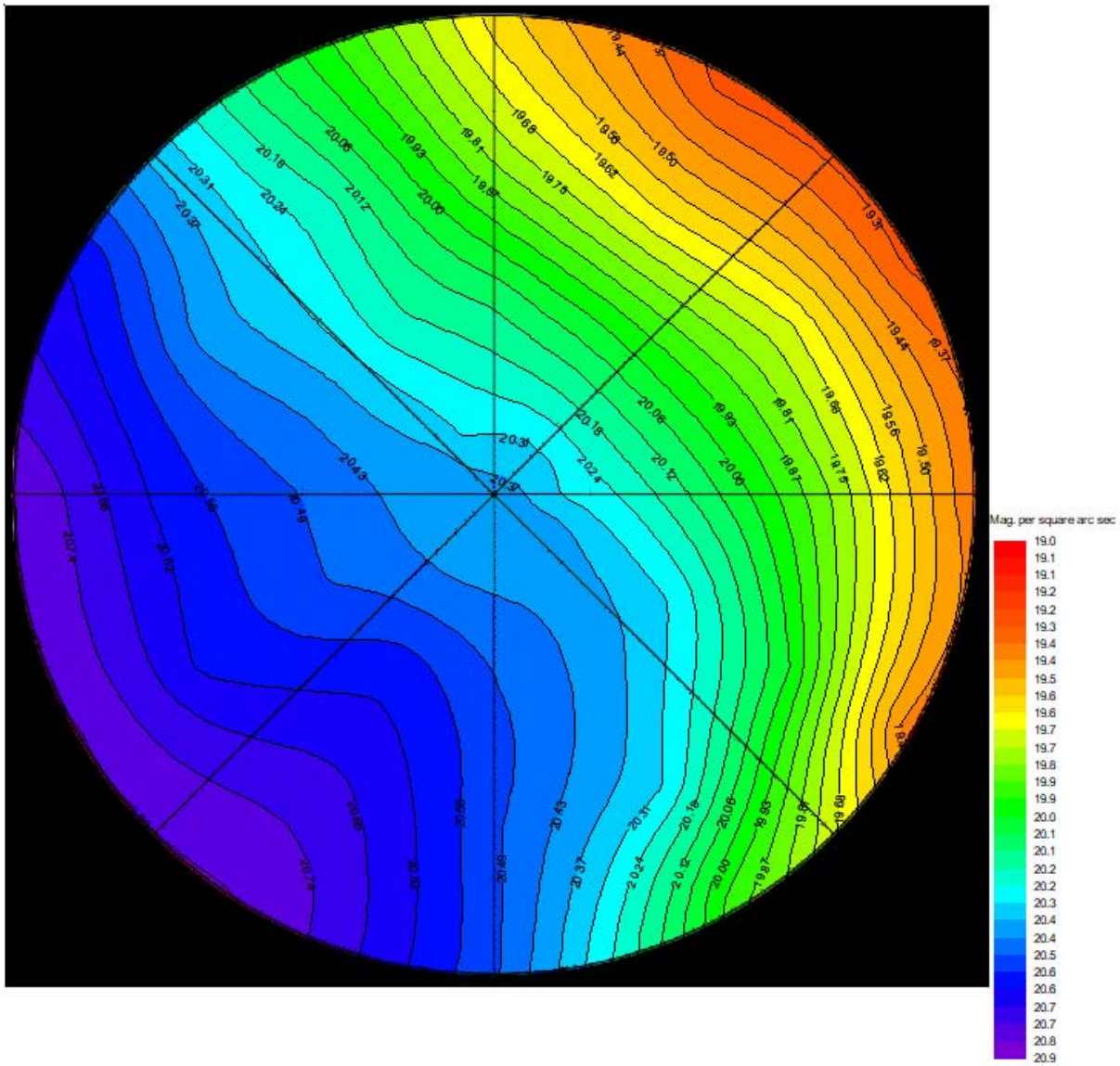


Figure 15.2 All-sky brightness contour plot

The Sanap Cliffs site has moderate light pollution sources ranging in direction from the north-east to the south-east. The source of light pollution is due to built-up areas that are located northwards. In this direction, the light pollution emanating from Rabat can be clearly measured with an increase in the night sky background of 19.3 mag/arcsec^2 at azimuth 030° (north-east). Another source with the same brightness of 19.3 mag/arcsec^2 at azimuth 060° (east-north-east) is also observed. This brightening of the night sky coincides with the direction of Xewkija (Gozo). The night sky background above these two directions is equivalent to nine times brighter than that of a sky free from light pollution.

An amount of sky glow was also recorded at azimuth 150° (south-south-east) at a brightness of 19.9 mag/arcsec^2. This coincides with the direction of Ċirkewwa terminal on the Maltese mainland.

The sky above the site darkens as the angle of viewing is increased when we move away from these sources. At the zenith, the sky was recorded at a mag/arcsec^2 brightness of 20.4 seven times brighter than natural night sky levels. As the light sources occupy a wide range in azimuth, the direction of the darkest part of the sky was offset to the south-west. In fact, the darkest areas recorded at 20.8 mag/arcsec^2 were observed at azimuth 210° (south-south-west), 240° (west-south-west) and 270° (west).

SUGGESTED MITIGATION MEASURES

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented since there is no direct contribution from local light sources.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

15 - SANAP CLIFFS

Figure 15.3

SITE NR. 16
LOCATION: GĦADIRA TA' SARRAFLU - GOZO
Geographic coordinates: Lat 36.0346°N Lon 14.2005°E

SITE LOCATION

Figure 16.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

50 to 100 pairs of Yelkouan Shearwater are estimated to breed in the cliffs between Dwejra/Wardija Point and Xlendi Bay, as well as around 700 pairs of Scopoli's Shearwaters (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

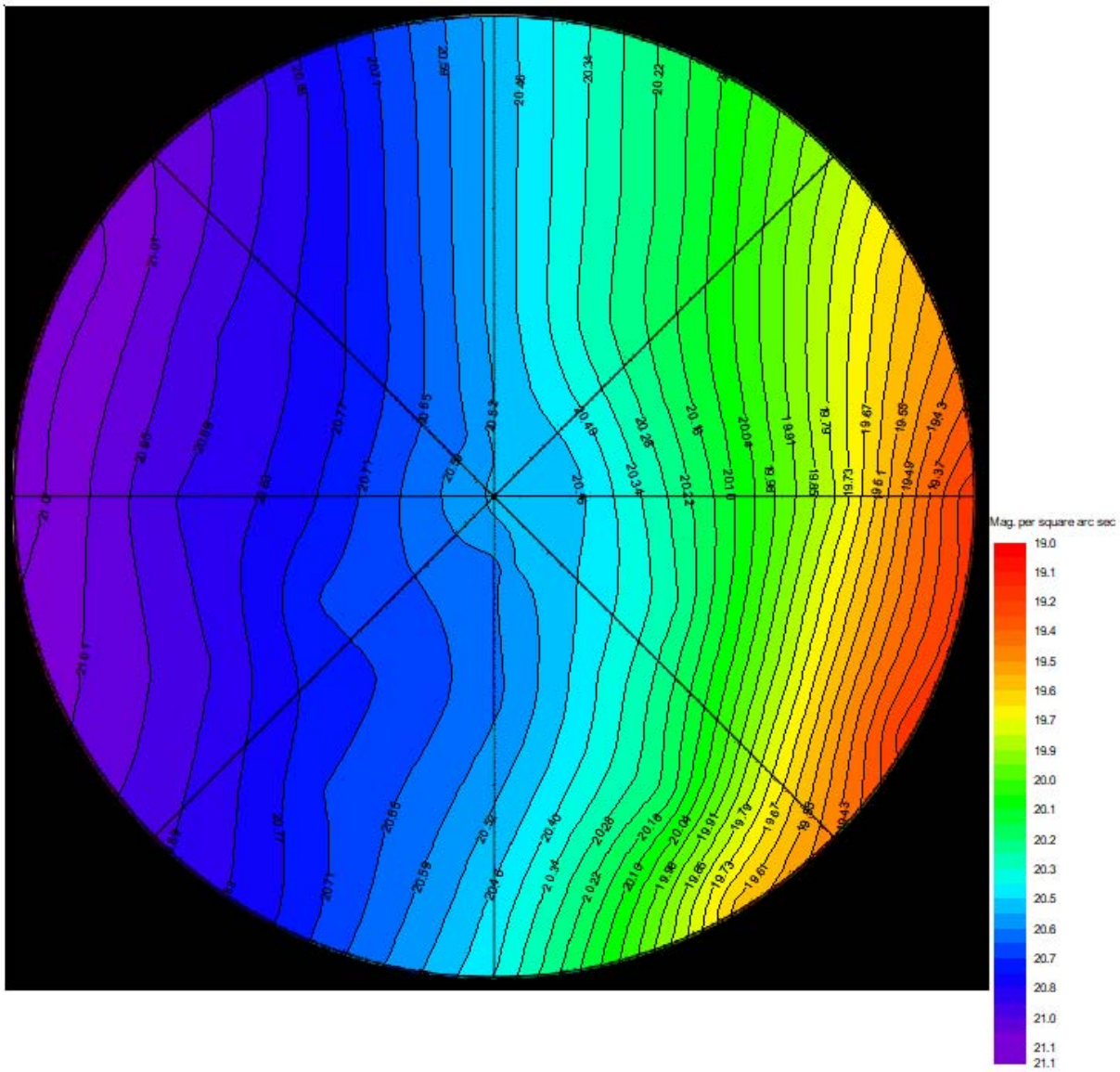


Figure 16.2 All-sky brightness contour plot

The distribution of light pollution sources for this site are concentrated towards the east at azimuth 090° and east-southeast direction at azimuth 120°. The brightness of the sky above these two sources was recorded at 19.2 mag/arcsec^2, which makes it equivalent to a sky brightness that is ten times brighter than a site free of light pollution. The foremost reading corresponds to the direction of Rabat and Fontana. However, slightly northwards from the location, Santa Lucija and Kerċem are also near to easterly direction at an approximate azimuth of 70° (east-north-east). The light sources from these locations are likely to be shown as an orange above the said azimuth direction.

The light pollution map above reveals that the night sky background gets darker away from these sources with the darkest direction being towards azimuth 240° (west-south-west) where the darkest reading was measured at 21.00 mag/arcsec^2. This brightness estimate shows that the night sky above this point is very dark when compared to other areas within the Maltese Islands as this is just less than two times brighter than the natural night sky background.

The brightness of the sky at the zenith (overhead) was recorded at 20.5 mag/arcsec^2. This is relatively dark for a site in the Maltese islands and has the potential of being one of the darkest places in the Maltese archipelago.

SUGGESTED MITIGATION MEASURES

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented since there is no direct contribution from local light sources.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

16 - GĦADIRA TA’ SARRAFLU

Figure 16.3

SITE NR. 17
LOCATION: SAN LAWRENZ
Geographic coordinates: Lat 36.0655°N Lon 14.1858°E

SITE LOCATION

Figure 17.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

The cliffs north from Dwejra to San Dimitri point are estimated to hold 30 to 50 pairs of Yelkouan Shearwater and 350 pairs of Scopoli's Shearwater (Sultana et al. 2011). Moreover a colony of European Storm-Petrels was discovered in recent years and is estimated between 30 to 60 pairs (Barbara et al. 2015).

SOURCES OF LIGHT POLLUTION

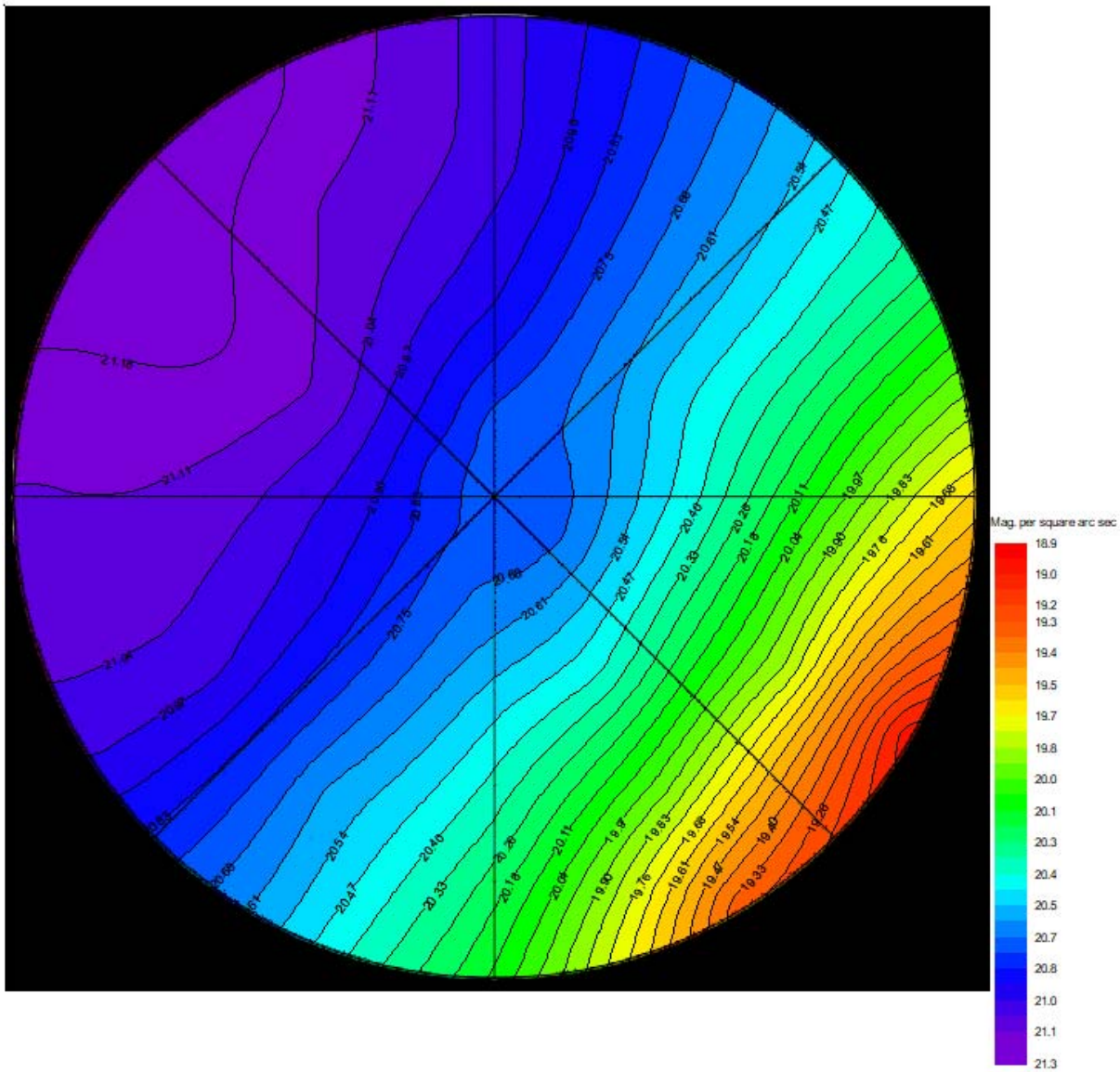


Figure 17.2 All-sky brightness contour plot

The site at San Lawrenz could be described as being one of the darkest places in the Maltese Islands. The brightest sources of light pollution are situated in the direction of Għarb and Rabat that coincidentally are both in the same direction at azimuth 120° (east-south-east) at 19.0 mag/arcsec^2. The sky in this direction was measured as being twelve times brighter than a location free of light pollution. A source of lesser brightness was recorded towards the town centre of San Lawrenz at azimuth 150° (south-south-east).

For the remaining part of the night sky, the light pollution intensity diminishes gradually to achieve one of the darkest readings obtained over the Maltese archipelago of 21.2 mag/arcsec^2. This reading was recorded at azimuth 300° (west-north-west) and 330° (north-west) over the sea.

At the zenith, the sky brightness was recorded as 20.7 mag/arcsec^2. This is equivalent to a night sky that is about three times brighter than a site free from light pollution.

SUGGESTED MITIGATION MEASURES

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented since there is no direct contribution from local light sources.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

Figure 17.3

SITE NR. 18
LOCATION: WIED IR-RAĦEB
Geographic coordinates: Lat 36.0743°N Lon 14.1943°E

SITE LOCATION

Figure 18.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

Until recently seabirds had not been documented breeding in the cliffs between San Dimitri and Wied il-Mielaħ but Scopoli's Shearwaters have been confirmed to nest in 2016 and probably so do Yelkouan Shearwaters.

SOURCES OF LIGHT POLLUTION

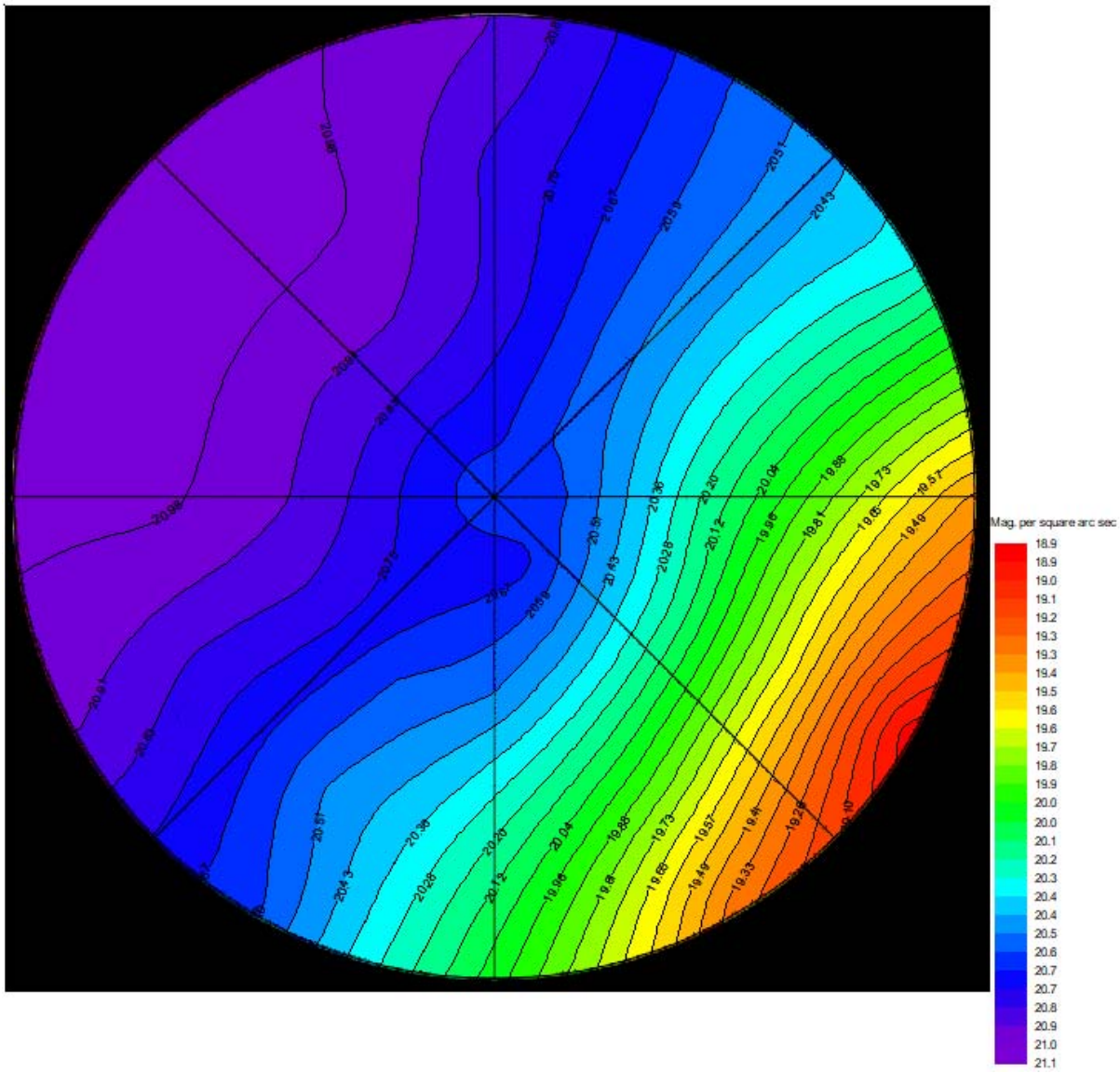


Figure 18.2 All-sky brightness contour plot.

Wied ir-Raħeb is one of the darkest sites within the Maltese Islands. Unfortunately, the site is badly effected by light pollution at azimuth 150° (south-south-east) which coincides with the direction of Ta' Pinu Church and Rabat. The light emitted from this direction could be substantially improved if lighting sources at Ta' Pinu Church were better shielded and of lesser intensity. In this direction the sky glow generated by these sources was recorded at 19.3 mag/arcsec^2 which is equivalent to being ten times brighter than that at a site free of light pollution.

On the other hand, the darkest readings at azimuth 270° (west), 300° (west-north-west) and 330° (north-west) were measured at 21.0 mag/arcsec^2 that is the same brightness for a sky that is two times brighter than the natural sky brightness background.

At the zenith (overhead) the sky was recorded at 20.6 mag/arcsec^2 that has the same brightness as a sky that is three times brighter than that of a sky free from light pollution.

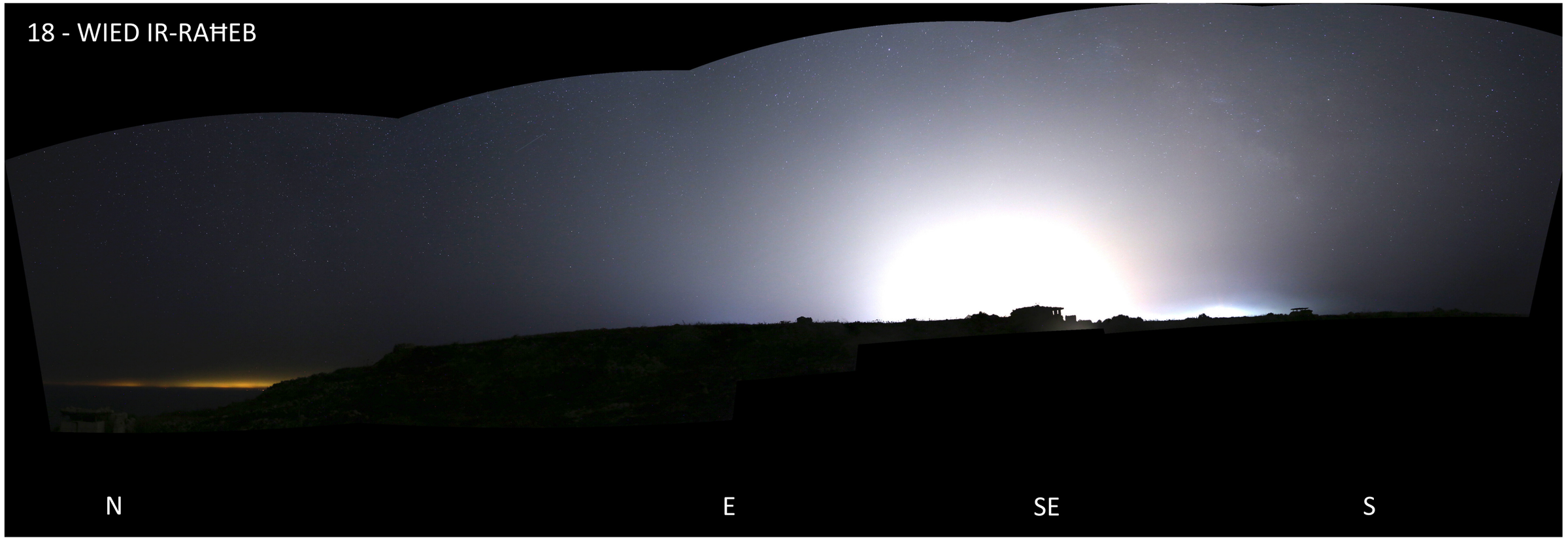
SUGGESTED MITIGATION MEASURES

As mentioned Ta' Pinu church, located towards the south-easterly direction from this site, contributes significantly to the sky glow in this location.

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented since there is no direct contribution from local light sources.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

18 - WIED IR-RAḤEB



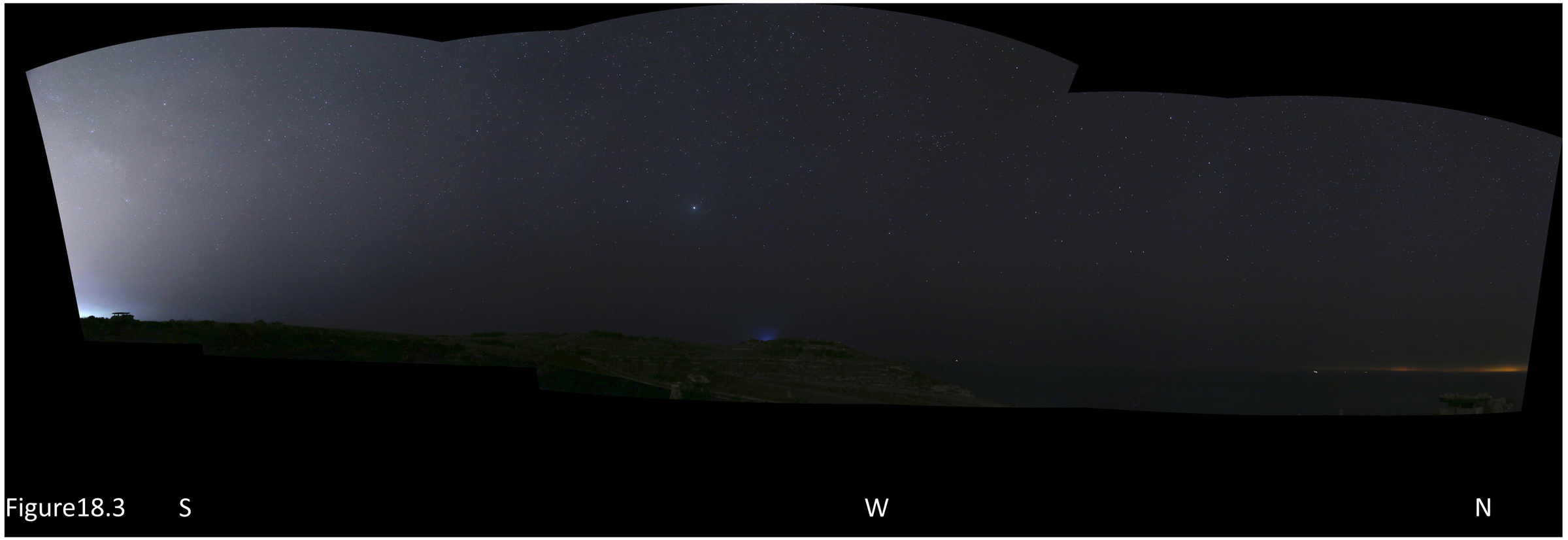


Figure18.3

SITE NR. 19
LOCATION: GĦAJN BARRANI – QORTIN LANDFILL
Geographic coordinates: Lat 36.0668°N Lon 14.2705°E

SITE LOCATION

Figure 19.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

20 to 30 Yelkouan Shearwater pairs are estimated to nest in the area of the Qortin landfill (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

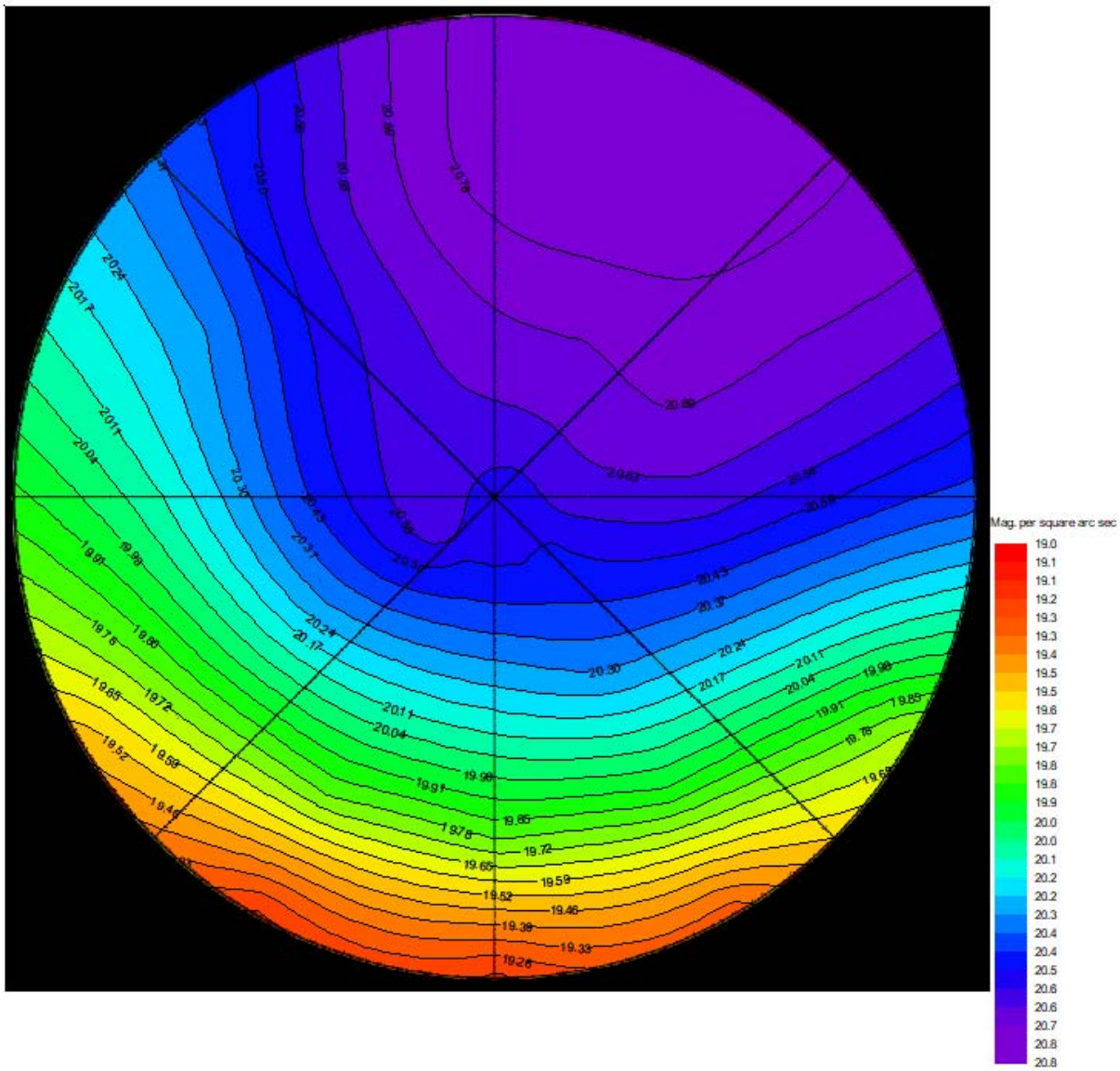


Figure 19.2 All-sky brightness contour plot

This site is situated on an inland cliff with land sloping towards the sea. It enjoys a 180° view of the sea, starting from 300° azimuth (west-north-west) to 120° going through the northern direction. The site is not heavily light polluted as the sources of sky brightness are either some distance away or do not have intense lighting.

The light pollution map identifies three sources at azimuth 150° (south-south-east), 180° (south) and 210° (south-south-west). The direction of these sources coincides with Nadur, Xagħra and Rabat with some overlap in between.

The sky bright at azimuth 150° (south-south-east) was recorded at 19.3 mag/arcsec^2 at nine times the natural background brightness of the night sky. The azimuth directions of 180° and 210° degrees have had their brightness recorded at ten times the brightness of a site free from light pollution.

The sky at the zenith was recorded at 20.5 mag/arcsec^2 equivalent to a night sky brightness factor of around three times.

Overall, this site would have enjoyed a relatively dark sky environment if the light sources at the Southern direction were not so widespread.

SUGGESTED MITIGATION MEASURES

This site is relatively dark but affected by skyglow from nearby towns, as mentioned above.

As with other sites an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented since there is no major direct contribution from local light sources.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

19 - GHAJN BARRANI

Figure 19.3

SITE NR. 20
LOCATION: QORTIN TA' ISOPU - GOZO
Geographic coordinates: Lat 35.9904°N Lon 14.3735°E

SITE LOCATION

Figure 20.1 Daytime aerial view of the site in question.

PRESENCE OF SEABIRD COLONIES

50 to 80 Yelkouan Shearwater pairs are estimated to nest in the area of the Qortin ta' Isopu (Sultana et al. 2011).

SOURCES OF LIGHT POLLUTION

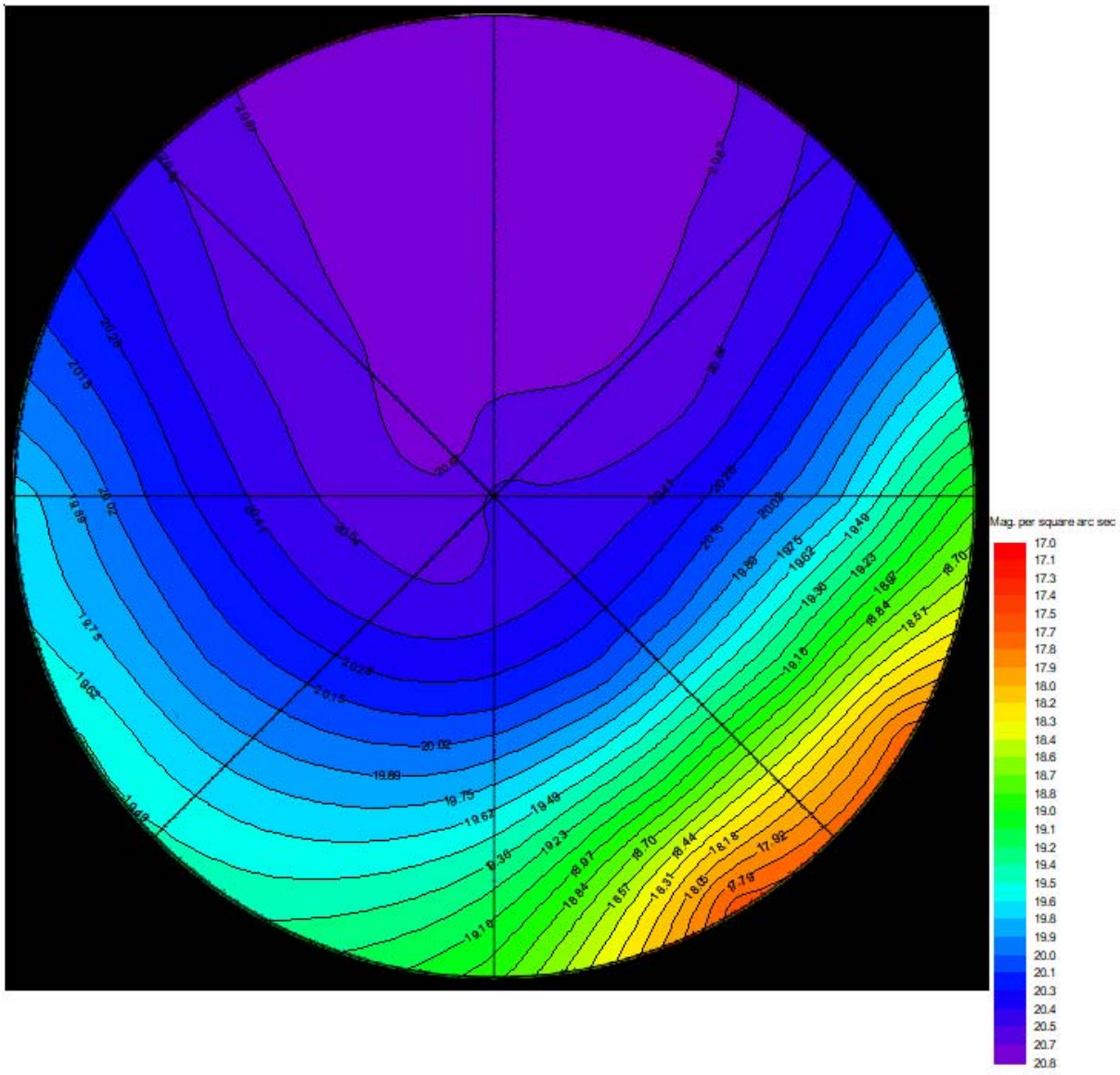


Figure 20.2 All-sky brightness contour plot

This site is situated on a peninsula-shaped cliff side facing the direction from the north-west to the south-east. The site enjoys good dark surroundings except towards the azimuth direction of 120° (east-south-east) and 150° (south-south-east).

For the north-west facing cliff, the sky was measured at 17.7 mag/arcsec^2 while the south-east one was measured at 17.6 mag/arcsec^2. The brightness of night sky at these values is equivalent to forty times the brightness of the natural night sky. These measurements imply

that the source of light pollution is within the environs of the site. In fact, readings obtained from the direction of the source coincide with the security light of a nearby military barracks. The lighting fixtures used do not have any provision to shield stray light which is not useful as a security measure. Therefore, it is recommended that the high intensity light sources at the barracks are substituted with full cut-off lighting with enough intensity to do the job. Such measures will certainly improve the night sky environment at this site by ensuring that the night sky is darker.

The brightness at the zenith at 20.5 mag/arcsec^2 indicates that the overall quality of the night sky would certainly improve if the offending light sources are tackled.

The darkest reading at this site was recorded at 20.8 mag/arcsec^2 at azimuth 0° (north). This is equivalent to just two times brighter than that of a sky free from light pollution.

SUGGESTED MITIGATION MEASURES

This site is relatively dark but affected by direct light sources from adjacent military barracks. Discussions should be entered into with the relevant authorities such that a gradual replacement of all non-conforming exterior lighting be made over a defined period of time towards full cutoff fittings having a CCT <3000K.

As with all other sites a contribution to skyglow from adjacent towns is clearly noticeable and an appreciable improvement can only be achieved once a national policy on exterior lighting is implemented.

Local actions should be concentrated on the extension of polices such as the Planning Authority's 'Dark Sky Heritage Areas' policy to cover the entire island not just part of it (map 13.8 – Gozo and Comino Local Plan, Planning Authority 2006).

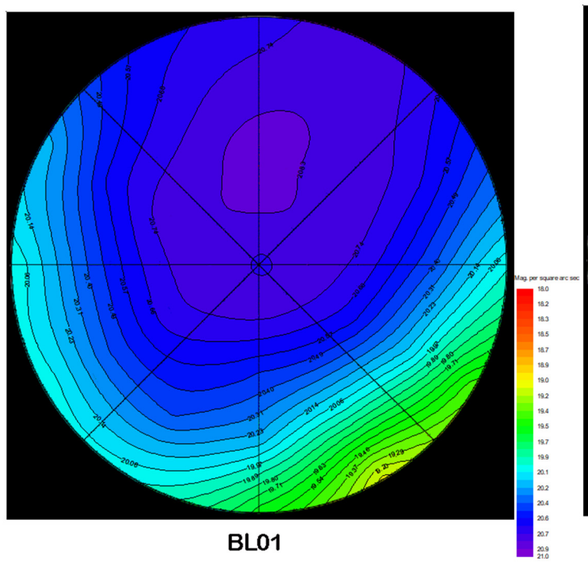
20 - QORTIN TA’ ISOPU

Figure 20.3

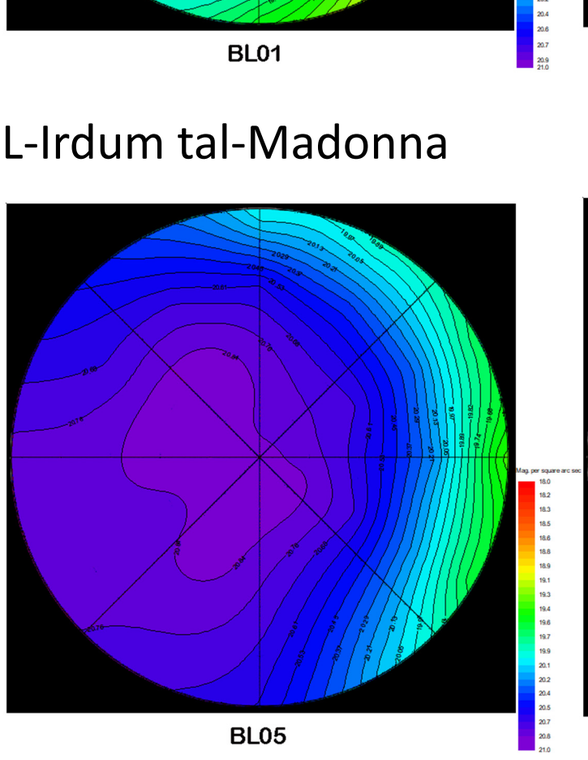
NIGHT SKY BRIGHTNESS PLOTS MOSAIC

A series of plots is being presented which present a quick visual comparison between all the twenty sites taken into consideration. All plots have been plotted using the same colour value scale, as opposed to the plots presented in the preceding pages where each plot is calculated individually in order to present as much detail as possible.

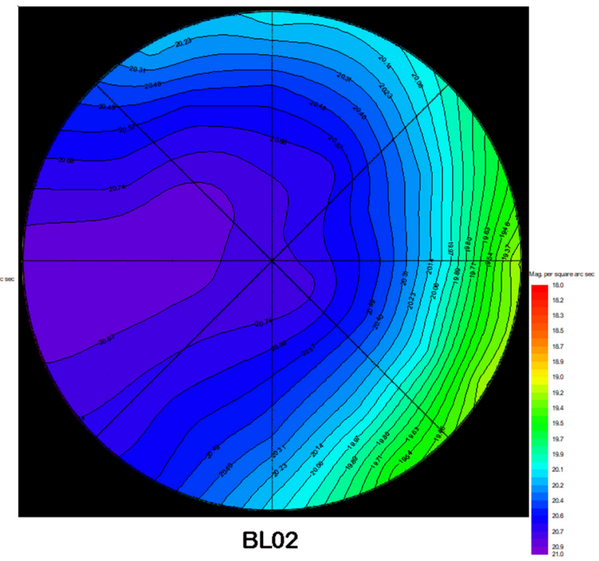
Sites which are predominantly blue/purple indicate that they have relatively dark areas of night sky at the altitude and in the direction indicated on the plot itself. Reddish areas constitute the brighter regions of the sky – mostly along the horizon. One must also bear in mind that it is not just the skyglow component which causes most distress to these bird colonies but also all direct line-of-sight installations.



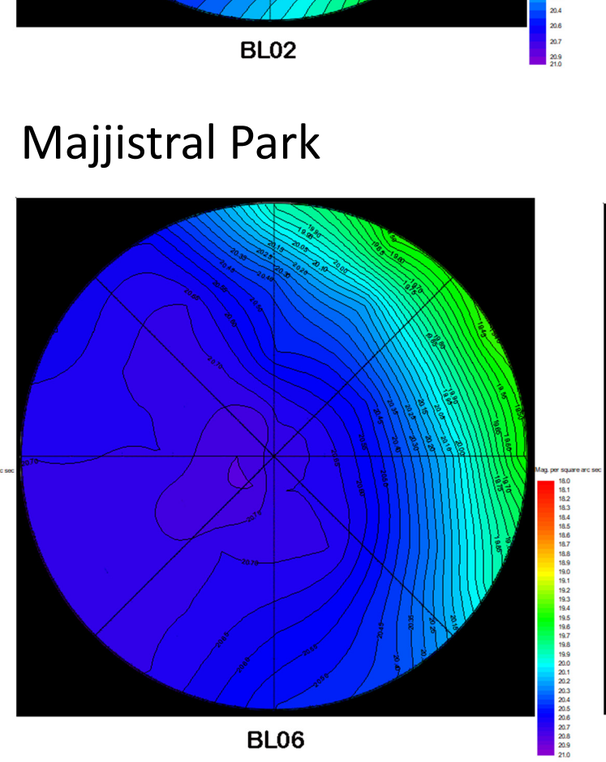
L-Irdum tal-Madonna



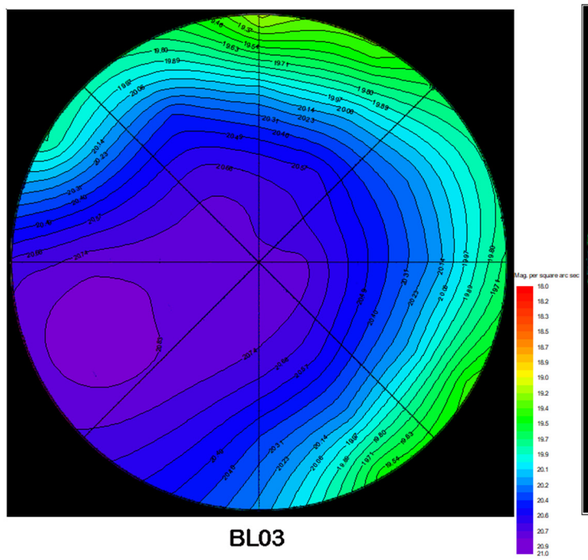
Fomm ir-Riħ



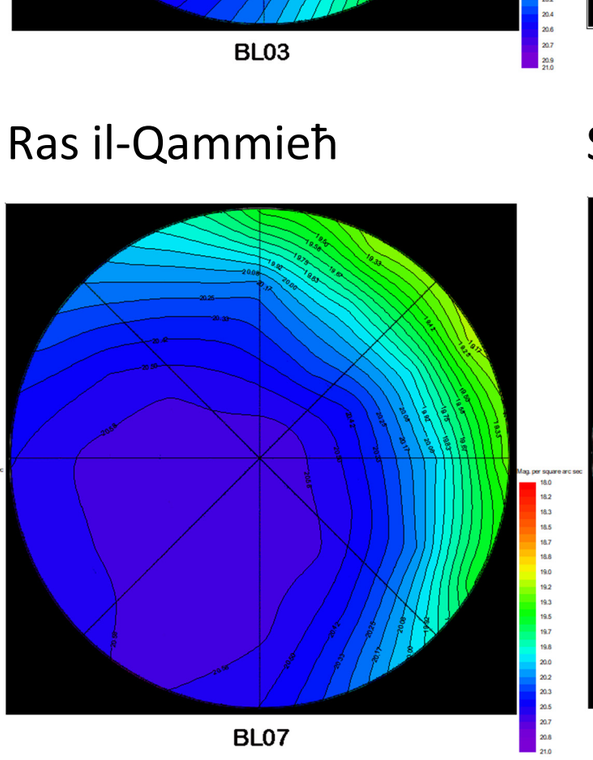
Majjistral Park



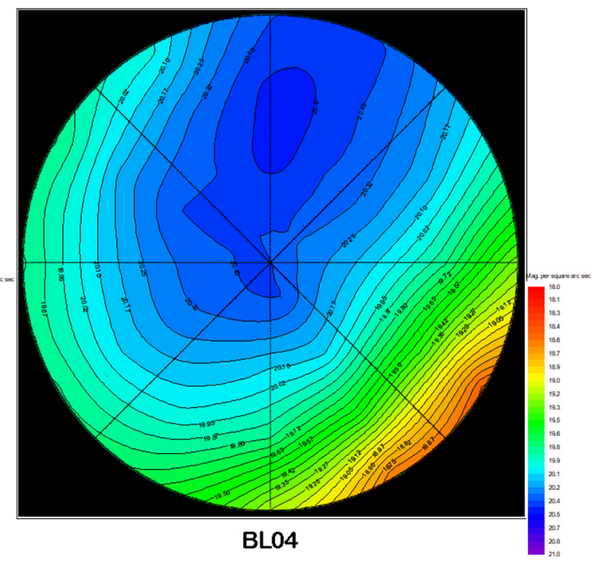
Miġra Ferħa



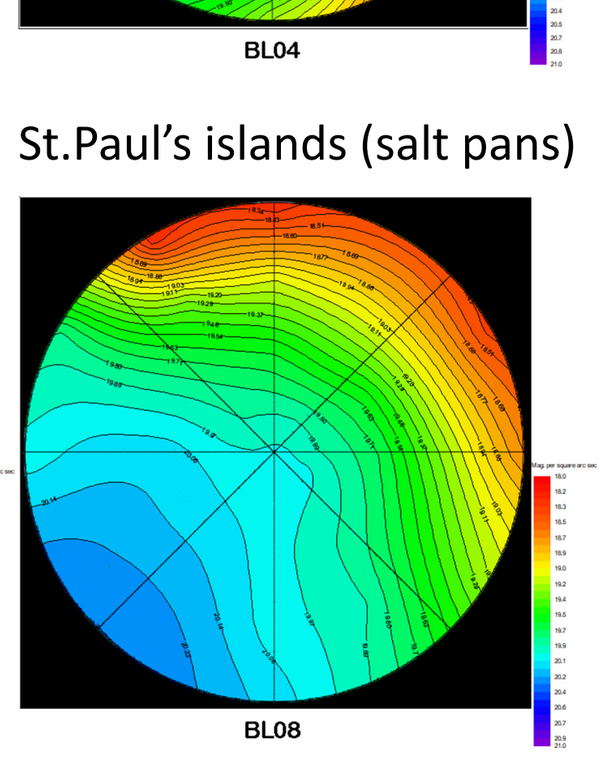
Ras il-Qammieħ



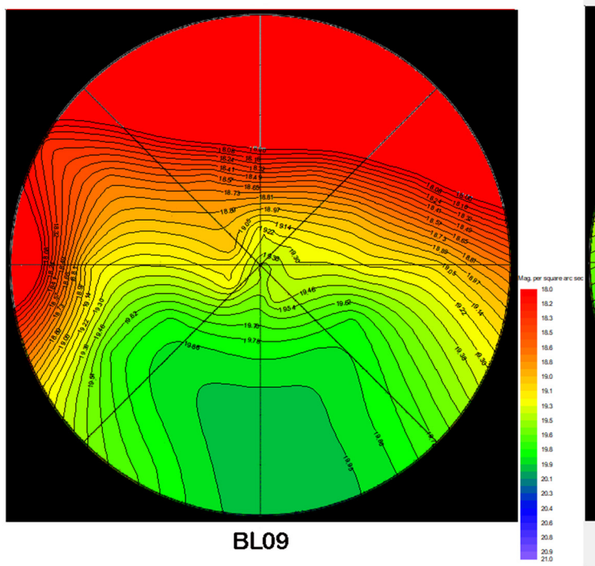
Il-Fawwara



St.Paul’s islands (salt pans)

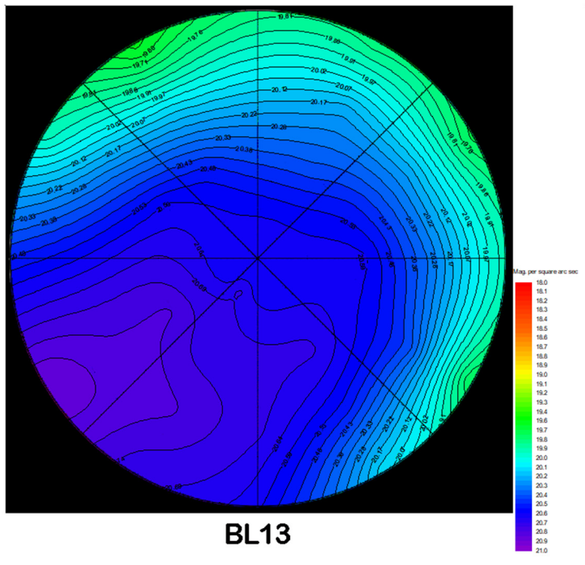


Għar Lapsi



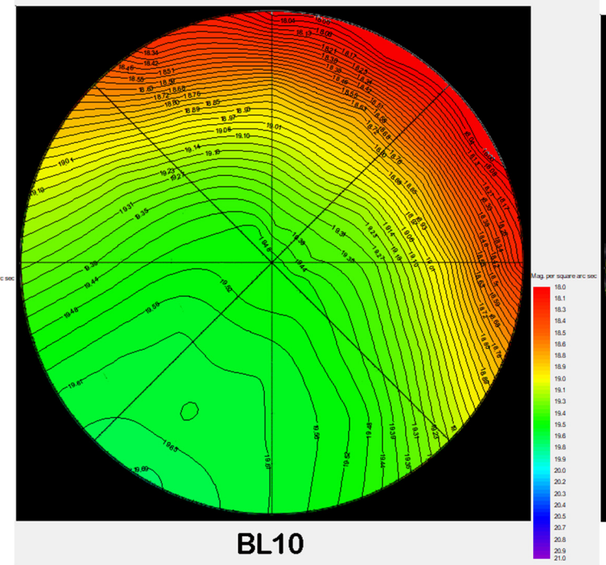
BL09

Wied Babu



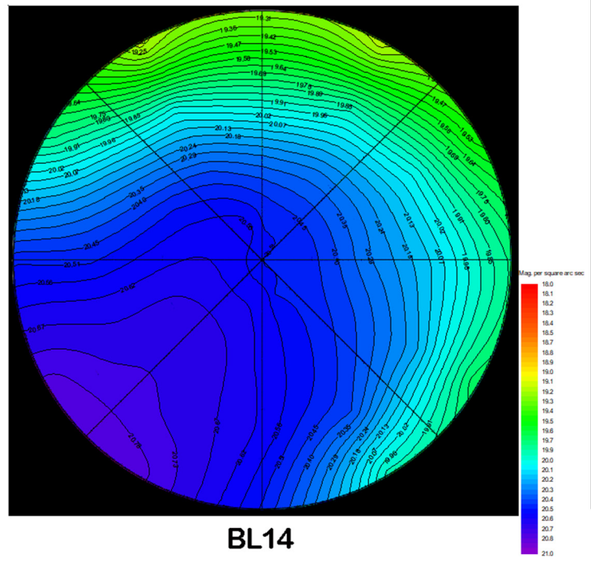
BL13

Ta’ Ċenċ (2)



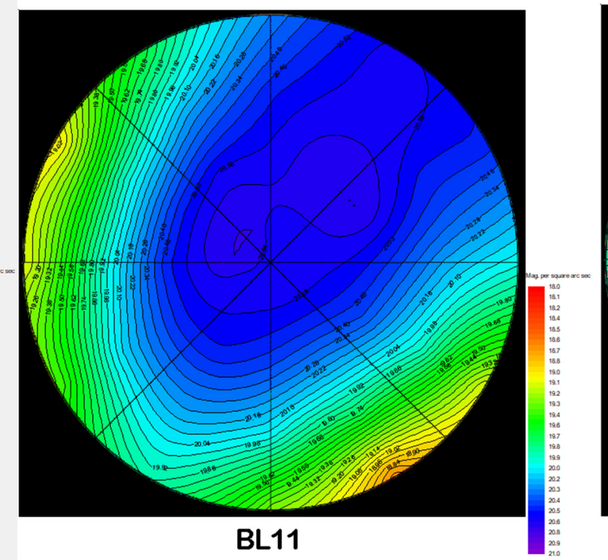
BL10

Ħal Far



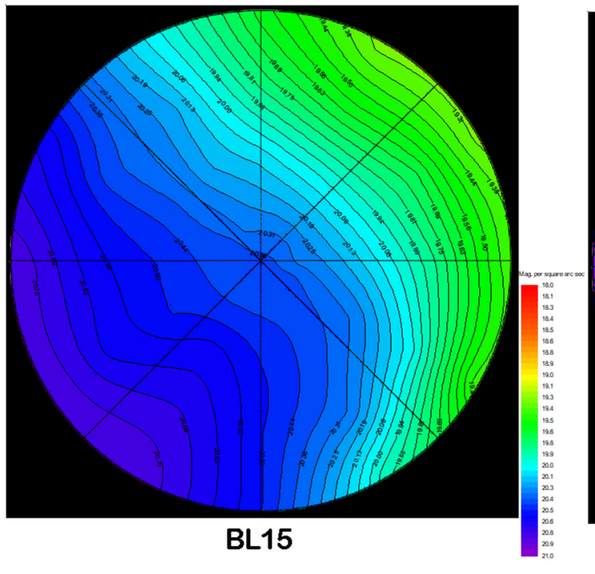
BL14

Ta’ Ċenċ (1)



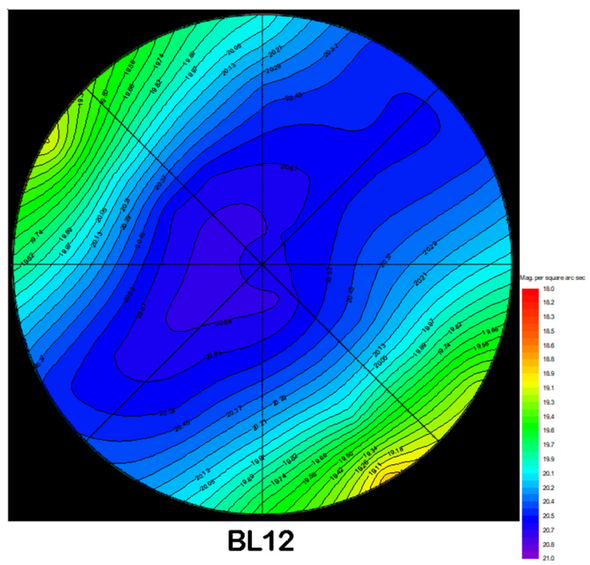
BL11

Comino Santa Marija



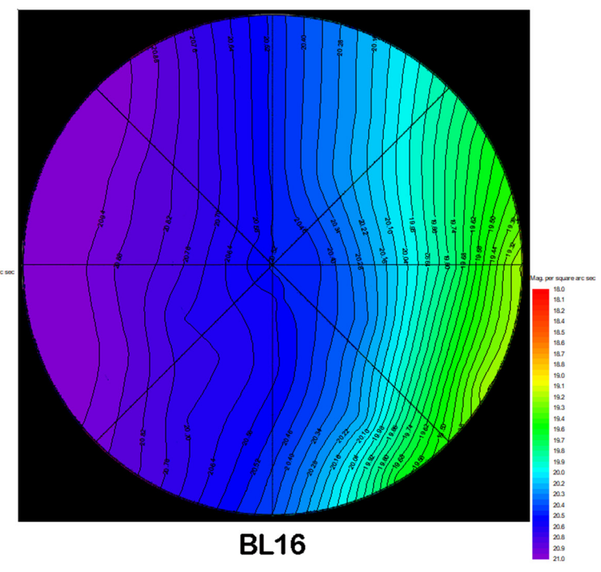
BL15

Sanap cliffs



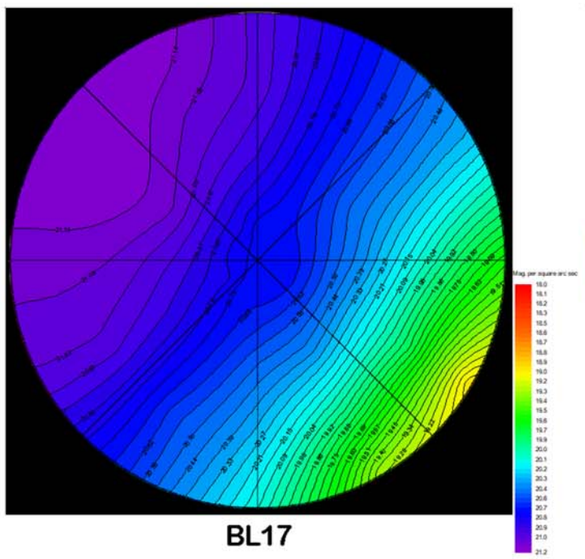
BL12

Comino Blue Lagoon



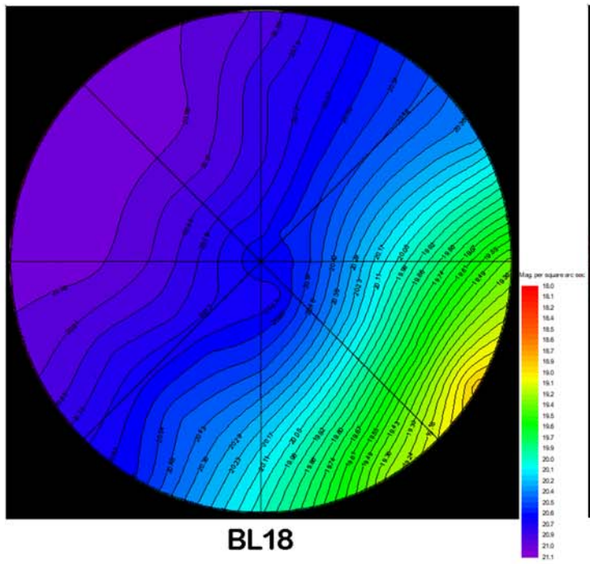
BL16

Ta’ Sarraflu



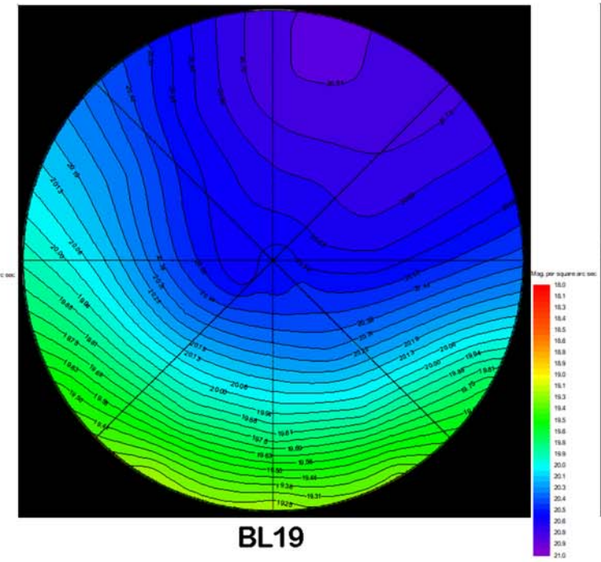
BL17

San Lawrenz



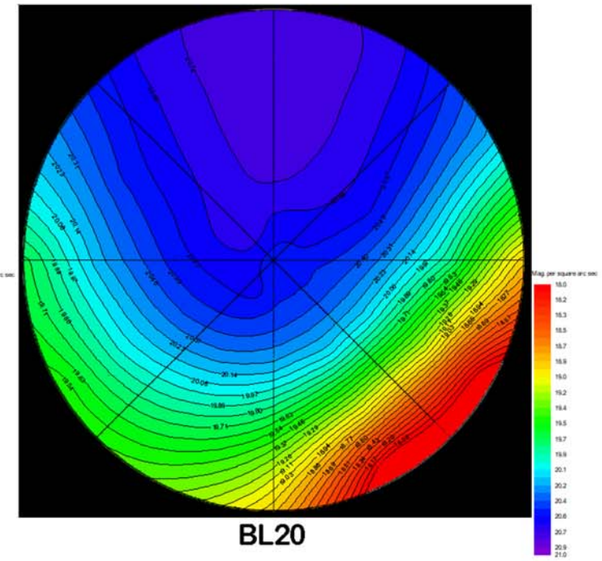
BL18

Wied ir-Raħeb



BL19

Għajn Barrani



BL20

Il-Qortin ta’ Isopu

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