

Environmental Impact Assessment

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Maldives: Greater Malé Waste-to-Energy Project – Waste to Energy Plant (Part B)

Main Report

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Design and Pre-construction Phase Noise Level Measurements

200. Ambient noise level measurements were conducted in 2022 (November and December) and in 2023 (January, February and March) in the same five sampling stations identified in Table 32 above. Thilafushi is considered an industrial area and the EPA has no noise level standards, thus, results of ambient noise level measurements were referred to the WB-IFC EHS Guidelines April 2007 (Table 1.7.1) of 70 dBA for both daytime and nighttime. Hourly noise levels were measured during daytime and nighttime using a handheld sound level meter, BK Precision Sound Level Meter 732A. At each sampling station, hourly 7-8 readings are recorded for a duration of 30-50 seconds. Minimum, maximum and average of ambient noise level in dB(A) were recorded and the average noise level at each location is given in Table 35. Results show that noise levels in all the sampling stations are below the limit of 70 dB(A) for industrial area. Compared to the ambient noise levels measured on 25 August 2019 in the same sampling stations from the EIA (July 2020), the results in November and December 2022 were lower which may be attributed to the extent or level of commercial and industrial activities at the time of measurements. Results of noise level measurements in January, February and March 2023 are within the limit of 70 dB(A) set by WHO for industrial area. The complete results of noise level measurements are given in Appendix 23.

Table 35: Noise Level Measurements in 2022

Station	Measured from 5-6 November 2022		Measured from 27-29 December 2022	
	Noise level (dBA) daytime	Noise level (dBA) nighttime	Noise level (dBA) daytime	Noise level (dBA) nighttime
NQ1	59	36.87	57.63	50.95
NQ2	43.59	23.24	53.40	51.60
NQ3	39.22	30.17	55.0	53.10
NQ4	46.89	24.28	53.16	44.13
NQ5	40.75	31.52	47.30	35.90
WHO Guidelines Value for Noise Levels Measured Out of Doors (One Hour LAeq in dBA) Source: Guidelines for Community Noise. WHO. 1999	70	70	70	70

4. Groundwater Quality

201. On 2 April 2019, groundwater samples were collected from eight wells in Thilafushi. See Figure 85 below for the locations of these wells. These wells include four old wells (GW1 – GW4) and four freshly dug wells (GW5 – GW8).

Figure 83: Groundwater Sampling Stations



202. For each location, the samples were collected from mid-water level in clean two 500 ml PET bottles and one 250 ml glass bottle, after rinsing with water from the sampling points. For microbial tests, samples were collected in 300 ml sterile bags.

203. Samples for microbiology testing were stored in an icebox and transferred to MWSC Quality Assurance Laboratory for testing. Other samples were sent to Sri Lanka (at Bureau Veritas laboratory) for testing. All groundwater samples were tested for conductivity, pH, salinity, temperature, turbidity, chloride, total dissolved solids (TDS), total coliform, heavy metals (As, Mn, Fe, Pb, Hg, Cd), ammonia, nitrates, oil and grease, and polynuclear aromatic hydrocarbons (PAH). The results of these laboratory tests are shown below in Table 36. Copies of laboratory analyses are in Appendix 10.

204. Based on the analysis, water samples collected did not comply with parameters on coliform, total dissolved solids (TDS), iron (Fe), and manganese (Mn) based on the National Drinking Water Quality Standards (NDWQS). Therefore, if not treated, the groundwater is not an acceptable source of drinking water.

205. Additional groundwater quality monitoring and sampling activities shall be undertaken by the DBO Contractor during the detailed design phase of the project to establish better and more robust baseline data. The DBO Contractor shall include results of laboratory analyses from these groundwater sampling activities in the updating of the EIA report during the detailed design phase.

206. **Design and pre-construction sampling.** In July 2022, groundwater sampling was conducted to establish the baseline at this stage. Sampling was done from the same locations identified in the EIA (July 2020). However, following the GPS locations, some of the sampling sites were no longer accessible or may have been changed by the developments in Thilafushi. Original location of GW5, which is in the WAMCO site, was paved and a new location has been identified within the southeast corner of the WAMCO premises, about 67 m south of the original location. This new sampling location for GW5 was identified after consultations with the PMU and

WAMCO in September 2022. Similarly, for GW3 and GW2, new locations have been identified by the PMU through consultations with the Housing Development Corporation, Ltd. (HDC). The new location of GW2 is in the souvenir marine, 94 m west of the original location while the new GW3 is in the STO Gas premises, about 47 m northeast of its original location. With the changes in the location, groundwater samples were collected only from GW1, GW4, GW6, GW7, and GW8 in July 2022 and in September 2022, samples were collected from GW2, GW3 and GW5. Figure 86 shows the location of the original groundwater sampling stations as well as the new sampling stations for GW2, GW3 and GW5.

207. **Method of sampling.** Water samples were collected from mid-water level in clean two 1.5 liter (L) PET bottles and one 1 L glass bottle for GW3, GW4, GW6, GW7, GW8 and one 1.5L PET bottle, one 8000 ml glass bottle and 750 ml glass bottle for GW1, GW2, GW5 after rinsing with water from the sampling stations. In-situ measurements of pH, temperature, DO and EC was conducted using a handheld Hach SensION +MM156 water quality measurement meter. For microbial tests, samples were collected in sterile glass bottles and tested in the MWSC laboratory.

208. Samples for testing were stored at appropriate temperature (about 6°C) in iceboxes and transferred to Sri Lanka (at Bureau Veritas laboratory) within 16 hours from taking samples for testing. Samples collected for testing in MWSC were also kept in iceboxes and submitted to the laboratory within 12 hours of taking the sample. All groundwater samples were tested for conductivity, pH, salinity, temperature, turbidity, chloride, TDS, total coliform, heavy metals (As, Mn, Fe, Pb, Hg, Cd), ammonia, nitrates, oil & grease, and polynuclear aromatic hydrocarbons (PAH). On 28 November 2022, groundwater sample was not collected from GW5, located in the WAMCO site, as there was no water at the time of sampling. GW5 was filled with sediments and suggests that the groundwater well may not have been properly constructed/installed. GW5 was constructed by Maldives Transport and Contracting Company (MTCC) and assigned to the DBO Contractor to obtain samples for environmental monitoring. Given this situation, a new groundwater well needs to be constructed for environmental monitoring. Another sampling was done in February 2023.

209. Results show that GW2 is consistently high in chloride and electrical conductivity suggesting saline water intrusion. All the eight groundwater quality sampling stations indicate the presence of total coliform. Results of analyses done to water samples collected did not comply with parameters on coliform, TDS, iron, and manganese based on the NDWQS. Thus, groundwater, if not treated, is not an acceptable source of drinking water. Water sampling for construction on 13 March 2023 also show high level of electrical conductivity, and thus, will not be used for drinking. Groundwater quality results are shown in Table 37 while Table 38 gives the results of in-situ measurements.

Figure 84: Groundwater Sampling Station, 2022



Table 36: Groundwater Quality Test Results

Parameters	Results								LoQ	Unit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8			
Date of Sampling: 2 April 2019											
Physical Appearance	Clear	Pale brown with particles	Pale yellow with particles	Pale yellow with particles	Olive green with particles	Olive green with particles	Yellow with particles	Cloudy and opaque	-	-	-
Chloride	183	1715	7200	470	3125	6325	6125	1005	-	mg/l	In-house Method (Adapted from M926 Chloride analyzer)
Nitrate*	1.7	6.1	5	7.5	25.5	34.5	12.2	3.4	-	mg/l	Method 8171(Adapted from HACH DR5000)
Phosphate*	0.07	0.23	0.21	<0.05(Lo Q)	0.46	0.57	2.27	0.72	0.05	mg/l	Method 8048(Adapted from HACH DR5000)
Total Coliforms	>2420	291	>2420	1986	>2420	10	>2420	4	-	mg/l	Colilert®-18/Quanti-Tray®2000
Turbidity*	1.3	4	0.6	0.4	151	177	1845	348	-	NTU	APHA 23rd ed: 2017: 2130 B
pH at 25°C*	7.3	7.2	7.4	8	7.1	6.7	7.9	7.8	-	mg/l	APHA 23rd ed: 2017: 4500H+
Iron (as Fe) *	0.4	3.9	0.6	ND	5.9	5.7	0.7	0.4	-	mg/l	APHA 23rd ed: 2017: 3125 B
Manganese (as Mn)	0.02	0.09	0.006	ND	0.2	0.3	0.01	0.07	-	mg/l	APHA 23rd ed: 2017: 3125 B
Arsenic (as As)	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
Total Dissolved Solids*	794	4020	12946	1003	6155	11554	11327	2188	-	mg/l	APHA 23rd ed: 2017: 2540 C
Electrical Conductivity at 25°C*	1.39	7.39	20.6	1.87	12.3	25	18.7	3.8	-	mS/cm	APHA 23rd ed: 2017: 2510 B
Cadmium (as Cd)*	ND	ND	ND	ND	ND	ND	ND	ND	0.0001	mg/l	APHA 23rd ed: 2017: 3125 B
Lead (as Pb)"	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
Mercury (as Hg)	ND	ND	ND	ND	ND	ND	ND	ND	0.00005	mg/l	APHA 23rd ed: 2017: 3125 B
Polynuclear Aromatic Hydrocarbons*											

Parameters	Results								LoQ	Unit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8			
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD-AN-00576
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[a]anthracene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[a]pyrene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[e]pyrene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Indeno[1,2,3-cd]pyrene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Dibenzo [a,h]anthracene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[g,h,i]perylene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[b]fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[j]fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[k]fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	1	µg/l	CPSD -AN-00576

Table 37: Results of Groundwater Sampling, 2022

Parameters	Date of Sampling: 28 November 2022								LoQ	Unit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8			
Physical Appearance	Clear with particles	Clear with particles	Pale yellow with particles	Pale yellow with particles		Clear with particles	Clear with particles	Clear with particles	-	-	Visual
BOD	3	3	3	-	-	6	3	4	-	mg/l	HACH Method 8043
Nitrate*	0.3	3.9	4.6	-	-	0.3	1	0.1	-	mg/l	HACH Method 8171
COD*				-	-				0.05	mg/l	HACH Method 8000
DO	8.87	8.92	9.07	8.2	-	8.6	9.02	8.81	-	mg/l	In-house Test method (Adapted from HACH BOD LDO® Probe (Model LBOD10101) manual)
Chloride	99	21,100	3,750	-	-	188	14	49	-		In-house Test method (Adapted from M926 Chloride analyzer Operation Manual)

Parameters	Date of Sampling: 28 November 2022								LoQ	Unit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8			
Sulphate	<10 (LoQ is 10 mg/L)	3,050	225			95	16	41			HACH Method 8051
Phosphate	0.15	0.10	0.32			0.15	0.23	0.06			HACH Method 8048
Turbidity*	0.4	0.2	0.3	0.1		0.5	2.8	0.5	-	NTU	APHA 23rd ed: 2017: 2130 B
pH at 25°C*	7.3	7.2	8.5	7.6		7.6	7.5	7.6	-	mg/l	APHA 23rd ed: 2017 :4500H+
Total Coliform	>2,420 (01/12/2022 15:00)	3 (01/12/2022 15:00)	>2,420 (01/12/2022 15:00)			>2,420 (01/12/2022 15:00)	>2,420 (01/12/2022 15:00)	>2,420 (01/12/2022 15:00)			Colilert®- 18/Quanti- Tray®@2000
Iron (as Fe) *	ND	ND	ND	ND		ND	0.02	ND	-	mg/l	CPSD-AN- 0581:2019-V15by ICP-MS
Manganese (as Mn)	ND	ND	ND	ND		0.018	ND	ND	-	mg/l	CPSD-AN- 0581:2019-V15by ICP-MS
Arsenic (as As)	ND	ND	ND	ND		ND	ND	ND	0.001	mg/l	CPSD-AN- 0581:2019-V15by ICP-MS
Total Suspended Solids*	ND	ND	ND	ND		6	38	13	-	mg/l	APHA 23rd ed: 2017: 2540 C
Electrical Conductivity at 25°C*	481	58,000	10,800	5,700		1,206	571	582	-	mS/cm	APHA 23rd ed: 2017: 2510 B
Cadmium (as Cd)*	ND	ND	ND	ND		ND	ND	ND	0.0001	mg/l	CPSD-AN- 00581:2019-V15by ICP-MS
Lead (as Pb)"	ND	ND	ND	ND		ND	ND	ND	0.001	mg/l	CPSD-AN- 00581:2019-V15by ICP-MS
Mercury (as Hg)	ND	ND	ND	ND		ND	ND	ND		mg/l	CPSD-AN- 00581:2019-V15by ICP-MS
Oil and Grease	ND	ND	ND	ND		ND	ND	ND		mg/l	APHA 23rd ed: 2017: 5520 B
Polynuclear Aromatic Hydrocarbons											
Naphthalene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Acenaphthylene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Acenaphthene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Fluorine	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Phenanthrene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576

Parameters	Date of Sampling: 28 November 2022								LoQ	Unit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8			
Anthracene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD-AN-00576
Fluoranthene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Pyrene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[a] anthracene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Chrysene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[a]pyrene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[e]pyrene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Indeno[1,2,3-cd]pyrene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Dibenzo [a,h]anthracene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[g,h,i]perylene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[b]fluoranthene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[j]fluoranthene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576
Benzo[k]fluoranthene	ND	ND	ND	ND		ND	ND	ND	1	µg/l	CPSD -AN-00576

Table 38: In-situ Groundwater Quality Testing, 30 November 2022

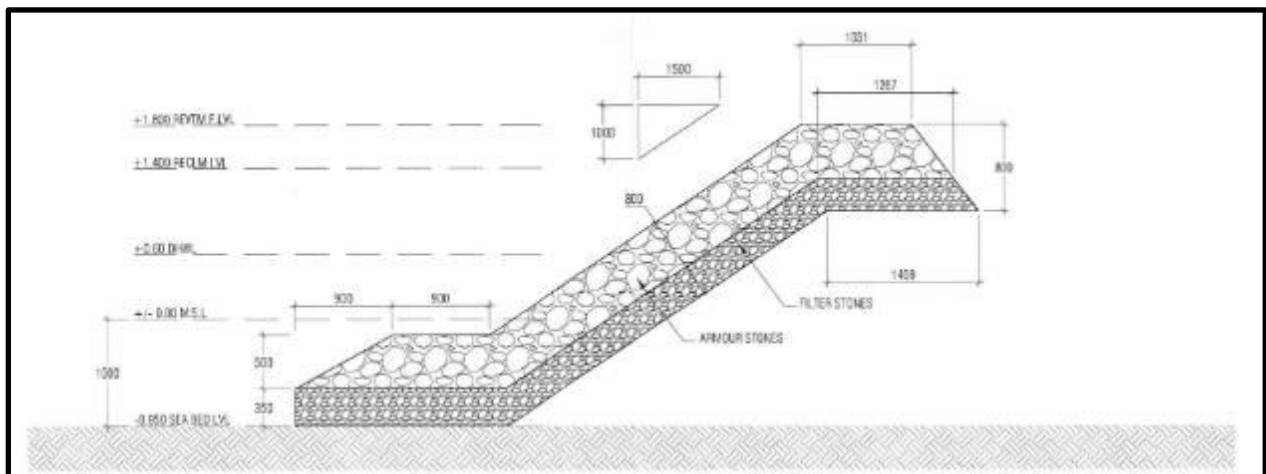
Parameter	Groundwater Quality Sampling Station							
	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8
pH	8.49	7.69	8.70	8.15	-	8	8.19	8.20
EC (µs/cm)	470	44500	10550	1514	-	1303	534	551
DO (mg/l)	8.87	8.92	9.07	8.2	-	8.6	9.02	8.81
Temperature °C	27.5	29.9	29.3	28.4	-	29.9	30.8	31.0

D. Coastal Environment

210. The coastal environment of the proposed site for the development RWMF is protected by coastal protection structures. 877 m long rock boulder revetment has been constructed on southern side to protect the reclaimed land while on northern side of the reclaimed land is protected with a 911 m long concrete quay wall. A section of the rock boulder revetment is shown in Figure 87 and Figure 88 shows the cross section of the quay wall.

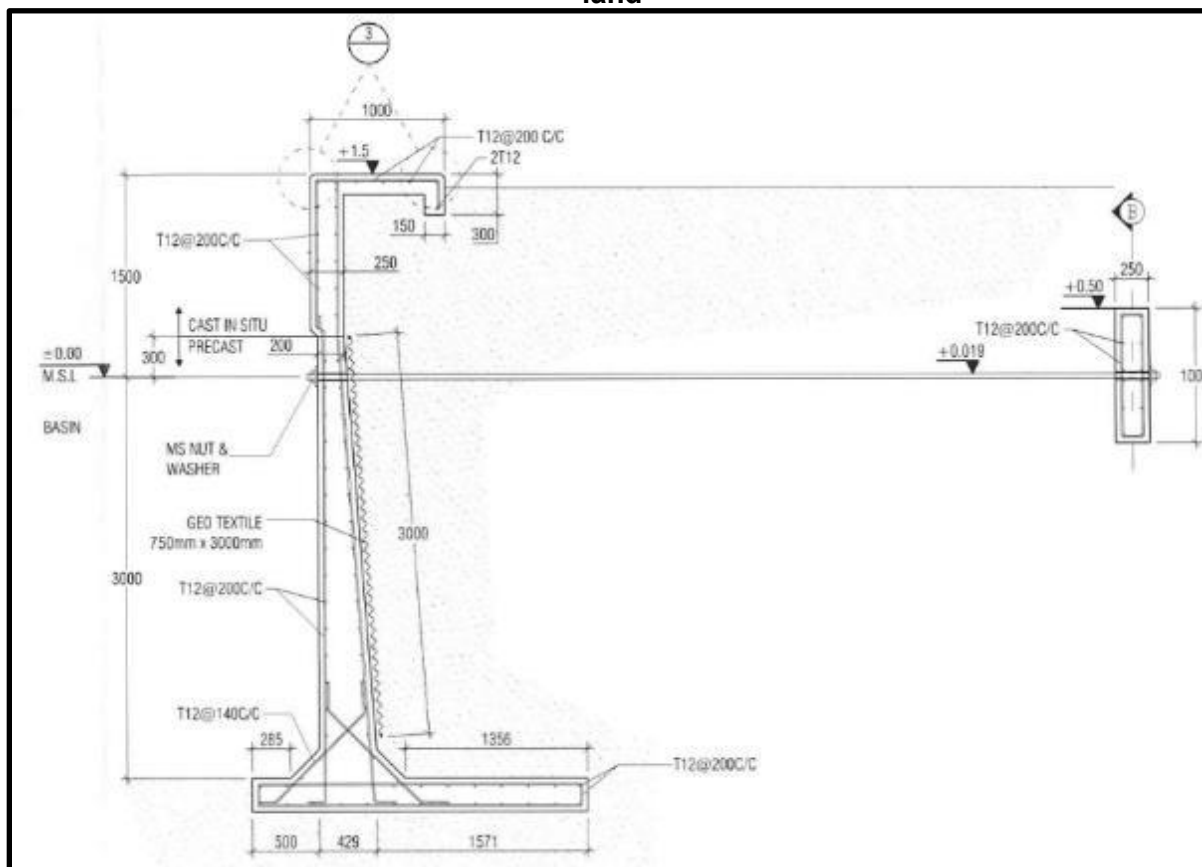
211. The revetment runs from the seafloor about -1m MSL to the crest level at MSL +1.8m. The slope of the revetment is 1 in 2 with rock boulders.

Figure 85: Design details of the rock revetment protecting the southern side of the reclaimed land



212. The quay walls are constructed with prefabricated reinforced concrete elements which are placed on the boundary of the reclaimed area. The elements are coupled by a capping beam as shown in Figure 88.

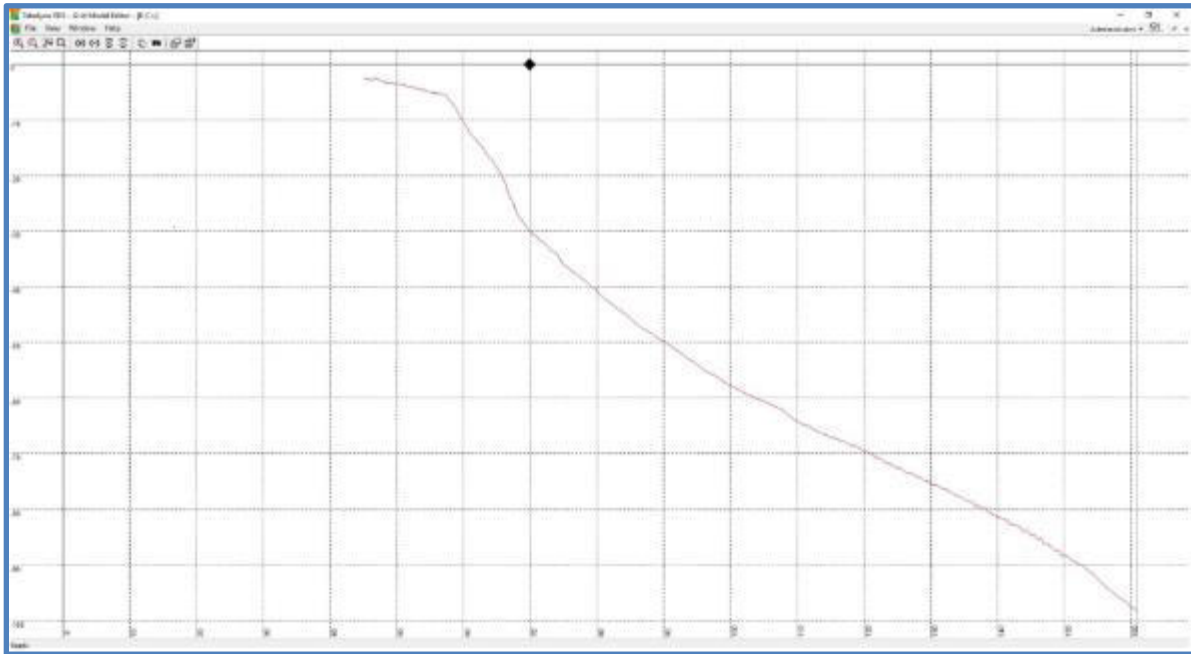
Figure 86: Design details of the quay wall protecting the northern side of the reclaimed land



1. Bathymetry

213. A detailed bathymetric survey of the southern side of Thilafushi reef system has been undertaken by PMU through its consultant, Water Solutions. The reef system of the Thilafushi Island comprises of an ocean ward reef flat, a lagoon ward reef and a central deep lagoon. The reef flat areas on the ocean ward side of the reef system (south of the proposed location) have a fairly flat depth ranging from -1.0 m to -1.5 m MSL. The reef system hosting Thilafushi does not host any other islands. The reef system is approximately 4.65 km long, 0.94 km wide (width of ring reef, including the lagoon area). The profile of this ocean-ward side of the reef system is shown in Figure 89 below.

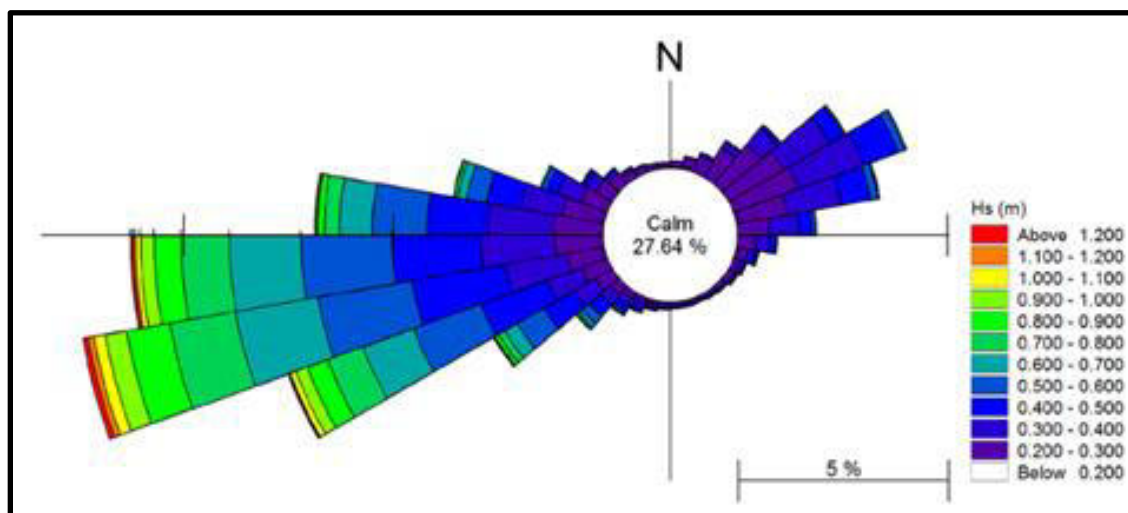
Figure 87: Bathymetry of the Reef System at Southern Side of Proposed Project Site



2. Hydrology

214. **Wave.** Two major types of waves have been reported on the coasts of the Maldives: waves generated by local monsoon wind and swells generated by distance storms. The local monsoon predominantly generates wind waves which are typically strongest during April-July in the southwest monsoon period. During this season, swells generated north of the equator with heights of 2m-3 m sustained for periods of 18-20 seconds have been reported in the region. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves. Thilafushi Island is exposed to wind generated waves during NE monsoon and during transition periods. It is also expected to experience swell waves throughout the year. The southern side is likely to experience residual swell waves approaching from the Southwest and direct swell waves approaching from the SE (Naseer, 2003). LHI (2018) reported maximum significant wave height observed was over 1.2 m based on the field measurements that were taken in the Thilafushi reef system. Figure 90 graphically illustrate the wave height distribution pattern in terms of direction, occurrence and height.

Figure 88: Annual Wave Height Distribution



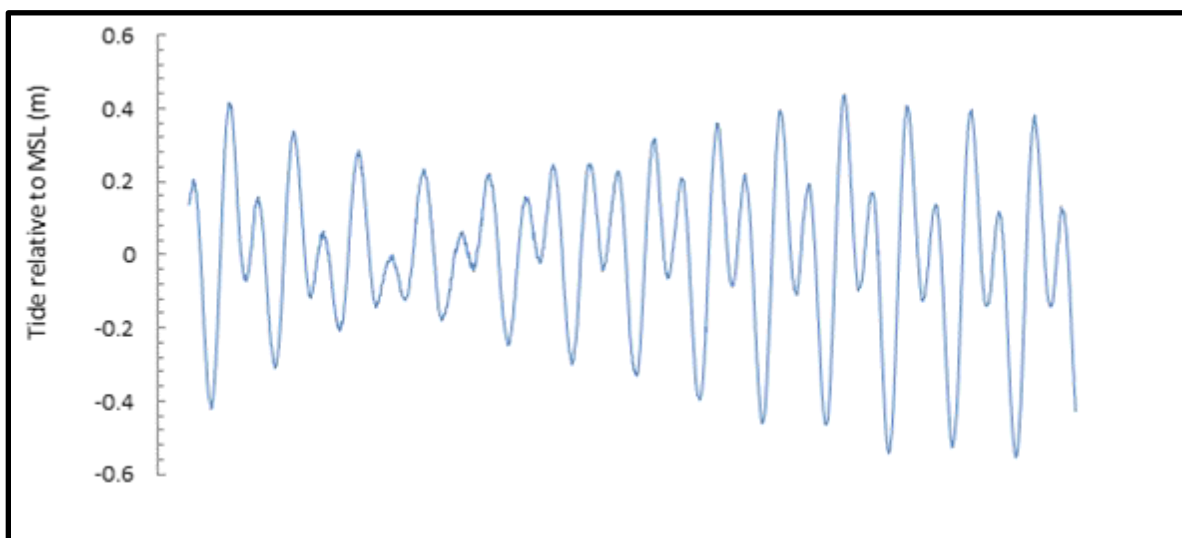
(Source: LHI, 2018)

215. Distant cyclones and low-pressure systems originating from the intense South Indian Ocean storms are reported to generate long distance swells that occasionally cause flooding in the Maldives. The swell waves that reached Malé and Hulhule in 1987 are thought to have originated from a low-pressure system off the west coast of Australia and had significant wave heights in the order of 3 meters.

216. In addition, the Maldives have been subject to earthquake generated tsunami reaching heights of 4.0 m on land (UNEP, 2005). Historical wave data from the Indian Ocean countries show that tsunamis have occurred in more than 1 occasion, most notable been the 1883 tsunami resulting from the volcanic explosion of Krakatoa (Choi and others, 2003) as well as the Indian Ocean tsunami of 2004.

217. The proposed site is located away from the ocean-ward side and protected on the atoll lagoon with the presence of land. The proposed land for the development of the RWMF is unlikely to be affected by wave activity provided the proposed coastal protection measures for the reclaimed land would be undertaken as planned.

218. **Tide.** The tide observed in Maldives can be classified as a mixed diurnal tide. The tidal variations are small and the average tidal range in Maldives is approximately 1 m (MEE, 2016). The variations of the tidal levels for the respective stations are given in the Figure 91. Tide affects wave conditions, wave generated and other reef-top currents. Tide levels are believed to be significant in controlling the amount of wave energy reaching the island, as no wave energy crosses the edge of the reef at low tide under normal conditions. In the Maldives where the tidal range is small (1 m), tides may have significantly important influence on the formation, development and sediment movement process around the island tides also may play an important role in lagoon flushing, water circulation within the reef and water residence time within an enclosed reef highly depends on tidal fluctuations.

Figure 89: Tide observed in Malé is mixed diurnal in nature

219. Tide data is important information in any coastal development project as it determines the elevation of the structures relative to a datum. A permanent tidal record station has been established at Velana International Airport by Maldives Meteorological Service. The maximum tidal range recorded at this tide station is 1.2 m. The highest astronomical tide level is +0.62 m (MSL) and lowest astronomical tide level is -0.72 m MSL. Table 39 gives a summary of the tide levels for the tide datum has been widely used in Maldives.

Table 39: Summary of the Tide Levels Hulhule Island, Male Atoll

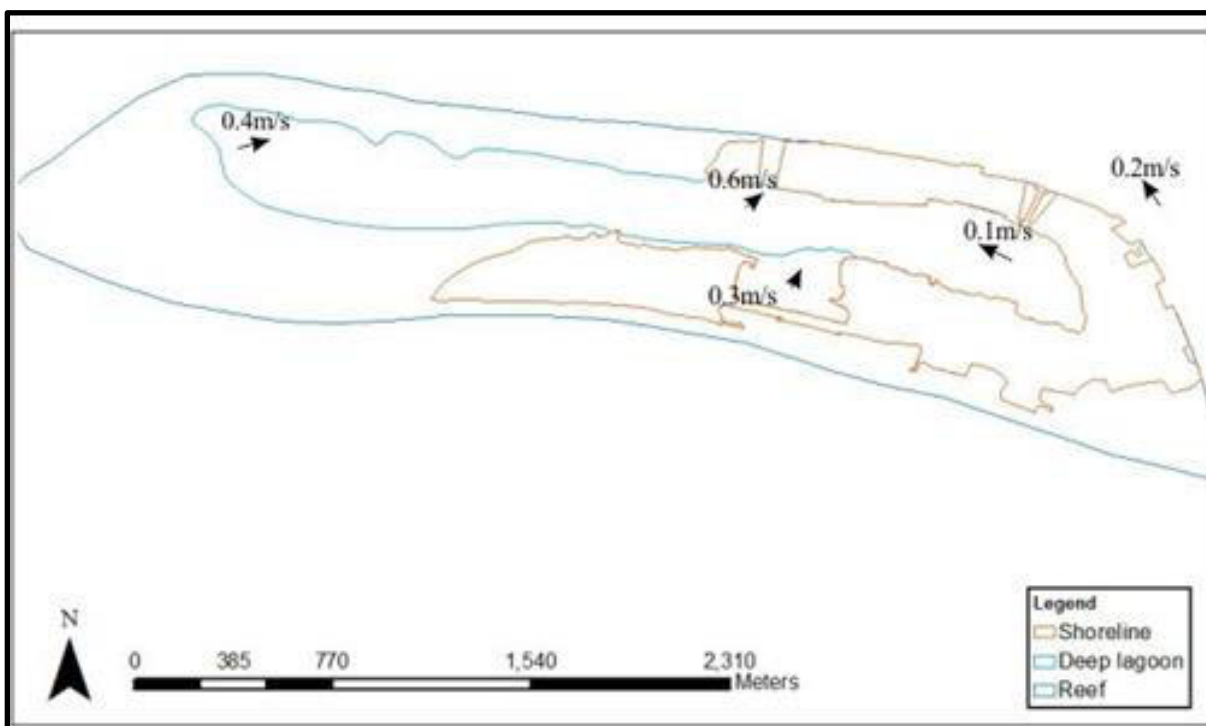
Water level from MSL (m)	Malé (2007-2011)
Highest High water (HHW)	0.62
Mean Highest High water (MHHW)	0.34
Mean High water (MHW)	0.33
Mean Low water (MLW)	-0.36
Mean Lowest Low water (MLLW)	-0.37
Lowest Low water (LLW)	-0.72

Source: MEE (2016).

220. **Surface Currents.** Currents that affect the reef system of Thilafushi can be caused by tidal currents, wind-induced currents and wave-induced currents. Generally current flow through the country is defined by the two-monsoon season winds. Westward flowing currents are dominant from January to March with the change in current flow pattern taking place in April and December. In April the westward currents become weak while the eastward currents start to take over. In December the eastward currents are weak with the westward currents becoming more prominent. Hence, currents within the site are very likely to be heavily influenced by the monsoons.

221. Current measurements were undertaken on the island in June 2017 during the field assessment phase. Generally, long term studies are required to establish the prevailing site-specific current patterns. However, due to time limitations of the present study a snapshot assessment was undertaken using drogue technique. The findings of the measurements are presented in Figure 92.

Figure 90: Measurement of Currents at the Reef System



222. The open ocean currents were generally slow during flood and ebb tides but increased closer to the Thilafushi channel during the flood tide. Current speeds within the lagoon showed a consistent average speed between 0.1 m/s - 0.2 m/s. This was mainly due to the blocked nature of the inner lagoon. The speed increased an average of 0.3 m/s close to the Thilafushi Channel.

223. **Sea Surface Salinity and Sea Surface Temperature.** Sea Surface Temperatures (SST) of Malé region, based on satellite derived measurements, generally vary between 28 and 29 (Singh et al, 2001). It was also reported in Addu Atoll (Stoddart, 1966). Singh et al. (2001) reported that there has been a gradual increase in SST in the order of +1.6°C per decade along the central regions of the Maldives. Salinity measurements in the open ocean and within the atoll lagoon of Maldives usually range between 33 - 35‰ (Stoddart, 1966). However, there is a slight salinity gradient observed on the reef flat, especially from the island coastline to the reef edge. This gradient is highest following heavy rainfall (Stoddart, 1966).

224. The results of the field assessment for SST and Salinity by CDE (2011) reported that the temperature values recorded were uniform across the sampling sites and depths in the Thilafushi reef system. Slight variations in salinity were observed between the outer reef and inner lagoon. The salinity was reported at 30.5 ‰ while the temperature was 23.1°C.

225. For the purpose of EIA, in situ testing was carried out for temperature and salinity changes at depth with the use of a Valeport mini sound velocity profiler (SVP). Although the SVP is designed to measure sound velocity with depth, the device also records temperature and computes salinity. As a result, it is possible to obtain conductivity, temperature and depth (CTD) profiles from the SVP. The purpose of the use of SVP's was to determine the temperature and

salinity fluctuations within the first 30 meters of the water column. Figure 93 and Figure 94 below outline the CTP profiles taken from the SVP.

Figure 91: CTD profiles obtained from water sample locations (SW1–SW4) (3rd July 2018).

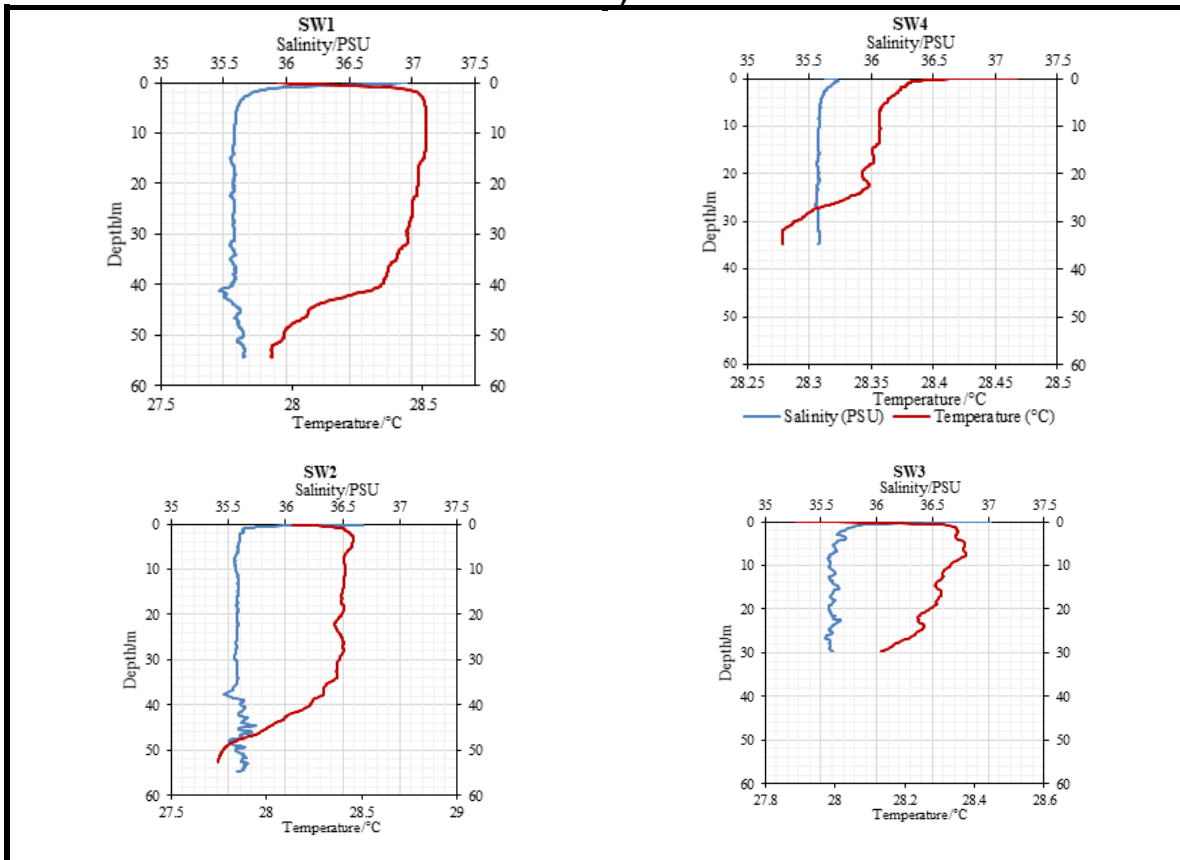
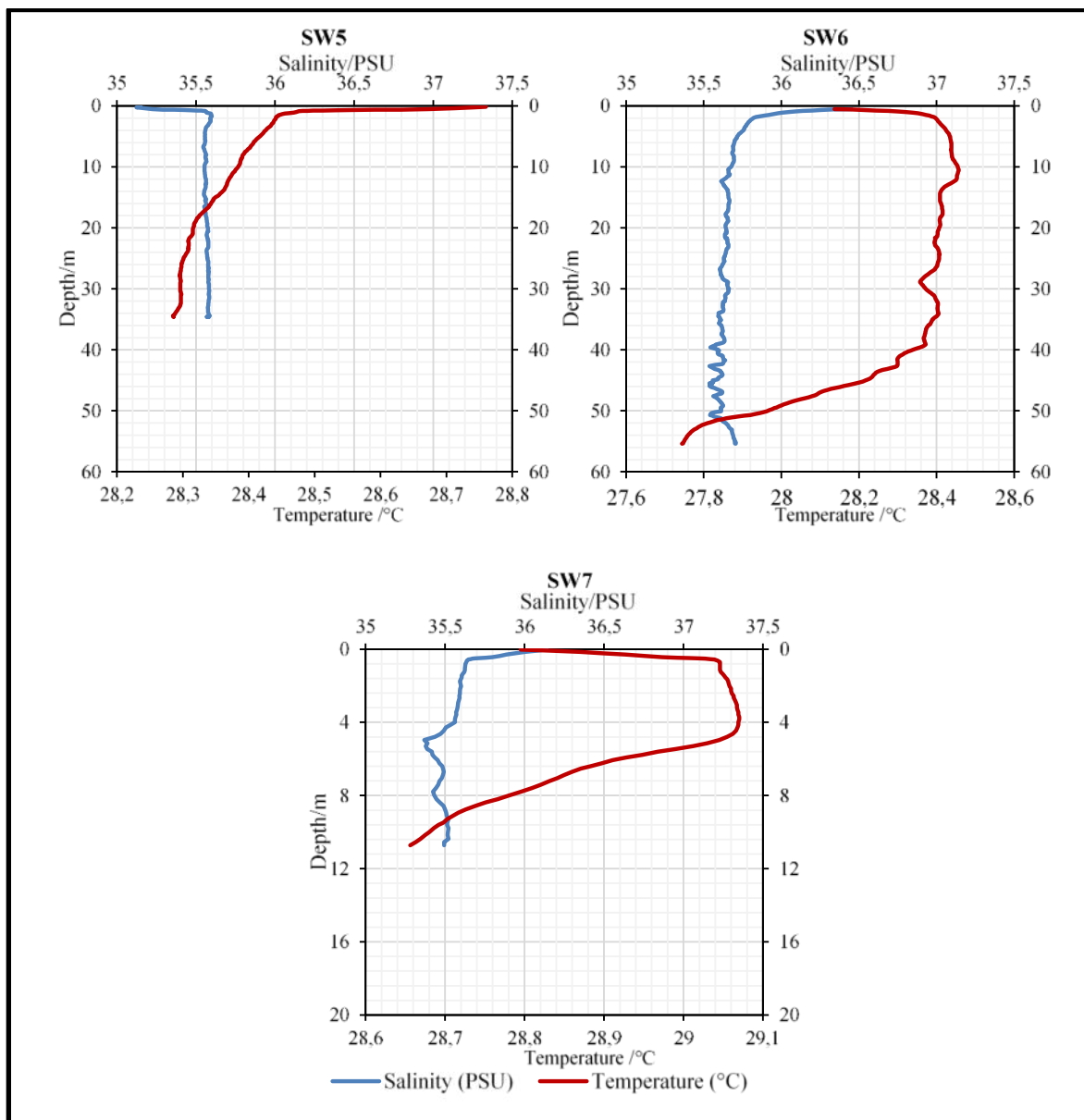


Figure 92: CTD profiles obtained from water sample locations (SW5 – SW7) (3rd July 2018).



226. Marine water quality. The primary objective of the marine water quality sampling was to determine the baseline conditions of the marine water around the project area. Qualitative and quantitative assessments were made on seawater from sites SW1 – SW7. Laboratory analysis were done for heavy metals (As, Cr, Cu, Ni, Pb, Zn, Hg, Cd), ammonia, nitrates, pH, turbidity, oil and grease and BOD. BOD was analyzed in MWSC, Malé. The remainder of the parameters were tested at Bureau Veritas laboratory, Sri Lanka. Table 40 presents the results of the laboratory tests while Figure 95 shows the sampling stations. These results show compliance with the Maldives Marine Monitoring Standards. Copies of the laboratory analyses are consolidated in Appendix 11.

227. Quarterly marine water quality data gathering at these sampling locations or sites shall be undertaken strategically during the design phase of the project. The DBO Contractor shall:

- (i) undertake marine water quality measurements for each season of the year at the identified sampling locations or sites used in this EIA report (and any other locations as may be deemed by the DBO Contractor as important sampling locations or sites);
- (ii) follow required sampling methodology per requirements of the Maldives EPA; and
- (iii) include results of analyses in the updating of the EIA during the detailed design phase.

228. **Additional baseline data gathering for marine water quality.** Marine water quality sampling was done on 29 November 2022 and on 15 February 2023 from the same seven locations identified in the EIA (July 2020) given in Figure 96 below. Laboratory analysis of marine water was done by the Bureau Veritas Laboratory, Sri Lanka for the following parameters - heavy metals (As, Cr, Cu, Ni, Pb, Zn, Hg, Cd), ammonia, nitrates, pH, turbidity, salinity, five-day biochemical oxygen demand (BOD)₅, and oil and grease (see Table 41). The samples were brought to Sri Lanka and delivered to the laboratory within 24 hours from the field sampling. All the samples are kept in ice boxes to maintain the appropriate temperature and to conserve the samples. In-situ recording of pH, temperature, dissolved oxygen (DO), and electrical conductivity (EC) for each sample was conducted by using a handheld Hach SensION +MM156 water quality measurement meter. Results were referred to the available limits from the Great Barrier Reef Marine Park Authority (GBRMPA, 2009) which showed that biochemical oxygen demand (BOD) are higher than the limit of 2 mg/liter (L) in all the seven stations.

Figure 93: Marine Water Quality Sampling Locations

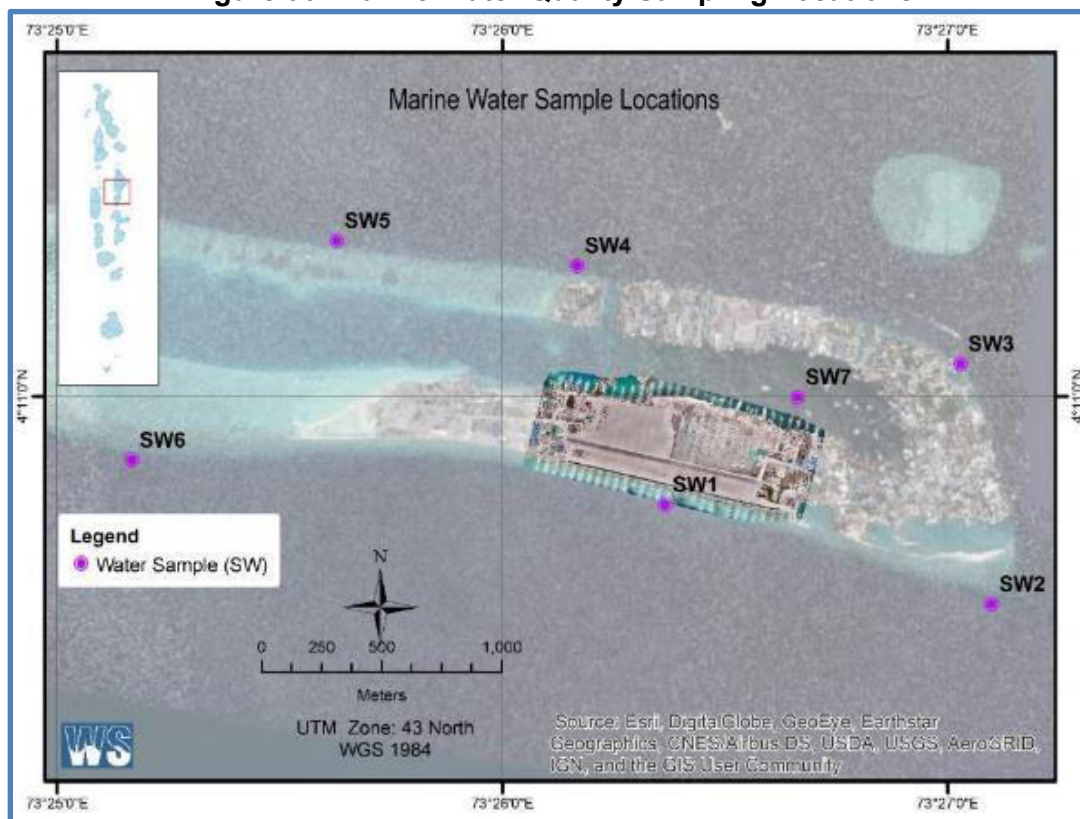


Table 40: Water quality results from sites SW1 to SW7

Parameters	Sites Date of Sampling: 03 July 2018							LOQ ²⁴	Unit	Test Method	Corresponding Maldivian Marine Monitoring Standard	
	SW1	SW2	SW3	SW4	SW5	SW6	SW7				Parameter	Reference
Temperature at receiving (°C)	24.2	24.2	24.2	24.2	24.2	24.2	24.2	-	°C	APHA 20 th Edition – 2250B	18 – 32 °C	GBRMPA, 2009 ²⁵
Biological Oxygen Demand (BOD)	1	1	1	1	< 1 LoQ 1 mg/l	< 1 LoQ 1 mg/l	< 1 LoQ 1 mg/l	< 1 mg/l	mg/l	HACH Method 8043	<2mg/l	
Turbidity	0.3	0.2	0.1	0.2	0.3	0.2	0.2	-	NTU	APHA 2130 B	3 – 5 NTU (max)	
pH at 24°C	8.4	8.4	8.4	8.4	8.4	8.4	8.2	-	-	FD-MTHD-007:2013 Reference to APHA 4500H+	8 – 8.3	
Nitrate (NO ₃ ⁻)	0.3	0.4	0.4	0.4	0.5	0.3	0.5	-	mg/l	APHA 4500 – NO ₃ -E	< 5mg /l	
Oil & Grease	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.0	mg/l	FD-MTHD-032:2013 Reference to APHA 5520B	n/a	
Free Ammonia (NH ₃)	0.05	<0.02	<0.02	<0.02	0.05	0.05	<0.02	-	mg/l	SLS 614 Appendix A:2013	2 – 3 mg/l (max)	
Salinity	36	37	37	37	36	37	36	-	ppt	Alpha 2520	32 – 42 ppt	GBRMPA, 2009
Heavy Metals												
Arsenic (As)	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l	CPSD-AN-00581-MTHD with ICP-MS	n/a	
Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	0.0001	mg/l		n/a	
Lead (Pb)	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l		n/a	
Mercury (Hg)	ND	ND	ND	ND	ND	ND	ND	0.00005	mg/l		n/a	
Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l		n/a	
Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l		n/a	
Zinc (Zn)	ND	0.003	0.004	ND	ND	0.003	0.008	0.001	mg/l		n/a	
Chromium (Cr)	ND	ND	ND	ND	ND	ND	ND	0.001	mg/l		n/a	

²⁴ Limit of Quantitation: the lowest concentration of the contaminant that can be reliably measured.

²⁵ Great Barrier Reef Marine Park Authority (2009) Outlook Report 2009

Table 41: Results of Marine Water Sampling, 2022

Parameters	Sampling Location														LOQ ¹	Unit	Corresponding Standard/GBRMPA, 2009
	Date of Sampling –29 November 2022																Parameter
	SW1	BL	SW2	BL	SW3	BL	SW4	BL	SW5	BL	SW6	BL	SW7	BL			
Temperature at receiving (°C)	29.4	24.2	28.7	24.2	28.9	24.2	28.9	24.2	29.6	24.2	29.3	24.2	30.1	24.2		°C	18-32
BOD	2	1	2	1	2	1	1	1	2	<1	3	<1	2	<1	<1	mg/L	<2 mg/L
DO	7.24		7.03		7.14		7.01		7.03		7.02		7.1		-	mg/l	NA
TSS	4		3		6		6		3		3		8		-	mg/L	NA
pH at 24°C	8.56	8.4	8.52	8.4	8.51	8.4	8.49	8.4	8.41	8.4	8.55	8.4	8.30	8.2	-	-	8-8.3
Nitrate	0.3	0.3	0.5	0.4	0.3	0.4	0.3	0.4	0.3	0.5	0.4	0.3	0.4	0.5	-	mg/L	<5 mg/L
Oil and grease	ND	<2	ND	<2	ND	<2	ND	<2	ND	<2	ND	<2	ND	<2	2	mg/L	NA
Free Ammonia	ND	0.05	ND	<0.02	ND	<0.02	ND	<0.02	ND	0.05	ND	0.05	ND	<0.02	-	mg/L	<2-3 mg/L
Salinity	35	36	35	37	36	37	36	37	35	36	33	37	36	36	-	ppt	32-42
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0001	mg/L	NA
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00005	mg/L	NA
Nickel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA
Copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	mg/L	NA

¹Limit of Quantitation (LOQ) is the lowest concentration of the contaminant that can be reliably measured.

BL – from EIA (July 2020), Table 29: Water quality results from sites SW1 to SW7

229. **Sediments.** The sediment regime around the present waste disposal area is likely to reflect the leaching of pollutants from the dumped wastes at the Thilafushi Island. As unplanned dumping of wastes on this island has the potential to contaminate sediments of the inner lagoon and outer reef flat area, six sampling stations were selected to get a representative status of the extent of contamination of the sediments due to the current waste disposal methods (see Figure 96). Results of sediment analysis show heavy metal contents (cadmium, lead, zinc, copper, chromium, nickel, mercury, arsenic) are below the trigger values. Table 42 presents the results while Figure 97 shows the sediment sample at Inner Lagoon.

Figure 94: Sediment Sample Locations

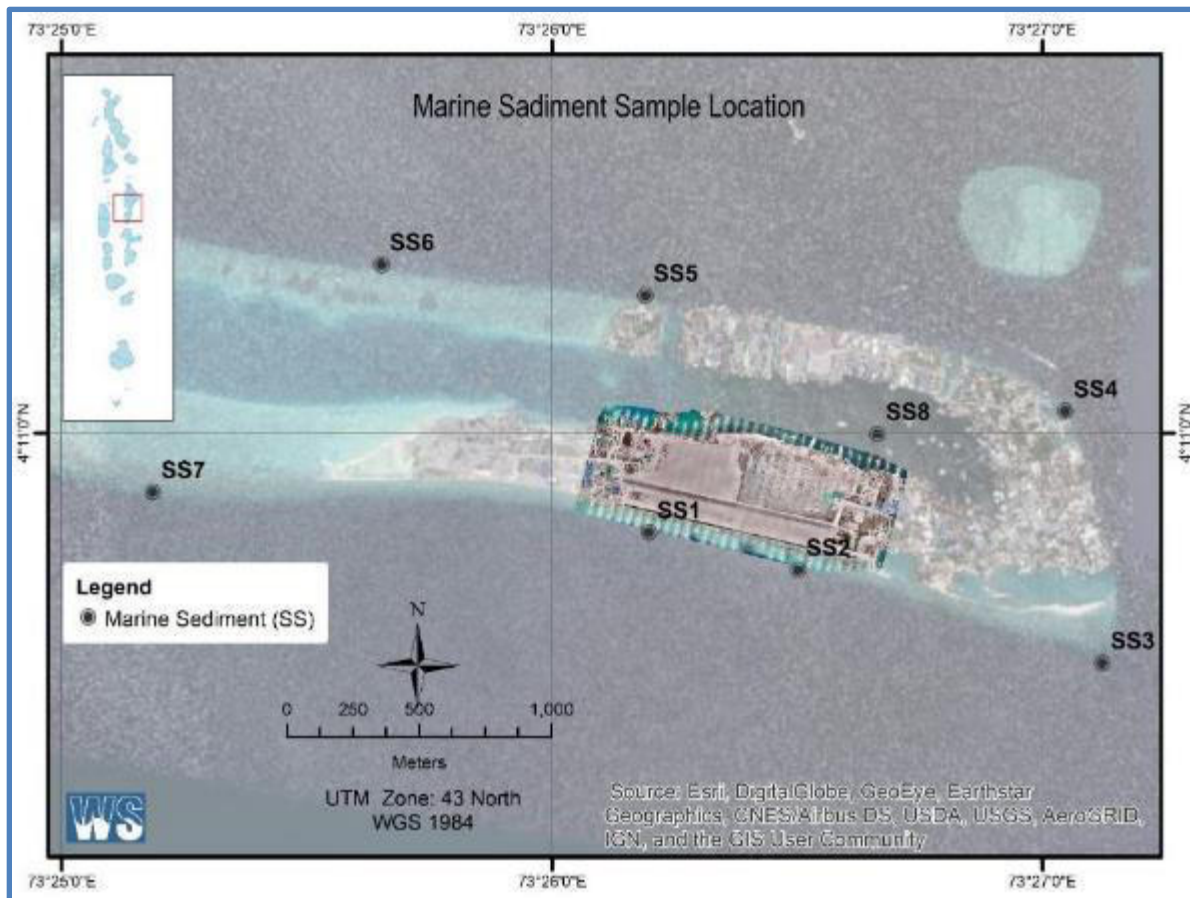


Figure 95: Sediment Grab and Sediment Sample from Inner Lagoon (SS8)



Table 42: Sediment chemical properties from sites SS1 to SS8

Test	Unit	Test method	Date of Sampling: 23 – 24 April 2018								Limit of Determination	Trigger Value ²⁶
			SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8		
Cadmium (Cd)	mg/kg	Microwave Digestion/ Detection by ICP-Md	ND	ND	ND	ND	ND	ND	0.06	0.07	0.05	1.5
Lead (Pb)	mg/kg		0.06	ND	ND	4.0	0.6	0.3	ND	8.2	0.05	50
Zinc (Zn)	mg/kg		ND	ND	ND	ND	ND	ND	0.3	10.6	0.05	200
Copper (Cu)	mg/kg		ND	0.3	0.1	2.7	0.08	0.6	0.3	15.9	0.05	65
Chromium (Cr)	mg/kg		0.2	0.4	0.4	1.7	0.3	0.4	ND	2	-	80
Nickel (Ni)	mg/kg		ND	ND	ND	ND	ND	ND	ND	ND	0.05	
Mercury (Hg)	mg/kg		ND	ND	ND	ND	ND	ND	ND	ND	0.05	
Arsenic (As)	mg/kg		0.2	0.2	0.2	1.1	0.2	0.2	0.2	1.0	-	20
Polycyclic aromatic hydrocarbons (PAH)	-	-	-	-	-	-	-	-	-	-	-	

Note: ICP – MS – Inductively Coupled Plasma Mass Spectrometry/ND: Not Detected.

²⁶ Trigger values, values below which it is unlikely that there will be any biological disturbance for organisms inhabiting the sediment. Values used are those published by the Australian and New Zealand Environment Conservation Council (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality National Water Quality Management Strategy Paper No. 4*

E. Biological Environment

230. The marine environment of Thilafushi consists of shallow lagoon, deep lagoon, reef-flat, and reef slope areas. Thilafushi Island is situated on the southern rim of North Male 'Atoll near Gulhifalhu. Almost half of Thilafushi lagoon is now reclaimed. The deep lagoon area is used as a mooring basin.

1. The Lagoon and Reef System

231. Thilafushi consists of deep, shallow lagoon, reef flat and reef slope areas. More than half of the shallow lagoon or reef flat area is now reclaimed. The south wing of Thilafushi is wider compared to north wing. The widest reef flat area is on the south wing on the west side of the reef. The enclosed deep lagoon area towards east is well protected with very restricted water movement. This area is used by vessels as a mooring basin. The stagnant water coupled with waste dumping in this area has degraded the lagoon environment on the east side. The deep lagoon of this area has very low visibility, the bottom substrate of the deep lagoon consists mainly of sand. Towards the east of deep lagoon, the bottom substrate is mainly mud and garbage debris.

232. A coral reef survey of Thilafushi reef was carried out to establish a baseline of the existing coral reef environment. The baseline assessment assessed the diversity and abundance of coral reef, fish, and significant invertebrates that are commonly associated with the reef environment of Maldives. The method involved determining percentage of various benthic substrate (categories) using standard benthic categories for coral reef benthic substrate sampling as described by Hodgson et.al (2006) in Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring.

233. **Benthic Survey of April 2018.** All surveys were carried out by underwater SCUBA diving. The marine surveys were carried out by surveyors who had been trained to undertake Reef Check surveys as outlined in the Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring (2006). Based on the Guide to Reef Check Coral Reef Monitoring (2006) photo quadrat surveys were done in order to measure the benthic composition at 7 sites (M1 – M7) located on the outer reef around Thilafushi island. At each of the survey sites benthic composition and fish abundance was surveyed at depths of 5 meters and 10 meters. The inner lagoon was not surveyed as the area is not of ecological importance.

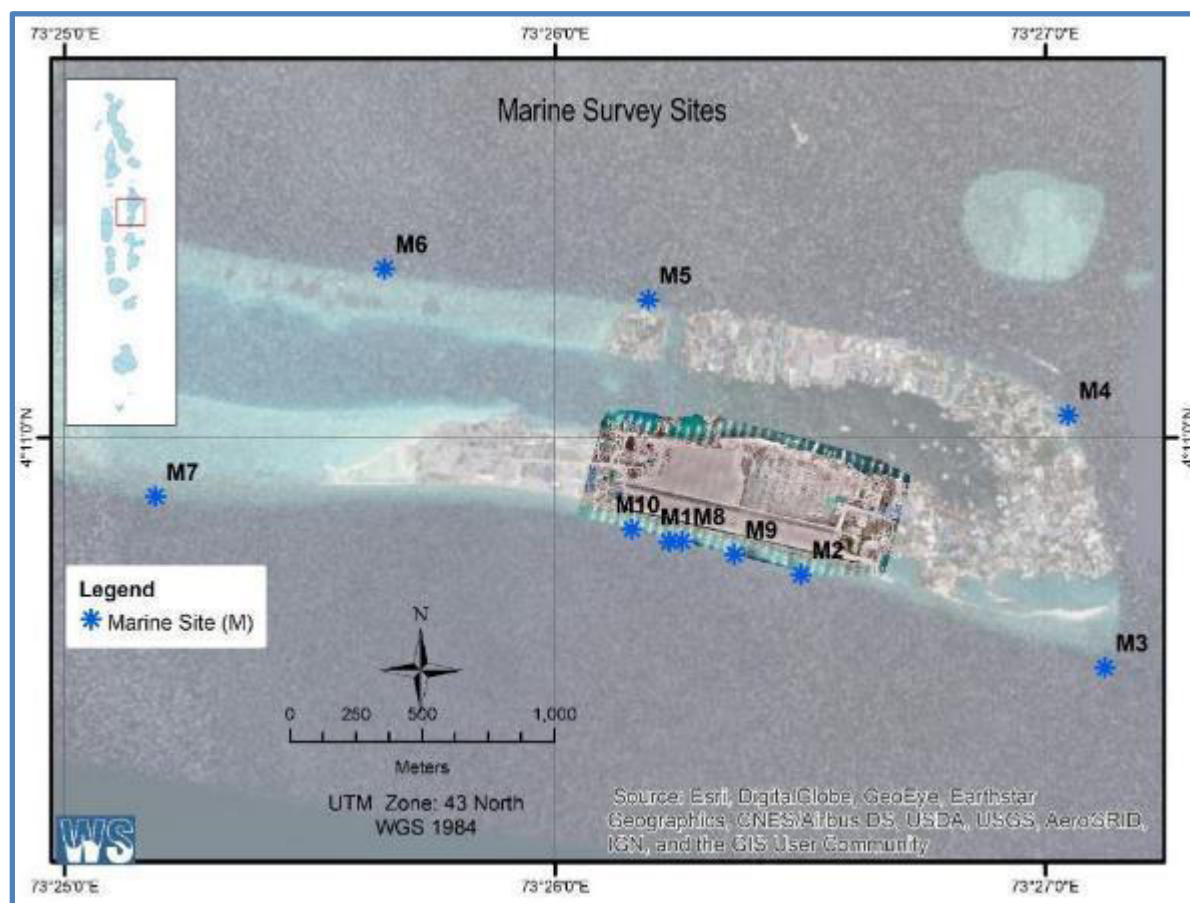
234. The photo quadrat surveys were undertaken. A transect line of 20 meters at each site is set out, the surveyor then places a half a meter quadrat made from PVC along the transect line and takes a photo directly from vertically above. The second photo is then taken along in the same manner after approximately 1 m away from the first photo. In this manner, photos are taken along the transect line and in total, 10 photos on each transect line are taken. In each of the sites 4 transects were placed in two depths (5 m & 10 m). The surveys were undertaken on 23-24 April 2018.

235. **Reef Profile and Underwater Marine Life Survey of September 2019.** Three additional sites (M8 – M10) were surveyed on 1 September 2019 using photo quadrat methods. This particular underwater survey was conducted to provide more in-depth information at three alternative sections of the southern coastal boundary of the proposed project site where the cooling water discharge line from the WTE plant will be laid. Section V provides the detailed discussions on the result of this additional survey. Unlike the conventional reef transect surveys, the three sections were assessed for benthic composition by undertaking photo quadrats from

the top reef of up to 30 meters, along the reef profile. Before start of the survey, the starting points of the three sections were marked using a plastic bottle tied with a rope and weight at its end. The weight rested at the top reef, approximately 5 meters from the reef slope. This allowed the divers to descent from the exact required location up to 30 meters. Photos were taken using the half meter quadrat made from PVC along the transect line (vertical) and takes a photo directly from above. The second photo is then taken along in the same manner after approximately 1 below the first photo. In this manner, photos are taken along the transect line.

236. Figure 98 below shows the locations of the marine surveys undertaken in April 2018 and September 2019.

Figure 96: Underwater Marine Survey Locations (M1–M10)



237. **Data Processing Methodology.** Analysis of the photos was done using a computer program called, CPCe (Coral Point Count with Excel extensions). This is an internationally recognized software used all over the world to assess the benthic composition of the reefs. In this program, photographs are analyzed using pre-defined benthic categories. Depending on the type of survey, these categories can be user defined at any given level. Users can have very complex levels ranging from individual coral families or have broader assessment categories. As the objective of this survey was to assess the impact of dredging and reclamation, it made sense to use a broader category. Hence, benthic categories adopted by the Reef Check protocol were utilized. A text file containing these categories was created and imported to CPCe. The Reef

Check protocol allows categorizing life forms followed under the Reef Check protocol, which emphasizes on benthic composition categorizing such as hard corals, sand, rock and others. The emphasis is not on recording corals to their species levels, but rather the general coral and other life forms such as hard and soft corals. This method is more accurate as the percentage of healthy coral cover and other life forms can be more accurately recorded even by a non-experienced surveyor.

238. The following are definition of benthic categories used in this survey.

- (i) **HC:** All living coral including bleached coral; includes fire, blue and organ pipe corals
- (ii) **SC:** Include zoanthids but not anemones (OT)
- (iii) **DC:** Coral that has died within the past year; appears fresh and white or with corallite structures still recognizable
- (iv) **ALG:** All macro-algae except coralline, calcareous and turf (record the substrate beneath for these); Halimeda is recorded as OT; turf is shorter than 3cm.
- (v) **SP:** All erect and encrusting sponges (but no tunicates).
- (vi) **RC:** Any hard substrate; includes dead coral more than 1 year old and may be covered by turf or encrusting coralline algae, barnacles, etc.
- (vii) **RB:** Reef rocks between 0.5 and 15cm in diameter
- (viii) **SD:** Sediment composed of particles of less than 0.5cm in diameter; in water, falls quickly to the bottom when dropped.
- (ix) **SI:** Sediment that remains in suspension if disturbed; recorded if color of the underlying surface is obscured by silt.
- (x) **OT:** Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrate.
- (xi) **SG:** All types of sea grass observed categorized in the field SG.

239. Each of the 10 photos from transect are imported, cropped and prepared for analysis. The CPCe program then generates a matrix of random points overlaid on the image for each point to be visually identified. Users can then input the defined categories for each photo and once all the photos are analyzed, the results are displayed on a table.

240. **Status of Site 1 (M1).** Site 1 was selected from the Southern rim of the island reef. The site was chosen as the site was adjacent to the proposed waste rehabilitation center. The substrate at the site is dominated by rock at depths of 5 ($58 \pm 14.2\%$) and 10 (64.5 ± 2.78) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (19.5 ± 5.91) and 10 (21 ± 2.68) meters. Massive porites were the dominating the group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, damselfishes and butterflyfishes. Fishes observed to be abundant at a depth of 10 meters were anthias, damselfishes and triggerfishes. Figure 99 shows the graph outlines the status of site 1(M1) at depths of 5 meters and 10 meters while Figure 100 shows the photos.

Figure 97: Percentage Benthic Composition at site 1(M1) at Depths of 5 and 10 meters \pm Standard Error (SE) (23 April 2018).

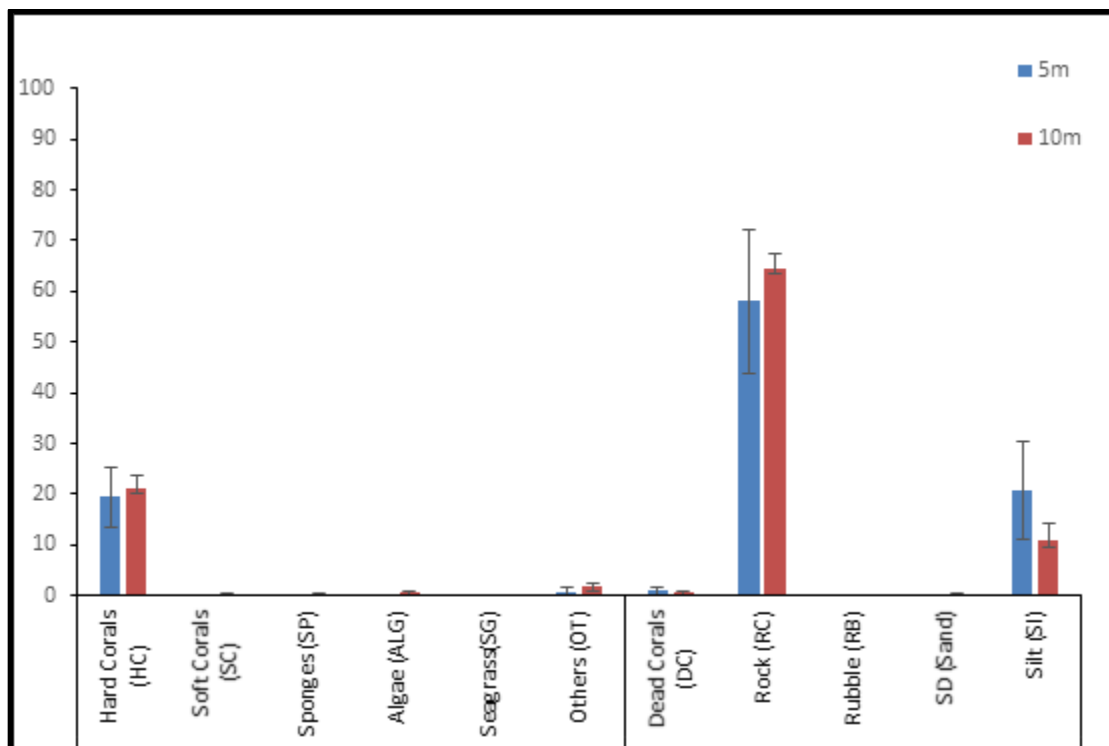
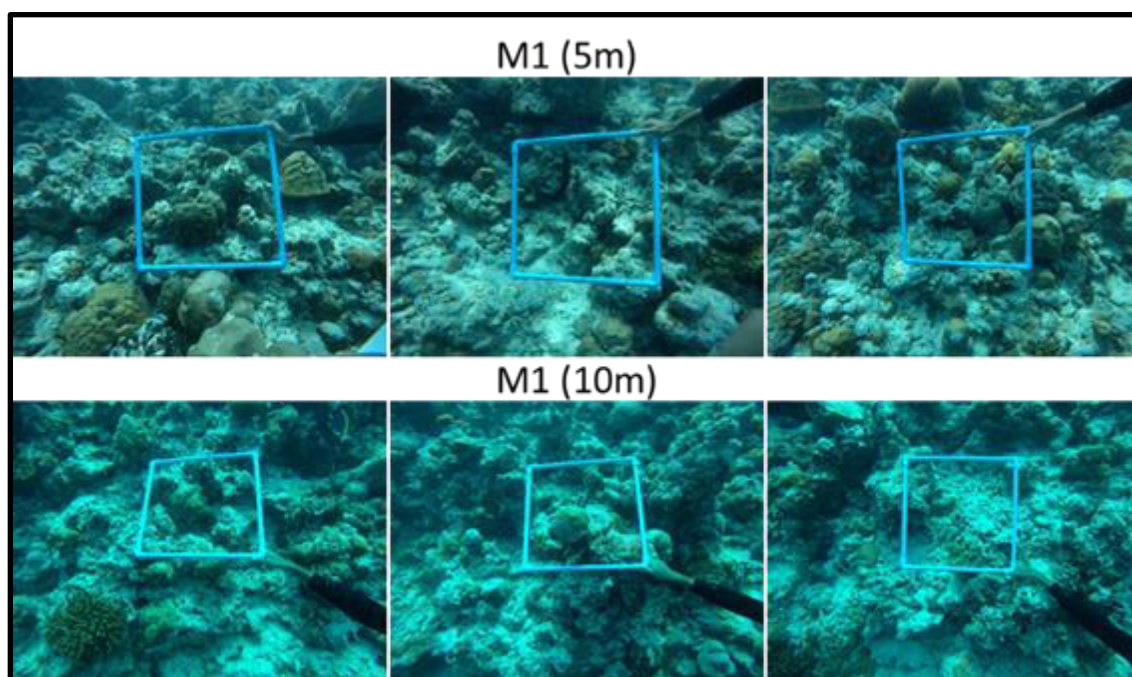


Figure 98: Photos Taken from Site 1 at Depths of 5 and 10 meters (M1) (23 April 2018).



241. **Status of Site 2 (M2).** Site 2 was selected from the Southern rim of the island reef east of site 1. The site was chosen as the site was adjacent to the proposed waste rehabilitation center. The substrate at the site is dominated by rock at depths of 5 ($71.25 \pm 3.86\%$) and 10 (63 ± 6.14) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (22.25 ± 2.95) and 10 (23.25 ± 5.17) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at depth of 5 meters were anthias, surgeon fishes, damselfishes, parrotfishes, triggerfishes and butterflyfishes. Fishes observed to be abundant at depth of 10 meters were anthias, damselfishes, butterflyfishes and triggerfishes. Figure 101 shows the graph outlines on the status of site 2(M2) at depths of 5 meters and 10 meters while Figure 102 shows the photos.

Figure 99: Percentage Benthic Composition at Site 2 (M2) \pm SE (24 April 2018)

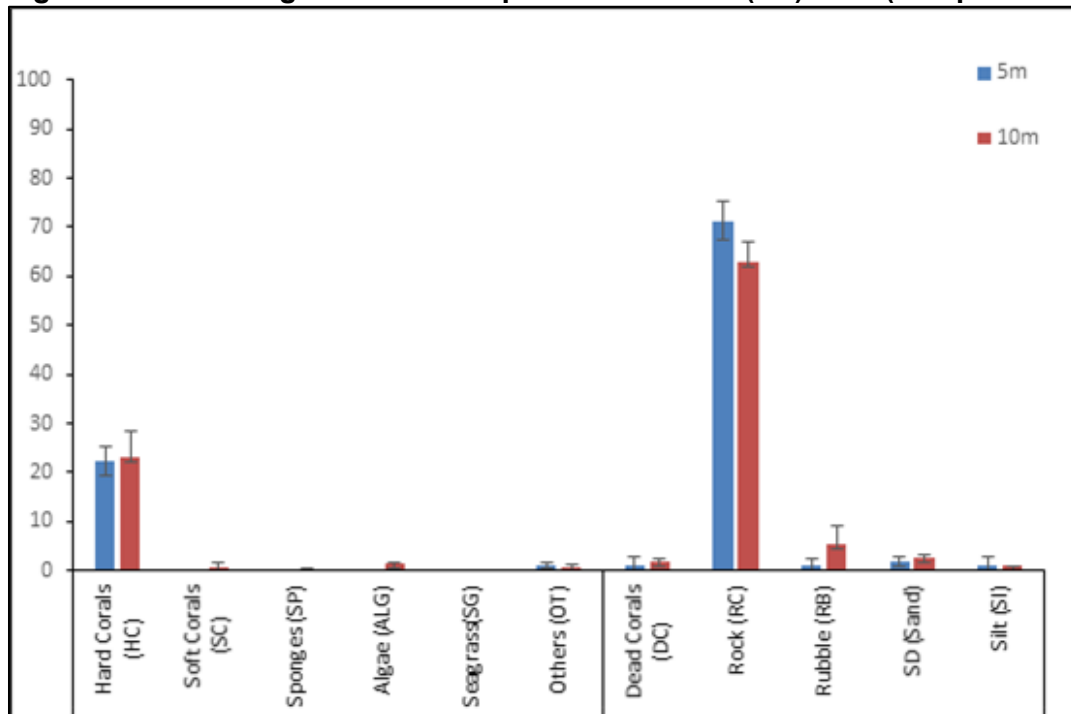
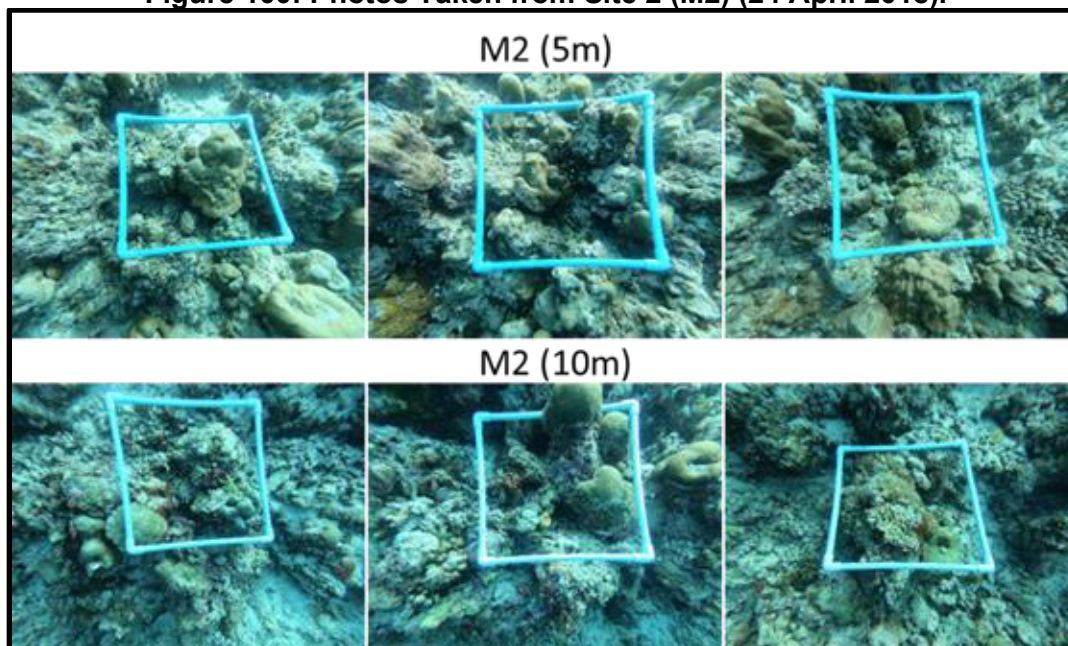


Figure 100: Photos Taken from Site 2 (M2) (24 April 2018).



242. **Status of Site 3 (M3).** Site 3 was selected from the Southern eastern corner of the island reef. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 ($76.25 \pm 2.10\%$) and 10 ($65.75 \pm 2.46\%$) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (17 ± 2.48) and 10 (16.5 ± 0.65) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes and jacks and trevallies. Fishes observed to be abundant at a depth of 10 meters were anthias, damselfishes and triggerfishes. Figure 103 presents the graph outlines on the status of site 3(M3) at depths of 5 meters and 10 meters while Figure 104 shows the photos.

Figure 101: Percentage Benthic Composition at Site 3 (M3) \pm SE (23 April 2018)

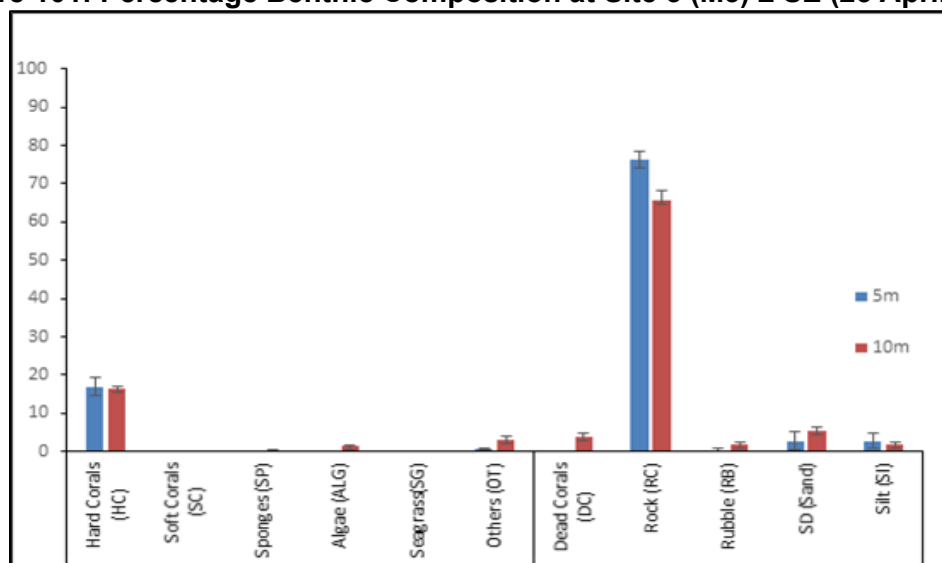
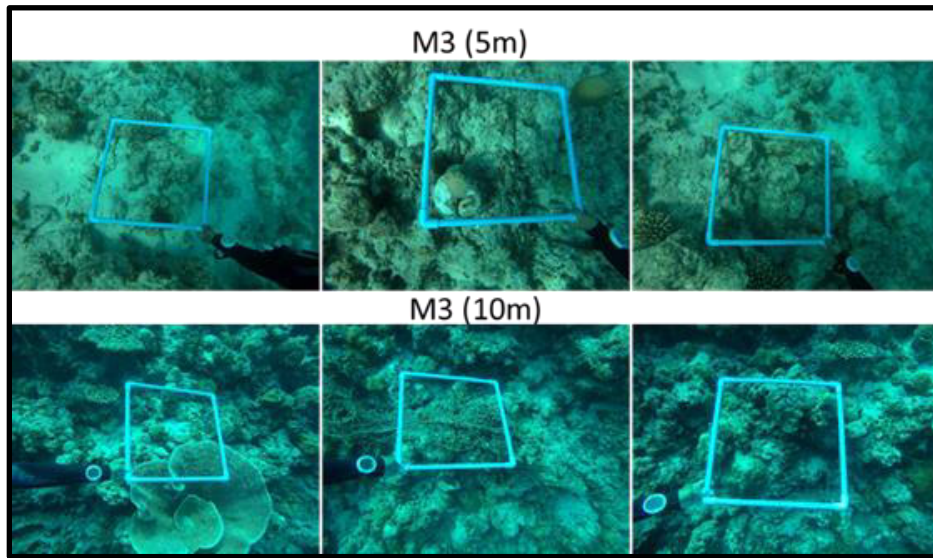


Figure 102: Photos Taken from Site 3 (M3) (23 April 2018)



243. **Status of Site 4 (M4).** Site 4 was selected from the North-eastern rim of the island reef. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rubble at depths of 5 ($67 \pm 4.49\%$) and 10 ($60 \pm 6.42\%$) meters respectively. Hard coral cover was not observed at the site at depths of 5 and 10 meters. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, butterfly fishes and fusiliers. Fishes observed to be abundant at a depth of 10 meters were only fusiliers. Figure 105 presents the graph outlines on the status of site 4(M4) at depths of 5 meters and 10 meters while Figure 106 shows the photos.

Figure 103: Percentage Benthic Composition at Site 4 (M4) \pm SE (24 April 2018).

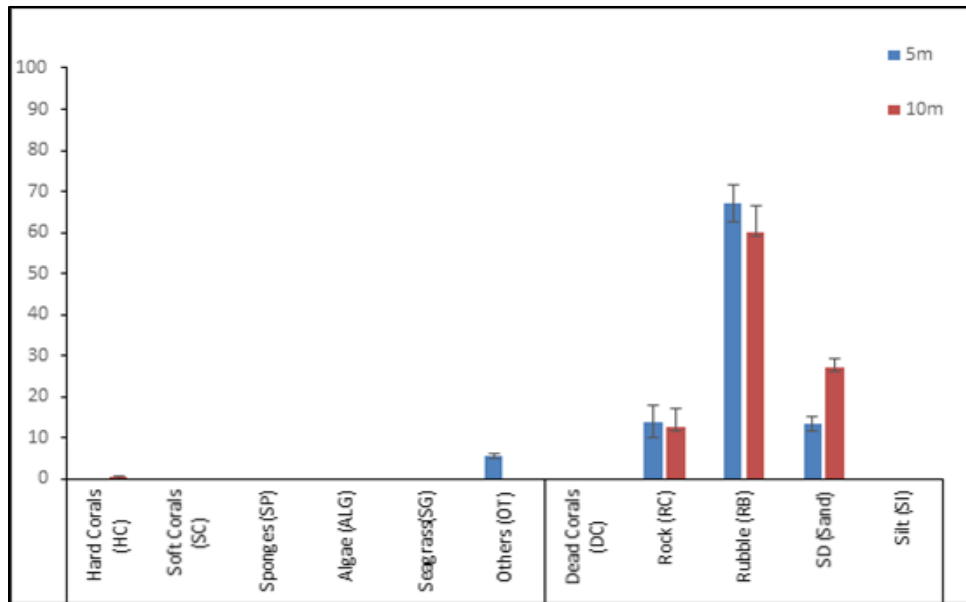
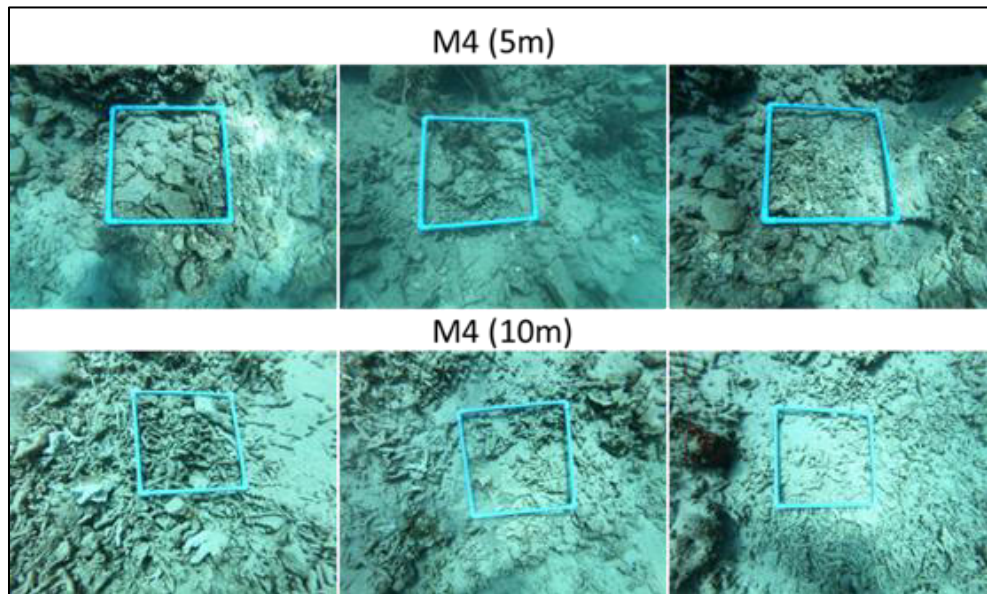


Figure 104: Photos Taken from Site 4 (M4) (24 April 2018)



244. **Status of Site 5 (M5).** Site 5 was selected from the Northern rim of the island reef close proximity to the entrance channel. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 ($46.75 \pm 6.28\%$) and 10 (51.5 ± 5.81) meters respectively. Hard coral cover was observed to be low at the site at depths of 5 (5 ± 1.58) and 10 (4.25 ± 0.75) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes and parrotfishes. Fishes observed to be abundant at a depth of 10 meters were surgeon fishes, damselfishes and triggerfishes. Figure 107 presents the graph outlines on the status of site 5(M5) at depths of 5 meters and 10 meters while Figure 108 shows the photos.

Figure 105: Percentage Benthic Composition at Site 5 (M5) ± SE (24 April 2018)

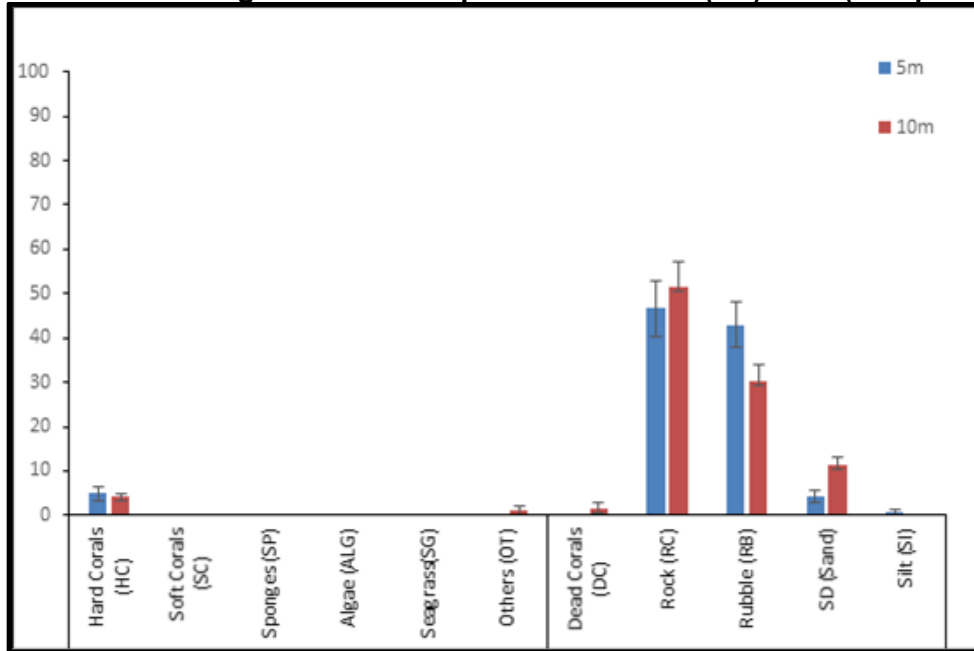
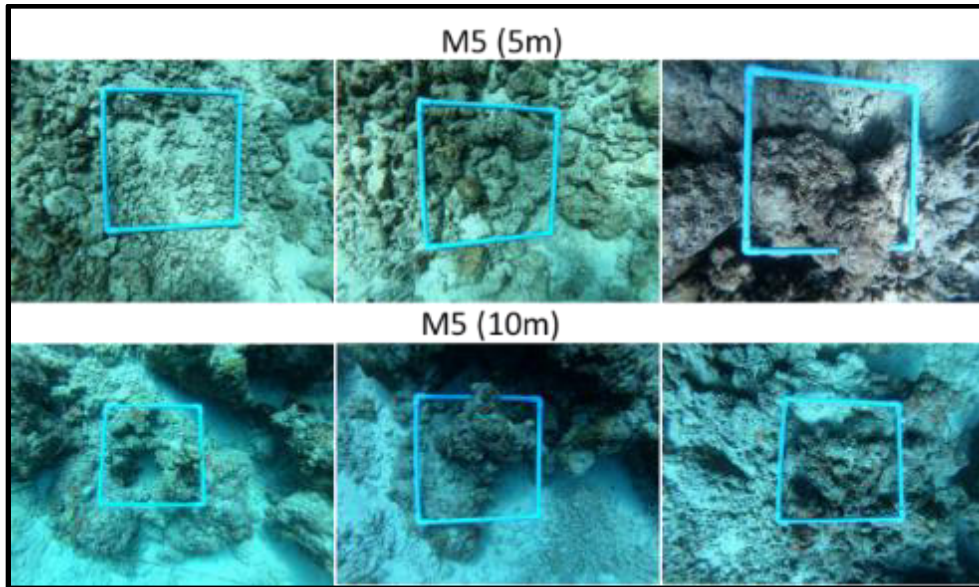


Figure 106: Photos Taken from Site 5 (M5) (24 April 2018)



245. **Status of Site 6 (M6).** Site 6 was selected from the Northern rim of the island reef west of site 5. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 ($80.5 \pm 4.19\%$) and 10 ($36.5 \pm 5.85\%$) meters respectively. Hard coral cover was observed to be low at the site at depths of 5 (8.75 ± 2.53) and 10 (14 ± 2.58) meters. Particular group of hard corals were not observed to dominate the substratum. A diverse group of corals from groups such as *Acropora*, *Pocillopora* and *Porites* were observed at the site. Fishes observed to be abundant

at a depth of 5 meters were surgeon fishes, wrasses, triggerfishes, damselfishes and butterfly fishes. Fishes observed to be abundant at a depth of 10 meters were surgeon fishes, damselfishes, triggerfishes and butterfly fishes. Figure 109 gives the graph outlines on the status of site 6(M6) at depths of 5 meters and 10 meters while Figure 110 shows the photos.

Figure 107: Percentage Benthic Composition at Site 6 (M6) \pm SE (24 April 2018)

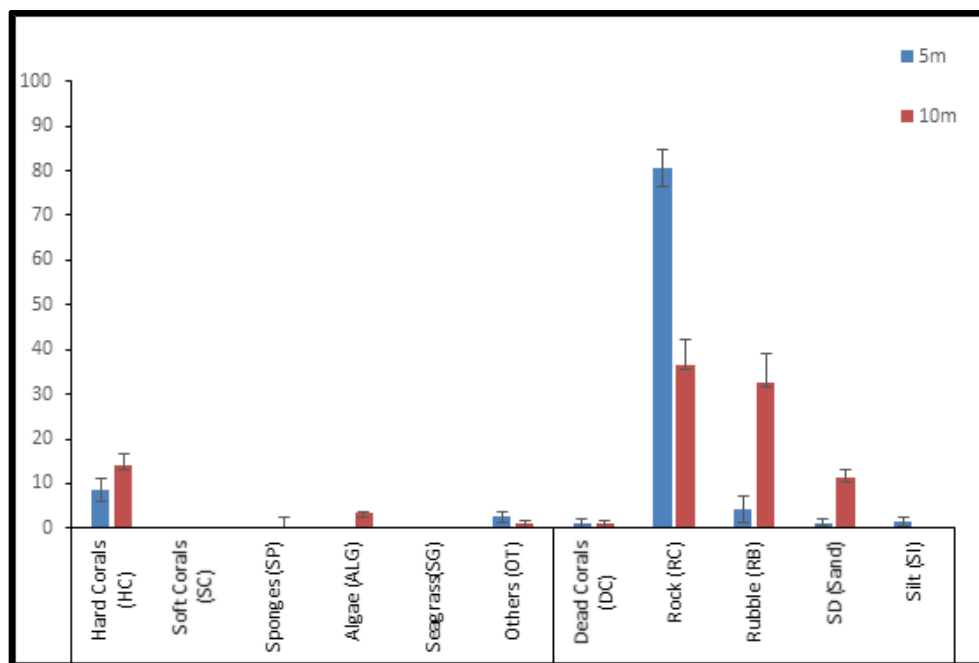
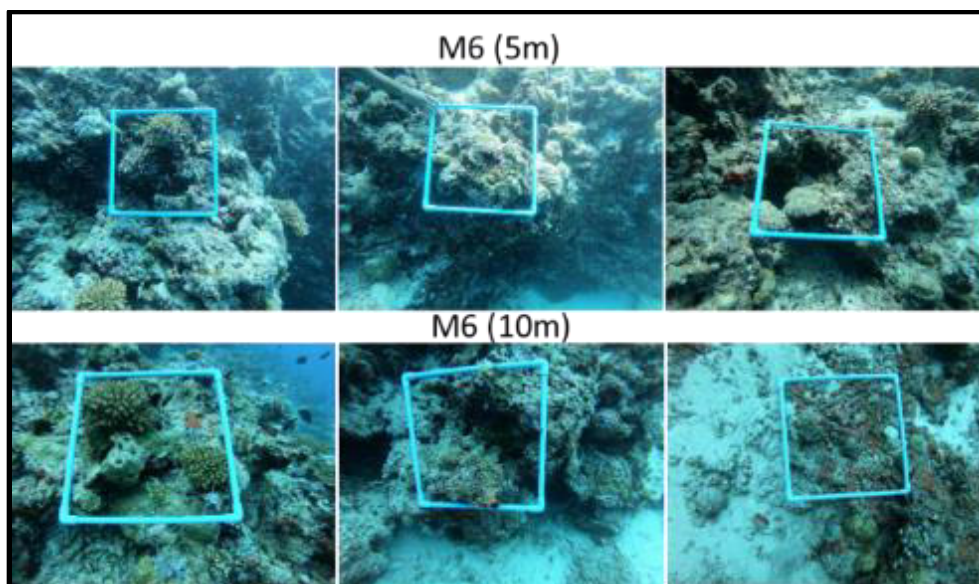


Figure 108: Photos Taken from Site 6 (M6) (24 April 2018)



246. **Status of Site 7 (M7).** Site 7 was selected from the Southern rim of the island reef west of site 1. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5

($76 \pm 5.87\%$) and 10 (77.75 ± 3.33) meters respectively. Hard coral cover was observed to be low at 5 meters ($5 \pm 1\%$) and moderate in 10 meters (17.5 ± 3.2). Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, damselfishes and butterfly fishes. Fishes observed to be common at a depth of 10 meters were surgeon fishes. Figure 111 presents the graph outlines on the status of site 7 (M7) at depths of 5 meters and 10 meters while Figure 112 shows the photos.

Figure 109: Percentage Benthic Composition at Site 7 (M7) \pm SE (23 April 2018)

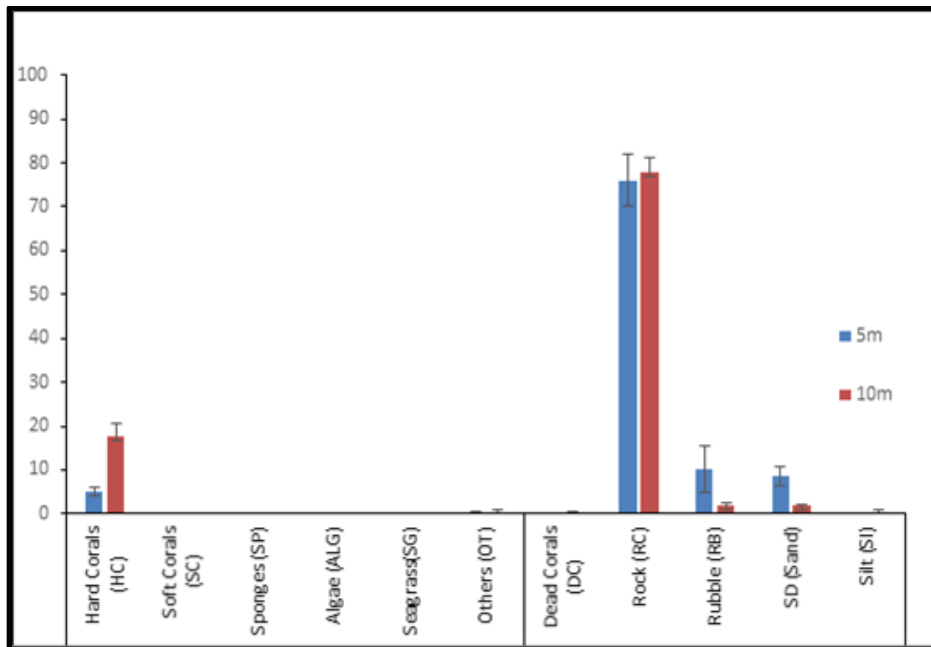
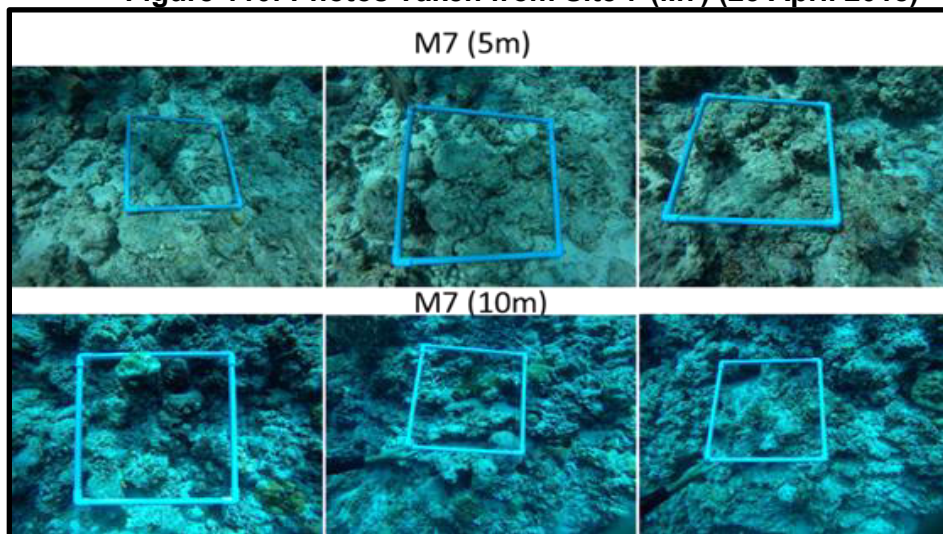


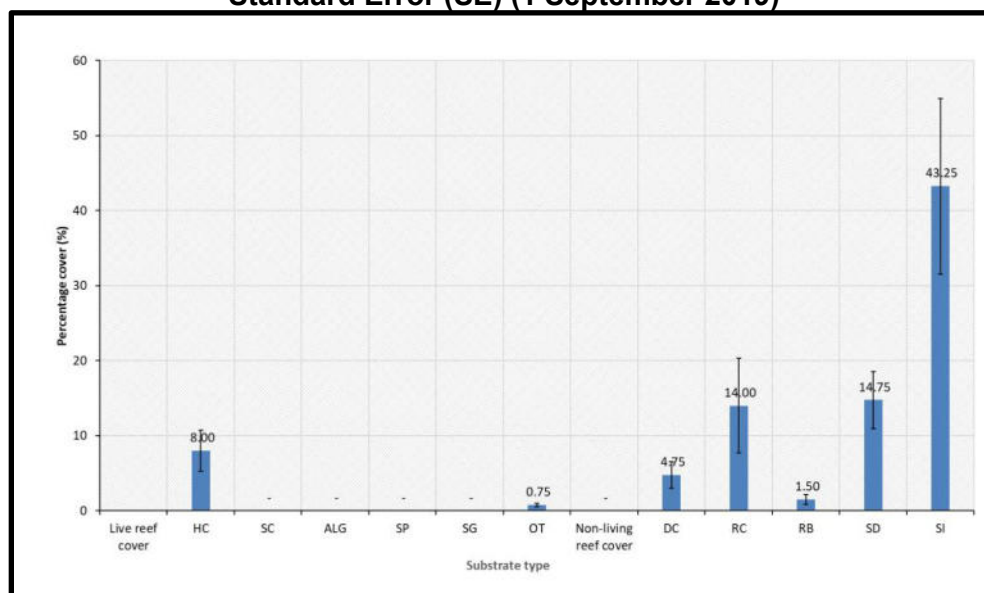
Figure 110: Photos Taken from Site 7 (M7) (23 April 2018)



247. **April 2018 Underwater Survey Results.** The highest coral cover was observed at the depth of 10 meters in site M2 adjacent to the current waste dumping area. Therefore, there is the possibility the leachate from landfill is not having any negative impacts on the reef at site M2.

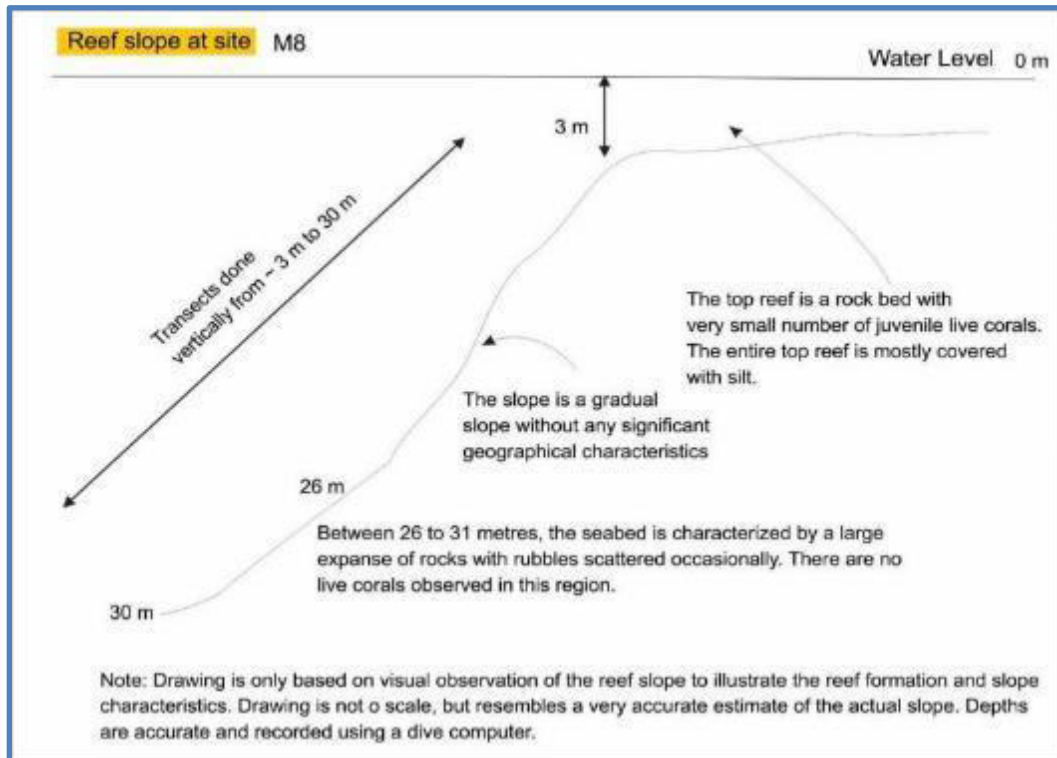
248. Status of Site M8. Site M8 was selected from the Southern rim of the island reef. The site was chosen as the best alternative location to lay the hot water discharge line and outfall (see Section IV on Alternative Analysis). The substrate at the site is dominated by silt along the entire transect line ($43 \pm 11.69\%$). Hard coral cover was observed to be low (8 ± 2.71). Massive porites were the dominating the group of hard coral observed at the site. Fishes observed to be very rare. It is to be noted that just a week prior to the survey, due to the severe weather, this entire stretch of reef has been hit by strong waves causing the sediments on the western side of the Thilafushi to be spread along most part of the southern side. This has resulted in large areas of the reef being covered with silt, which were observed at various sampling sites (M9 and M10). Figure 113 below outlines the status of site M8.

Figure 111: Percentage benthic composition at site M8 at depths from ~ 3 to 30 meters \pm Standard Error (SE) (1 September 2019)



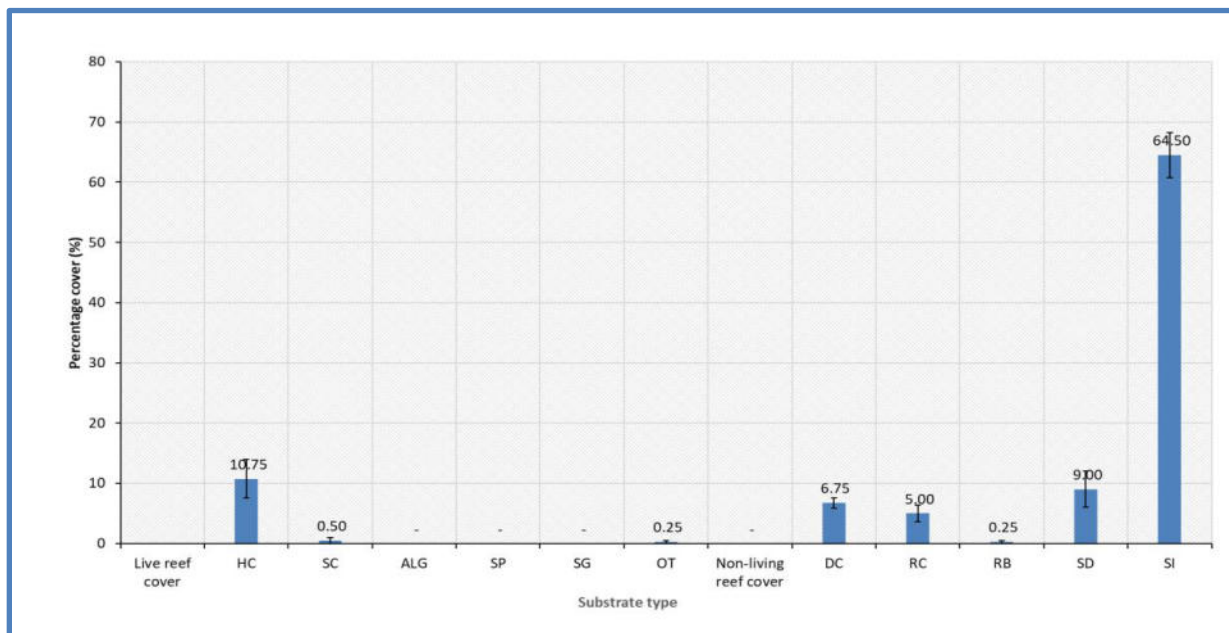
249. Figure 114 illustrates the reef slope characteristics at site M8.

Figure 112: Reef Slope Characteristics at M8 (1 September 2019)



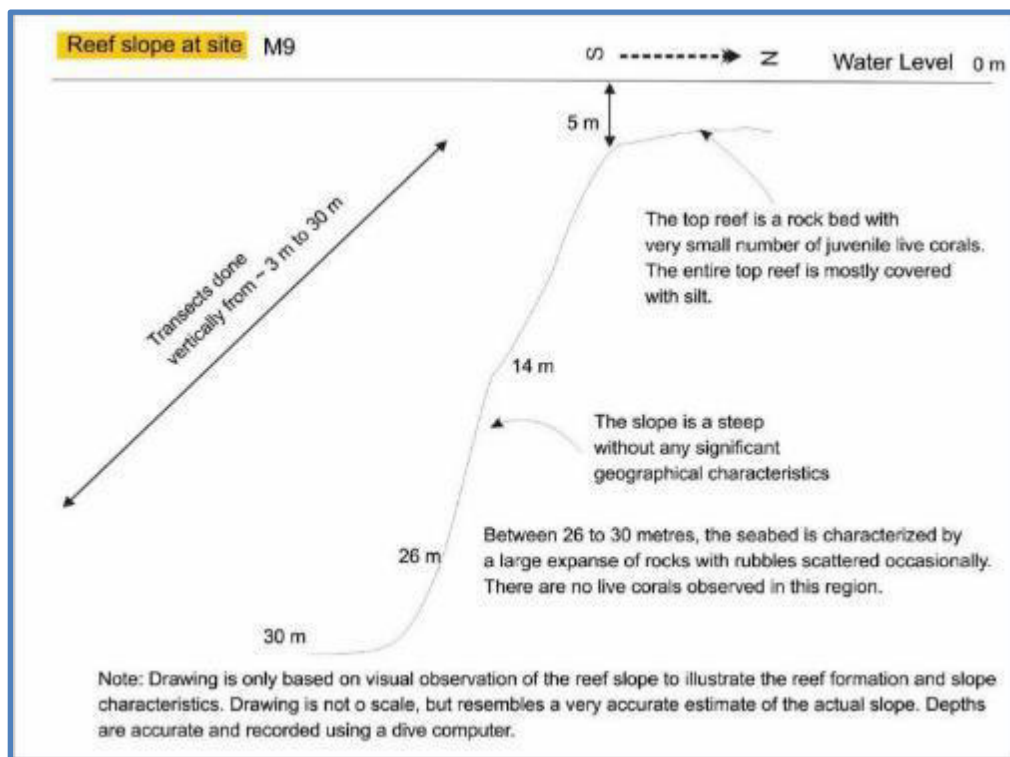
250. **Status of Site M9.** Site M9 was also selected from the Southern rim of the island reef east of site 1. The site was also chosen as an alternative location to lay the hot water discharge line and outfall (see Section IV on Alternative Analysis). The substrate at the site is dominated by silt ($64.5 \pm 3.77\%$). Hard coral cover was observed to be low along the surveyed depths from approximately 3 to 30 meters (10.75 ± 3.22). Massive porites were the dominating group of hard coral observed at the site. Fishes observed were very low and includes anthias and surgeon fishes (refer to the fish census table for details). Figure 115 shows the graph outlines the status of site M9.

Figure 113: Percentage benthic composition at site M9 at depths from ~ 3 to 30 meters ± SE (1 September 2019)



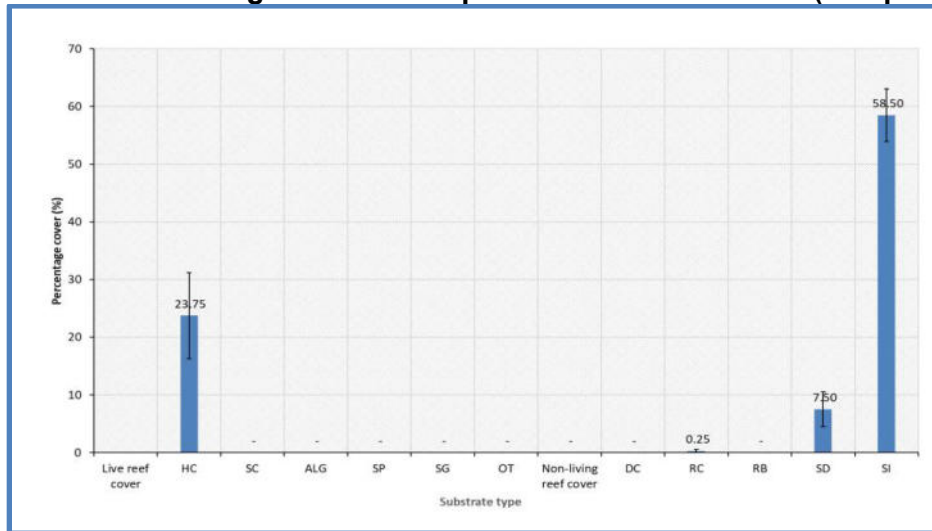
251. Figure 116 illustrates the reef slope characteristics at site M9.

Figure 114: Reef slope characteristics at M9 (1 September 2019)



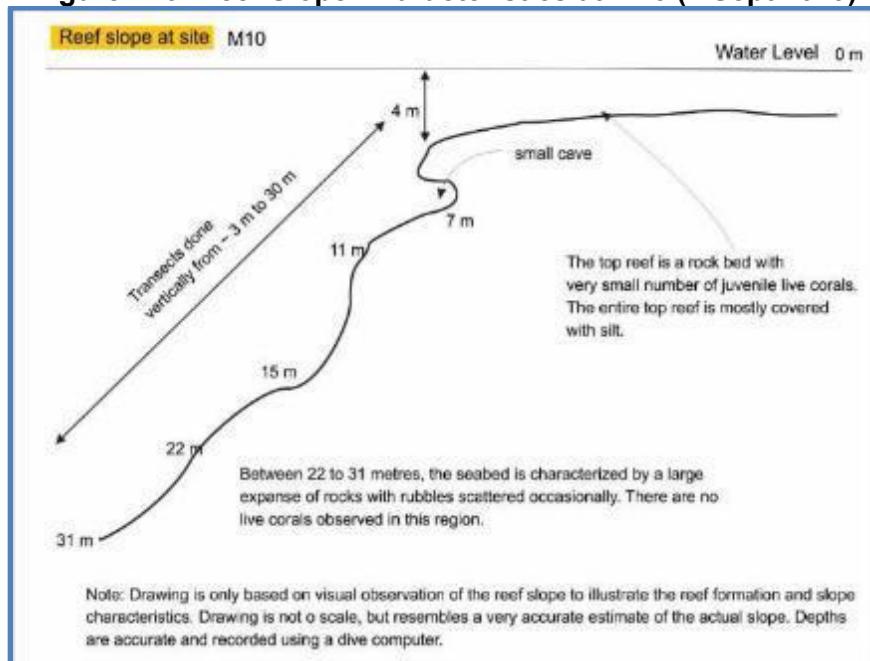
252. **Status of site M10.** Site M10 was also selected from the Southern side of the island reef. The site was also chosen as an alternative location to lay the hot water discharge line and outfall (see Section IV on Alternative Analysis). The substrate at the site is dominated by silt (58.50 ± 4.57 %). Hard coral cover was observed to be moderate (23.75 ± 7.43). Massive Porites were the dominating group of hard coral observed at the site. Fishes observed to be very low. Figure 117 presents the graph outlines on the status of site M10.

Figure 115: Percentage benthic composition at site M10 ± SE (1 Sept 2019)



253. Figure 118 illustrates the reef slope characteristics at site M10.

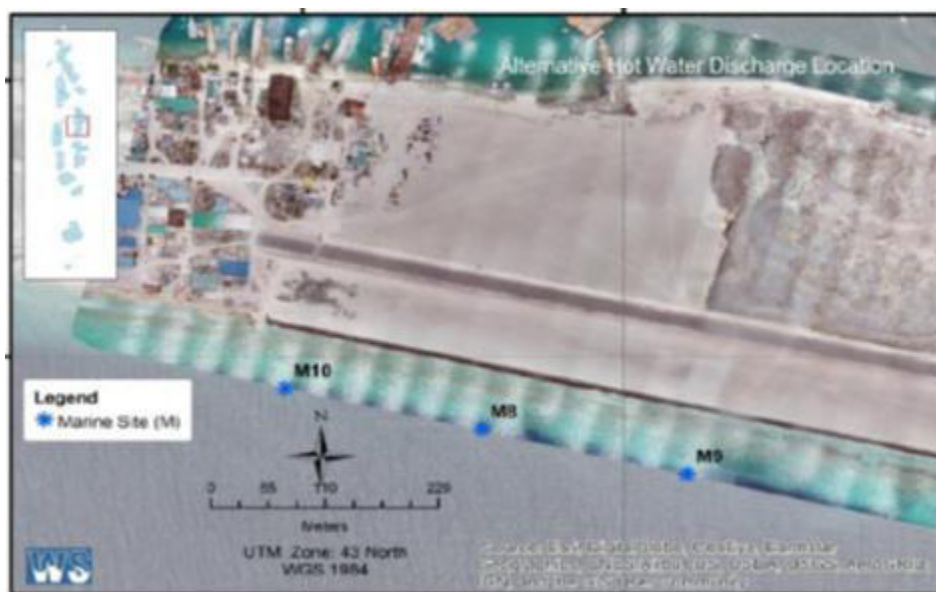
Figure 116: Reef Slope Characteristics at M10 (1 Sept 2019)



254. **Additional baseline data gathering for marine underwater ecology.** Reef benthic survey was conducted on 16 June 2022 and on 24 December 2022 in locations M10, M9 and M8 (see Figure 119). A standard approach, established by the Maldives EIA community and approved by the Environmental Protection Agency (EPA), was employed to study the benthic cover and fish populations. Following the establishment of the GPS locations, transects surveys were conducted at two depths: 5 m and 10 m in each station based on the methods established by Hodgson et.al (2006) in Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring. Three transects of 20 m length were laid, one after the other along the reef ensuring transect falls to the specific depth. A quadrat of size 0.5 m x 0.5 m was laid sequentially on the transect and photo images were taken with the quadrat in the middle making sure the is quadrat in the center of the frame. In this way, every transect would have at least 10 images. Three such transects would have around 60 images from each depth.

255. Analysis of the images were conducted using CoralNet (an online resource for benthic images analysis - <https://coralnet.ucsd.edu/>) which uses artificial intelligence allowing for automatic classification following sufficient training on the training set – the first 40 of slides. Twenty-five points were randomly thrown over to the image. Benthic cover was classified by 14 attributes as given below. They are HC – Hard Coral, ENSP – Encrusting Sponge, SC – Soft Coral, Sand – Sand, Sediment – Sediment, Silt – Silt, D_coral – Dead Coral, Rock – Rock, Rubble – Rubble, SHAD – Shadow, WAND – wand (image of the quadrat), Turf – Turf, Turf-rubble – Turf Rubble, Seagrass – Seagrass.

Figure 117: Location of Underwater Marine Ecology Survey



Survey on 16 June 2022

256. **Status of Site M8:** This site was selected because it is one of the locations that will be used for the discharge of water from waste treatment plant and brine outfall. Substrate cover at both 5 m and 10 m depths shows hard coral cover within 26%-28%, turf is higher at 10 m depth (25%) than the 5 m-depth (9%). and dead coral cover is similar at both depth (14-15%). Rock and turf rubble cover are higher at 5 m depth (24%-21% respectively), Rubble and turf rubble cover are less at 10 m depth (12%-17%, respectively). Encrusting corals and sponges are slightly higher at 5 m depth but the overall cover in both depths is less than 5%. Massive porites were

the dominating group of hard coral observed at the site. Triggerfish, surgeon fish (Powder blue), wrasse (labridae) basslets were common. Grazers (*Acanthurids* or *Scarids*) were not seen, and this result is consistent with what was obtained with earlier assessment. Photographs of the transect quadrats are shown in Figure 118 and Figure 119. Benthic composition of M8 at both 5 m and 10 m depth is in

Figure 118: Photos Taken from Site 8 (M8) (16 June 2022) at 5 m depth

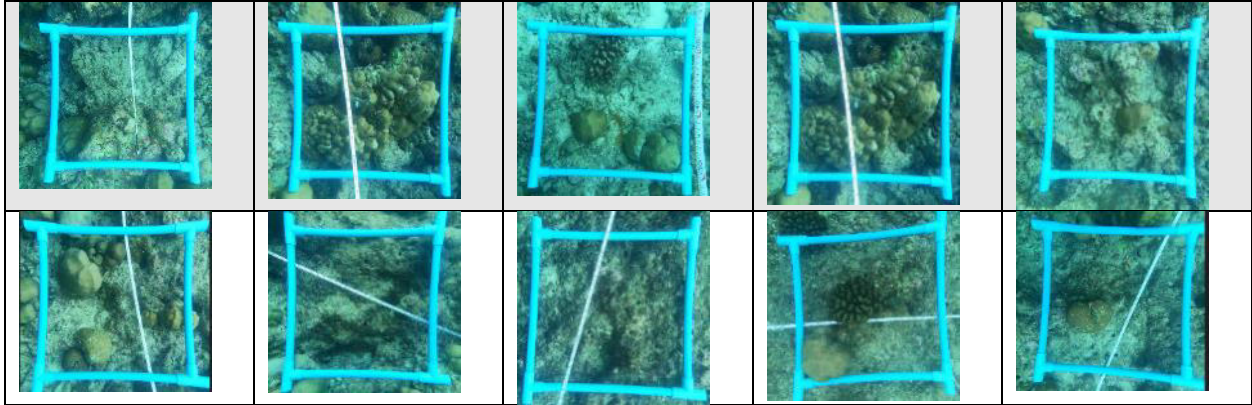


Figure 119: Photos Taken from Site 8 (M8) (16 June 2022) at 10 m depth

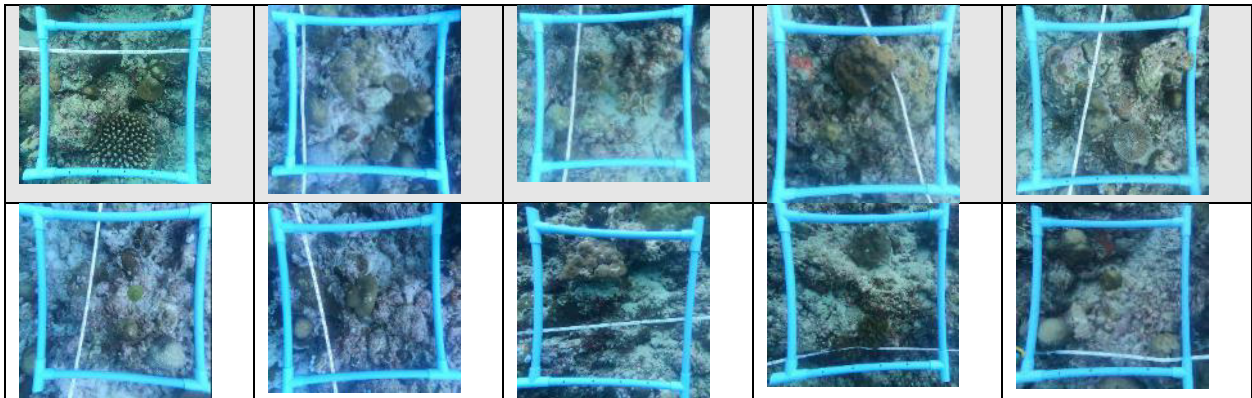
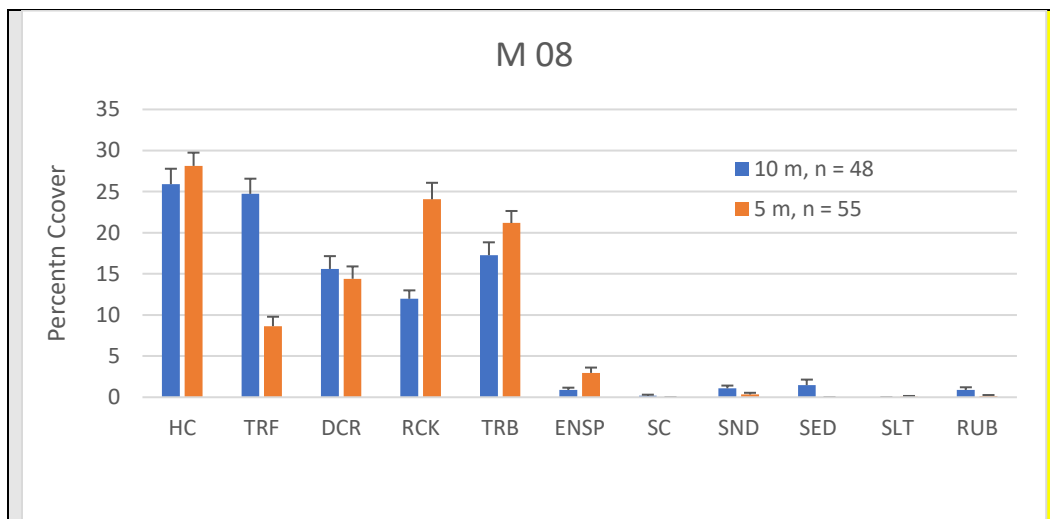


Figure 120: Average benthic cover and their standard error for M8 at both 5 m and 10 m depth



Key: . HC – Hard coral, TRF – Turf, DCR – Dead Coral, RC – Rock, TRB – Turf Rubble, ENSP– Encrusting Sponge, SND – sand, SED – Sediment, SLT – Silt, and RUB – Rubble, n is the sample number in this number slides analyzed

257. **Status of Site M9:** This location was identified as an alternative for brine discharge and wastewater outfall. This is close to the WtE site at the southern reef of Thilafushi Island. Substrate survey shows hard coral cover over 40% at both depths. Similar to M9, turf cover is higher at 10m (27%) than 5 m depth (11%) while dead coral rock is higher at 5 m (31%) than 10 m depth (21%). Porites are the dominant hard live coral encountered in the area in the transects and fairly large amount table corals were found on the reef flat at about 2 m depth. Trigger fish, surgeon fish (Powder blue), wrasse (labridae) basslets were common. Grazers (*Acanthurids* or *Scarids*) were not seen, and this result is consistent with what was obtained with earlier assessment. Photographs of the transect quadrats are shown in Figure 121 and

. Benthic composition of M8 at both 5 and 10m depth is in Figure 122: Photos Taken from Site 9 (M9) (16 June 2022) at 10 m depth

Figure 121: Photos Taken from Site 9 (M9) (16 June 2022) at 5 m depth

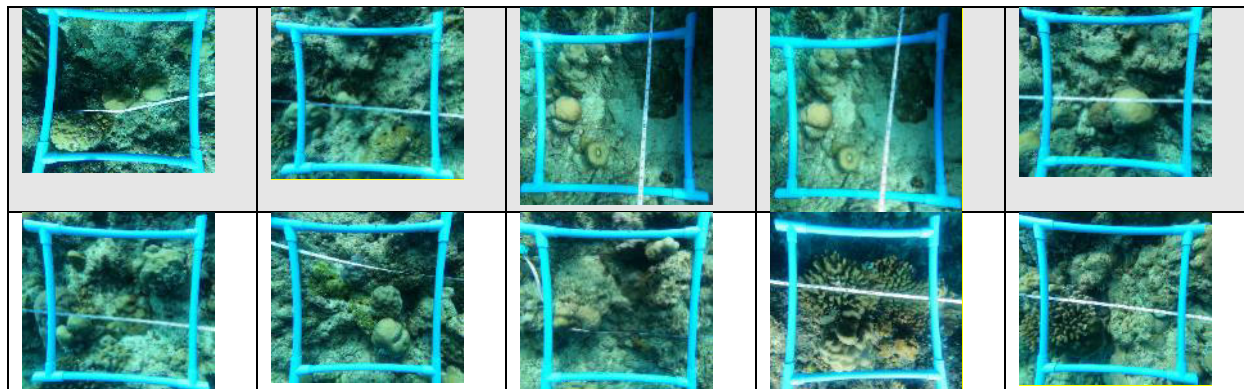


Figure 122: Photos Taken from Site 9 (M9) (16 June 2022) at 10 m depth

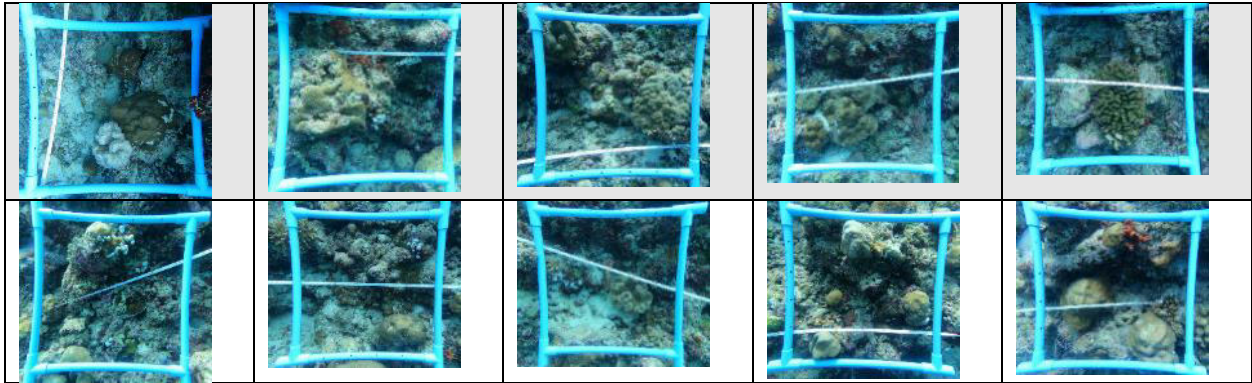
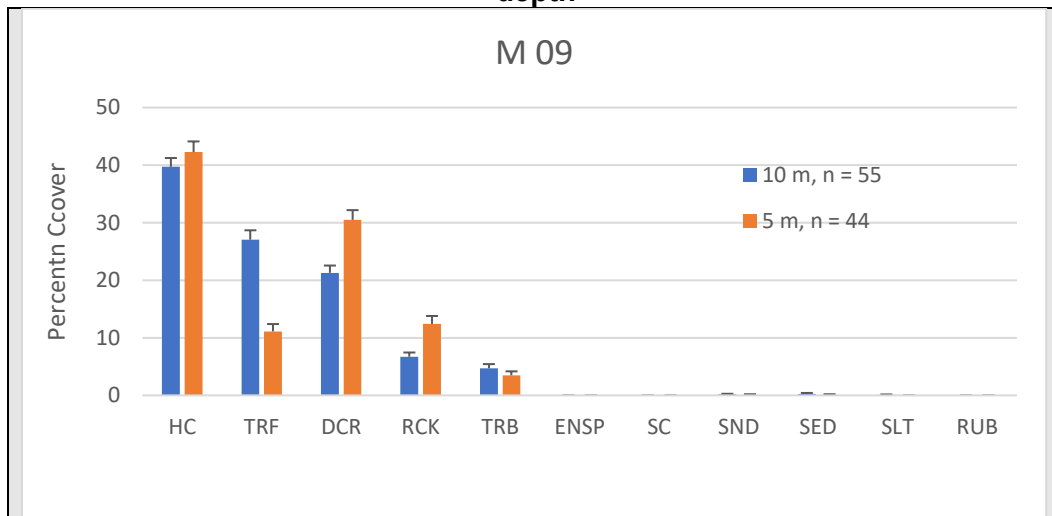


Figure 123: Average benthic cover and their standard error for M9 at both 5 m and 10 m depth



Key: . HC – Hard coral, TRF – Turf, DCR – Dead Coral, RC – Rock, TRB – Turf Rubble, ENSP– Encrusting Sponge, SND – sand, SED – Sediment, SLT – Silt, and RUB – Rubble, n is the sample number in this number slides analyzed

258. **Status of Site M10:** This location has been identified in the EIA report as a potential alternative for the discharge of brine water and wastewater. The location is very close to the WtE facility, and it is on the southern reef of Thilafushi Island. In the substrates the cover at both 5 m and 10 m depths include hard corals 38% turf and dead coral 24% and 26% respectively. Rock and turf rubble are less than 10% silt and sand are less than 2%. Massive Porites were the dominating group of hard coral observed at the site. Trigger fish, surgeon fish (Powder blue), wrasse (labridae) basslets were common. Grazers (Acanthurids or Scarids) were not seen, and this result is consistent with what was obtained with earlier assessment. Photographs of the transect quadrats are shown in Figure 1186 and Figure 119. Benthic composition of M8 at both 5 m and 10 m depth is in

Figure 122: Photos Taken from Site 9 (M9) (16 June 2022) at 10 m depth

8.

Figure 124: Photos Taken from Site 10 (M10) (16 June 2022) at 5m depth

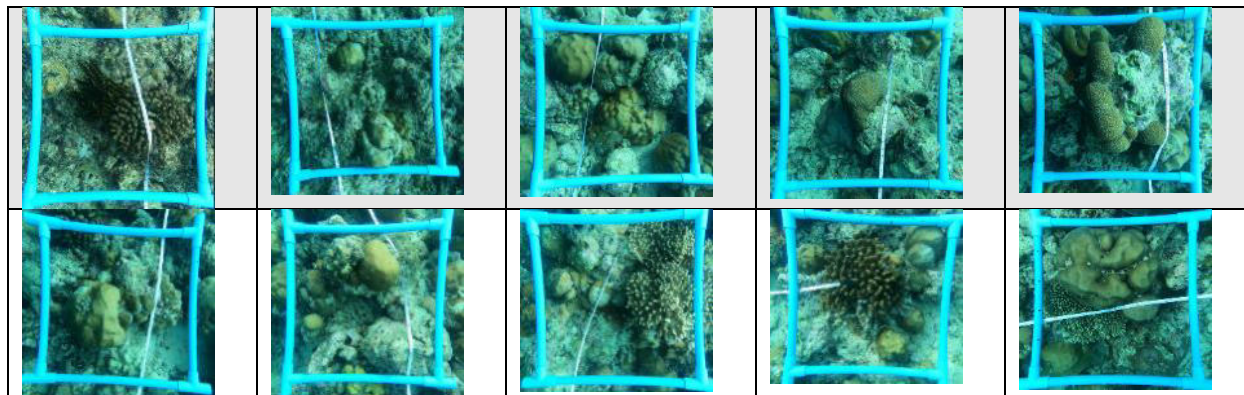


Figure 125: Photos Taken from Site 10 (M10) (16 June 2022) at 10 m depth

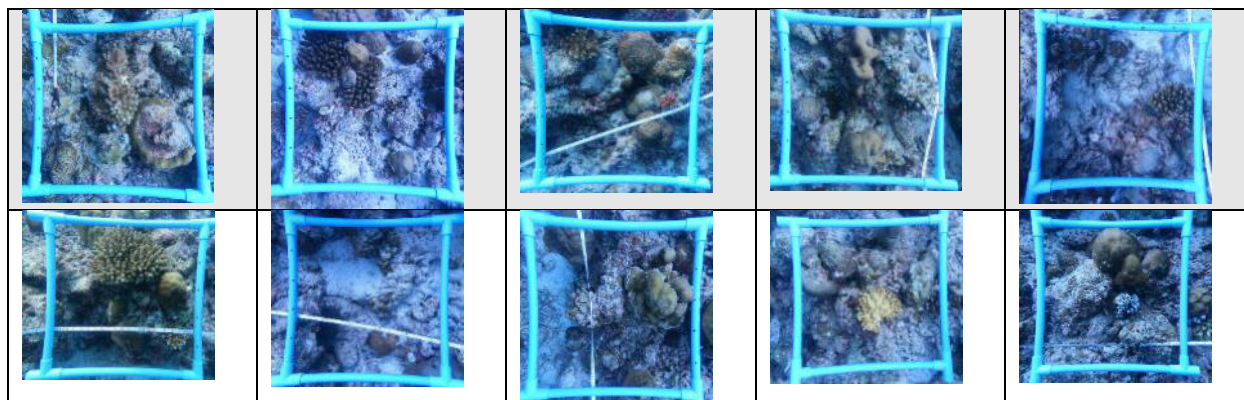
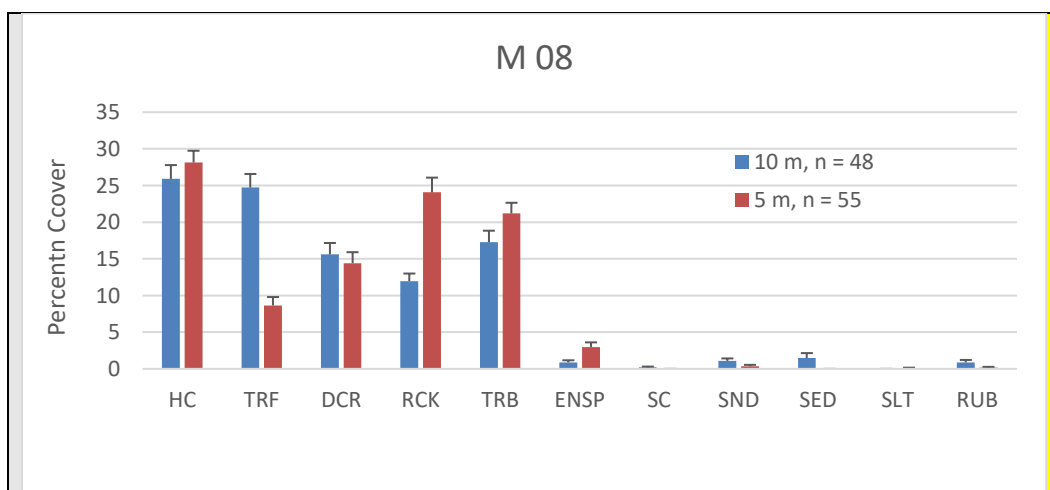


Figure 126: Average benthic cover and their standard error for M9 at both 5 m and 10 m depth



Key: . HC – Hard coral, TRF – Turf, DCR – Dead Coral, RC – Rock, TRB – Turf Rubble, ENSP– Encrusting Sponge, SND – sand, SED – Sediment, SLT – Silt, and RUB – Rubble, n is the sample number in this number slides analyzed

Survey on 24 December 2022

259. A re-evaluation of the baseline was established in June 2022, and the following report is based on the survey conducted on 24 December 2022.

260. The data collected in June 2022 was analyzed using CoralNet (an online resource for benthic images analysis - <https://coralnet.ucsd.edu/>), which utilizes artificial intelligence for automatic classification. However, for the December 2022 survey, analysis was conducted using CPCe (Coral Point Count of Excel Extension)²⁷. Like CoralNet, CPCe involves randomly placing points over the quadrat space on the image, but in this case, the points are identified by humans. Twenty-five points were randomly placed on the entire photo image. The points were then classified under the following categories, as listed in **Error! Reference source not found.3**.

Table 43: Substrate categories and their codes.

Category	Code
ROCK (R)	RCK
CORAL (C)	HC
SAND AND SILT (S)	SND
CORALLINACEAE (CO)	CON
MACRO ALAGE (MA)	ALG
CORAL RUBBLE (CR)	RUB
SPONGE (SP)	ENSP
TUNICATE (TU)	TUN
ZOANTHARIAN (ZO)	ZON
SOFT CORAL (SC)	SC
TURF ALAGE (TUR)	TRF
BLEACHED CORAL (BLC)	BCO
UNKOWN (UN)	UNC
SEAGRASS (SG)	SGR
INVERTEBRATES (INV)	INV

261. The following presents the findings and observations from under marine ecological surveys conducted at the monitoring location at Thilafushi reef.

262. **Status of Site M8:** The site is the location that will be used for discharge of wastewater from the brine outfall. The survey conducted in June 2022 reported hard coral cover within 26%-28%. In December 2022, the mean hard coral cover for both depths was around 25%-26% which is more or less the same. Rocks cover 48% of the substrate in at 5 m depth and 25% at 10 m depth. Sand cover was more (37%) at 10 m while at 5 m, it was 15%. Coraline algae cover was around 5% which is like what was obtained earlier. Most of the live coral was massive and sub-massive corals.

263. Fish diversity was highest for one species of Balistidae, *Odonusniger* and fusilier (*Pterocaesio tile*). The Chromid, Chromisdimidia, were observed as abundant, which means

²⁷Kohler, K.E., Gill, S.M., 2006. Coral Point Count with Excel Extension (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32, 1259–1269.

>40 individual on average at each 20 m transect. Photographs of the transect quadrats are shown in Figure 130 and Figure 119131. Benthic composition of M8 at both 5 m and 10 m depth is in Figure 132.

Figure 127: Photos Taken from Site 8 (M8) (24 December 2022) at 5 m depth

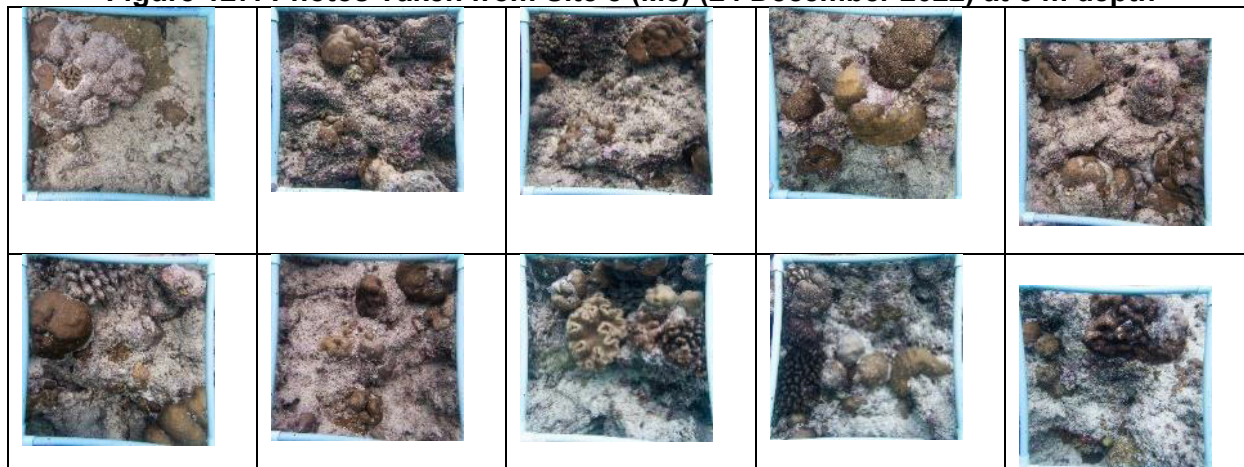


Figure 128: Photos Taken from Site 8 (M8) (24 December 2022) at 10 m depth

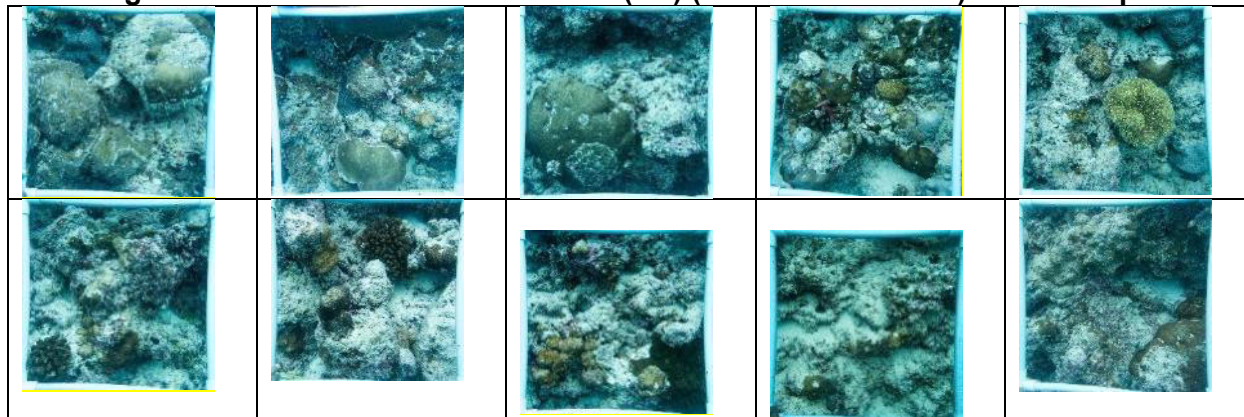
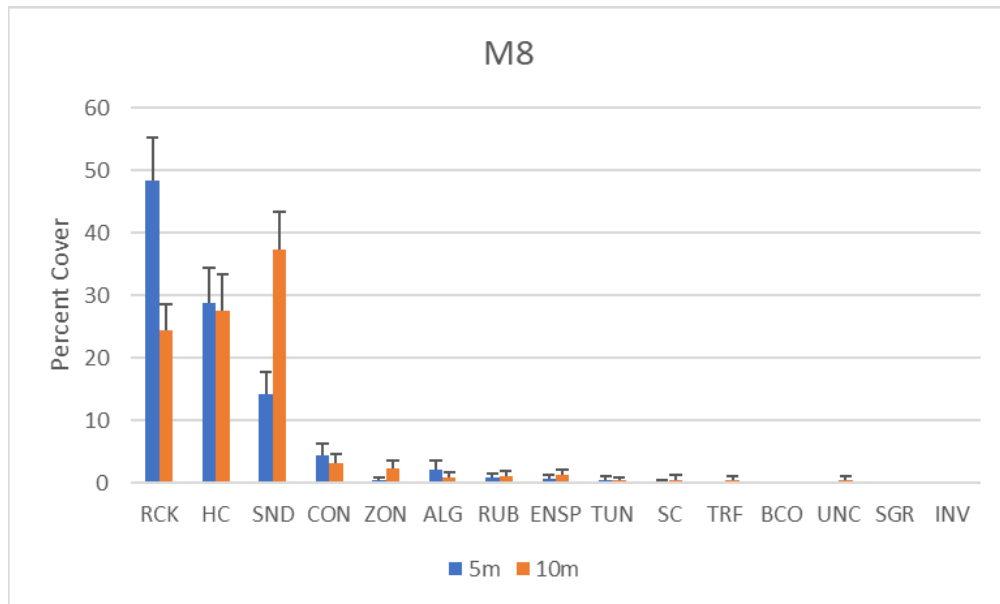


Figure 129: Average benthic cover and their standard error for M8 at both 5 m and 10 m depth



264. **Status of Site M9:** This location was identified as an alternative for brine discharge and wastewater outfall. This is close to the WtE site at the southern reef of Thilafushi Island. Substrate cover was qualitatively similar to the results obtained for the survey conducted in June. Like Site M8, the highest substrate cover was rock, some 50%-60% of the 0.5 m x 0.5 m quadrat, followed by live coral. Live coral cover was also qualitatively like M8. Sand cover was around 5%-15%, much lower at 5 m. Rubble cover also was low.

265. With regards to fish, *Chormisdimidia* was abundant, occurring > 40 individuals along 20 m transect. Also, the *Pomacentrid philippinus* and *Pterocaesio tile* were common at site. Photographs of the transect quadrats are shown in Figure 121133 and 134. Benthic composition of M8 at both 135 m and 10 m depth is in Figure 122: Photos Taken from Site 9 (M9) (16 June 2022) at 10 m depth 35.

Figure 130: Photos Taken from Site 9 (M9) (24 December 2022) at 5 m depth

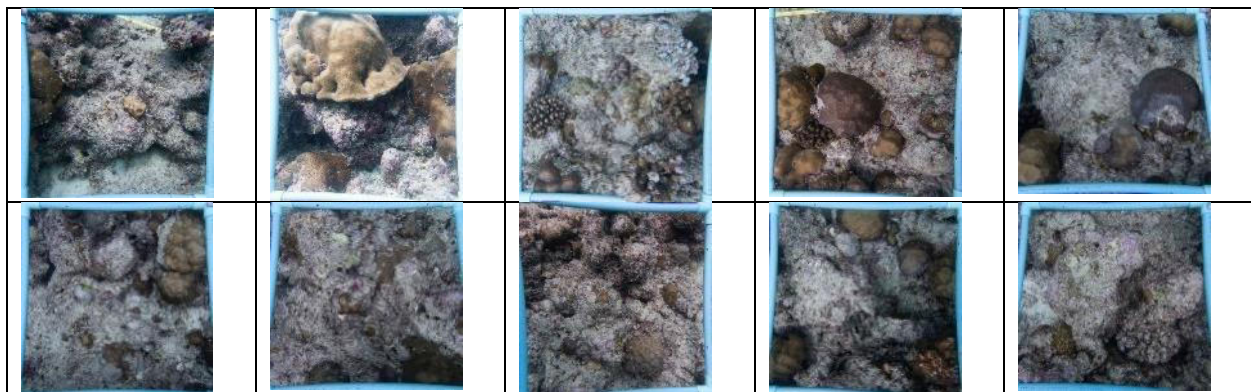


Figure 131: Photos Taken from Site 9 (M9) (24 December 2022) at 10 m depth

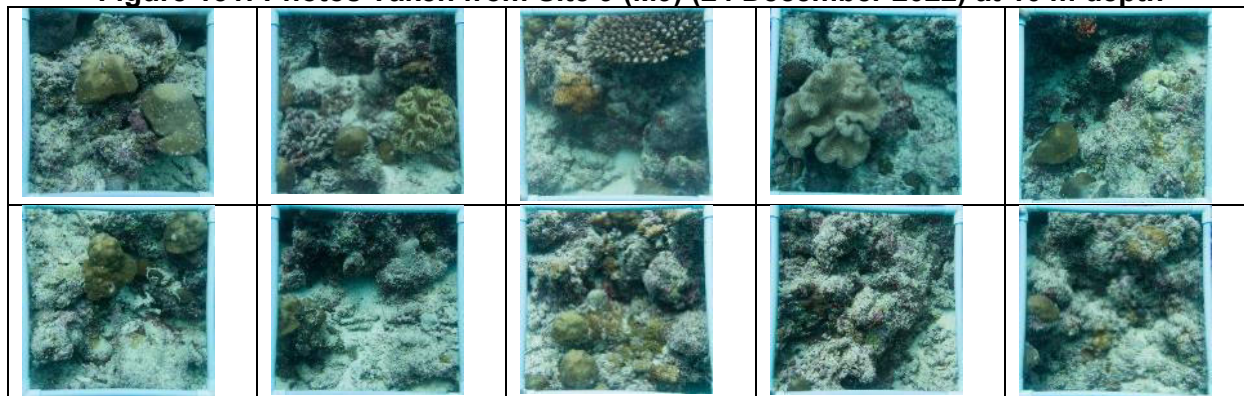
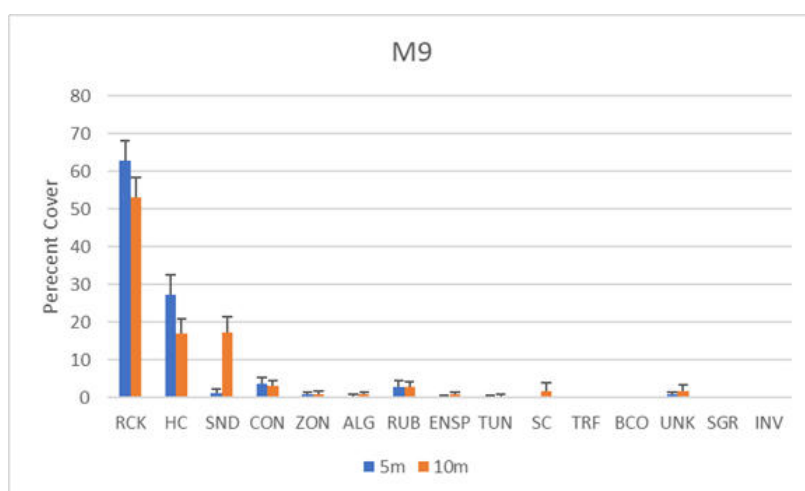


Figure 132: Average benthic cover and their standard error for M9 at both 5 m and 10 m depth



266. **Status of Site M10:** This location has been identified as a potential alternative for the discharge of brine water and wastewater. The location is very close to the WtE facility and it is on the southern reef of Thilafushi Island. Site M10 had the largest cover for rock, hard coral and sand (around 4%-40%) although rock was significantly lower at 10 m depth, while sand cover was lower about 15% at 5 m and slightly over 30% at 10 m depth. Corallinaceae cover is slightly higher at 10 m than 5 m depth 8% and 3 %, respectively. Micro algae and rubble cover on the substrates are higher at 5 m than 10 m. At 5 m depth, micro algae cover does not exceed 5% of substrate while rubble content is over 5%. At 5 m depth and 10 m depth, both micro algae and rubble content is below 3%.

267. With regard to fish, *Chormisdimidia* was the only abundant fish found in the area. Common occurrence of any species was not recorded at this location. Photographs of the transect quadrats are shown in Figure 118136 and Figure 119137. Benthic composition of M8 at both 5 m and 10 m depth is in the graph in Figure 135.

Figure 133: Photos Taken from Site 10 (M10) (24 December 2022) at 5 m depth



Figure 134: Photos Taken from Site 10 (M10) (24 December 2022) at 10 m depth

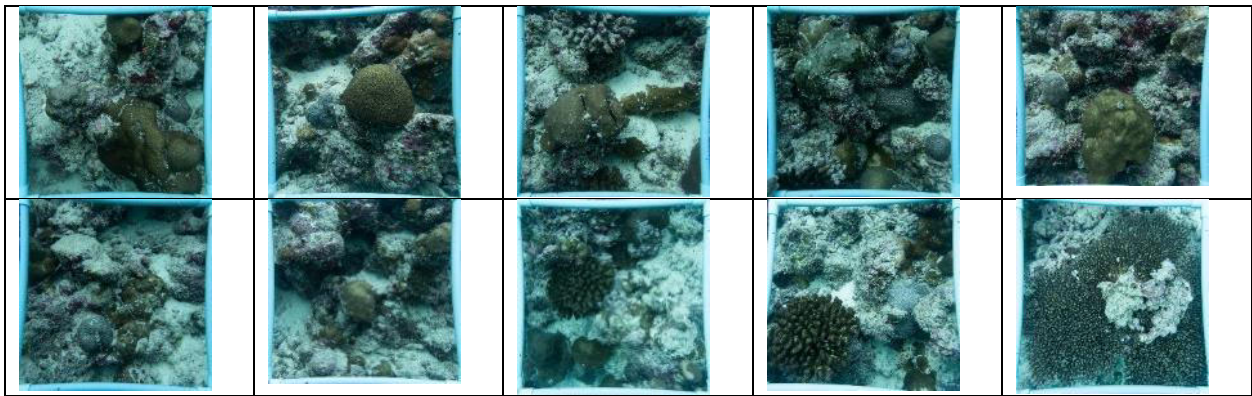
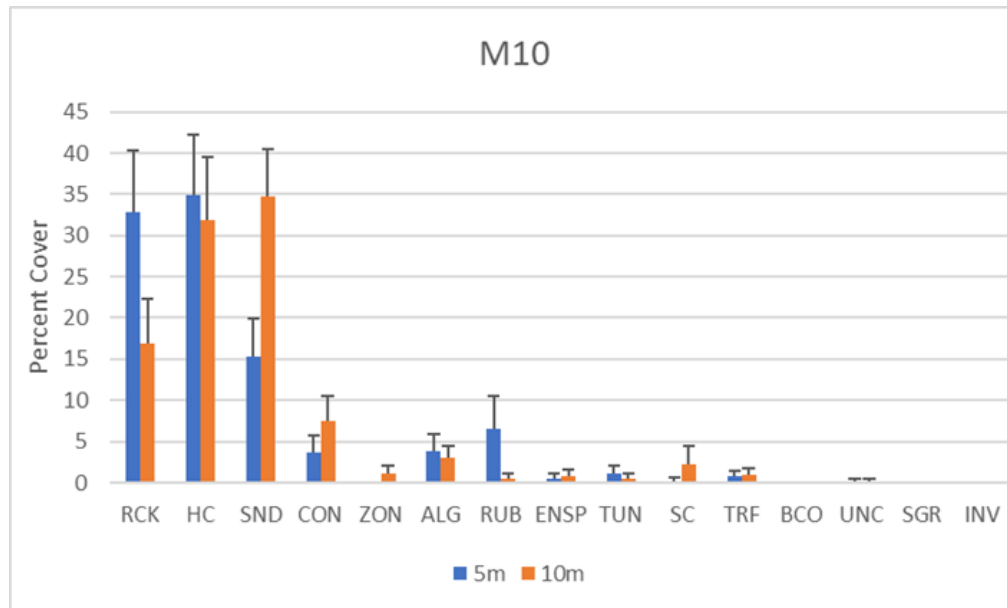


Figure 135: Average benthic cover and their standard error for M9 at both 5 m and 10 m depth



268. To ensure that the fish were not disturbed while data on substrate was being collected, a visual assessment of the fish was performed after the transect was laid. As previously mentioned, at each transect and at each depth (5 m and 10 m), three transects of 20 m length were observed. The counts were estimated in the field and the average count of each depth was taken as the mean abundance. The mean abundance was then categorized into three arbitrary scales: "Rare" (no fish to 20 fish), "Common" (20-40 fish), and "Abundant" (counts over 40 fish).

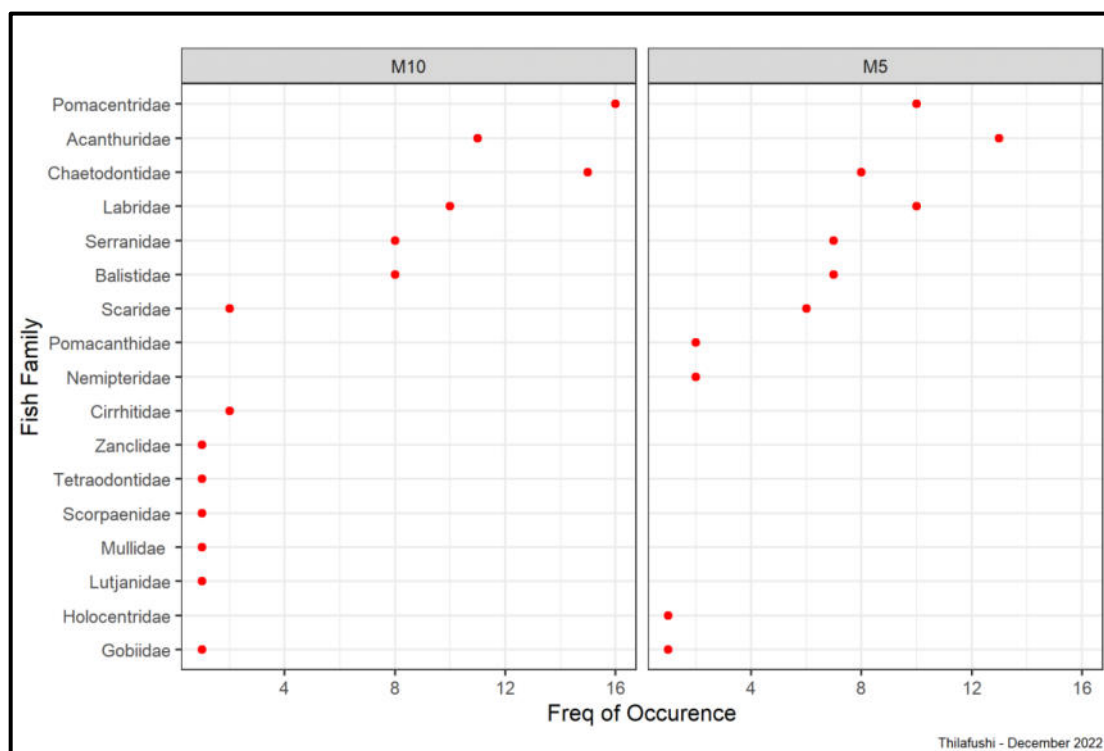
269. Summaries of the data collected at each site (combining both depths) are provided in **Error! Reference source not found.**4. The majority of the fish observed were considered rare. However, there were instances of Pomacentrids (2 species) and Balistidae (*Odonus niger*) being common at M8 and M9, and Pomacentrid, Chormisdidmiata being abundant at M9 and M10. In M8, only *Anthias (Pseudanthias evansi)* was considered abundant.

270. When examining the data at the family level and by depth (5 m and 10 m) for all three sites, it appears that Pomacentrid (*C. didmidata*) was more common in deeper waters, while Acanthuridae was more common in shallower waters. However, it is important to note that fish composition can vary greatly due to a variety of factors such as time of day, currents and other environmental conditions. Therefore, it is difficult to generalize about the fish composition based on this data.

271. Figure 139 shows frequency of occurrence of fish families at two depths. There appears to be no difference in occurrence of fish families at depth, although there are some indication occurrences are more frequent at 10 m (M10)

Table 44: Summary of fish census for three sites ordered as Rare, Common and Abundant

Site	Family	Scientific Name	Abundance	Site	Family	Scientific Name	Abundance	Site	Family	Scientific Name	Abundance
M8	Acanthuridae	<i>Acanthurus leucosternon</i>	Rare	M9	Acanthuridae	<i>Acanthurus bifasciatus</i>	Rare	M10	Acanthuridae	<i>Acanthurus leucosternon</i>	Rare
M8	Acanthuridae	<i>Acanthurus nigricauda</i>	Rare	M9	Acanthuridae	<i>Ctenochaetus striatus</i>	Rare	M10	Acanthuridae	<i>Acanthurus nigricauda</i>	Rare
M8	Acanthuridae	<i>Ctenochaetus striatus</i>	Rare	M9	Acanthuridae	<i>Ctenochaetus truncatus</i>	Rare	M10	Acanthuridae	<i>Acanthurus thomsoni</i>	Rare
M8	Acanthuridae	<i>Naso brevirostris</i>	Rare	M9	Acanthuridae	<i>Naso brevirostris</i>	Rare	M10	Acanthuridae	<i>Ctenochaetus striatus</i>	Rare
M8	Balistidae	<i>Balistapus undulatus</i>	Rare	M9	Acanthuridae	<i>Zabramus deajardinii</i>	Rare	M10	Acanthuridae	<i>Ctenochaetus truncatus</i>	Rare
M8	Balistidae	<i>Odonus niger</i>	Rare	M9	Acanthuridae	<i>Zabramus scopas</i>	Rare	M10	Acanthuridae	<i>Naso brevirostris</i>	Rare
M8	Balistidae	<i>Odonus niger</i>	Common	M9	Balistidae	<i>Balistapus undulatus</i>	Rare	M10	Acanthuridae	<i>Zabramus deajardinii</i>	Rare
M8	Balistidae	<i>Sufflamen bursa</i>	Rare	M9	Balistidae	<i>Melichthys indicus</i>	Rare	M10	Acanthuridae	<i>Zabramus scopas</i>	Rare
M8	Chaetodontidae	<i>Chaetodon collaris</i>	Rare	M9	Balistidae	<i>Odonus niger</i>	Rare	M10	Balistidae	<i>Balistapus undulatus</i>	Rare
M8	Chaetodontidae	<i>Chaetodon falcula</i>	Rare	M9	Balistidae	<i>Odonus niger</i>	Common	M10	Balistidae	<i>Melichthys indicus</i>	Rare
M8	Chaetodontidae	<i>Chaetodon guttatisimus</i>	Rare	M9	Balistidae	<i>Sufflamen bursa</i>	Rare	M10	Balistidae	<i>Odonus niger</i>	Rare
M8	Chaetodontidae	<i>Chaetodon kleinii</i>	Rare	M9	Chaetodontidae	<i>Chaetodon guttatisimus</i>	Rare	M10	Chaetodontidae	<i>Chaetodon falcula</i>	Rare
M8	Chaetodontidae	<i>Forcipiger flavissimus</i>	Rare	M9	Chaetodontidae	<i>Chaetodon kleinii</i>	Rare	M10	Chaetodontidae	<i>Forcipiger flavissimus</i>	Rare
M8	Chaetodontidae	<i>Hemichromis diphyreutes</i>	Rare	M9	Chaetodontidae	<i>Chaetodon madagascariensis</i>	Rare	M10	Chaetodontidae	<i>Hemirhamphichthys zoster</i>	Rare
M8	Cirrhitidae	<i>Paracirrhites arcatus</i>	Rare	M9	Chaetodontidae	<i>Forcipiger flavissimus</i>	Rare	M10	Chaetodontidae	<i>Hemichromis diphyreutes</i>	Rare
M8	Cirrhitidae	<i>Paracirrhites forsteri</i>	Rare	M9	Labridae	<i>Hemirhamphichthys zoster</i>	Rare	M10	Chaetodontidae	<i>Hemichromis pluripunctatus</i>	Rare
M8	Labridae	<i>Bodianus diana</i>	Rare	M9	Labridae	<i>Bodianus axillaris</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Halichoeres cosmetus</i>	Rare	M9	Labridae	<i>Halichoeres cosmetus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Halichoeres hursulianus</i>	Rare	M9	Labridae	<i>Halichoeres hortulanus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Labroides bicolor</i>	Rare	M9	Labridae	<i>Labroides bicolor</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Pseudochellinus hexataenia</i>	Rare	M9	Labridae	<i>Pseudochellinus hexataenia</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Pseudochellinus hexataenia</i>	Rare	M9	Labridae	<i>Thalassoma amblycephalum</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Labridae	<i>Thalassoma amblycephalum</i>	Rare	M9	Labridae	<i>Thalassoma amblycephalum</i>	Common	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Centropyge multispinis</i>	Rare	M9	Labridae	<i>Urolophus hillebrandi</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Chromis dimidiata</i>	Rare	M9	Pomacentridae	<i>Scoropopsis bilineata</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Chromis dimidiata</i>	Common	M9	Pomacentridae	<i>Chromis dimidiata</i>	Common	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Chromis webberi</i>	Rare	M9	Pomacentridae	<i>Chromis dimidiata</i>	Abundant	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Pomacentrus caeruleus</i>	Rare	M9	Pomacentridae	<i>Chromis opercularis</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Pomacentridae	<i>Pomacentrus philippinus</i>	Common	M9	Pomacentridae	<i>Plectroglyphidodon lacrymatus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Scaridae	<i>Chlorurus sordidus</i>	Rare	M9	Pomacentridae	<i>Pomacentrus chrysurus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Scaridae	<i>Scarus tricolor</i>	Rare	M9	Pomacentridae	<i>Pomacentrus nagasakiensis</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Amyrperodon leucogrammicus</i>	Rare	M9	Pomacentridae	<i>Pomacentrus philippinus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Cephalopholis argus</i>	Rare	M9	Scaridae	<i>Hippocampus harid</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Cephalopholis leopardus</i>	Rare	M9	Scaridae	<i>Scarus tricolor</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Epinephelus spilotoceps</i>	Rare	M9	Serranidae	<i>Amyrperodon leucogrammicus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Pseudanthias evansi</i>	Abundant	M9	Serranidae	<i>Cephalopholis argus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
M8	Serranidae	<i>Pseudanthias squamipinnis</i>	Rare	M9	Serranidae	<i>Cephalopholis leopardus</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
				M9	Serranidae	<i>Pseudanthias evansi</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
				M9	Tetraodontidae	<i>Canthigaster valentini</i>	Rare	M10	Chaetodontidae	<i>Paracirrhites arcatus</i>	Rare
								M10	Chaetodontidae	<i>Zenopsis cornutus</i>	Rare

Figure 136: Fish Families ordered with frequency of occurrence

2. Manta Tow Survey

272. Table 45 below outlines the results of the Manta Tow survey around the reef edge.

Table 45: Manta Tow Survey Results of Approximate Substrate Cover

	Live Coral cover%	Dead coral cover%	Soft corals cover%	Rock cover %	Rubble cover %	Silt cover %	Benthic diversity	Fish diversity
5 meters								
	5	8	-	15	2	70	low	low
10 meters								
	10	6	-	27	7	50	Low	low

273. The Manta Tow survey showed that coral reef system along the surveyed stretch at M8, M9, and M10 sections is not in very good conditions in term of percentage live coral cover, diversity of corals, benthic and pelagic life. The overall live coral cover of the reef system appeared to be approximately 5% at 5 meters depth and approximately 10% at 10 meters depth. The reef substrate at both these depths were dominated by silt. Abundance and diversity of fish was also lower along the stretch. The live coral cover was highest at 10 meters. The corals in most abundance were massive type coral head belonging to the genus *Porites*.

274. **Protected marine species.** During the Manta tow survey, no protected marine species such as sharks were observed and recorded.

275 **Reef Aesthetics.** This attribute was assessed by visual observations based on the observer's judgment and experience of the relative merits of a reef in the Maldives. This value judgment incorporated coral cover, diversity of life forms, fish life, reef structure and general appeal. The following categories were used to determine aesthetics of the reef system:

- (i) **Very poor** (mostly dead corals, pelagic life not abundant and diversity very low, structure uniform).
- (ii) **Poor** (Lot of dead corals, pelagic life not abundant and diversity low, some differences in structure).
- (iii) **Average** (Live corals about 10%, pelagic life abundant, diversity low, some structural variations exists).
- (iv) **Good** (Live corals about 20% pelagic life abundant, diverse, structural variations exists).
- (v) **Very good** (Live corals about 30%, pelagic life abundant, diverse, overhangs, and other structures).
- (vi) **Excellent** (Live corals over 40%, pelagic life very abundant, very diverse, lots of different structures, overhangs, caves, gullies, and different habitat types exists).

276. Reef aesthetics of Thilafushi's coral reef system (along the 500 meters) is regarded as very poor, given that substantial level of the reef is covered in silt and poor diversity of life forms. Fish life and abundance are very poor at the time of surveying and generally this stretch of reef can be considered to be "very poor".

1. Fishery

277. The amount and type of fish present at a given site can be a good indicator of the marine environment. For example, increased grazers are generally a sign of increased nutrients in the area, thus decreased coral cover and increased algal cover. 15-minute fish counts were done in sites M1-M7 in depths of 5 and 10m. The counts include mega fauna in addition to fishes. The fishes were identified to family level, however some protected species such as the napoleon wrasse, were identified to species level. However, the abundance of this species is rare at site M3, which is more than 1 km away from the project location. Table 46 outlines the fish count survey at all the sites.

Table 46: Fish abundances observed at sites 1 to 7 at a depth of 5 and 10 meters

Family/Subfamily	Site M1		Site M2		Site M3		Site M4		Site M5		Site M6		Site M7	
	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Anthias (Anthiadae)	R	A	A	A	R	A	C	-	R	C	C	C	R	-
Surgeonfishes (Acanthuridae)	A	C	A	C	A	C	A	C	A	A	A	A	A	C
Wrasses (Labridae)	C	C	-	C	-	-	C	C	C	C	A	-	C	-
Parrotfishes (Scaridae)	C	C	A	C	R	R	C	R	A	-	C	C	C	-
Triggerfishes (Balistidae)	C	A	A	A	-	A	R	-	C	A	A	A	C	-
Boxfishes (Ostraciidae)	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Damselfishes (Pomacentridae)	A	A	A	A	-	A	C	-	R	A	A	A	A	-
Groupers (Serranidae)	R	-	R	R	R	-	R	-	R	R	R	R	R	-
Moorish idol (Zanclidae)	R	R	R	R	R	R	R	R	C	R	R	R	R	R
Butterflyfishes (Chaetodontidae)	A	C	A	A	C	C	A	C	R	C	A	A	A	-
Goatfishes (Mullidae)	-	-	R	R	-	-	C	C	R	-	R	-	R	-
Hawkfishes (Cirrhitidae)	-	-	R	R	R	-	-	-	R	-	R	-	-	-
Threadfin and Whiptail breems (Scolopsis)	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Octopus (Octopodidae)	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Fusiliers (Caesionidae)	-	-	-	-	-	-	A	A	-	-	-	-	-	-
Rabbitfishes (Siganidae)	-	-	-	-	-	-	R	-	-	-	R	-	-	-
Gobies (Gobiidae)	-	-	-	-	R	-	-	R	R	-	-	-	-	-
Pipefishes and seahorses (Syngnathinae)	-	-	-	-	-	-	R	-	R	R	-	-	-	-
Puffers (Tetraodontidae)	-	-	-	-	R	-	R	-	C	-	R	-	-	-
Emperors or scavengers (Lethrinidae)	-	-	-	-	-	-	-	-	C	-	R	-	-	-
Jacks and Trevallies (Carangidae)	-	-	-	-	A	-	-	-	R	-	-	-	-	-

Family/Subfamily	Site M1		Site M2		Site M3		Site M4		Site M5		Site M6		Site M7	
	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Angelfishes (Pomacanthidae)	-	-	-	-	-	-	-	-	R	-	R	R	-	-
Lizardfishes (Synodontidae)	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Squirrelfishes, soldierfishes (Holocentridae)	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Grunts and Sweetlips (Haemulidae)	-	-	-	-	-	-	-	-	-	R	R	-	-	-
Eels and Morays (Anguilliformes)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Napoleon Wrasse (Cheilinus undulatus)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Sharks & Rays (Elasmobranchii)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Sea Turtles (Chelonioidae)	-	-	-	-	-	R	-	-	-	-	-	-	-	-

A= Abundant (Meaning that during the 15-minute time swim survey, species counts were recorded more than 50, hence it is difficult to count their numbers).
C=Common (Meaning that during the 15-minute time swim survey, they were spotted occasionally and throughout the survey, but their numbers were less than 50).
R=Rare (Meaning that during the survey, only few of these species were observed, often 1 or 2).

2. Aquatic Biology

278. Plankton are the base of the marine food chain. The phytoplankton and zooplankton abundances in the area could possibly be affected by the presence of heavy metals. If the plankton community is thriving in these areas the heavy metals maybe bio accumulating in the food chain. Therefore, plankton counts were done around Thilafushi Island in order to establish a baseline. A plankton net of 50µm mesh was built to carry out the survey. The plankton tows were carried out at sites where the marine water samples were collected.

279. **Data Collection Methodology.** A plankton net of opening 0.48 m x 0.48 m was tied to a 20 m rope and released from a vessel. The net was allowed to drift for 20 meters and then towed towards the boat. Any organisms or particles larger than 50µm gets caught up in the net and collected in the cod end.

280. **Zooplankton.** Analyses of the samples were done using a microscope using a Sedgewick rafter counting chamber. The chamber has a volume of approximately 1 ml. The samples collected from the net were approximately 150 ml – 250 ml in volume. For the zooplankton count, the samples were transferred to a beaker diluted to approximately 500 ml – 900 ml and the volume recorded. The purpose of dilution is to reduce the number of plankton in the optical view of the microscope for ease of counting. Two sub-samples were counted from each sample. To calculate total count in the sample, the counts in the subsamples were averaged. Thereafter the average value in the sub samples were multiplied with the total volume in the diluted sample to obtain the total count in the sample. From the total count in the sample and from the opening area of the net and the distance towed, the abundance of zooplankton per meter cube was calculated using the formula, $Abundance = total\ count\ in\ the\ sample / (distance\ towed \times opening\ area)$. During the survey the zooplankton were classified into Rotifera, Protozoa, Chordata, Mollusca, Annelida, Cnidaria, Crustacea and Chaetognatha. Additionally, Copepods were classified into three groups, Calanoida, Cyclopoida and Harpacticoida.

281. **Phytoplankton.** Analyses of the samples were done using a microscope using a Sedgewick rafter counting chamber. The chamber has a volume of approximately 1 ml. The samples collected from the net were approximately 150 ml – 250ml in volume. For the phytoplankton count, the samples were transferred filtered through a 200 µm sieve to remove large zooplankton for ease of counting. Thereafter the sample was transferred to a beaker and diluted to approximately 500 ml – 900 ml and the volume recorded. The purpose of dilution is to reduce the number of plankton in the optical view of the microscope for ease of counting. Two sub-samples were counted from each sample. To calculate total count in the sample the counts in the subsamples were averaged. Thereafter the average value in the sub samples was multiplied with the total volume in the diluted sample to obtain the total count in the sample. From the total count in the sample and from the opening area of the net and the distance towed, abundance of zooplankton per meter cube was calculated using the formula, $Abundance = total\ count\ in\ the\ sample / (distance\ towed \times opening\ area)$.

282. **Limitations of the methodology.** The above method gives approximate estimates of abundances for each group/genera of plankton. Using a Sedgewick rafter to count zooplankton limits the subsample volume to 1 ml thus, rare groups in plankton would likely not be observed in the counts. The method is reliable to estimate the total abundance of common groups of zooplankton which are greater than 50 µm in size and phytoplankton greater than 50 µm and less than 200 µm.

283. **Zooplankton Abundance - Common Phyla.** Crustaceans were observed to be of the highest abundance amongst the zooplankton from all 7 sites. Additionally, the highest abundance of zoo plankton was observed from site 7 (PKT 7). The lowest abundance of zooplankton was observed from site 5. Table 47 and Figure 139 to Figure 140 outline the variation in zooplankton abundance between the sites.

Table 47: Abundance of common phyla of zooplankton from sites PKT 1 to PKT 7

Phyla	Abundance at sites (Individuals/m ³)						
	PKT 1	PKT 2	PKT 3	PKT 4	PKT 5	PKT 6	PKT 7
Rotifera	174	760	1,270	293	195	814	1,519
Protozoa	260	2,170	1,563	1,172	781	1,628	868
Chordata	347	705	1465	977	391	746	217
Mollusca	87	163	391	NA	98	339	217
Annelida	174	54	98	NA	98	68	NA
Cnidaria	217	380	98	488	NA	NA	NA
Crustacea	3,212	7,378	16,113	9,277	1,465	6,782	21,267
Chaetognatha	43	109	488	98	NA	NA	217
Total Zooplankton	7,769	19,151	37,598	21,582	4,492	17,158	45,573

Figure 137: Abundance of common phylum of zooplankton from sites PKT1 to PKT7.

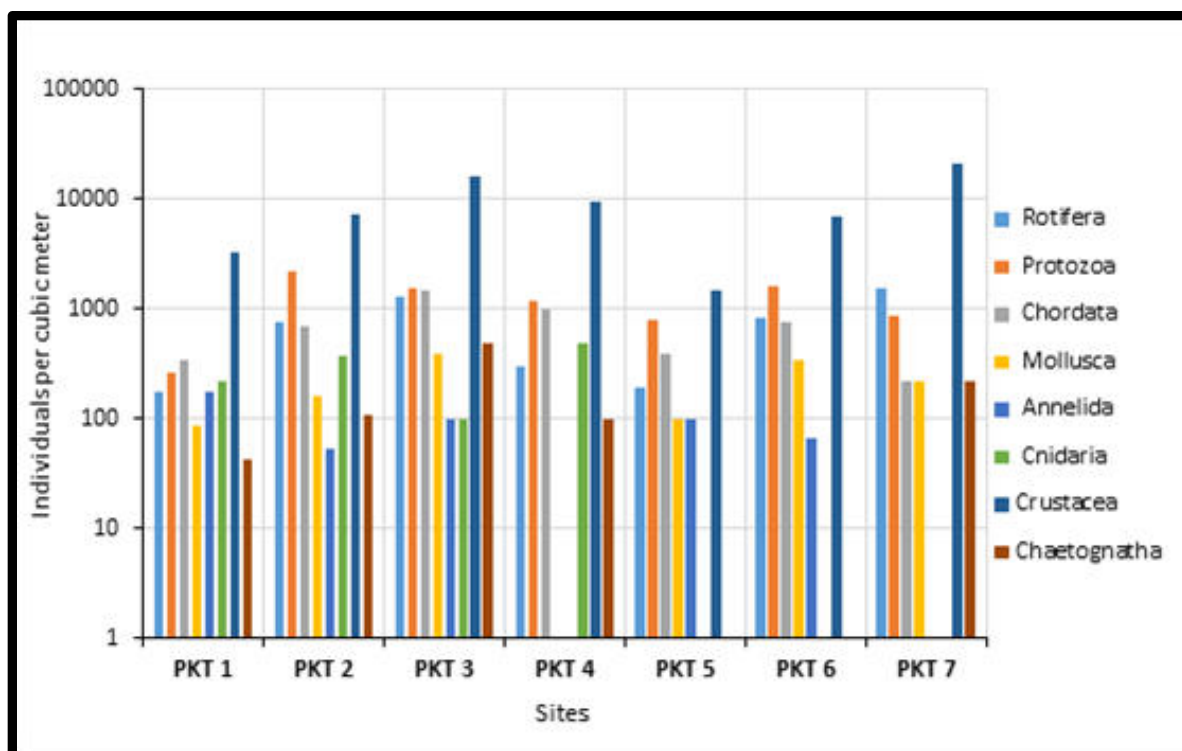
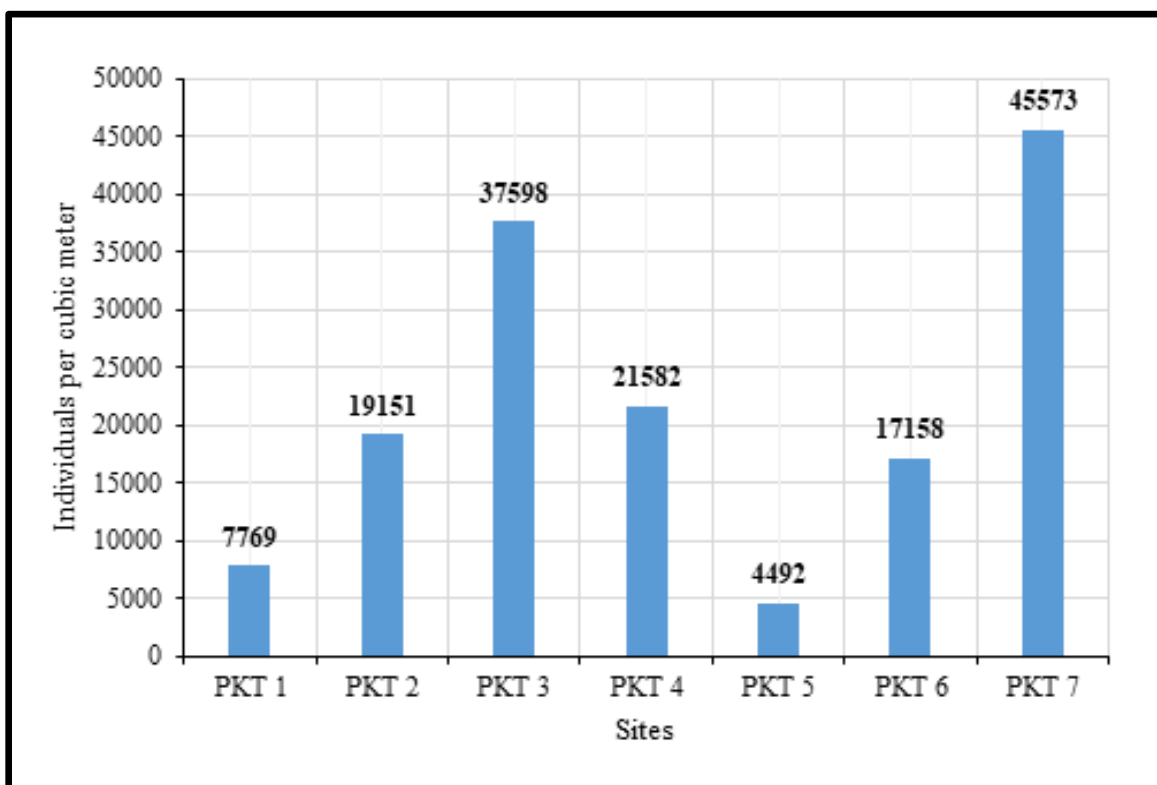
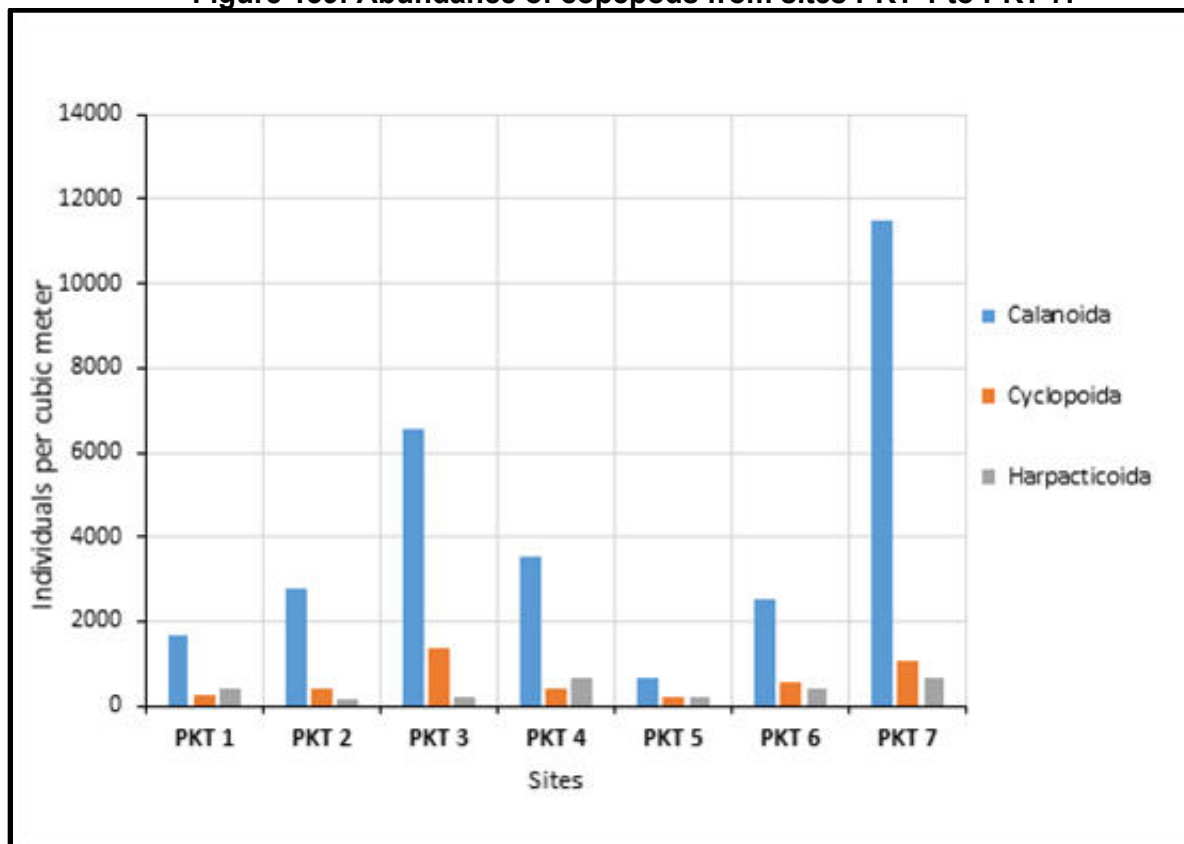


Figure 138: Total abundance of zooplankton from sites PKT 1 to PKT 7.

284. **Zooplankton Abundance - Copepods.** The dominating group of copepods observed in the sites were calanoids. The highest abundance of copepods was observed at site 7 and the lowest abundance of copepods at site 5. Table 48 and Figure 141 outline the variation in copepod abundance between the sites.

Table 48: Abundance of copepods from sites PKT 1 to PKT 7

Order	Abundance at Sites (Individuals/m ³)						
	PKT 1	PKT 2	PKT 3	PKT 4	PKT 5	PKT 6	PKT 7
Calanoida	1693	2767	6543	3516	684	2509	11502
Cyclopoida	260	434	1367	391	195	543	1085
Harpacticoida	391	163	195	684	195	407	651

Figure 139: Abundance of copepods from sites PKT 1 to PKT 7.

340. Phytoplankton Abundance. Diatoms were observed to be of the highest abundance, amongst the phytoplankton from all 7 sites. Additionally, the highest abundance of phytoplankton was observed from site 7 (PKT 7). Additionally, the lowest abundance of phytoplankton was observed from site 5. Figure 122 and Figure 123 below show the variation in phytoplankton abundance between the sites.

Figure 140: Abundance of diatoms and dinoflagellates from sites PKT 1 to PKT 7

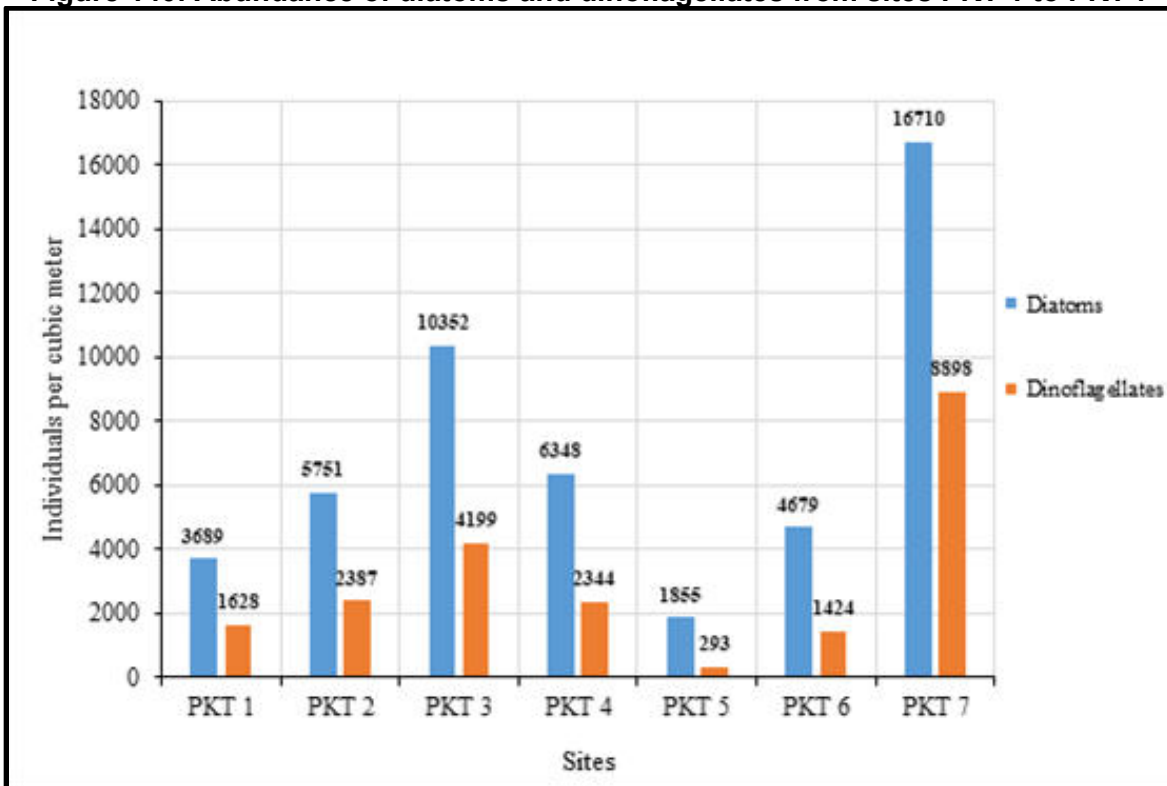
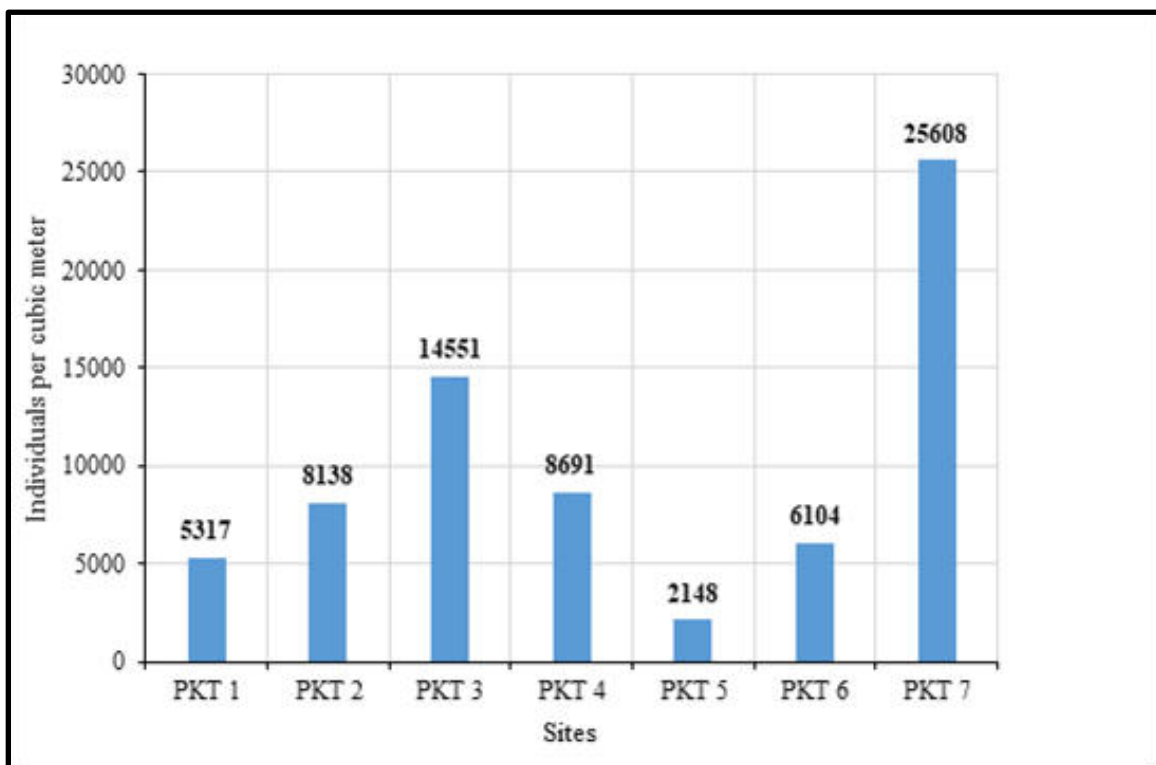


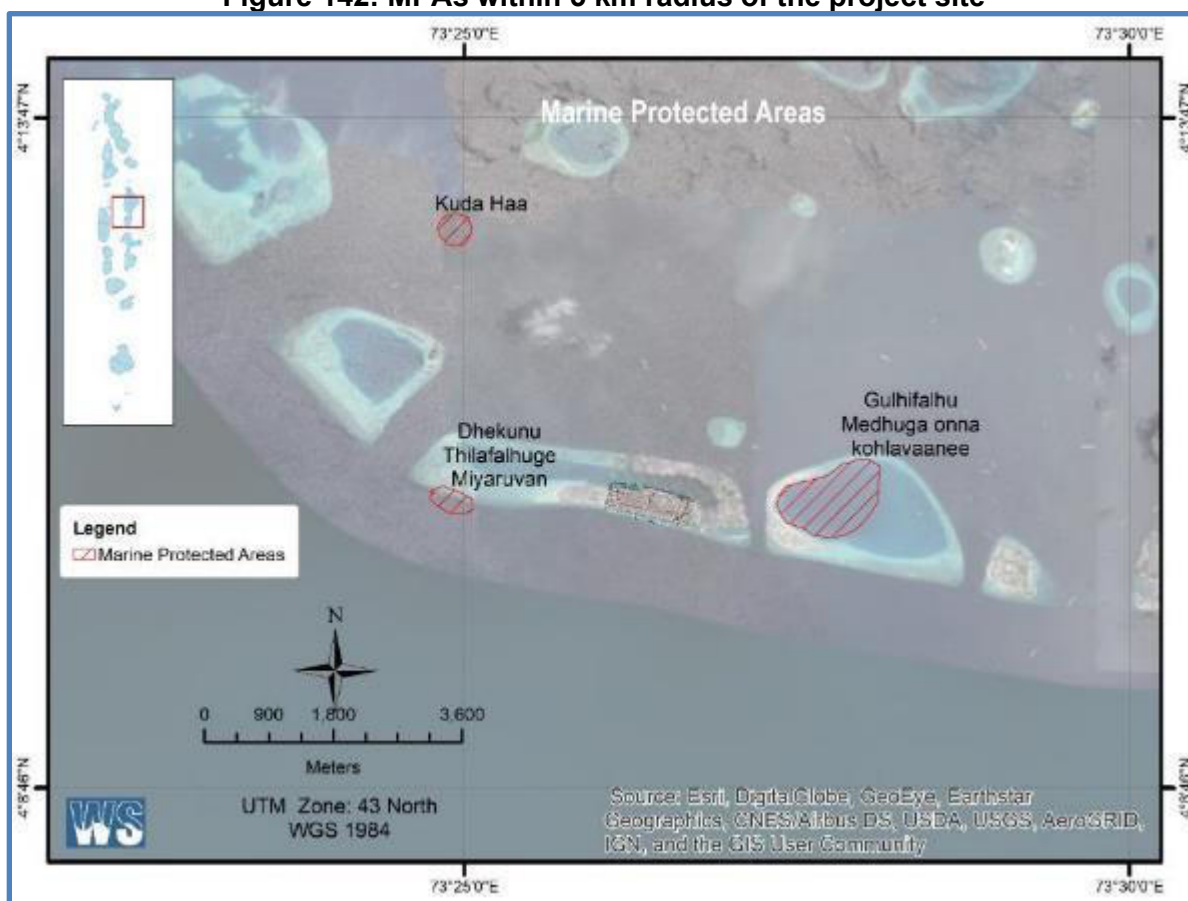
Figure 141: Total abundance of phytoplankton from sites PKT 1 to PKT 7



F. Protected Areas and Critical Habitats

341. **Marine Protected Areas.** According to Maldives EPA, there are 3 Marine Protected Areas (MPAs) within 5 km radius from the project site. They are; (i) Dhekunu Thilafalhuge Miyaruvani – this area is also referred to as Lions Head and is on the outside of the South Malé Atoll facing south into Vaadhoo Channel. (ii) Gulhifalhu Medhuga Onna Kollavaanee – this area is referred to as Hans Hass Place, which is the deep lagoon area at Gulhifalhu and (iii) Kuda Haa – isolated reef standing up from a sandy bottom at 30m, north to Giraavaru Island. In addition to the marine protected areas there are other areas that are also designated as ecologically sensitive areas in Kaafu atoll. However, none is located within 5 km radius of the project site (Figure 124).

Figure 142: MPAs within 5 km radius of the project site



342. Dhekunu Thilafalhuge Miyaruvani (also known as “Lions Head”) is the closest MPA to the project area. The edge of Lions Head is about 1 km from the project site’s boundaries. Lions Head is on the outside of North Malé Atoll facing south into Vaadhoo Channel. From the reef edge at about 8m there is a step down to a steep rubble slope where one can sit to watch the sharks. To the right (west) as one faces out is a large overhang that leads down to over 30 m depth. To the left (east) there is a line of small overhangs in 10-15m that continues for about 150 m. The Maldives EPA consider the Lions Head as a protected seascape (IUCN Category V) which covers ocean with a natural conservation plan which accommodates a range of for-profit activities. It has been a marine protected site since 01 October 1995. As Thilafushi and its surrounding area have undergone a transformational development in the past two decades, Maldives EPA is considering

declassifying Lions Head from being a marine protected area to a more appropriate status reflecting current land use (industrial zone).

343. Gulhifalhu Medhuga Onna Kollavaanee (also known as “Hans Hass Place”) is on the outer reef of North Malé Atoll facing south into Vaadhoo Channel. It is an area about 100 m long set back in a large recess in the reef. The reef top is at about 3m and drops vertically to a line of overhangs at 8 m-10 m. The western end is marked by a large cavern at 10 m-15 m. There are further overhangs at 20 m-25 m. Hans Hass Place is named in honor of the great pioneer of diving in Maldives.

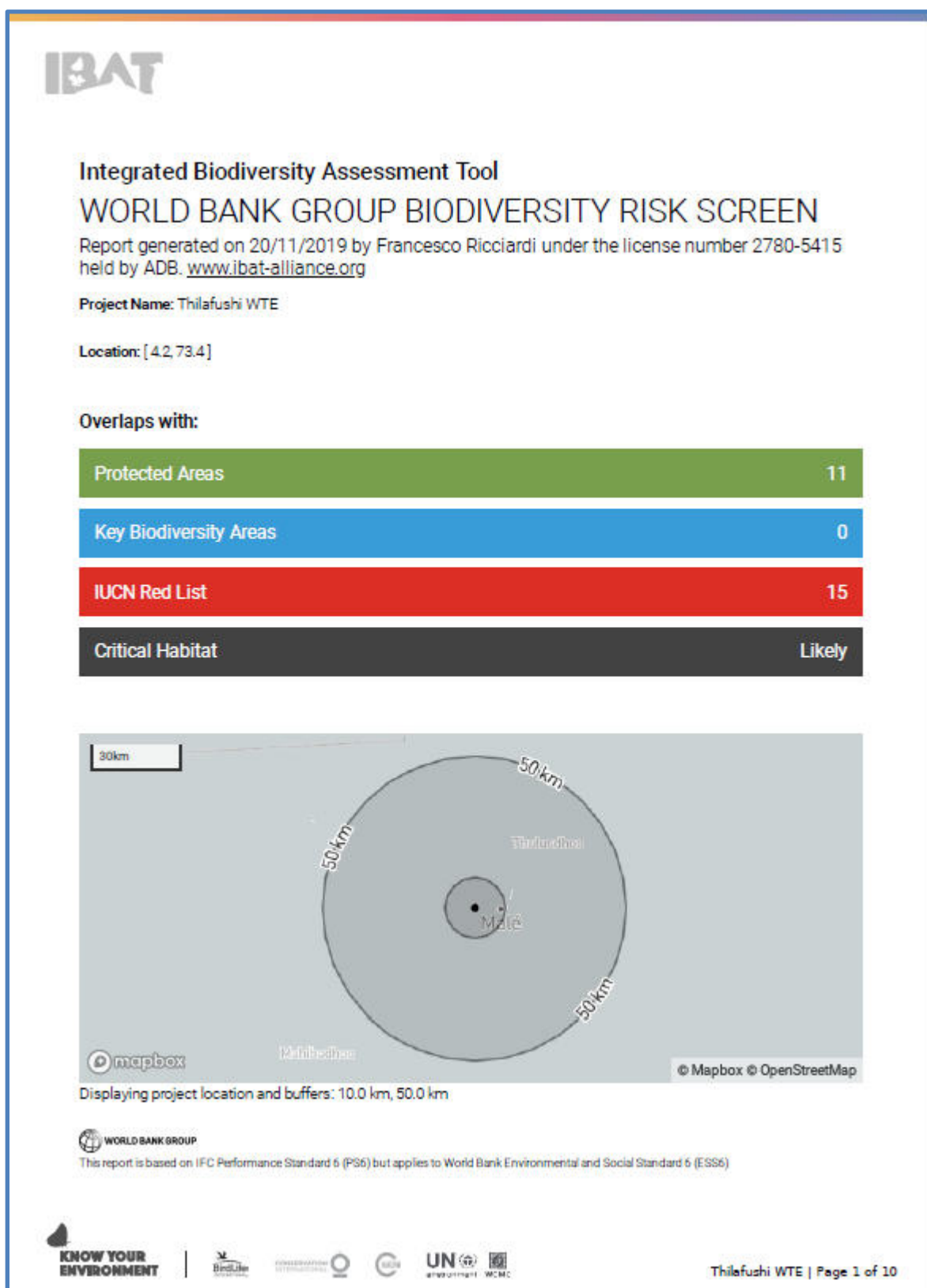
344. Kuda Haa is located about 4 km north from the project site. It assumed that no direct impact will be caused to this MPA due to the distance and location.

345. Within the MPAs, anchoring (except in an emergency), coral and sand mining, dumping of waste, removal of any natural object or living creatures, fishing of any kind with exception of traditional live bait fishing and any other activity which may cause damage to the area or its associated marine life are prohibited under the Environment Act.

346. **Critical Habitats.** The Integrated Biodiversity Assessment Tool (IBAT) was initially used to screen and assess potential risks on the protected areas or critical habitat that may exist around the project site (default area of analysis of 50 km radius). Initial screening results show there are no key biodiversity area around the project site but likely to be critical habitat due to the identified MPAs and IUCN Red List species. Hence, a critical habitat assessment was undertaken. Results of the assessment show that the area of analysis, which encompasses the project site, is likely to be a critical habitat at least for a terrestrial insect (*Enallagma maldivense*). This insect normally thrives in freshwater habitats such as ponds. As the project is in Thilafushi, an island with no freshwater body, it is highly unlikely that this insect is present within and around the island. More so that this insect is not found in the coastal areas and open seas surrounding Thilafushi island. The complete critical habitat assessment report is in Appendix 12. As precautionary measure, the EIA provides measures to ensure no critical habitats, or features for which they are qualified as critical habitats, will be impacted.

347. Figure 125 below shows the screen shots of the IBAT Proximity Test Results.

Figure 143: Screen Shot of IBAT Proximity Test Result for Thilafushi Island (50-kilometer)



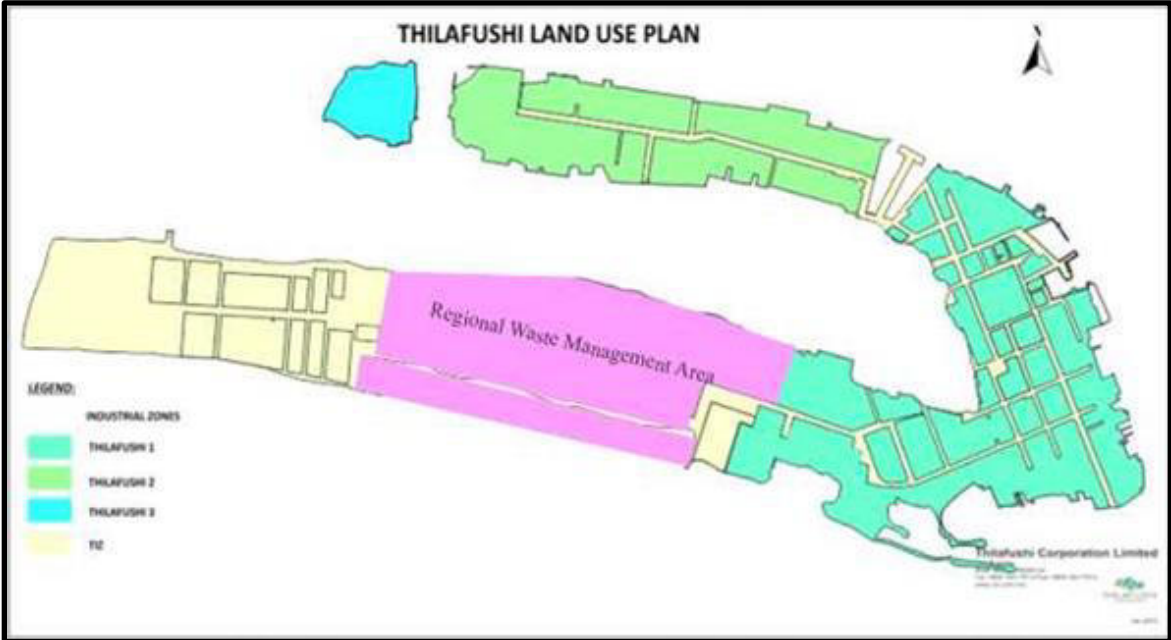
G. Socio-Economic Conditions

1. Physical Infrastructures

348. **Land Use.** Thilafushi is an island that has been reclaimed by dumping of wastes on the submerged “Thilafalhu” lagoon area since December 1992. The island was initially developed as a sand bank using dredged material from the Thilafushi Reef. Since then, land has been reclaimed by placing solid waste in dredged holes on the reef flat and later topping it up with fresh lagoon sand.

349. The land use system of Thilafushi was developed in an ad hoc manner without a master plan. Hence, the present land use patterns show a mixed approach to development with a variety of industrial, manufacturing and warehousing activities being undertaken on the island.

Figure 144: Thilafushi Land Use Plan



Source: Thilafushi Corporation Limited.

350. The bulk of the land in Thilafushi is used for manufacturing or industrial activities. These include activities like aluminum product assembly, construction prefabrication, boat building and workshops, among others. Most of these developments are located at Thilafushi 2 (see the legend in Figure 126). This is primarily due to the large plots of land leased from these areas. A number of new manufacturing activities have appeared on the old Thilafushi 1 Island, primarily in the form of workshops, construction related manufacturing and boat building. Some of these plots were initially allocated for warehousing.

351. **Industries.** With the development of Thilafushi as an industrial zone, numerous small and middle industries have been established on the island. The current (major) industrial activities in the island are boat manufacturing, cement packing, methane gas bottling and various large-scale warehousing. In March 2015, the Maldivian government decided to relocate the central commercial port from Malé to Thilafushi. This project is still pending.

352. **Commercial and Industrial Activities.** The major activities in Thilafushi are industrial activities, importing and stockpiling of construction materials and warehousing facilities, wholesale and retail trade, workshops and other industrial and commercial activities. There are more than 60 different companies established in Thilafushi, the number is more likely to get higher each year. There are both foreigners and locals employed in the island.

353. **Infrastructure facilities.** Desalinated water is supplied in bulk to the doorstep of each plot by the Maldives Water and Sewerage Company (MWSC), who operate a 150 m³/day desalination plant on the island. There are also some small private desalination plants operating on the island. There is a high percentage of plots that use rainwater as the main source of drinking water. Drinking water is usually obtained from rainwater and desalinated water. Based on the socio-economic survey conducted in August – September 2019, 415 respondents confirmed they have flush latrine connected to a piped sewer system. Field surveys shows that 31% of the plots had their toilets connected to the sea and 68% had septic tank systems. There is no organized waste collection and management system on the island. Each tenant is responsible for daily and periodic waste collection and disposal to the dump site located on southern side of the island.

354. The main emergency services on the island the Fire Services and Police. The fire service is operated by Maldives National Defence Force (MNDF) 24 hours a day and is equipped to counter small to moderate fire events. The island is patrolled by the Maldives Police Services.

355. **Transportation.** The access to Thilafushi could be made by a ferry joining the capital Malé and operating every 30 minutes. Like other Islands Thilafushi is accessible through some docking points for speed boats and vessels. There is no other public transportation on the island. Transportation could be organized with the help of WAMCO, GMLZ or other private parties by car or lorries.

356. **Power Sources and Transmission.** Power is provided by the State Electric Company (STELCO) and from private generators (diesel generator sets). There is no exclusivity provision for STELCO as is the case in inhabited islands. However, 80% of the plots use STELCO electricity.

357. **Agriculture Development and Tourism.** Thilafushi is dedicated to industrial development and has no strategy and plans to become an agriculture or tourism island.

2. Social and Cultural Resources

358. **Population and Communities.** According to the 2014 census, there were 2,052 persons in Thilafushi Island. The total number of males and females are 2,048 and 4, respectively. Out of the 2,052 persons on the island, 333 persons were Maldivian. The dominant age group is 20-24 years comprising about a quarter of the population. Table 49 presents the population in Thilafushi.

Table 49: Living population at Thilafushi

Total			Maldivian			Foreigners		
Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
2,052	2,048	4	333	332	1	1,719	1,716	3

359. There are no communities/residential areas in Thilafushi. The island is an industrial zone. A socio-economic survey was conducted in August to September 2019 as the Government of Maldives does not have an updated database that could describe the socio-economic conditions

in the island. The overall objective of the survey is to ascertain the baseline socio-economic profile of the workers in Thilafushi and residents in Gulhifalhu Islands. The survey also provides insight on the population’s needs, current waste disposal practices and the willingness of the companies to pay for waste management services. A complete report of this socio-economic survey is attached as Appendix 13.

360. The survey was carried out using random sampling and two questionnaires, one questionnaire for individuals working and/or residing in Thilafushi and Gulhifalhu and the other for companies based on these islands. Four hundred and thirty (430) individuals and 35 companies were surveyed across Thilafushi and Gulhifalhu Islands (Table 50 and Table 51). Respondents were mainly located in Thilafushi. Spatial distribution of these surveyed workers and companies in the islands are illustrated in Figure 127 and Figure 128 below.

Table 50: Number of Individuals Surveyed

Island	Individuals	Percentage	Males	Females
Thilafushi	374	86.98%	373	1
Gulhifalhu	56	13.02%	56	0
Total	430	100%	99.77%	< 1%

Table 51: Number of Companies Surveyed

Island	Companies	Percentage	Males	Females
Thilafushi	32	91.43%	31	1
Gulhifalhu	3	8.57%	3	0
Total	35	100%	97.14%	2.86%

Figure 145: Spatial Distribution of Surveyed Workers in Thilafushi and Ghulee Fahlu



Figure 146: Spatial Distribution of Surveyed Companies in Thilafushi and Ghulee Fahlu

361. As these islands are mainly used for manufacturing and industrial activities, respondents of the survey were predominantly male. There were only 2 female respondents, 1 for each of the individual and company questionnaires. The woman who responded to the individual questionnaire is 40 years old from Bangladesh living in Thilafushi in accommodation provided by the employer. The woman who responded to the company questionnaire is Maldivian and works for a company in Thilafushi that provides housing to their employees in Malé. Her company provides health insurance for their employees. Three employees from her company were reported to have health issues within the past year for fever and common cold. They sought medical attention in a health facility in Malé. The respondent believes that the practices of waste disposal in Thilafushi, including burning, is causing health issues to her and her employees.

362. There are 319 individuals surveyed that stay in Thilafushi and 52 stay in Gulhifahu, which totals 371 (Table 52). Of these, 367 or 98.92% are provided housing by their employers. As a result, the overwhelming majority of individuals surveyed that are staying in Thilafushi and Gulhifalhu are provided housing by their employers. The remaining respondents live in Malé (51) and in other islands such as Hulhumalé and Villimalé. Almost 89% of all respondents are provided housing by their employers (Table 53).

Table 52: Location of Accommodation of Individuals Surveyed

Island	Number of Respondents	Percentage
Thilafushi	319	74.19%
Gulhifalhu	52	12.09%
Malé	51	11.86%
Other islands	8	1.86%
Total	430	100%

Table 53: Housing Arrangement of Individuals Surveyed

Housing	Number of Respondents	Percentage
Provided by employer	382	88.84%
Renting	39	9.07%
Own property	5	1.16%
Not paying rent	4	< 1%
Total	430	100%

363. The individuals surveyed range from 18 to 67 years old and are mostly Muslims (81%)

from Bangladesh (66%). The education level of the respondents' showed that 9% did not have any education, 12% had basic literacy skills, and 25% completed primary school. An estimate of 50% obtained secondary level education or higher but only 4% have completed a degree. Thus, an estimate of 56% of the respondents are unskilled laborers, 36% are skilled workers, 7% have a supervisor level position and <1% are managers. None of those surveyed are believed to be involved in fishing activities. Table 54 to Table 58 describe the profile of respondents and results of the survey.

Table 54: Age of Individual Respondents

Age (years)	Number of Respondents	Percentage
18-29	186	43.26%
30-39	150	34.88%
40-49	68	15.81%
50-59	20	4.65%
60-67	6	1.40%
Total	430	100%

Table 55: Religion of Individuals Surveyed

Religion	Number of Respondents	Percentage
Islam	349	81.16%
Hinduism	53	12.33%
Buddhism	18	4.19%
Christianity	10	2.33%
Total	430	100%

Table 56: Nationality of Individuals Surveyed

Country of Nationality	Number of Respondents	Percentage
Bangladesh	283	65.81%
Maldives	66	15.35%
India	46	10.70%
Sri Lanka	23	5.35%
Nepal	10	2.33%
Indonesia	2	.47%
Total	430	100%

Table 57: Education Level of Individuals Surveyed

Education Level	Number of Respondents	Percentage
Secondary level and higher (non-degree)	216	50.23%
Primary level	108	25.12%
Basic literacy skills	50	11.63%
No education	37	8.60%
Degree level	19	4.42%
Total	430	100%

Table 58: Employment Level

Level	Number of Respondents	Percentage
Unskilled/ laborer	230	53.49%
Skilled/ expert	153	35.58%
Supervisor	32	7.44%
Manager	3	< 1%
Unknown	12	2.79%

Level	Number of Respondents	Percentage
Total	430	100%

364. Of the 35 companies surveyed, 18 did not provide detail on their type of business. The remaining 17 companies are engaged in the activities listed in Table 59. About 86% of companies surveyed reported that their employees are housed in Thilafushi and an estimate of 77% provide health insurance for their workers.

Table 59: Types of Companies Surveyed

Island	Business
Thilafushi	cooking
Thilafushi	tin sheet manufacturing
Thilafushi	sea and land transportation
Thilafushi	logistics
Thilafushi	boat repair and logistics
Thilafushi	water plant and electrical work
Thilafushi	Oil supplier; boat yard; port harbor; workshop
Thilafushi	garage
Thilafushi	tea shop
Thilafushi	repair and maintenance of heavy vehicles
Thilafushi	diesel seller
Thilafushi	boat building and repair
Thilafushi	police services
Thilafushi	cargo loading and unloading
Gulhifalhu	electricity provider
Gulhifalhu	island development
Gulhifalhu	storage and workshop

Table 60: Location of Employee Housing

Island	Number of Respondents	Percentage
Thilafushi	30	85.71%
Malé	4	11.43%
Gulhifalhu	1	2.86%
Total	35	100%

365. Twenty-four (24) or 69% of company respondents reported that they segregate their waste but only 10 or 29% stated that their waste is collected. Of those who reported that waste was collected from their company, collection frequency varied from daily to once a month. Thirteen (13) of the companies surveyed sell their recyclable waste.

366. Most of the laborers and companies are aware of the health issues related to inadequate waste management. The employers surveyed believe that the present waste disposal practices in Thilafushi affect their health and the health of their employees. The main reason was pollution due to burning of waste. Twenty-one (21) companies reported that they pay for waste disposal. However, of these, 18 reported that they were poorly satisfied with the waste collection services.

367. Of the total company respondents, 25 companies have stated their willingness to pay a higher amount than what they're currently paying for improved waste collection services. The survey found that smoke inhalation is perceived to be the main problem as the smoke can at times impair the visibility in Thilafushi. There are no fishing activities within the study area.

368. **Health Facilities.** Nearby healthcare facilities and hospitals are located in Malé. A health facility was opened in Thilafushi only recently in July 2019. However, the facilities and services offered are limited.

369. **Education Facilities.** There is no evidence of education facilities on Thilafushi. Nearby schools, high schools and other education facilities are located in Malé.

370. **Physical Cultural Resources.** No evidence of physical and cultural heritage could be found at Thilafushi. Similarly, no evidence of historical or archeological sites could be found at Thilafushi.

371. **Current use of land resources for traditional purposes.** No evidence of current use of land for traditional purposes could be found at Thilafushi.

372. **Sensitive Receptors.** Based on the results of the socio-economic survey (see discussion of survey results above), individuals were assessed if they will be directly affected negatively by the WTE project at any point during its implementation. Further, the extent of impact, if any, of the WTE project to these individuals was also assessed.

373. Assessment of the results of the survey show that the most sensitive receptor individuals are those workers who are employed without security of tenure and the elderly (65 years old and above). However, the project does not have influence or control over these individuals, nor will the project have impact on them. Summary of this assessment is in Table 61:

Table 61: Assessment of Project Impacts to Potential Sensitive Receptors

Criteria Based on ADB SPS	Findings in the Survey	Impact of the Project
Below Poverty Line / Poor	The individuals surveyed are all employed at various positions and levels, from managerial positions to unskilled laborers.	None. The project will not cause displacement of workers in the island. Neither will the project impact the workers who may or may not be classified as belong to below the poverty line.
Female-headed HH	Not applicable. All workers including women in the island stay in housing or accommodation provided by employers. The island is not a residential area, and the status of determining households as female-headed or not is not applicable in this case.	None.
Landless or Without Legal Title to Land	Not applicable. All workers in the island stay in housing or accommodation provided by employers. The status of being landless or without legal title to land is not applicable in this case.	None. The project has not or will not displace any individual or entity with ownership to land or property. The project site is owned by the government (a reclaimed land) and no legal or illegal settlement exists on this site.
Elderly and Persons with Disabilities	No individuals surveyed were found to have disabilities. The senior citizen age in the Maldives is 65 years old. Of the 430 individuals	None.

Criteria Based on ADB SPS	Findings in the Survey	Impact of the Project
	surveyed, only 2 individuals are 65 years old or above. Both are laborers who perceive their economic status to be middle income level. One lives in Malé and the other lives in Thilafushi in housing provided by their employer.	
Security of Employment	The majority of those surveyed stated that they have work permits. However, 51 foreign individuals (not Maldivian) surveyed have reported that they do not have work permits or visas.	None. The project does not have any control on the vulnerability of these workers who may lose their jobs at any time. Likewise, the project does not impact the viability of the companies where these workers are employed.
Indigenous Peoples	None.	None.

374. The workers who are currently working at the dumpsite are contractually or permanently employed by WAMCO. Once the WTE Project operates and the dumpsite stops operation, these workers will still be working as WAMCO employees and may be assigned to other works SWM operations.

H. Additional Baseline Data Gathering.

375. During the detailed design phase of the project, the baseline survey shall be conducted to include monthly baseline data on ambient air quality, and quarterly groundwater quality and marine water quality. The DBO Contractor shall undertake progressive monitoring and sampling activities during this period to ensure robust baseline data and pre-works environmental conditions are documented. The results of the baseline survey are considered in the final detailed design of the project. In particular, the DBO Contractor shall:

- (i) undertake ambient air quality measurements, marine water quality analysis, and marine underwater ecology survey for each season of the year at the identified sampling locations in this EIA report (and any other locations in and around Thilafushi island as may be deemed by the DBO Contractor as important sampling locations);
- (ii) follow required sampling methodologies and locations, including appropriate averaging time for ambient air quality measurements as indicated in the WHO Ambient Air Quality Guidelines; and
- (iii) include results of analyses in the updating of the EIA during the detailed design phase and consider these results in the final detailed design of the project as applicable.

376. Additional baseline data gathering on ambient air quality, marine water quality, and marine underwater ecology surveys were conducted starting in June 2022. Sampling followed the required methodologies and appropriate averaging time for ambient air quality as indicated in the WHO ambient air quality guidelines. As well, pre-construction environmental monitoring for ambient noise and groundwater quality were carried out the same time as additional baseline sampling. Results of environmental sampling will be considered in the detailed design as appropriate.

VI. ANTICIPATED ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

A. Overview of Anticipated Impacts and Mitigation Measures

377. Potential environmental impacts of the proposed WTE Plant for Project area in Thilafushi are presented in this section. Mitigation measures to minimize and/or mitigate negative impacts, if any, are recommended along with the agency responsible for implementation. Monitoring actions to be conducted during the implementation phase are also recommended to reduce the impact.

378. Potential environmental impacts are categorized into four categories considering subproject phases: location impacts, design impacts (pre-construction phase), construction phase impacts, and operations and maintenance phase impacts.

379. Location impacts include impacts associated with site selection and include loss of on-site biophysical array and encroachment either directly or indirectly on adjacent environments. It also includes impacts on people who will lose their livelihood or any other structures by the development of that site.

380. Design impacts include impacts arising from project design, including technology used, scale of operation/throughput, fly ash and bottom ash production, discharge specifications, pollution sources and ancillary services.

381. Construction impacts include impacts caused by site clearing, earthworks, machinery, vehicles and workers. Construction site impacts include erosion, dust, noise, traffic congestion and waste production.

382. Operation and maintenance impacts include impacts arising from the operation and maintenance activities of the infrastructure facility. These include routine management of operational waste streams, and occupational health and safety issues.

383. Screening of environmental impacts has been based on the impact magnitude (negligible/moderate/severe – in the order of increasing degree) and impact duration (temporary/permanent).

384. As mentioned earlier, the project will be implemented under a Design-Build-Operate (DBO) contract and the detailed design phase will be carried out by the selected DBO Contractor. Hence, the impacts are based on the preliminary design prepared for the purpose of this EIA.

385. This section identifies the possible project-related impacts, in order to identify issues requiring further attention. ADB SPS requires that impacts and risks during pre-construction, construction and operational stages should be analyzed in the context of the project's area of influence.

B. Impacts Due to Location of Project

386. The location of the project is in the proximity of the dumpsite at Thilafushi. Thilafushi is an industrial island with the oldest and largest landfill in the country and host to numerous industrial companies. The WTE plant and ancillary facilities will be developed 15 hectares government-

owned land which has been reclaimed from shallow lagoon. The old dumpsite, adjacent to the project site, will be closed and remediated when the WTE plant becomes operational.

387. Locating the WTE project in Thilafushi will reduce environmental risks associated with locating the project in another site or island, especially when the dumpsite is to be rehabilitated in the future anyway (impacts are limited to only one area, rather than in two areas). At the same time, Thilafushi is an industrial island and no residential areas will be affected. Therefore, no negative impacts are envisaged because of the location of the project.

C. Impacts Due to Physical Integrity of the Site

388. The physical integrity of proposed project site cause serious damage to the WTE Plant is not considered in the final detailed design of the project. In order to ensure the integrity of infrastructures of the WTE Plant, there is also a need to ensure the integrity of the project site itself. The Ministry of Environment will be responsible for undertaking a geotechnical study on the site and the DBO Contractor will ensure the WTE Plant infrastructure design considers the results of the geotechnical study. The DBO Contractor will also be responsible for undertaking a climate risk and vulnerability assessment on the site and ensure the WTE Plant infrastructure design considers the results of the assessment.

D. Impacts Due to Design of Project

389. Many aspects of the WTE Plant operations will negatively impact the environment if no proper measures are included or integrated in the detailed design of components of the plant. This section discusses all the design considerations that will be included in the final detailed design to ensure no adverse impact occur to the environment.

390. **Performance Guarantees.** Simultaneous with the preparation and conduct of EIA, the project has already undertaken preliminary steps to ensure it will not impact the environment significantly during its operations. As a project to be awarded under a DBO arrangement, a number of important measures have been proposed in the bidding and DBO contract documents. The bid document shall ensure that it requires the DBO contractor to meet the following performance requirements that will ensure the project will comply with applicable environmental standards as discussed in Section III hereof. Table 62 presents the summary of the performance requirements:

Table 62: WTE Plant Performance Requirements Per DBO Bid Document Related to Environmental Safeguards

Parameters	Performance Requirements ^a
Performance Guarantee (PG) 6: Total organic carbon-content bottom ash (TOC)	The Contractor shall ensure that the annual averaged TOC content of bottom ash shall be less than 3.0% by weight while none of the samples shall be with a TOC greater than 3.5%. The average TOC content shall be determined by analyzing two representative samples monthly (i.e. approximately one sample every 15 days). None of the measured TOC contents shall exceed 3.5% by weight dry matter. Measurement of TOC according to British Standard EN 131317. Six samples per year tested by external accredited laboratory.
PG 7: Temperature of cooling water outlet	The Contractor shall design and build the plant so that the cooling water outlet temperature shall be not more than 3 degrees Celsius above receiving water ambient temperature.
PG 8: Air emission standards	The Contractor shall operate the plant so that none of the half hourly and none of the daily aggregated pollutants' measurements and none of

Parameters	Performance Requirements ^a																																																																						
	the discontinuously measured pollutants' concentrations exceed the limits stipulated in Annex VI of Directive 2010/75/EU of the European Parliament and the Council (Technical Provisions Relating to emission standards for waste incineration plants and waste co-incineration plants any time. Measurement will be done thru CEMS and calibrated every third year (at least) by an accredited laboratory or certification agency.																																																																						
PG 9: Combustion conditions	<p>The Contractor shall ensure that combustion conditions (temperature = 850 degrees Celsius for at least 2 seconds residence time) are maintained at all times. The requirements as per Chapter 5.16 (Permits and Licenses to be Obtained) of the bidding document shall be considered, which specifies the trial operations and performance guarantees test. Combustion conditions include the need for proof by Contractor of maintaining the temperature and residence time, by submitting a methodology for how to validate that residence time and temperatures are kept under most unfavorable conditions.</p> <p>Combustion conditions shall be met any time during tests to be done on the completion of WTE plant construction and thereafter.</p>																																																																						
PG 10: Leachate treatment plant (LTP) discharge standards	<p>The maximum permissible concentrations of pollutants discharged from the LTP into the environment are specified in the bidding document, which lists the effluent standards that should be complied with:</p> <table border="1" data-bbox="561 905 1408 1566"> <thead> <tr> <th colspan="2">Parameters</th> <th>unit</th> <th>Limit</th> </tr> </thead> <tbody> <tr> <td>Chemical Oxygen demand</td> <td>COD</td> <td>mg/l</td> <td>200</td> </tr> <tr> <td>Biological Oxygen demand</td> <td>BOD₅</td> <td>mg/l</td> <td>20</td> </tr> <tr> <td>Total Inorganic Nitrogen</td> <td>N_{tot, inorg}</td> <td>mg/l</td> <td>70</td> </tr> <tr> <td>Nitrite</td> <td>NO₂-N</td> <td>mg/l</td> <td>2</td> </tr> <tr> <td>Sulfide</td> <td>S</td> <td>mg/l</td> <td>1</td> </tr> <tr> <td>Total Phosphate</td> <td>P_{tot}</td> <td>mg/l</td> <td>3</td> </tr> <tr> <td>Lead</td> <td>Pb</td> <td>mg/l</td> <td>0.5</td> </tr> <tr> <td>Cadmium</td> <td>Cd</td> <td>mg/l</td> <td>0.05</td> </tr> <tr> <td>Total Chromium</td> <td>Cr</td> <td>mg/l</td> <td>0.5</td> </tr> <tr> <td>Chromium (VI)</td> <td>Cr VI</td> <td>mg/l</td> <td>0.1</td> </tr> <tr> <td>Mercury (total)</td> <td>Hg</td> <td>mg/l</td> <td>0.02</td> </tr> <tr> <td>Nickel</td> <td>Ni</td> <td>mg/l</td> <td>1</td> </tr> <tr> <td>Zinc</td> <td>Zn</td> <td>mg/l</td> <td>2</td> </tr> <tr> <td>Copper</td> <td>Cu</td> <td>mg/l</td> <td>0.5</td> </tr> <tr> <td>Arsenic</td> <td>As</td> <td>mg/l</td> <td>0.1</td> </tr> <tr> <td>Conductivity at 25°C*</td> <td>-</td> <td>μS/ cm</td> <td>2,500</td> </tr> </tbody> </table> <p style="text-align: center;">*used to monitor the performance of the LTP only</p>			Parameters		unit	Limit	Chemical Oxygen demand	COD	mg/l	200	Biological Oxygen demand	BOD ₅	mg/l	20	Total Inorganic Nitrogen	N _{tot, inorg}	mg/l	70	Nitrite	NO ₂ -N	mg/l	2	Sulfide	S	mg/l	1	Total Phosphate	P _{tot}	mg/l	3	Lead	Pb	mg/l	0.5	Cadmium	Cd	mg/l	0.05	Total Chromium	Cr	mg/l	0.5	Chromium (VI)	Cr VI	mg/l	0.1	Mercury (total)	Hg	mg/l	0.02	Nickel	Ni	mg/l	1	Zinc	Zn	mg/l	2	Copper	Cu	mg/l	0.5	Arsenic	As	mg/l	0.1	Conductivity at 25°C*	-	μS/ cm	2,500
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PG 11: Wastewater treatment discharge standards	<p>The maximum permissible concentrations of pollutants discharged from the wastewater treatment plant into the environment are specified in the table of effluent standard for wastewater (see also Table 17 of the EIA report):</p> <table border="1" data-bbox="561 1787 1408 1885"> <thead> <tr> <th colspan="2">Parameters</th> <th>unit</th> <th>Threshold Value</th> </tr> </thead> <tbody> <tr> <td>Chemical Oxygen demand</td> <td>COD</td> <td>mg/l</td> <td>150</td> </tr> </tbody> </table>			Parameters		unit	Threshold Value	Chemical Oxygen demand	COD	mg/l	150																																																												
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Parameters	Performance Requirements ^a			
	Biological Oxygen demand	BOD ₅	mg/l	40
	Suspended Solids	-	mg/l	100
	Ammonia-N	NH ₄	mg/l	15
	Total N	N	mg/l	30
	N-hexane extract (mineral oils, grease)	-	mg/l	10
PG 12: Sound pressure level	Sound pressure levels shall not exceed the 80 dBA at 1 min distance from the emitting source and different sound pressure levels at the site boundary: 70 dBA from 0700 to 2200 hours and 50 dBA from 2200 to 0700 hours. Measurement will be in-situ using decibel meter. Frequency of measurement specified in the EMP.			

^a Performance standard from the Maldives Environmental Protection Agency and international guideline values as specified in EU Directives are compared and whichever is more stringent is applicable.

391. **Air Pollution Control (APC) system.** The WTE Plant shall be equipped with dry flue gas cleaning with a reactor, sodium bicarbonate injection and limestone, activated carbon injection, bag filter and selective non-catalytic reduction (SNCR) for nitrogen oxides. The APC system shall be designed so that bypass operations are not required.

- (i) Flue gas cleaning.
 - a. The reactor shall be designed so that flue gases, sodium bicarbonate, limestone and activated carbon are mixed efficiently.
 - b. For the regulation of the flue gas temperature, a quench with water shall be provided.
 - c. The residues from the landfill leachate treatment shall be disposed of via the reactor.
 - d. The bag house filter shall be designed with a maximum filter surface area load of 0.8 m³/m² min. and a maximum operation temperature of 200°C.
 - e. The pressure loss shall be smaller than 14 mbar.
 - f. The bag filter shall be equipped for fully automated and controlled (by differential pressure measurement) cleaning of the filter hoses by compressed air impulses.
 - g. The separated dust shall be transported via a water-cooled discharge screw into a big-bag filling station. The filled big bags shall be stored in a separate area of the adjacent landfill.
- (ii) Nitrogen oxide removal system.
 - a. The NO_x-removal system shall be a SNCR.
 - b. With a SNCR-system, ammonia water with ammonia content < 25% or a water-urea-solution shall be injected in the first pass of the boiler at a temperature level of approximately 900°C.
 - c. The system shall be required with 3 levels of injection nozzles in the first boiler pass.
 - d. The tank for the ammonia water shall be an unpressurized vessel with a capacity of 30m³.

392. **Continuous Emission Monitoring System (CEMS).** For each of the stacks (i.e. incineration train), the DBO Contractor shall design and supply a CEMS with the following requirements:

- (i) Include the necessary flue gas sampling points for the emission measurements. The flue gas sampling points shall be located at an appropriate height above the ground that shall allow easy access.
- (ii) In addition to the continuously measured parameters covered in the performance guarantees, the pressure, flue gas temperature and flow, oxygen, water and carbon dioxide concentration shall be also continuously measured.
- (iii) The flue gas samples shall be routed via heated pipes to avoid condensation under all operating conditions to the measuring room or a measuring container.
- (iv) The analyzers shall be installed in cabinets. In addition, a computer and the holders for the test gas cylinders (zero gases and calibration gases), sample gases and carrier gases shall be arranged in the measuring room.
- (v) The measuring room or container, respectively, shall be air-conditioned.
- (vi) The analyzers shall be equipped with a periodically self-calibrating system using the test and calibrating gas. Each analyzer shall be provided with a suitable measurement range to allow the collection of emission data beyond the half hourly emission standards without compromising the accuracy in its lower measurement range.
- (vii) The measuring instruments used shall comply with EN 14181 and EN 15267 or US EPA CFR 11 Part 60 and Part 75.
- (viii) Raw emission data shall be compiled by the emission evaluation program to facilitate emissions statements according to the regulatory requirements.
- (ix) The emissions computer shall be equipped with special software, e.g. according to DIN EN 16258, which fulfils the following requirements:
 - a. Formation of overage values
 - b. Correction calculation for O₂, temperature, pressure and flue gas humidity
 - c. Simultaneous calculation of the concentration
 - d. Archiving the raw data and the classified averages values with date and time stamp for stamp minimum 5 years.
- (x) All measurement results shall be forwarded to the DCS and be displayed in the central control room. Subject to the requirements of the EPA, the emission data shall be also transmitted to EPA.

393. **Dust control system.** Notwithstanding the obligation to limit the dust emissions from the stack, the DBO Contractor shall design and build the facilities to prevent any dust emissions due to unloading, loading, landfilling or conveying and processing any dust prone materials such as bottom ash, chemicals for the APC system, APC residues etc. Any potential explosion hazard due to a dust laden environment shall be prevented. Subject to the considerations of the DBO Contractor, the design shall consider wherever appropriate measures such as, but not limited to:

- (i) Covering all conveyors to prevent materials to be blown away by wind;
- (ii) Using dust free bulk loading chutes during unloading or loading;
- (iii) Dust free filling from or discharging into jumbo bags;
- (iv) Using dust filter to remove dust from an exhaust;
- (v) Minimizing drop height of automatic unloading or discharging systems; and
- (vi) Operating dust laden atmosphere under sub-atmospheric pressure.

394. Signage to instruct the DBO Contractor's personnel of any potentially dust laden area and to use protection equipment shall be provided.

395. **Odor control system.** Odor emission from the plant may be due to handling waste, wastewater or chemicals (such as urea or ammonia). The DBO Contractor shall apply appropriate measures in the design of the plant such as but not limited to:

- (i) Operating odorous atmospheres under sub-atmospheric pressure and deodorizing the atmosphere by using it as primary air for the combustion system (e.g. bunker, tipping hall);
- (ii) Monitoring the continuous operation of ventilating systems (fans) and alarming in the event of failures;
- (iii) Using gas tight connectors while unloading urea/ammonia; and
- (iv) Providing an efficient and sufficient aeration to the wastewater treatment.

396. The DBO Contractor shall determine the potential fugitive and localized emission sources and shall submit these jointly with the odor control concept during the concept design phase.

397. **Landfill system.** The DBO Contractor shall ensure that the design of the residual waste landfill will be able to accommodate the volume of all generated incinerator bottom ash and fly ash during the entire operation of the WTE Plant, with the assumption that no bottom ash will be recycled and/or reused. The DBO Contractor shall include in the design the following criteria:

- (i) The landfill arrangement shall be designed to maximize the useable landfill volume of the site;
- (ii) The residual waste landfill cell arrangements shall be designed to allow for the progressive closure of individual landfill cells on completion and thereby to minimize the amount of leachate requiring treatment over the lifetime of the landfill;
- (iii) The design shall allow for the development of individual cells in a coherent and logical sequence and in a manner, which ensures the stability of all working faces and of the waste mound as a whole.
- (iv) The design shall incorporate appropriate back-up systems in the event of failure of any component of the environmental control and management systems;
- (v) The residual waste landfill concept shall be designed to minimize the lateral and vertical extent of the working face and thereby the amount of deposited waste (bottom ash and fly ash) that is exposed to the environment;
- (vi) The design shall ensure that residual waste can be deposited in a manner that prevents damage to the engineered barrier or liner, the leachate control system, and the collection and transfer system.
- (vii) The residual waste landfill design shall incorporate an internal access corridor to allow for safe traffic movement and to accommodate site services and monitoring devices;
- (viii) Measures shall be provided for controlling unauthorized access to the residual waste landfill including, as appropriate, the provision of ditches, berms, planting and fencing;
- (ix) Slopes shall be graded to ensure long term slope stability. Graded slopes shall be a maximum of 25%;
- (x) Soil erosion and dust generation shall be minimized;
- (xi) All residual waste landfill construction materials shall be free of organic matter and debris; and
- (xii) Measures shall be provided to monitor and manage groundwater beneath and

adjacent to the residual waste landfill area.

398. With reference to the waste characteristics in Table 1, the wastes have the potential to contain hazardous substances. Therefore, both the bottom ash and fly ash may likewise contain these hazardous substances that could impact the environment if no sufficient measures are taken to contain them. In order to avoid this impact, the DBO Contractor shall design the residual waste landfill facility by applying international best practices on landfilling of hazardous wastes, such as the relevant requirements indicated in the EU Directive on the Landfill of Wastes.²⁸ Table 63 below summarizes these requirements.

Table 63: General Requirements for Hazardous Waste Landfills

Design Parameters	Design Considerations and Requirements
Water control and leachate management	<p>Appropriate measures shall be taken, with respect to the characteristics of the landfill and the meteorological conditions, in order to:</p> <ul style="list-style-type: none"> (i) control water from precipitations entering into the landfill body, (ii) prevent surface water and/or groundwater from entering into the landfilled waste, (iii) collect contaminated water and leachate, (iv) treat contaminated water and leachate collected from the landfill to the appropriate standard required for their discharge following Table 17 of this EIA report.
Protection of soil and water	<p>The landfill must be situated and designed so as to meet the necessary conditions for preventing pollution of the soil, groundwater or surface water and ensuring efficient collection of leachate as and when required. Protection of soil, groundwater and surface water is to be achieved by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a top liner during the passive phase/post closure.</p> <p>The geological barrier is determined by geological and hydrogeological conditions below and in the vicinity of a landfill site providing sufficient attenuation capacity to prevent a potential risk to soil and groundwater.</p> <p>The landfill base and sides shall consist of a mineral layer which satisfies permeability and thickness requirements with a combined effect in terms of protection of soil, groundwater and surface water at least equivalent to the one resulting from the following requirements:</p> <ul style="list-style-type: none"> - landfill for hazardous waste: $K \leq 1.0 \times 10^{-9}$ m/s; thickness ≥ 5 m, <p>Where the geological barrier does not naturally meet the above conditions, it can be completed artificially and reinforced by other means giving equivalent protection. An artificially established geological barrier should be no less than 0.5 meters thick.</p> <p>In addition to the geological barrier described above a leachate collection and sealing system must be added in accordance with the following principles so as to ensure that leachate accumulation at the base of the landfill is kept to a minimum.</p>

²⁸ Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste.

Design Parameters	Design Considerations and Requirements																											
	<p style="text-align: center;"><i>Leachate collection and bottom sealing</i></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 33%;">Landfill category</th> <th style="width: 33%;">non hazardous</th> <th style="width: 33%;">hazardous</th> </tr> </thead> <tbody> <tr> <td>Artificial sealing liner</td> <td style="text-align: center;">required</td> <td style="text-align: center;">required</td> </tr> <tr> <td>Drainage layer $\geq 0,5$ m</td> <td style="text-align: center;">required</td> <td style="text-align: center;">required</td> </tr> </tbody> </table> <p>If the DBO Contractor finds that the prevention of leachate formation is necessary, a surface sealing may be prescribed. Recommendations for the surface sealing are as follows:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 33%;">Landfill category</th> <th style="width: 33%;">non hazardous</th> <th style="width: 33%;">hazardous</th> </tr> </thead> <tbody> <tr> <td>Gas drainage layer</td> <td style="text-align: center;">required</td> <td style="text-align: center;">not required</td> </tr> <tr> <td>Artificial sealing liner</td> <td style="text-align: center;">not required</td> <td style="text-align: center;">required</td> </tr> <tr> <td>Impermeable mineral layer</td> <td style="text-align: center;">required</td> <td style="text-align: center;">required</td> </tr> <tr> <td>Drainage layer $> 0,5$ m</td> <td style="text-align: center;">required</td> <td style="text-align: center;">required</td> </tr> <tr> <td>Top soil cover > 1 m</td> <td style="text-align: center;">required</td> <td style="text-align: center;">required</td> </tr> </tbody> </table>	Landfill category	non hazardous	hazardous	Artificial sealing liner	required	required	Drainage layer $\geq 0,5$ m	required	required	Landfill category	non hazardous	hazardous	Gas drainage layer	required	not required	Artificial sealing liner	not required	required	Impermeable mineral layer	required	required	Drainage layer $> 0,5$ m	required	required	Top soil cover > 1 m	required	required
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Nuisances and hazards	<p>Measures shall be taken to minimize nuisances and hazards arising from the landfill through:</p> <ul style="list-style-type: none"> - emissions of odors and dust, - wind-blown materials, - noise and traffic, - birds, vermin and insects, - formation and aerosols, - fires. <p>The residual waste landfill shall be equipped with appropriate form of physical barriers so that dirt originating from the site is not dispersed onto public roads and the surrounding land.</p>																											
Stability	<p>The emplacement of waste on the site shall take place in such a way as to ensure stability of the mass of waste and associated structures, particularly in respect of avoidance of slippages. Where an artificial barrier is established it must be ascertained that the geological substratum, considering the morphology of the residual waste landfill, is sufficiently stable to prevent settlement that may cause damage to the barrier.</p>																											
Barriers	<p>The residual waste landfill shall be secured to prevent free access to the site. The gates shall be locked outside operating hours. The system of control and access to each facility should contain a program of measures to detect and discourage illegal dumping in the facility.</p>																											

399. **Storm water collection system.** The DBO Contractor's design shall include surface water and storm water collection and diversion systems in order to protect the residual waste landfill area and minimize the generation of leachate. Sedimentation ponds shall be established to contain polluted drainage and runoff containing soil and sediment.

400. **Leachate treatment system.** The DBO Contractor shall ensure that design of the Leachate Treatment Plant (LTP) will also follow applicable requirements in the EU Directive on

Landfill of Wastes as enumerated in Table 18 in order to prevent leachate contamination of marine water and groundwater. In addition to these requirements, the DBO Contractor shall also include the following requirements in the design of the LTP:

- (i) An acid and alkali resistant floor finish shall be provided for all sections of the leachate treatment facility that may be exposed to acid or lye;
- (ii) A drainage system shall be provided to collect liquids, spills etc. that is connected to the site's sewer system;
- (iii) A collection and disposal system shall be provided for reverse osmosis rinsing and flushing liquids;
- (iv) The necessary IT linkage shall be made to the site's LAN and telephone network and linkage to the DCS network;
- (v) The level of the engineered barrier shall be no deeper than 1.5 meters above mean sea level and in accordance with the applicable environmental standards;
- (vi) The leachate collection system shall provide for the progressive installation of control measures for the management of leachate;
- (vii) The design shall ensure that piping is not blocked by sedimentation, debris, algal or fungal growth and that structural integrity is maintained at all times;
- (viii) The system shall be capable of dealing with the maximum leachate flow at any time during the lifespan of the landfill;
- (ix) Leachate shall be treated to meet the effluent discharge standards;
- (x) The design shall provide for the segregation of surface water from leachate;
- (xi) The design and selection of materials for the leachate management and storage system and location of discharge point into the sea shall be discussed with, and approved by, the Maldives EPA;
- (xii) The design shall provide a suitable system for the transfer of leachate from the collection system to the leachate treatment plant;
- (xiii) Leachate levels shall be monitored continuously and shall be capable of being read electronically; and
- (xiv) The leachate treatment system shall be capable of running automatically between and above specified leachate levels and volumes.

401. All components of the leachate collection, extraction, transfer and treatment system shall be capable of being maintained in a clean condition to ensure effective operation. Concentrate may be re-injected in the flue gas treatment process of the WTE plant. The Contractor shall design and build or organize a system for the re-injection of the LTP concentrate.

402. **Wastewater treatment system.** An on-site wastewater treatment plant will be provided to treat the wastewater generated from floor/vehicle washing and from staff/visitors. The treated effluent will be reused in the incineration plant or for washdown and landscape irrigation within the facility. Efforts will be taken so that no effluent would be discharged to the ground or sea. Should wastewater be discharged, the DBO Contractor shall ensure the design of the wastewater treatment plant will comply with the effluent standards in Section III hereof and consistent with the applicable performance guarantee in the DBO Contract as indicated in Table 62.

E. Impacts on Marine Protected Areas

403. Thilafushi is still the largest waste management center in greater Malé and more widely in Project area and beyond. The impacts of waste to the marine environment through transferring or disposing still continues. This problem is exacerbated as the current situation lacks proper docking facilities and infrastructure. Further, toxic components of general waste and particularly

ELVs are poorly managed and risks of contaminating surrounding water are high. Improvements to the waste vessel harbor and facilities enabling handling of large containers carrying waste from within Greater Malé and around Project area will reduce this risk.

404. There are three marine protected areas (MPAs) located near the project site. Illustration and maps showing the proximity of these MPAs are in Figure 124. The details of the sites are provided in Table 64 below.

Table 64: Protected areas in the vicinity of Thilafushi

Name	Type	Notes	Location relative to project site
Dhekunu Thilafalhuge Miyaruvani (Lions Head)	Reef	Situated on the reef face of the outer atoll, favored dive spot	Immediate Southwest of Thilafushi Island at a distance of around 1km from the project site.
Gulhee Falhu Kollavaani (Hans Hass Place)	Reef	Deep lagoon area	East of Gulhifalhu Island, 0.4km to the East of Thilafushi Island, and 2km from the project site.
Giraavaru Kuda Haa	Reef	Isolated reef approximately 30m above lagoon floor	4 km North (NNE) of Thilafushi Island.

405. The Lions Head is the closest and the most vulnerable MPA for this project. This is a famous dive site as many gray reef sharks were seen from this site. However, big fishes are not seen as often as it was in the past. On the steep outside, the reef has caves, colorful washouts and overhangs at about 10m of depth. From the 7 marine location surveys conducted for this EIA, live corals were found along the reef where Lion Head is located. Other areas mainly consisted of rock and rubble. The Maldives EPA is currently considering reclassifying “Dhekunu Thilafalhuge Miyaruvani” from Protected Landscape/seascape (IUCN Category V) to Protected Area with sustainable use of Natural resources (IUCN Category VI), in terms of reflecting current land use in the surrounding areas and conserve ecosystems and habitats, together with associated cultural values and traditional, natural resource management.

406. The dive site Hans Hass place located about 2 km from the project. It is expected that the project will have no impact to this site knowing the distance and Gulhee Fahlu island that encloses it from the western side where Thilafushi is located. Giraavaru Kuda Haa is located about 4 km north from the project site. It expected that no direct impact will be caused to this MPA due to the distance and location.

407. The construction activities that will have impact on the marine environment includes laying the discharge pipes for brine, sewerage and cooling water from the incinerators, construction of the coastal protection measures and berth. Moreover, the project site consists of a recently reclaimed land. The construction impacts are discussed in the section on construction phase impacts and operational phase impacts.

408. The overall potential impact for this location due to the project will be long term, positive and significant and will cover both the immediate area around the islands and the wider marine environment in Project area and beyond.

F. Impacts on Groundwater and the Terrestrial Environment

409. Thilafushi Island is an artificial island and therefore, any vegetation present is from weed colonization and tree planting efforts by the different existing locators (industrial and commercial). Furthermore, there are no trees in or in the proximity of the project site.

410. The groundwater in Thilafushi is presumed to be highly contaminated from the leachate generated from the open waste dumpsite. Baseline data for the quality of ground water in the island are documented in this EIA report and will serve as reference in future monitoring activities under the project. The quality of the groundwater is expected to improve after the remediation of the dumpsite (although not part of the project that is subject of this EIA). Therefore, the impact will be positive, significant and long-term.

G. Impacts on Avifauna

411. The birds attracted to the island as well as water birds that frequent surrounding waters will benefit from both the improved handling and treatment to remove hazardous fractions onto the landfill or into surrounding waters. The beneficial effect will be significant and long-term.

H. Impacts on Critical Habitats

412. In order to assess whether the WTE project is located in a critical habitat, an initial screening was undertaken using the Integrated Biodiversity Assessment Tool (IBAT).²⁹ Results show that the location of the WTE project is likely a critical habitat. Therefore, a critical habitat assessment is needed to confirm the results. Critical habitat assessment ideally takes place across sensible ecological or political units that are sufficiently large to encompass all direct and indirect impacts from the project. These areas of analysis (AoAs) are thus often much broader than the direct project footprint. AoAs may be separate or combined, depending on the ecology of the biodiversity concerned. Considering the extent of potential impacts on aquatic biodiversity from the project, an aquatic AoA for the project was identified as the 50-km study area to make consistent with the default range in the IBAT Screening. This area is approximately within the Zone 3 of Maldives, within which common biological communities and/or management issues exist.

413. The critical habitat assessment considered if critical habitat-qualifying biodiversity candidates or species identified in the IBAT Screening are actually or potentially present within the AoA. The IFC Guidance Note 6 (2019)³⁰ has been used to identify if a certain biodiversity candidate or species can qualify the project AoA as Critical Habitat. Reasons are identified for each biodiversity feature likely meeting or not meeting Critical Habitat.

414. Results confirmed that the site is likely a critical habitat only for one terrestrial insect (identified as *Enallagma maldivensis*). As discussed in this EIA report, the insect thrives in freshwater environment. Therefore, this particular species is highly unlikely to be present within

²⁹ The Integrated Biodiversity Assessment Tool (IBAT) is a multi-institutional programme of work involving BirdLife International, Conservation International, IUCN, and UNEP-WCMC. IBAT provides a basic risk screening on biodiversity. It draws together information on globally recognised biodiversity information drawn from a number of IUCN's Knowledge Products: IUCN Red List of Threatened Species, Key Biodiversity Areas (priority sites for conservation) and Protected Planet/The World Database on Protected Areas (covering nationally and internationally recognised sites, including IUCN management categories I–VI, Ramsar Wetlands of International Importance and World Heritage sites).

³⁰ https://www.ifc.org/wps/wcm/connect/5e0f3c0c-0aa4-4290-a0f8-4490b61de245/GN6_English_June-27-2019.pdf?MOD=AJPERES&CVID=mRQjZva

or around the vicinity of the WTE project site. However, as a precautionary measure, the critical habitat assessment and EIA recommend continuous monitoring around Thilafushi island to confirm the extent of biodiversity in various seasons of the year, including assessment of features pertinent to critical habitats. As part of the detailed design, the DBO contractor in coordination with PMU will be required to undertake additional biodiversity assessment around the project site. This is to ensure pre-construction works conditions and biodiversity risks are considered in the design, construction and operation, and to examine and mitigate the potential impacts of the project on areas significant for biodiversity. In cases when future information determines the existence of critical habitat, the WTE project should be able to demonstrate that:

- (i) It does not lead to measurable adverse impacts on those biodiversity values for which the critical habitat was designated, and on the ecological processes supporting those biodiversity values;
- (ii) It does not lead to a net reduction in the global and/or national/regional population of any Critically Endangered or Endangered species over a reasonable period of time; and
- (iii) It has integrated into its management program a robust, appropriately designed, and long-term biodiversity monitoring and evaluation program.

I. Impacts on Socio-Cultural Resources

415. **Loss of land and effects on property.** No private property will be affected, and no land acquisition will be required. No encroachment to any private property is expected at any stage of the project implementation. The project will utilize its own land, including the lands and ports of WAMCO, during the design and mobilization stage of the project. Table 65 presents the summary of impacts based on location.

Table 65: Summary of impacts based on location

Potential Impact	Assessment
Marine environment and ecosystem	Long term, Beneficially significant
Groundwater and terrestrial environment	Long term, Beneficially significant
Avifauna	Long term, Beneficially significant
Land and effects on property	NIL

J. Impacts During Construction Phase

1. Air Pollution and Noise

416. Air pollution sources during the construction phase will consist of vehicular pollution, and pollution from machineries used in construction work, which will release exhaust and cause dust to be produced. The ambient levels of air pollution at the site is already very high. The released pollutants are not expected to remain stagnant to any particular area as the site is close to the coast on both sides and therefore the pollutants would be dispersed.

417. Similar to the sources of air pollution, noise and vibrations generated in the construction site also caused by the operation of machinery, equipment and vehicles. As there are few residents living in Thilafushi and they do not live in close proximity to the project site, the impacts on human life in minimal. Furthermore, the residents in this environment are engaged in industrial activity.

418. The impacts of air pollution, noise and vibrations although negative, will be temporary and not significant during construction.

2. Water Pollution and Impacts to Marine Environment

419. Impacts on the marine environment during the construction will largely be from the construction of the berth and the discharge pipes for hot water from the incinerator and the utilities such as sewerage and brine from desalination. The berth is proposed to be located at the enclosed lagoon in the island. Excavation in the area will result in sedimentation. As this semi-enclosed area is quite stagnant, settlement rate will be higher than an area with regular currents and water flow. This will also be short lived as the size and scale small, if excavation is required. The marine survey conducted for this EIA shows that this area mostly consists of rock and rubble and hardly any live coral. Therefore, impacts for coral due to sedimentation is negligible. The discharge pipes will be directed towards the South into deep sea. As some live corals are located in this area, according to the marine survey, pipes should be laid during calm sea conditions, with as much care as is feasible.

420. Sea vessels can cause risks of water pollution, in the events of leaks and spills of fuel, lubricants, hydraulic fluids or other fluids used for vehicle operation. These may be hazardous waste. Although this area is already contaminated, care should be taken to mitigate the risks and impacts of any spills of hazardous waste. Although these impacts will be negative, it is short term and not significant.

3. Waste Generation

421. Waste generation will be expected during the construction phase. Expected wastes will include packaging of construction materials, equipment, fuels, lubricants, food and some rubble where existing structures need to be demolished. Mitigation measures for handling and disposal of these wastes are included in the EMP. Some specialist lubricants and paint may be hazardous. These will also be disposed of at the appropriate locations following the measures in the EMP. For toxic materials, approvals must be obtained from appropriate agency prior to importing materials rated as hazardous under the Globally Harmonized System of Classification and Labelling of Chemicals. Therefore, the potential impact is not significant.

4. Land-based and Marine Traffic Congestion

422. As there are few vehicles on Thilafushi, there will be no significant impact on land-based traffic. All vehicle and heavy equipment movements during construction phase will only be limited within the boundary of the project site.

423. Delivery of construction equipment and raw materials may increase marine traffic in the area. In order to avoid this impact, all delivery of equipment during mobilization phase and raw materials for the construction activities will be utilizing the exclusive docking ports of WAMCO, which are near or adjacent the project site. These docking ports or quays are where current solid wastes are unloaded from various parts of Project area. With this scheme, it is expected that no marine traffic and port congestion are expected that will affect the local industries and workers at the island. Figure 129 below shows the marine route that will be utilized during construction and operation phase of the project. The figure also shows the location of docking ports of workers going in and out of the island, including the docking ports of ferries and other private marine vehicles.

Figure 147: Marine Traffic Route and Docking Port for the Project



5. Community and Occupational Health and safety

424. Impacts and risks for community and occupational health and safety are associated with heavy equipment in trafficked areas. The DBO contractor will be required to appoint a full-time environmental health and safety managers and maintain a pool of trained engineers to ensure the effective implementation of both environmental and occupational health and safety measures at the project site. The DBO Contractor shall establish its health and safety plan to be adopted at the site following international best practices and the World Bank EHS guidelines on construction and decommissioning activities. The DBO contractor has the responsibility to provide labor camps for migrant workers, and sufficient space for equipment, construction materials, consumables, and other supplies that will be required during construction phase. Office policies, benefits, facilities and compensations should not be distinguished between migrant and non-migrant workers.

425. During the detailed design phase, the DBO Contractor shall integrate international good practices on community and occupation health and safety in its construction methods and practices, such those included in ADB SPS and Section 4.2 of World Bank EHS Guidelines on Construction and Decommissioning activities.³¹ Minimum requirements shall be the following:

³¹ IFC World Bank Group. 2007. Environmental, Health, and Safety (EHS) Guidelines – General EHS Guidelines: Construction and Decommissioning.

Community Health and Safety

- (i) identify and assess the risks to, and potential impacts on, the safety of affected communities during the design, construction, operation, and decommissioning of the project, and will establish preventive measures and plans to address them in a manner commensurate with the identified risks and impacts;
- (ii) avoid or minimize the exacerbation of impacts caused by natural hazards, such as landslides or floods, that could result from land use changes due to project activities;
- (iii) inform affected communities of significant potential hazards in a culturally appropriate manner;
- (iv) be prepared to respond to accidental and emergency situations. This preparation will include response planning document(s) that addresses the training, resources, responsibilities, communications, procedures, and other aspects required to respond effectively to emergencies associated with project hazards. Appropriate information about emergency preparedness and response activities, resources, and responsibilities will be disclosed to affected communities;
- (v) engage qualified and experienced experts, separate from those responsible for project design and construction, to conduct a review as early as possible in project development and throughout project design, construction, and commissioning. This will ensure that structural elements or components situated in high-risk locations will not fail or malfunction and threaten the safety of communities;
- (vi) implement risk management strategies to protect the community from physical, chemical, or other hazards associated with sites under construction and decommissioning;
- (vii) restricting access to the site, through a combination of institutional and administrative controls, with a focus on high risk structures or areas depending on site-specific situations, including fencing, signage, and communication of risks to the local community;
- (viii) removing hazardous conditions on construction sites that cannot be controlled affectively with site access restrictions, such as covering openings to small confined spaces, ensuring means of escape for larger openings such as trenches or excavations, or locked storage of hazardous materials; and
- (ix) implement measure to prevent proliferation of vectors of diseases at work sites;
- (x) adequate space and lighting, temporary fences, shining barriers and signage at active work sites;
- (xi) contractor's preparedness in emergency response;
- (xii) adequate dissemination of GRM and contractor's observance and implementation of GRM; and
- (xiii) upon availability, local people should be given an opportunity for work in the project activities.

Occupational Health and Safety

- (i) Communication and Training
 - (a) Training of all workers on occupational health and safety prior to construction works;
 - (b) Conduct of orientation to visitors on health and safety procedures at work sites;

- (c) Signages strategically installed to identify all areas at work sites, including hazard or danger areas;
 - (d) Proper labeling of equipment and containers at construction and storage sites; and
 - (e) Suitable arrangements to cater for emergencies, including: first aid equipment; personnel trained to administer first aid; communication with, and transport to, the nearest hospital with an accident/emergency department; monitoring equipment; rescue equipment; firefighting equipment; and communication with nearest fire brigade station;
- (ii) Physical Hazards
- (a) Use of personal protective equipment by all workers such as earplugs, safety shoes, hard hats, masks, goggles, etc. as applicable, and ensure these are used properly;
 - (b) Avoidance of slips and falls through good house-keeping practices, such as the sorting and placing loose construction materials or demolition debris in established areas away from foot paths, cleaning up excessive waste debris and liquid spills regularly, locating electrical cords and ropes in common areas and marked corridors, and use of slip retardant footwear;
 - (c) Use of bracing or trench shoring on deep excavation works;
 - (d) Adequate lighting in dark working areas and areas with night works;
 - (e) Rotating and moving equipment inspected and tested prior to use during construction works. These shall be parked at designated areas and operated by qualified and trained operators only;
 - (f) Specific site traffic rules and routes in place and known to all personnel, workers, drivers, and equipment operators; and
 - (g) Use of air pollution source equipment and vehicles that are well maintained and with valid permits;
- (iii) General Facility Design and Operation
- (a) Regular checking of integrity of workplace structures to avoid collapse or failure;
 - (b) Ensuring workplace can withstand severe weather conditions;
 - (c) Enough workspaces available for workers, including exit routes during emergencies;
 - (d) Fire precautions and firefighting equipment installed;
 - (e) First aid stations and kits are available. Trained personnel should be available at all times who can provide first aid measures to victims of accidents;
 - (f) Secured storage areas for chemicals and other hazardous and flammable substances are installed and ensure access is limited to authorized personnel only;
 - (g) Good working environment temperature maintained;
 - (h) Worker camps and work sites provided with housekeeping facilities, such as separate toilets for male and female workers, drinking water supply, wash and bathing water, rest areas, and other lavatory and worker welfare facilities; and

- (i) Maintain records and make reports concerning health, safety and welfare of persons, and damage to property. Take remedial action to prevent a recurrence of any accidents that may occur.

426. **Construction Camps.** The construction camp site and accommodation of workers shall be established following international best practices to ensure welfare of workers is protected.³² The DBO Contractor shall consider the following requirements, whichever are applicable, in building these camps and accommodation facilities at the site, if any.

- (i) The temporary campsite location should:
 - (a) Be free from any risk of flooding.
 - (b) Be sited a reasonable distance and have clear physical separation from any construction work, equipment and/or machinery.
 - (c) Provide clear separation between the camp and construction area through such means as a footpath, fence, etc.
 - (d) Where possible, be sited outside the boundary of the construction zone.
- (ii) The site design should ensure:
 - (a) Adequate space to accommodate the number of workers throughout the project period, for accommodation, meals, toilets, bathing, etc.
 - (b) Considerations for needs of all types of workers: e.g. women, local laborers or travelers, etc.
 - (c) Adequate drainage is provided to prevent any stagnant water which can attract mosquitos and vermin and spread disease among workers,
 - (d) Buildings are structurally sound and can withstand wind and rain.
 - (e) Ensure that the worker camp area will have adequate ground surfacing (e.g. gravel, wood sheeting, grass) such that residents may move freely between buildings in their off time without walking through mud and water.
 - (f) Designated area for small fires during colder months, located a safe distance from buildings and any flammable materials.
- (iii) The workers' accommodation should comply with the following requirements:

Dimensions and Design

- (a) The height of room shall not be less than 2.4 meters.
- (b) The sleeping area or resting area shall not be less than 3 m² per person.
- (c) Separate bed for each worker provided, with minimum of 1-meter space between each bed.
- (d) Separate sleeping areas are provided for men and women, except in family rooms if needed.

³² From the draft Construction Code of Practice developed for urban development projects in Kathmandu, Nepal. This COP was developed with reference to the following: "Workers' accommodation: processes and standards: A guidance note by IFC and EBRD", IFC and EBRD, 2009 https://www.ebrd.com/downloads/about/sustainability/Workers_accomodation.pdf; and "Malaysian standards of temporary construction site workers' amenities and accommodation – code of practice. (MS 2593, 2015) http://www.sirim.my/srmc/documents/Aug-Sept-2014/12D024R0_PC.pdf

- (e) Sleeping area should be separate from cooking/canteen areas, and far enough distance from toilets to avoid odors.
- (f) Where possible, prefab-type structures could be considered.

Light and Air

- (a) Both natural and artificial lighting are provided and maintained in living facilities. It is best practice that the window area represents not less than 5% to 10% of the floor area. Emergency lighting is provided.
- (b) For cold weather months, accommodation must be such that the temperature is kept at a level of around 20 degrees Celsius notwithstanding the need for adequate ventilation.
- (c) In warmer months, adequate ventilation (either cross-ventilation and/or fans) is provided.

Materials

- (a) Roofing materials must be such that the structure can withstand high winds without risk of collapse and be leak-free during rainy season.
- (b) Flooring material should be easily cleanable and free of bare nails or other sharp objects.

Provisions/furnishing

- (a) Each worker is provided with a comfortable mattress, pillow, cover and clean bedding.
 - (b) Double or triple-deck bunk beds are prohibited. Double deck bunks may be used in special circumstances but must be approved by the Engineer or competent person of the DBO Contractor.
 - (c) Each resident is provided facilities for the storage of personal belongings, such as a locker or shelving unit.
 - (d) Every resident is provided with adequate furniture such as a table, a chair, a mirror and a bedside light (small solar lights may be a good option). These may be shared among several workers.
 - (e) Separate storage provided for work boots and PPE. Drying/airing areas may need to be provided for PPE depending on conditions.
 - (f) Mosquito nets are provided in areas where mosquitos are present and/or at the request of workers.
 - (g) Rubbish bin with cover provided in each room and emptied regularly.
 - (h) Electrical outlets provided for charging mobile phones, radio, etc. Ensure that electrical wiring is done properly and presents no risk of electrical fire.
 - (i) All doors and windows should be lockable and be provided with mosquito screens.
- (iv) The workers kitchen area should comply with the following requirements:
- (a) The minimum area of kitchen should be not less than 4.5 m² and the minimum width should be more than 1.5 meters.
 - (b) Adequate height of kitchen should be not less than 2.25 meters.
 - (c) Provide where clean drinking water is always available – ensure that any open water tanks are covered.

- (d) Kitchens are provided with facilities to maintain adequate personal hygiene including a sufficient number of washbasins designated for cleaning hands with clean water and materials for hygienic hand-drying.
 - (e) In order to enable easy cleaning, it is good practice that cooking stoves are not sealed against a wall, and benches and fixtures are not built into the floor.
 - (f) Design should consider if the kitchen within the camp will be used to service all workers for all meals (e.g. meals prepared for day laborers as well as residents) or will be limited to self-preparation of meals by residents.
 - (g) Wall surfaces adjacent to cooking areas are made of fire-resistant materials.
 - (h) Food preparation tables are equipped with a smooth, durable, easily cleanable, non-corrosive surface made of non-toxic materials.
 - (i) All cupboards and other fixtures have a smooth, durable and washable surface.
 - (j) All kitchen floors, ceiling and wall surfaces adjacent to or above food preparation and cooking areas are built using durable, non-absorbent, easily cleanable, non-toxic materials.
 - (k) Cooking gas canisters provided
 - (l) Fire extinguisher provided outside of cooking area.
 - (m) Rubbish bin(s) provided with cover
 - (n) Adequate facilities for cleaning, disinfecting and storage of cooking utensils and equipment are provided.
- (v) The workers toilets should comply with the following requirements:
- (a) Toilets should be located within same general area as accommodation, but at least 30 meters away from sleeping area/kitchen. Should not be more than 60 m away.
 - (b) Toilets should be located at least 30 meters away from any water wells.
 - (c) An adequate number of toilets should be provided to workers. Standards range from 1 unit per 15 persons to 1 unit per 6 persons.
 - (d) Toilet rooms shall be located so as to be accessible without any individual having to pass through any sleeping room
 - (e) Toilet dimensions should be at least 1.5 m × 0.75 m (minimum width)
 - (f) Toilet facilities should be installed so as to prevent any odors reaching dining facilities or sleeping areas.
 - (g) Separate facilities provided for men and women.
 - (h) An adequate number of handwash facilities is provided to workers. Standards range from 1 unit per 15 persons to 1 unit per 6 workers. Handwash facilities should consist of a tap and a basin, soap and hygienic means of drying hands.
 - (i) Toilets should be constructed such that they are structurally sound during high winds and free from leaks during rains.
 - (j) Every toilet should be provided with natural lighting and natural ventilation by means of ≥ 1 openings, providing a total area of $>0.2 \text{ m}^2$ per toilet. Such openings shall be capable of allowing a free, uninterrupted passage of air.
 - (k) In addition, all toilet rooms should be well-lit, with natural lighting and artificial lights at night.
 - (l) Ensure no discharge of toilets and showers that will contaminate water sources or common areas

- (m) Sanitary and toilet facilities are designed to provide workers with adequate privacy, including ceiling to floor partitions and lockable doors
 - (n) Ensure toilets have rubbish bin in each cubicle
- (vi) The shower and washing facilities should comply with the following requirements:
- (a) An adequate number of shower facilities is provided to workers. Standards range from 1 unit per 15 persons to 1 unit per 6 persons.
 - (b) Shower/bathing facilities are provided with an adequate supply of clean water.
 - (c) Separate facilities for men and women.
 - (d) The flooring for shower facilities should be of hard washable materials, damp-proof and properly drained.
 - (e) Suitable light, ventilation and soap should be provided.
 - (f) Adequate space and hooks must be provided for hanging clothes/towels while bathing.
 - (g) Area for washing/drying clothes provided, including washbasin, soap and drying lines. Either piped water to the basin or standpipe for filling basins should be within close distance.
 - (h) Ensure area drains well and doesn't create a muddy environment.
- (vii) Optional Amenities and Other Good Practices that should be followed as applicable:
- (a) Paint the camp buildings to present a tidy and satisfactory appearance – this will help encourage workers to keep their camp in good condition.
 - (b) Provide signage in kitchen area, canteen, toilets, and other common areas to encourage good hygiene practices, cleanliness of kitchen and personal spaces, worker conduct, worker responsibilities, safety evacuation plan, etc.
 - (c) Involve laborers in design of the camp, e.g. to get their inputs on siting of buildings, and any specific needs of women.

427. Refer to Table 3 on the updated requirements for camps and accommodation facilities at the site comparing the EIA (July 2020) and this update. Table 66 presents the summary of impacts during the construction phase.

Table 66: Summary of Impacts During the Construction Phase.

Potential Impact	Assessment
Water pollution to marine environment	Short term, negative, not significant
Air pollution and noise	Short term, negative, not significant
Waste generation	NIL
Land-based and Marine Traffic Congestion	Short term, minimal negative, not significant
Community and occupational health and safety	Short term, negative, not significant.

428. **Response to emerging infectious diseases.** The DBO Contractor shall also adhere to necessary protocols in response to emerging infectious diseases such as the corona virus disease (COVID-19) consistent with the guidelines of relevant government healthcare agencies and the World Health Organization. A standard operating procedure (SOP) has been prepared

by the project management unit at the Ministry of Environment which can be used by the DBO Contractor. This SOP is a living document that can be updated from time to time based on circumstances and developments about COVID-19 (or any emerging infectious diseases in the future). This SOP is attached as Appendix 14.

K. Impacts during Operational Phase

1. Air Pollution Due to Emission from WTE Plant

429. The DBO Contractor will finalize the detailed engineering design and O&M Manual based on the following:

- (i) Incorporation of EHS Guidelines on Waste Management Facilities³³ such as prevention, minimization and control of air emissions through:
 - a. Conduct of waste segregation and/or presorting, subject to feasibility or practicality, by collaborating with the waste supplier to avoid incineration of wastes that contain metals and metalloids that may volatilize during combustion and be difficult to control through air emission technology (e.g., mercury and arsenic). However, regardless of any practical waste segregation effort, the DBO Contractor shall ensure full and efficient functioning of the APC system of the WTE plant at all times;
 - b. Follow applicable national requirements and internationally recognized standards for incinerator design and operating conditions, mainly rapid quenching of the flue gas after leaving all combustion chambers and before entering any dry particulate matter air pollution control device but also combustion temperature, residence time, and turbulence.³⁴ Standards for stationary incinerators which include temperature and afterburner exit gas quenching (i.e. rapid temperature reduction) requirements are preferred in order to nearly eliminate dioxins and furans. In case where rapid quenching is not practical for the WTE plant, follow applicable national requirements and internationally recognized standards for incinerator design and operating conditions, such as combustion temperature, residence time, turbulence, and reduced residence time of dust laden exhaust gases in the temperature range of 450°C to 200°C;
 - c. Introduce wastes into the incinerator only after the optimum temperature is reached in the final combustion chamber.
 - d. The waste charging system should be interlocked with the temperature monitoring and control system to prevent waste additions if the operating temperature falls below the required limits;
 - e. Minimize the uncontrolled ingress of air into the combustion chamber via waste loading or other routes;
 - f. Optimize furnace and boiler geometry, combustion air injection, and, if used, NOx control devices using flow modeling;

³³ IFC World Bank Group. 2007. Environmental, Health, and Safety (EHS) Guidelines For Waste Management Facilities.

³⁴ For example, according to Article 6 of EU Council Directive 2000/76, the gas resulting from the incineration process should be raised, after the last injection of combustion air to a temperature of 850 degrees Celsius (1,100 degrees Celsius for hazardous wastes with a content greater than 1% of halogenated organics) for a period of two seconds. Additional details on operating conditions are provided in this reference. Other sources of emissions standards include the U.S. EPA regulations for air emissions from stationary sources at 40 CFR Part 60.

- g. Optimize and control combustion conditions by the control of air (oxygen) supply, distribution and temperature, including gas and oxidant mixing; the control of combustion temperature level and distribution; and the control of raw gas residence time;
- h. Implement maintenance and other procedures to minimize planned and unplanned shutdowns;
- i. Avoid operating conditions in excess of those that are required for efficient destruction of the waste;
- j. Use auxiliary burner(s) for start-up and shut down and for maintaining the required operational combustion temperatures (according to the waste concerned) at all times when unburned waste is in the combustion chamber;
- k. Use a boiler to transfer the flue-gas energy for the production of electricity and/or supply of steam/heat, if practical;
- l. Use primary (combustion-related) NO_x control measures and/or selective catalytic reduction (SCR) or selective noncatalytic reduction (SNCR) systems, depending on the emissions levels required;
- m. Use flue gas treatment system for control of acid gases, particulate matter, and other air pollutants;
- n. Minimize formation of dioxins and furans by ensuring that particulate control systems do not operate in the 200°C to 400°C temperature range; identifying and controlling incoming waste composition; using primary (combustion-related) controls; using designs and operation conditions that limit the formation of dioxins, furans, and their precursors; and using flue gas controls;
- o. Consider the application of waste-to-energy to help off-set emissions associated with fossil fuel-based power generation.³⁵

2. Analysis of Impacts Based on Stack Emission Dispersion Modeling

430. Municipal waste incineration produces various pollutants that can affect air quality and human health. These pollutants are released through two specific waste products of incineration process known as bottom ash and fly ash. These wastes can include a combination of various heavy metals, dioxins and furans, and other persistent organic pollutants. Specifically, fly ash is the more hazardous waste product due to size and density that can go airborne with the combustion gases when released to the atmosphere and impact air quality.

431. Heavy metals and dioxin and furans are highly toxic compounds which when inhaled or ingested by humans may in the long-term cause cancer and neurological damage, congenital malformations and infant mortality, respiratory illnesses, etc. Hence, it is paramount that the adoption of incineration technology has to come with it an accompanying APC technology or process which will enable efficient recovery of these toxic pollutants. However, even with the most advance technologies to date, complete removal of these toxic substances in the flue gases is difficult to achieve. It is for this reason that good international industry practices and standards, such as the emission standards in Annex VI of Directive 2010/75/EU of the European Parliament and the Council, are established to ensure emissions from these specific facilities do not impact the ambient conditions of the environment. Concomitantly, height of stack from where emissions

³⁵ The possibility of applying waste-to-energy technologies depends on a number of issues which may include the project design specifications established by local government as well as laws applicable to the generation and sale electricity. Also, it should be noted that recycling options may often save more energy than what is generated by incineration of mixed solid waste in a waste-to-energy facility.

should be discharged needs to be calculated and followed to ensure pollutants from emissions do not degrade the ground level ambient air quality. Air dispersion modeling is normally used to simulate how air pollutants disperse in the atmosphere and to analyze the potential impacts of these pollutants to ambient air quality given specific project and site information.

432. **AUSTAL2000.** The dispersion modeling for the pollutants was carried out using the dispersion model AUSTAL2000. The computer program AUSTAL2000 is a reference implementation developed on behalf of the German Federal Environmental Agency.³⁶ It also available in English version as it is used by other EU-member states.

433. AUSTAL2000 calculates the spread of pollutants and odors in the atmosphere. It is an extended implementation of Annex 3 of the German regulation TA Luft (Technical Instruction on Air Quality Control) demands for dispersion calculations using a Lagrangian particle model in compliance with the German guideline VDI 3945 Part 3. The modeling work was carried out by Ulbricht Consulting (Germany). The dispersion modeling report is attached as Appendix 15.

434. Steady-state Gaussian plume models assess pollutant concentrations and/or deposition fluxes from a variety of sources associated with an industrial source complex. Unlike the Gaussian models commonly used, this flexible modeling procedure used in AUSTAL2000 provides realistic results even when buildings and uneven terrain influence flue gas dispersion. The model calculates the contribution of specified air pollutants from a given point source to the background concentrations present in the ambient air at ground level in the area surrounding the source.

435. **Emission mass flow.** Using the calculation methodology from the German regulation TA Luft, the various substances potentially present in the emission coming out of the stacks use the mass concentration limits indicated in the said German regulation. Summary of resulting mass flows of each substance is outlined in Table 67 below. Table 67 is updated based on the increase in the power output from 10 MW to 13 MW resulting from thermal efficiency. The updated operating data will be considered in the re-run of the air quality dispersion modeling during the detailed design phase in the final update of this EIA.

Table 67: Emission mass flow

EIA July 2020					EIA Update (2023)			
Emission mass flow (for R = 115 713 m ³ /h, T = 180 °C, Ø = 2.12 m)					Emission mass flow (for R = 123088Nm ³ /h, T = 145 °C, Ø = 2.12 m)			
Substance	Mass Concentration [24-hour]	Mass Flow Q in kg/h	Factor S	Q/S in kg/h ^a	Mass Concentration [24-hour]	Mass Flow Q in kg/h	Factor S	Q/S in kg/h ^a
Total dust, including particulate matter (No 5.2.1 TA Luft)	5 mg/m ³	0.579	0.08	7.2	5 mg/Nm ³	0.615	0.08	7.68
Fluorine and its compounds, indicated as hydrogen fluoride (5.2.4 Class II TA Luft)	1 mg/m ³	0.116	0.0018	64.3	1 mg/Nm ³	0.123	0.0018	68.3
Gaseous inorganic chlorine compounds, indicated as hydrogen chloride (5.2.4 class III TA Luft)	10 mg/m ³	1,157	0.1	11.6	10 mg/Nm ³	1.231	0.1	12.31

³⁶ Available as a free download at <https://www.umweltbundesamt.de/themen/luft/regelungen-strategien/ausbreitungsmodelle-fuer-anlagenbezogene/austal2000n-download>

EIA July 2020					EIA Update (2023)			
Emission mass flow (for R = 115 713 m ³ /h, T = 180 °C, Ø = 2.12 m)					Emission mass flow (for R = 123088Nm ³ /h, T = 145 °C, Ø = 2.12 m)			
Substance	Mass Concentration [24-hour]	Mass Flow Q in kg/h	Factor S	Q/S in kg/h ^a	Mass Concentration [24-hour]	Mass Flow Q in kg/h	Factor S	Q/S in kg/h ^a
Ammonia (5.2.4 class III TA Luft)	10 mg/m ³	1,157	-	-	10 mg/Nm ³	1.231	-	-
Sulfur oxides (sulfur dioxide and sulfur trioxide), expressed as sulfur dioxide (5.2.4 Class IV TA Luft)	50 mg/m ³	5,786	0.14	41.3	50 mg/Nm ³	6.154	0.14	43.9
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	150 mg/m ³	11,108*	0.1	111.08*	150 mg/Nm ³	11.816*	0.1	118.16
Carbon monoxide (5.2.4 para. 2 sentence 1 TA Luft)	50 mg/m ³	5,786	7.5	0.77	50 mg/Nm ³	6.154	7.5	0,82
Organic substances (expressed as total C) (TA Luft 5.4.10.20)	10 mg/m ³	1,157	0.1	11.6	10 mg/Nm ³	1.231	0.1	12,3
Mercury and its compounds, reported as Hg (No 5.2.2 Class I TA Luft)	0.03 mg/m ³	0.00347	0.00 013	26.7	0.03 mg/Nm ³	0.00369	0,00013	28,38
Dioxins and furans	0.1 ng/m ³	0.0000000116	-	-	0.1 ng/Nm ³	0.0000000123	-	-
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	0.5 mg / m ³	0.05786	0.05 0.1	1.157 0.579	0.5 mg / Nm ³	0.06154	0,05 0,1	1.2308 0.61
Thallium and its compounds (5.2.2 TA Luft class I) cadmium	0.05 mg / m ³	0.00579	0.005	1.16	0.05 mg / Nm ³	0.00615	0,005	1.23
Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr) (5.2.7.1.1 TA Luft Class I)	0.05 mg / m ³	0.00579	0.00005	115.7	0.05 mg / Nm ³	0.00615	0,00005	123

^a According to point 5.5.3 TA Luft, the emission of nitrogen monoxide is based on a conversion rate of 60% to nitrogen dioxide, and is based on a ratio of NO/NO₂ = 90%/10%, cf. Annex 1.1

436. **Control of the necessity for dispersion calculation.** Following the guidance and methodology in the German regulation TA Luft, the determination of the emission characteristics is not required if the emissions of the air pollutants do not exceed the minor mass flows indicated in the regulation. Table 68 below summarizes these minor mass flows in the regulation and compared with the expected WTE mass flow. Table 60 is updated comparing the values used in the EIA (July 2020) and the values at this stage with the increase in output due to thermal efficiency. These changes will be considered during the re-run of the air quality dispersion modeling in the final EIA update at the detailed design phase.

Table 68: Minor Mass Flow According to TA Luft and WTE mass flow

Pollutants	EIA (July 2020)		EIA Update (2023)	
	Minor mass flow	WTE mass flow	Minor mass flow	WTE mass flow
	in kg/h		in kg/h	
Emissions derived from stacks				
Dust (without consideration of dust contents)	1	0.579	1	0.615
Fluorine and its compounds, indicated as hydrogen fluoride (5.2.4 Class II TA Luft)	0.15	0.116	0.15	0.123
Gaseous inorganic chlorine compounds, indicated as hydrogen chloride (5.2.4 class III TA Luft)	-	1.157	-	1.231
Ammonia (5.2.4 class III TA Luft)	-	1.157	-	1.231
Sulfur oxides (sulfur dioxide and sulfur trioxide), expressed as sulfur dioxide (5.2.4 Class IV TA Luft)	20	5.786	20	6.154
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	20	11.108	20	11.816
Carbon monoxide (5.2.4 para. 2 sentence 1 TA Luft)	-	5.786	-	6.154
Organic substances (expressed as total C) (TA Luft 5.4.10.20)	-	1.157	-	1.231
Mercury and its compounds, reported as Hg (No 5.2.2 Class I TA Luft)	0.0025	0.00347	0.0025	0.00369
Dioxins and furans	-	0.000000116	-	1.23×10^{-8}
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	0.025 lead, nickel (class II)	0.05786	0.025 lead, nickel (class II)	0.06154
Thallium and its compounds (5.2.2 TA Luft Class I)	0.0025	0.00579	0.0025	0.00615
Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr) (5.2.7.1.1 TA Luft Class I)	0.0025	0.00579	0.0025	0.00615

437. From Table 68 above, most of substances the values are below the minor mass flows. For mercury as well as heavy metals and their components (referred to thallium and arsenic/cadmium

and lead/nickel) the values are over the minor flows, therefore there is a need to perform the dispersion modeling for these substances.

438. For ammonia and hydrogen chloride (5.2.4 Class III TA Luft), for carbon monoxide, for organic substances (expressed as total C) as well as dioxins and furans no minor mass flow are set in the regulations therefore there is no need to undertake a detailed dispersion modeling for these parameters either.

439. **Emergency Gen-set.** For the emissions mass flow calculation of the air pollutants of the emergency Gen-set, data from PMU have been made available. The following pollutants have to be considered. The exhaust gas volume flow was given as $V_n = 12\,470 \text{ m}^3/\text{h}$ and the exhaust gas temperature to $T = 180^\circ \text{ C}$.

Table 69: Minor mass flow according to Section 4.6.1.1 TA Luft - system mass flow

Substance	Minor mass flow	Plant mass flow
	in kg / h	
Dust (without consideration of dust contents)	1	0.9976
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	20	3.99
Carbon monoxide (5.2.4 (2) sentence 1 TA Luft)	-	.741
Formaldehyde - HCHO	-	0.748

440. The minor mass flows have also been not exceeded by the Gen-set emission values, so that no dispersion calculation has to be carried out for these substances. For carbon monoxide and formaldehyde no minor mass flow has been set in the regulation. For these substances, no dispersion calculation is to be carried out.

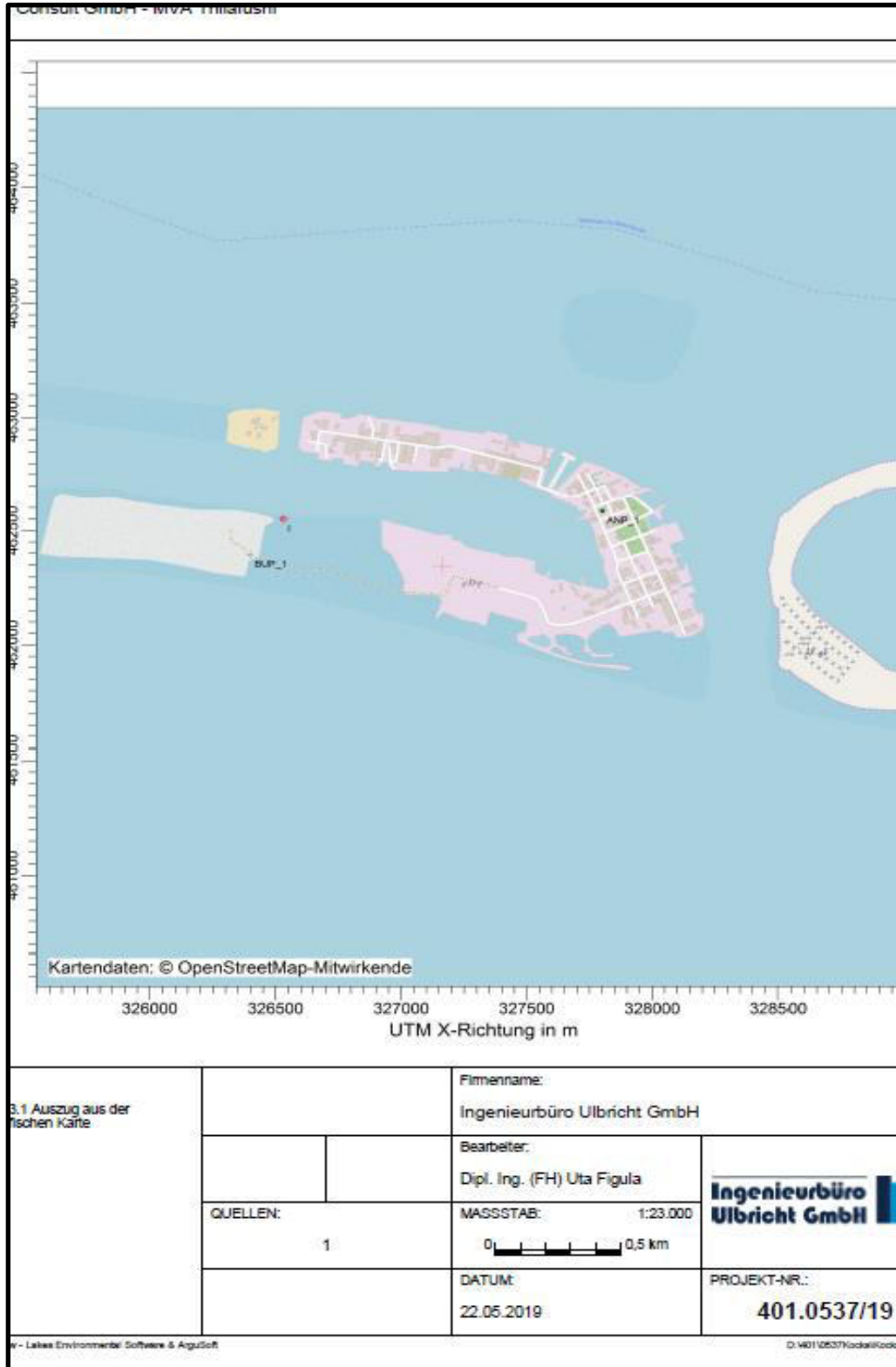
441. **Air dispersion modeling for relevant parameter.** In order to estimate exposures to airborne pollutants from the incineration and emergency electricity generation, dispersion modeling was carried out. Modeling was done for the pollutants from the emergency electricity generator sets, such as dust, nitrogen monoxide and nitrogen dioxide, carbon monoxide, and formaldehyde. Similarly, modeling was done for the pollutants from the WTE plant, such as total dust including fine dust, fluoride and its compound specified as hydrogen fluoride, ammonia, sulfur (sulfur dioxide and sulfur trioxide), specified as sulfur dioxide, nitrogen oxide (nitrogen monoxide and nitrogen dioxide) specified as nitrogen dioxide, and mercury and its compound specified as mercury. The study zone was defined as a 5,000 m radius of influence from incinerator stack at Thilafushi.

442. **Emission from installations.** The following emission sources have been considered:

- (i) Exhaust stack: WTE
- (ii) Operation time: 8,000 hours/year

443. **Emissions from guided sources.** For the incineration plant, the following pollutants have been taken into account in the dispersion calculation. The exhaust gas volume flow was given as $V_n = 115,713 \text{ m}^3/\text{h}$ and the exhaust gas temperature as $T = 180^\circ \text{ C}$. The air dispersion calculation was made with a stack height of 46.0 m. Increasing the stack height to 50 m has been recommended. Therefore, the calculated emissions are presenting the worst case. With the extension of the stack, the ambient air concentration value will be reduced at the reception point.

Figure 148: Location of the emission points where maximum load was calculated and examined



444. The following results apply exclusively taking into account the characteristics of the emission sources as discussed above. While the dispersion calculation is required only for mercury, all other results in Table 70 are presented for information only. As a guide, a comparison is made with the irrelevance values of the Technical Instruction on Air Quality Management. The detailed calculation results and the grid diagram for the substance mercury are given in Appendix 15.

Table 70: Ambient air quality additional charge (IZ) (including statistical uncertainty)

Ambient air quality points	Irrel. IZ	IW	BUP 1	ANP 1
Substance				
Mercury g/(m ² d)	0.05	1	0.007	1.0
PMDEP g/(m ² d)	0.0105	0.35	0.0001	0.0001
PM10 µg/m ³	1.2	40	0	0
Hydrofluoric µg/m ³	0.04	0.4	0	0.005
Sulfur dioxide µg/m ³	1.5	50	0	0.2
Nitrogen oxides µg/m ³	1.2	40	0	0.4
Ammonia µg/m ³	-		0	0.04
Lead µg/(m ² d)	5	100	0.2	17.0
Nickel µg / (m ² d)	0.75	15	0.122	17.1
Thallium µg / (m ² d)	0.1	2	0.01	1.7
Cadmium µg / (m ² · d)	0.1	2	0.01	1.7

445. A pre-pollution with air pollutants at the site is not known (baseline), so it is assumed that the calculated values represent the total load.

446. **Evaluation point BUP 1.** At assessment point BUP 1, the values are below the “irrelevance thresholds” of TA Luft for the substances.

447. **Analysis point ANP 1.** At the ANP 1 analysis point, the air pollutants PM10, dust precipitation, sulfur dioxide, nitrogen oxides, hydrogen fluoride fall below the irrelevance values according to TA Luft.

448. If an orienting comparison is made with the air quality values of TA Luft, the following can be stated:

- (i) For lead, thallium, cadmium, arsenic, the ambient air quality value of TA Luft is below. For mercury, the ambient air quality value of TA Luft is reached (not exceeded).
- (ii) The specified ambient air quality value in the TA Luft for nickel is exceeded. In the calculation, the heavy metal nickel was considered representative of the group of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III).
- (iii) Taking into account the volumetric flow and the desired mass concentration (corresponding to the emission limit value (class II according to 5.2.2 TA Luft) for the group of heavy metals, the emission mass flow for the group of heavy metals was assigned to the substance nickel. From a technical perspective it is not expected that none of the further elements of the heavy metal group occur in the exhaust gas, so that the exceeding of the ambient air quality value for nickel is likewise not expected.

449. **Ammonia.** No ambient air quality value is specified for ammonia. The desired mass concentrations by means of flue gas cleaning are below the values specified in the TA Luft (limit values). A negative impact on the environment is therefore not expected.

450. **Hydrogen chloride, total C, carbon monoxide (CO), dioxins and furans.** No ambient air quality values are specified for these substances. The mass concentrations aimed at by means of flue gas cleaning are below the values stated in the TA Luft (limit values). A negative impact is therefore not to be feared.

Figure 149: Additional Load Mercury-Deposit from the Dispersion Model.

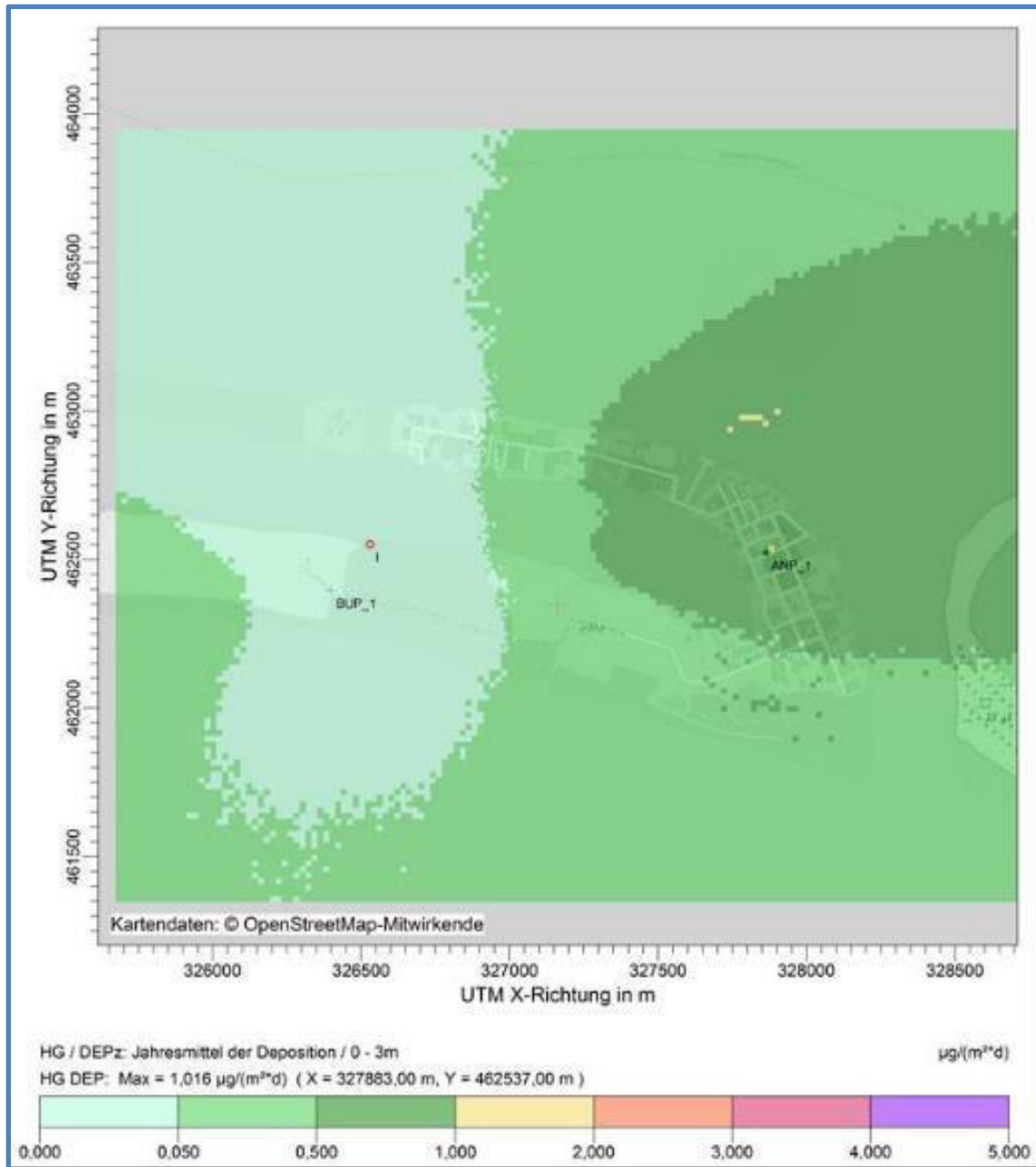


Figure 150: PM-Deposit from the Dispersion Model

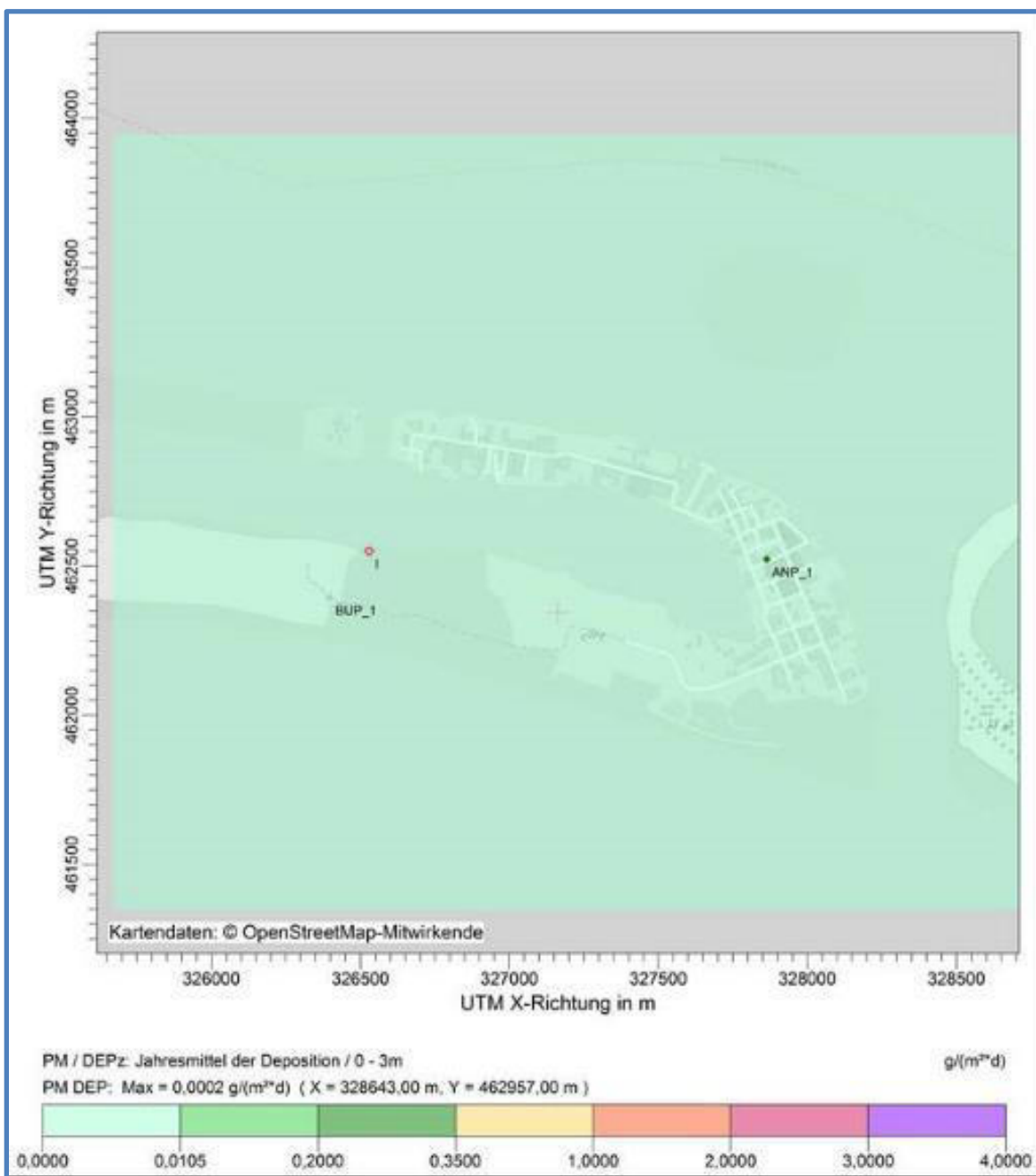


Figure 151: F-Deposit from the Dispersion Model

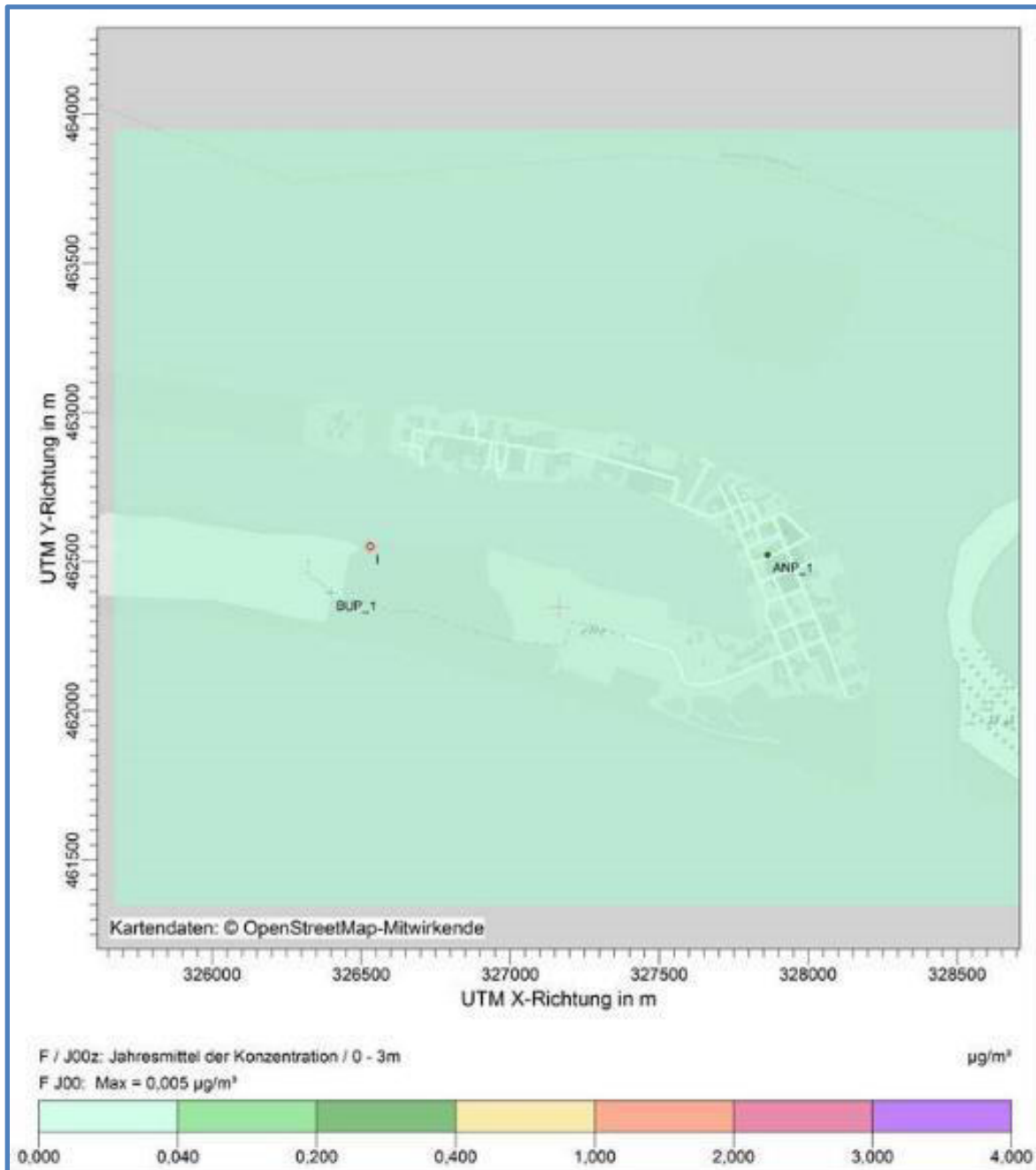


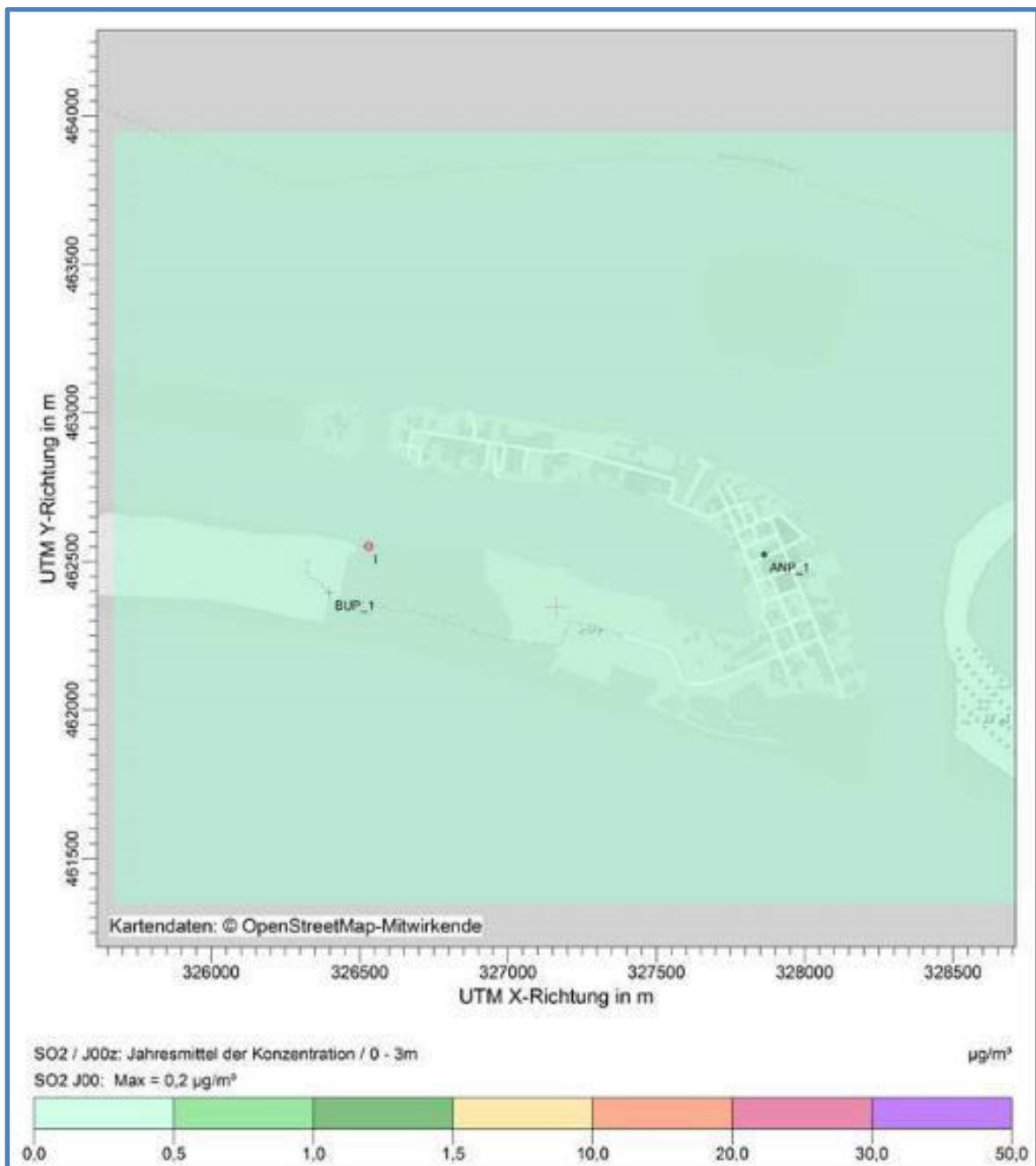
Figure 152: SO₂-Deposit from the Dispersion Model

Figure 153: NOx-Deposit from the Dispersion Model

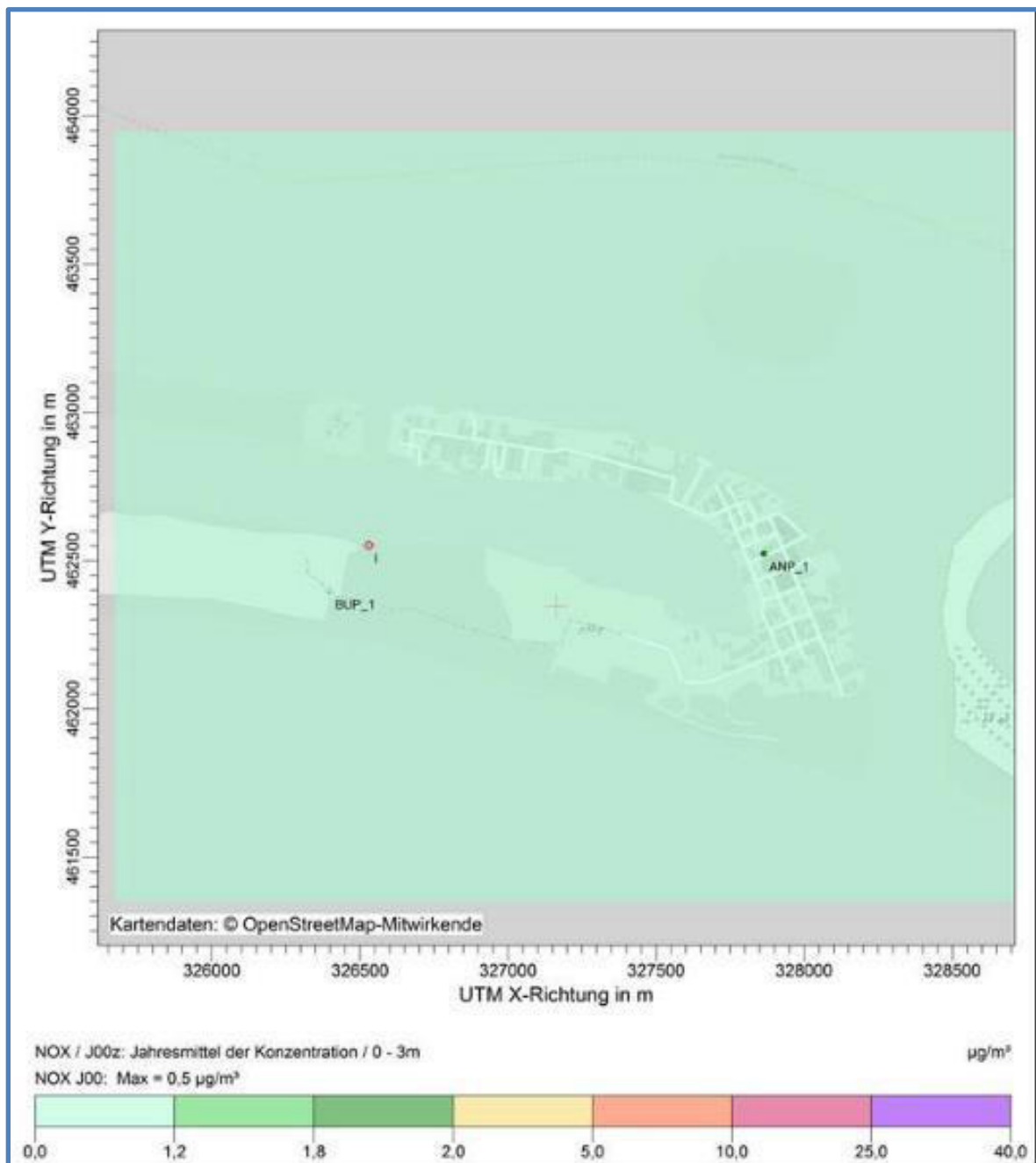


Figure 154: Pb-Deposit from the Dispersion Model

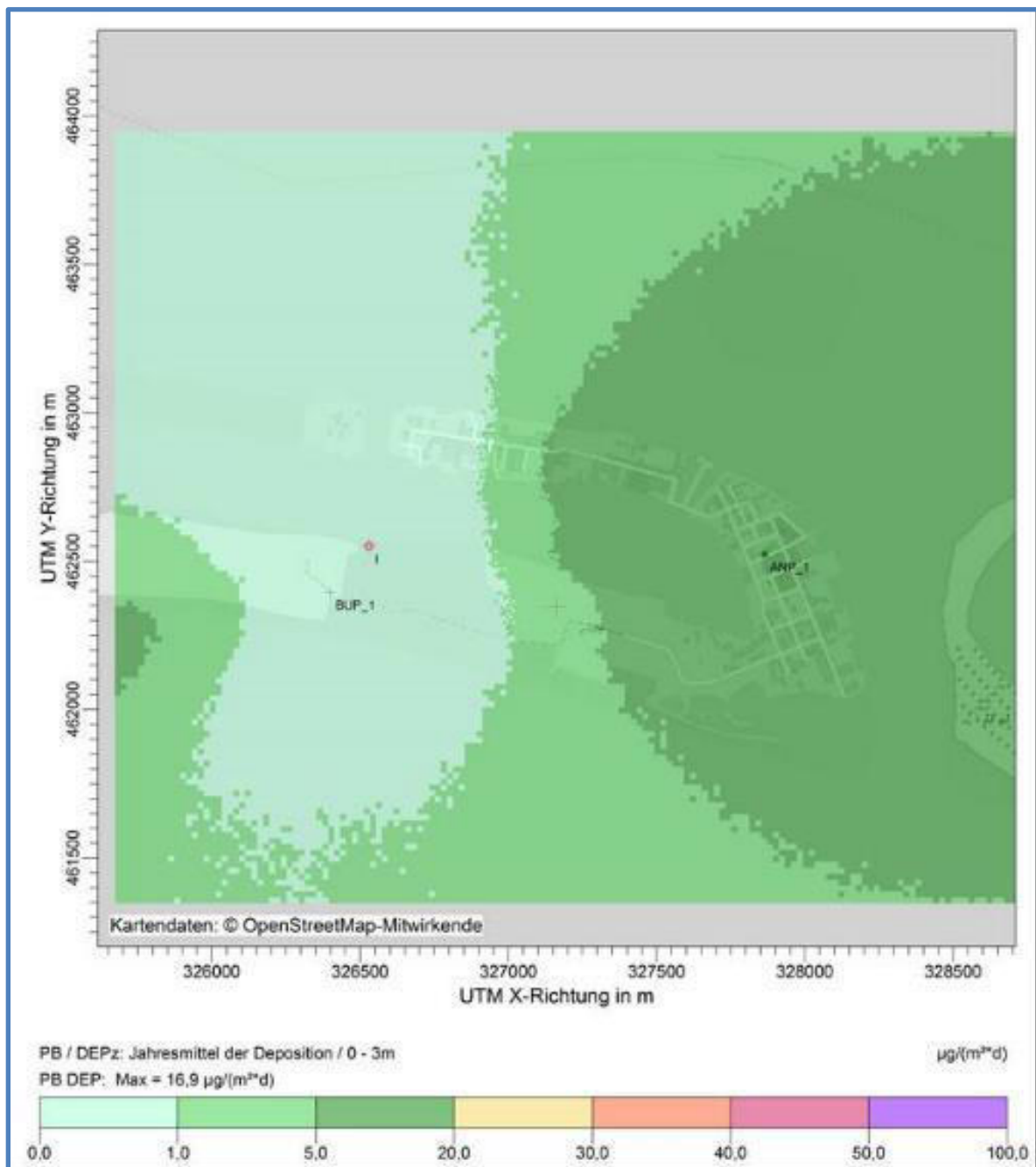


Figure 155: Ni-Deposit from the Dispersion Model

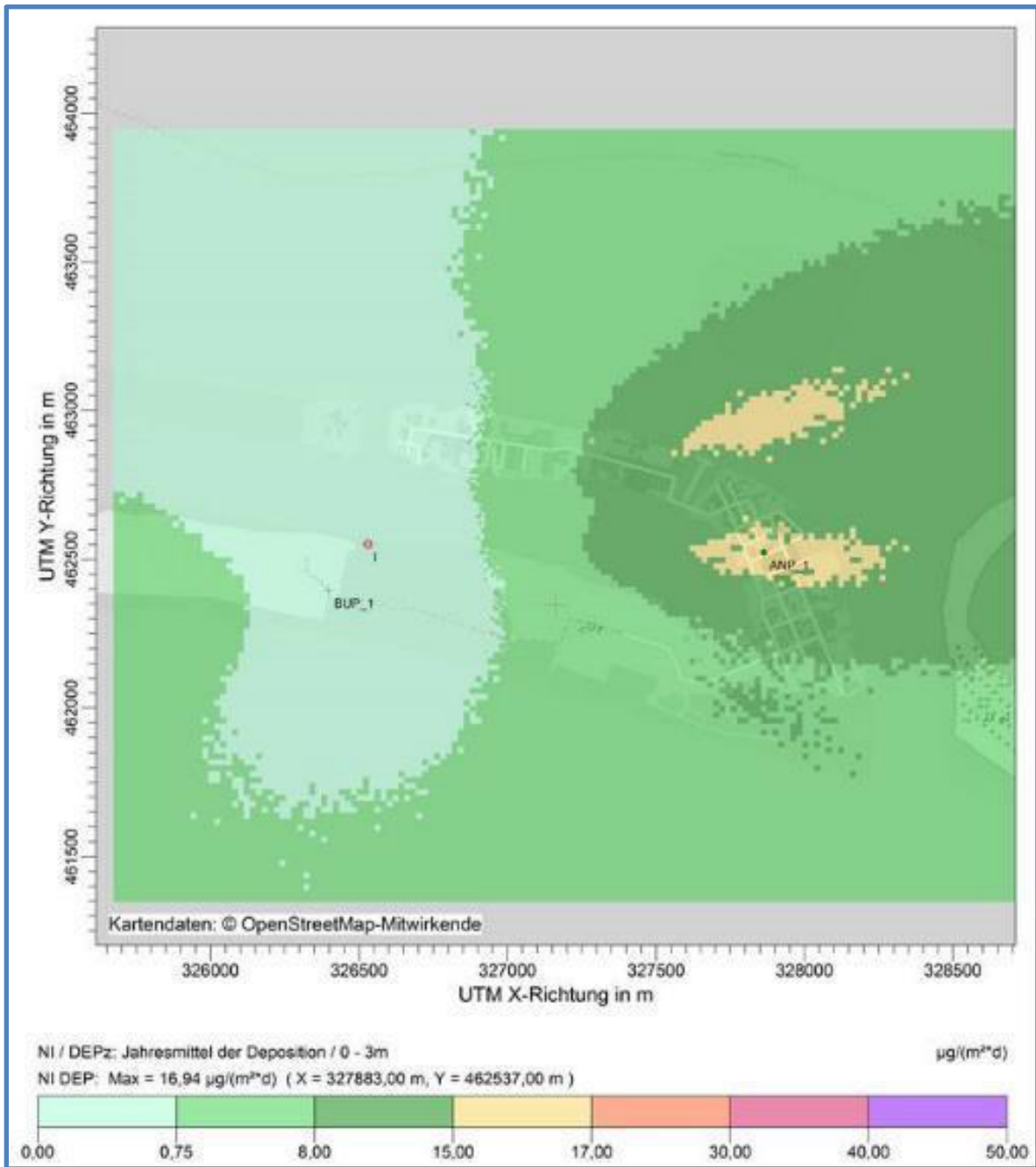


Figure 156: TI-Deposit from the Dispersion Model

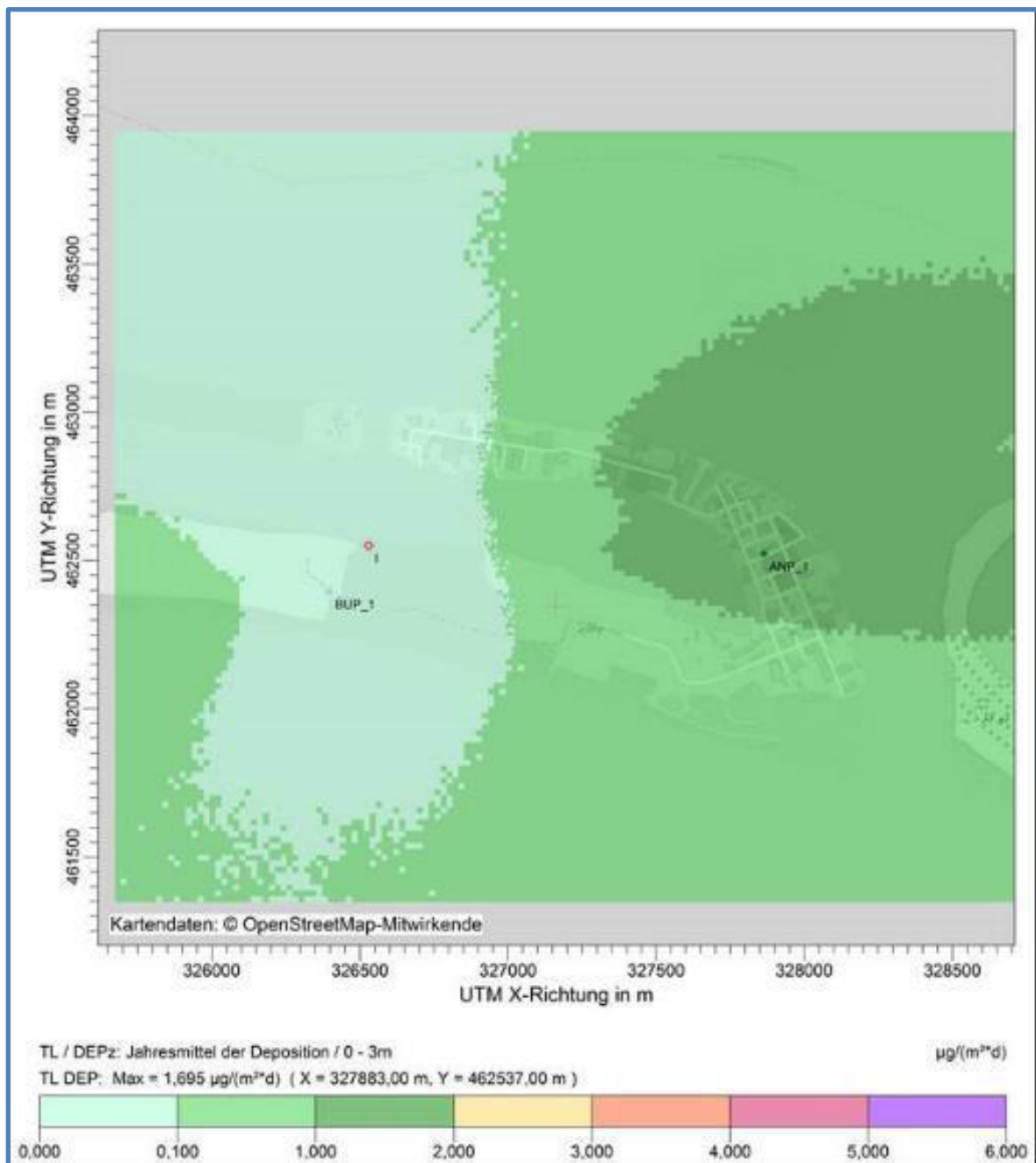


Figure 157: Cd-Deposit from the Dispersion Model

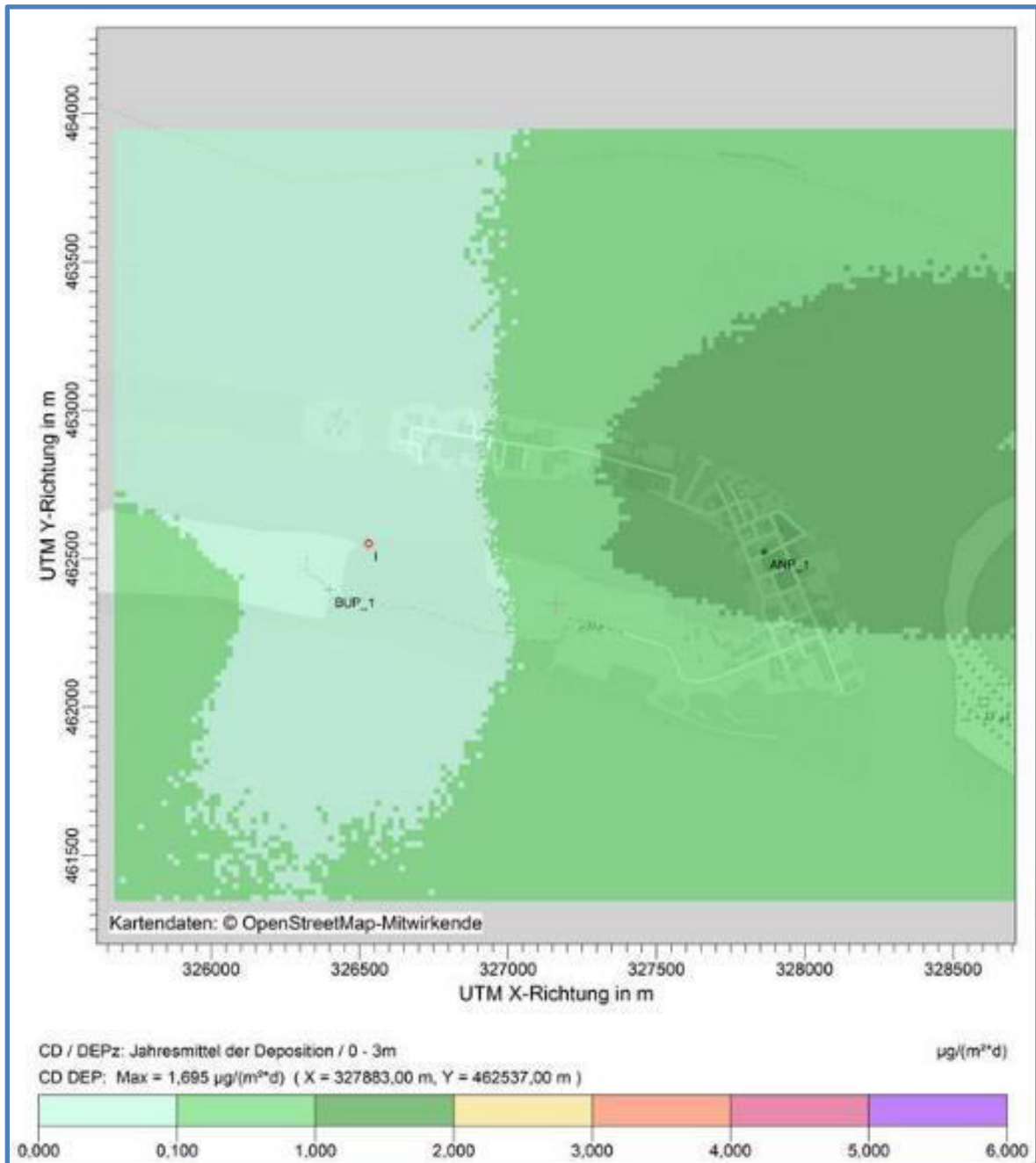
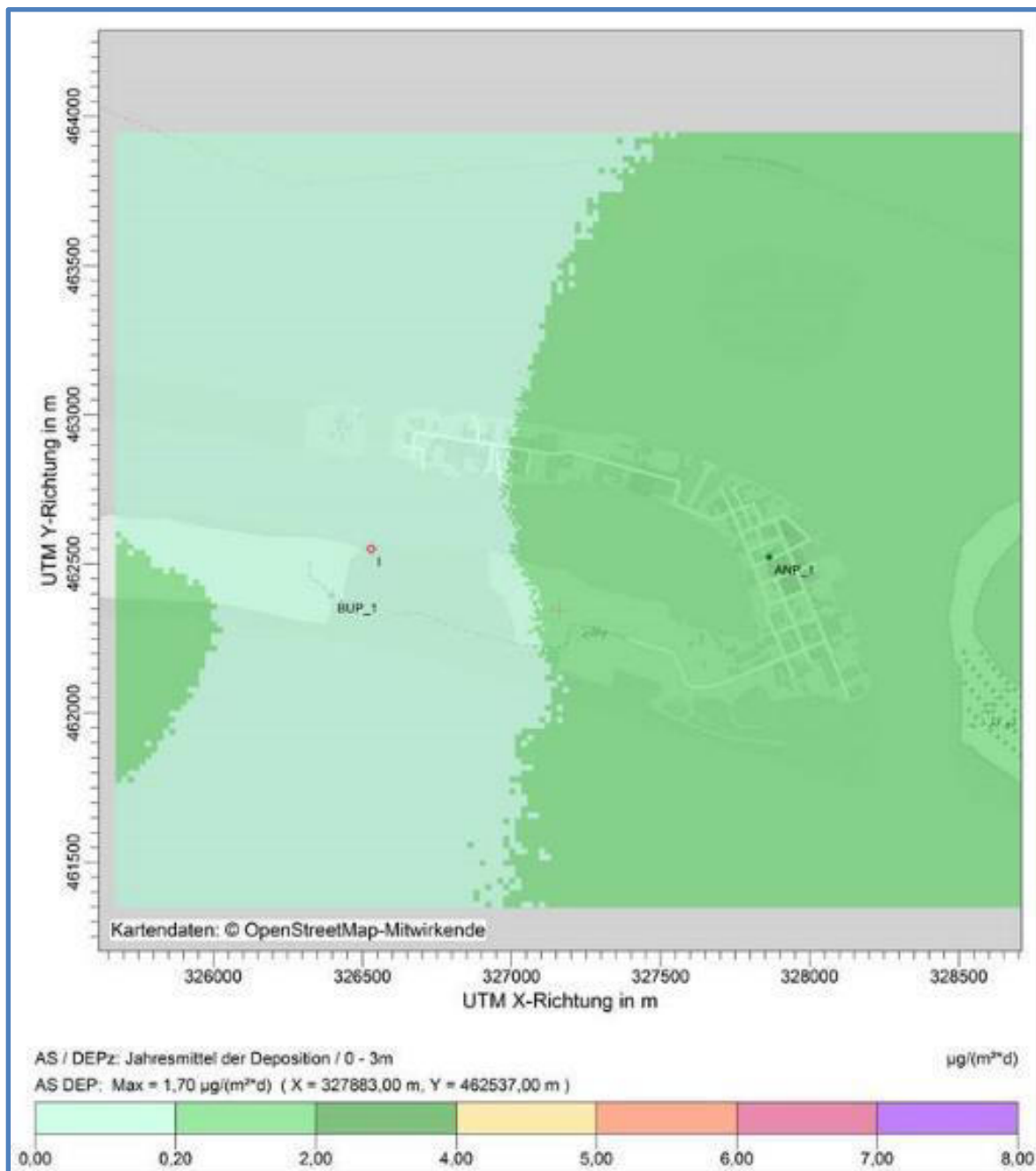


Figure 158: As Deposit from the Dispersion Model



451. The overall air quality of the project site is expected to improve with time. More significantly when the existing dumpsite is closed. Therefore, a long term and positive significant impact is expected with the operation of this project.

452. **Conclusion.** The ambient air quality status of Maldives had been unknown due to the lack of air quality monitoring data. The air quality is generally considered good as the sea breezes flush the air masses over the small the islands. However, rapid urbanization and economic growth

in the recent years has shown noticeable changes in the air quality, particularly in the Malé region. Thilafushi Island is being used to dump huge volume of wastes from the neighboring inhabited islands (Malé, Villingili and Hulhumalé) and nearby resort islands. Open burning of mixed wastes is being practiced at the island to reduce the volume of the waste. The smoke generated from burning increases the air pollutant load in the local air shed and also affects the air quality of the island.

453. The air quality at the Thilafushi Island is expected to be polluted i.e. the values for the pollutants such as $PM_{2.5}$, PM_{10} , SO_2 and NO_x are expected to be higher in the region downwind of Thilafushi as the smoke plume generated from the open burning of waste frequently passes through this region. The numbers of stations and their locations was selected to collect ambient air quality data that is representative of the baseline air quality of the Thilafushi Island and its surrounding areas.

454. Air quality monitoring for baseline was conducted at four locations. One station was selected in the downwind direction of the plume of smoke from the WTE stack while another station was placed at the crosswind direction of the plume. One station was selected in the crosswind direction of the smoke plume from the existing dump site at Thilafushi. Additional station was selected at Vilingili as a control site. See Figure 81.

455. The ambient air quality results obtained from the monitoring at Villingili undertaken indicate that all parameters were within the WHO guidelines for ambient air quality at station AQ-4 (Villingili Island). The stations at AQ-1 AQ-2 and AQ-3 had all parameters that were beyond the WHO guidelines for ambient air quality. The monitoring results showed that the air quality of Thilafushi which are on downwind wind direction of the existing waste dump site is degraded with the smoke from the dumpsite.

456. In order to estimate exposures to airborne pollutants from the incineration and emergency electricity generation, air pollutant dispersion modelling was carried out. Modelling was done for the pollutants: total dust including fine dust, fluoride and its compound specified as hydrogen fluoride, ammonia, sulfur (sulfur dioxide and sulfur trioxide), specified as sulfur dioxide, nitrogen oxide (nitrogen monoxide and nitrogen dioxide) specified as nitrogen dioxide and mercury and its compound specified as mercury from the waste to energy plant.

457. The dispersion modelling for the pollutants was carried out using the dispersion model AUSTAL2000. The computer program AUSTAL2000 is a reference implementation developed on behalf of the German Federal Environmental Agency. AUSTAL2000 is a steady-state dispersion model that is designed for long-term sources and continuous buoyant plumes. Given that poor meteorological data coverage near the proposed project site, the dispersion model AUSTAL2000 was preferred to a popular dispersion model AERMOD, which requires high quality meteorological data to run the AERMOD.

458. The proposed site for the establishment of the WTE was reclaimed in 2018. The entire Island and the project location are mainly on the main level over MSL and do not present any substantial elevation.

459. The stack emission dispersion modelling showed, except for mercury as well as heavy metals and their components (referred to thallium and arsenic/cadmium and lead/nickel), maximum mass concentrations was achieved by the flue gas cleaning and will be mass concentration of the emission from the stack. Hence emission characteristics was not required as the emissions of the air pollutants do not exceed the minor mass flows. For mercury as well as

other heavy metals and their components the values were over the minor flows, therefore dispersion modelling was carried out for these substances.

460. Dispersion modelling showed that the level of lead, thallium, cadmium, arsenic, would be below the ambient air quality value and for mercury, level in the ambient air quality would be reached but not exceeded. It is not expected that heavy metal group occur in the exhaust gas, so that the exceeding of the ambient air quality value for nickel is not expected. The desired mass concentrations by means of flue gas cleaning are below the limit values for ammonia and a negative impact on the environment is therefore not expected. Similar is with hydrogen chloride, total carbon, carbon monoxide, dioxins and furans as desired mass concentrations by means of flue gas cleaning would achieve below the emission value limits.

461. Based on the predicted concentrations and the post project concentrations of concerned pollutants, it can be inferred that the ambient air quality of the area is unlikely to be affected significantly due to proposed project. The overall air quality of the project site is expected to increase with time. More significantly when the existing dumpsite is closed. Therefore, a long term, positive, and significant impact is expected with the operation of this project.

462. AERMOD. AERMOD validation modeling was conducted in comparison with the Austal2000 German Lagrangian model. In said report, it was highly acknowledged that AERMOD is a "Stronger model" compared to Austal2000 in complex and urban terrain. It was also noted that Austal2000 was used as an alternative only because of the complexity of the meteorological data requirement of AERMOD. For the AERMOD validation run, the meteorological (metdata) provides a strong advantage because it accounts land use data, surface and upper air and its influence mechanical and convective mixing among other Planetary Boundary Layer (PBL) Parameters included met data set.

463. AERMOD meteorological data utilize surface characteristics in the form of albedo, surface roughness and Bowen ratio, plus standard meteorological observations such as wind speed, wind direction, temperature, and cloud cover. Using the AERMOD metdata processor AERMET, it calculates the PBL parameters such as: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, mixing height, and surface heat flux. These parameters are then passed to the Interface within AERMOD where similarity expressions in conjunction with measurements are used to calculate vertical profiles of wind speed, lateral and vertical turbulent fluctuations, potential temperature gradient, and potential temperature. The AERMOD processes the MM5 formatted data to generate *.SFC and *.PFL met data files. See snapshot of the generated *.SFC met data file and *.PFL met data file. Figure below also shows the AERMOD treatment of boundaries parameters.

464. In the same way as the Austal2000 model, AERMOD validation run has considered the effects of building downwash. Waste to Energy (WTE) dimensions: Approx. Length x width x height [m]: 100 x 70 x 30. Surrounding building location have been considered according to land use plan, topographical survey and Google Earth maps. The height of the buildings has been considered to maximum 10 m. This is another strong feature in AERMOD that the aerodynamic turbulence induced by nearby buildings cause a pollutant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations.

465. Terrain effects, such as elevations, were also incorporated which have impact on the air dispersion, deposition modeling results and potential risk to human health and the environment. Terrain elevation is the elevation relative to the facility base elevation. Complex Terrain are those elevations defined as anywhere within 50 km from the stack, are above the top of the stack being

evaluated in the air modelling analysis. Terrain consideration was determined using SRTM3 terrain data processed by AERMAP terrain processor and has noted that highest elevations in the project area is at 7 meters only above sea level. Nevertheless, this AERMOD validated executed terrain situations using SRTM3 terrain data processed by AERMAP terrain processor where model considers terrain height exceeds stack base elevation, model receptors are also assumed on elevated terrain. Terrain elevations for receptors in the receptor Pathway are also considered.

466. Output of model run includes: 1-hour, 24-hour, and 1 year averaging time plot files, isopleths diagrams, and table of worst-case scenarios. Meteorological data used is based on TIER 4 meteorological data, NCAR MM5 (5th-generation Mesoscale Model) prognostic meteorological model was the basis for meteorological background of the areas. Prognostic MM5 meteorological model are specified location and site domain. Once the MM5 preprocessing has been completed, the MM5 output file is converted into a format recognized by the AERMET model (meteorological preprocessor for the AERMOD model). The final output is generated by creating a pseudo met station at the specified site location.

467. **Area Sensitive Receptors (ASRs).** Area Sensitive Receptors (ASRs) include, but are not limited to residential areas, hospitals, schools, daycare facilities, elderly housing and convalescent facilities. These are areas where the occupants are more susceptible to the adverse effects of exposure to air pollutants. Extra monitoring and abatement efforts must be taken when dealing with contaminants and pollutants in close proximity to areas recognized as ASRs. For the WTE project and for the purpose of assessing potential impacts, Thilafushi islands' industrial areas are considered as ASRs as there are identified facilities with workers quarters. ASRs are located in the following area and details are provided in the main text of this report: (i) ASR1-ENE; (ii) ASR2-SSE; (iii) ASR3-NNE; (iv) ASR4-SSW; and (v) ASR5-NNW 474 to 1273 meters upwind and downwind directions from the center of the domain at UTM coordinates easting 326540 and northing 462472. This AERMOD Report includes results of the dispersion model showing the highest predicted ground level concentrations (GLC) in the ASRs.

468. The results and outputs of the models are compared with TA Luft Standards as specified in the Austal2000 Report and applicable United States Environmental Protection Agency (USEPA) standards and World Health Organization Air Quality Guidelines.

469. **Total Dust (TD).** Predicted short term (1 hour) for controlled³⁷ total dust (TD) maximum ground level concentrations is 7.60 ug/m³ located 280 meters ENE from the center of the domain. The 24-hour controlled total dust (TD) maximum ground level concentrations is 3.188 ug/m³ located 608 meters ENE from the center of the domain. Simulated concentrations for maximum ground level concentration for 1-hour total dust (TD) are generally very low. There is no available the Ambient Air Quality Standards for total dust in the Austal2000 Report. For the total dust (TD) deposition, AERMOD results shows 0.00754 g/m² for 1-hour, 0.038505 g/m² for 24 hr, and 0.43394 g/m² for 1 year deposition. Deposition simulations are all below the TA Luft precipitation limit of 0.35 g/m²-d. There are no applicable USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at Universal Transverse Mercator (UTM) coordinates Easting 326540 and Northing 462472.

³⁷Controlled emission parameters refer to post-air pollution control devices. For the WTE, each stack will include baghouse and electrostatic precipitators.

470. **Particulate Matter 10 (PM-10).** Predicted short term (1 hour) for controlled particulate matter 10 (PM₁₀) maximum ground level concentrations is 0.102 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled PM₁₀ maximum ground level concentrations is 0.02844 ug/m³ located 100 meters E from the center of the domain. Simulated concentration for maximum ground level concentration for 24-hour PM₁₀ is below the 35 ug/m³ TA Luft standards. There is no available Ambient Air Quality Standards for PM₁₀ in the Austal2000 report. For the PM₁₀ deposition, AERMOD results shows 0.00037 g/m² for 1 hour, 0.0007g/m² for 24 hour and 0.025 g/m² for 1 year deposition. There is no TA Luft precipitation limit for PM₁₀ in the Austal2000 report. Results are below WHO Air Quality Guideline Values. There are no USEPA standards. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

471. **Sulfur Dioxide (SO₂).** Predicted short term (1 hour) for controlled sulfur dioxide (SO₂) maximum ground level concentrations is 10.34 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled SO₂ maximum ground level concentrations is 2.85 ug/m³ located 100 meters E from the center of the domain. For 1-year averaging time, result of maximum concentration is 0.25302 ug/m³. All simulated concentration for maximum ground level concentration for 1 hour, 24 hour and 1-year SO₂ are all below the TA Luft standards of 350 ug/m³ for 1 hour, 125 ug/m³ for 24 hr and 50 ug/m³ for 1 year, respectively. Results are below USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

472. **Nitrogen Oxides (NOx)** Predicted short term (1 hour) for controlled NO₂ maximum ground level concentration is 48.91 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled NO₂ maximum ground level concentrations is 14.16 ug/m³ located 100 meters E from the center of the domain. For 1-year averaging time, results of maximum NO₂ concentration is 2.1 ug/m³. Simulated concentration for maximum NO₂ ground level concentration for 1 year is below the TA Luft standards of 18 ug/m³. Results are below USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

15. **Mercury (Hg).** Predicted short term (1 hour) for controlled mercury (Hg) maximum ground level concentrations is 0.00643 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled Hg maximum ground level concentrations is 0.00178 ug/m³ located 100 meters E from the center of the domain. For 1-year averaging time, result of maximum concentration is 0.0057 ug/m³. Simulated concentration for maximum ground level concentration for 1-year Hg is below the TA Luft standards of 0.05 ug/m³. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

473. **Ammonia (NH₃).** Predicted short term (1 hour) for controlled ammonia (NH₃) maximum ground level concentrations is 2.066 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled NH₃ maximum ground level concentrations is 0.57123 ug/m³ located 100 meters E from the center of the domain. There are no NH₃TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates easting 326540 and northing 462472.

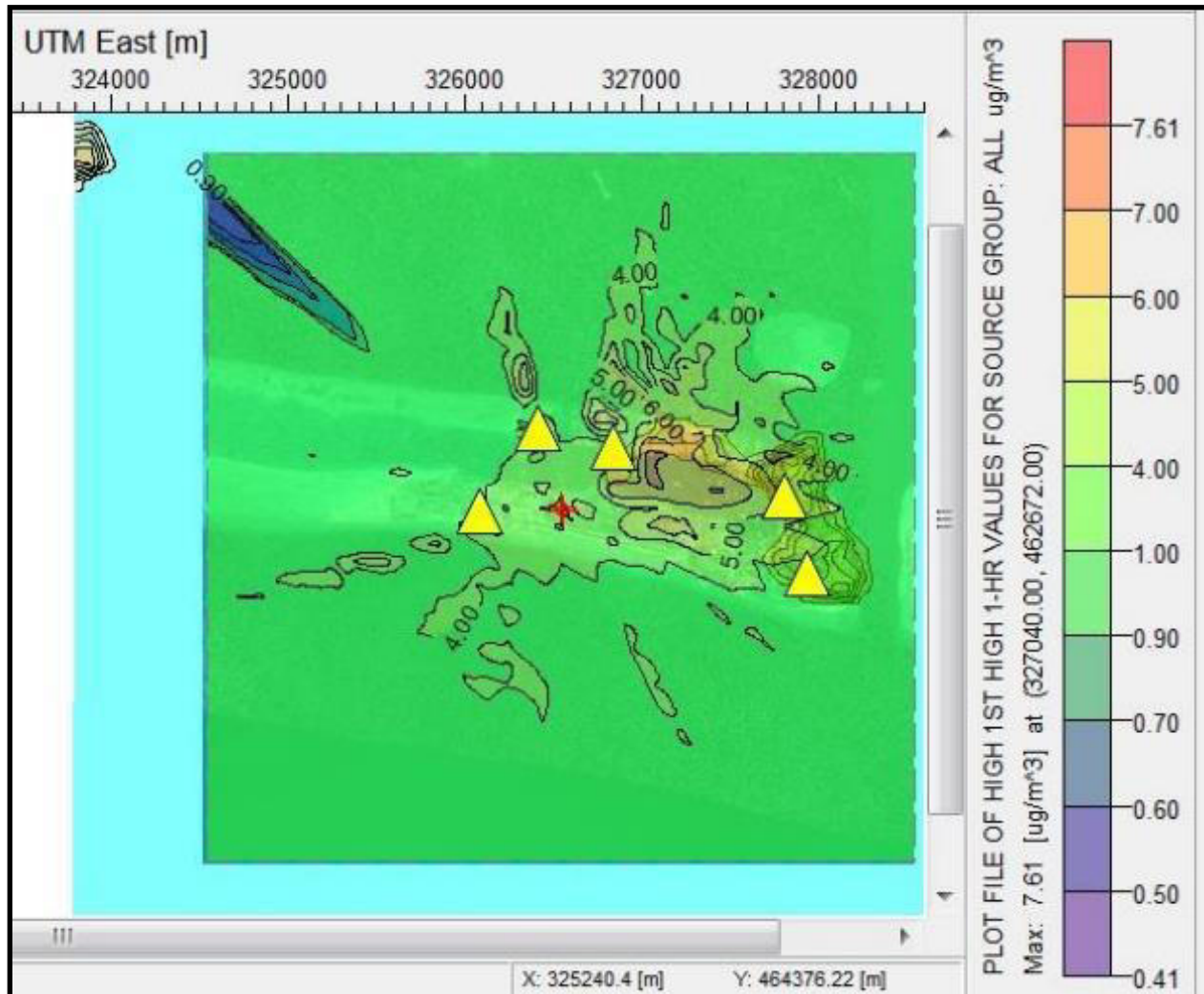
474. **Hydrogen Chloride (HCl).** Predicted short term (1 hour) for controlled hydrogen chloride (HCl) maximum ground level concentrations is 2.066 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled NH₃ maximum ground level concentrations is 0.57123

ug/m³ located 100 meters E from the center of the domain. There are no HCl TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

475. **Hydrogen Fluoride (HFI).** Predicted short term (1 hour) for controlled hydrogen fluoride (HFI) maximum ground level concentrations is 2.066 ug/m³ located 100 meters E from the center of the domain. The 24-hour controlled HFI maximum ground level concentrations is 0.57123 ug/m³ located 100 meters E from the center of the domain. There are no HFI TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

476. **Dioxins and Furans (D/F).** Predicted short term (1 hour) for controlled dioxins and furans maximum ground level concentrations is 0.0258 ug/m³ located 100 meters E from the center of the domain. The 24 hour-controlled dioxins and furans maximum ground level concentrations is 0.00569 ug/m³ located 100 meters E from the center of the domain. There are no dioxins and furans TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values also. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Figure 159: Total Dust (TD) (1 HR) (Isopleth in microgram/m³)

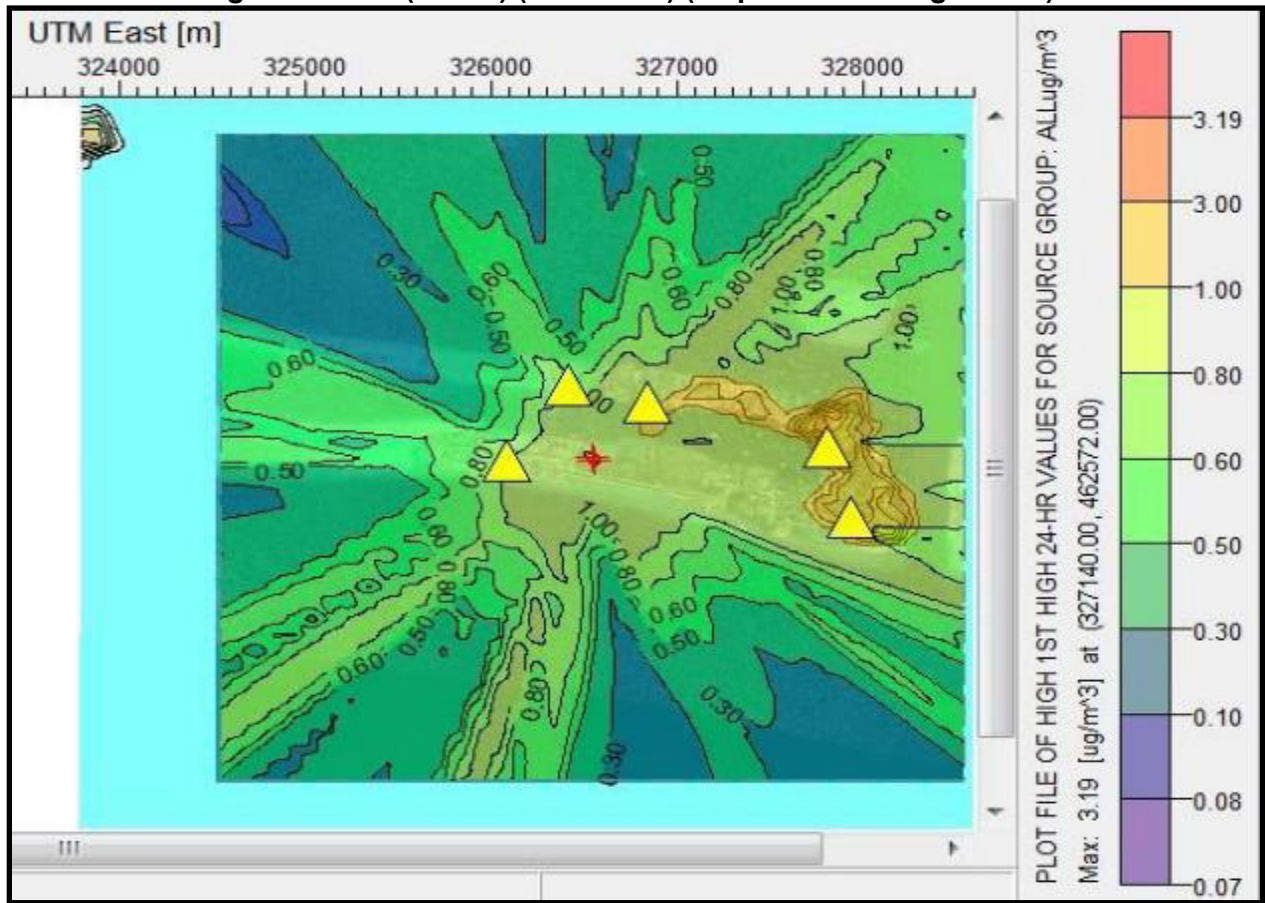


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 160:TD (24-HR) (1-HR RUN) (Isopleth in microgram/m³)

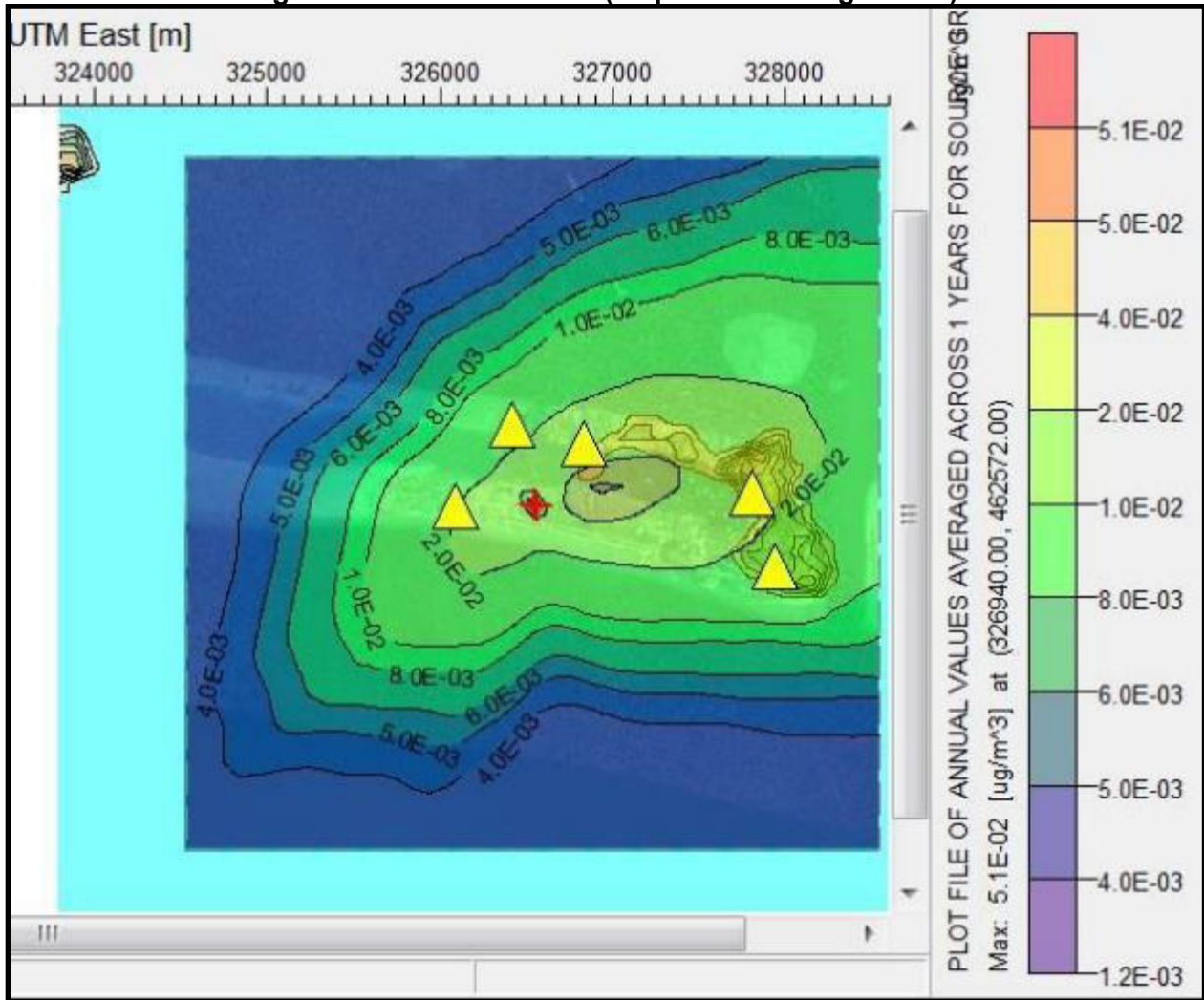


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 161: Total Dust 1YR (Isopleth in microgram/m³)

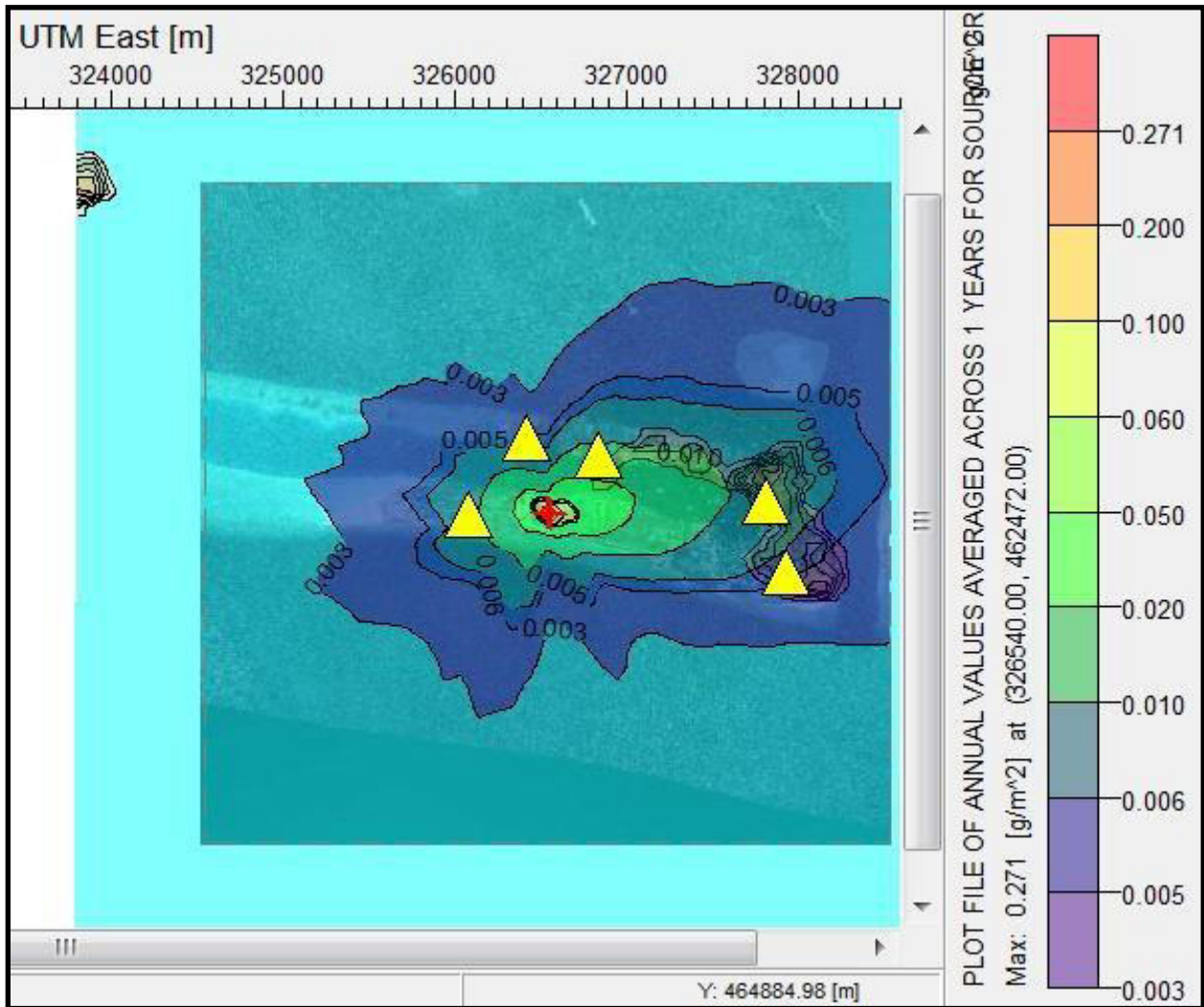


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 162: Total Dust 1YR Deposition (Isopleth in microgram/m³)

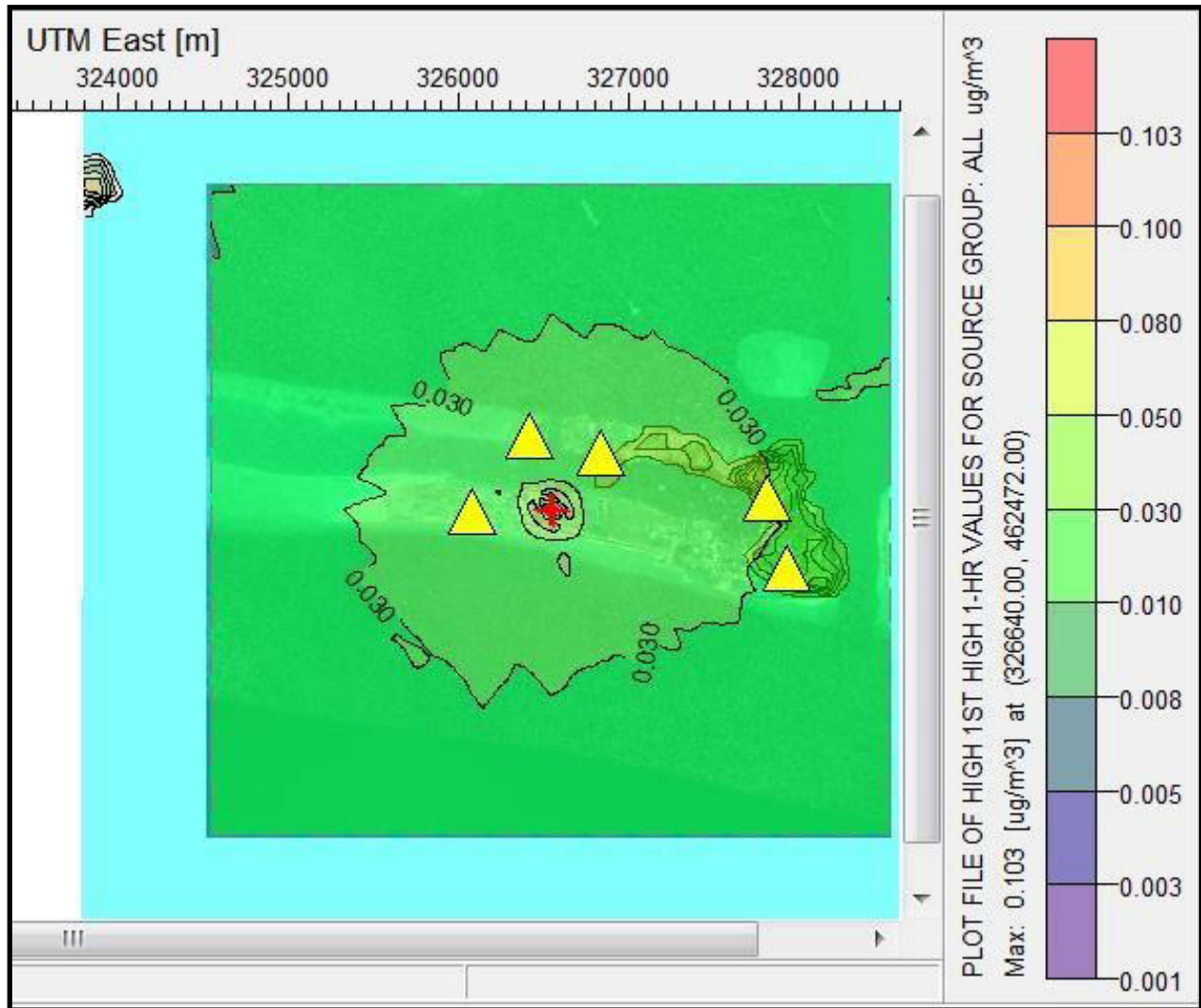


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 163: PM10 1 HR (Isopleth in microgram/m³)

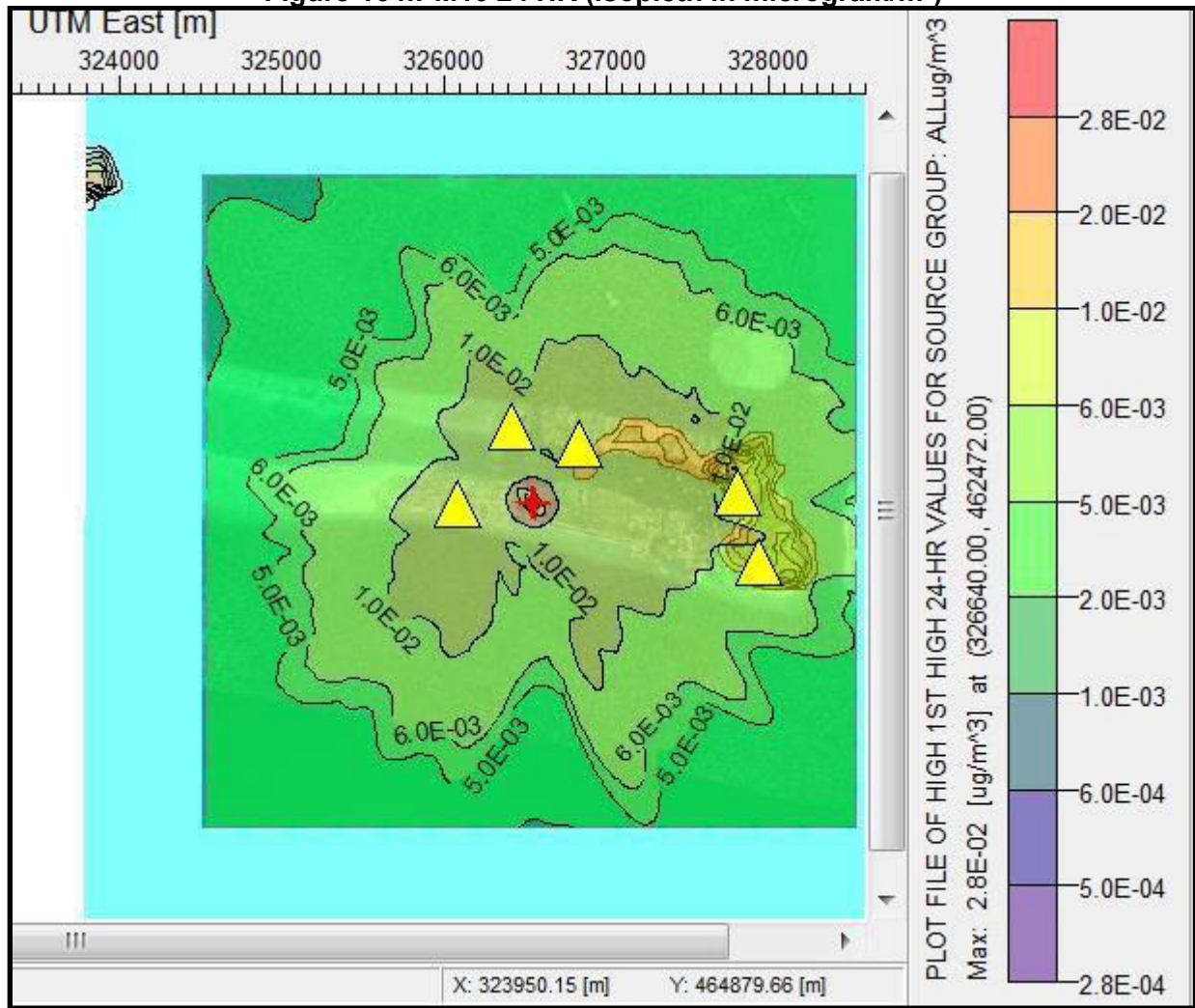


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 164:PM10 24 HR (Isopleth in microgram/m³)

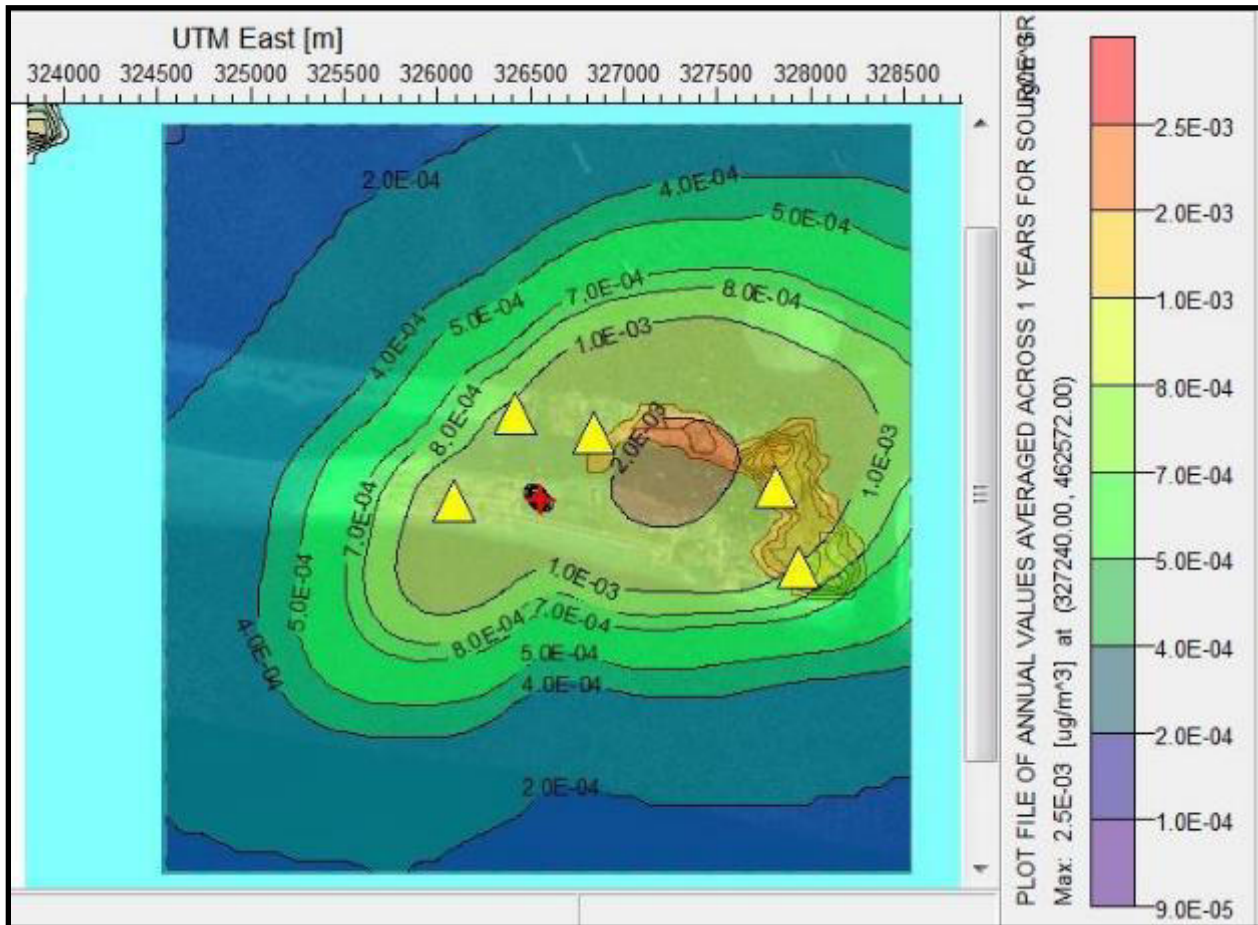


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 165: PM10 1 YR Deposition (Isopleth in microgram/m³)

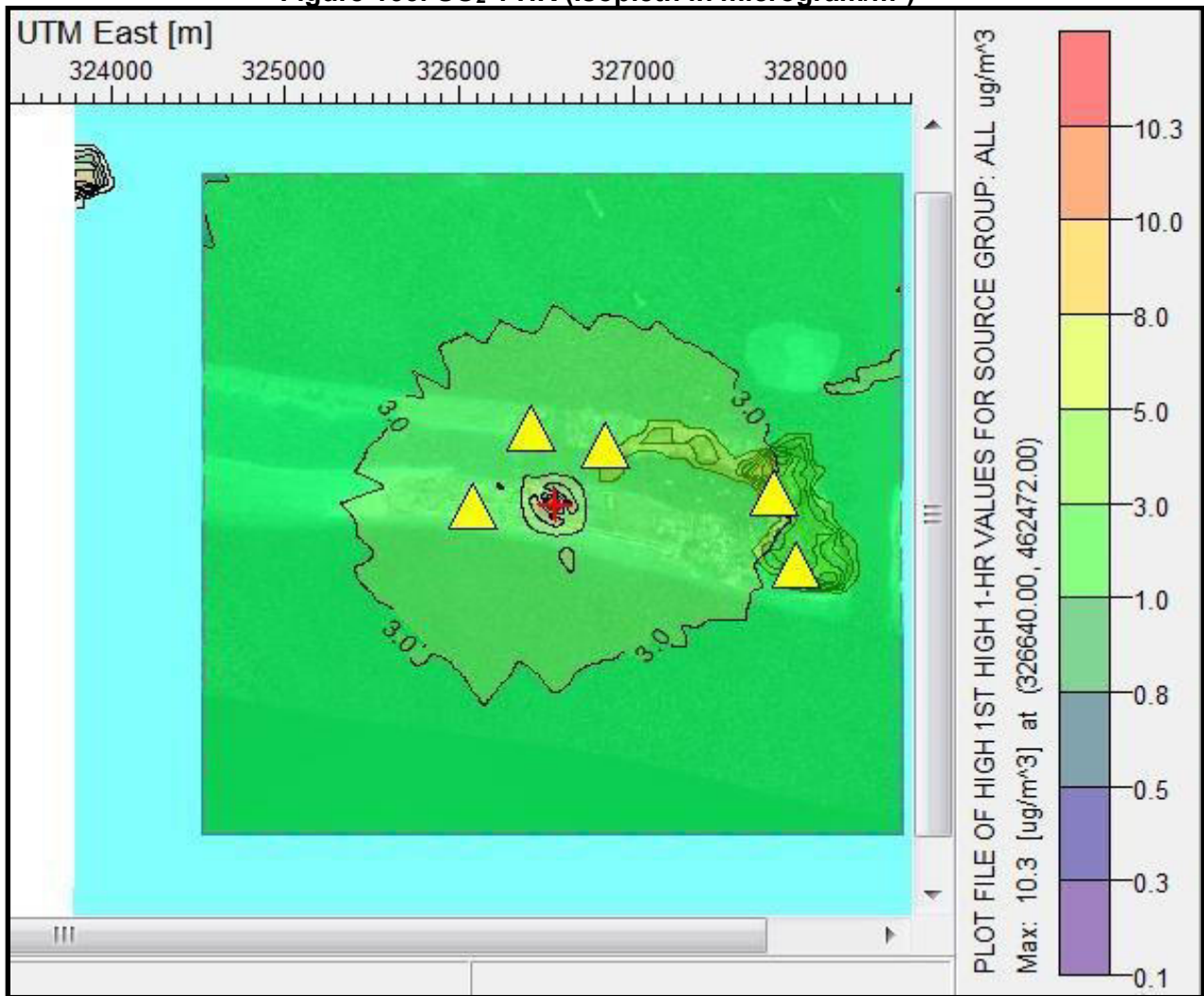


LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

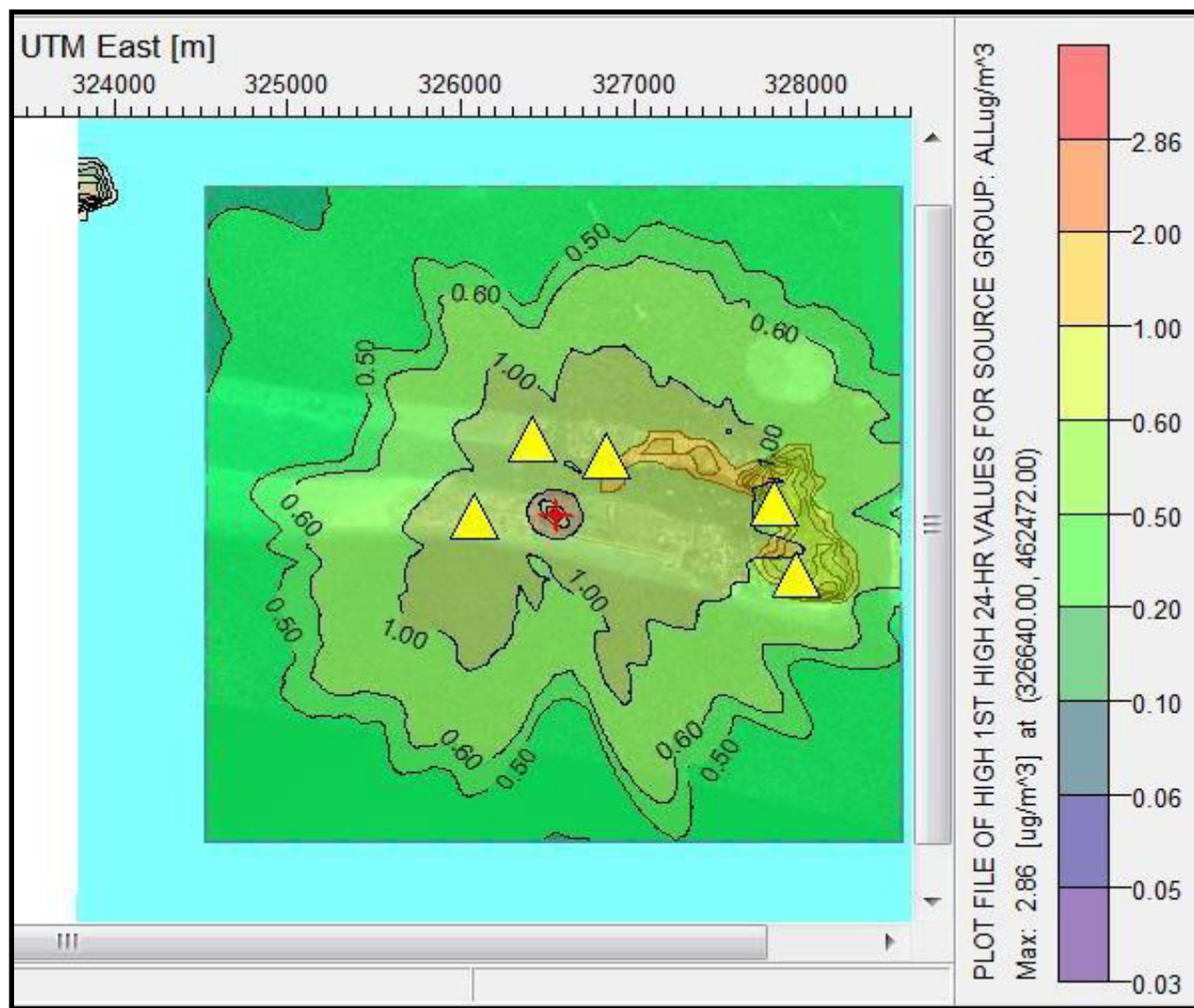
Figure 166: SO₂ 1 HR (Isopleth in microgram/m³)



LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

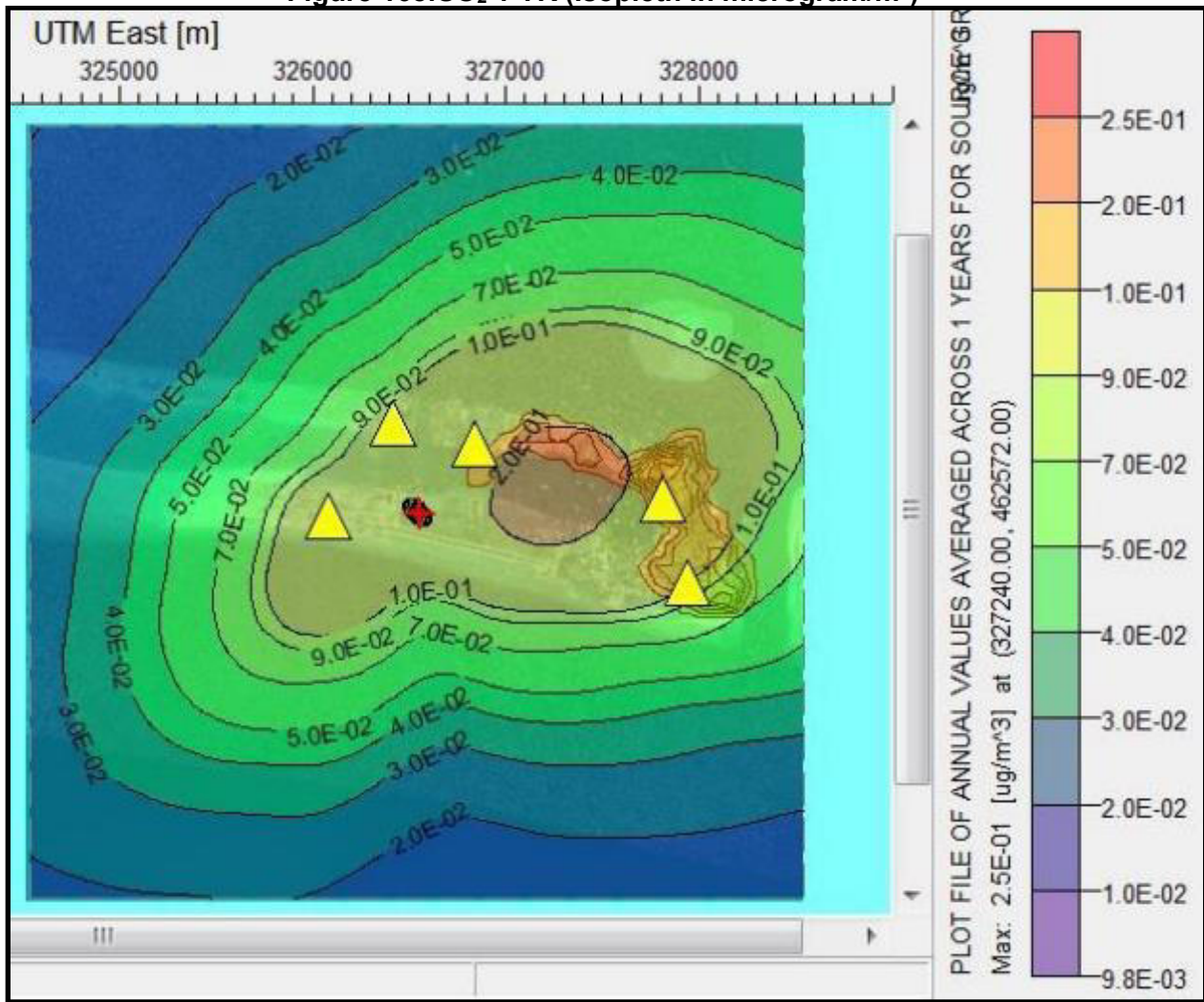
Figure 167: SO₂ 24 HR (Isopleth in microgram/m³)

LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

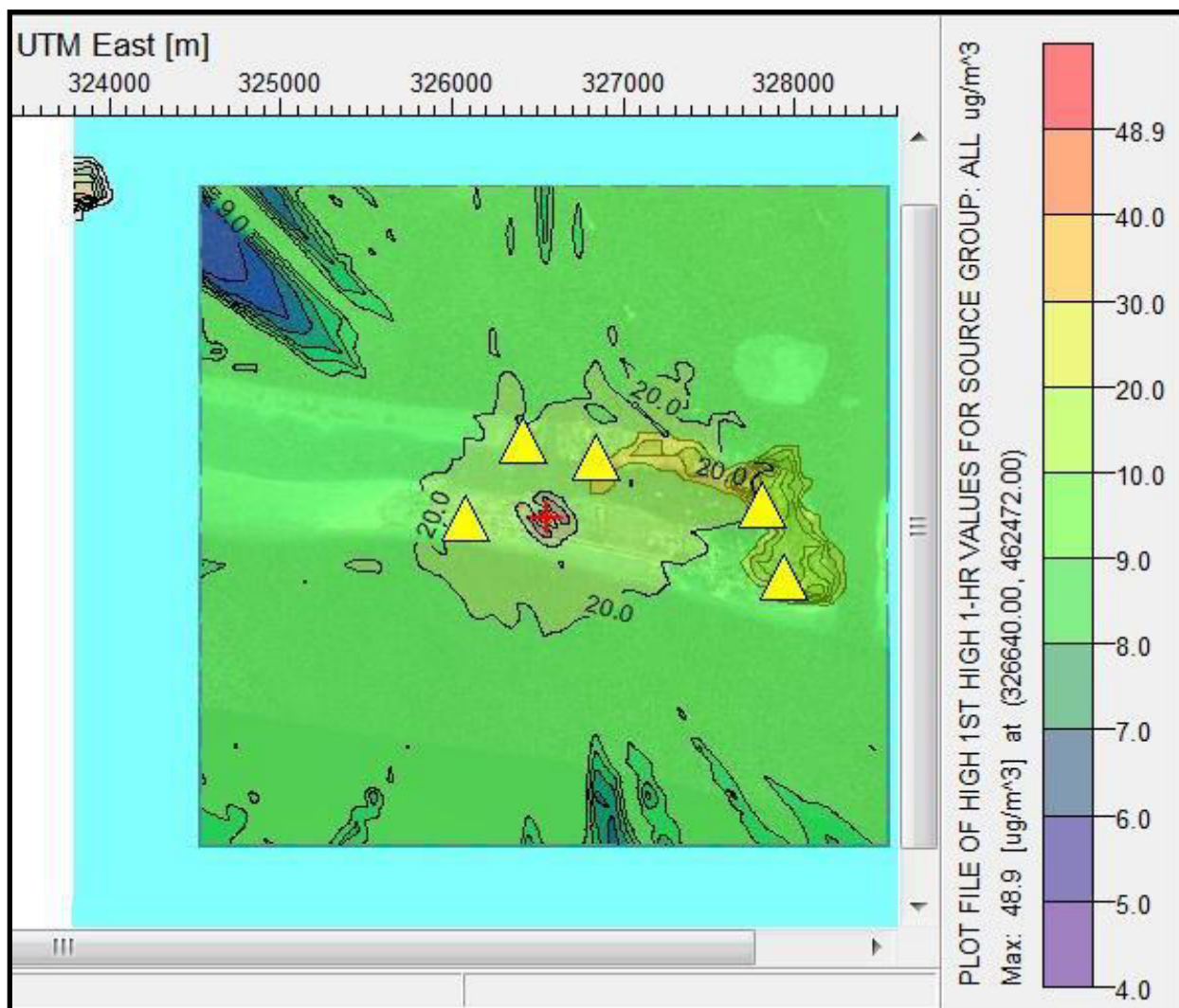
Figure 168:SO₂ 1 YR (Isopleth in microgram/m³)



LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

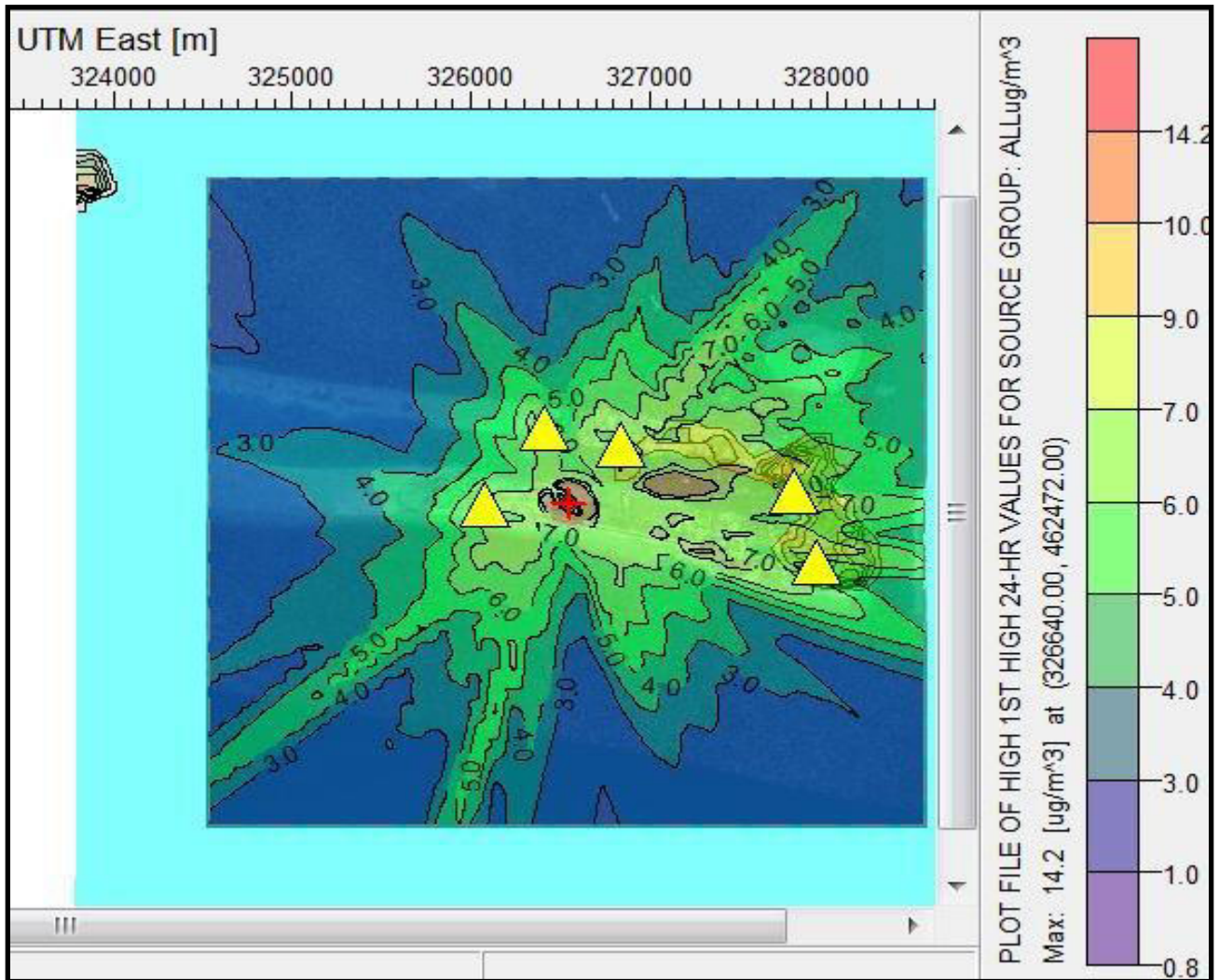
Figure 169: NO₂ 1 HR (Isopleth in microgram/m³)

LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 170: NO₂ 24 HR (Isopleth in microgram/m³)

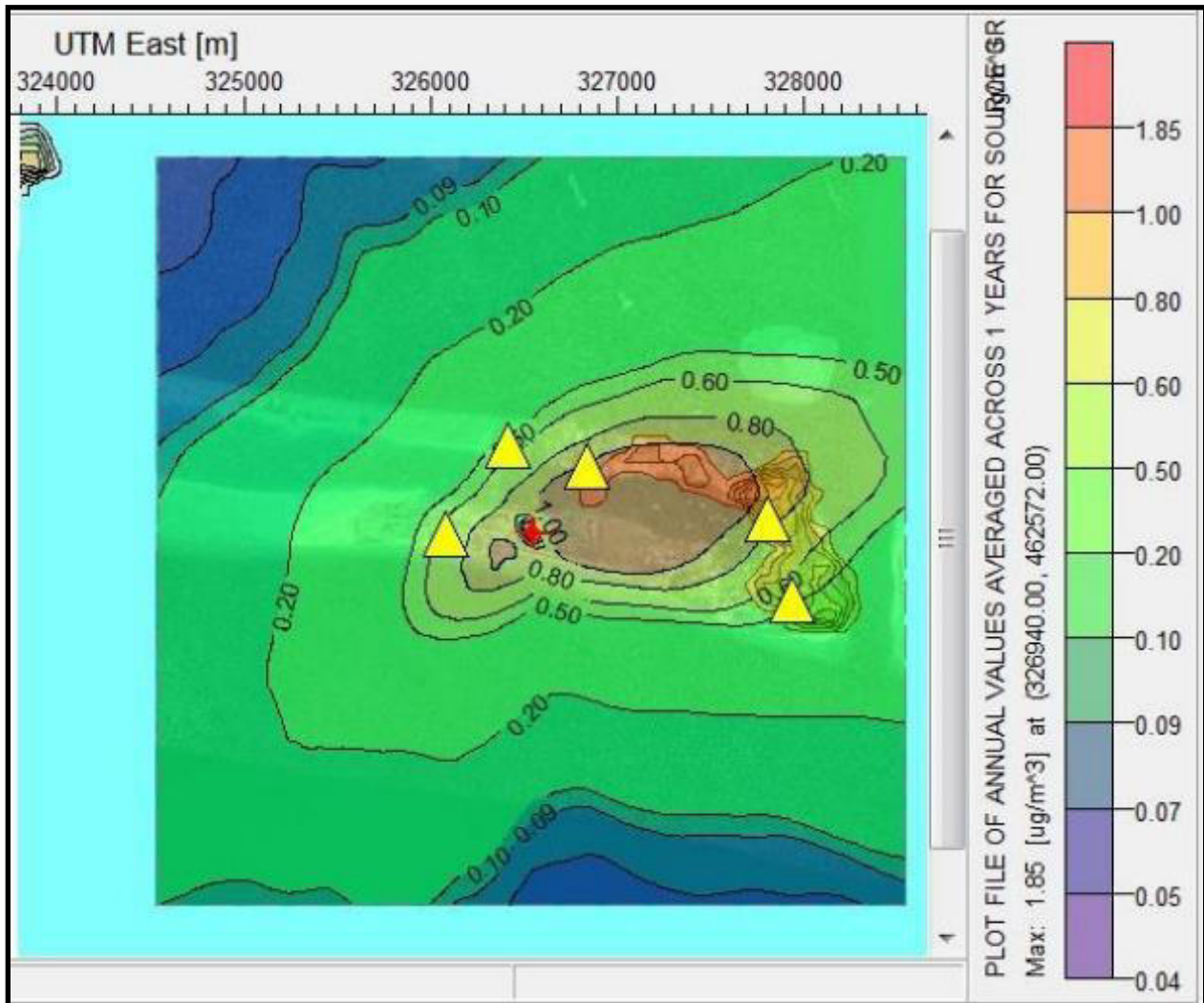


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	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

Figure 171: NO₂ 1 YR HR (Isopleth in microgram/m³)



LEGEND:

Yellow Triangles refer to identified Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929