8

Oceanic Process and Natural Features

This chapter reports on the local physical oceanographic processes (Section 8.1); the potential impacts that the proposed dredging and coastal construction works are expected to impose on the oceanographic processes (Section 8.2); the management of impacts (Section 8.3); and project commitments (Section 8.4). The understanding of the potential impacts is mainly based on interpretation of hydrodynamic and wave model outcomes, as well as on numerical simulations of dredging and spoil disposal activities.

8.1 Existing Environment

Darwin Harbour (Figure 8-1) is a large ria system, or drowned river valley, formed by post-glacial marine flooding of a dissected plateau. The Harbour was formed by rising sea levels about 6000 to 8000 years ago. The Harbour has a surface area of about 500 km^2.

In its southern and south-eastern portions, the harbour has three main components: East, West and Middle Arms, which merge into a single unit, along with the smaller Woods Inlet, before opening into Beagle Gulf to the north. The harbour extends for more than 30 km along this north-north-east – south-south-westerly oriented axis. The Elizabeth River flows into East Arm, while the Darwin and Blackmore rivers flow into Middle Arm. Freshwater inflow into the Harbour occurs from January to April, when estuarine conditions prevail in all areas (Hanley, 1988).

The Darwin region is in general characterised by low, flat plateaus with an average elevation of about 15 m AHD, and occasional rises of up to 45 m AHD. Since the Harbour formation, surface erosion from the adjoining flat terrestrial environment has carried substantial quantities of sediment into the Harbour. This sediment now forms much of the intertidal flats that veneer the bedrock.

The main channel of the Harbour is around 15-25 m AHD deep, with a maximum depth of 36 m (Figure 8-2).

The channel favours the eastern side of the Harbour, with broader shallower areas occurring on the west side. Intertidal flats and shoals are generally more extensive on the western side than on the eastern side. The channel continues into East Arm, towards Blaydin Point, at water depths of more than 10 m below Lowest Astronomical Tide (LAT). The bathymetry in this area has been already previously modified by dredging for the development of the EAW. A slightly deeper channel extends into Middle Arm, up to the western side of Channel Island. A shallower channel (about 10-15 m below LAT) separates Wickham Point from Channel Island.

The proposed development area is situated at the eastern side of the Harbour, forming the southern limit to Frances Bay and the northern entrance to East Arm.

Tides

Darwin Harbour is characterised by a macro-tidal regime with a maximum range of 8.1 m (e.g. Harper, 2010). The highest expected tidal level at any location is termed Highest Astronomical Tide (HAT); it is 4.0 m AHD in Darwin Harbour. Depending on the super-position of the Sun's and Moon's gravitational attractions, HAT occurs once each 18.6 year period, although at some sites tide levels similar to HAT may occur several times a year. The mean neap tidal range is 1.9 m, while spring tides have an average range of 5.5 m.

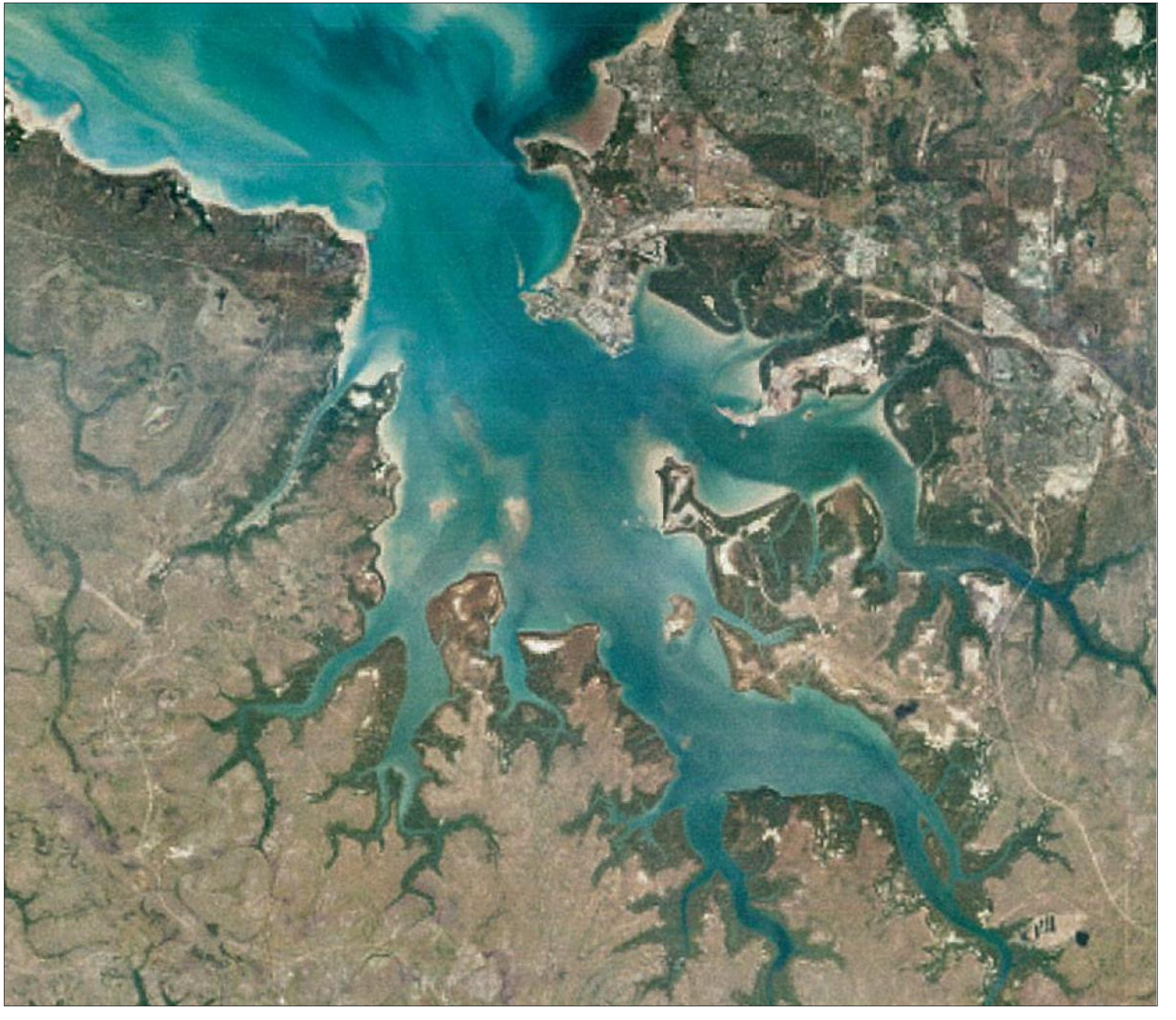

Figure 8-1 Aerial View of Darwin Harbour

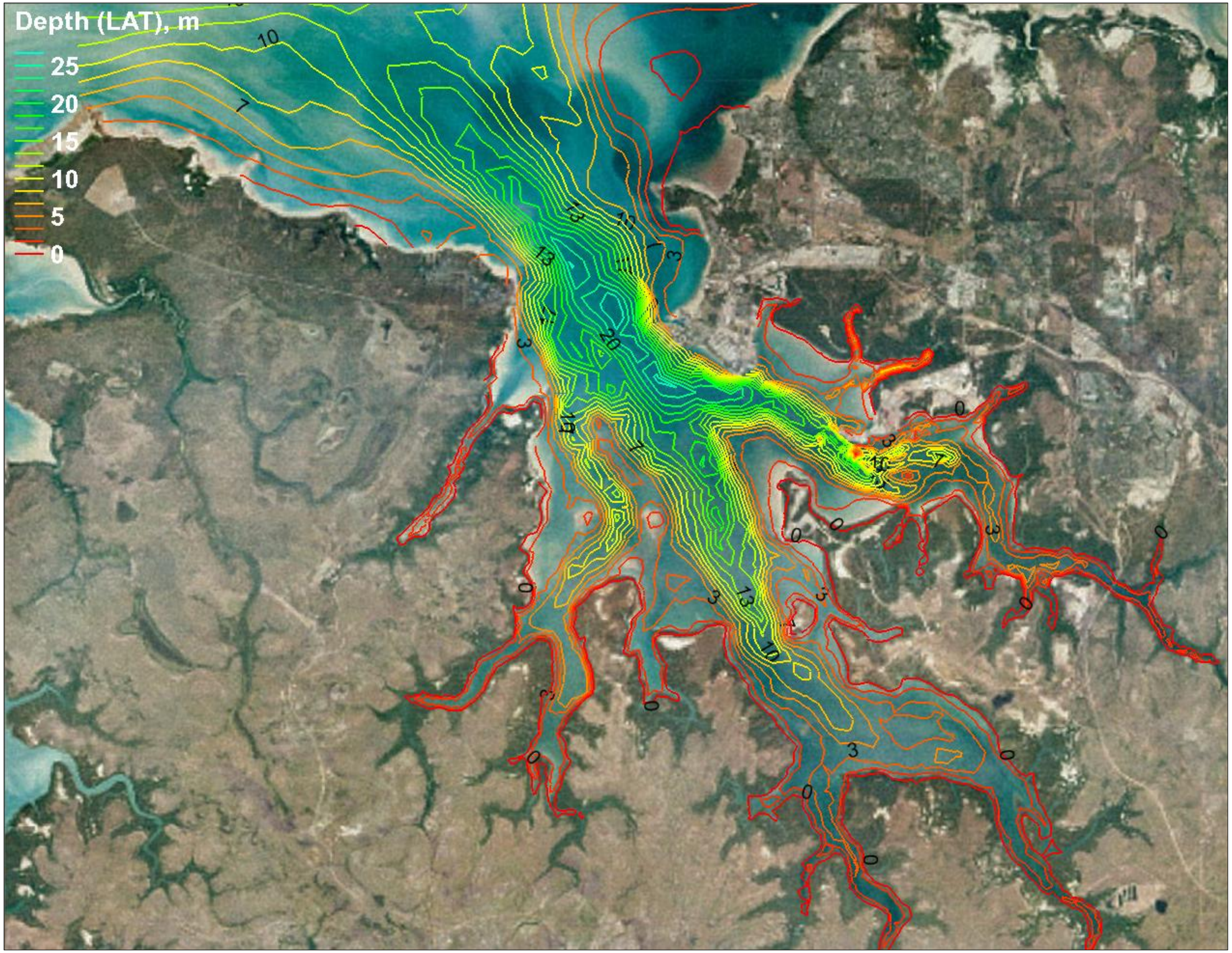

Figure 8-2 Colour Coded Bathymetry of Darwin Harbour (Depths are positive, relative to LAT)

8 Oceanic Process and Natural Features

Tides

Darwin Harbour is characterised by a macro-tidal regime with a maximum range of 8.1 m (e.g. Harper, 2010). The highest expected tidal level at any location is termed Highest Astronomical Tide (HAT), it is 4.0 m AHD in Darwin Harbour. Depending on the super-position of the Sun's and Moon's gravitational attractions, HAT occurs once each 18.6 year period, although at some sites tide levels similar to HAT may occur several times a year. The mean neap tidal range is 1.9 m, while spring tides have an average range of 5.5 m.

Tides are predominantly semidiurnal (two highs and two lows per day), with a slight inequality between the successive tides during a single day. Nearly diurnal tides occur for a two day period during the neaps. The lowest spring tides of the year occur during October, November and December, while the highest spring tides take place in June and July. Tidal excursions range from 8 to 15 km during springs and 2 to 8 km during neaps (e.g. Semeniuk, 1985; Hanley & Caswell, 1995). Peak spring tide flows measured along a line from East Point to Mandorah are in the order of 120,000 m^3/s (e.g. Williams et al., 2006).

Currents

Due to the above-mentioned macro-tidal regime of the Harbour, prevailing currents are of tidal origin. One of the most recent studies of currents in Darwin Harbour, which included both field measurements and numerical simulations using two different hydrodynamic models, was financed by INPEX for the Ichthys Gas Field Development Project (INPEX 2010a and 2010b).

The produced INPEX numerical modelling results were consistent with the collected current records and reflected the following:

- Maximum flood current speeds near the entrance to the Harbour varied from 0.3 m/s (neaps) to 1 m/s (springs), while the maximum ebb speeds varied from 0.5 m/s (neaps) to 1.6 m/s (springs). In comparison Williams et al. (2006) indicate that speeds can peak at 2–2.5 m/s during spring tides.
- At the inner-harbour locations, maximum spring current speeds varied from 0.7 to 1.3 m/s, and maximum neap speeds from 0.1 to 0.4 m/s, depending on the bathymetry and proximity to the shore (INPEX 2010b).

Figure 8-3 and Figure 8-4 present examples of typical flood and ebb current fields within the Harbour.

An assessment was also carried out on the impact of the wet season freshwater inflow on the current speeds within East Arm (INPEX 2010a). Hydrodynamic numerical modelling of the Elizabeth River time-varying flow data demonstrated that the flow had some impact in terms of current speed at the upstream extent of East Arm only, where the speed may increase by as much as 0.2 m/s as a result of rain. Any influence of this would be hardly traceable by midway along East Arm.

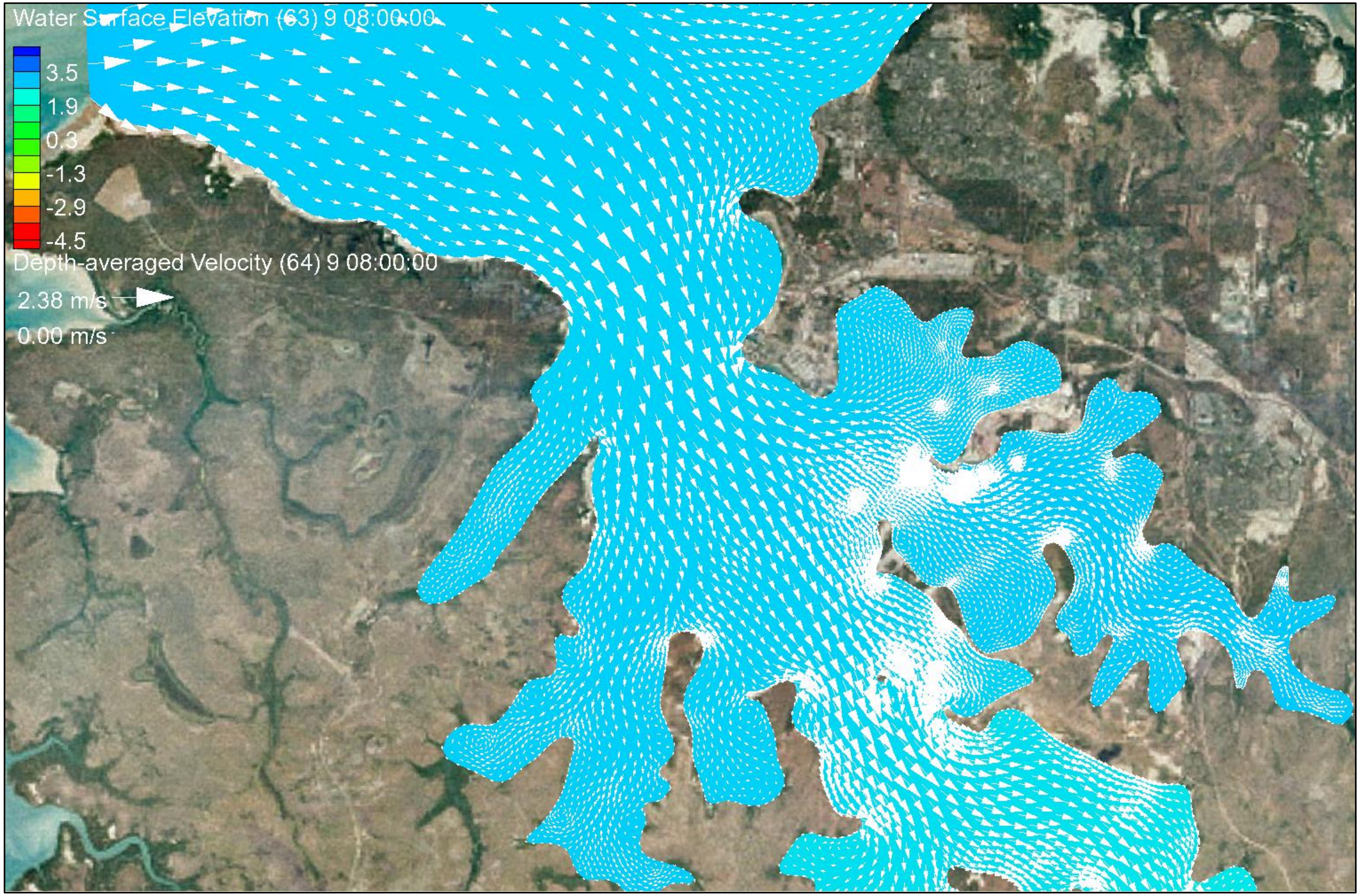

Figure 8-3 Typical Flood Current Vectors with Colour-Coded Water Surface Elevation

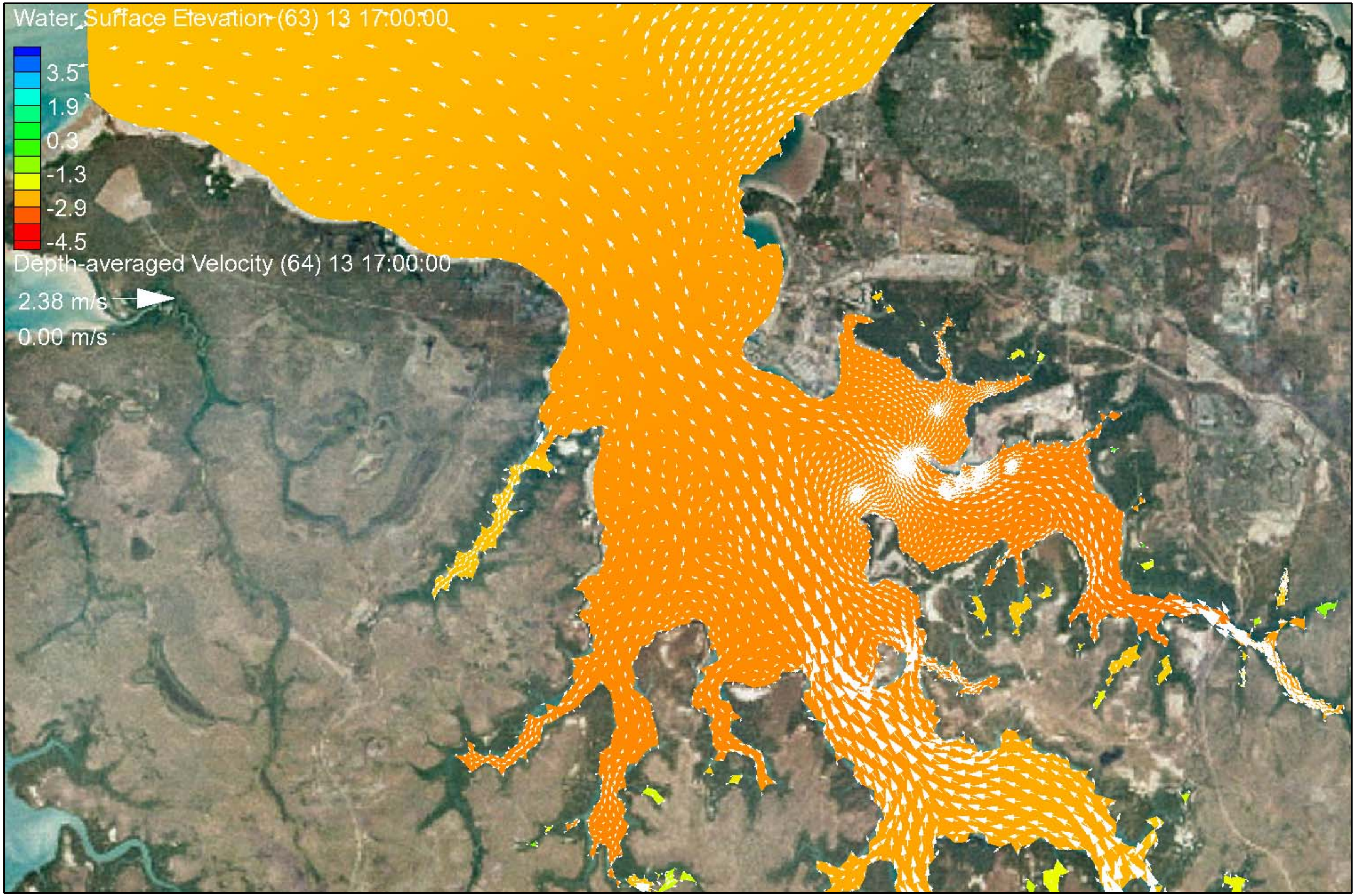

Figure 8-4 Typical Ebb Current Vectors with Colour-Code Water Surface Elevation

Waves

Darwin Harbour is well sheltered from long period tsunami and ocean swell waves by the Tiwi (Melville and Bathurst) Islands. Several wave measurement (e.g. INPEX 2010a) and wave modelling (e.g. GHD MacKnight, 1997) studies consistently demonstrated that waves within the Harbour are generally of short (3-5) mean periods with heights well below 1.0 m.

Due to the harbour orientation, bathymetry and coastline configuration, energy of long period waves entering the Harbour quickly dissipates and thus wave heights decrease dramatically. Using Cyclone Tracy-scale winds, extreme wave conditions were modelled by GHD-MacKnight (1997). Waves with the significant wave height of 4.5 m and mean wave period of 7.5 s at the harbour entrance were reducing in height down to 0.7 m inside the Harbour.

8.2 Potential Impacts

The assessment of potential oceanographic processes impacts has been compiled through:

- A baseline assessment of the existing environment;
- A quantitative assessment of bathymetry and coastline modifications based on hydrodynamic and wind wave numerical modelling, as well as estimates of bed shear stress;
- A quantitative assessment of dredging and coastal construction activities at three out of four main development sites, incorporating conservative production rate and particle size distribution of suspended sediments in conjunction with numerical simulations of sediment transport.

The three considered main developments and associated works, which may affect hydrodynamic and wave regime were as follows:

- Dredging of the approach channel and coastline change due to construction of the barge ramp and hardstand
- Dredging of the approach channel to the MSB and coastline change due to construction of the EAW extension works
- Dredging of the approach channel and the berth for Tug and Small Craft Mooring.

8.2.1 Potential Impacts on Currents, Waves and Bed Shear Stress

The potential for the abovementioned developments to alter a number of existing hydrodynamic processes within Darwin Harbour including water circulation patterns, wave regime and bed shear stress with a specific emphasis on the area around the East Arm Port facilities was analysed and presented in *Technical Report: Hydrodynamic and Wind Wave Modelling, and Bed Shear Stress Estimates*, **Appendix D.**

The quantitative assessment of the potential current, wave and bed shear stress modifications over both the wider (Darwin Harbour) and more localised (East Arm) scales were conducted through a numerical modelling using ADCIRC and STWAVE from the SMS modelling package as well as Mud Transport Module from the MIKE modelling package.

Comparative analysis of the obtained results included the generation of sample currents and wave fields for one pre-construction (present day Base case) and two post-construction (Dredged and Alternative dredged) scenarios. The differences imposed by the proposed developments were further quantified and analysed.

The hydrodynamic model used was validated against both the dry and the wet season field measurements of currents. Using the validated model, numerical current simulations were carried out for two one-month periods covering the typical dry and wet season tidal spring-neap cycles.

The modelling results suggest the current velocities and directions would be modified to a different degree at 8 comparison sites within the proposed developments: at some sites, there might be a decrease in maximum current velocities by as much as 45% (0.15 m/s at the site of concern – refer Appendix D), while at the others there might be an increase of up to 9% (0.07 m/s at the site of concern).

The wave modelling results suggest that both short and long waves entering the harbour decay significantly before the waves reach the East Arm Port area, and that both of the proposed developments would lead to wave energy attenuation. Parameters of regularly observed, short wind waves with the significant wave height of 1 m and the peak period of 5 s, which enter and propagate through Darwin Harbour, would not change due to the proposed developments, because the circular particle motion under such waves do not reach (and thus "do not feel") the bottom.

The modelling suggests that larger and longer waves (with the significant wave height of 5 m and the peak period of 10 s), which occur in Beagle Gulf rarely (5 occurrences per year - refer INPEX [2010b]), would undergo a further attenuation due to the proposed dredging and construction, compared to the present day conditions for wave propagation.

For instance, as a result of "Optional dredging (Figure 2-1)" and positioning the MSB wharf at the "Alternative location" (both pertaining to the Alternative dredged scenario), the maximum decrease of the significant wave heights was estimated as 0.81 m (from 0.88 m to 0.07 m at the site of concern).

An analysis of the possible change in bed shear stress was conducted to predict the cumulative effect of changes in the tidally driven currents and the wave energy over the entire domain. The mean bed shear stress estimates were calculated for each cell of the model domain over a typical tidal cycle period using the Base case, Dredged and Alternative dredged currents and waves.

There would be areas of both decreased and increased bed shear stress around the East Arm Port with the differences ranging from -0.05 N/m^2 to +0.05 N/m^2. The positive differences imply higher than present day deposition rates/possible sediment accretion, while the negative differences indicate areas of increased re-suspension and erosion rates.

However, the magnitudes of the differences are below the deposition and erosion thresholds used for Darwin Harbour in several recent sediment transport studies, e.g. 0.10 N/m^2 for erosion and 0.12 N/m^2 for deposition in Wasko et al. (2010), and 0.10 N/m^2 for erosion and 0.20 N/m^2 for deposition in **Appendix E**.

8.2.2 Potential Impacts on Suspended Sediment Concentration and Sediment Bottom Thickness

Dredging operations

The potential impacts of dredging activities associated with the EAW developments for the MSB, the barge ramp and hardstand area, and the tug and small vessel berths, in terms of elevated suspended sediment concentration and deposition of unconsolidated silt, were evaluated and presented in

Technical Report: Dredge Dispersion and Spoil Disposal Modelling for the EAW Expansion (refer **Appendix E**).

Due to MSB dredging operations, the highest levels of suspended sediment would occur around the dredge location and along the EAW, with the 95th percentile concentrations of 2.0-5.0 mg/l. Deposition of suspended sediments would occur to the north of the EAW, with the unconsolidated thickness of 1.0-5.0 mm; it would be less than 1.0 mm elsewhere.

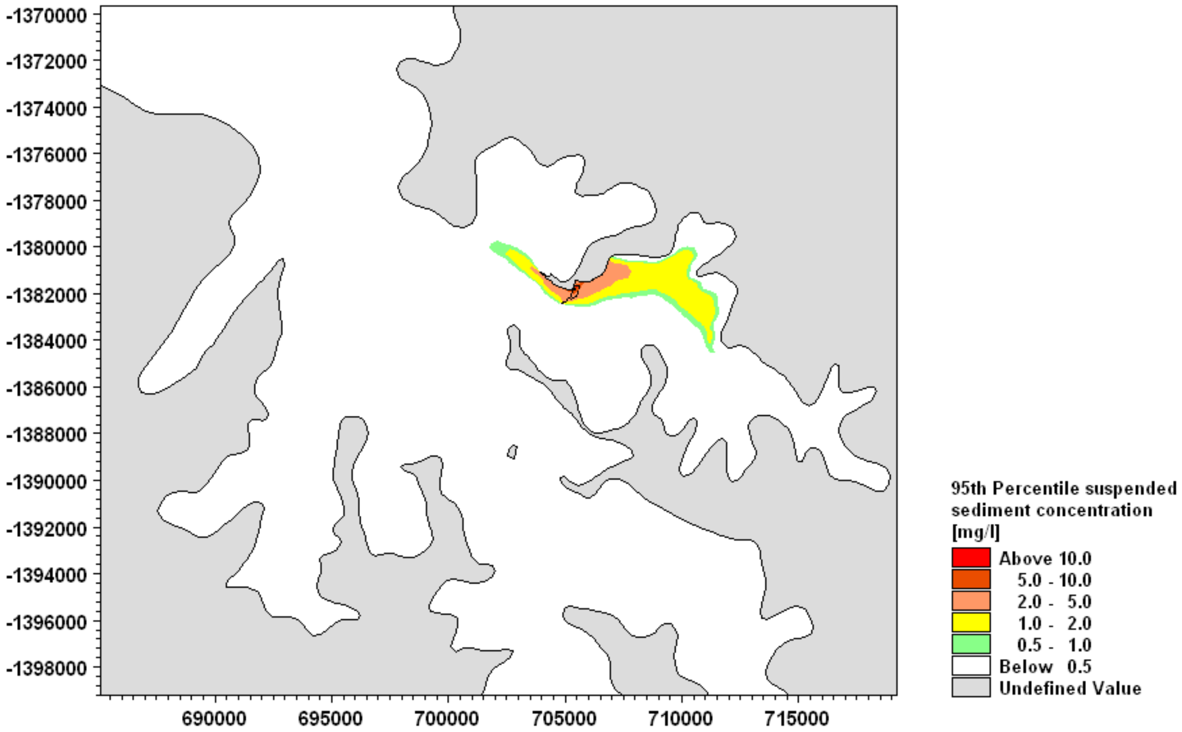

Figure 8-5 95th percentile suspended sediment concentration

Barge ramp dredging operations would produce a suspended sediment plume with the 95th percentile values of 1.0 - 2.0 mg/L, which drop to 0.2 mg/L within a distance of 100 m from the dredging plant; unconsolidated deposition would not exceed 0.5-1.0 mm.

Dredging operations at the Tug and Small Craft Mooring would contribute 2.0 - 5.0 mg/L of suspended sediment concentration on top of the background concentrations, and up to 0.1-0.5 mm bottom deposition on top of the existing bottom sediments.

The simulated values suggest that suspended sediment concentrations due to the dredging operations would stay below the average values measured in the harbour (approximately14.0 mg/L, see Chapter 9), while unconsolidated deposition would be of order of few millimetres, which would be hardly noticeable in the Harbour's energetic environment.

Spoil disposal operations

The spoil disposal operations would lead to small, quickly dispersing, plumes of suspended sediments transported by the prevailing tidal current. Outside Darwin Harbour, in Beagle Gulf, current velocities and resulting bed shear stress are sufficient to prevent deposition and encourage dispersion of the suspended sediment.

Therefore sediment would be dispersed at low concentrations with the 95th percentile value less than 3.0 mg/L. This again suggests that suspended sediment concentrations due to these operations would stay below the average values measured in the harbour (approximately14.0 mg/L, see Marine Water chapter).

The deposition area would be sensitive to wave conditions during the dumping operations, with the waves encouraging sediment re-suspension and thus slightly increasing local suspended sediment concentrations. Thickness of the deposited unconsolidated sediment resulting from the spoil disposal operations would not exceed 0.1-0.5 mm, which would be hardly noticeable in the Gulf's energetic environment.

8.3 Management of Impacts

8.3.1 Objectives and Standards

Management of potential oceanographic processes impacts will be in accordance with relevant standards. These include:

- ANZECC *Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000)
- *The Framework for Marine and Estuarine Water Quality Protection* (DEWHA 2002)
- *Darwin Harbour Strategy* (NTG, 2010)
- DPC EMP
- *Mangrove Management in the Northern Territory* (DIPE, 2002)
- *Marine Pollution Act 2004*
- *Waste Management and Pollution Control Act 2003.*

The environmental management process will follow a general framework of:

- Impact avoidance
- Impact assessment
- Impact minimisation
- Identification of mitigation measures
- Assessing mitigation measure effectiveness
- Mitigation plan selection and
- Monitoring and adaptive management.

8.3.2 Management Requirements

Management of potential impacts during dredging and construction phases will be addressed separately as part of the Dredge Management Plan (Chapter 27) and the CEMP. As discussed in Section 2.1.6, the dredging methodology will depend on the availability of dredgers and the contractor's preferred construction method. Some of the typical dredging management actions to control sediment discharges/re-suspension are:

- High rates of sediment removal, enabling shorter timeframes for discharges
- Reduction of propeller wash by using high tide for access
- Relocation of the dredge plant to a different dredging area until more favourable conditions prevail

- Depending on location, dredging only on favourable run-of-tide
- Offshore disposal further away from high productivity potential impact areas
- Reduction of dredging to single shift
- Use of sediment control devices (e.g. shroud for cutter-suction dredge) at source.

The management of potential impacts post construction will be addressed in future operational EMPs.

8.3.3 Monitoring and Reporting

An oceanographic process monitoring network will be required for long-term monitoring, to comply with objectives and standards. The monitoring of current, wave, suspended sediment and bottom sediment monitoring equipment would be located near the proposed dredging locations, and data would be collected during dredging operations.

The collected data would include suspended sediment concentrations/turbidity, bottom sediment thickness and bed load transport; this would be subject to amendment in accordance with future operational EMPs.

Annual reporting would be undertaken in accordance with construction and operational EMPs.

8.4 Commitments

- *Implement preventative actions as in the Dredge Management Plan and relevant EMPs*
- *Review oceanographic processes monitoring data and findings to determine need for corrective action*
- *Undertake annual reporting on results of monitoring of oceanographic processes*
- *The management of potential limpacts on oceanographic processes will be in accordance with relevant standards.*

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