HR Wallingford

Working with water

Hamriyah 1800 MW CCGT Power Plant

Dispersion modelling

DER5948-RT001-R02-00

June 2018

Document information

Document permissions	Confidential - client
Project number	DER5948
Project name	Hamriyah 1800 MW CCGT Power Plant
Report title	Dispersion modelling
Report number	RT001
Release number	R02-00
Report date	June 2018
Client	Mott MacDonald
Client representative	Rouba Abou-Atieh
Project manager	Elfed Jones
Project director	Matthew Wood

Document history

Date	Release	Prepared	Approved	Authorised	Notes
27 Jun 2018	02-00	TEJ	MJW	MJW	Minor change to text
05 Jun 2018	01-00	TEJ	MJW	MJW	

Document authorisation

Prepared

Approved

Authorised

Summary

The Sharjah Electricity & Water Authority (SEWA) has agreed to acquire electricity generated by an 1800 MW CCGT (plus distillate fuel) power plant in Hamriyah, Sharjah, which is being developed by GE Energy Financial Services and Sumitomo Corporation (the “Sponsors”). Mott MacDonald is undertaking an Environmental Social and Impact Assessment (“ESIA”) on behalf of the Sponsors. As part of the ESIA, Mott McDonald has retained HR Wallingford to perform a hydrodynamic modelling and recirculation/dispersion study of the power plant to help determine the impact that the discharge of cooling water from the power plant is expected to have. The power plant will use the existing common seawater supply and return system for various facilities at the site including an existing 20 MIGD desalination plant. In the future, an additional 60 MIGD desalination plant is to be developed.

Hydrodynamic modelling and recirculation/dispersion studies have been undertaken to determine the dispersion of the cooling water discharge from the proposed power plant with and without the existing and future nearby desalination plants. A local three-dimensional model was built using TELEMAC-3D, using boundary conditions from a calibrated regional hydrodynamic model of the Arabian Gulf. Further confidence in the local model’s predictions could be obtained through the collection of local current and water level measurements, and subsequent model verification using the data.

The cooling water from the power plant and reject brine from desalination plants will be discharged via a common shoreline outfall into Hamriyah Port. Depending on the proportion of effluent that comes from desalination, the combined discharge will be either positively or negatively buoyant.

Environmental compliance is assessed in terms of the extent of the area where the plume temperature is more than 3°C above the background and the salinity is more than 5% above the ambient seawater salinity. These areas represent the temperature and salinity “mixing zones” of the discharge.

For scenarios with either the power plant operating alone or in combination with the existing 20 MIGD desalination plant, the combined discharge will form a positively buoyant plume. The maximum areas of the temperature mixing zones are in the range of 200-400 ha (the average mixing zone areas are less than 100 ha). In these cases there are no salinity mixing zones as the salinities of the discharges are already within 5% of the background.

For a scenario with the additional 60 MIGD desalination plant operating, the combined discharge will form a negatively buoyant plume which will sink to the seabed in the port and then flow seaward along the bottom of the port approach channel. The maximum areas of the temperature mixing zones are around 100 ha, and the average mixing zone areas are around 50 ha). The maximum areas of the salinity mixing zones are in the range 100-150 ha, and the average areas are around 70 ha.

Recirculation of warm water between the outfall and intake is predicted to be limited to around 0.7°C maximum and below 0.5°C on average. Depth-averaged excess salinities at the intake are predicted to be up to 0.5 ppt.

Contents

Tables

1. Introduction

The Sharjah Electricity & Water Authority (SEWA) has agreed to acquire electricity generated by an 1800 MW CCGT (plus distillate fuel) power plant in Hamriyah, Sharjah (Figure 1.1), which is being developed by GE Energy Financial Services and Sumitomo Corporation (the “Sponsors”). Mott MacDonald is undertaking an Environmental Social and Impact Assessment (“ESIA”) on behalf of the Sponsors. As part of the ESIA, Mott McDonald has retained HR Wallingford to perform a hydrodynamic modelling and recirculation/dispersion study of the power plant to help determine the impact that the discharge of cooling water from the power plant is expected to have. The power plant will use the existing common seawater supply and return system for various facilities at the site including an existing 20 MIGD desalination plant. In the future, an additional 60 MIGD desalination plant is to be developed.

Figure 1.1: Project site

This report describes dispersion modelling of the cooling water plume from the power plant to support the ESIA.

1.1. Report conventions

In this report, the horizontal coordinate system is WGS84 UTM Zone 40. The vertical datum is Mean Sea Level (MSL). At the project location, MSL is approximately 1.18 m above Chart Datum (CD) (or 1.09 m above Halcrow Sharjah Datum (HSD)).

In accordance with normal meteorological and oceanographic conventions, winds come from the specified direction while currents and water displacements are towards the specified direction.

2. Hamriyah 1800 MW CCGT plant

The new plant will built at the Hamriyah Free Zone. The cooling water will be drawn from an existing intake channel and the warm water will be discharged to an existing outfall channel, such that the cooling water will flow directly into Hamriyah port.

The outfall channel is already being used to discharge reject brine from a 20 MIGD desalination plant. An additional 60 MIGD desalination plant is to be built in the future.

Three operational scenarios were modelled:

1. New 1800 MW CCGT power plant only.
2. New 1800 MW CCGT power plant plus existing 20 MIGD desalination plant.
3. New 1800 MW CCGT power plant plus existing 20 MIGD and future additional 60 MIGD desalination plants.

The flow, temperature and salinity data for the three individual plants are shown in Table 2.1, while the combined discharged parameters used to simulate the three operational scenarios are shown in Table 2.2. For the modelling we have assumed that the streams from the individual plants are fully mixed in the receiving basin before being discharged.

Table 2.1: Individual plant flow, temperature and salinity data

Plant	Intake flow (m^3/s)	Outfall flow (m^3/s)	ΔS (ppt)	ΔT (°C)
Power plant	34	34	0	7
Existing 20 MIGD desalination	2.9	1.9	23.47	0
Future 60 MIGD desalination plant	8.8	5.7	23.47	0

Source: Based on data provided by Mott Macdonald and EFS. 60 MIGD plant data scaled from existing 20 MIGD data

Table 2.2: Combined flow, temperature and salinity data for input to dispersion simulations

Operational scenario	Intake flow (m^3/s)	Outfall flow (m^3/s)	ΔS (ppt)	ΔT (°C)
New Power plant only	34	34	0	7
New power plant plus existing 20 MIGD desalination	36.9	35.9	1.24	6.63
New power plant plus existing 20 MIGD desalination plus future 60 MIGD desalination plant	45.8	41.6	4.27	5.73

Source: Based on data provided by Mott Macdonald and EFS

3. Hydrodynamic modelling

HR Wallingford's established Arabian Gulf regional model was used to provide time- and space-varying boundary conditions for a detailed local model at Hamriyah. This procedure, commonly known as nesting, is a well-established technique for modelling hydrodynamics over wide areas with varying resolution.

3.1. Regional model

The regional Gulf model is built using TELEMAC, an established state-of-the-art finite element model, which is currently being used by more than 200 professional and research organisations worldwide. The TELEMAC-2D module solves the depth-averaged shallow water equations and is used to model various hydraulic phenomena such as tidal and coastal flows, storm surges, etc. The TELEMAC system is developed under a quality assured system, which includes the application of stringent validation tests. TELEMAC uses a completely flexible triangular mesh. As meshes are unstructured, they resolve coastlines and other important structures efficiently and accurately.

The computational mesh of the Gulf model is shown in Figure 3.1. The model covers the Arabian Gulf, the Straits of Hormuz and the Gulf of Oman, and extends out into the Arabian Sea. Currents and water levels are driven by astronomical tides and spatially-varying wind and pressure fields. Predicted water levels have been calibrated against tidal elevation data at 36 locations spread across the Arabian Gulf and Gulf of Oman.

Time- and spatially-varying currents and water levels were extracted from the regional model and used to drive the local Hamriyah model.

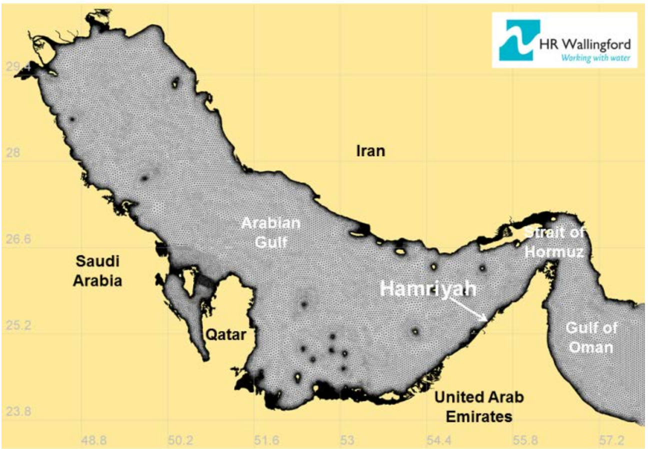

Figure 3.1: HR Wallingford's regional Gulf model mesh

3.2. Local flow modelling

The local Hamriyah model was built using TELEMAC-3D, which solves the equations of motion and transport in multiple layers, and includes the important effects of buoyant spreading, inhibition of vertical mixing associated with sharp density gradients, shear of wind-driven currents, and atmospheric heat exchange. Each of these processes is vital for the accurate simulation of brine and cooling water discharge dispersion and recirculation.

The computational mesh of the local model is shown in Figure 3.2.

The model bathymetry was based on data from international hydrographic offices (Figure 3.3). Bed levels in the outfall and intake channels were assumed to be -3.18 m MSL (-2 m CD or -2.09 m HSD), and -6.09 m MSL (-4.91 m CD or -5m HSD), respectively. Dredged bed levels in the port area were set between -15 m MSL and -16 m MSL (Figure 3.4).

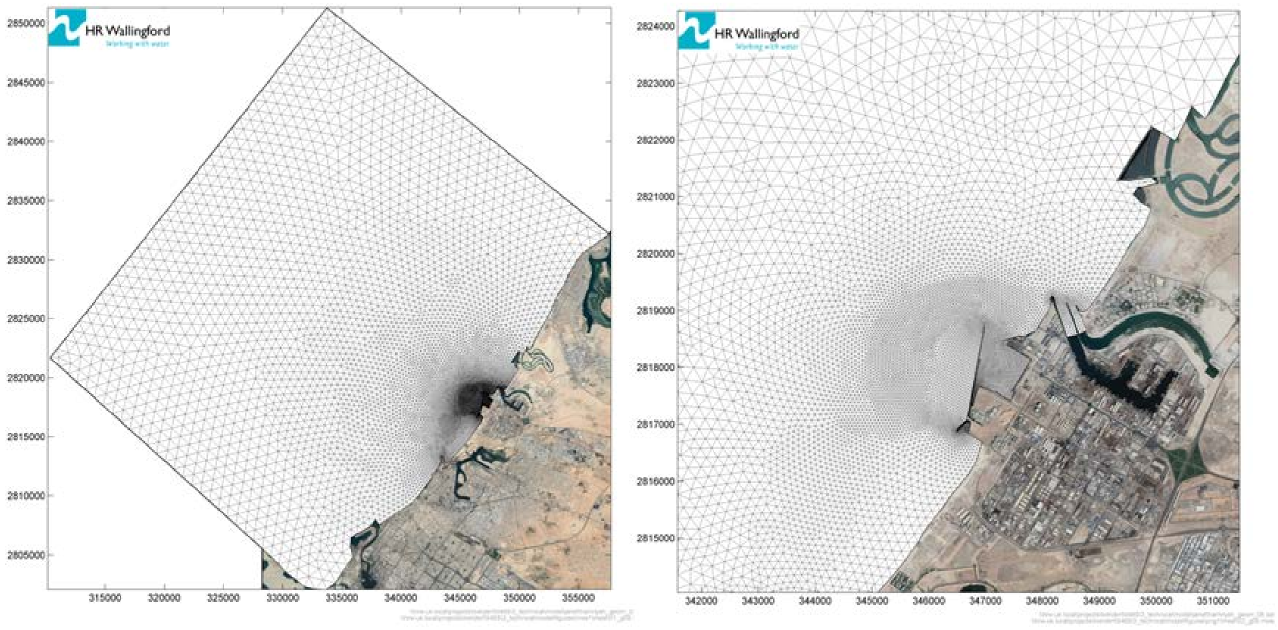

Figure 3.2: Model mesh

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

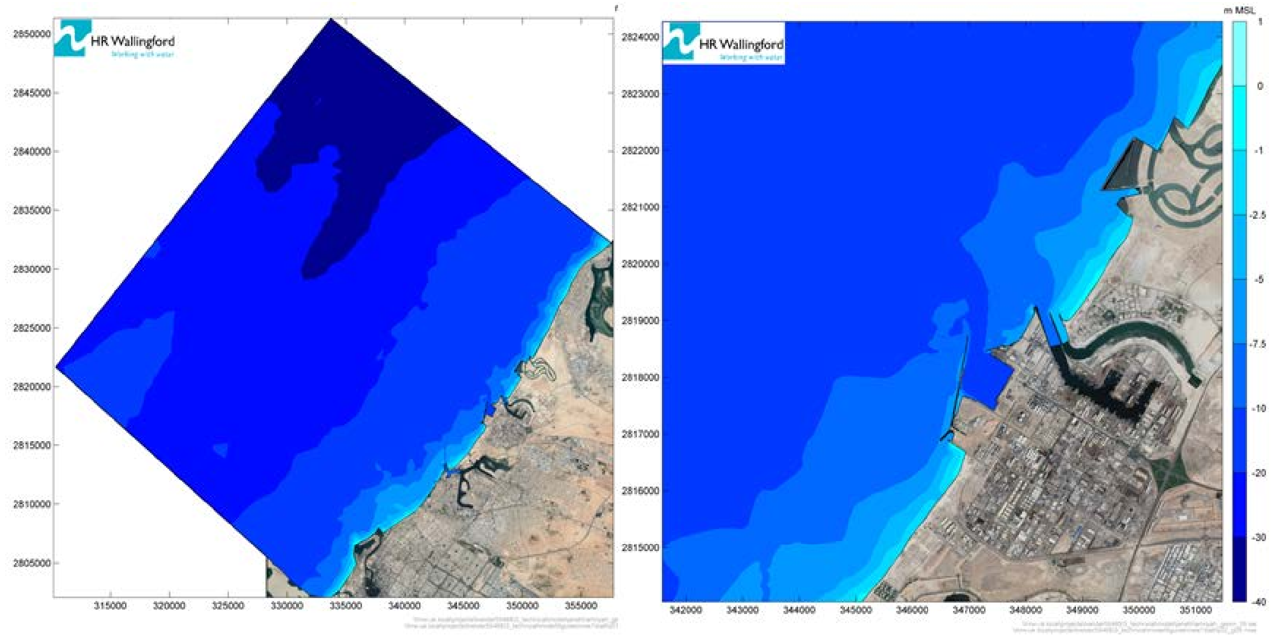

Figure 3.3: Model bathymetry

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

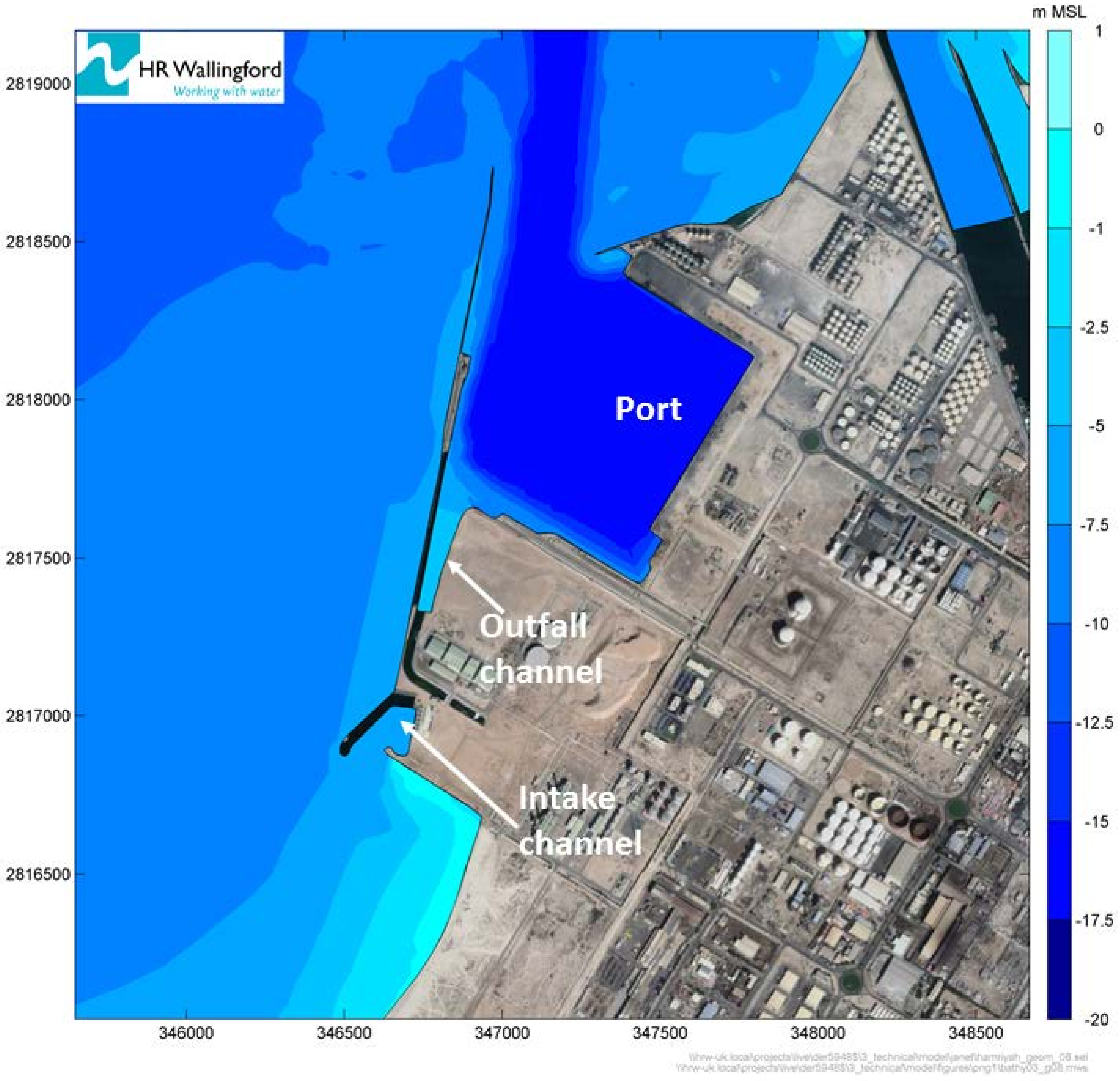

Figure 3.4: Model bathymetry close to the plant

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

As described in Section 3.1, the model was driven by tidal levels taken from the calibrated regional Gulf model. Further confidence in the local model's predictions could be obtained through the collection of local current and water level measurements, and subsequent model verification using the data.

The model was run for 17 days (including a 2-day "spin-up' period) to cover a full spring-neap cycle. Example snapshots of peak currents predicted in the vicinity of the site are shown in Figure 3.5. These figures also include a tide curve, to show the timings of the snapshots in the tidal cycle. Peak current speeds are predicted to be in the order of 0.3-0.4 m/s immediately offshore of the free zone, with areas of higher speeds (up to 0.6 m/s) near the breakwater at the mouth of the port. There are also areas of lower current speed (below 0.1 m/s) in the shadow of the port breakwater.

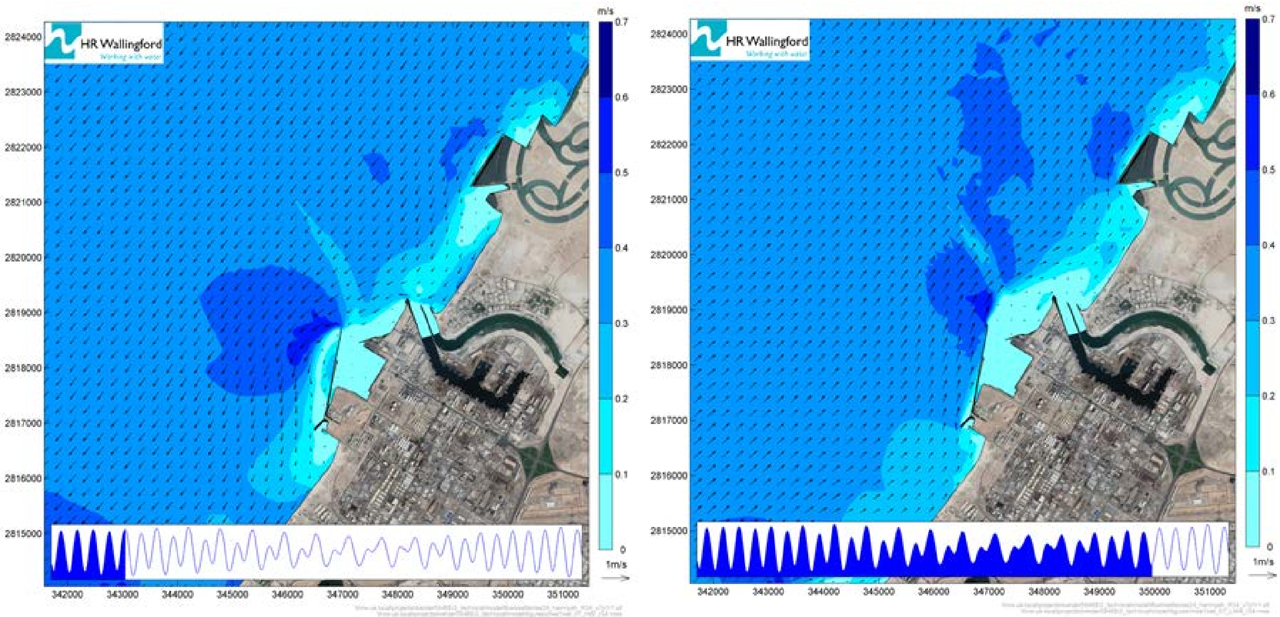

Figure 3.5: Peak south-west and north-east predicted currents

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

4. Dispersion/recirculation modelling

4.1. Wind conditions

Wind conditions at the site were simulated using data from Dubai International Airport accessed through the National Climatic Data Center (NCDC) database of the United States National Oceanic and Atmospheric Administration (NOAA). A rose showing the wind climate at Dubai International Airport is presented in Figure 4.1. Winds from west to north-west occur frequently at speeds of around 5 m/s. Weaker winds with speeds of around 3 m/s also frequently occur from south and east.

Data for Sharjah Airport were also considered. In general the measured wind data are very similar at both airports, with similar wind events and directional distributions. The winds measured at Dubai are slightly faster than those at Sharjah, possibly because Dubai Airport is closer to the coast. Therefore, Dubai Airport data were used as being most representative of winds at the coast in this region of UAE.

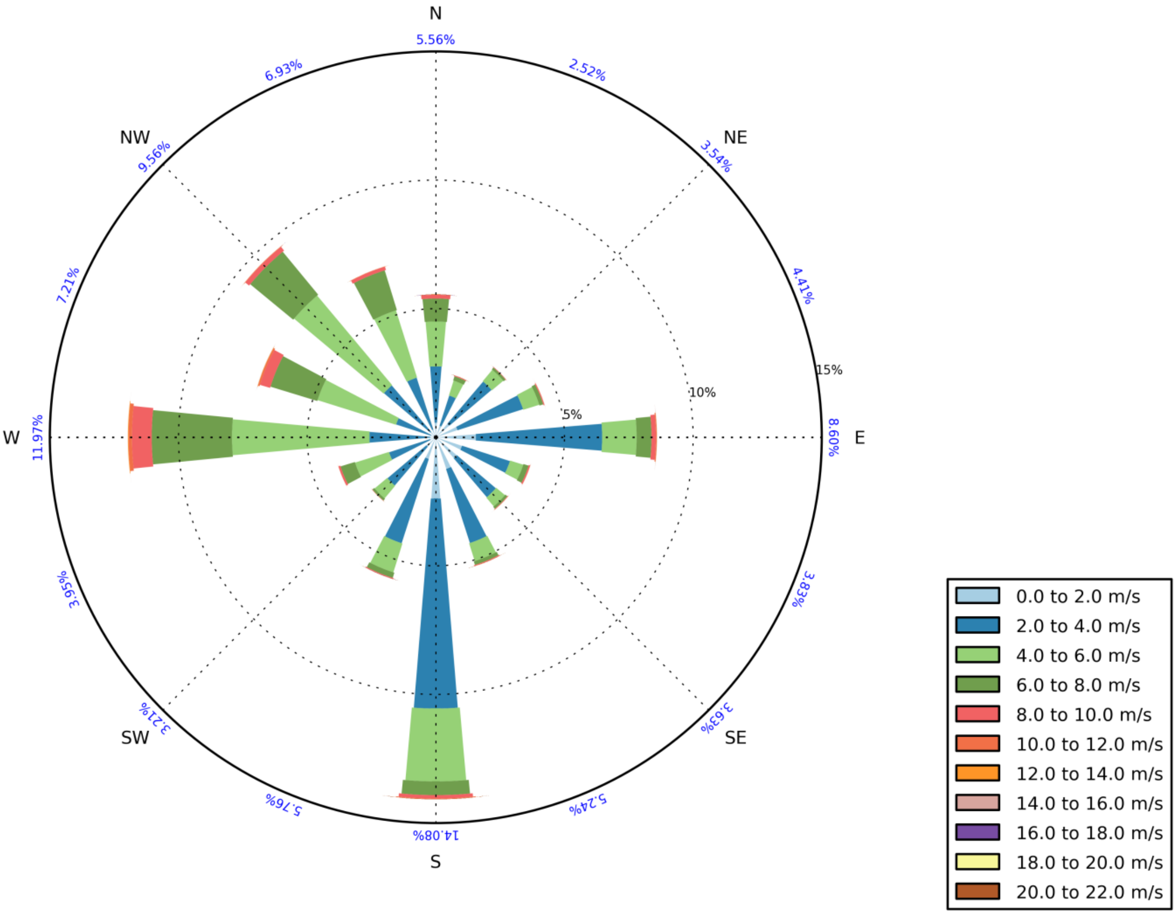

Figure 4.1: Winds at Dubai International Airport, 1983 – 2017

Source: NOAA NCDC

For the far-field dispersion assessment, winds were applied for a 17-day period from 19 October to 5 November 2017. Wind speeds and directions for this period are shown in Figure 4.2. Winds were generally weak (on average around 3 m/s) with characteristic diurnal pattern associated with onshore/offshore sea breeze. From analysis of wind speeds at Dubai International Airport (Table 4.1), winds of around 3 m/s occur 41% of the time. A second period (5-22 December 2009) was simulated to assess the influence of stronger wind events. Wind speeds and directions for this period are shown in Figure 4.3. Winds on average are around 7 m/s and include a sustained period of easterly winds which may be adverse in terms of thermal/saline recirculation for the simulated intake and outfall configuration. From Table 4.1, winds of around 7 m/s occur 11% of the time.

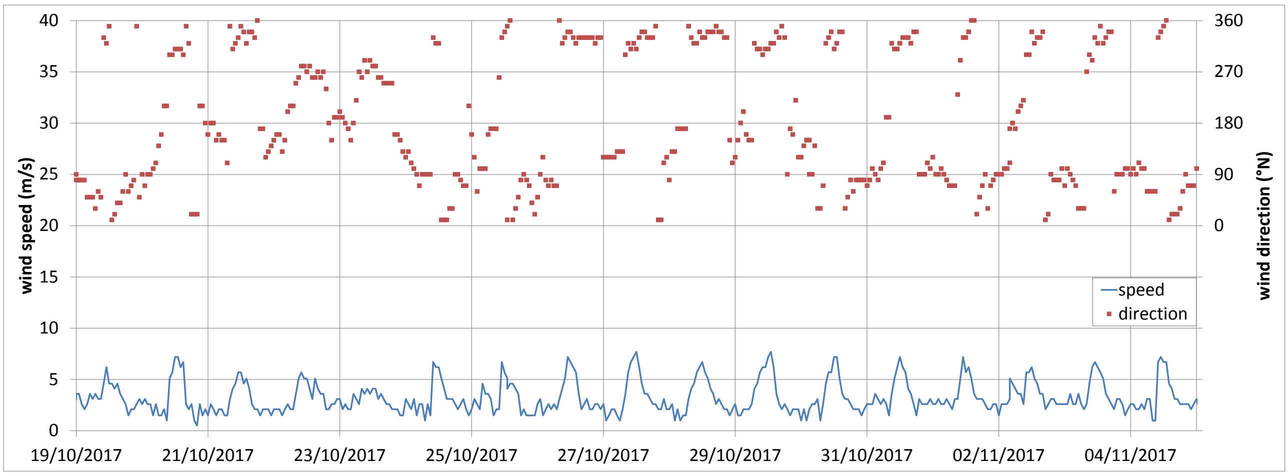

Figure 4.2: Winds at Dubai International Airport, 19/10/2017- 5/11/2017

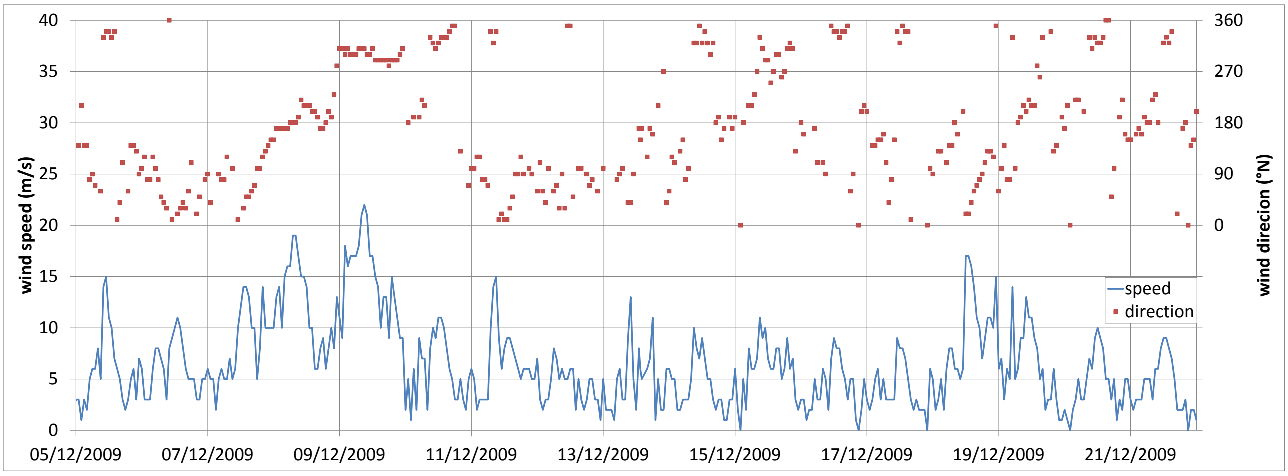

Figure 4.3: Winds at Dubai International Airport, 5/12/2009- 22/12/2009

Table 4.1: Percentage occurrence of wind speeds at Dubai International Airport, 1983-2017

Wind speed (m/s)	Percentage occurrence (%)
< 2	19
2 to 4	41
4 to 6	26
6 to 8	11
8 to 10	2
>10	< 1

4.2. Seawater temperature and salinity

Seawater temperatures used for the simulations were based on the design heat and mass balances provided by EFS (Reference 1). These gave a typical summer temperature of 32°C and winter temperatures between 20 and 23.5°C (a temperature of 22°C was chosen for the simulations).

A seawater salinity of 42 ppt was used for the simulations. This was based on the preliminary modelling carried out by Sogreah in 2009 (Reference 2).

4.3. Test conditions

Dispersion and recirculation of the cooling water discharge were simulated for the two wind periods described in the previous section (referred to as “weaker winds” and “stronger winds”), as well as representative summer and winter seawater conditions. Each simulation was conducted for 17 days to include a full spring-neap cycle, to allow sufficient model “spin-up” time, and to allow dispersion patterns to reach a dynamic equilibrium. The simulated test conditions are summarised in Table 4.2.

Recirculation was included in the simulations by increasing the discharge concentrations appropriately during periods when the plume reached the intake.

Table 4.2: Simulated test conditions

Simulation	Operating scenario	Operating plants			Seawater temperature	Wind condition
		New CCGT	Existing 20 MIGD	Future 60 MIGD		
1	**1**	✓			summer	weaker
2	**2**	✓	✓		summer	weaker
3	**3**	✓	✓	✓	summer	weaker
4	**1**	✓			winter	weaker
5	**2**	✓	✓		winter	weaker
6	**3**	✓	✓	✓	winter	weaker
7	**1**	✓			summer	stronger
8	**2**	✓	✓		summer	stronger
9	**3**	✓	✓	✓	summer	stronger
10	**1**	✓			winter	stronger
11	**2**	✓	✓		winter	stronger
12	**3**	✓	✓	✓	winter	stronger

4.4. Results format

Model predictions are presented as:

- Contour plots of average excess temperature and excess salinity at the sea surface and seabed;
- Contour plots of maximum excess temperature excess salinity at the sea surface and seabed;
- Tabulated temperature and salinity mixing zone areas;
- Tabulated recirculation temperatures and salinities.

These were calculated over 15 days containing a full spring-neap cycle.

It should be noted that the maximum and average plots show the maximum and average values predicted at each model node over the course of the simulation. As the maxima and averages do not occur at the same time at each location, these plots should be thought of as overall plume “footprints”.

The results for the various environmental conditions are largely similar, so only plots for the summer case (with weaker winds) are shown here.

4.5. Dispersion results

For Scenario 1 (CCGT plant only), the discharge forms a buoyant plume that is warmest at the water surface, although close to the outfall, and in shallower waters near the coast, the plume can also be seen near the seabed (Figure 4.4 and Figure 4.5). Once outside the port area the plume is advected along the coast towards both north-east and south-west under the action of tidal and wind-driven currents.

Introducing the reject brine from the existing 20 MIGD desalination plant in Scenario 2 reduces the buoyancy of the plume. This leads to larger areas of elevated temperature and salinity at the seabed, although the increases at the seabed are relatively low as shown in Figure 4.6 and Figure 4.7 (temperature), and Figure 4.10 and Figure 4.11 (salinity).

In Scenario 3, with the reject brine from the future 60 MIGD plant included, the increased salinity of the effluent leads to a negatively buoyant plume. The warmest and saltiest parts of the plume occur at the seabed, as shown in Figure 4.8 and Figure 4.9 (temperature), and Figure 4.12 and Figure 4.13 (salinity). Outside of the port the plume tends to flow along the bottom of the port approach channel.

In all three scenarios, the regions of highest excess temperature and excess salinity are predicted to be largely confined to the port area.

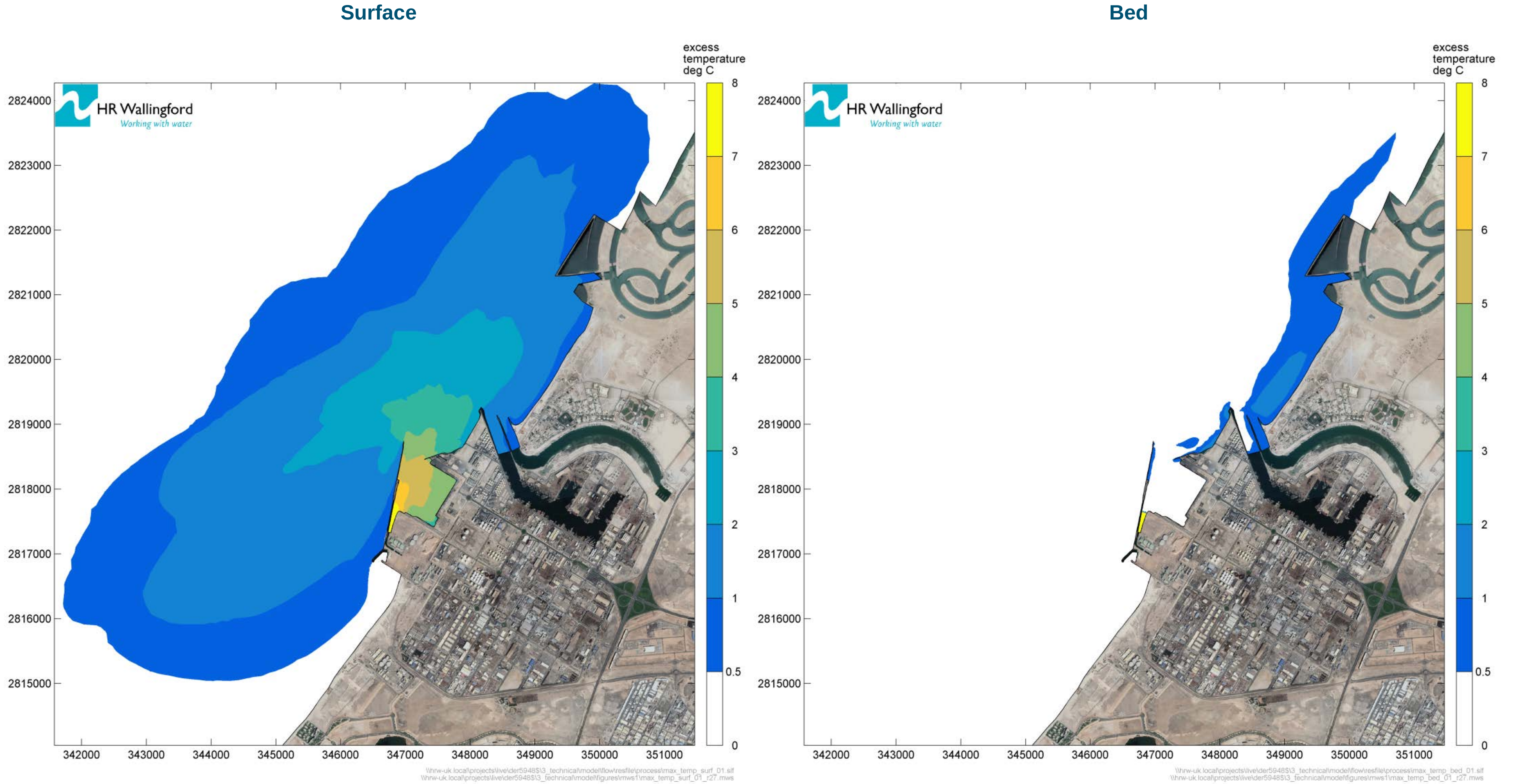

Figure 4.4: Maximum predicted surface and bed temperature with weaker wind, summer Scenario 1

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

Surface **Bed**

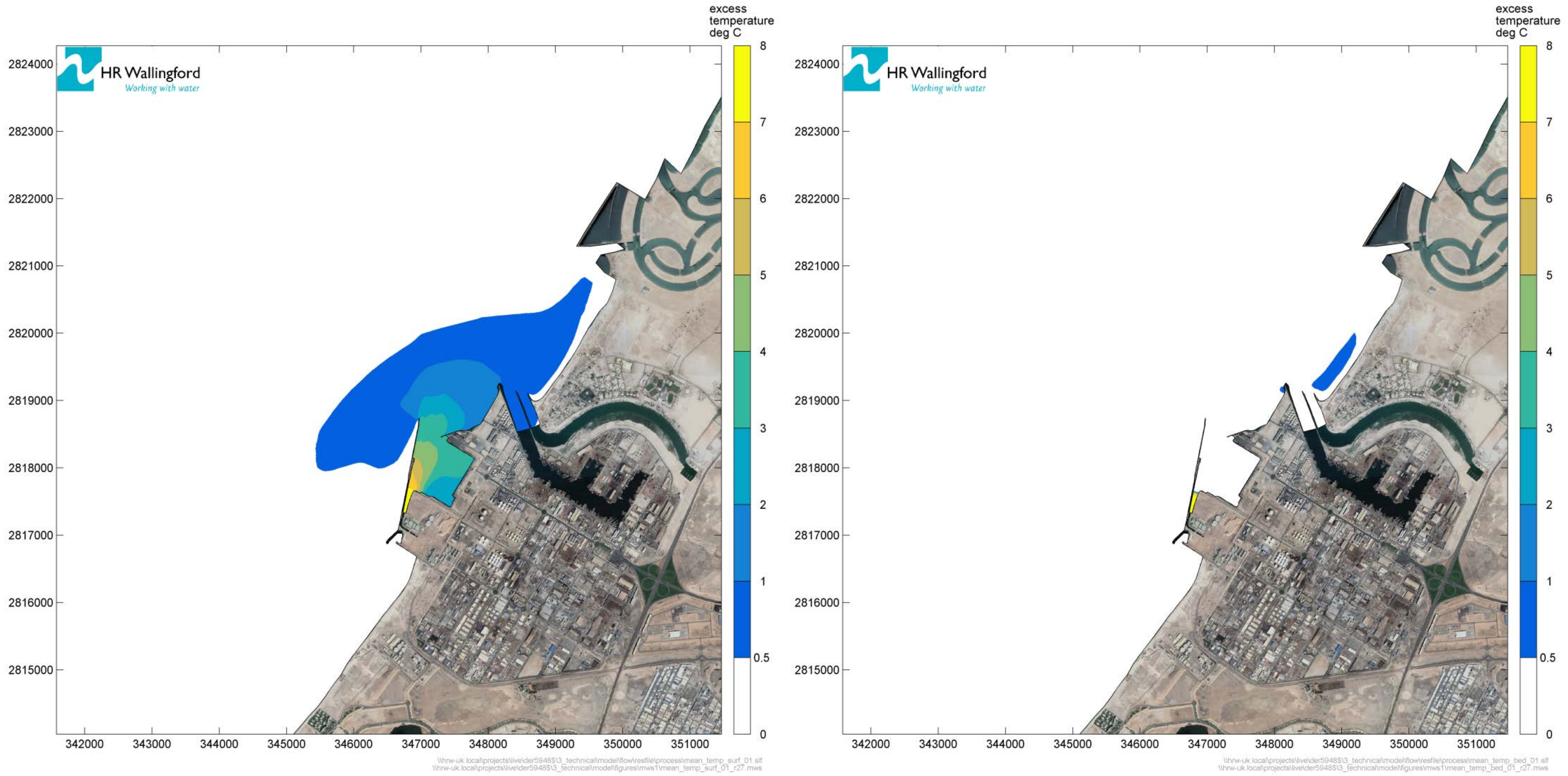

Figure 4.5: Average predicted surface and bed temperature with weaker wind, summer Scenario 1

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

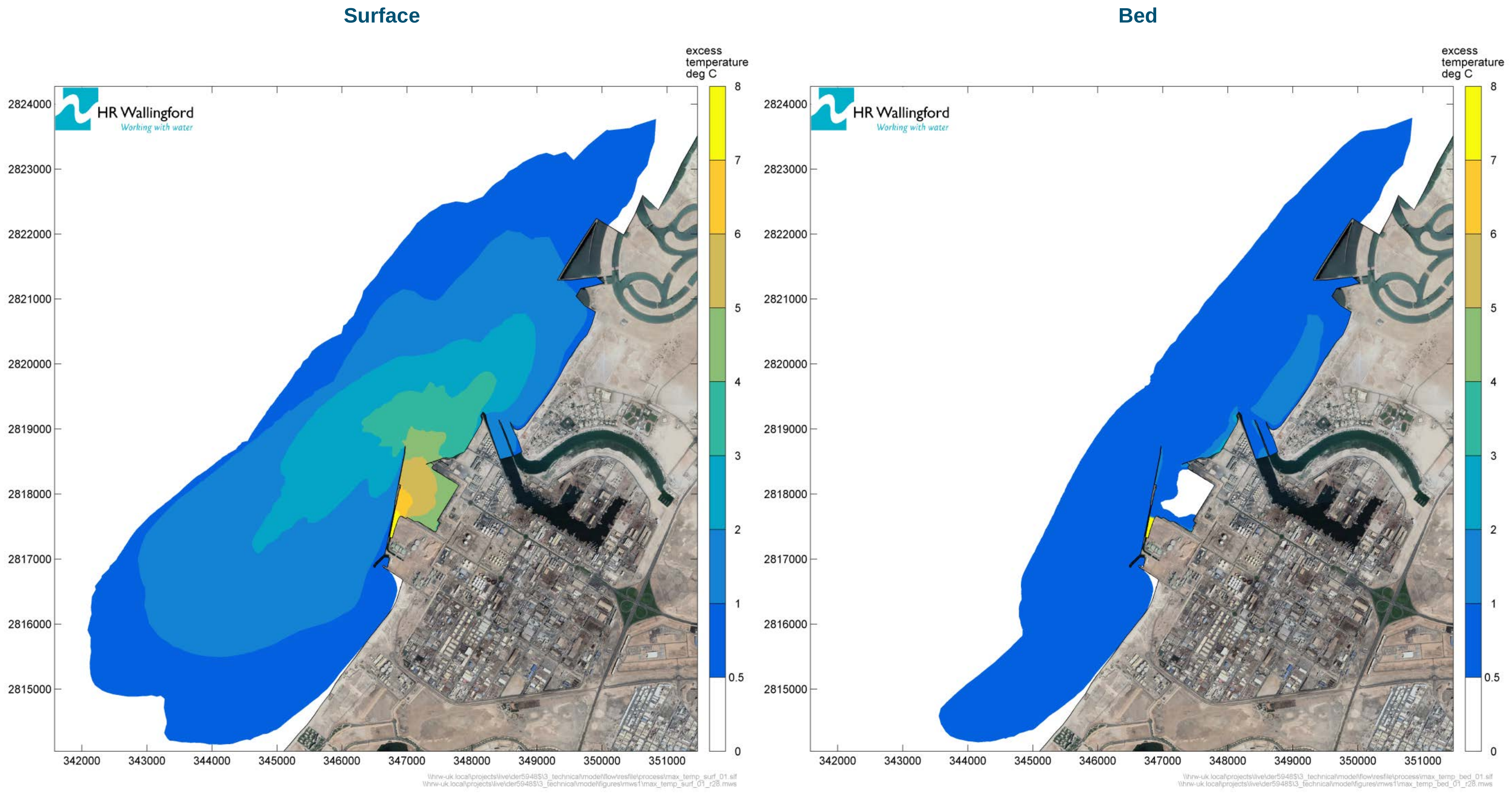

Figure 4.6: Maximum predicted surface and bed temperature with weaker wind, summer Scenario 2

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

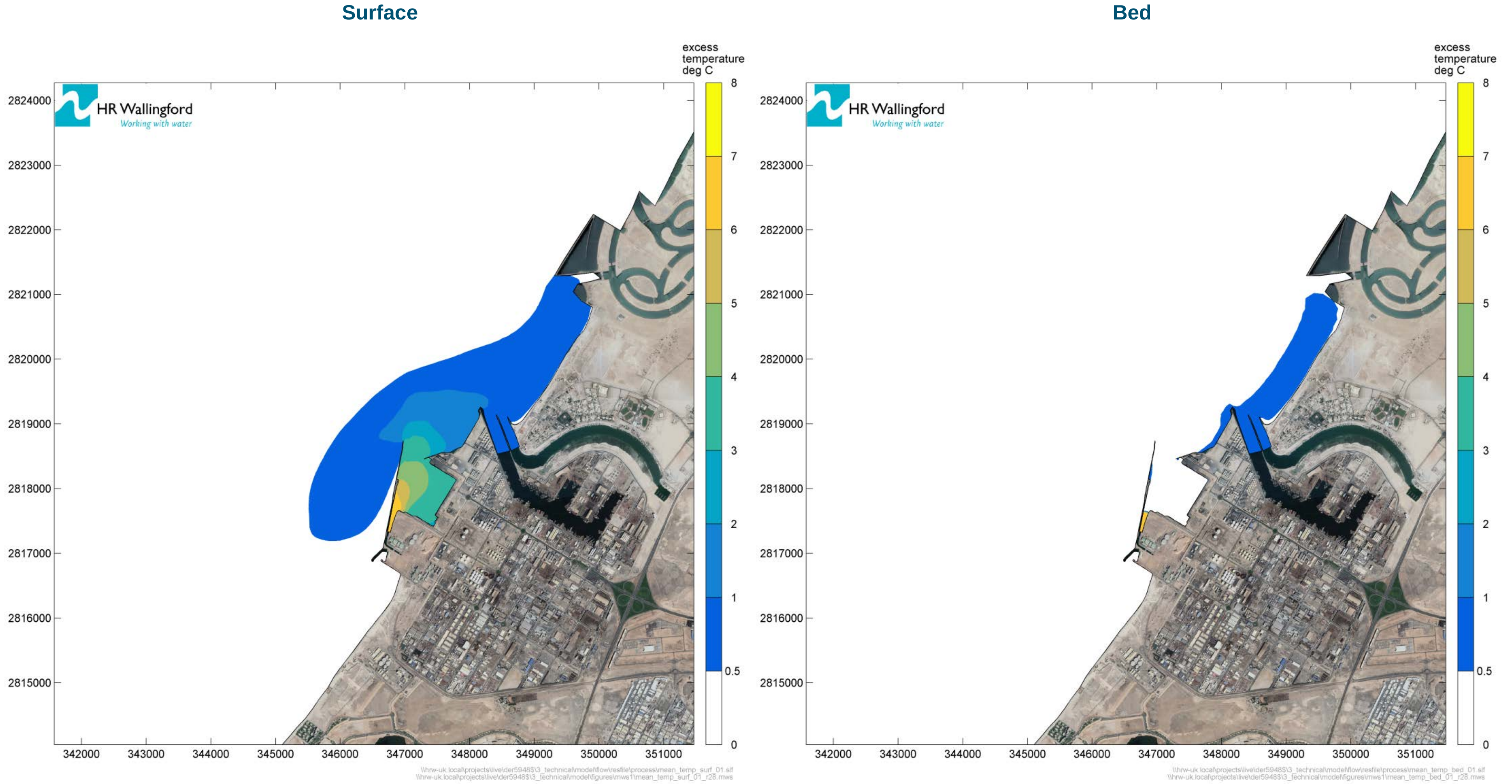

Figure 4.7: Average predicted surface and bed temperature with weaker wind, summer Scenario 2

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

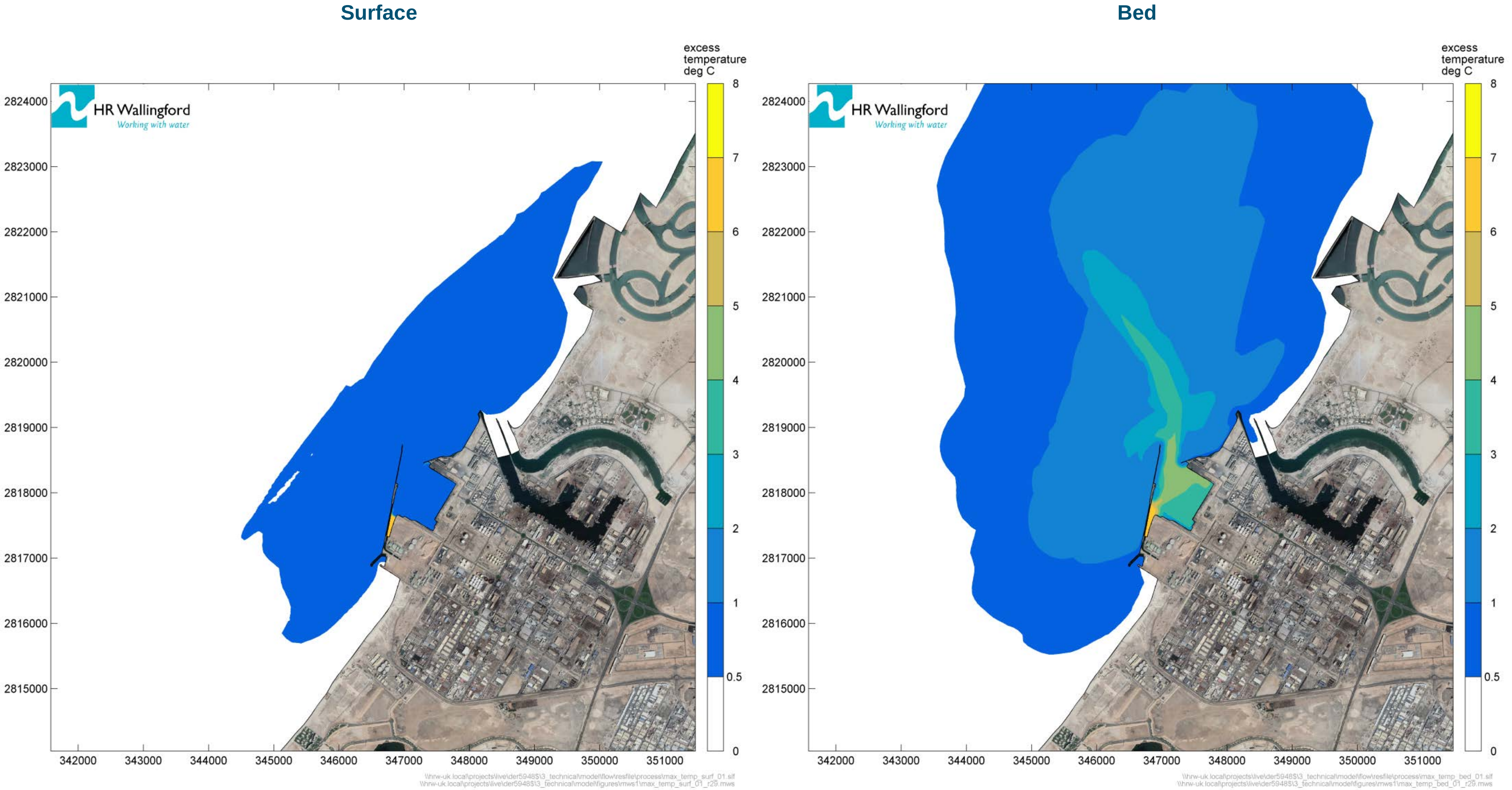

Figure 4.8: Maximum predicted surface and bed temperature with weaker wind, summer Scenario 3

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

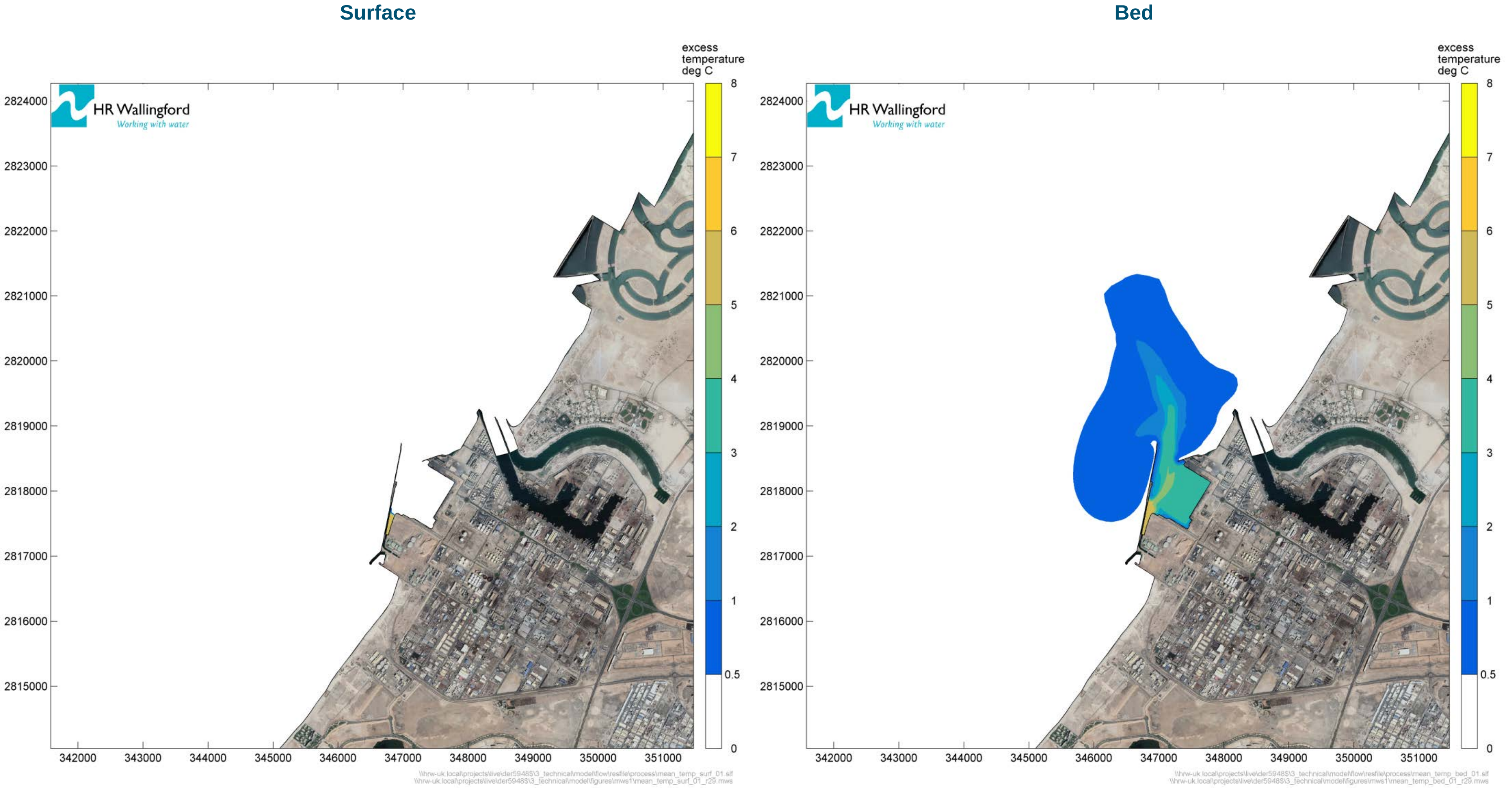

Figure 4.9: Average predicted surface and bed temperature with weaker wind, summer Scenario 3

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

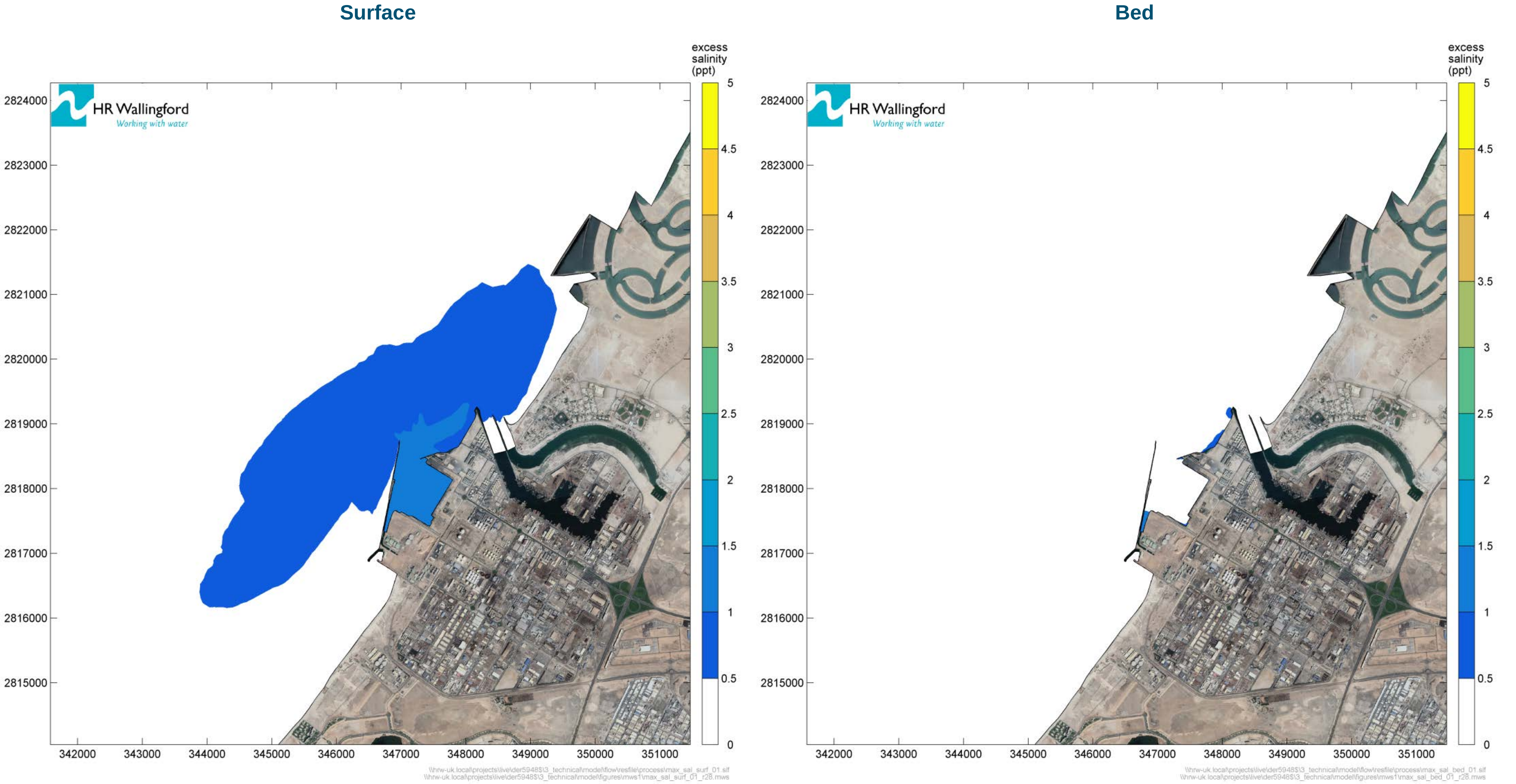

Figure 4.10: Maximum predicted surface and bed salinity with weaker wind, summer Scenario 2

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

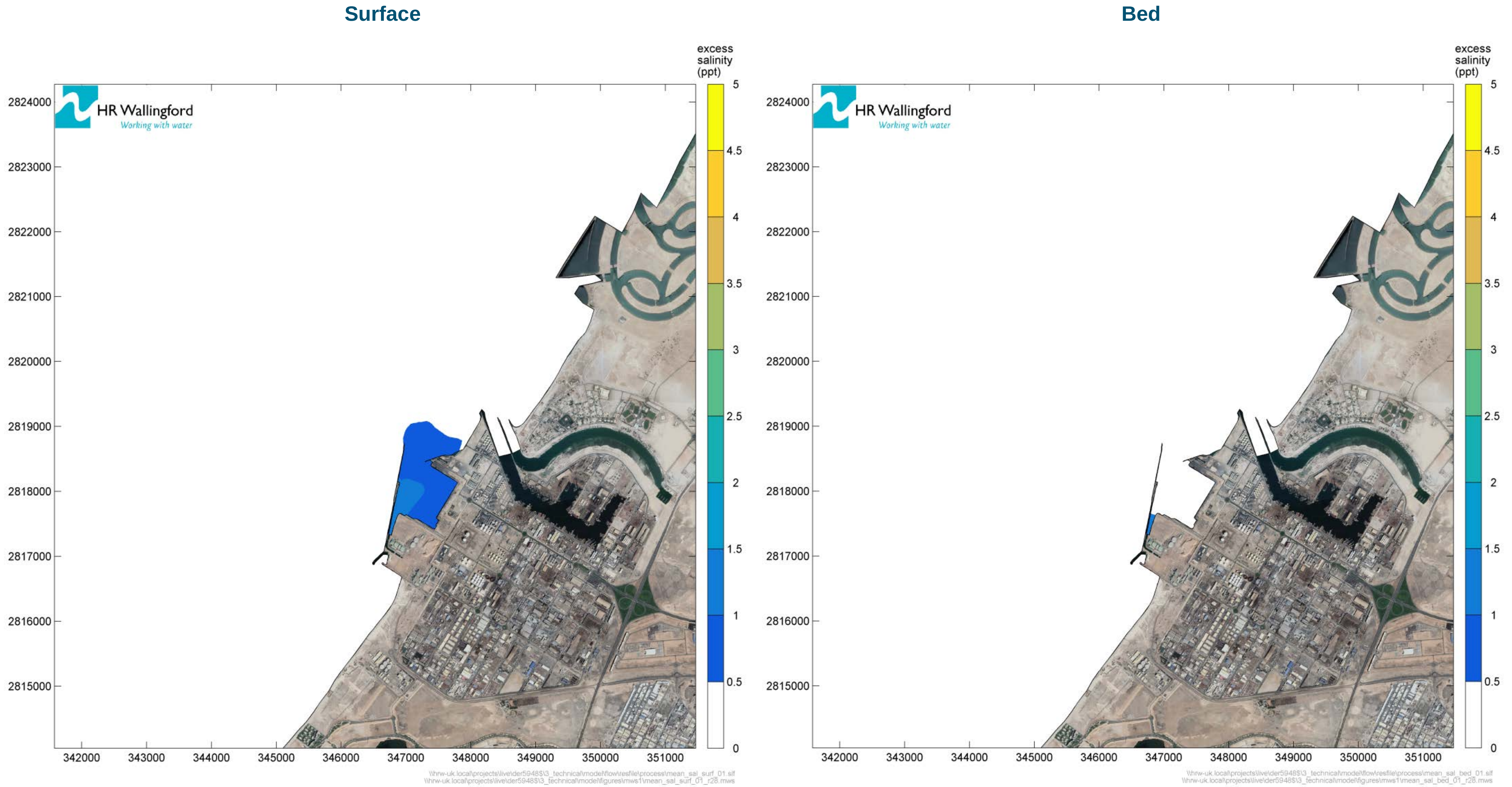

Figure 4.11: Average predicted surface and bed salinity with weaker wind, summer Scenario 2

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

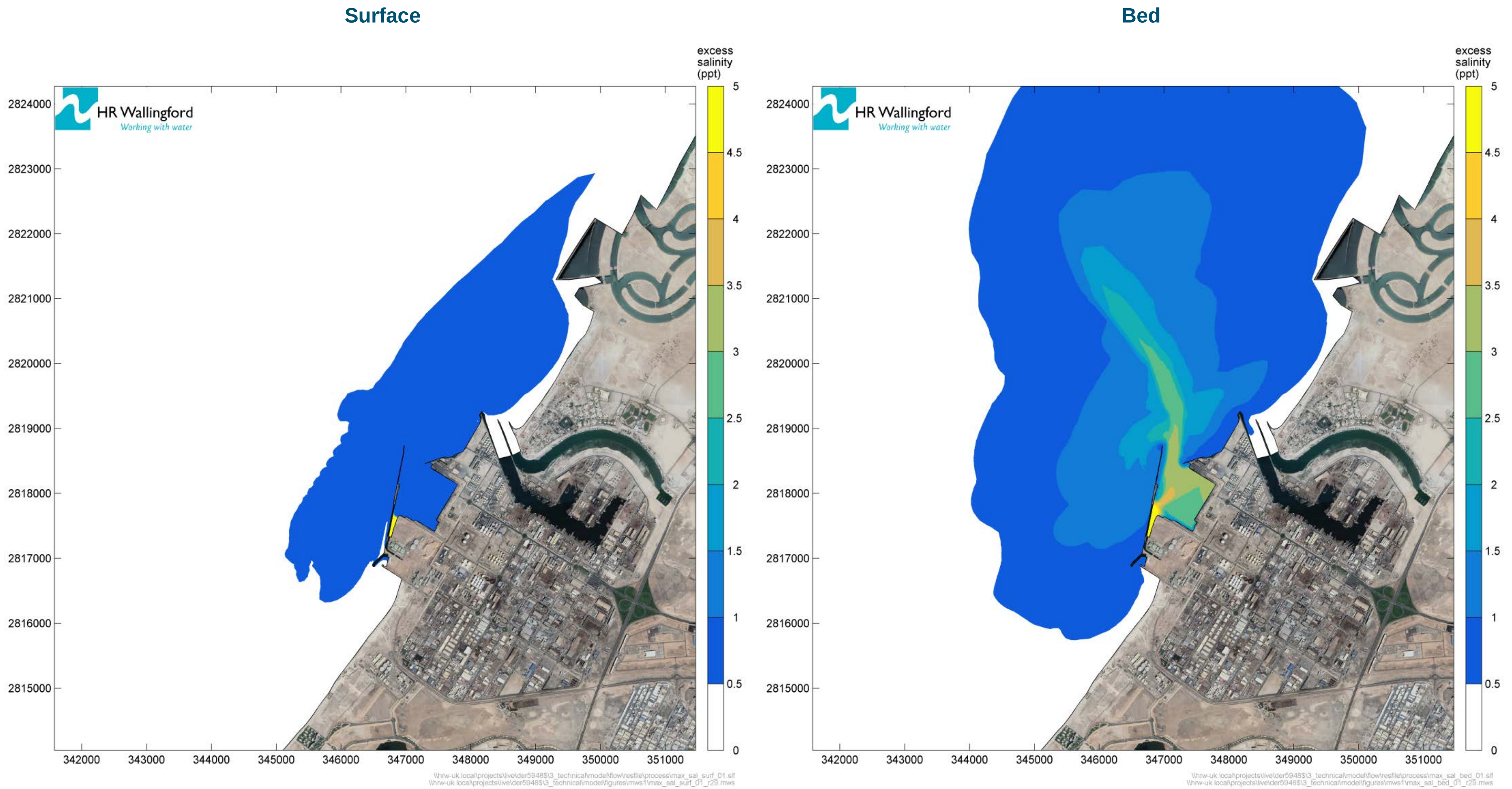

Figure 4.12: Maximum predicted surface and bed salinity with weaker wind, summer Scenario 3

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

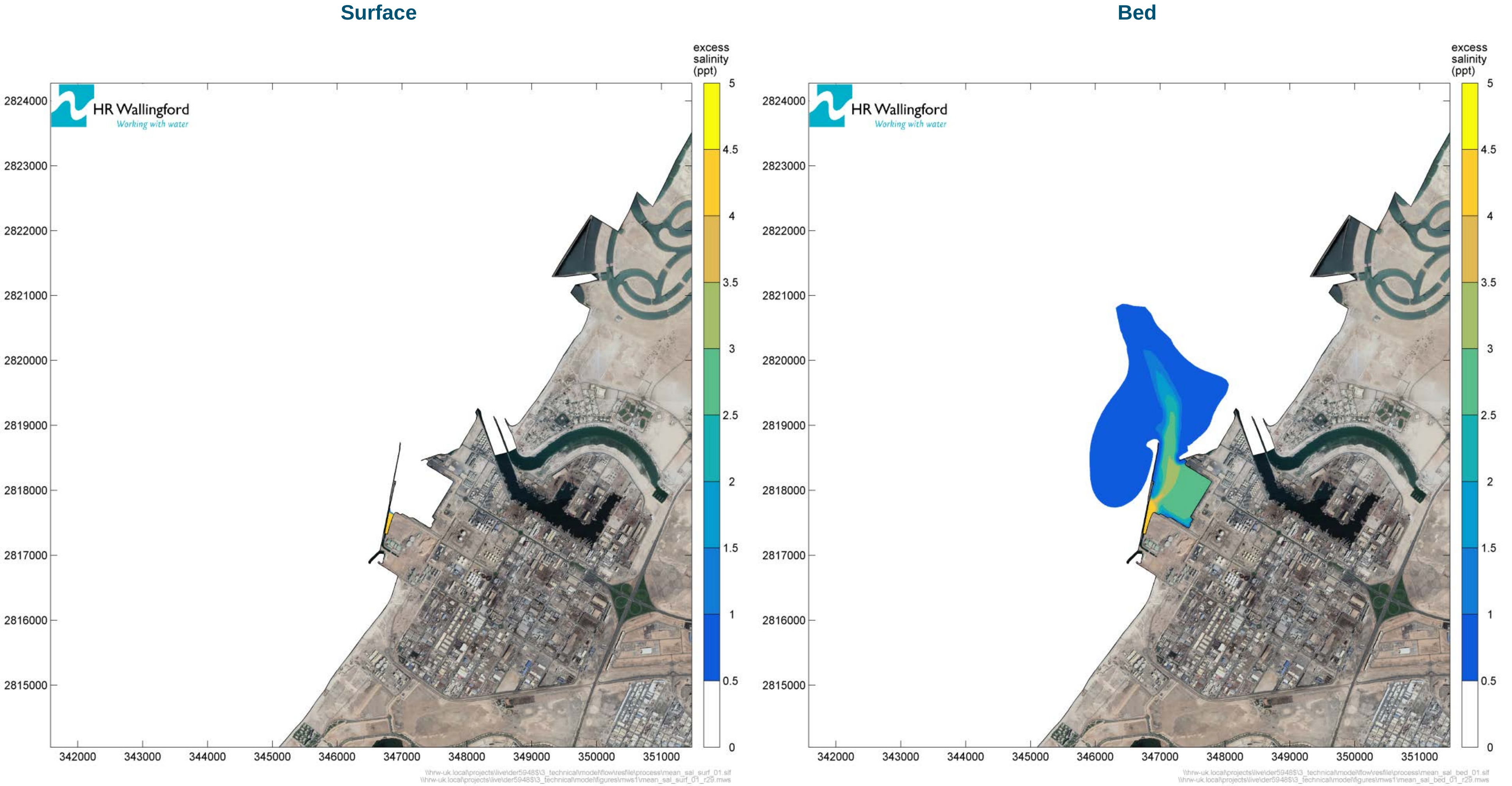

Figure 4.13: Average predicted surface and bed salinity with weaker wind, summer Scenario 3

Source: Background image ©Google Earth (Data ©: SIO,NOAA, US Navy, NGA, GEBCO Image: © Digital Globe)

4.5.1. Environmental compliance

Sharjah's environmental regulatory has advised Mott MacDonald that either the Abu Dhabi or Dubai water quality standards can be used to assess the discharge.

Abu Dhabi's marine water quality standards have been adopted for this analysis. These set temperature and salinity "mixing zones" as follows:

- Temperature: the area over which the plume temperature is more than 3°C above background;
- Salinity: the area over which salinity is more than 5% above background. As the design sea water salinity is 42 ppt, we have assumed that the salinity mixing zone corresponds to the +2 ppt excess salinity footprint.

The standards do not specify an extent for these mixing zones, so they need to be assessed on a site-by-site basis.

Predicted temperature mixing zone areas are shown in Table 4.3 for weaker winds and in Table 4.4 for stronger winds. The plan area of the port is approximately 80 ha, while the plan area of the discharge channel that is included in the model is about 2 ha. Therefore, mixing zone areas less than 100 ha indicate that mixing zone is contained largely within the port area, while areas of around 2 ha indicate that the mixing zone does not extend beyond the discharge channel.

For the scenario with only the power plant operating, and the scenario with the 20 MIGD desalination plant added the predicted temperature mixing zone areas under the weaker winds are qualitatively similar, with maxima of 175-400 ha at the surface, and around 2 ha at the bed. Predicted average mixing zone areas are 66-85 ha for these two cases. The maximum mixing zone extents are larger under stronger winds, but the averages are generally smaller.

For the scenario with the 60 MIGD desalination plant added, temperature mixing zone areas of around 100 ha are predicted at the bed and 2-3 ha at the surface for both wind conditions.

Table 4.3: Predicted temperature mixing zone areas, weaker winds

	Mixing zone area (ha)							
	summer				winter			
	maximum		average		maximum		average	
	surface	bed	surface	bed	surface	bed	surface	bed
Power plant only	177.6	1.9	66.3	1.9	263.9	2.0	84.5	1.9
Power plant + 20 MIGD desal	235.7	2.0	81.4	1.9	381.5	2.2	84.6	2.0
Power plant + 20 MIGD + 60 MIGD desal	2.1	116.2	2.0	71.1	2.0	104.8	2.0	66.3

Table 4.4: Predicted temperature mixing zone areas, stronger winds

	Mixing zone area (ha)							
	summer				winter			
	maximum		average		maximum		average	
	surface	bed	surface	bed	surface	bed	surface	bed
Power plant only	228.9	2.0	28.1	1.9	299.3	2.2	36.8	1.9
Power plant + 20 MIGD desal	245.7	3.6	32.8	1.9	300.3	8.9	48.2	2.0
Power plant + 20 MIGD + 60 MIGD desal	3.0	103.3	2.0	50.8	2.4	96.0	2.0	43.6

Predicted salinity mixing zones are shown in Table 4.5 (weaker winds) and Table 4.6 (stronger winds).

For the power plant operating on its own, the discharge is at the same salinity as the receiving seawater, and therefore has no salinity mixing zone. When the cooling water is combined with reject brine from the existing 20 MIGD desalination plant, the excess salinity at discharge will be less than 5% of background (assuming that the streams from the individual plants are fully mixed in the receiving basin before being discharged).

With reject brine from the future 60 MIGD plant included, predicted salinity mixing zone areas at the bed are up to 150 ha as a maximum and 60-75 ha on average. Surface excess salinities greater than 5% of background are likely to be largely confined to the discharge channel itself.

Table 4.5: Predicted salinity mixing zone areas, weaker winds

	Mixing zone area (ha)							
	summer				winter			
	maximum		average		maximum		average	
	surface	bed	surface	bed	surface	bed	surface	bed
Power plant + 20 MIGD desal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Power plant + 20 MIGD + 60 MIGD desal	2.1	145.2	2.1	71.3	2.1	123.7	2.0	73.2

Notes: 1. Discharge salinity for power plant only case is same as background. 2. Discharge excess salinity is less than 5% of background with reject brine from 20 MIGD desalination plant added.

Table 4.6: Predicted salinity mixing zone areas, stronger winds

	Mixing zone area (ha)							
	summer				winter			
	maximum		average		maximum		average	
	surface	bed	surface	bed	surface	bed	surface	bed
Power plant + 20 MIGD desal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Power plant + 20 MIGD + 60 MIGD desal	7.0	124.3	2.0	67.7	2.9	112.2	2.0	63.7

Notes: 1. Discharge salinity for power plant only case is same as background. 2. Discharge excess salinity is less than 5% of background with reject brine from 20 MIGD desalination plant added.

4.5.2. Recirculation

Table 4.7 and Table 4.8. These were generally predicted to be relatively low:

- maximum depth-averaged excess temperatures were up to 0.7°C;
- mean depth-averaged excess temperatures were up to 0.5°C;
- maximum depth-averaged excess salinities were up to 0.5 ppt;
- mean depth-averaged excess salinities were up to 0.2 ppt.

Table 4.7: Maximum and averaged depth-averaged intake excess temperature

	Excess temperature (°C)							
	weaker wind				stronger wind			
	summer		winter		summer		winter	
	max	mean	max	mean	max	mean	max	mean
Power plant only	0.3	0.2	0.4	0.2	0.3	0.1	0.4	0.2
Power plant + 20 MIGD desal	0.6	0.3	0.7	0.4	0.5	0.2	0.6	0.2
Power plant + 20 MIGD + 60 MIGD desal	0.6	0.1	0.5	0.1	0.4	0.1	0.4	0.1

Table 4.8: Maximum and averaged depth-averaged intake excess salinity

	Excess salinity (ppt)							
	weaker wind				stronger wind			
	summer		winter		summer		winter	
	max	mean	max	mean	max	mean	max	mean
Power plant + 20 MIGD desal	0.2	0.1	0.4	0.2	0.2	0.1	0.2	0.1
Power plant + 20 MIGD + 60 MIGD desal	0.5	0.1	0.4	0.1	0.4	0.1	0.4	0.1

Note: Salinity not modelled for power plant only case.

5. Conclusions

Hydrodynamic modelling and recirculation/dispersion studies were undertaken to determine the dispersion of the cooling water discharge from the proposed power plant with and without existing and future nearby desalination plants. A local three-dimensional model was built using TELEMAC-3D, using boundary condition from a calibrated regional model of the Gulf. Further confidence in the local model's predictions could be obtained through the collection of local current and water level measurements, and subsequent model verification using the data.

The cooling water from the power plant and reject brine from desalination plants will be discharged via a common shoreline outfall into Hamriyah Port. Depending on the proportion of effluent that comes from desalination, the combined discharge will be either positively or negatively buoyant.

Environmental compliance is assessed in terms of the extent of the area where the plume temperature is more than 3°C above the background and the salinity is more than 5% above the ambient seawater salinity. These areas represent the temperature and salinity "mixing zones" of the discharge.

For scenarios with either the power plant operating alone or in combination with the existing 20 MIGD desalination plant, the combined discharge will form a positively buoyant plume. The maximum areas of the temperature mixing zones are in the range of 200-400 ha (the average mixing zone areas are less than 100 ha). In these cases there are no salinity mixing zones as the salinities of the discharges are already within 5% of the background.

For scenarios with an additional 60 MIGD desalination plant operating, the combined discharge will form a negatively buoyant plume which will sink to the seabed in the port and then flow seaward along the bottom of the port approach channel. The maximum areas of the temperature mixing zones were around 100 ha, and the average mixing zone areas were around 50 ha). The maximum areas of the salinity mixing zones were in the range 100-150 ha, and the average areas were around 70 ha.

Recirculation of warm water between the outfall and intake was predicted to be limited to around 0.7°C maximum and below 0.5°C on average. Depth-averaged excess salinities at the intake were predicted to be up to 0.5 ppt.

6. References

1. GE, SEWA IPP, Heat Balance Diagram MEI13108 (November 2017).
2. Sogreah Consultants Hamriyah Power Station thermal plume report, February 2019.

HR Wallingford
Working with water

HR Wallingford is an independent engineering and environmental hydraulics organisation. We deliver practical solutions to the complex water-related challenges faced by our international clients. A dynamic research programme underpins all that we do and keeps us at the leading edge. Our unique mix of know-how, assets and facilities includes state of the art physical modelling laboratories, a full range of numerical modelling tools and, above all, enthusiastic people with world-renowned skills and expertise.

FS 516431
EMS 558310
OHS 595357

HR Wallingford, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com
www.hrwallingford.com